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PRINCIPAL ACADEMIC TUTOR
Antonella Contin,
DAStU Politecnico di Milano

ACADEMIC TUTORS
Francesca De Filippi,
DAD Politecnico di Torino
Giancarlo Vecchi,
MIP Politecnico di Torino
Pedro Ortiz,
Multilateral Consultant
Aldo Treville,
PhD MSLab Politecnico di Milano
Alessandro Frigerio,
PhD MSLab Politecnico di Milano

EXTERNAL INSTITUTIONS
Conservation International Brazil
Economia e Sostenibilità (ESTà)
Municipality of Nova Iguaçu
OndaVerde
Pontifical Catholic University of Rio de Janeiro (PUC-Rio)

Floriana Acconcia,
Architecture Politecnico di Milano

Irene Sofia Ceron,
Architecture Politecnico di Milano

Benedetta Gatti,
Architecture Politecnico di Milano

Bianca Gentili, Architecture Politecnico di Milano

Melissa Latella,
Environmental & Land Engineering
Politecnico di Torino

Simone Mazzero,
Architecture & Construction City
Politecnico di Torino

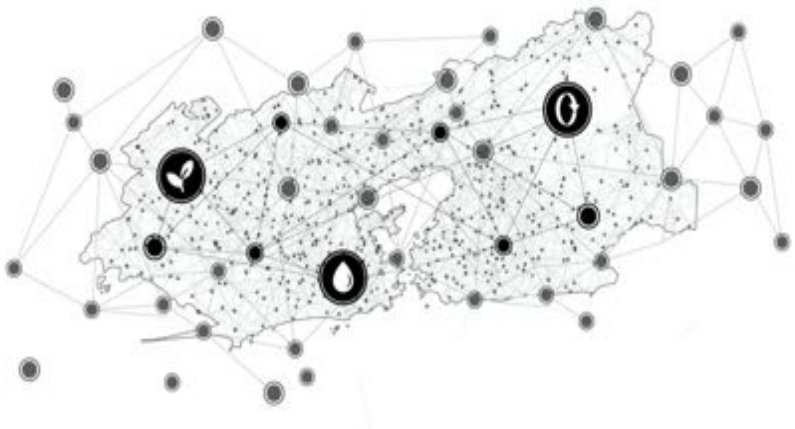
M.A.RIO
Metropolitan Approach for Rio de Janeiro

Executive summary

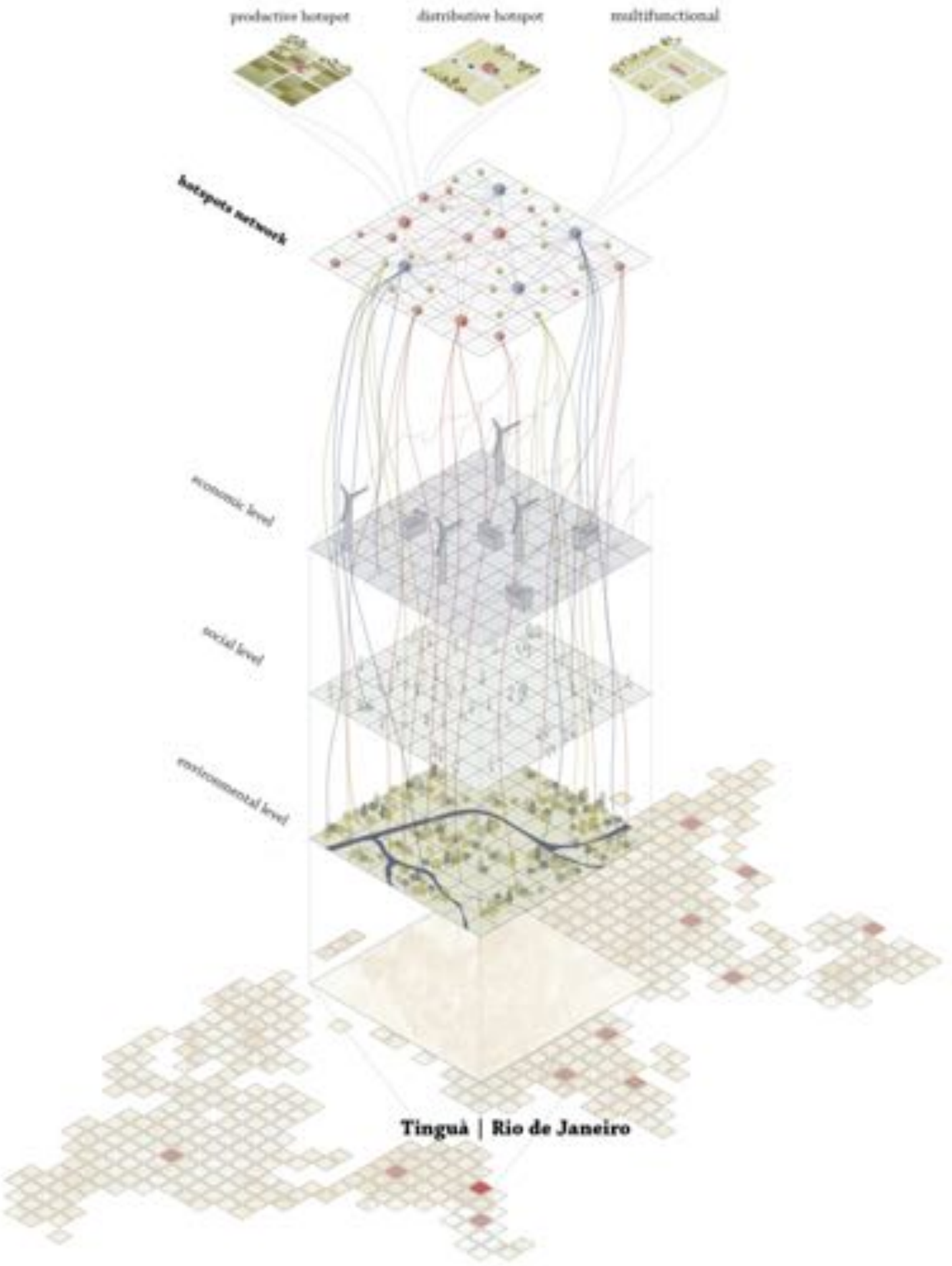
Urbanisation is a global phenomenon that is gradually transforming the traditional relation between urban and rural areas. In metropolitan regions, where cities extend to peri-urban and rural areas, this interconnection often witnesses a disparity in the population's living conditions disadvantaging the periphery. However, with a responsive metropolitan planning, urban dynamics can be strategic drivers for sustainable development in rural areas. M.A.RIO's project aims to provide an innovative planning strategy, suitable to similar realities, on the basis of the analysis of Rio de Janeiro Metropolitan Region (RMRJ). The case study is Tinguá's valley, an underdeveloped rural area in the periphery of RMRJ, which has strong biological value and provides central municipalities with important ecosystem services such as food and water but is isolated in terms of infrastructures and services. The proposed solution is based on the recognition of familiar agriculture as a trigger for social, environmental and economic development. It also follows UN Guiding Principles of Rural-Urban Linkage, with the aim of combining the preservation and reinforcement of the biological value, the design of the rural landscape and the creation of an efficient model of circular economy. The team developed and applied a strategy focusing on the geographical interpretation of metropolitan complexity, combining maps and spatial information technologies to allow the identification of latent landscape patterns. The solution proposes the design of an implemented agricultural pattern activated by a model of circular economy that is founded on a network of small but focused interventions, defined as hotspots. The logic of the hotspot is that of an "incubator of possibilities", which acts not only as an immediate response to specific local needs, but also as a generator of value on the metropolitan scale. Such innovative planning becomes a tool to support metropolitan decision-making, shifting from the political, social and geographical dichotomy between urban and rural areas, towards their mutual interconnection to achieve a Sustainable Development.

Key Words

Urban Rural Linkage, Metropolitan Cartography, Urban Acupuncture, Circular Economy, Sustainable Development Goals.



The RMRJ network able to include peripheries through food and water system


productive hotspot
distributive hotspot
multifunctional
hotspots network
economic level
social level
environmental level
Tinguà | Rio de Janeiro

Project description written by the Principal Academic Tutor

The project is connotated by a strong metropolitan vision, aiming at the improvement of the current practices of metropolitan disciplines, with new competences *of* ***shaping and re-shaping the metropolis***. This vision implies an interdisciplinary approach integrating various disciplinary knowledge, and transversal management skills, and dealing with the metropolitan complexity and fragmentation. Also, it intends to bridge the gap between the theory and practice by specifying the metropolitan needs and defining the intellectual tools to overcome them.

In Latin America, the rapid growth of cities faces challenges in ensuring sustainable and equitable development of the metropolitan areas. The project, through the cooperation among universities and independent research centres in Italy and Brazil, aims to explore the city of Rio de Janeiro as a case study on the metropolitan scale and develop a toolkit based on the reading of the territory with a **multilateral approach** that includes geographical, architectural, economic, environmental and public policy perspectives. This new reading will highlight socio-economic inequalities and environmental issues, providing to the team the opportunity to define a more circumscribed study area, where to generate an innovative solution, based on the principles of circular economy and sustainable development.

In summary, the intent is to develop a framework for the analysis of the socio-economic dynamics in the Rio de Janeiro Metropolitan Region, focusing on management of ecosystem services and provision of infrastructure and services, and realize a strategy to trigger circular economy practices for the development of local food production activities, while preserving water resources and biodiversity in the Atlantic Forest. This strategy constitutes a tool for the municipal decision-makers and will be generated thanks to the cooperation between the team and various external institutions, among which Conservation International, local NGOs and politicians from Rio de Janeiro. International funding and partners will be search for pursuit the real implementation of the designed solution.

Team description by skill

All the members of team were deeply involved in the development of the project, and in the decision making, however we divided in two sub-groups to better address the specific needs and topics.

One group focused on the development of a territorial strategy and the design of a new landscape for the area, studying several literature references and developing and applying a specific methodology for this case study. This group deepened the study of David Governeur's approach to informality and Pedro Ortiz's theory of the MetroMatrix analysing his polycentric metropolitan model. Then applied it in the study of Rio de Janeiro Metropolitan Region understanding the regional dynamics to apply the methodology of metropolitan cartography. **Floriana Acconcia** focused more on Governeur's approach, **Bianca Gentili** on Ortiz's, **Irene Sofia Ceron** defined the metropolitan dynamics. These dynamics constituted the basis for **Benedetta Gatti** to implement metropolitan cartography and provide maps on various scales.
The other group looked into the implementation of the production and market system; **Simone Mazzero** studied circular economy models, while **Melissa Latella** specialized on urban acupuncture strategies and Sustainable Development Goals, while cooperating to develop the Hotspot Network Strategy.
This allocation of tasks was not a merely subdivision of the team, as it allowed each member to become an expert in relation to one topic and coordinate the colleagues' actions during the collaborative development of the project.

Also, the team was able to in touch with Brazilian references. In November 2017, three team members went to Rio de Janeiro for an on-field survey of the study area, while in April 2018, a delegation of Brazilian politicians participated in a one-week workshop to collaborate to the project and discover the rural innovation in the Milan countryside. A further meeting in Rio de Janeiro is expected in November 2018 to pursuit the real implementation of the project.

Goal

The project aims to provide an **innovative planning strategy for the sustainable development of informal settlements and their inclusion in the metropolitan dimension**. The planning strategy was developed to a case study in Rio de Janeiro Metropolitan Region, on the analysis of an under-developed rural area in the municipality of Nova-Iguaçu, near Tinguá Biological Reserve. Tinguá represents an emblematic case, since it shows the complexity of the governance in the metropolitan periphery, at the interface between urban and rural realities. In fact, although Tinguá provides precious ecosystem services, as water and natural tourism, to the whole region, it is cut out from Nova-Iguaçu municipality in terms of infrastructure and services.

The proposed solution is addressed to both impending environmental and socio-economic issues in Tinguá, considering that they are common to most of informal settlements worldwide. On the one hand, the biological and social value of the area must be preserved and reinforced action on the Atlantic Forest and the water reservoirs. On the other hand, the urban and economic development of the area must be fostered, it is essential to create new opportunities for the local community, with a particular attention to farmers, while realizing a monitoring system to collect sensitive data to support governance and planning activities.

The aim of this strategy is to suit the **UN 2030 SDGs Agenda**, focusing on **Goal#11: *"sustainable cities and communities"***. Especially on target 11.a which is *to sustain a positive social, economic and environmental link between rural and urban areas strengthening national and regional development planning.* This framework follows the Guiding Principles of **Rural-Urban Linkage** by UN-Habitat**, to achieve a sustainable trade system able to make Tinguá a relevant node in the metropolitan dimension.**

Understanding the problem

Mega Rio, Rio city, as well as the other urbanised centres, attract global and regional flows of people, capital and goods, and are supported by a strong infrastructure and service system. However, the **urban sprawl is constantly expanding throughout the region and pushing urbanisation towards underserved peripheral areas and areas of high biological value**. In fact, Brazilian territory, thanks to the Atlantic forest has the greatest biodiversity throughout the world. In this framework, the ever-growing urban expansion is threatening the natural heritage of RMRJ. In particular, the trend of increasing urban population results in a strong urban sprawl which sees the predominance of understructured informal settlements that have no access to services and facilities. Rio's peripheries are the most impaired by this phenomenon because, among the different municipalities that compose the RMRJ, there is not a unitary governance on the metropolitan scale.

Tinguá as a rural informal periphery has several weaknesses but also some unique values. The biological reserve and the water springs presents make this place an attractive pole for tourists and a huge hydro-electrical resource. In addition, the resiliency of the farmers' community who were able to re-arrange in a parallel informal system as they were excluded from the formal one, is a crucial value since the agriculture is the only activity that can employ Tinguá's inhabitants without making them dependent from bigger centralities.

Urban sprawl is threatening areas of high biological value

The reconstruction of the agricultural pattern

Exploring the opportunities

The collocation of Tinguá, its physical characteristics and social composition of its inhabitants offer some valuable starting points. The proximity to the metropolitan area, currently not expressed in term of accessibility to services, could attract greater interest from metropolitan council and inhabitants. The **ecosystem services**, acting as linkage among rural and urban areas, represent a topic of general interest, both in Rio de Janeiro and in other metropolitan areas. The informal setting of **familiar agriculture**, currently experiencing a great wave of interest in Brazilian planning strategies, offers undeveloped **social capital** to be addressed as triggers for an innovation of the market chain. The compresence of all these factors sets up a great opportunity to implement an innovative project, which would address the local issues with a multidisciplinary approach.

Generating a solution

The solution follows the guiding principles of rural-urban linkage proposing familiar agriculture as a multi-layered metropolitan link with the aim of combining the preservation and reinforcement of the biological value, the design of an agricultural pattern and the application of an efficient model of circular economy. Two tools based on the use of spatialized data and maps allowed for the understanding of Rio de Janeiro metropolitan dynamics. These tools, namely the MetroMatrix and the Metropolitan Cartography, provide a reading of territory and the identification of a latent agricultural pattern. Thus, the solution relied on the enforcement of this pattern by the creation of **Tinguá AGROpark**. In practice, the development of Tinguà's informal settlement and farming land was fostered by the implementation of the ***Hotspot Network Strategy*** (HNS) created by the team on the basis of urban acupuncture theories and Gouverneur's planning strategy. HNS consists of the strategic positioning of elements that could attract the establishment of the settlement in prior defined areas and protect natural resources. These elements consisted in punctual interventions called ***hotspots***. The mutual and synergic interaction among the various hotspots creates a network that provides facilities and services to the local farmers and constitutes a food production chain that is complementary to the already existing informal one. The network works accordingly to the principles of both **circular economy** and ***Participatory Market Chain Approach***, as hotspots do not solely consist in light infrastructures but also act as social facilitator for farmers, being the first forum for the share of initiatives and **social learning**. In parallel to the hotspot one, also a network of focused interventions in realized to prevent water contamination and promote a sustainable water management, while a data gathering system alongside the production chain allows for the collection of useful information that institutions can use for activities planning and decision-making.

In order to be aligned with international interests, some of the indicators associated to the SDGs' targets in the UN 2030 Agenda were selected to assess the effectiveness of the designed solution and its **social impact**.

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PRINCIPAL ACADEMIC TUTOR

Francesco Causone, Energy Department, PoliMi

ACADEMIC TUTORS

Valentina Fabi, DENERG, PoliTo

Marta Bottero, DIST, PoliTO

Marco Mussetta, Energy Department, PoliMi

Stefano Paolo Corgnati, DENERG, PoliTo

Marco Domenico, DEIB, PoliMi

EXTERNAL INSTITUTION

Siemens
Sara Filipponi, Energy Management and Digital Grid

TEAM MEMBERS

Kareem Abo Ayanah, Petroleum Engineering, PoliTO

Matteo Barsanti, Energy Engineering, PoliMi

Letizia Garbolino, Architecture for Sustainable Design, PoliTo

Benedetta Leway, Architecture Construction City, PoliTo

Muhammad Mansoor, Electrical Engineering, PoliMi

Giulia Realmonte, Energy Engineering, PoliMi

Rita Zeinoun, AUIC, Politecnico di Milano

DEMAND RESPONSE. BEHAVIORAL AND ENERGY ANALYSIS IN RESIDENTIAL ENVIRONMENTS

Executive summary

The energy system is undergoing a dramatic change, mainly driven by the diffusion of decentralized renewable generation, such as solar and wind. These sources are inherently less predictable, thus making it more difficult to guarantee a real-time balance between demand and supply on the grid.
Therefore, a higher degree of flexibility will be needed to facilitate the integration of intermittent green energy: the new paradigm will require demand to follow the electricity supply when available, with final customers playing an active role.
Demand Response (DR) refers to any change in end-use electricity consumption according to the needs of the grid: as for now, demand is not allowed to participate in the grid balancing in most of European countries, nevertheless, in Europe the majority of theoretical demand response potential lies with residential consumers, and this potential is still waiting to be exploited. The main barriers are related to a low consumer engagement with energy-related activities, and a lack of regulation specifically designed for this customer segment. Moreover, the level and the firmness of response that can be achieved is still uncertain.

The main goal of DR.BEAR project is to develop a Business Model to harness the potential flexibility coming from load shifting at household level, designing an appropriate customer engagement strategy and incentive scheme to involve them in such programs.
Our project will be particularly innovative for the italian case, as in this country few projects of the kind have been implemented so far; DR.BEAR framework can represent a good starting point for all those companies, including our main external partner Siemens, interested in developing a market for DR in Italy.
The innovation of our solution is in applying a behavioral approach to achieve demand side management, meaning that the focus will be on triggering a behavioral change in residential customers while involving them as active player of DR programs.

Key Words

Demand Response, Residential Customers, Customer Engagement, Behavioural Approach.

Project description written by the Principal Academic Tutor

Decarbonisation, decentralisation and digitalisation are considered the three big drivers of change of the power sector in the coming years. The decarbonisation agenda foresees a rising share of renewable energy sources on the production side, leading to a substantial decentralisation and to the phase out of high emission power plants. This might have, nevertheless, a drawback in terms of power grid management, since renewable energy supply is quite unstable and unpredictable. That is why the risk of blackouts or lack of energy might increase. In order to compensate unstable generation, storage systems are required; however, no technology is currently available and deployable to guarantee national grids balance. An alternative way to manage unstable generation is to provide flexibility on the demand side, for instance promoting demand-side response programs.

DR.BEAR, addressed the topic of energy transition, by investigating the potential of demand-side response programs for domestic buildings within the European energy market. The subject is highly multidisciplinary, and it requires knowledge, on building energy use, grid management, energy market, and occupant behaviour. In particular, no demand-side response program may be activated without a behavioural change of the final users. How to enable this behavioural change via the activation of a digital social market was the principal object of investigation of DR.BEAR. The project focused also on the industry point of view, studying potential business models to activate a flexibility market. A case study in Greenwich, UK, has been selected to provide a practical application of the research activities, which might lead to further actions in the coming years.

Team description by skill

- **Kareem Abo Ayanah:** Petroleum Engineering. Load Profiling, Stakeholder `analysis, and Economic assessment
- **Matteo Barsanti**: Energy Engineering. Load Profiling, Business Models development and techno-economic assessment
- **Letizia Garbolino**: Architecture for Sustainable Design. Communication coordinator. Questionnaire development and preferences assessment, App Interface design, and graphical representation
- **Benedetta Leway**: Architecture Construction City. Questionnaire development and behavioral analysis assessment, App Interface design, and graphical representation
- **Muhammad Mansoor:** Electrical Engineering. Load Profiling and Management, Analysis of Requirements, and Needs of Stakeholders
- **Giulia Realmonte:** Energy Engineering. Team Controller. Business Models development, and techno-economic assessment
- **Rita Zeinoun:** Sustainable Architecture. Questionnaire and analysis of the market, App Interface design, and graphical representation

Goal

The objective of DR.BEAR project is to develop a business model proposal to implement Behavioral Demand Response in the European market, harnessing the flexibility coming from residential consumers.

This project is based on a behavioral approach to achieve demand side management, that means the key focus will be on triggering a behavioral change in residential customers while involving them as active player of DR program.
In order to identify the most profitable Business Model, we have investigated both manual load shifting (Behavioral Demand Response *stricto sensu*) and the use of direct load controls with Smart Plugs (being an automated response, this pertain more to traditional DR programs). In both cases, a behavioral change is needed: in the former one, consumption patterns need to be changed manually by customers according to the DR signals received, in the latter one, the change is related to the attitude and the awareness of end-users towards energy consumption in order to increase their acceptance of digital technologies and automation, thus reducing override events.

Behavioral Demand Response requires a multidisciplinary approach, combining behavioral science and user experience, together with load management and multi-energy system optimization, therefore it results particularly suited for the diverse background of our team, combining Energy and Electric engineering skills, with data visualization and sustainable architecture knowledge.

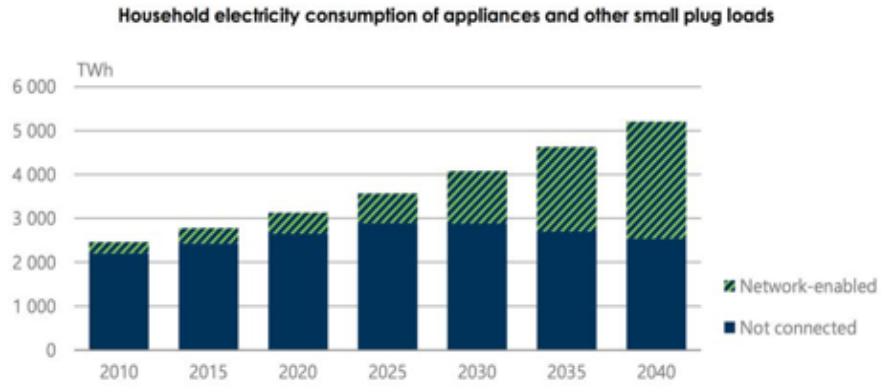

Figure 1: Role of digital technologies and IoT in the residential sector, source: IEA WEO 2017

Understanding the problem

The energy sector is undergoing a dramatic transition, that will change completely the way energy is produced and sold all around the globe. This is not only the result of stringent climate targets and global mitigation efforts, but it is also related to the rapid diffusion of low-carbon energy sources, given their cost-competitiveness with respect to traditional fossil-based generation. Therefore, three main trends are going to be the key driver for this transition: *decarbonisation, decentralization and digitalization*.

This transformation brings a number of challenges: the rapid retirement of fossil fuel-based generation together with the reduction in cost for wind and solar energy leads to a growth of non-dispatchable electricity generation that requires additional efforts to keep a real-time balance between demand and supply on the electric grid. Indeed, storage technologies are not yet cost-competitive to be deployed on a large scale, therefore a higher degree of flexibility is needed on the power network to face renewable intermittency, both from the electricity suppliers and from the demand side.

This implies a change in the paradigm of the power sector: from the traditional approach of supply following demand whenever it occurs, the future energy system will require demand to follow supply when available.

Demand Response (DR) actually refers to the changes in end-use electricity consumption according to the availability of generation and the needs of the grid, to guarantee a balance between demand and supply over time. In Europe most of theoretical Demand Response potential lies with residential consumers, and this capacity is still waiting to be exploited: currently, DR programs have been fully implemented in few European countries (UK, Germany and France are the main markets), focusing on industrial and commercial customers, as they are characterized by large loads, that can be scheduled and controlled in a reliable way.

The main barrier to access residential flexible potential are a low consumer engagement, combined with a general mistrust towards utilities, and the lack of regulation specifically designed for it (Parrish et al., 2016).

Exploring the opportunities

Electricity consumption in residential sector can be reduced by providing consumers with tailored information about their energy-related practices at home. When these techniques are coupled with demand response logics, the benefit of such programs may exceed greatly.

Considering the current market, a limited number of aggregators are already active in managing commercial and industrial loads to provide balancing services to the system operators in the UK, Germany and the US (e.g. KiWi Power, Flexitricity, and EnerNOC). However, for the residential sectors only some pilot projects have been done so far, in order to understand the technical and economic potential, assessing customers' response and its persistence in time.
At the same time, a number of solutions are already on the market to effectively engage customers, combining energy-related services (e.g. feedback on household consumption, energy efficiency advice, etc.) with gamification and social competition aspects (e.g. bonus collection, community-based rewards, etc.). The communication channels used range from mobile application to in-home displays and websites. Both of these aspects have been considered as a benchmark to develop our solution.

Given the uncertainties related to the residential segment, our case study will be represented by a pilot project currently carried out in the Royal Borough of Greenwich (London, UK) by KiWi Power, an existing aggregator active in commercial/industrial DR. The project will involve two social housing blocks (150 dwellings) recently retrofitted , in order to understand their load shifting potential. As it is still in the first phase, no evidence is available yet. However it developed a comprehensive strategy to effectively implement DR programs, considering the specific customer segment under analysis, coupled with a first economic evaluation. This is based on a number of assumptions that still needs to be validated through trial.

In parallel to the case study, a questionnaire has been developed to investigate the preferences of target customers for different services that could be offered within DR programs, providing at the same time a useful customer segmentation. It has been first spread out in Italy, specifically in the regions of Piemonte and Lombardia, in order to test its validity. It will also be applied to the case study during the first stage of user-experience design.

Generating a solution

To simplify the overall complexity of DR programs related to the large number of actors involved, we developed a **step-based approach**.

After a first stage of *user experience design*, supported by our questionnaire to segment customers and to tailor the communication strategy, an initial *customer engagement phase* is required. This strategy includes a wide service offering, so to increase their awareness in the energy field while making them ready to take action. These services range from the visualization of real-time and historical energy consumption, to detailed information on individual appliances, identifying possible inefficiency and providing useful advice to achieve savings in the electricity bill. The real *Demand Response* is implemented only in the last stage, asking customers to change their consumption habits, not only for a personal benefit as before (bill savings, increased self-consumption) but according to the need of the grid.

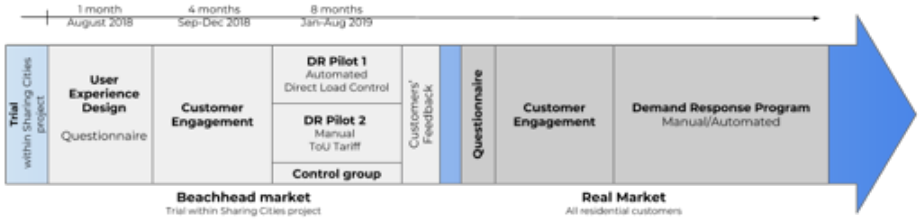

Figure 2: DR. BEAR concept timeline

Based on the current remuneration for demand flexibility, the financial incentive that can be given to each household is likely to be quite limited, given that a large number of customers need to be aggregated to reach a significant DR capacity. Therefore, different leverages have been identified, combined with gamification tools and social competition to trigger behavioral changes in end-users, keeping them engaged in the program.
The incentive scheme that we developed is based on the collection of virtual coins as a reward for each action that is undertaken by residential consumers.
The engagement strategy will be enabled by DR. BEAR platform, that connects all the different actors and represents the main communication channel to dispatch shifting request to customers through an app interface. The app has been designed by us, by referring to a previous version developed by our partner KiWi Power.

Figure 3: Real time interface is used to provide the users information about energy use in their household. Dr. Bear message box is accessible from each tab by tapping Dr. Bear icon in the top menu.

Figure 4: A comparison between current energy use and previous trends in the household is displayed in a graph. The users can choose which time frame to use for the comparison. Dr. Bear's pop-up messages keep the customer engaged.

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PRINCIPAL ACADEMIC TUTOR
Mario Grosso
DICA, Politecnico di Milano

ACADEMIC TUTOR
Stefano Caserini
DICA, Politecnico di Milano
Arianna Azzellino
DICA, Politecnico di Milano
Caterina Lanfredi
CoNISMa, DICA, Politecnico di Milano
Beatriz Barreto
DICA, Politecnico di Milano

EXTERNAL INSTITUTIONS
CO2Apps
CoNISMa

EXTERNAL TUTOR
Giovanni Cappello
Dennis Ross

TEAM MEMBERS

Mohamed Amr Aly, Petroleum Engineering, Politecnico di Torino

Alberto Bocchinfuso, Automation and Control Engineering, Politecnico di Milano

Matteo Bolognesi, Management Engineering, Politecnico di Milano

Sachin Nakkarike Aravinda, Mechanical Engineering, Politecnico di Milano

Davide Renda, Chemical Engineering, Politecnico di Milano

Gandolfo Scialabba, Aerospace Engineering, Politecnico di Torino

ACO2NE

Affordable CO_2 negative emissions through gasification, ocean alkalinization and CO_2 storage

Executive summary

The aim of the project is to achieve CO_2 negative emissions in an affordable manner. CO_2 concentration in the atmosphere is one of the important environmental problems of this era, as testified also by international treaties like the Paris agreement: the aim of the project is to take away CO_2 from the atmosphere combining different innovative processes.

The project starts with the study of an innovative chemical process that combines gasification and calcination, two well-known and established processes. Revenues are ensured by the hydrogen produced; other products are CO_2 and slaked lime.

To effectively achieve negative emissions, not only the CO_2 produced is stored, but this chemical process is followed up with ocean liming, i.e. the dispersion of slaked lime, one of the products, in the ocean.

The expected outcome of this study is a complete feasibility analysis of the process in its whole, from the plant to the CO_2 storage and the ocean liming, without neglecting the economical perspective.

Considering that the process can start using several fuels, ocean liming can be performed in several regions and the plant itself can be located in different parts of the world, multiple solutions have been explored.

After a thorough investigation of all the relevant points, the project ended with results about the best plant location, the ocean liming location and expected time period of ocean liming, the expected profitability of the process and the best combination of fuel and CO_2 storage to be used to achieve the goals.

Key Words

Ocean alkalinization, CO_2 storage, Negative Emissions, Gasification, Calcination

The group of ACO2NE the day of the final presentation

Project description written by the Principal Academic Tutor

Mounting research suggests that negative emissions technologies (NETs) have to play a major role in any global strategy to stabilize the climate, because a simple reduction of CO_2 emissions won't be sufficient to reach ambitious climate targets. Several published studies show that halting global warming at 2°C is likely to require CO_2 to be removed from the atmosphere on a large scale by the second half of this century.

Despite their significant mitigation potential, all of the known NETs have limiting factors, such as cost and energy requirements (i.e. for direct air capture), logistics of spreading materials over large areas (i.e. for enhanced weather technologies), and potential competition for land and freshwater (i.e. for afforestation and bioenergy with carbon capture and storage). Thus, there is an absolute need to find new solutions to reduce the CO_2 content of the atmosphere.

A new process is being developed, combining different technologies that address the CO_2 issue in terms of removing it from the atmosphere as well as decreasing its concentration in the oceans.

About 40% of the CO_2 released into the atmosphere by human activities is absorbed by the oceans. This helps slowing the rate of global warming but also increased ocean acidity, posing a serious threat to marine life.

The new technology includes coal gasification, CaO production, ocean alkalinisation, H_2 production and final CO_2 deep-water storage

The most critical aspects of the new proposed process need to be addressed, in order to come out with a feasibility study paving the road to a subsequent experimental stage, and later on to a pilot scale application.

This requires competences on the process design and optimization, on ocean chemistry, on mass and energy balances, on environmental assessment. Particular attention needs to be paid to the legislative and permitting issues, as well as to the acceptance of such an unconventional approach by the population and stakeholders. Communication then needs to play an important role.

Expected results are a preliminary validation of the feasibility of the technology, as well as some indications on possible sites where to apply it worldwide.

Team description by skill

Mohamed Amr Aly,

Alberto Bocchinfuso, Automation and Control Engineering, Politecnico di Milano: studied the ocean liming, in particular the ships that can be used.

Matteo Bolognesi, Management Engineering, Politecnico di Milano: studied the economic feasibility of the process.

Sachin Nakkarike Aravinda, Mechanical Engineering, Politecnico di Milano: studied the ocean liming process, ocean parameters in particular.

Davide Renda, Chemical Engineering, Politecnico di Milano: studied the technical feasibility of both the gasification and the calcination process for different configurations.

Gandolfo Scialabba, Aerospace Engineering, Politecnico di Torino: studied the ocean liming process, especially the mixing process in the wake of a ship.

Goal

CO_2 is a greenhouse gas which is causing the increase of the global temperature. Due to a rising attention from the public opinion, many nations signed an agreement in Paris setting a limit to the amount of CO_2 which can be emitted without causing any further increases of the global temperature. The aim of this project is not only to avoid any further emission but mainly achieving Negative Emission, i.e. the removal of part of the already existing CO_2 in the atmosphere.

As better explained later on, negative emissions are achieved through ocean liming, an innovative process still under active research. This process represents the core of the solution proposed, because it is the one that assures to achieve negative emissions, so particular attention is needed. Even though it is only theoretical, a deep study of its feasibility and potentiality are required. It is important to assess the potential environmental impact on the marine ecosystem due to ocean liming.

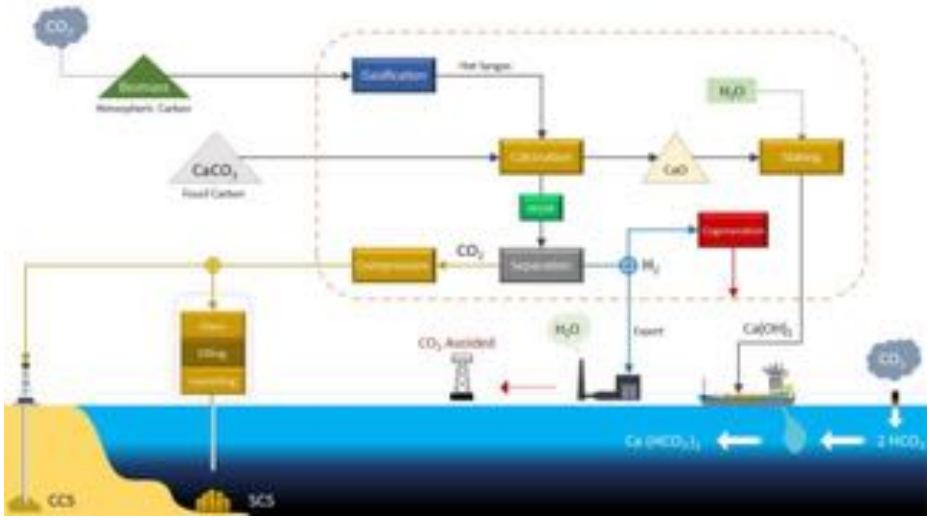
Furthermore, since removing large amount of CO_2 from the atmosphere requires this process to be carried out in a very large scale, the proposed solution do not want to aim only to governing institutions but also to the industrial sector. This is done by achieving negative emission in an affordable way, giving revenues to the investors.

To sum up, the aim of this project is to obtain a process which is both environmentally sustainable and economically feasible.

Understanding the problem

Our task is to study the feasibility of negative emissions technology, Ocean Liming. Since the starting point is a new chemical process, the first step is to study its potentialities; in parallel, the study the state of the art of ocean liming was carried out. The requirement was to evaluate the economic feasibility of the whole process.

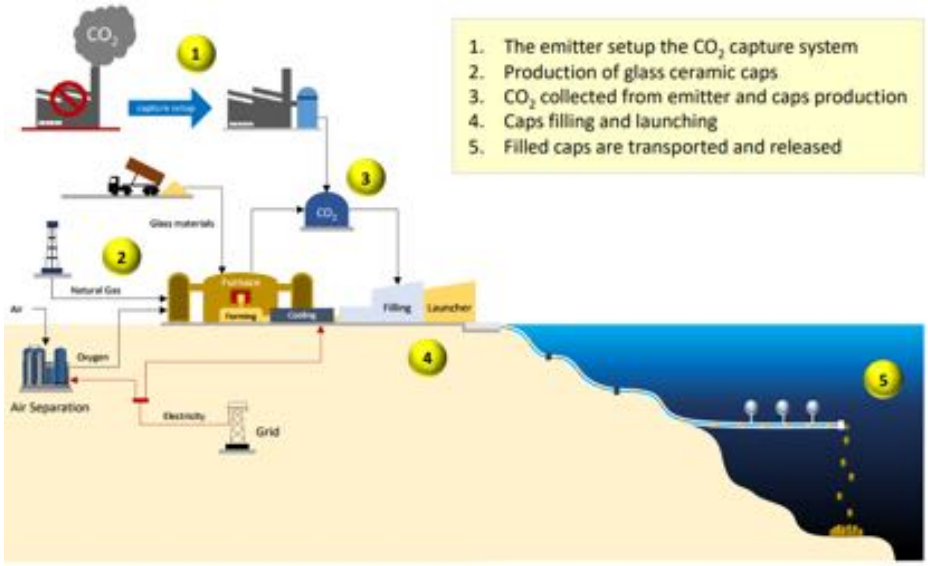
The principal subprocess is gasification, that is a chemical process which is used for producing syngas starting from organic matter, i.e. coal or biomass. Syngas can be used for a variety of production but, in this case it is used for producing hydrogen or ammonia. Both of them are highly valued compound with rising attention in these years and they represent the economical driving factor of the whole process.



Simplified version of the whole process

One of the drawbacks of the gasification process is that it also produces CO_2 as byproduct. However, since we want to achieve negative emission, we cannot emit CO_2 into the atmosphere. The solution is using a technology called Carbon Capture and Storage (CCS) where CO_2 is captured, instead of being emitted, and then stored in different formations. Here two different solutions were considered. The first is use CO_2 for Enhanced Oil Recovery (EOR) where it is used for increasing the productivity of depleted oil fields. The latter is to store it into glass capsule and then put them on the seabed in an innovative process called

Submarine Carbon Storage (SCS). While using CO_2 for EOR represents a revenue for the whole solution, its limited applicability needs to be considered for very large scale solutions. On the other hand, when EOR is not possible or already exploited, SCS represents a good solution since the seabed is a potential infinite sink of CO_2. However further studies are still required for assessing the best location and the real potential of this novel technology.



Carbon dioxide submarine storage in glass vessels

The combination of gasification and CO_2 storage allows to reach almost zero emissions. However, the aim of this project is to achieve negative emission and then removing CO_2 from the atmosphere. This is done through a process called ocean liming or ocean alkalinization.

Ocean is the biggest carbon sink where the carbon dioxide is constantly absorbed. The amount of carbon dioxide absorbed by the ocean depends on the ocean carbonate chemistry. When carbon dioxide is absorbed by the ocean, CO_2 dissolves to form carbonic acid. Carbonic acid further dissociates into bicarbonate and hydrogen ions. Artificial ocean alkalinization (AOA) or ocean liming is carried out to remove hydrogen ions (H^+) and trap more carbon as bicarbonate ions.

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$$

Slaked lime is used for ocean liming in this project. Discharging one mole of slaked lime ($Ca(OH)_2$) will result in sequestering 1.4 moles to 1.7 mole of CO_2 from the atmosphere. The impact of artificial ocean alkalinization (AOA) on the earth climate, ocean pH and carbonate saturation state in the long run has been investigated by different research groups and through different models. Adding 10 Gtons/year of $Ca(OH)_2$ for 80 years will remove 166 Gtons of carbon (602 Gtons of CO_2). This corresponds to a limiting value of only 1.4 moles of carbon dioxide per moles of slaked lime.

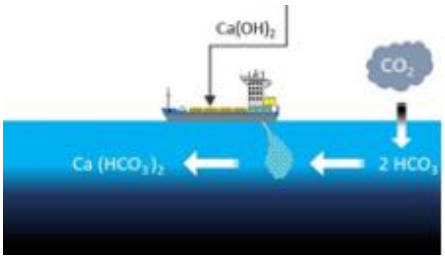
$$Ca(OH)_2 + 2CO_2 + H_2O \rightarrow Ca^{2+} + 2HCO_3^-$$

An important factor of ocean liming is the effect of pH raising on ocean species and ecosystems by means of alkalinity addition. Discharge of slaked lime should not change the pH of the water too much, which can result in harmful environment to the life form in the ocean. According to the water quality guidelines of both U.S Environmental Protection Agency (1976) and the Canadian Council of Ministers of the Environment (1999), human activities should not result in a change in environmental pH of more than 0.2 pH units from normally occurring values. Another important factor is the increase in the calcite concentration should not cross the calcite supersaturation limit. Once the calcite supersaturation limit is crossed, there is precipitation of calcite and the whole

process equilibrium is reversed resulting in CO_2 moving from the ocean to the atmosphere.

To estimate the discharge rate of slaked lime, the ocean parameters such as salinity, pH, Calcite supersaturation concentration, etc are required. Ocean parameters for this project is taken from the Global Data Analysis Project for carbon (GLODAP) data sets, January 2005 as reference. Slaked lime discharge can be mainly carried out using two ways. One is through discharging slaked lime on the wake of a ship and the second method is pointwise injection of slaked lime into the deep upwelling region. This project deals only with the concept of slaked lime discharge on the wake of the ship and calculating a safe discharge rate for the slaked lime slurry.

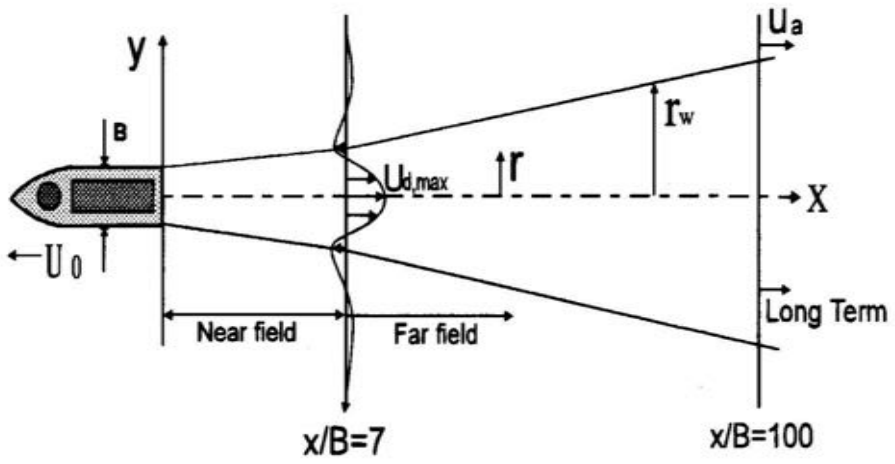
Upweling region



Point wise injection (Wake)

Among the different possible methods to perform ocean liming, dispersal in the wake of a cruising ship was analysed.

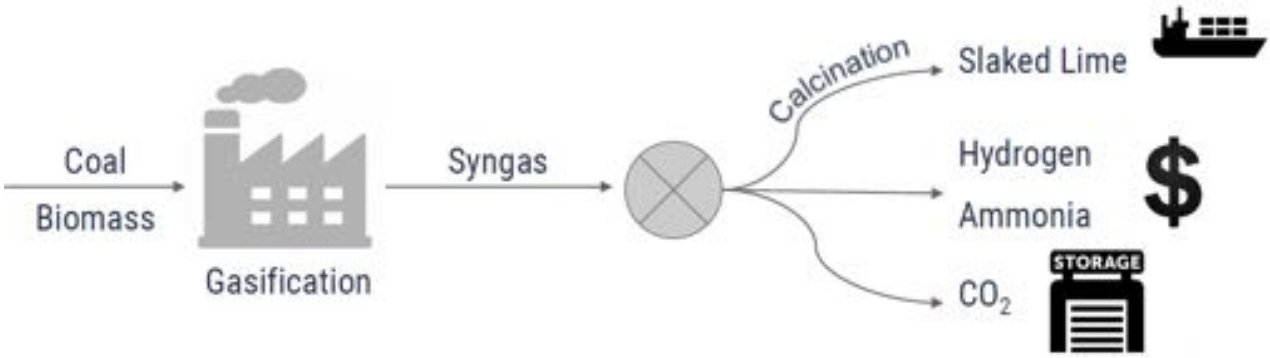
Turbulent motion in the flow region behind a cruising ship enhances the mixing process of slaked lime allowing a higher discharge rate. A momentumless homogeneous turbulent wake model has been considered, assuming a slurry of slaked lime and ocean water which is mixed on board and then dispersed. To keep the generality between different ships, the far field equation was considered for the whole region, since the near field is strictly depending on the ship geometry. Dilution rate is then defined as the ratio of initial concentration on board, which is assumed to be 10 times the supersaturation value for precipitation in the ocean, and the concentration level at a certain time. Subsequently the maximum discharge rate was computed as a function of ocean properties and time, in seconds, to reach a concentration value below the precipitation limit. Dilution rate of this model mainly depends on the speed velocity and width, other than the ocean properties and initial concentration, therefore three different sizes and two velocities for each of them were compared.



Schematic of the wake region subdivision

Exploring the opportunities

Our solution aims at combining the gasification process with the lime production, in a process called calcination, where limestone ($CaCO_3$) is decomposed thermally to lime (CaO). This represent a crucial part of the solution since this combination is never been done before and it allows to achieve both the production of lime, needed for the negative emissions through ocean liming, and hydrogen, the economically driving factor of the whole process.



Concerning ocean liming, in order to keep generality and study the possible different configurations, we select five different locations all over the world: Pacific Ocean, North Atlantic Ocean, Indian Ocean, European Atlantic Coast and Australian Coast.

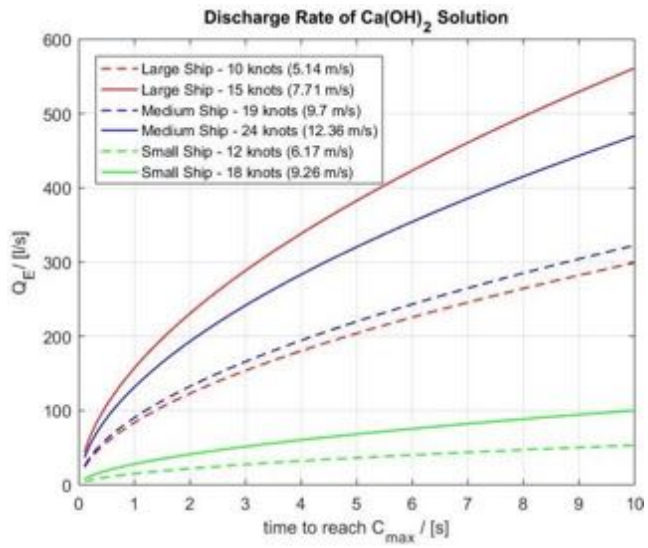
Size	Width\[m]	Speed\[Knots]	
		Maximum	Slow Steaming
Big	60	15	10
Medium	32	24	18.8
Small	15	18	12

Ships dimensions and speeds

Also, three different kinds of ships are selected, with different dimensions and two different speeds are chosen for every ship. In particular, it is worth mentioning the slow steaming speed, that is a speed used in order to reduce the emissions of the ships, so it is very relevant in the framework of this project.

Generating a solution

From the wake model different discharge rates were obtained for the five selected locations. In order to avoid long-time pH variation which could harm marine environment, the selected time intervals to reach a concentration value below precipitation were below 10 seconds. Ship sizes ranged from 15 to 60 meters and both cruising and slow steaming speeds were considered. In the sided graph results for the North Pacific Ocean are reported. For this situation, in case of a large ship (240.000 DWT) for a 5 seconds scenario and a slow steaming speed a total of 45 days would be needed for the total discharge time plus loading and traveling operations, with a discharge rate of 75,5 kg/s of Ca(OH)2.



For the chemical process, since many different fuels can be used, the productivity for each type of input was

evaluated. Five different type of fuel, between coal and woody biomasses, were chosen in order to represent the wide range of possibility in a proper way. Through the writing and the solution of both the material and energy balances, the productivity of each configuration were studied. These results are very important for the following studies since they are needed for assessing the impact of the whole process (from gasification to ocean liming) for unit of input.

For understanding the best location for the plant, Italy, China and US have been considered. For each country, the different process configurations have been analysed both from an economic perspective and also for the amount of CO_2 that is removed. The best configurations is using biomass, producing hydrogen and storing CO_2 through EOR. A sensitivity analysis has been done to test the robustness of the results.
At the end of the project, the team is able to affirm that, even though this is a theoretical analysis, the process is able to achieve CO_2 negative emissions in and affordable way. The best location is California, since it can have the best configuration and it is close to the North Pacific Ocean, which has good properties for what concerns the ocean liming.

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PRINCIPAL ACADEMIC TUTOR
Stefano Capolongo, Dept. ABC, Politecnico di Milano

ACADEMIC TUTOR
Claudia De Giorgi, Dept. DAD, Politecnico di Torino
Cesare Maria Joppolo, Dept. DENERG, Politecnico di Milano
Cristina Masella, Dept. DIG, Politecnico di Milano
Giulio Mondini, Dept. DIST, Politecnico di Torino
Gabriella Peretti, Dept. DAD, Politecnico di Torino
Riccardo Pollo, Dept. DAD, Politecnico di Torino
Francesco Scullica, Dept. DESIGN, Politecnico di Milano
Virginio Quaglini, Dept. ABC, Politecnico di Milano

EXTERNAL TUTORS:
Lino Ladini, Architect, CADOLTO
Thomas Fritsch, HT Group
Andrea Zamperetti, Architect, Salini Impregilo
Alberto Beretta, Engineer, Oppent
Antonio Cianci, Engineer, Airlite
Franco Mola, ECSD
Christine Nickl-Weller, ENAH
Maurizio Mauri, Doctor, CNETO & Fondazione CERBA
Fausto Francia, SItI – Società Italiana di Igiene
Daniela Pedrini, Engineer, SIAIS
Gaetano Settimo, Istituto Superiore di Sanità

TEAM MEMBERS

Francesca Bullo
Industrial Production Engineering, Politecnico di Torino

Emmananda De Martino
Civil Engineering
Politecnico di Milano

Natasha De Santis
Architecture
Politecnico di Milano

Chiara Fignon
Architecture
Politecnico di Milano

Zhao Shuyi
Systemic Design
Politecnico di Torino

Executive summary

Quick obsolescence of facilities, given to the rapid and technological evolution, is one of the main issues that hospitals have to face today. It has been demonstrated that hospitals' lifespan has reduced from almost 500 years to no more than 100 years. Therefore, hospital designers are challenged to find solutions to adapt to this rapidly evolving environment (CAPOLONGO, 2012).
Since XXI century many researchers, scholars and designers have tackled the subject of buildings' flexibility, trying to develop a concept that could respond to these fast-evolving needs, not only in the medical fields (Habraken, Astley, Kendall, etc..) However, when dealing with healthcare facilities, an additional element should be considered: complexity. In fact, first of all, the different requirements of several stakeholders have to be considered and satisfied. On the one hand, patients that should be hosted inside an environment where safety, decorum, comfort and hygiene are granted. On the other hand, medical, administrative staff as well as workers, volunteers and service providers should also be taken into consideration, since they have to spend a large amount of time inside the building and have completely different and sometimes conflicting needs. In addition, efficiency and rapidity should be constantly granted to patients and other users, therefore, the need for flexibility should not, in any way, stop or disrupt the daily activities performed inside the hospital.
Starting from these considerations, this project represents the second step of a research started two years ago by OPEN BUILDING group belonging to the ASP XI Cycle and has the objective of reinforcing the concept by demonstrating its technical feasibility and practical implementation as well as expanding it to several functions inside healthcare facilities. In fact, the concept was developed only for single and double inpatient room by the previous team.
Starting from the Open Building concept (Kendall, 2000), the previous project team was able to scale it down by providing a rough design of the Open Room, ensuring flexibility inside inpatient wards. According to their approach, the whole building, as well as the room are divided into three different parts depending on their durability: Primary, Secondary and Tertiary structure, which are closely interconnected.
The aim of HOS.T research project is, therefore, to deepen the analysis, precisely defining structural requirements, production, installation and transportation constraints and to try to adapt the previous Open Room concept to several different spaces inside an healthcare facility, such as for example staff break room, doctors' offices, ICU room and several others. of 9.6x2.5x3.5m, which is able to host several different functions, and that could easily be plugged in and out from a fixed structure. The room is divided into three separate and independent parts that perfectly fits with transportation maximum allowed sizes and that is able to grant adaptability both on the short and the long term. Once the three modules facility site to be "plugged-in" inside the Primary concrete structure, realized in parallel with the operations performed inside the manufacturing plant. Finally, internal spaces are defined by a series of removable panels, equipped with adaptable furniture that can respond to specific function needed. Given the module size and weight, many existing installation solutions were explored, to come up with the design of a customized platform and a specific mechanism used to easily push the module inside the "partially hollow" concrete structure. Since the concrete structure plays an important role in hosting the modules, it has been designed and equipped with innovative technologies, such as hydraulic jack and PTFE bearing pad, making it a very unconventional structure compared to the common building.
Due to the complexity of the subject, multidisciplinary approach was fundamental to address and find a balance between the several existing requirements and constraints. Several case studies and previous researches were analysed, and experts' points of view consulted during meeting and technical visits in healthcare facilities, in order to come up with a solution that could practically and technically be implemented. The advantages generated by this new approach cover multiple aspects, such as time saving, high flexibility and long-term cost reduction.
The time required to complete the building which is almost halved if compared to the one needed for a traditional construction. Off-site and on-site operations can be performed at the same time, reducing the project

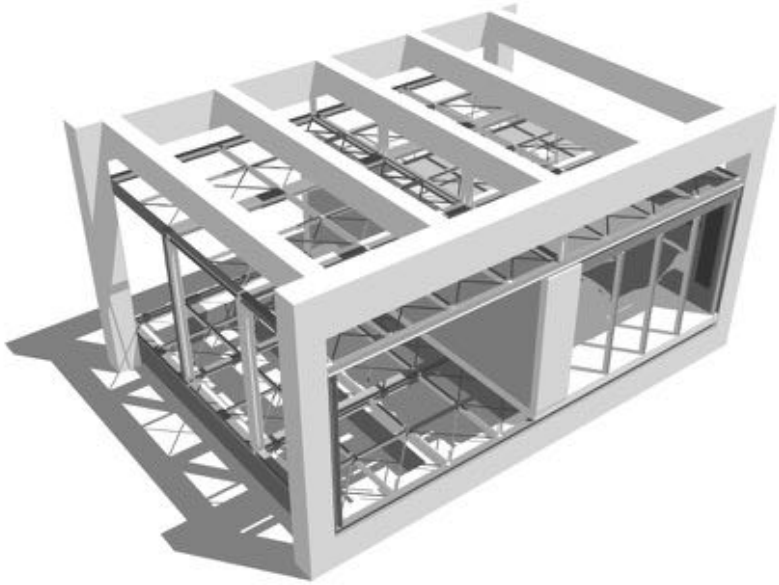
Wan Chih-Wei
Interior Design
Politecnico di Milano

Devin Tan
Civil Engineering
Politecnico di Milano

schedule, as well as the project budget. It can be argued that the prefabricated techniques are not excessively innovative solutions since they have been used for centuries. However, over the years, it has always been considered as low-quality technique, often used for temporary solutions. Today, opinions are changing, since new materials are being used which are characterised by a very high quality and long duration and several architects and designers are finally seeing the benefits brought by prefabrication. In addition, the more innovative element of this project is not really connected to the modules' construction technique, but rather to the concept that is hidden behind the Open Room: a flexible space that is able to keep up with changing demand, that can be easily moved and perform several functions, realized with high quality and hygienic materials.
On the other hand, the Open Room solution is able to create economic benefits, hidden behind a quite high initial investment. As a matter of fact, the cost estimation that was made referring to materials and standard operations prices revealed that the initial cost is much higher than the one generated and that the solution will be unlikely adopted by public institutions. Nevertheless, the time, money and interventions that are saved thanks to the implementation of this solution should also be considered as part of the cost estimation and analysis.

Key Words

Open Building, Flexibility, Healthcare System, Hospital, Prefab



Project description written by the Principal Academic Tutor

According to the World Health Organization (WHO), the environment is defined as 'an integrated system of human and physical factors exercising a significant effect on health, considered not only the absence of disease but as a complete physical, mental and social state'.

One of the most important challenges that architectures for health must cope with is to be resilient to social, economic and clinical changes and, meanwhile, to ensure that the healthcare system, services and assets respond to the constantly changing needs and the specificities of several country's healthcare system and organizational models.

The rapid evolution of medical knowledge and technological tools determined healthcare facilities' unsuitableness after few years of their construction. Therefore, scholars and professionals, involved in hospital design, are called to look at new strategies in order to respond to the current and future challenges.

Starting from these needs, the more consolidated approach is to ensure flexible health facilities. Flexibility is the ability of a building to respond to service change to different time cycles. In relation to the health issues, the flexibility in hospitals should include a multi-scale vision ensuring real efficiency of the services provided with respect to continuous changing systems, social and economic needs, epidemiological trends. Flexibility can range from the planning level to the local services' network system, from the health buildings in which delivers all the services to the mono-functional environmental units; all these layers should be structured with respect to organizational and managerial levels in an adaptive and resilient way.

In recent years, the knowledge in flexibility to adapt to service change has been developed and analysed by several scholars from different study fields: it is the ability of a structure to be able to change its functions and environments in the short, medium or long term, based on the costs and users' needs. This capacity for transformation can be ensured only by a building designed in the pre-design phase in accordance with technological, structural and plant engineering criteria specifically oriented towards the flexibility of the entity itself.

As a consequence, flexibility has become an essential key point which all the operative and future hospitals must achieve. In recent years research in the healthcare building sector has been focusing on systems highly adaptable from the technological to the structural scale, from the building plant engineering to functional level. Several research groups are developing design strategies to improve the flexibility for the design of significant spaces which are essential to ensure high levels of quality to the growing number of new demands.

Then it is clear that hospital project, often unsuitable to meet the organizational complexity's needs of a healthcare facility, is subject to changes over time. It is necessary to define technological and constructive solutions that permit the environmental flexibility to guarantee future changes with minimal impact on the entire building systems and users.

Currently, several scholars are deepening the Open Building approach: it deals with a strategy based on constant surface flexibility, the ability to change and to adjust to new layouts without increasing its area. There are spatial and functional redistributions and the attempts to design inner spaces with a high level of adaptability. By reducing excessive and useless dependencies and entanglements among these components of the project, it is possible to ensure their operation without interference or damage to the others. A preliminary distinction between durable elements and those that are more prone to be changed, allows easier, quicker and low cost actions and a greater level of customization. Sometimes, this kind of approach can be useful when dealing with quickly changing regulations and strict bureaucracy that does not suit the long timeframe of the designing and constructing process of complex structures, such as healthcare facilities. For the application of the Open Building approach to healthcare facilities, it is necessary to individuate three systems: Primary System (the Structure), Secondary System (the Components) and Tertiary System (the Equipment).

Starting from this approach, a research work is giving rise to a prefabricated module system for hospital environments able to guarantee maximum adaptability in inpatient wards. Starting from the know-how on prefabricated bathrooms and operating rooms, as well as several prefabricated hotel rooms, it is possible to imagine and design a prefabricated inpatient room during the construction phase. It

can be of easy installation and replaceable in case of changes for maintenance and/or modification of the function. This is easily seen that several existing hotels and office buildings are designed with prefabricated rooms that change for different users and present possible variations in creating the interiors by combining colours, materials, lighting, furniture, etc.
As new trends require greater emphasis on research and outpatient clinics' spaces, inpatient wards will always be present in a hospital. Its layout is very different from a hotel one for several logistical and functional aspects, but the user's rooms are very similar, although differences persist on their dimension, engineering plants, furniture and materials. The patient hotel tries to merge these two typologies, in fact it is a hotel that offers accessible rooms for discharged patients and some outpatient clinics and a specialized staff (nurses and doctors) within the structure.
The structural grid must be regular and should guarantee the maximum future flexibility (predictable layouts) and futuristic one (unpredictable layouts). It is crucial to understand and define the maximum adaptability of a structure over time and therefore the dimensional issues should guarantee several future scenarios. Current trends introduce technologies that permit the constant and variable flexibility. Moreover, structures realized with reinforced concrete or steel are preferable with structural framework between 7 and 8 m. In addition, several case studies present technologies that allow fix prefabricated modules to the façade, such as the Martini Hospital in Groningen, or to transform setbacks spaces, verandas and terraces to improve the environments' dimension.

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Team description by skill

The team is composed of Master students from different discipline and each of us contributes to the project in correspond to his/her capabilities. Given the size of the team, the communication is carried out in both verital and horizontal manner so that everyone is always updated and no information is lost. Regardless of our position in the structural organization, everyone plays an important role in making the project works as a whole. In overall, the job description for each member is listed as follow:

1. Devin Tan
   Role: Team Leader, Team Controller, Structural Engineer, and BIM Drafter
   Job Description: Arranging both internal and external meeting with tutors and stakeholders, Identifying and distributing workload according to deadline, Managing budget and project expense, Conceptual study of room layout, Conceptual and preliminary study of the structure and construction procedure, Integrating the structural drawing in BIM.
2. Emmananda De Martino
   Role: Structural Engineer and Construction Manager
   Job Description: Conceptual study of structural design and construction procedure, Cost estimation of the modular room, Construction time management of the modules.
3. Francesca Bullo
   Role: Logistic Manager, Production Manager and Business Analyst
   Job Description: Transportation analysis of the module, Production process of the module, Business model estimation, Cost and time estimation of the modular room.
4. Natasha De Santis
   Role: Design Coordinator and Architect
   Job Description: Coordinating the design team, performing preliminary and detailed design of the rooms including layout, wall panels, ceilings, and materials.
5. Chiara Fignon
   Role: Architect and Marketing
   Job Description: Performing preliminary and detailed design of the rooms including layout, wall panels, ceilings and materials, preparing project book and poster.
6. Zhao Shuyi

Role: Furniture Designer and Marketing
Job Description: Identifying and designing all of the furniture elements inside the rooms, 3D rendering of the rooms, Printing flyers, Making promotional video.

7. Wan Chih-Wei
Role: Lighting Analyst, BIM Manager and Marketing
Job Description: Conceptual study of room layout, Lighting analysis of the rooms, Integrating architectural drawing in BIM and checking BIM model to ensure zero clash between structure and architect element, 3D Rendering and Virtual Reality of the rooms, Making promotional video.

Goal

The concept of Open Room developped by a previous ASP research team is capable to solve the current flexibility issue. However, the concept still needs to be refined and explored even further. As a matter of fact, hospital is not only about inpatient rooms; there are other rooms whose functions can be considered essential so that the hospital can work as a whole. Moreover, different rooms have different needs and requirements, which means that some minor or even major adjustments might be required. In addition, flexibility is not restricted to a single room; it also concerns the interaction between each room and the possibility of changing the room layout every day due to different needs.

The aim of current HOS.T team is, therefore, mainly linked to the deepening and extension of the concept developed by the previous ASP Cycle. As a matter of fact, one of the main weaknesses of the previous Open Room project was the fact that just one room had been designed and studied, without considering the possibility of using the same concept to integrate other functions inside the same space. It is true, indeed, that single inpatients rooms are probably the most common and used environmental units inside an healthcare facilities, given to the increasing number of chronic diseases and the decrease of the average duration of hospitalization. Moreover, studies are showing that single rooms are preferred with respect to double or multiple rooms. However, several users should be considered inside hospital scenarios and several needs should be addressed too, to be able to offer the most complete, flexible and efficient solution.

Keeping all these elements in mind, a preliminary selection of environmental units was made, on the base of the function performed and the frequency with which these rooms could be found inside a healthcare facility. In addition, low implant redundancy has also been selected as a criterion to define the rooms and functions that the Open Room could address. More redundant and simple rooms were therefore selected, and several possible layouts proposed before coming up with the final one. Compared to the XI Cycle, HOS.T project provides a wider solution, gathering seven different functions inside one single room.

Beyond increasing room flexibility, HOS.T research group was also required to provide a "stronger" solution, especially from a structural point of view. The three structural layers – Primary, Secondary and Tertiary structure – should be thought and designed as a whole. Every part should be studied separately from the other ones, with its own characteristics and requirements but then, they should be joined together to be sure that no conflicts exists between the different elements. The final output of the project, indeed, was supposed to be a ready to be installed room for which all the possible issues connected to construction, module manufacturing, transportation and installation had been addressed and solved.

That is the reason why, compared to the previous project, the construction and installation phases were more deeply analysed and customised solutions were provided, in order to present a complete and functioning concept, under several points of view.

Understanding the problem

Healthcare infrastructure planning, design and its project management involve a complex interaction of factors that determines the distributions of its resources. In the planning process, these factors are interrelated and an interdependent multi-disciplinary approach is required in order to organize the hospital in an efficient way over the time. A strict division of works inside the team of designers (engineers, architects, etc.), producers and customers is impossible since the solution that can be functional from an engineering point of view, may be inapplicable for architectural needs or vice versa. At thé dame time the needs of producers and customers must be taken into consideration for the evaluation of the healthcare facility feasibility.

As a consequence, the designers should look for some “shearable constraints” in order to implement all the operations connected to such a project.

What is currently happening is that hospital designs are incapable of adapting to the needs connected to hospital organizational complexity and keeping up with the ever-growing capacity of hospital technologies (Astley et al., 2015).

As a consequence, the flexibility has become a key element for all the changes due to the progress of medical and technological acknowledges.

In addition to that, sustainability has become one of the most widely recognized issue around the world. Healthcare facilities, being one of the most integral, social and economic infrastructure to support the lifeline of a city, are also a subject of this matter.

In fact, hospital obsolescence has experienced a fast increase over the past decades, which ultimately will lead to a major sustainability issue (Capolongo et al., 2012).

In several developed countries, this issue has been tackled by governments that decided to incorporate this concept into their local regulations. As a result, new facilities nowadays are required to consider sustainability as an input in their design, while all the old facilities are to be assessed of its sustainability performances (Capolongo et al., 2014).

Exploring the opportunities

New technological trends and attention to patients' needs have strongly influenced the way in which new hospital layouts are designed.

From the architectural point of view, the main layout typology is the "slab" but new trends are introducing the "vertical monobloc" to shape the hospital. The functions hosted by the former layouts are mainly diagnosis and cure, administration and reception with an intrinsic flexibility in the spatial organization. For what concerns the second possibility, there can be 3 common different organizations of layout, that can be easily seen in the table below:

Double fold body

Triple fold body

Fivefold body

The research on hospital layouts and configurations is an ongoing process. It is of big interest the Piano-Veronesi (2001) made by the arch. Renzo Piano and the Italian Ministry of Health, dr. Umberto Veronesi, of that time. This research aimed at studying the functional organization and spatial distribution for the contemporary hospital, both considering the technical and social point of views. Four levels of intensity of care are considered: intensive care, high care, day care, day surgery, low care. The Piano-Veronesi project did not give structural design rules but offered functional and typological plans and sections with several proposals of spatial organization even at the inpatient room scale.

The evolution of the hospital layouts is going towards the application of the structural flexibility concepts; this leads to the use of primary structures which must be as much regular as possible in order to be easily divided into modules of dimensions 7 to 9 meters ensuring the passage of the wheeled beds in the inpatient rooms.

The first attempt of merging flexibility and prefabrication was in the 30s when Buckminster Fuller designed and produced prototypes of residential units easy to assemble with a two-piece prefabricated bathroom. After the Second World War, many studies were conducted on prefabrication so as to satisfy the rapid demographic growth; in the Sixties, flexibility became a dominant aspect in the building constructions.

It was not only a matter of housing, but also for healthcare facilities the concepts of flexibility were made in practice in the last decades. The first and most famous solution is the use of containers: it allows future expansions but it does not allow

changes in the so-called "primary" system since containers are also part of the structural element. However, their dimensions are small so that the comfort of the inpatients inside is reduced.

A second approach to solve the flexibility need is the use of some prefabricated panels which constitutes the internal walls of the hospital: the Industrial Flexible and Demountable (IFD) Building. This technique implies that there must be a complete planning and design of the internal layout of the room in advance so as to let the company produce all the panels. Some instructions must be given in order to mount on site the panels.

The advantages of this approach are multifold: the workers are exposed to less risks on site since the complete production of panels is done in a safe and controlled environment, the construction time is reduced since the production of panels starts even before the actual building phase and the time spent for the assembly is much lower than the one required for ordinary wet technologies, very high flexibility of the internal spaces since panels can be removed, changed or even upgraded.

Generating a solution

Having understood the complexity of a hospital, which are the needs of the community, the state of the art and the trends for the future, it has been possible to design a solution that took into consideration all the concepts aforementioned, with a specific attention towards flexibility.

The intention was to apply the Stephan Kendall's Open Building approach and the Open Room concept to develop a design procedure obtaining smart, contemporary and prefabricated rooms inside modular prefabricated elements deliverable on site. The aim of this innovative system is realizing multiple room layouts and configurations, within the same dimensions, in order to have a variety of solutions according to several different needs.

After a deep analysis of the two solutions advantages and drawbacks, the decision was taken to mix them together and come up with a concept which could grant flexibility both on the long and short term. Therefore, modules have been designed with an IFD approach in order to have the most flexible solution, without having to renounce to the advantages of a rapid construction and installation procedure. In fact, a prefabricated modular room, divided into three parts (modules) for easy transportation, have been designed. The modules are then put in a primary structural frame with a plug-in mechanism and assembled once positioned inside to form the different rooms. As a consequence, the flexibility would be ensured both in short terms (5-10 years with IFD approach) and in long terms (20-40 years with Plug-in concept).

National and international case studies have been analysed in order to define the most suitable structural grid for the primary system, which is between 6.00 and 9.00 meters. In addition, the study of hospital standards and spaces required to host furniture and technical equipment, finally led to the definition of a rectangular structural grid which could host seven different environmental units with different functions.

The secondary structure, composed of three separated modules as well as the tertiary system are totally manufactured inside the factory and are then transported on site to be plugged inside the primary structure.

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PRINCIPAL ACADEMIC TUTOR
Alessandra Zanelli, Architecture, Built Environment and Construction Engineering Department, POLITECNICO DI MILANO

ACADEMIC TUTOR
Giacomo Frulla, Department of Mechanical and Aerospace Engineering (DIMEAS), POLITECNICO DI TORINO

EXTERNAL INSTITUTIONS
Composite Research SRL (Italy)
TensiNet Association (Brussels)
Rasero SRL - Plastomer Engineering (Italy)

EXTERNAL TUTOR
Nicola Giulietti, Project Manager at Composite Research SRL
Andrea Micheletti, Departement of Civil Engineering and Computer Science Engineering, UNIVERSITY OF ROME TOR VERGATA

TEAM MEMBERS

Edoardo Marcandelli, MSc. Degree in Building Architecture, Politecnico di Milano

Francesca Perego, MSc. Degree in Building Engineering Architecture, Politecnico di Milano

Roberto Rossi, MSc. Degree in Civil Engineering , Politecnico di Milano

Eleonora Teruzzi, MSc. Degree in Interior Design, Politecnico di Milano

Eleonora Valle MSc. Degree in Architecture, Politecnico di Milano

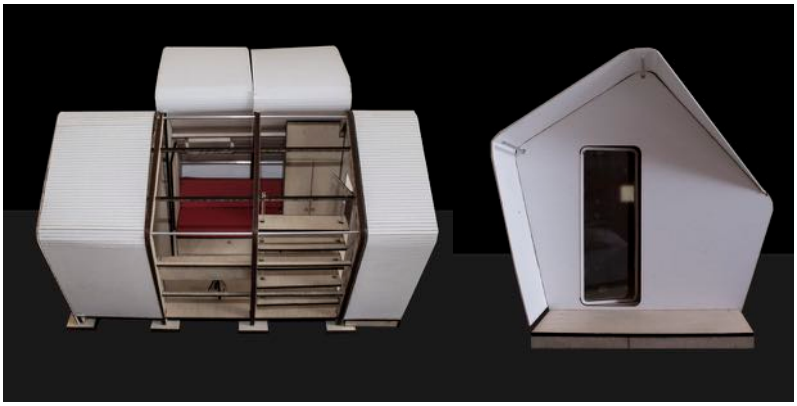
FLEX-HAB

Executive summary

FlexHab project investigates a possible field of application for a new composite material, the MadFlex, and develops a specific construction technology regarding flexible housing solutions. The material has been developed by Composite Research srl: it is a lightweight composite panel sandwich-like structured. It has two innovative features, from a mechanical point of view: it is flexible and rollable on one side, while is stiff and crushproof on the other; from an energetic point of view it has good thermal performances in relation to its thickness.
Concerning the different possible fields of application, from the preliminary analysis emerged how the potential of MadFlex is addressed to the critical context of disaster management and can be efficiently deployed for the construction of emergency shelters. In the Italian context, the "Recovery period" is conventionally split into "Medium-term supplementary reconstruction sub-period" and "Definitive reconstruction sub-period", in which shelter solutions employed are wooden houses, containers and SAE (Soluzioni Abitative di Emergenza meaning "emergency housing solutions"). The FlexHab project proposes a solution able to eliminate the first sub-period and to significantly reduce the overall timing of the "Recovery period".
Some crucial points of the research were how to approach an innovative material and which constructive and technical systems choose according to the materials properties and the specific requirements of the emergency shelters topic. The main goal of FlexHab is to conceive a shelter solution for both private and public market, allowing for a revolution of the disaster management processes and combining the requirements of comfort, flexibility, affordability, smart technical solutions and life cycle sustainability.

Keywords:

Emergency shelter
Madflex
FLEXible HABitat



Final solution, model 1:20

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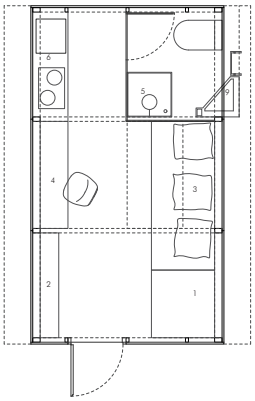
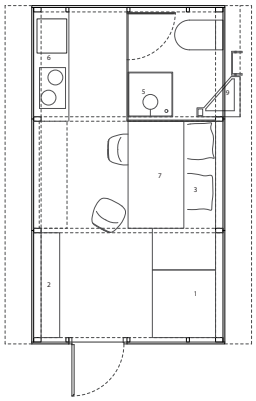


1 Closed wardrobe
2 Hanged shelves
3 Sofa-bed
4 Flap desk
5 Shower
6 Kitchen forn
7 Flap-table
8 Curtain
9 Washbasin

pm



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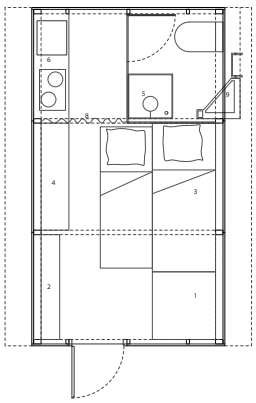


Rendering and plants of the shelter interiors depending on daily activities

Project description written by the Principacipal Academic Tutor

The project will be concentrated on creating a technology push for a new material. The MadFlex (PCT WO2016120785 A1) is a lightweight asymmetric composite material panel, having a sandwich-like structure. It exhibits two order-of-magnitude difference in bending stiffness, depending by the direction of the applied bending moment, thanks to a reversible buckling phenomenon of one of its skins: it is flexible, even rollable, on the one side, while it is rigid like a traditional sandwich panel on the other one. In addition, its foam core confers to the MadFlex good insulation properties.
The design and development of a novel flexible habitat starting from the potentialities of the new material will face a multiplicity of research needs which will be integrated into a systemic approach and organized in four main steps:
1. The requirements identification: at the material / building component / habitat level. The new material will be tested and its characterization will orient the right matching with a set of technical requirements for adaptive structures and flexible skins.
2. The form + structure integrated design process: supported by advanced form-finding design tools and performance-based modelling tools.
3. The experimental phase where a first demonstrator of the new adaptive skin will be installed and tested to validate the behavior of the new habitat and to optimize its final design.
4. The study of different application of the novel habitat solutions and the evaluation of social, economic and environmental impact by using multi-criteria analysis, Life Cycle Cost (LCC) and Life Cycle Assessment (LCA).

Team description by skills

The FlexHab team is composed by five students from the field of architecture, engineering and interior design. To each component a specific role was assigned in order to develop a strategic topic:

Edoardo Marcandelli: (MSc. Degree in Building Architecture, Politecnico di Milano) study of details of mono-material and/or hybrid structural solutions, study of the thermal performances.

Francesca Perego: (MSc. Degree in Building Engineering Architecture, Politecnico di Milano) optimization of the packaging and transportation issues, study of environmental and economical sustainability of the solution (LCA and costs survey).

Roberto Rossi: (MSc. Degree in Civil Engineering, Politecnico di Milano) structure optimization.

Eleonora Teruzzi: (MSc. Degree in Interior Design, Politecnico di Milano) study of the interior spaces, space optimization through the use of furniture considering the user perception (user friendly solution).

Eleonora Valle: (MSc. Degree in Architecture, Politecnico di Milano) morphological study, settlement and architectural composition strategy, design of interior spaces and functions.

Goal

The FlexHab project goal is to design and develop of a novel flexible habitat starting from the potentialities of the new material, the MadFlex.
The main objectives are:

1. Apply a multi-functional, flexible, "aeronautics-derived" composite material (MadFlex) to figure out futuristic habitat solutions.

2. Improve a revolutionary approach to the building system introducing an innovative technology

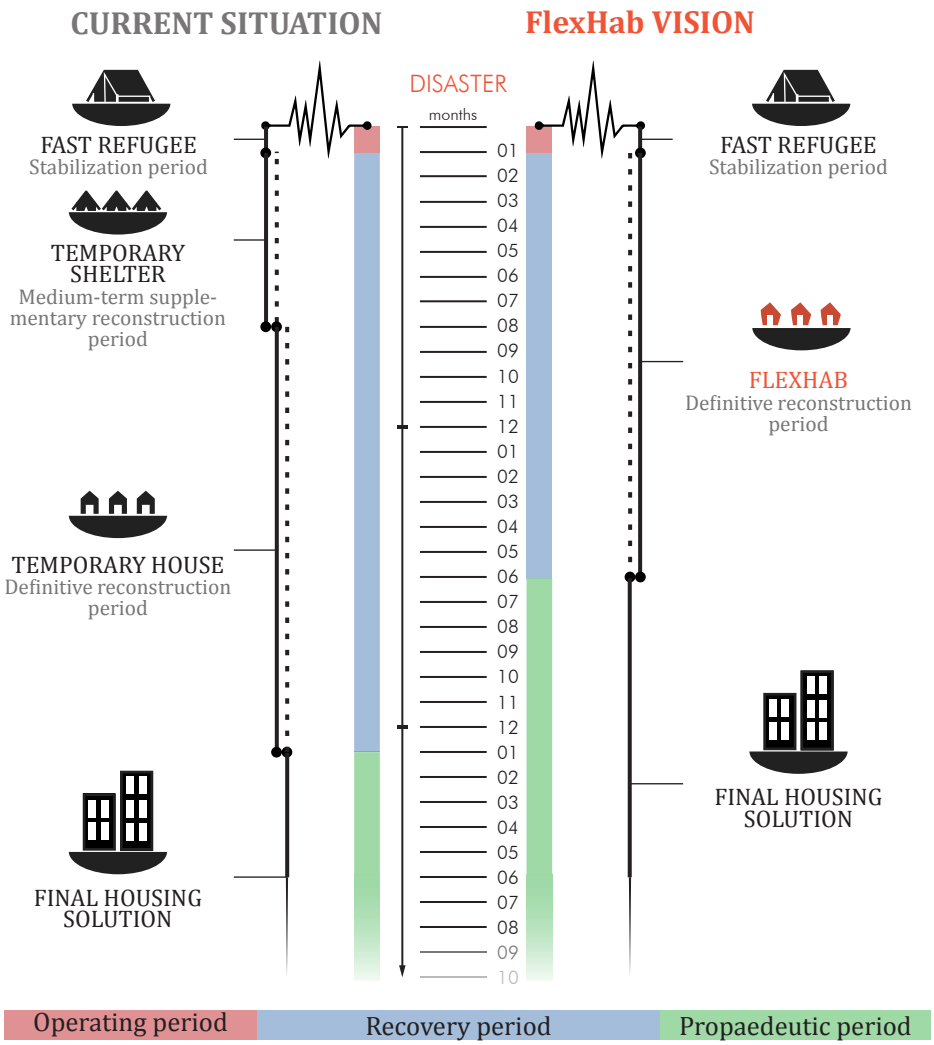
3. Envision an innovative building skin, seamless and integrated with the structure, considering the industrial production requirements.

4. Satisfy user needs through an economical and social sustainable solution.

5. Investigate performances and the economic feasibility of a basic adaptive habitat.

Understanding the problem

The MadFlex (developed by Composite Research srl) is a composite material panel with a layered structure, practically a sandwich-like structure. The uniqueness of the MadFlex consists in its mechanical feature: the panel of MadFlex is flexible, even rollable, on the one side, while it is crushproof on the other. Investigating the possible scenarios where MadFlex properties could be determinant to perform a revolution inside the market, emerged that the Emergency Shelter field was the most suitable to develop new innovative solutions. In fact, in the Emergency field the more relevant requirements are: transportability, MadFlex is rollable and lightweight; constructability, MadFlex is lightweight and could be equipped in the production phase; performances, MadFlex has good thermal and mechanical performances; customizability, MadFlex could be customized with different finishing.
Looking for possible stakeholders involved in the Italian scenario and analyzing their needs, the main requirements were outlined. Victims of calamitous events demand an increasing of comfort and quality of life inside the emergency shelters as well a more user-friendly solution closer to their houses. Institutions as government and Protezione Civile department require a decreasing of costs and time of the solution and an increasing of performances and social sustainability. Finally stakeholders interest in trade, production and advertising of the FlexHab proposal are in concern about competitiveness of the project solution that must be more sustainable, in terms of cost and social impact, of the existing ones.
In Italy, the management period of post calamitous event is conventionally split in different phases to which correspond different emergency housing solution. Firstly, temporary shelters as containers and wooden houses are used to provide an immediate aid; nevertheless, they are not positively evaluated by the population because of the lack of comfort and security. Meanwhile, SAE (meaning "emergency housing solutions") are built to host the disaster victims. They are well appreciated because of their tendency to look like as permanent houses, on the other hands they are available too far from the catastrophic event.
Therefore, the FlexHab project proposes in a unique solution the positive aspects of the existing solutions: the "just in time" deployment of the shelter and the high level of comfort.



The emergency management process, Current situation applied in italy and FlexHab innovative scenario.

Exploring the opportunities

The potential of MadFlex is better addressed to the critical context of disaster management and can be efficiently deployed for the construction of emergency shelters, thanks to many peculiarities intrinsic in the material. For instance being flexible and rollable on one side, and stiff and crushproof on the other, it allows both an easy and efficient transportation/stock, and a rigid livable skin. In consequence one of the main assets was design a shelter that would be easily stocked in a FlexHab-kit that, as for common tents kits, is easy to transport, built and dismantled for future uses. Moreover, conversely to many composite materials, MadFlex can be moulded and accessorized in a continuous flow process, saving up to 50% of the cost spent with a warming process and meanwhile, addressing constructive needs as introduction of joints, during the production phase. Facing the emergency shelter issues, low cost, easy and fast implementation are fundamental requirements. In consequence, modularity becomes a smart answer to fit industrial production necessities as well for the settlement and the architectural composition of the artefact. Furthermore, from an energetic point of view it has good thermal and acoustic performances in relation to its thickness guaranteeing good thermal level of comfort for the shelter.

Goal

The FlexHab project proposes an efficient solution to manage the "Recovery period". This revolutionary impact on the disaster management is allowed by the integration of the tent technology, as easy and fast to deploy, with the home archetype, as private and human scaled space, in a unique FLEXible HABitat.
"Flex" as flexible, since the initial point for the project has been the innovative material of MadFlex and its main peculiarity. Its morphology mirrors some of the potentialities of the materials. Flexible both for the material's behavior and for the internal space's conception: in fact the design of the furniture integrated in the structure allows for a different arrangement of the living areas according to daytimes and night-times. "Hab" refers to habitat, the space of domesticity, a new and starting living fulcrum to heal the loss of a house.
Thanks to the pentagonal modular design and innovative joints introduced in the production phase, the whole envelope can be set up through a single construction gesture. No specialized craftsmanship, specific tools or heavy machineries is needed: only a complete "kit" with assembly instructions and technical support would be provided.

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PRINCIPAL ACADEMIC TUTOR
Stefano Carabelli,
Dipartimento di Automatica e Informatica
Politecnico di Torino

ACADEMIC TUTOR
Pietro Nume,
IAAD – Istituto di Arte Applicata e Design

EXTERNAL INSTITUTIONS
Etra Project S.r.l.s.
Italtecnica S.r.l.

EXTERNAL TUTOR
Matteo Barale,
Etra Projects S.r.l.s.
Girgor Hili,
Design Project Responsible.

TEAM MEMBERS

Jacopo Berlusconi,
Energy Engineering
Politecnico di Milano

Marco Boretto,
Mechanical Engineering
Politecnico di Torino

Paolo Marini,
Management Engineering
Politecnico di Milano

David Nchekwube Chukwudi,
Mechatronic Engineering
Politecnico di Torino

Andrea Radicioni,
Mechanical Engineering
Politecnico di Milano

RISCIO'

Executive summary

Car sharing providers are trying to enable the concept of Mobility as a Service (MaaS) in Cities. However the business is not profitable. This is due in particular to the use of vehicles that are not designed for the sharing purpose. For this reason car sharing services do not completely satisfy users' requirements and generate excessive costs. Risciò project aims to produce a platform that can enable MaaS in a profitable way, connecting users, providers of the service and vehicles. Drivers of the solution are modularity, adaptability and essentiality of the platform. Inspiration was often searched outside the automotive field.

The ASP team developed a completely new User Interface that integrates smartphone and steering wheel, and designed a new Heating Ventilation and Air Conditioning (HVAC) system that provides users with personal thermal comfort but cuts energy consumptions. The innovative and sustainable business model exploits Risciò's competitive advantages focusing on small-medium sized locations. Renders, physical demonstrators and simulations were produced to prove the proposed concepts.

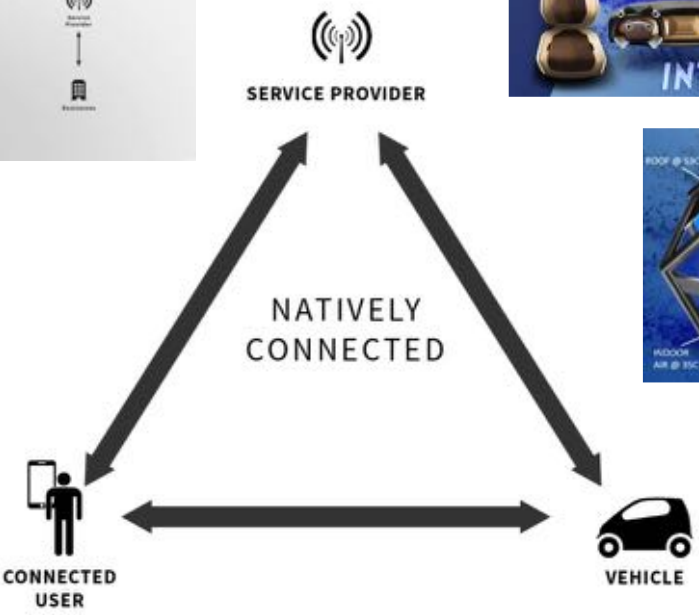
Key Words

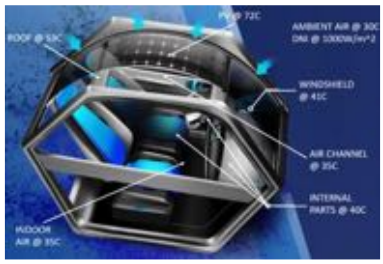
Mobility as a Service (MaaS), Car sharing, Business Models, HVAC, User Interface.

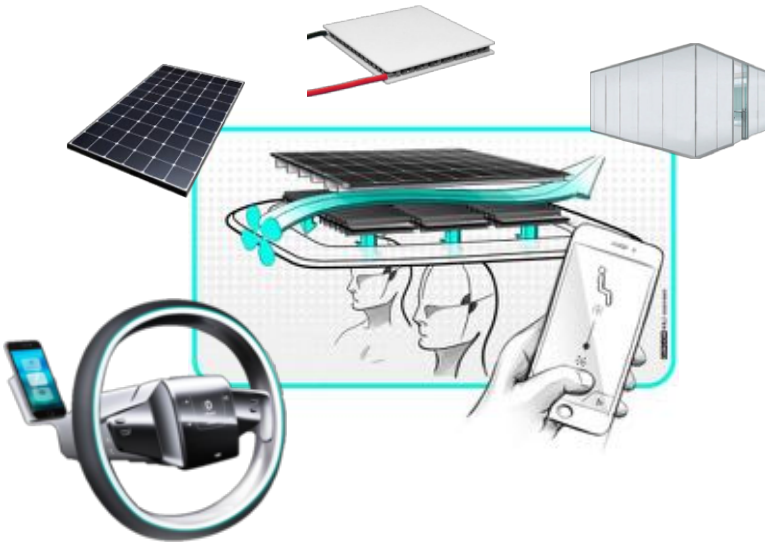
risciò

Born to be shared


BESPOKE
ON DEMAND
INTERIORS


SERVICE PROVIDER
NATIVELY
CONNECTED
CONNECTED
USER
VEHICLE





Project description written by the Principal Academic Tutor

In the Mobility as a Service context, and in particular regarding car sharing, Risciò Project aims to address the needs for a platform "born to be shared", flexible enough to be exploited in different kind of shared economy frameworks, and able to provide a complete service in a profitable way. According to this vision, the platform should not only consist in an urban mission dedicated vehicle, but needs to comprehend add-in devices, an app that permits configurations by the user and an IT system that manages the service. All the phases of the service are considered, starting when the user is off board, accompanying him/her during the driving phase until he/she stops the ride, and allowing for full connectivity during the whole process. With the aim to develop such a platform, the ASP Risciò Project focused on developing innovative technological and business solutions, specifically designed for a well-defined niche of customers and users. From the technological perspective, the team worked on the User Experience for an urban vehicle to be used in different kind of sharing economy scenarios such as car-sharing or corporate fleets. Designed to be integrated with an innovative modular rolling chassis that supports patented battery pack and electric motors, previously developed by the project's technological and design partners, the main technologies developed by the ASP team regard the Heating Ventilation and Air Conditioning (HVAC) system and the vehicle User Interface. In particular, in the developing of the HVAC system the main focus has been to reduce the energy consumptions of the acclimatization system, that cause a range reduction of about 25% in standard electric cars, and even more in vehicles employed in car sharing, due to the short and frequent trips characterizing the service. Concerning the User Interface, the proposed solution aims to reduce the complexity of the user interactions along the whole service, integrating off and on board phases in a complete and safe experience. From the ergonomic perspective, the team focused on realizing a solution that fosters safety and intuition, defining "Eyes On Road" and "Hands On Wheel" as driving principles. Moreover, the proposed UI can also reduce interiors related production costs, by optimizing the number of components involved, reduced to only four buttons and a wheel mounted screen. To prove the validity of what designed, the ASP team developed a thermodynamic analysis modelling the key features of the HVAC solution, the mock up of the User App and demonstrators of both the HVAC system and User Interface. Finally, from a business perspective, Risciò Project explored innovative solutions that can sustain small-scale application, in order to take advantage from the agility that characterizes growing startups and the relative availability of local investors. Moreover, a sound simulation of the revenue and cost model has been carried out to evaluate the impact of the Risciò platform adoption, bringing evidence of improvements in profitability of car sharing businesses, tackling mobility problems in both small and large cities.

Team description by skill

The team is totally composed by engineering students, coming from the Politecnico di Milano and Politecnico di Torino.

Jacopo Berlusconi, Energy engineering, Polimi, Thermodynamics, Power production and Management.

Marco Boretto, Mechanical engineering, Polito, FEM analysis, CAD Prototyping, Ergonomics developer.

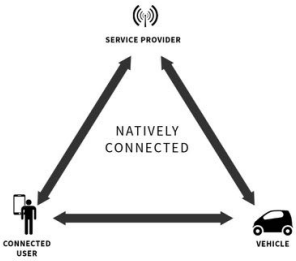
Paolo Marini, Management engineering, Polimi, Business analysis, accounting, project management.

Nchekwube Chukwudi David, Mechatronic Engineering, Polito, software developer, electronics, circuit design, App prototyping.

Andrea Radicioni, Mechanical engineering, Polimi, Automotive, Product and Manufacturing developer, electronics.

Goal

Risciò project is aimed at developing an innovative platform, constituted by vehicles, softwares, and technologies, designed to suit and empower sustainable business models for Mobility as a Service (MaaS), adopting a B2B approach. The goals of the ASP team are the development of specific elements of the platform: the User Interface, the HVAC system and the business model, integrating them with the chassis and powertrain previously developed for Risciò by the project partners. The team aims to produce the conceptual design of UI, HVAC and business model, to translate the key features in physical demonstrators, and to perform simulations able to prove the effectiveness of proposed solutions. In the following are explained specific goals for the three parts. User Interface: design of a new UI, integrating different media of interaction, with the specific purpose to simplify and enhance the user experience within the service. HVAC: design of an innovative configuration able to ensure user comfort while minimizing energy consumptions, weight and cost. Business model: definition of contexts and strategies providing Risciò with competitive advantages and profit opportunities.



Understanding the problem

Modern cities are characterized by congestion and pollution, largely related to transportation issues. Many solutions worldwide were adopted to tackle these problems, spreading the MaaS paradigm. In particular, car sharing is a growing phenomenon well coupled with the present sharing economy trend. This market is dominated by big players as Oil and Gas companies, automotive enterprises and big battery manufacturers. However, the current business models are not profitable since the costs per vehicle and per user are too high. Players believe that growing numbers of vehicles can bring to an exponential increase of users that allow for higher user per vehicle ratio, utilization rates and consequently profits. A different approach is to reduce the cost per vehicle by changing the vehicle. According to Seat CEO Luca de Meo: "car sharing is not profitable since vehicles are not designed for the sharing purpose". In order to solve the pollution issue and also to be aligned to new automotive trends, modern urban shared vehicles must be electric. This is challenging because few cities have a dense distributed charging infrastructure and market shows that users are eager to free floating car sharing, in order not to be constrained to pre-defined parking spots. Users in today society are willing to reduce the inactive time while driving, being always connected to the external world and with a safe, ergonomic and enjoyable user experience (UX), which is not happening with current sharing solutions. From this analysis it is evident the request of the market for an integrated platform designed for the car sharing purpose, enabling connectivity, based on electric vehicles with an extended range.

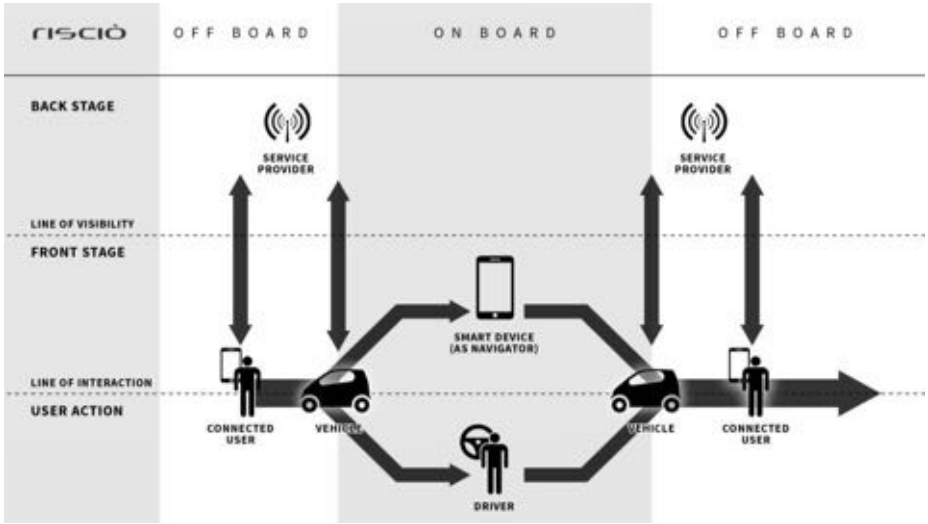
Exploring the opportunities

While developing the envisioned platform able to achieve profitability and sustainability in its operation, the team explored many innovative ideas, frequently inspired by different fields of application. Both from technology and marketing perspective, Risciò team searched for successful patterns that could be applied to the proposed solution, and ended up with two main "mantras" to follow in each aspect of the project. The first mantra is "*Best is made of essentiality*", inspired by the successful strategy adopted by One Plus in the Mobile industry,

based on the distinction between real needs of the customer and features which are unnecessary. One Plus focused on high quality in all the important features of the product (offering a top performing smartphone at very low price), while saving money on extra activities (for instance advertisement and logistics, adopting an invitation-based purchasing mechanism). The second mantra, "*Put Exclusivity in place*", refers to the ability of a product of being perceived as exclusive because of the identity associated to it. The concept was taken by the successful story of Swatch in the watches market, who associated its brand to travels and personality by selling their customizable products in airports.

Generating a solution

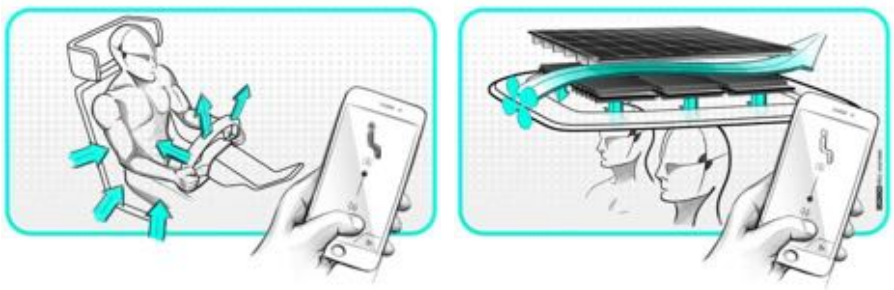
The technologies which were already available before the Team joined the project are the basic elements of Risciò's chassis and powertrain. These are a modular structurally safe chassis, with patented electric in-wheel motors and battery pack, suitable to sustain a light electric vehicle and to be assembled at contained cost even in small lots. The proposed business model focuses on car sharing services in small-medium cities and remote locations, leveraging on specifically designed features that provide Risciò platform with strong competitive advantages over competitors in those contexts. The solution elaborated by the Team focuses on how to build this competitive advantage, providing Risciò users with better experience, and Risciò customers with better profits than they would have with a traditional car sharing. Risciò platform is a solution "born to be shared", meaning that user-centered and customer-centered design are applied, focusing on the needs of car sharing providers and car sharing users, which are different from the needs of traditional mobility players. This leads to increase the autonomy of each vehicle, extending range and reducing O&M; to take into account that trips will be urban, short and frequent, with related impact on user's priorities and comfort perception; to consider that the business model will be sustainable if multiple locations are served, thus flexibility to suit the characteristics of different locations is needed. Considering this analysis, modularity is an enabler to align with essentiality and flexibility mantras.



Car sharing platform and interactions

The HVAC system is inherently modular due to a decentralized approach, based on the substitution of the standard central vapor compression cycle with a combination of components, each one dedicated to a specific function and a user. These components are sometimes chosen from automotive solutions (heated wheel, heated seats, electrically heated window coating) and sometimes borrowed from different application fields (smart glass, Peltier cells, PV panels). The latter group of components is integrated in an innovative element of the upper body, the Smart Roof, which works as follows: PV panels harvest energy from the sun, at the same time providing passive shadowing to the roof, the smart glass can be switched to opaque for active shadowing, and a Peltier cells layer can provide

cooling or heating to the passengers below the roof, respectively releasing or absorbing heat from the external air layer between cells and PV. This configuration allows for flexibility and essentiality because the sizing of components can be customized by changing the number of installed modules.



HVAC solution in winter and summer condition

Essentiality is also a key driver for the User Interface (UI), which is characterized by the elimination of all elements that are not really needed by the user, determining ease of usage, safety and cost savings. To reduce the UI complexity, the whole User Experience of a car sharing user has been considered, from off-board phases to on-board driving, aiming to offer an integrated and complete solution. The proposed UI makes use of a smartphone app through with which the user can access the service and customize his experience by setting many options usually present on current cars dashboards, such as navigation and ambient temperature. Once on board, instead of employing different screens and controls dislocated in the vehicle, the solution presents few media of interaction, located close to the steering wheel and the driver's field of vision. Moreover, the intelligent smartphone positioning and a dynamic steering wheel interface allow the driver to stay connected with his device in a comfortable and safe way. Modularity and Flexibility are ensured since all the elements of the user interface are presented as add in, so they can be independently and easily changed according to each customer's requirements.

Proposed User Interface

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PRINCIPAL ACADEMIC TUTOR
Marco Carlo Masoero, DENERG, Politecnico di Torino

ACADEMIC TUTOR
Giulio Ceppi, Design Department, Politecnico di Milano
Marco Simonetti, DENERG, Politecnico di Torino

EXTERNAL INSTITUTIONS
Ivano Panizzo, Italdesign S.p.a.

EXTERNAL TUTOR
Ivano Panizzo, Italdesign S.p.a.

TEAM MEMBERS

Francesco Pilosio, Mechanical Engineering, Politecnico di Milano

Enrica Raheli, Energy Engineering, Politecnico di Torino

Daniele Ramirez, Mechanical Engineering, Politecnico di Milano

Federico Ribatti, Mechanical Engineering, Politecnico di Torino

Saverio Tavernese, Aerospace Engineering, Politecnico di Torino

Inno-VACS

Executive summary

One of the largest obstacles to mass adoption of electrical vehicles (EVs) is their relatively low driving range, compared to traditional combustion engine cars. A possible way to solve this issue can be reduce the power consumption of the vehicle's auxiliary systems. In particular, the most consuming auxiliary system is the Heating, Ventilation and Air Conditioning (HVAC) system, which can lead to a range reduction up to 50%, depending on outside weather conditions and driving cycle.

Inno-VACS project aims at applying a novel model-based design process to the car cabin of Pop.Up, an innovative concept developed by Italdesign, in order to minimize HVAC power consumption. The first step of the novel procedure consisted in devising a detailed thermal model of the cabin, implementing conventional technologies and materials used at present in the automotive industry. Secondly, a sensitivity analysis was performed, which consisted in registering through simulations how the Air Conditioning load changed by adjusting some design parameters of the car cabin (e.g. transmissivity of glazing, thermal transmittance of insulation). The outcomes of the sensitivity analysis were then used as guidelines for the selection of innovative technologies for the cabin. Specifically, advanced high reflectivity coatings for external opaque surfaces, controllable opacity electrochromic glasses and aerogel insulation material were identified as the set of solutions able to minimize AC load and maximize passenger thermal comfort. The adoption of these technologies leads to a range extension from 12% to 28% for the Pop.Up, depending on the considered scenario. On top of this, the insulation weight of the vehicle can be reduced by 22%. Thermal efficiency of the cabin is expected to increase by 66%, while the theoretical size of the HVAC system is expected to be reduced by 73%. Finally, using unprecedented control strategies, the temperature fluctuations inside the cabin air volume can be suppressed and the energy consumption can be decreased up to 15%.

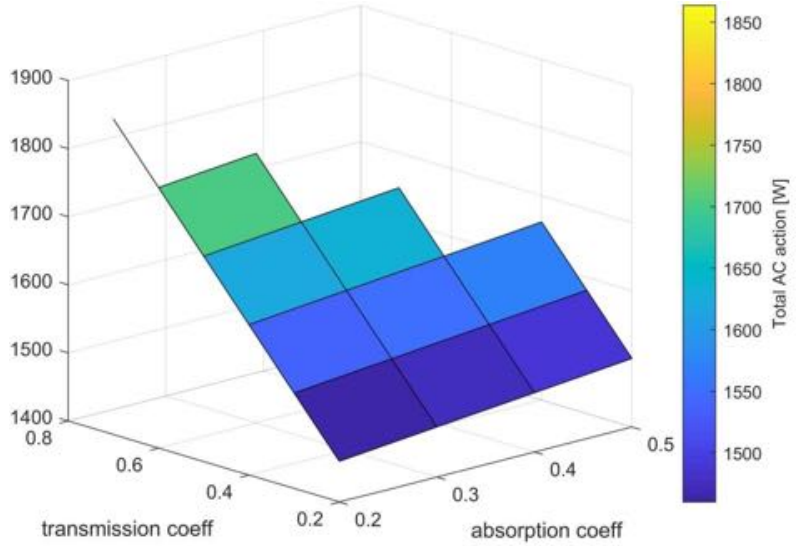
Key Words

Air Conditioning - Smart materials - Thermal comfort

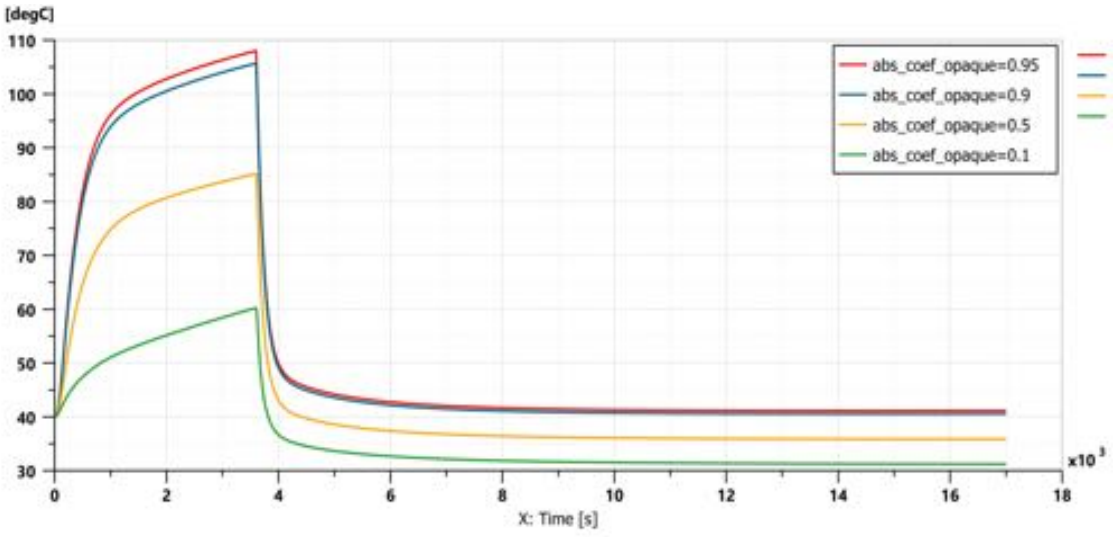
Sustainable mobility - Range extension

Pop.Up prototype: air and ground modules

Inno-VACS team at Italdesign Virtual Reality Lab



Example of outcome of the sensitivity analysis: influence of glazing properties on the AC load



Transient evolution of cabin roof temperature during pull-down test with different roof reflectivity

Project description written by the Principal Academic Tutor

Mobility is undergoing a profound revolution, driven by concern on energy sustainability, environmental impact and safety. The technological revolution of the transportation sector involves a number of disruptive technologies, namely IoT and electrical propulsion: autonomous driving, fully electric vehicles are set to become a key player in future smart cities. However, some critical technological challenges still have to be solved in order to make such vehicles the key players in the market, particularly the range extension that is now capped by the limited capacity of available batteries. Therefore, the reduction of auxiliary systems energy consumption - among which the Air Conditioning System (AC) is by far the main contributor - becomes one of the key goals to achieve.

The ASP Inno-VACS project has tackled this complex problem, combining the academic expertise of students and faculty of several cultural areas (Mechanical, Aerospace and Energy Engineering, and Industrial Design) with the industrial expertise of one of the key players of the automotive sector, Italdesign. Italdesign proposed the case study on which the ASP Team has worked: the Pop.Up, jointly developed by Italdesign and Airbus. Pop.Up is a modular, fully electric, zero emission vehicle system, designed to relieve traffic congestion in crowded megacities. Pop.Up envisages a modular system for multi-modal transportation that makes full use of both ground and airspace.

The students' team has developed a novel model-based design approach to achieve AC sizing and improve the cabin thermal efficiency. A detailed, dynamic numerical model of the cabin and AC system was developed using the multidomain simulation software Amesim, which served as the main tool for the optimization process. A sensitivity analysis was then developed to investigate the effect of the thermal parameters of the car cabin: surface reflectivity, glass solar transmissivity and thermal insulation. A thorough literature research was conducted to identify the most promising technological solution for passive thermal control of the car cabin. A parallel literature search was carried out on the active AC technologies, identifying alternative solution for the production of heating and cooling. Finally, novel control strategies have been investigated to achieve further efficiency improvements.

Team description by skill

Being the project a multidisciplinary work, the skills required in order to find the best solutions have been several and different. The team is composed by three mechanical engineers, an energy engineer and an aerospace engineer.

A crucial contribution was given by the Energy Engineer Enrica Raheli. Exploiting her knowledge about thermodynamics, the team was able to realize an accurate thermal model of the cabin and face with great confidence the issues concerning passenger thermal comfort.

Great contribution to the whole cabin modelling has been given by the Mechanical Engineer Daniele Ramirez. Thanks to his knowledge in controls' theory, the team has been also able to develop innovative and unprecedented model based controllers able to sensibly reduce the energy consumption of the AC unit.

The core of the project has been the research and study of new materials and technologies able to reduce the thermal loads entering the cabin. This ambitious goal has been reached thanks to the efforts of the Mechanical Engineer Francesco Pilosio, who carried on a deep analysis of coating technologies for opaque surfaces, and of the Mechanical Engineer Federico Ribatti who instead studied solutions concerning innovative glass technologies and insulation materials.

The expertise of Aerospace Engineer Saverio Tavernese has been very important in order to focus the attention of the team on the physical requirements needed for a flying car cabin. His contribution has been relevant also in the phase of individuation of the main stakeholders of the project.

Goal

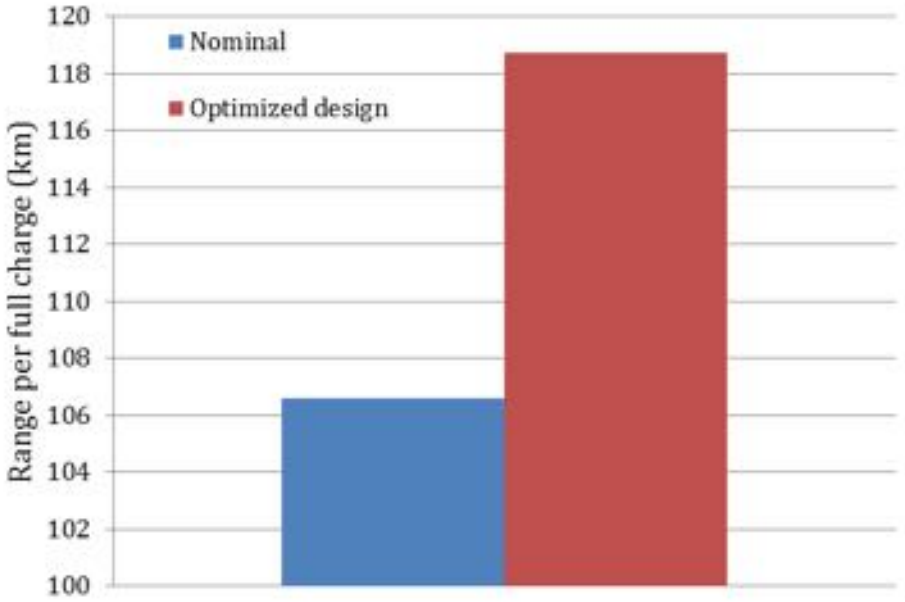
Inno-VACS is a team project born to design the Air Conditioning system of the innovative vehicle concept Pop.Up. Pop.Up is a revolutionary modular, electric, zero-emission vehicle, capable to provide multi-modal transportation, both on ground and up in the sky. It is one of the most ambitious projects, both from a technological and service point of view, in the scenario of future mobility.

Air conditioning innovation could seem to play a little role in this foreseen future. However, the AC system is the second largest power drawn from the electric battery. Lowering the required AC power in electric cars has the effect of increasing the vehicle driving range, and this phenomenon is crucial for this future mobility scenario. The team has been assigned the ambitious goal to produce a general design of the Air Conditioning system of the cabin, taking into consideration the specific requirements of the vehicle, along with economic and market factors influencing the development of the product and its commercialization. The strong inter and multidisciplinarity of the team members and of the academic tutors, jointly with the fruitful contribution of the industrial client Italdesign, has led to the remarkable results of this investigation.

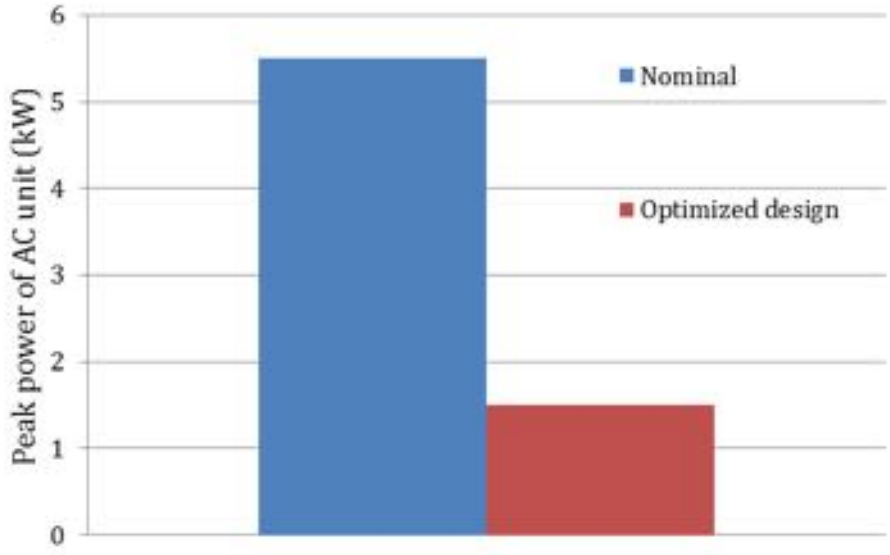
Understanding the problem

One of the biggest issues related to electrical vehicles is their driving range, which is low and incomparable with traditional combustion engine's driving range, due to the much lower energy density of current Li-Ion batteries with respect to conventional liquid fuels. Achieving operational driving ranges above 300 km is often impossible due to the limited capacity-weight ratio of current batteries. While research is slowly and steadily increasing this index, an alternative path to overcome the problem can be identified in reducing the power consumption of the vehicle's auxiliary systems. The HVAC system of an electric car is the second largest power drawn from the battery after the electric motor itself. In particular, the HVAC system can lower the range of an EV from 5% to 50%, depending on the outside weather conditions, driving cycle and vehicle size. Recovering this electric energy, through thermal efficiency of the car cabin, is a viable and immediate solution to decrease the instantaneous energy consumption in EVs, thus increasing the range. The term "thermal efficiency" indicates whether cooling or heating the cabin is effortless or demanding: a better thermally efficient car cabin requires less cooling/heating power in order to maintain the desired inner temperature, thus resulting also in a more economic, light and compact HVAC system.

State of the art methods for sizing HVAC systems and thermally design a car cabin are not able to provide the above stated objectives. Indeed, the common practice in the automotive industry relies on a well-established linear workflow, where the cabin thermal design and HVAC system sizing are based on the designer's expertise, heuristic non-model-based calculations or outdated experimental results. With our work, we propose a novel model-based design process to achieve Air Conditioning (AC) sizing and improving the cabin's thermal efficiency.



Driving range comparison: traditional materials vs optimized design



Peak AC load comparison: traditional materials vs optimized design

Exploring the opportunities

Differently from the current methods, the novel model-based design relies on precise thermal models, developed for our specific cabin prototype. Using this approach, it is possible to identify the main thermal contributions to the AC load and the most suitable technologies to lower them.

In order to devise the model, the Siemens' software Simcenter Amesim has been used. Simcenter Amesim is a commercial integrated simulation platform for numerical modelling of multi-domain systems. The tool provides complex nonlinear time-dependent models for representing the system's hydraulic, pneumatic, thermal, electric or mechanical behavior. The use of this software allowed us to build a quite complex model, taking into account the intrinsic non-stationary nature of the problem and its complex geometry. Thanks to this software, it was possible to simulate standard test conditions (pull-down test for air conditioning and warm-up test for heating) and evaluate performances of different HVAC solutions and materials.

Generating a solution

Based on the results of the sensitivity analysis, the team has analyzed, classified and benchmarked the most promising technologies to achieve the maximum AC load reduction. This topic constitutes a totally novel scientific research and gives valuable insights to designers who are approaching the thermal management problem of car cabins. The most promising technologies for glazing surfaces, opaque surfaces and insulation materials have been identified to be respectively:

• Electrochromic glasses, which allow to control the solar radiation entering the cabin (high flexibility)

• Radiative cooling reflective coatings, which allow to reflect most of solar radiation and emit infrared heat back to the environment

• Aerogel insulation, which ensures excellent insulation properties, low specific weight and high recyclability

The application of those technologies drove to an increase of thermal efficiency by 66% and a reduction by 73% of HVAC size. Thanks to the adoption of these innovative technologies, the driving range was significantly improved. Moreover, it was possible to increase the passenger thermal comfort, avoiding that inner surfaces reach high temperatures (e.g. roof and seats).

The problem of AC load minimiazation has also been tackled from a control point of view. The team has investigated the possible implementation of novel model-based controllers for AC control and glass transparency control. In the research, several new Model Predictive Control (MPC) architectures have been developed, as well as new hybrid controllers, whose performances have been proven to be significantly better compared to conventional PID controllers. In particular, hybrid controllers for AC and glass transparency control were found to be 15% more efficient and able to eliminate temperature fluctuations in the cabin.

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PRINCIPAL ACADEMIC TUTOR
Luigi Buzzacchi, DIST, Politecnico di Torino

ACADEMIC TUTORS
Alessandra Colombelli, DIGEP, Politecnico di Torino
Antonio De Marco, DIGEP, Politecnico di Torino
Emanuele Giraudo, DIG, Politecnico di Milano
Luca Grilli, DIG, Politecnico di Milano
Fabrizio Lamberti, DAUIN, Politecnico di Torino
Giuseppe Scellato, DIGEP, Politecnico di Torino
Paolo Tamborrini, DAD, Politecnico di Torino

EXTERNAL INSTITUTION
CONSOB, Commissione Nazionale per le Società e la Borsa

EXTERNAL TUTOR
Luca Ricciardi, CONSOB

TEAM MEMBERS

Eleonora Acero, Management Engineering, Politecnico di Torino

Andrea Cammi, Management Engineering, Politecnico di Milano

Lorenzo De Castro, Management Engineering, Politecnico di Milano

Gianluca Giorgini, Management Engineering, Politecnico di Milano

Massimo Tumolo, Computer Engineering, Politecnico di Torino

Jessica Vetere, Interior Design, Politecnico di Milano

FiLE - Financial Literacy and Entrepreneurship

Executive summary

Poor financial decision-making seems to be a widespread phenomenon among common people (Hung, et al., 2009), with dramatic long-term consequences on the economic system, undermining its basis and stability (Hung, et al., 2009).

CONSOB is the institution that supervises the Italian financial market and safeguards categories from investors to savers. From its perspective, it was clear that the financial literacy problem must be addressed from its roots. However, the problem is shared by many stakeholders, that the team encountered during the project, as I3P and PoliHub incubators and the Turin Chamber of Commerce.

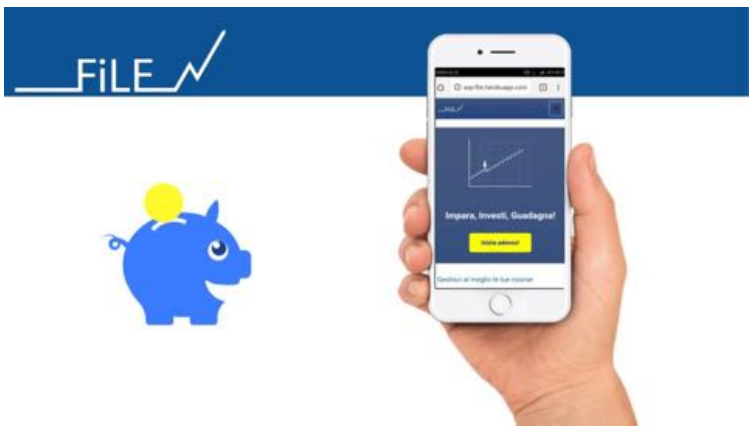
Existing solutions are mainly based on frontal lessons, workshops and MOOCs. Being aware of the limits of the existing solutions, such as poor engagement, and the special target the project is addressing, i.e. new-born time-eager entrepreneurs, the FiLE platform has been designed following an approach never implemented in financial teaching, but successful in other fields.

The idea consists in a platform which allows users to interact over the time and which follows a reverse learning paradigm: the user is first asked to respond to questions of different levels and then, if he answers the wrong way, there is an explanation so that he can learn from his errors. When the user accesses the platform for the first time, a placement test is proposed. This test's results allow users to start using the platform from a difficulty level which is tailored on his previous knowledge. A learning path is proposed to the user on relevant financial topic as Business Law, Corporate finance, Entrepreneurial Finance and Accounting.

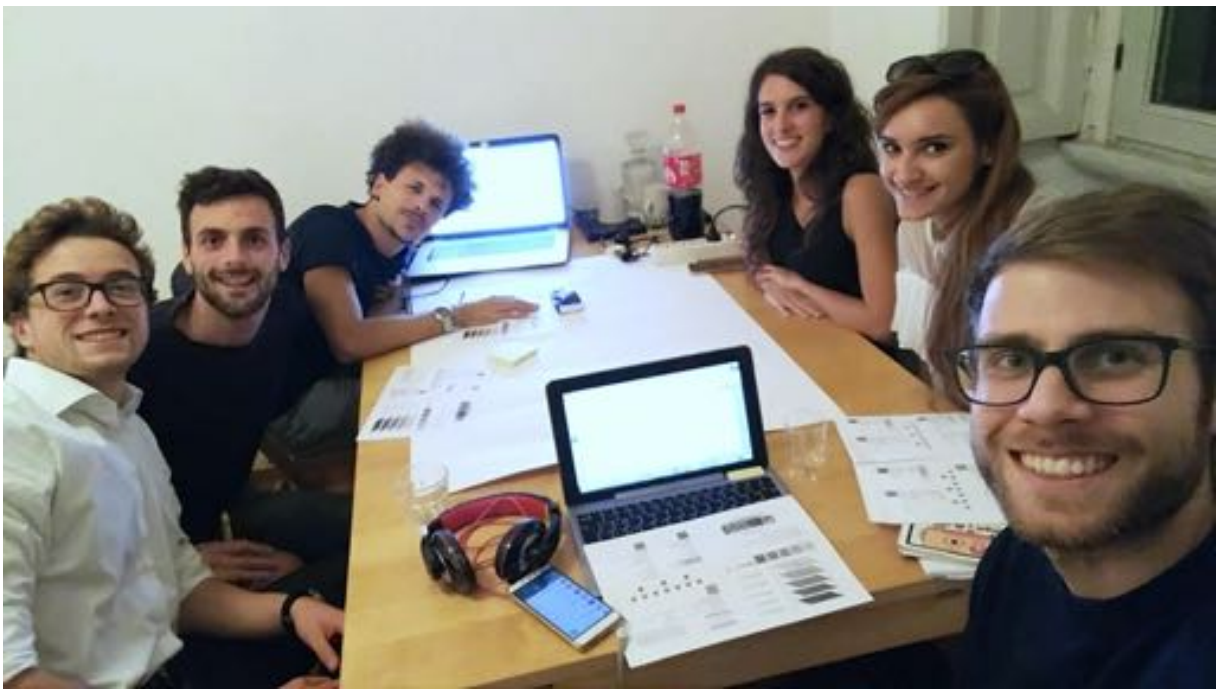
The platform and the idea behind it have generated great interest by the stakeholders, which showed their interest to continue the development and finalization of the platform even though the academic project is concluded.

Key Words

Financial Literacy, Financial Education, Entrepreneurs, Web-Platform



FiLE Platform



Picture of the night in which the FiLE platform was designed. After long days spent searching through the literature for problems, hints and related works, the team gathered for a massive brainstorming that lead to big results.

FiLE meets future stakeholders: the Turin's Chamber of Commerce.

Project description written by the Principal Academic Tutor

Entrepreneurship represents a fundamental driver for job creation, innovation, structural change and long-run economic growth. Financial literacy, business acumen and attitude towards risks are the three keys that can make an entrepreneur successful.

Nowadays, the typical approach to spread financial education is through books or frontal lessons and workshops. These methods' efficacy is a subject of discussions in the literature because of the inability to engage and motivate the target.

In line with the literature, CONSOB realized that this gap in the financial education is particularly felt in Italy and decided to investigate possible solutions. Following the CONSOB mission, the FiLE team explored a technological solution that gained the interest of the Camera di Commercio for a possible application in Schools.

The FiLE platform is a web application that leverages first on existing successful teaching mechanisms, and second on consolidated methods for evaluating financial literacy, to engage the user in a learning itinerary trough business law, entrepreneurial finance, corporate finance, and accounting. After a first assessment, the platform suggests the difficulty based on the user preparation, and then the user is guided by a carefully designed user experience through the learning process, until his proficiency is strong enough to deal with the most common problems.

Team description by skill

The team is composed by six members: Andrea, Eleonora, Gianluca, Jessica, Lorenzo, Massimo. The main area of expertise is management and finance, with additional expertise in computing and design.

Andrea Cammi is a Management Engineer with focus on Finance. After exploring the world by studying in Italy, London, Paris and Berlin, he decided to explore new fields and started coding during his semesters abroad.

Eleonora Acero is a Management Engineer with focus on Innovation. A person with many hobbies and a creative spirit, Eleonora has no time to sleep, and she can survive better than most people and even take beautiful pictures of them.

Gianluca Giorgini is a Management Engineer with focus on Social Innovation and Sustainable Operations. With is rebel spirit, Gianluca proven himself to be a precious resource by starting the most productive discussions in the group.

Jessica Vetere is an Interior Designer. Flexible and open-minded, Jessica applied the creativity developed during her studies on a totally different area, the design of a web platform. After she got promoted to Communication Coordinator, she decided to find a new life in Norway.

Lorenzo De Castro is a Management Engineer with focus on Finance. He surely learnt a lot from his Internship in the management consulting firm BCG, as he proved by sketching time diagrams and fluently interacting with the stakeholders.

Massimo Tumolo is a Computer Engineer with focus on Networking. Passionate about software, he found himself coding for physicists at CERN. Due to his need of organization, he has lead the team. Truth is, the task was easy with such a skilled team.

Overall, the team has a variegated set of skill in finance, software development, design, art, flexibility and cocktail-drinking.

Goal

Entrepreneurship represents a crucial leverage to boost economic growth, and its effects are even stronger in Italy nowadays. Every entrepreneur has to face many complex choices during its daily activities and many of them are related to financial topics. Indeed, it has been shown that better financial literacy helps to improve entrepreneurial firms' performances. On the other hand, previous studies have spotted many gaps in entrepreneurs' financial literacy. Because of the importance of financial knowledge, this issue should not be neglected and so, the aim of the FiLE platform is to help to bridge this gap. FiLE tries to assess and educate entrepreneurs, having a particular focus on high-tech ones. To do so, the modern digital technologies may be exploited to put forward new approaches to financial literacy assessment and education. Moreover, digital platforms are more suited to address the high-tech entrepreneurs and the so-called start-uppers' culture. Moving from traditional financial literacy questionnaires to a digitalized approach has many challenging opportunities and the aim of FiLE is to exploit them. Putting together these new opportunities coming from digital technologies, design tools available to better interact with the respondents and sound literature-based contents, the FiLE platform aims to better understand entrepreneurs' financial literacy to help them to succeed.

Understanding the problem

Financial literacy, whose importance has risen worldwide during the last decade, is nowadays considered a critical skill, especially for individuals that have to deal with a complex financial environment. However, poor financial decision-making seems to be still a widespread phenomenon among common people (Hung, et al., 2009), as well as the lack of comprehension of some basic financial concepts (Messy & Atkinson, 2012). Such illiteracy can have serious long term consequences for the individual's financial security since bad savings and investment decisions build over time and often go unobserved until a point of crisis. Overall, the lack of financial knowledge has dramatic long-term consequences on the economic system as a whole, undermining its basis and stability (Hung, et al., 2009).
Therefore, governments around the world are highly interested in finding effective tools to improve the financial capabilities of their citizens; such rising concern stimulates the research in this field, although results are still fragmented. Findings show that financial knowledge level varies with age, gender and education and that frequently there is relevant discrepancy between individuals' self-evaluation and their actual financial literacy score.

Although no standard definition of financial literacy exists, it can be described as "a combination of awareness, knowledge, skill, attitude and behavior necessary to make sound financial decisions and ultimately achieve individual financial wellbeing." (Messy & Atkinson, 2012).

With regard to the most appropriate way to measure financial literacy, which is a hot point of the debate in this field (Allgood & Walstad, 2016), Lusardi and Mitchell (Mitchell & Lusardi, 2014) identified three main concepts contributing to the saving and investment choices: *numeracy and capacity to do calculations related to interest rates*, *understanding of inflation* and *risk diversification*.

Other studies, such as the INFE and FSA (Reyniers, et al., 2008) ones, developed survey instruments to capture a broader concept, namely financial capability, which combines financial literacy with a set of beneficial attitudes, behaviors and external factors (Lusardi, 2012). However, the fundamental relationships between literacy, education and behavior remain a controversial issue since a knowledge gap persists in this literature domain, also for the lack of adequate data; researchers found evidences that financial literacy affects financial behavior but no causal relationship was find (Allgood & Walstad, 2016).
In fact, financial literacy only identifies what is required to have an appropriate financial behavior but does not guarantee this will occur; this happens because decision-making is influenced by the individual's psychology, cognitive and behavioral biases and eventually by external circumstances. (Huston, 2010)

This suggests that education aiming at improving financial decision-making should not only focus on teaching financial concepts but rather on training thinking skills to try overcoming unconscious biases (Reyniers, et al., 2008).
However, in Italy financial education initiatives are still fragmented and have very modest forms of results monitoring, making difficult to identify best practices to be carried on.

As far as entrepreneurs are concerned, in a financial literacy context they differ from consumers for the type of financial decisions and challenges they have to face every day and, moreover, for the potential consequences such choices can have on their own family members', employees', suppliers' and costumers' livelihoods.

So, the international curricula agree on including in financial education programs for entrepreneurs topics like financial and risk management, record keeping and compliance, finance providers and their requirements.
Finally, above from the contents, it is difficult to identify the best educational form to meet entrepreneurs' availability and motivation.

File Platform – Choosing the section

FiLE Platform – Correct answer

Exploring the opportunities

Teaching to entrepreneurs, in particular Financial Literacy, is not an easy task: it has been long recognized as a problem, however the available solutions are not effective. Undertaking this kind of activities requires an optimal leveraging of several factors, that could not be addressed together so far.

First, learning is a time-consuming activity, unfit for Entrepreneurs and Startuppers, people with a very busy schedule. Traditional didactic approaches are rejected for their rigidity in terms of time and space constraints to leave room for online applications. Second, understanding the optimal teaching content has the highest priority. Entrepreneurs must not be taught as they would in a academic course, instead their learning should have a real and visible impact on their activities. The FiLE team had continuous confrontation with potential users to understand how to choose the content of the FiLE application. Finally, learning online is an activity that may lead to boredom and dropouts. The FiLE project is therefore structured in a way to keep users always engaged throughout their experience.

Generating a solution

The FiLE platform is based on a self-developed database of more than 170 multiple-choice questions based on financial literacy academic literature. It is divided into four main sections selected according to the main stakeholders' indications and literature analysis: Entrepreneurial Finance (*Finanzimento Startup*), Corporate Finance (*Finanza Aziendale*), Accounting (*Contabilità*), Business Law (*Diritto Societario*). For every question in these four sections, the user's financial literacy is not only tested but also improved with literature-based explanations of his answers. What mainly characterizes the FiLE platform is its continuous interaction with the user. Indeed, the platform evolves from the traditional features of a questionnaire. While a questionnaire oftentimes represents a one-shot interaction with the respondent, in the FiLE platform the "respondent" becomes a "user" because he or she is stimulated to interact several times with the digital platform and the platform can recognize who the user is. So, questions' difficulty can be tailored to the user's financial literacy according to the user's previous answers' correctness. In addition, also various engagement tools as user's performance tracking and statistical comparisons have been developed. Thanks to this structure, the FiLE platform aims at being always challenging and useful for the user. This continuous interaction with a motivated user provides data on its literacy not only once but continuously over the time and, most importantly, the platform can also improve the user's literacy while testing it.

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PRINCIPAL ACADEMIC TUTOR
Giambattista Gruosso
Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano

ACADEMIC TUTORS
Luca Bascetta
Dipartimento di Elettronica, Informazione e Bioingegneria, Politecnico di Milano
Marco Piras
Dipartimento dell'Ambiente, del Territorio e delle Infrastrutture, Politecnico di Torino

EXTERNAL INSTITUTION
Azienda Agricola Pecchenino (Dogliani, CN)

TEAM MEMBERS

Beggio Silvia,
Management Engineering, Politecnico di Milano

Ghio Chiara,
Environmental Engineering, Politecnico di Torino

Rontini Martina,
Management Engineering, Politecnico di Milano

Sernaque Chunco Adrian Vladimir,
Mechanical Engineering, Politecnico di Torino

Simon Tania,
Mechanical Engineering, Politecnico di Milano

MUFFIN40

Farm 4.0: Mobile manipUlation in agriculture For precision FarmINg

Executive summary

The objective is the realization of a Precision Viticulture technology and the design of a service that, based on this technology, is able to help winegrowers in the vineyard health monitoring.

The first part of the project consisted in a preliminary analysis of agriculture and technology, with a specific focus on the Italian panorama. Through surveys and interviews it was possible to understand needs and expectations of the farmers as well as the difficulties in the introduction of new technologies. Based on the outcome of this phase, a feasible service architecture was developed: it consists in an autonomous rover provided with a series of cameras able to analyse the vigour of the vines through the NDVI indicator. Thanks to the data provided, the user can have a record of the historical behaviour of the field, see the health situation of each plant and plan future actions in order to prevent diseases and increase productivity. The technology has to be cheap and easy to use in order to ease the adoption.

The development of the technological part has been divided into two parallel branches, the rover and the sensor and data analysis. For what concerns the rover the best design solutions has been investigated in order to produce a machine able to work in a harsh environment as the vineyard. A sizing of the fleet based on the autonomy and the average traveling speed was made. About the choice of the sensors, a low-cost solution was developed obtaining data with two cameras (Pi and PiNoIR) with the support of GPS localization. Also, a user-friendly interface was developed to control data acquisition. All the considerations made resulted in the production of 1:5 scale prototype, which was tested at Azienda Agricola Pecchenino, the main stakeholder of the project.

At last, a business model was developed using the Business Model Canvas methodology, representing how this technology can be profitably sold in the Italian market, and the Net Present Value of the proposal was computed.

Key Words

Precision viticulture; Precision farming; Agriculture4.0; Rover; Sensors; Plant vigour monitoring

Project description written by the Principal Academic Tutor

Agriculture is facing many challenges, such as the growth in the world population, resource shortages, the increasing demand for energy, dietary changes and the increase in competition on world markets. Traditional agricultural methods are not able to sustain all these changes, so technology comes to the rescue. Precision agriculture (PA), or precision farming, is a modern farming concept which exploits digital techniques to optimize agricultural production processes. PA practices are the most effective way to significantly reduce the negative impact of farming on the environment while still producing enough food to satisfy a growing demand. The introduction of advanced sensing capabilities allows monitoring at plant level, spotting problems before they spread. The introduction of advanced perception and action capabilities brings in a leading-edge technological approach to farming, allowing for observing, measuring and acting. In the last years it has entered successfully the market, but, because of the high cost, it has been applied only on very large farms and valuable productions.

The objective of the project is the design and demonstration of a service for precision farming, including drone technology (UGV (unmanned ground vehicle) first, but UAV (unmanned aerial vehicle) also can be considered as well), mobile robotics, Internet of Things and Software Platforms. The main result of the project is the definition of a new way of thinking in agriculture, introducing typical approaches/technologies that already proved to be successful in other industrial environments. In particular, the ability to sense, collect and analyze data through IoT platforms and Bigdata methodologies offers the opportunity to introduce a new approach in agriculture, based on fleet of ground and/or air autonomous vehicles and mobile manipulation techniques. Considering the competences available within the team, the service had to be set up considering both a technological and an economical perspective.

The solution has to be suitable to the Italian agriculture context, made of small farms, and in particular focusing on the most exclusive and celebrated production in Italy, wine grapes. Wine is an international market characterized by growing competition. Consequently, winegrowers need to achieve high standards of quality in their vineyards. The reduction of inputs as fertilizers, pesticides, energy, water and the increase in the wine quality and its production sustainability are the objectives of new agricultural techniques. Indeed, the objective is the realization of a Precision Viticulture technology and the design of a service that, based on this technology, is able to help winegrowers in the vineyard health monitoring, in the identification of potential problems and in the application of chemicals, fertilizers, pesticides with high precision, just when needed and in the smallest necessary amount.

Team description by skill

•Turin sub-team:

The sub-team was in charge for software development and testing activities for which programming competences, held by Adrian Sernaque being a mechanical engineer, and data analysis competences, held by Chiara Ghio as an environmental engineer, are necessary.

• Milan sub-team:

The sub-team was characterized by two management engineers (Silvia Beggio and Martina Rontini) and one mechanical engineer (Tania Simon). The main activities were studying needs and users requirements, prototyping and building the business model.

Understanding the problem

Precision agriculture is a way to apply the right treatment in the right place at the right time. Precision Viticulture (PV) consists mainly in the identification and management of the variability within vineyards. Its aim is to increase productivity and/or quality while at the same time reducing the cost of inputs and the environmental impact.

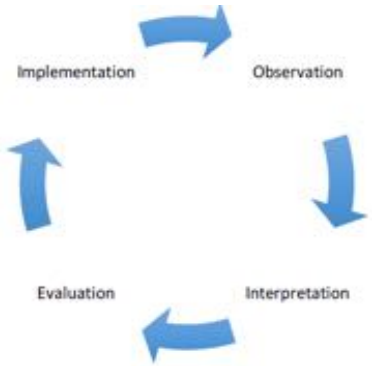

Figure: The process of precision viticulture

The understanding of the problems started with the exploration of the existing technologies in the field of agriculture and the investigation of several case studies demonstrating the profitability of such solutions. The visit of the Milan sub-team to the Agritechnica Fair in Hannover, the biggest fair about agricultural machines, was also useful to enrich the analysis. A panoramic of the structure and the properties of a typical vineyard (Veronesi, 2011-2012) was performed for understanding the challenges to overcome. For example, we understood that the small trees develop mostly on the vertical plane, allowing the detection of a greater amount of information using a ground vehicle instead of airborne one. Furthermore, the disposition of the rows (e.g. ritocchino and girappoggio) and, consequently, the slope can be fundamental factors in the choice of the level of mechanization.

Then, the literature on the matter was studied in order to have an insight on the reasons that lead to the diffusion or to the rejection of such technologies. What emerged is that the main drivers towards adoption are increases in productivity and reductions in the costs of the inputs, advantages whose importance is even bigger considering the current competition in the markets. Diffusion is delayed due to the need of costly investments and to the lack of an innovation culture in agriculture. For these reasons, adoption is limited to medium and big producers. However, diffusion is broader in viticulture more than in other kind of cultures due to the higher margins and to the high importance given to quality.

After this general overview about the market, the specific needs of the vine growers were identified by means of questionnaires and interviews. It was confirmed that the features that would make adoption easier are easiness of use and low investment cost.

Exploring the opportunities

Different technologies have been studied to maximize the quality, the sustainability and the efficiency of vineyards. According to Matese (2015), a wide range of sensors is applied in the two ways of monitoring: remote and proximal monitoring. The first alternative collects reflectance information from satellites or airborne systems (e.g. UAV platforms) using optical sensors such as hyperspectral or multispectral cameras. These cameras allow the acquisition of different electromagnetic spectral bands that can be combined for detecting the vigour and the photosynthetic activities of the plants. The second alternative allows the collection of detail information near the surface by a vehicle or an operator. Due to the development of low cost and open source technology applicable, this opportunity has become more and more common. The proximal monitoring includes: mechanical and electrical sensors that can detect properties

of the soil, directly connected to the quality of the wine; optical sensors such as multispectral cameras and LIDAR sensors; fruit dendrometer to perform a non-destructive analysis of the percentage of sugar in the grape.

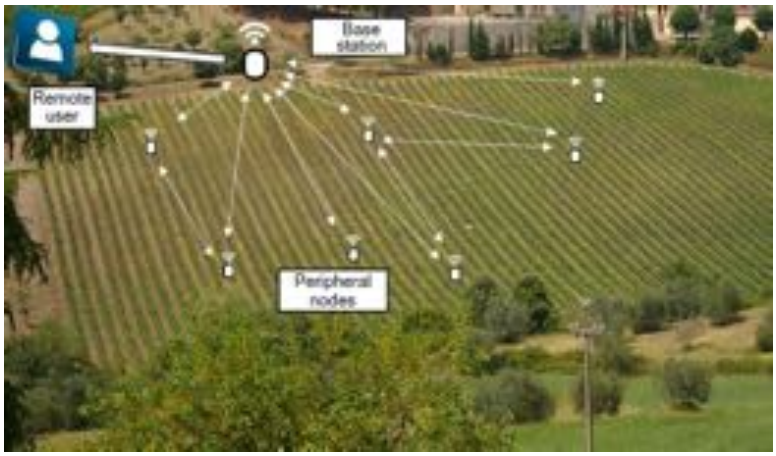

Figure: Wireless network sensors

In the last years, vehicles have been automatized and equipped with monitoring sensors to perform site-specific operations without human help. Even if the use of robotics in viticulture is still at the beginning of its life, new prototypes are on their way to become reality because of more investments on PA. However, the greatest limitation is still linked to the high cost of this technology.

In order to make easier the introduction of precision technologies in the Italian viticulture, the team started focusing on low cost sensors interfaced to a low cost single-board computer such as Arduino or Raspberry Pi. These sensors use the same system of data acquisition as the expensive ones already present in the market, reaching performance similar to theirs. For example, we understood that the same acquisition of multispectral images as done by the multispectral camera can be performed by two different cameras: a normal RGB camera detecting Red, Green, Blue bands and a NIR camera detecting Near InfraRed bands.

Generating a solution

Figure: Architecture of the service

Taking into account the state of the art and the main needs already described in the paragraphs above, we developed our solution for giving to the farmers a greater advantage in terms of quality and crop monitoring. We decided to use a rover travelling across the vineyards and equipped with cameras taking pictures of the vegetation. Images are post-processed to get a visual vertical map of the Normalized Differential Vegetation Index (NDVI) describing the health or the stress of the plants when it is not yet perceived by the human eyes. The first application of this information is to provide immediate alerts to the farmer against diseases or lacks of fertilizers. Moreover, by looking at the historical data, future actions can be planned to prevent the onset of complications.

The team developed a prototype of the rover in model scale 1:5, provided with all the sensors that would be mounted on the real one. The movement of the rover

was controlled by Arduino board through an user-friendly interface on a computer or smartphone connected to the rover with a Wi-Fi system. The rover was equipped with rubber belts because of the type of traction needed to travel in irregular and sloped terrain and it was designed in terms of dimensions, positions of the payload and material to use. Moreover, a sizing of the fleet based on the autonomy and the average travelling speed was made. We chose optical sensors that can detect the sunlight reflected by plants in terms of visible bands (RGB Camera Pi) and near infrared bands (PiNoir Camera). Both cameras were positioned in a small box designed ad hoc on the top of a telescopic stick, adjustable to have the right height and inclination, and connected through a Multiplexer to Raspberry Pi board. In order to know exactly the location of each image taken, a GPS device was connected to Raspberry Pi and GPS raw data were post-processed to improve the accuracy in the localization. The GPS and the Raspberry Pi were put in a box designed ad hoc and located at the base of the rover in the back for balancing the weight of the motors in the front. A user-friendly interface was designed to start and stop the measurements.

Figure: The prototype (above) and details: GPS box (down left) and the camera box (down right)

The prototype was tested in a vineyard of Azienda Agricola Pecchenino to verify the ability of the architecture developed. The results satisfied the expectations: despite the harsh terrain and the high slopes the rover managed to overcome all difficulties without rolling over and limited vibrations. The RGB and NIR images of the vegetation were well superimposed and the NDVI mosaic showed values close to the maximum for all the plants, proving they were healthy.

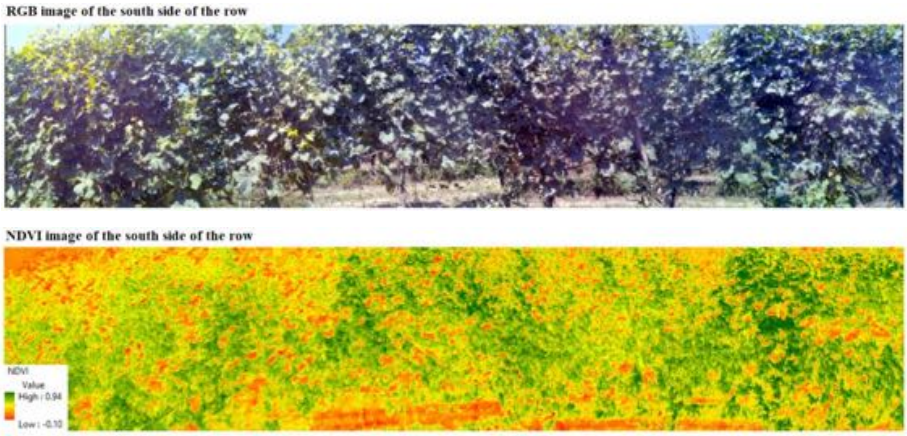

Figure: RGB image of the south side of the row (above) and corresponding NDVI image (below)

At the same time of the realization of the PV technology, the team considered three different business solutions representing how this technology could be sold in the Italian market: selling the rover, renting the rover and selling the service of vigour mapping. Due to the highest Net Present Value for selling the rover, this solution was adopted in the development of the Business Model Canvas.

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PRINCIPAL ACADEMIC TUTOR
Fabio Armao, DIST PoliTO, GANGCITY
Paolo Mellano, DAD PoliTO
Marco Imperadori, ABC PoliMI
ACADEMIC TUTOR
Marina Bravi, DIST PoliTO
Matteo Poli, DATSU PoliMI
EXTERNAL INSTITUTIONS
Department of Juvenile Justice and Community and the Italian Ministry of Justice
EXTERNAL TUTOR
Mila Sichera, DAD PoliTO, GANGCITY
Gemma Tuccillo, Dipartimento della Giustizia Minorile e di Comunità
Marella Santangelo, DiARC Università degli Studi di Napoli Federico II
Paolo Giardiello, DiARC Università degli Studi di Napoli Federico II
Claudio Bernardini, Milano Skateboarding
Patrizia Alfano, UISP
Walter Macaluso, Rider's Academy
Roberto Grippiolo, Impresa Cavallo
Patrizia Alfano, UISP

TEAM MEMBERS

Federica Pennino, Communication Design, PoliMi

Daniele Ricciardi, Interior Architecture, PoliMi

Aleksandra Katmerova, Design & Engineering, PoliMi

Luisa Viotti, Architecture for the Sustainable Design, PoliTo

Marco Felicioni, Architectural Design and History, PoliMI

Seda Ayvazyan Interior Design, PoliMi

Luca Bussolino, Architecture Construction City, PoliTO

SKATEPARK ITALY

Executive summary

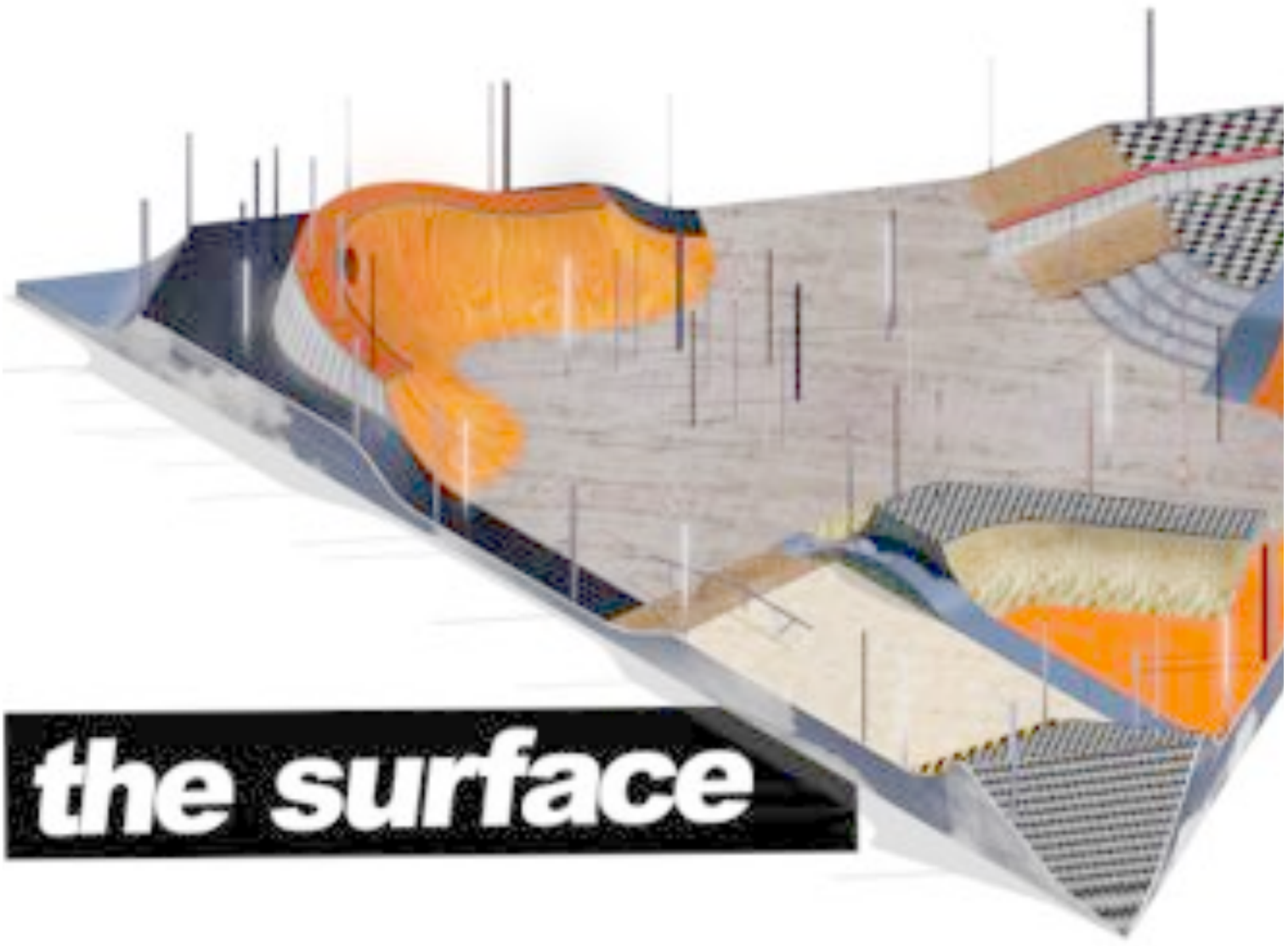
The Surface is the designed space for *SkatePark Italy* project, it is a strategical tool of urban regeneration through the construction of skate parks in peripheral urban areas: the skate park can act both as a *social stage* as well as a sportive platform and can trigger a process of reclaiming for neglected public spaces. It tackles the ever-expanding issue of **safety in peripheral urban areas**, and is a pilot project potentially replicable anywhere, through a set of guiding principles on how to start new activities on the territory in order to claim back urban spaces from criminal gangs and clans.

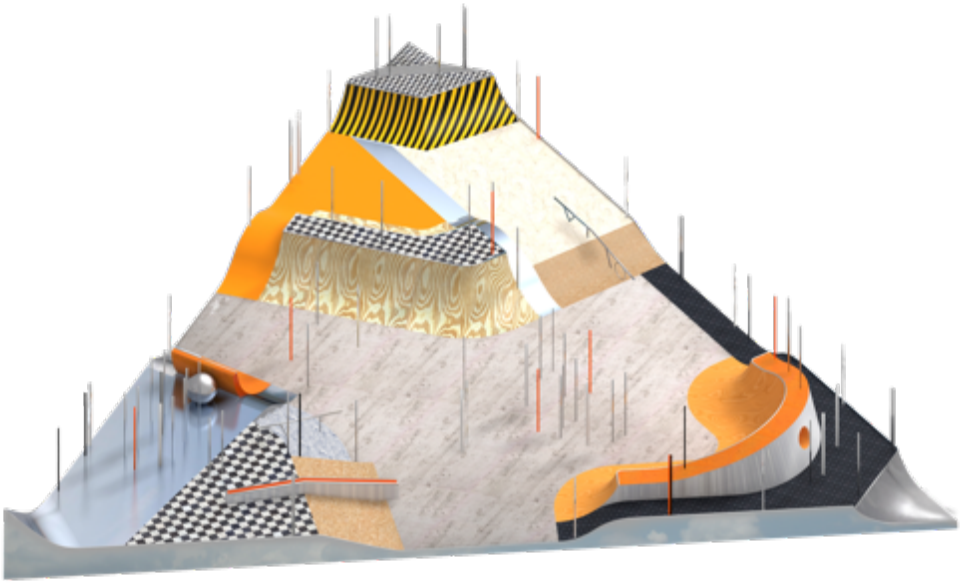
Although *The Surface* hasn't been constructed yet, one suburban area in Milan (chosen through a weighted criteria evaluating system) was selected as the most suitable for its first application. It is a strategy adaptable to peripheries of cities, based on the idea that the involvement of the citizens can be more effective than any institutional involvement in leading to crime reduction. For this reason it also raised the interest of the Department of Juvenile Justice and Community, which looked for a possible application of *The Surface's* framework inside jails and prisons, for the rehabilitation and reinsertion of past criminals into society.

Key Words

PERIPHERY, URBAN REGENERATION, SKATEBOARDING, SENSE OF COMMUNITY, SAFETY

Render of *The Surface* on Parco Franco Verga





Model of "the surface", the texture applied to the materials can be changed

Project description written by the Principal Academic Tutor

"The SkatePark SkateParkItaly (S.P.I.) is a spin-off project from Gangcity, a cultural project supported by a program of scientific research that has completed studies, surveys and reflections on the complex world of the gangs and their spin-off cultures. It documents troubled peripheral urban areas, void of any form of control, to initiate regeneration, re-appropriation and upkeep of private and public spaces and to develop innovative and sustainable operative solutions for the problems of urban clusters. These represent the fertile terrain for the proliferation of gangs and criminal activity. SkateParkItaly is a pilot project organized by the Dipartimento di Giustizia Minorile e di Comunità (DGMC) of Ministero di Giustizia and Gangcity. Through sporting activities it identifies a model of inclusion and integration of marginalized and fragile young members of the communities. The plans can be corroborated by the creation of a common facility – the skate park – destined for leisure activities and sharing free time. A strong bond connects the educational vision of Ministero di Giustizia and Gangcity, that endorses the role of training and publicising through brainstorming between students, lecturers, artists, politicians and entrepreneurs, to join forces with the citizens to produce the mutations of the locations and to intervene on their aesthetic qualities; these can be described as actions of contrast and preventative opposition to the formation of gang cities, interpreted as undeniable 'alternative' devices of self-organisation from grassroots level of the physical spaces of the city and the relative social rules of management, and even dominance.

The re-appropriation of a social space or context using recognized and coded mechanisms facilitates the emergence of youths and groups that join together in a quest for an identity that has been denied. The participation in the construction process for a skateboard park and its associated essential services will create dialogue that is difficult to initiate and develop. It also facilitates the relationship dynamics between individuals – particularly adolescents – who do not belong to any gangs. The actions will develop on a few levels rich with implications; these are geared to the evolution of theoretical thinking, the practical experience and the ethical dimension of the gangs based in the urban environments, to produce programs and projects that can act as treatments to heal the urban environment, like devices for social control, as instruments of growth for the common good. The methodological approach offers multiple contamination options that touch on research disciplines and styles. It proposes a fertile meeting between architecture, design and art, in peripheral locations found in a condition, if not the geographical dimension, to welcome and integrate the gangs and their cultures with new cognitive forms. The objective is to replace at a grass roots level the control afforded by the groups with creative strategies and devices. This will redesign and upgrade the collective spaces through architecture and social design, art and sport, with innovative and visionary combinations of rules. This will drive initiatives of re-appropriation of the spaces under the banner of brotherhood, sharing and self-organization. "

- Prof. **Fabio Armao**

Team description by skill

In the whole process we tended to be all involved in every activity, in order to have a multidisciplinary view of every aspect. However we defined a sort of "director" for each part of the process:

Luisa Viotti: team controller, budget and report

Luca Bussolino & Daniele Ricciardi: theoretical part and design of the architectural project

Marco Felicioni: stakeholder research, report supervision

Federica Pennino: founder of *CONTEXT* association, video and poster production

Seda Ayvazyan: local activities research and event organization

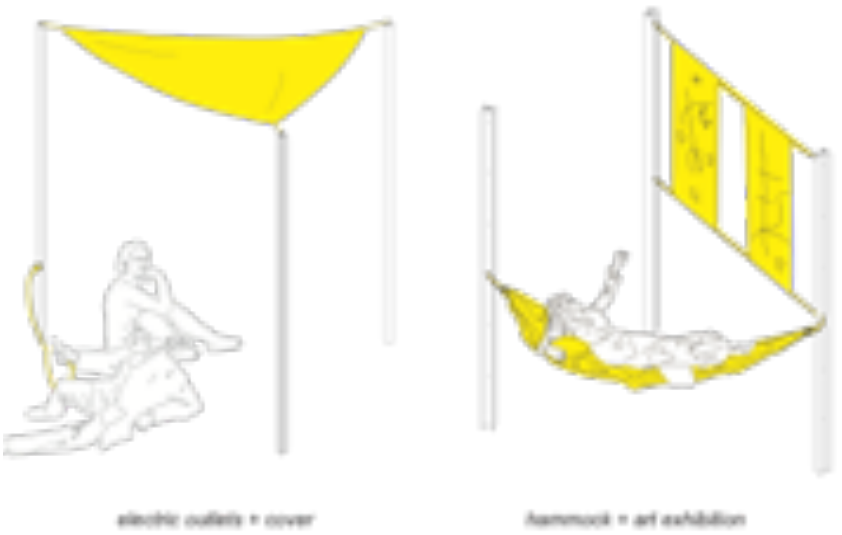
Aleksandra Katmerova: material research and development.

Goal

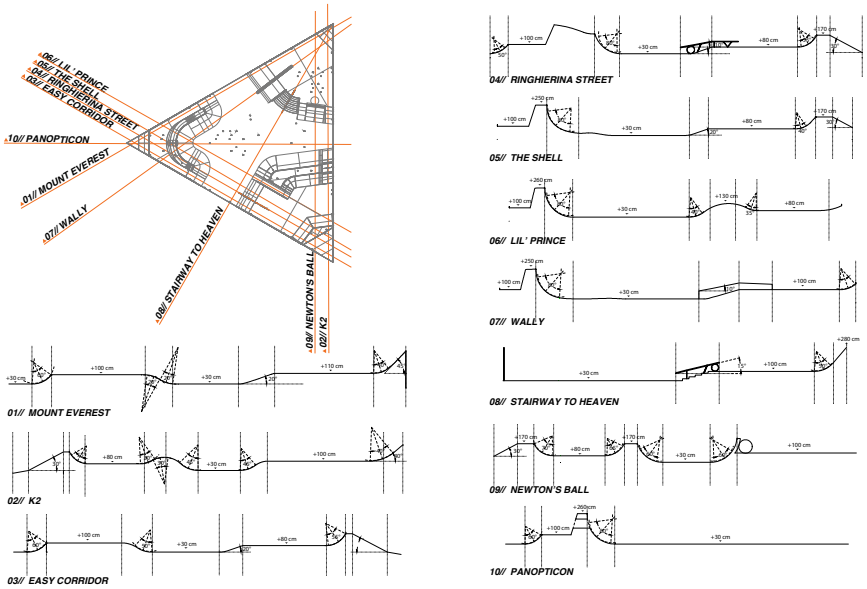
The project SkateParkItaly, in collaboration with DGMC, the associations of UISP - Unione Italiana Sport per tutti [The Italian Union of Sport for All], Milano Skateboarding, Kanikenhaus, and Gangcity attempts to trace a map for returning to the public some peripheral areas of Italian cities. The idea is to create skate parks as design devices that can call on the ethical and financial responsability of the institutions and entice them to overwrite the existing structures and reconfigure the abandoned and damaged public spaces. The key factor is to pro-actively involve the multiple actors in the process. Our goal is to **develop a urban solution** that can create a synergy between skaters and citizens trough the activities that can happen in this designed stage. *The Surface* encompassed extremely ***feasible*** operations, based on low-budget, easily mountable and dismountable interventions and guarantees attractiveness to skaters of any levels because the technical design of the ramps (inclinations, dispositions, etc…) has been aided by the external consultancies of designers who practice skateboarding, thus know the users' specific needs and expectations. *SkatePark Italy* envisions a ***sustainable*** methodology because it seeks the help of local associations active on the territory in safeguarding each intervention. The inhabitants of the neighbourhoods are not just spectators of the initiatives: they become part of it, being involved into performances or recreational activities. Once the designed initiative is ended, the associations and the sense of community projected on the space should therefore stay, leading the short-term output toward a long-term one, with lasting consequences (e.g. sense of belonging, resilience in the community).

Understanding the problem

"The gang phenomenon has been resolved in the past years in relation to the progressive reduction of the costs associated with welfare and the privatization of many publicly managed sectors. Taking advantage of the increase in civil conflict and social inequality, criminal groups practice expansionary "commercial" actions and transform entire urban areas into strategic hubs for the management of illicit goods traffics and the establishment of migrant groups with solid cohesion internal and a strong identity character." [Gangcity, *About* [Online] - Available at Gangcity.it [Accessed September 2018] In the outskirts of every city there are many problems related to **criminality**. Citizens often do not recognize any common space as a safe place to meet. Rather than focusing on crime punishment or on those who perpetrate violence, the project addresses the *spaces* in which such violence thrives. In fact, any strategy aiming at making a place safer through an enforcement, as in the case of *gated communities* where private forces are called upon to establish security, cannot possibly deal with the threat of internal enemies, such as gangs, terrorists, clans or any other *violent non-state actors*. Addressing these invisible threats requires that the urban space is made safer by the very presence of its citizens acting on it, hence a radical change in the way space is experienced and inhabited by the people.



Typology of activities supported by the pole forest in the stage



Skate movement analysis in the surface, considering the pole forest

Exploring the opportunities

Our model is a generic structure that can be adapted to any city. This allows *SkatePark Italy* to develop interventions in any suburb in Italy that requires our help. How can we find the right places? In the first place we answered to this question was to develop an online communication strategy that can involve a certain group of people: skaters and young citizens. We will ask them which kind of places will need our intervention and we will develop a specific solution based on our model. On the other hand we need a good group of designers, architects and engineers that could help for each solution, for this reason we founded *"CONTEXT",* a cultural association aimed to find urban solutions. This bottom up process can be the best way to find new opportunities.

Considering that the major innovative features of our project are essentially 3:

1. *The Surface* is an **itinerant object** that can revitalize the city in more than one site through an ephemeral intervention

2. Moreover it has **functional flexibility**, that is the ability to host at the same time multiple generationally and socially integrative activities LOL

3. The program is not only centered on skate parks, we create a **resilience** projected on the spot and this is the basis of a urban bottom up regeneration based on the self help logic

Generating a solution

The Surface is not merely an architectural project aiming at building skate parks: it is **innovative** in the sense that it is a social experiment, providing local communities with a clear strategy of urban appropriation: the building of a skate park is just a sparkle that generates attractiveness, but it necessarily has to be supported with the organization of activities and the involvement of communities. The project revolves around these three main points:

1. **Object** - the starting point for the regeneration process. It is made by a skateable itinerant wooden structure whose morphology has been mitigated to obtain a non-traditional carousel, within which numerous activities can be staged simultaneously. Above *The Surface* pole forests are planted, conceived as spatial devices able to generate a spatial overwriting, aiding exhibitions or supplemental activities through the implementation of electrical outlets or tensile structures. Some external structures, called *add-ons*, can be given to guarantee additional activities (bar/café, music pavilion, covered room, seating […]), consisting of a light padded frame with panels of chosen materials, according to the preferred narrative.

2. **Place** - Considering the value of urban and social redevelopment, positioning places are chosen based on a weighted system of defined criteria (e.g. *social criteria*: age, income, multiculturalism - *architectural criteria*: feasibility, dimensions, geometry - *urban criteria*: location, accessibility, proximity to related services). Those instances are instrumental in the chain process that involves many city areas - since *The Surface* is expected to be mounted in several places over time - so the carousel can thus assume an itinerant value that can support the concept of resilience in as many areas as possible.

3. **Program** - any collateral activity that will be performed on and around the skate park. *The Surface* can be considered as a passive carousel when exclusively used as a skate park. It assumes an active role when a timeline of events is structured, closely related to the place in which it arises. This also means a great cooperation with local associations; this leads to different uses and a continuous management over time. This allows the structure to provide a schedule of intergenerational and inclusive activities that can make the community more compact, moreover, attract users from outside

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PRINCIPAL ACADEMIC TUTOR
Giulio Zotteri, DIST, Politecnico di Torino

ACADEMIC TUTOR
Francesca Montagna, DIGEP, Politecncio di Torino

EXTERNAL PARTNER
Procter & Gamble

EXTERNAL TUTORS
Iolanda Napolitano, Procter & Gamble, IT Project Manager
Vittorio Sapio, Gillette, Wouthern Europe Senior Brand Manager

TEAM MEMBERS

Luca Airola
Politecnico di Torino

Eugenio Boltri
Politecnico di Torino

Antonio Canu
Politecnico di Milano

Alessandro Giordano
Politecnico di Torino

Davide Maio
Politecnico di Torino

Francesco Rebaudi
Politecnico di Torino

Silvia Zanardi
Politecnico di Milano

DESIGN AND INNOVATE SALESFORCE PROCESSES @ P&G

Executive summary

Design and Innovate Salesforce Processes @ P&G (DISP) project was developed in collaboration between Procter & Gamble (P&G) and Alta Scuola Politecnica in order to examine why the sales volume of Gillette, one of its leading brands, has dropped over the past years and to recommend ways of addressing this issue.

Gillette is worldwide the leader of the male wet shave market. Its "razor and blades" business model implies that the profit comes from the cartridges that are often replaced, and not from the handle which is a one time only purchase.

As of 2017 in Italy, P&G, Energizer, and Bic represent 96% of the wet shaving market in value, with Gillette owning 78% on its own. The total market is worth $250 million and has been experiencing a slow but steady decline since 2013. Despite the relative share of Gillette being unchanged, the market decline is heavily impacting the Company's revenues due to the dominant position of the brand.

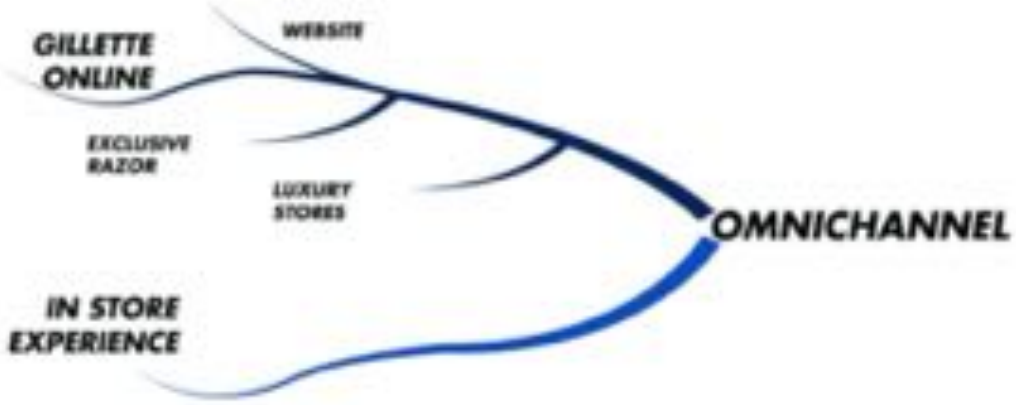
Moreover, Gillette in Italy is threatened by the rise of a phenomenon already suffered in other geographical regions, that is the emerging of the direct to consumer sales through the online channel. Some start-ups in US have been shaking the male shave care market with main disruptive traits such as an aggressive marketing, a low price strategy, and convenient sale processes.

DISP team must therefore exploit new technologies and business models to protect Gillette leadership. The project scope touches different fields, from digital transformation, to data analysis, to marketing and communication strategy; the goal is to design a seamless and effective omnichannel purchase experience

Gillette Omnichannel Online In-Store Communication

(From 3 to 5 key words)

Caption Example (image dimension: 10,5x7 cm)


GILLETTE ONLINE
WEBSITE
EXCLUSIVE RAZOR
LUXURY STORES
IN STORE EXPERIENCE
OMNICHANNEL


DISPOSABLES
SYSTEM
OTHER BRANDS
TOTEM


PLANS


WHY
HOW IT WORKS
TIPS & TRICKS


CONFIRM
REGISTER
PAY

Project description written by the Principal Academic Tutor

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Team description by skill

The team brought to the project a wide array of skills and capabilities from engineering, design and architecture fields. Mainly the team developed a complex economic model that was sustained by strong mathematical, statistical and financial knowledge. These tools come from a solid background in management and mechanical engineering. Then the team further expanded the platform scheme thanks to the studies in production and sales processes derived from the industrial engineering and product innovation students. Then the students were able to develop creative solutions thanks to the design and architecture members. Tutors along with team members helped consolidating a robust logistics and supply chain management solutions. The team was well balanced and able to fully cover all the aspects of the project and develop a seamless omnichannel experience.

Goal

Gillette management presented the current Italian market situation, sharing their concerns and findings. Gillette, in brief, was trying to comprehend all the causes behind its business performance decline and identify the appropriate corrective actions to revert this trend. Moreover, Gillette management expressed their interests towards the investigation of topics such as Millennial's adoption of blades and razors shaving and the increasing competition within the market. It was the team's goal to develop its work in aspects of the client ventures that could produce valuable results and feedback.

An essential objective before a proper initiation of the project was the analysis of the current state of the wet shaving Italian market and its consumers' behaviour. Furthermore, it was important to analyse the dynamics within foreign markets, such as US and UK ones, while acknowledging potential similarities and differences. As a matter of fact, diverse markets showed contrasting trends, mainly due to consumers' habits and companies playing in the specific landscape. In this phase, a study of Gillette value proposition and its main competitors was made to create a base on which to build the idea generation and design phase. The research was mainly divided in two different areas: the first one concerning the enhancement of current in-store experience; the second one considering the rise of e-commerce market entrants and their impact on Gillette business.

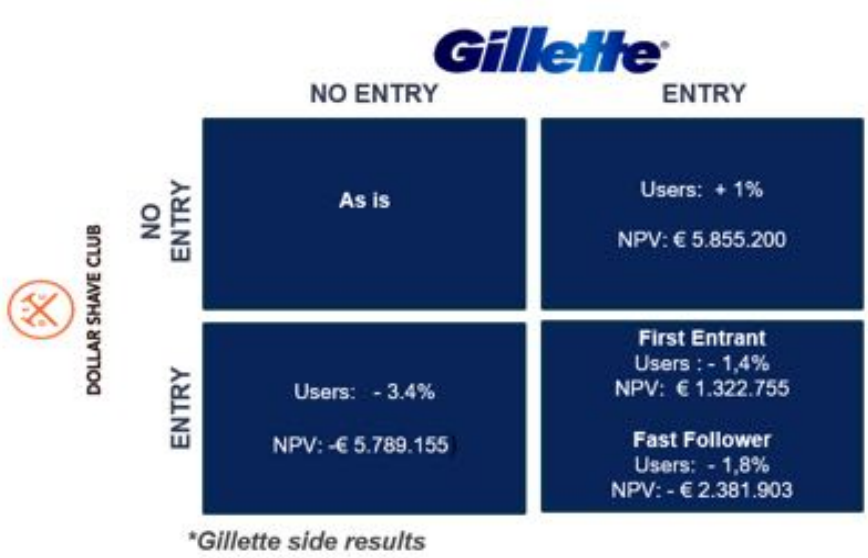
A supplementary, but crucial objective, was to develop a business model for wet shaving e-commerce market. The model would require considering issues such as strategic interaction with current and future stakeholders in the market or competitors, and the evaluation of different scenarios to understand where the client should head to achieve the most favourable outcome for its brand. In addition, as support for the online channel the team developed also a new communication plan for the Company following the up to date fashion trends and investigated the possibility of creating synergies within P&G's existing assets outside of the traditional retail mode.

Understanding the problem

Given the amplitude of the problem Gillette is facing, DISP team decided to use a precise methodological approach to reach a greater level of detail of the findings; market sales data, male shave care market customer journeys, and Gillette portfolio were analysed to investigate the current situation.

The customer journey analysis was used as an explorative method to identify possible pain points in the purchasing experiences of the different segment the brand targets. Following this first phase, DISP team validated the emerged issues through the analysis of last years Gillette sales data, expert interviews and a wide spread survey.

Three main issue emerged: first a change frequency issue, which concerns the frequency with which customers replace blades that is far from the suggested one; second a differentiation issue, since shavers do not recognize features of Gillette blades both within its own assortment and with respect to competitors' products; third, the communication strategy in use from Gillette is not appealing to younger generations. Consequently, a survey was distributed to deeply examine several aspects emerged along the project and design experts were interviewed to assess Gillette products features. In this way, DISP team was able to identify precise needs and requirements, ultimately allowing them to be included in the idea generation and solutions definition phases.



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Caption Example (image dimension 12,2x8,2 cm)

Exploring the opportunities

The problem identification phase allowed to understand better which are the top offender issues that are leading the current Gillette declining trend, namely the change frequency, effective differentiation, and difficult purchasing process in-store. Moreover, analyses highlighted how distant Gillette communication strategy is from the new entrants in the emerging online market. All of the above constitutes a solid understanding upon which to build the next phases of the project.

According to the very broad needs and requirements that the company provided to us at the beginning of the project, a deep problem identification was absolutely necessary. In relation to the main findings summarized above, the team decided to propose two different branches of solutions, the first one related to the online world and the new emergent business models, and the second one more related to the already existing Gillette in store way of business. A simulation model was built in order to assess the sustainability of the online subscription business model considering the interaction with other competitors as well. Moreover, a new concept of communication was formulated: except for the website concept

definition, it also included the design of a new razor that could be attractive to Millennials to be sold exclusively through the online channel.

Generating a solution

The two presented strands of solutions were deliberately kept separate to allow a detailed analysis to be carried out avoiding any correlation that would have unnecessarily complicated the situation in an early phase of the project. These solutions were conceptually designed to be merged into a single macro solution that allows the development of an omni-channel shopping experience for the final consumer, who can use both the online and the offline channel at will by finding a clear, coherent and shared offer from both mentioned channels. The increase in the competitiveness of the wet shaving market entails the need to find new methods of attracting consumers and in this perspective, the possibility of being able to exploit the still predominant presence of Gillette in the retailer-offline world with the addition of an innovative online experience could represent for the brand a real competitive advantage to buy back the market share lost recently and re-consolidate its historic leadership.

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PRINCIPAL ACADEMIC TUTOR
Prof. Paolo Paolini
Department of Information Electronics and Bioengineering, Politecnico di Milano

ACADEMIC TUTOR
Prof. Nicoletta di Blas
Department of Information Electronics and Bioengineering, Politecnico di Milano
Dr. Stella Casola
Politecnico di Milano

EXTERNAL INSTITUTIONS
IBM

EXTERNAL TUTOR
Ing. Alessandro Faraotti, IBM
Ing. Fabrizio Renzi, IBM

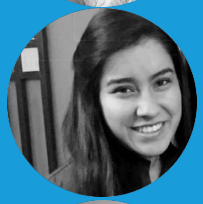
Andrea Belli, Politecnico di Milano

Damla Ezgi Akçora, Politecnico di Torino

Luca Lodi, Politecnico di Milano

Filippo Vanella, Politecnico di Torino

Marina Berardi, Politecnico di Torino



Daniela Nossa Diaz, Politecnico di Torino

Stefano Falletta, Politecnico di Torino

CHECK(CHatbots in Education and Cultural Knowledge acquisition)

Executive summary

The CHECK project (CHatbots in Education and Cultural Knowledge acquisition) aims to bridge the gap between raw unedited teaching material present on the web and its easy conversational fruition, by developing a reusable chatbot architecture (iCHAT), able to adaptively guide students even when they cannot count on the guidance of a teacher. The novelty with respect to current approaches lies in the fact that the chatbot rather than being an expert on the subject is an expert on a body of content covering a subject. In other words, the chatbot is tasked with efficiently (and empathically) interacting with the learner while being backed up by a complex system, powered by instructional intelligence, that adaptively provides the most suitable items of content when needed. We named this novel approach Content-Oriented Learning Assistant (COLA).

Key Words

Chatbot, IBM Watson, Education, Intelligent Tutoring Systems

Project description written by the Principal Academic Tutor

The use case of developing a chatbot to help the secondary school's students recover learning gap about equation (math chatbot), had driven the research, the design, and the development of the iCHAT architecture. This real-world application is based on real contents edited by real teachers, and thus stand out as a proof of concept for both the architecture and the COLA approach. A working demo of the math chatbot was developed through an iterative design approach, and helped understand the main limitations and strong points of the overall approach. The supporting technology was created in cooperation with IBM, partner of the project. The COLA approach can be exploited by different education providers to reach a guided scalable access to big corpus of educational material. In fact, the advantage of adapting the content's index to the user inclinations by a conversation flow is more evident on large corpora like for example university Massive Online Open Courses (MOOCs). As a matter of fact, COLA is now being deployed in the frame of a European project to create a chatbot that supports students enrolled to a Coursera course on Recommender Systems. The research effort aims at being a step on the path towards educational chatbots' "industrial production", to inexpensively give a second life to the educational material, sometimes forgotten, that populates the web.

Team description by skill

Andrea Belli An enthusiastic management engineer that has also a technical background complementing his leadership skills. He coordinated the team while developing the Watson-based conversation engine.

Damla Ezgi Akçora A computer engineer working on Computer Vision and Artificial Intelligence. Being the team leader, participated both in the technical development and the organization of the project as interface with the board.

Luca Lodi A technology lover with the interest in other disciplines and the knack for simple but elegant solutions. Main architect and implementer of the proposed solution, as well as interface with the professors.

Filippo Vannella A telecommunication engineer with a passion for Artificial Intelligence. He took part in the technical development and in the editing of the content.

Marina Berardi An energetic, passionate, and hard-working management engineer. She took part in the analysis of the linguistic formulations as well in the organization of the content.

Daniela Nossa Systemic designer that participated on the analysis of the user, understanding the linguistic features of the student and professors.

Stefano Falletta A physicist with passion for complex systems and their technological applications.

Goal

iChat was designed considering several expectations in both the technical capabilities and user sides. To cite the most significant goals that also challenged the entire process could be listed as follows:

- *Creating a generalized technology*: The idea is to build a combination of tools resulting into a unique data driven system capable of driving conversations (rather than being a passive system) and be easily re-usable in other contexts. The tools support the front-end (e.g. proposition of contents conversation itself) and back-end activities (e.g. preparing the content).

- *Creating a framework for the modular architecture of data driven chatbots*: The chatbot has to be based on a modular architecture where a few key actions are always executed in series and continuously. If we think how a conversation between humans takes place, we could design a conversational process. First, there is the exchange of information among the individuals, who, secondly, store and interpret the data received according to their backgrounds. Finally, the response flow is produced and delivered. - Providing a valid user "experience" The objective is to stimulate users' interest. Usually, other educational solutions, such as MOOCs and other online courses, do not either catch the attention or keep teenagers interested since they are based on non-interactive media. The chatbot makes the user live an out of the ordinary experience. The key is to drive engagement and interest.

- *Creating an effective interaction:* The chatbot should be effective in delivering contents and adapting to the faced user. Students have different learning capabilities from each other, thus, educational solutions must consider this constraint while designing content paths. What our projects aims at is to supply a flexible solution that is, at the same time, aware of students' difficulties, capable of identifying their areas of interest and using them to engage students more in the conversation.

- *Keep the student interested:* The human span attention is the ability of a person to focus on a task without being distracted. It can vary according to age, physical health, emotional status, degree of interest in the topic and type of attention required. As regards long-term attention, researchers estimated an average of 20 minutes for deep concentration in teenagers with no apparent health problems. The attention span resulted higher when the task to be performed was enjoyable and enough challenging to feed self-determination and perceived capabilities. In iChat design, we focused also on understanding how to keep the student interested during the interactive session. This idea applies also for other domains since all the chatbots aim to engage the user to get involved in the conversation.

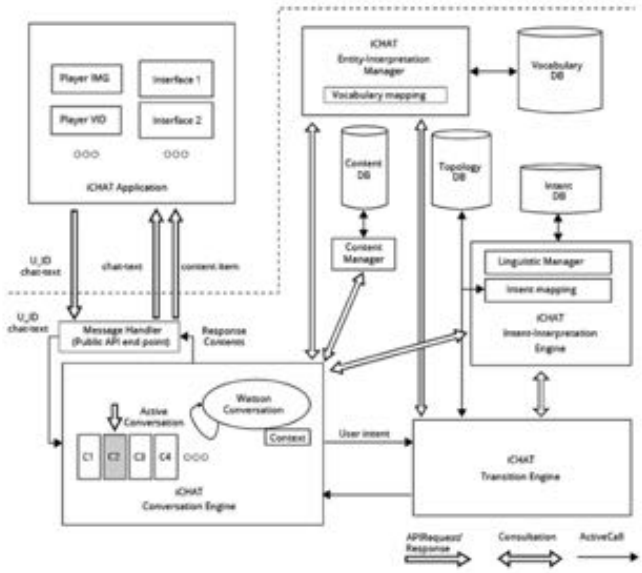
Understanding the problem

Chatbot interfaces simplify the user interaction with information systems, by exploiting the machine natural language understanding capabilities developed in recent years. In fact, they let the user express intentions and receive information through the natural flow of a conversation, improving the overall user experience, steeping the learning curve and better fitting the user needs. However, most of these technologies are tailored for specific conversation scenarios and thus intrinsically coupled with the content (knowledge base) of the conversation. This characteristic jeopardizes the code re-usability in different contexts (topics), independently of their similarity. Nowadays, chatbots are mainly forged through an artisanal, rather than industrial, process. Everyday, a huge amount of learning objects and resources are created and stored in the web, but they are poorly accessible due to the limits of the "search oriented" nature of the web. Educational content must wait to be edited into books or websites (time and cost hungry operation), before it can be properly used. The CHECK project (CHatbots in Education and Cultural Knowledge acquisition) aims to bridge the gap.

On one hand, we had to face the difficulties of interpreting and understanding the natural language, in order to deliver an emphatic and simple-to-use chatbot. But on the other hand, we also had to tackle the complexity of education strategies, in order to adapt the conversation to the student's needs. These challenges extend

to two main research fields: The Natural Language Processing, to empower the chatbot to "talk", and the Artificial Intelligence / Machine Learning, to enforce the student's adaptativity. There are technologies and frameworks to address these problems, but many of them are business-oriented (eg: booking interface for a restaurant), and thus are user-centered and do not present any form of proactivity. In education, this is a limitation that need to be overcomed, since usually the student need guidance and is not expert of the whole corpus of content. On top of this, we needed to work under some simplifying assumptions.

The COLA approach involve a chatbot that is expert in the body of content, rather than on the application field. Thus, we need to organize this corpus, splitting into "items" (atoms of informations), organized into topologies (possible paths of items). From this emerges that both choosing the right item's granularity and devise some mechanism to navigate and generate these topologies are problems of paramount importance.



iCHAT architecture.

Exploring the opportunities

We tested many possible alternatives throughout the project, from a completely proactive chatbot, able to mimic the teacher's behaviour to a solution that enhances the user's agency. The design of iCHAT has been a significantly challenging task since all the functionalities have been researched from scratch and there was not clear path to follow. The design path shown in the figure on the right was updated incrementally every time we discovered a problem. The first idea that we came up with was implementing a proactive, content-driven chatbot architecture which can be used in several fields. The prototype architecture was meant to be tested on two use-cases, namely mathematics and cultural heritage. We explored the tradeoff between degree of specificity of the content, that degrade reusability, and its performances with the support of some of the best IBM cognitive tools, such as Watson Assistant, to produce a novel approach to chatbot generation. Also, we started to test the limitations of the system by writing conversations. To be able to gather all the improvements and see how the system so far works, we prepared the first version of the cultural heritage demo. Analyzing the performance of the chatbot at this demo, we came up with one the key idea of the whole project: the creation of different engines to manage the conversation flow, namely the Transition Engine (TE) responsible for the transition to the next item, the Interpretation Engine (IE) that propose contents in the best way possible according to the user profile given some input variables, and the Conversation Engine (CE) responsible to manage the conversation. Despite these components never changed in the name throughout the project, their role and importance changed a lot to explore the previously

introduced tradeoff between reusability and performances. It is possible to split the "smart/logic" element of the chatbot between these components, to achieve a better proactivity (complex Interpretation Engine), or an improved adaptivity (complexity in the Transition Engine). For a relevant part of the project duration, one of the primary goals was to mimic the didactic proactivity of a teacher, inside the Interpretation Engine. This lead to an increased complexity of that component. In the end, it was almost impossible to check the correctness of the Interpretation Engine rules, and thus it was decided to partially drop the goal, to focus on a simpler didactic strategy, based on the superposition of simpler heuristics. We tried to figure out how we could dynamically adapt the current situation of the user. The team agreed on using a set of variables which are updated according to user input. Following this, linguistic formulations were studied in order to give more flexibility to the model and interpret the expressions. At this point, we prepared an online survey to evaluate the public expectations of a chatbot to improve user experience in the design of iCHAT.

Generating a solution

Through an iterative design, supported by agile development methods, we developed a chatbot architecture that is mainly reusable, and thus is able to cut costs. This solution exploits the hierarchy of knowledge to modify the minimum amount of knowledge from one application to another. The supporting technology was created in cooperation with IBM, partner of the project. It consists of four engines (components) that take care of different aspects of the conversation. A Conversation Engine, built on top of IBM's cognitive platform Watson, profiles the user understanding the natural language (intention and mood) and adapts the style of the replies to the user. Explicit reference to the conversation's object are resolved by an Entity Interpretation Engine, exploiting a hierarchical vocabulary. An Interpretation Engine manages the flow of the conversation deciding the best dialogic action to perform according to the dynamic profile of the user status. It is driven by a hierarchical set of rules. Finally, a Transition Engine decides which one of the "items" (atom of the content corpus, e.g: videos, texts, html pages) to propose to the user, based on the history of previous feedback and on a "topology" (graph that semantically organize the

items in some paths). On the one hand the author has still to split the material into items (choosing the right granularity) and organize them into topologies, even though assisted by machine learning tools. But on the other hand, due to hierarchical nature of vocabulary, of language expressions and of educational choices (taken into consideration in the engines' design), most of the components can be reused in a similar application context or easily adapted in a modular way. This enhances the scalability and the re-usability, improving thus the economic feasibility of the approach. The research effort sustained during this project aimed to provide an abstract reusable architecture (iCHAT) to develop COntent-based Learning Assistants, as well as a proof of concept for its flexibility and reusability, necessary to enable an chatbot development "industrial process". A chatbot to assist secondary school students in bridging their gaps about math equations was developed up to the stage of fully functional demo, through an agile development process that involved many iterations. This chatbot implemented a subset of the iCHAT architecture, but was anyway able to deliver many of the required functionalities, proving the feasibility of the architecture for real-life applications. A side output of this iterative development process is a constellation of tools that aim to support and speed up the editing of the contents, as well as enhancing the configurability of the developed chatbot and boost a continuous improvement of its configuration by interpreting the usage feedback. In fact, a fundamental characteristic in order to create an industrial process is the presence of a tool ecosystem, supporting the authoring process, and enabling of the monitoring and improvement of the performance on the product after the interaction with the users.

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EARTH OBSERVATION AND THE DIGITAL HUMANITARIANS

PRINCIPAL ACADEMIC TUTOR:

Maria Antonia Brovelli, Department of Civil and Environmental Engineering, Politecnico di Milano

OTHER ACADEMIC TUTORS:

Piero Boccardo, Interuniversity Department of Regional and Urban Studies and Planning, Politecnico di Torino

Daniela Carrion, Department of Civil and Environmental Engineering, Politecnico di Milano

Andrea Monti-Guarnieri, Department of Electronics, Information and Bioengineering, Politecnico di Milano

Daniele Oxoli, Department of Civil and Environmental Engineering, Politecnico di Milano

Barbara Pernici, Department of Electronics, Information and Bioengineering, Politecnico di Milano

EXTERNAL TUTORS FROM EXTERNAL INSTITUTIONS:

Cristiano Giovando, Humanitarian OpenStreetMap Team (HOT)

Paolo Pasquali, ITHACA

Pierre-Philippe Mathieu, ESRIN

TEAM MEMBERS:

Igor Donevski, Communications and Computer Networks Engineering, Politecnico di Torino

Luca Guida [Team Controller and Communication Coordinator], Computer Science and Engineering, Politecnico di Milano

Leonardo Lo Schiavo, Communications and Computer Networks Engineering, Politecnico di Torino

Executive summary

Emergency agencies, civil protection authorities and non-governmental disaster relief organizations are crucial for timely assistance to affected areas. The effectiveness of disaster relief activities is usually limited by the amount of immediate information such as scarcity of updated reports about caused damages, and the number of people involved. With the objective of improving emergency response, the EODH team was guided by three external institutions that have driven the project's demands: ESRIN, one of the five European Space Agency (ESA) specialized centers in Europe which provided the team with satellite data and the open source software tools to process it; Humanitarian OpenStreetMap Team (HOT), an US-based organization supporting volunteers that work on humanitarian mapping in the context of OpenStreetMap project, encouraged the team to use Free and Open Source Software, as humanitarian work demands; ITHACA, an applied research center

for distribution of IT products and services in support of humanitarian operations, pushed the team to find alternative methodologies to assess damages to buildings in case of bad lighting and cloudy weather conditions. In such way the team strived to aid disaster response activities by developing an integrated software pipeline which is completely free and open source (FOSS) and compatible with all the major platforms. Such pipeline encapsulates in a QGIS Python plugin a sequence of pre-processing and Coherent Change Detection algorithms by hiding the procedures' complexity from the final user. The plugin represents an end-to-end tool for automatic damage assessment, which has been tested and validated on earthquake case studies. A great advantage of this pipeline is that it is both fully modular and fully open source, thus it potentially facilitates any volunteer humanitarian contribution with little effort. This results in a software that can be very useful to the demand drivers as our automatic assessment of damages ensures rapidity in mapping activities, especially when lighting and weather conditions make the use of optical imagery unfeasible. To further aid the objective of improving emergency response, the team tried to integrate the SAR-based damage assessment with the use of user-generated content extracted from social media platforms and more specifically with the usage of Tweets for damage assessment purposes, considering the same case study of the SAR-based approach. All in all, it is expected that in the near future the results and user experience of both approaches might be improved by testing different case studies, publishing the finished plugin on the QGIS Python Plugins Repository to make it available to the whole QGIS community and the source code on GitHub, using computer vision algorithms to automate the analysis of damages in social media photos and enabling the automatic recognition of known places in images posted on social networks.

Key Words:

"Remote Sensing", "Damage Assessment", "SAR", "Humanitarian"

Project description written by the Principal Academic Tutor

We live in the era of big data and that means outstanding opportunities to get insight into manifold phenomena that shape or affect our communities and territories. On the other hand, a fair access and use of this information have to be advocated in order to turn data into valuable actions that foster safety, development, and cooperation at any level of the society. These are the baselines on which The Earth Observation and Digital Humanitarians (EODH) project is developed. The EODH project aims at providing cutting-edge tools and methodologies in support of natural and man-made disaster response. This, by taking the best advantage of the new geospatial big data such as satellite imagery and user-generated contents. In particular, the EODH project proposes a semi-automatic procedure to assess damage on buildings and infrastructures in a short time after a disaster strikes. This is achieved by exploiting the frequent-pass Synthetic Aperture Radar (SAR) imagery captured by the European Space Agency (ESA) Sentinel-1 mission, and distributed with an open license by the Copernicus program of the European Commission. Multitemporal SAR imagery stacks are processed using an ad-hoc developed procedure that exploits Free and Open Source Software (FOSS) tools to automatically quantify - by means of Coherent Change Detection techniques - and map building damages. Ancillary information from other big data sources, such as Twitter, has been employed to validate as well as improve the procedure. The central Italy earthquake of 2016 and the 2017 Southern Mexico earthquake were selected as initial case studies.

The EODH project is co-design with leading external partner and stakeholders active in the fields of Earth Observation, disaster management and humanitarian aid. These are namely the ESA Center for Earth Observation (ESRIN), the Humanitarian OpenStreetMap Team (HOT), and the Information Technology for Humanitarian Assistance, Cooperation and Action (ITACHA) that is an Italian research center of applied remote sensing for emergency response. The partners contributed to the project by outlining technical and user requirements for the implementation of the damage assessment procedure.

Part of the EODH team attending the ISPRS Technical Commission III Symposium in Beijing China to present the developed pipeline. From left to right: principal academic tutor Maria A. Brovelli, non-member Monia E. Molinari, member Igor Donevski, and member Leonardo Lo Schiavo.

The outcome of the EODH project consists of a software application that integrates the full data processing pipeline, from the raw SAR acquisitions to the final damage grading map. The application is provided as an experimental plugin of QGIS, one of the premier FOSS Geographic Information System (GIS) platform. This allows a free access to functionalities as well the source code thus potentially enabling users to replicate as well as to improve the procedure. This valuable feature coupled with the exploitation of open Earth Observation represents the main strength of the EODH project, which ultimate goal is to

demonstrate the critical role of both open technologies and open data policies in emerging societal challenges such as the disaster management.

The entrance to the IGARSS 2018 conference in Valencia, Spain (image on the right) as photographed by team member Luca Guida (image on the left) as an attendee

Team description by skill

The EODH team was originally composed seven members but reduced to the following three members:

Luca Guida: with his Computer Science and Engineering expertise he contributed with his skills in software engineering and scripting in Python and GNU Octave, as well as application development at creating the QGIS change detection pipeline and further analyze its performance.

Igor Donevski: with his Communications and Computer Networks Engineering expertise he contributed with his skills in signal processing and image processing at analyzing SAR pre-processing and conduct the Twitter image feasibility analysis.

Leonardo Lo Schiavo: with his Communications and Computer Networks Engineering expertise he contributed with his skills in signal processing, application development and image processing, at defining the SAR pre-processing module, validation, and performance analysis.

The EODH team, from left to right, principal tutor Maria Brovelli, Igor Donevski, Luca Guida, and Leonardo Lo Schiavo

Goal

The Earth Observation and Digital Humanitarians project aims at supporting disaster response activities in post-earthquake scenarios by providing buildings damage assessment as relevant information that actors involved in response efforts might exploit to take selective actions. Such assessment is the result of an automatic unitary framework in which open source high-quality satellite imagery given as input is processed by a set of software tools and then the outcomes are visualized in a Geographic Information System. Moreover, the project investigates the opportunity of using contents directly generated by users through social media platforms to integrate and validate the results obtained from the previously presented framework.

Understanding the problem

The main challenge that the team was asked to address was finding new ways to support disaster management activities by leveraging the power of open data sources and User-Generated Content (UGC). In general, disaster response activities require a quick and effective reaction to unforeseen events; right after a flood, a hurricane or an earthquake the main priority is to provide an immediate assistance to the population, but also a timely assessment of damages to buildings and infrastructures in order to promptly restore critical services. Emergency management agencies, civil protection authorities, but also non-governmental disaster relief organizations play a crucial role in the first phases of disaster response, but their action is often limited by the inaccuracy of the available information, or by the scarcity of updated reports about the area affected by the disaster, the actual effects on physical structures, or the number of people involved. The damage assessment process is typically supported by damage surveys carried out by specialists who visit the area affected by the disaster, inspect buildings and other physical structures, and classify the damages occurred. In recent years, UAVs and satellite optical imagery were adopted to assess major structural damages in a faster way, before than technicians could reach the areas stroked by the disaster event. However, the detection of changes by photo-interpretation is not straightforward, while bad weather conditions may harm the quality of these manual assessments, thus limiting the actual applicability of these techniques. Novel techniques are required to address those limitations.

Exploring the opportunities

In the recent years, high-quality satellite imagery, such as the one provided by the European Commission in partnership with the European Space Agency (ESA) through the Copernicus Earth observation program is becoming widely available. Moreover, the rise of user-generated content platforms, such as social networks and citizen journalism websites, allows monitoring of events and disastrous phenomena almost in real-time. In addition, the availability of accurate and frequently-updated cartographic resources, such as the ones provided in the form of Volunteered Geographic Information (VGI) through platforms like OpenStreetMap, provides extremely useful information even to non-profit institutions who may want to contribute to disaster relief activities.

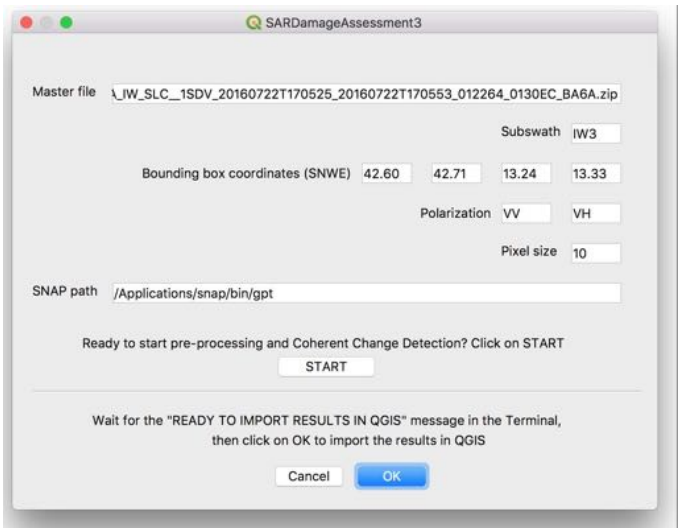
The damage assessment procedure was decided upon by investigating the opportunity of using Synthetic Aperture Radar (SAR) imagery as novel damage assessment approach substituting to the traditional detection of changes through photo-interpretation of UAVs and satellite optical imagery. The team was also required to build and test a software exploiting Coherent Change Detection (CCD) algorithms to automatically detect potential damages to buildings and other physical structures by analyzing pre-processed SAR images of the area affected by a seismic event. This approach has an opportunity in being very sensitive to detecting destructions on ground level as proved by the amatrice case study. Moreover, considering that effective disaster management requires up-to-date information about the affected area, the team was asked to extend the aforementioned SAR-based methodology by integrating valuable information about the post-disaster scenario coming from user-generated content platforms and social networks such as Twitter. This approach has great opportunity to solve some peculiar scenarios in disaster relief, given that the local populace uses the technology.

Generating a solution

Having the goal of creating an easily accessible automated buildings damage assessment mechanism, the team decided to create a framework which is available on all the major platforms (Windows, macOS and Linux) and which hides the complexity of the processing by incorporating all the processing steps into a single plugin of the Free and Open Source Software (FOSS) Geographic Information System (GIS) application QGIS, in such a way that both amateurs and experts could download the tool and use it without requiring any specialized

hardware or particular expertise. For this the team developed damage assessment mechanism that consists of three steps.

The first step that a user need to undertake manually is the data acquisition step. Here the user decides the area of interest to perform damage assessment on and then manually download from ESA Copernicus Open Access Hub pre-disaster and post-disaster images available along the specified period. The images chosen in this step must be taken by Sentinel-1 satellite according to the Synthetic Aperture Radar (SAR) technology since this kind of imagery ensures better performances also in case of clouds and bad weather conditions in comparison with traditional optical imagery.



The interface of the developed plugin that a user would work on when trying to perform his humanitarian work

The second step is the processing step: within the QGIS platform, the user simply specifies some parameters before executing the aforementioned plugin, which calls a Python script that is responsible to perform a set of pre-processing operations to the downloaded SAR images in order to create a data unit called interferometric stack. The pre-processing procedure was decided upon careful revision of the available signal processing tools in order to be the input of the Coherent Change Detection (CCD) Algorithm. The CCD run in the FOSS GNU Octave environment and responsible of determining with a given resolution the latitude and longitude coordinates of the points that have changed in the post-disaster images with respect to the pre-disaster images as a way to perform damage assessment. The choice of the usage of a Coherent Change Detection Algorithm in this step is justified by the fact that such class of algorithms allows detecting even very slight changes in the scene, and its main drawback of the high number of false alarms obtained (i.e. undesired and incorrect change detections) is reduced by acquiring as many as possible SAR images over the same area both before and after the disaster event.

The third and final step that a user of the developed solution needs to go through is the visualization step. In this case, the user just confirms to visualize in the QGIS platform on top of a base map provided by OpenStreetMap the points of change detected and obtained as result of the previous step. This is where a humanitarian user would report the possible damages of the unfortunate event to the responsible authorities for review.

The result of a run of the algorithm (red points) over the Amatrice earthquake in comparison with the European Space Agency building damage grading (structure shaped geometries with four different building grading)

Afterwards there were attempts to confirm the data through social media platforms. Using data provided by posts on Twitter, the performance of the evaluation may need to rely on fewer acquisition to reach better precision. In addition, as a long run solution, it can be considered that a computer vision project will allow for full automation of the detection of the images posted to their accompanying text. Of all 252 tweets a guideline called “Procedure for post event analysis of Twitter data for damage assessment” was developed. The goal of this procedure was to trivialize the search for geolocating a location of a captured disaster in order to be later assessed. In the end, the team was able to decide on damages on some buildings.

Successfully geolocated damaged buildings (in yellow) by using the Twitter dataset

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PRINCIPAL ACADEMIC TUTOR
Roberta Ingaramo, DAD|PoliTO, Department of Architecture & Design

OTHERS ACADEMIC TUTORS
Isabella Lami, DIST|PoliTO Interuniversity Department of Regional and Urban Studies and Planning
Marzia Morena, DABC|PoliMI Department of Architecture, Built Environment and Construction Engineering
Matteo Robiglio, DAD|PoliTO, Department of Architecture & Design
Elena Sezenna and Sabrina Saponaro, DICA|PoliMI Department of Civil and Environmental Engineering

EXTERNAL INSTITUTIONS
Emanuela Canevaro, Comune di Settimo Torinese
Marina Dragotto, AUDIS| Associazione Aree Urbane Dismesse
Marco Cantamessa, I3P|Incubatore Politecnico di Torino
Federico Zardi, CEIP| Centro Estero per l'Internazionalizzazione

TEAM MEMBERS

Beatrice Cappuccilli, PoliMI, Architecture

Dennis Saiello, PoliMI, Architecture

Federico Lucchi, PoliMI, Architecture & Building Engineering

Marini Saripusa Dini, PoliMI, Urban Planning

Sebastian Reimann, PoliMI, Management Engineering

Re-Implant

Executive Summary:

Premise The rapid de-industrialization of Western economies has left an enormous impact on the urban landscape in Europe. Once thriving eco-systems of industrial growth have vanished and left behind vacant warehouses and production facilities. Urban planners are reintegrating these 'brownfields' into the urban fabric as mixed-used developments and are therefore overwriting their industrial heritage, which is undeniably a part of our cities. Furthermore, the disappearance of manufacturing caused many people to lose their jobs and for their skills to become obsolete, thus leaving an even greater impact on society itself. An ex-steel mill in Settimo Torinese, just outside of Turin, is one such example that was abandoned by the dissipating metallurgy industry years ago and has been left to decay. Based on this case study, we argue that the reintegration of these brownfields can lead to more benefits than affordable living space in undesirable areas in the outskirts of urban agglomerations. In fact, sustainable re-industrialization can reinvigorate a stagnant economy, create jobs and allow manufacturing to return to our cities.

Case Study The case study is based on the former industrial site of Lucchini, which manufactured steel on the 93.000m2 area located in an industrial cluster in the municipality of Settimo Torinese. Its two manufacturing halls were vacated in 2002 and left to degenerate. Today, the structures remain in place, severely damaged, partially collapsed and covered with vegetation and graffiti. The lax environmental rules of the time have left their mark on the territory in the form of heavy metal pollution in the backfill material covering the soil. Isolation from the city center, poor accessibility for pedestrians and the location within an industrial zone make this site inadequate for any form of residential development.

The strategy is based on exploiting three core elements that these cases have in common: industrial heritage, productivity and innovation. Industrial productivity has fueled growth all over the world and although most large- scale manufacturing has been outsourced, it still forms the backbone of our economy. Industrial activity creates jobs and wealth for society, while shaping the identity of our cities over the last two centuries. Industrial heritage is an integral part of our modern history, and worth perpetuating. In fact, our focus is on adaptive reuse, which finds use in the existing structures, rather than preserving them as an industrial museum. Yet, re-shoring low-skill mass-manufacturing is not a sustainable strategy and urban manufacturing has since undergone a transformation

towards the advanced manufacturing. Innovation plays a key role in this environment and recognizing this transformation allows us to develop a solution that shows that manufacturing is ready to make a comeback and fuel dynamic growth. These three core elements are the recurring themes that appear throughout the project and act as a red line for the development of the masterplan.

Analysis A thorough market analysis identified two potential functions for the site, logistics and manufacturing. The logistical function is rooted in the current market conditions and the excellent accessibility of the site, underlined by an existing logistics cluster in the area. The analysis of the manufacturing sector found more complex trends that pointed towards the use of advanced manufacturing, which is the foundation for Industry 4.0. Advanced manufacturing is based on innovative technologies such as 3D printing and robotics, interconnected through the cloud and supported by big data analytics. This transition into high-tech manufacturing, which is focused on low volume and high variety, requires a highly skilled work force, as well as a functioning eco-system and support infrastructure for innovative small businesses. Both of these aspects were found to be present in Turin already, reinforcing our strategy to focus on advanced manufacturing. This analysis led to the concept of the Industry 4.0 Campus.

Business Solution The Industry 4.0 Campus is a technology innovation center that unites all aspects of the new industrial reality. It connects different actors in a local and virtual community to enable exchange of knowledge and expertise, while developing innovative products on-site. Researchers investigate current trends related to Industry 4.0 from a technological and economic perspective, while students and makers work on their individual prototypes in state- of-the-art labs. SMEs will find space to set-up and test small production lines within the same building, while large companies enjoy the privacy of a separate, customizable facility. In addition to exhibition spaces and offices, rooms are available for educational activities such as training and workshops. All of the infrastructure is supported by an IT system which allows researchers to assess the entire value chain from a system's perspective using data analytics. The concept is focused on creating a collaborative community, enabled by common spaces around the site designed to bring people together and allow everyone to learn from each other. Additionally, a modern, Industry 4.0 enabled distribution center will be located on the campus, leased to an external logistics provider, yet integrated into the community of the site. The common spaces are also open to the public, with regular cultural events intended to attract interest to the site and its activities.

Architectural Solution A sustainable development consists of a business model and an architectural masterplan that complement each other in all aspects. Based on the principles of adaptive reuse, the design juxtaposes the old and the new. The aim of the project was not to retain the site as an industrial museum and thus, buildings only remain if they have a future use, and new building were constructed where necessary. The logistics and production buildings are, in fact, new constructions due to the requirements of these specific functions. However, the main structure on the site remains as an industrial cathedral, a large open space, delimited by its concrete columns and steel trusses that once used to carry a roof. Within this space, community functions and services will be hosted, immersed in an urban green space meant to foster communication. In addition, the design plays with the contrast of open and closed spaces, which represents the difference between traditional and modern manufacturing. The former, noisy, smelly and polluting, hidden away in the industrial belts around the city versus the latter, clean, green, quiet and inviting. The technological solution adopted relies on modularity and expandability to ensure the flexibility of the space, while the materials used reflect the elements that defined the old site like steel and iron yet interspersed with modern elements of glass and timber.

Feasibility and Implications In addition to the preliminary market analysis, the feasibility of the project is demonstrated by a discounted cash flow analysis, which estimates a net present value of approximately €10 million. The construction process is carried out in phases based on cash flows and risk mitigation, while the business is scaled up as the phases are completed. The numbers show that the project could be attractive to investors and developers who are interested in stepping out of their comfort zone and approach this innovative solution to industrial redevelopment. This strategy has the potential reinvigorate the local economy by bringing an evolved form of industry back to a region whose identity is strongly tied to manufacturing, without erasing its industrial heritage. It will create jobs for people who have the chance to be retrained, learn new skills and foster innovation through research and development in an integrated laboratory. Teaching activities and cultural events will attract young people to Settimo Torinese and turn the city into a hub for advanced manufacturing and learning. Small enterprises will be able to transition towards Industry 4.0 with the help and resources of the Industry 4.0 Campus and further contribute to growth in the region. This project demonstrates that the sustainable re-industrialization can have far-reaching benefits for all stakeholders.

Key Words: Industry 4.0 campus, innovation, industrial productivity, industrial heritage, adaptive reuse

Project description written by the Principal Academic Tutor

The industry had a key role in the development of contemporary cities. From the eighties, delocalization of production facilities in east countries left behind huge voids, large unused skeletons, partially transformed by post-industrial development programs. Today, the occurring shift inside an economic model in crisis, a digitalized production process and the necessity of a re-organized energy model underline the importance of production as a key factor of innovation in the development of our cities.

The project defines and tests on a real case study a holistic approach to the regeneration of dismissed industrial sites, developing mixed uses design where production and life are connected in the same model. Adaptive reuse, preservation of industrial heritage and identity in different time phases guided the construction of the scenario. Economic feasibility and possible revenues are part of the project. The approach is based on the multidisciplinary integration of knowledge and skills during the whole design: risk assessment, remediation, and construction process in order to define real policy proposals trying to improve the technical framework for more sustainable reuse procedures.

The site of analysis and design chosen is the ex-industrial plant of Acciaierie Lucchini, the last steel plant appeared on the municipality of Settimo Torinese and symbol of a glorious industrial past, almost buried today. The factory was located on an existing plant, built by Maggio and Baldi, traders in ferrous materials since 1955. In 1966 the Lucchini company acquired the small foundry, bankrupted in the previous year, starting the first expansion of the site. The complex was definitely closed in 2000, putting an end to the steel industry in Settimo.

In a new industrial shift, the renewal of this urban industrial complex can bring new value to the city of Settimo, transforming an abandoned space into a innovative industrial hub able to combine logistic, production, leisure and temporary living, experimenting mixed-use programs and becoming an example of the new relation between innovative production and the city.

Team description by skill

Our team consists of five members, with a background in engineering and architecture. As a small team, we used an integrated approach and collaborated on all essential parts of the projects. Task leadership rotated based on the task at hand and each team member contributed with their expertise in several fields.

Beatrice Cappuccilli: Architect, coordinator of the team and responsible for the architectural design, analysis of case studies, drawings and the appraisal of the land.

Marini Saripuspa Dini: Urban planner, responsible for the analysis of the urban context, analysis of social structures and development of the core strategy.

Federico Lucchi: Building Engineer/Architect, responsible for the environmental analysis of the soil, the structural components of the design and the architectural cost analysis.

Sebastian Reimann: Management Engineer, responsible for market analysis, feasibility analysis and general strategy of the project.

Dennis Saiello: Architect, responsible for the architectural design, analysis of case studies and drawings.

Goal

This project is emblematic for the reintegration of a mixed-use facility, in abandoned browfields. The goal is to develop a strategy for the **sustainable reindustrialization** of these sites. While the project is anchored in the development of the masterplan for the ex-Lucchini area in Settimo Torinese, its aim goes beyond the constraints of the case study. This term was chosen deliberately as it unites the three sub-goals of the project itself. **Innovation** is a process of finding solutions that are more effective, efficient and longer-lasting, hence sustainable. Industrialization, because the designated use of the site is meant to be productive from an industrial standpoint and re-industrialization, because the site already possesses an industrial heritage that we aim to emphasize. Other examples show that the adaptive reuse of industrial building stock has become a common challenge for the modern urban planner, especially in the vicinity of previously heavily industrialized cities. The goal should therefore be to demonstrate a viable strategic approach that could be applied to a variety of similar cases throughout Italy and Europe. However, rather than developing a basic blueprint to be applied blindly, the strategy should present the planner with the right tools to consider all relevant factors for each individual project. While they all have certain things in common like the goal to preserve the industrial heritage and reclaim the land for productive use, each site has its own story and external conditions that cannot be generalized. Finally, the masterplan developed for this particular case study is supposed to show that the strategy can lead to desirable results, although the output can vary depending on the perspective and priorities of the designer.

Understanding the problem

The industrial revolution changed societies and landscapes around the world and introduced technological innovation at a pace never seen before. The industrial revolution caused a spike in life expectancy, productivity, education and globalization. On the other hand, industrialization also led to increased exploitation of resources and pollution. Most importantly though, the industrial revolution led to rapidly transforming societies. Europe, as the birth place of industrialization, has experienced this transformation like no other place. Higher living standards drive up the cost of manufacturing, while globalization enables products to be outsourced to cheaper locations, leaving behind a brief but intense industrial heritage. Unlike Roman ruins and medieval castles, this type of heritage is often not proudly shown off, but rather hidden away experiencing abandonment and decay. These structures where built to last, yet the lack of consideration for the environment during construction and operation created polluted and hazardous brownfields, which are difficult to reintegrate into the modern city. However, just like, Roman aqueducts, Greek temples and catholic churches, these sites *"are important milestones in the history of humanity, marking humanity's dual power of destruction and creation that engenders both nuisances and progress."*

This project is concerned with the fundamental aspects of industrial heritage and how to incorporate brownfields back into the urban fabric as a value- adding element. The real case study for this elaboration is an abandoned steel mill in Settimo Torinese, a suburb of Turin in northwestern Italy. Located in the region of Piedmont, Turin is known for its industrious past. As the centre of Italian automobile manufacturing, Turin experienced a similar fate as Detroit in the United States in the late 20th century when FIAT had to let go of almost 75% of its work force and Turin lost almost 30% of its population.2 With the decline of the automotive industry came the decline of all heavy manufacturing, including steel production. The abandoned steel mill in Settimo Torinese demonstrates the classic features of an industrial brownfield of the second half of the 20th century. Founded in the 1960s and closed indefinitely in 2000, the site consists of two large manufacturing halls and is located in an industrial area, just outside the city of Settimo Torinese. Soil pollution is omnipresent due to the industrial practices and lax environmental standards of the time and the remaining buildings are overgrown by weeds, prone to collapse. These considerations bring up the question of what to do with the site and how to design its requalification.

Lucchini Ex-mill Production Building

Exploring the opportunities

The strategy's goal is the 'rebirth of a wasteland', through the understanding of the significance of the existing document. The strategy converges the three branches of innovation, productivity and Industrial heritage and find a commonality that allows the design of a masterplan that on the one hand respects all pre-conditions, but on the other hand presents a viable business model for the project. The design and the business model have to be complementary in nature to be sustainable. The first step of the analysis began with the Industrial Heritage and how the site can fit into the context of the environment while the next step introduces elements of analysis, evaluating the potential of certain functions in the new space. Although manufacturing and logistics both have proven to be viable options, certain conditions apply, as became evident in the analysis. Not all types of manufacturing and logistics would make sense in this context and innovation consists not only in new technologies, but in the way value is created today. Businesses have to adapt their business models in order to be truly innovative. In this case, the innovative eco-system of the city is the driver for a masterplan that satisfies the three conditions and serves as a building block for a sustainable business model. Industry 4.0 is the combination of productivity and innovation. On the other hand, adaptive reuse is the key word for an innovative way to deal with industrial heritage nowadays.

Generating a solution

However, neither Industry 4.0 nor adaptive reuse satisfy all three conditions. Therefore, we use the term 'Sustainable Re-Industrialization' that aims to converge the three core elements together for this project. It is re-industrialization because it respects its industrial past, without dwelling on it. It does not aim to bring back what is gone, but transform into a new form of industry, which is what makes it sustainable. It is sustainable because it relies on productivity and innovation, looking towards the future. From this concept we derived our final master plan: 'The Manufacturing Campus'.

The Industry 4.0 Campus is a concept that aims to create synergies between researchers, experts and learners by bringing them together in the same space. A space that combines the historical significance of industry with the modern understanding of production: clean, green and quiet. The campus is an eco-system that fosters collaboration along the value chain. Researchers study the trends of industry 4.0 in state-of-the-art labs and provide support for students, makers and SMEs who are working on their own projects in a collaborative environment. From the design, to simulation, prototyping and testing, all the way to manufacturing using the latest technology: additive manufacturing, robotics and cloud computing. The campus is divided into four components: a high-tech distribution center, a manufacturing facility, a research and development lab and community spaces. These components, which will be presented in detail in the next slides, all work together to create an unique open innovation community.

Masterplan Solution

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PRINCIPAL ACADEMIC TUTOR
Stefano Mariani, Civil and Environmental Engineering, Politecnico di Milano

ACADEMIC TUTOR
Stefano Invernizzi, Structural, Geotechnical & Building Engineering, Politecnico di Torino
Giovanna Piccinno, Department of Design, Politecnico di Milano

EXTERNAL TUTOR
Hamid Akbarzadeh, Bioresource & Mechanical Engineering, McGill University

TEAM MEMBERS

Haykaz Poghosyan, Architectural Design, Politecnico di Milano

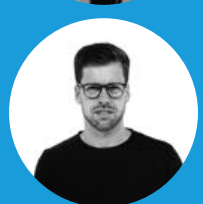
Isabella Flore, Architecture, Politecnico di Milano

Mahsa Bohlooli Zamani, Management of Built Environment, Politecnico di Milano

Massimo Fontana, Building Engineering / Architecture, Politecnico di Milano

Nataliia Antonenko, Interior Design, Politecnico di Milano

Nina Romanova, Urban Planning and Policy Design, Politecnico di Milano



Timothy Liddell, Product Design for Innovation, Politecnico di Milano

SBINBEN:

Smart Bio-inspired Building Envelopes

Executive summary

This project explores the formal characteristics and architectural potential of programmable textiles. Specifically, it is shown how dynamic 3D surface geometries may be generated by printing rigid 2D patterns onto pre-stretched fabric. The resulting surfaces have aesthetic and structural properties similar to adaptive skins found in nature. The SBINBEN report demonstrates the value of this shape-making process, focusing on its potential to substantially improve the design, manufacture and performance of building facades.

The project responds to a pressing question in today's quickly urbanizing world: How might buildings perform better to ensure the health of people and the planet? In particular, how can building skins achieve greater human comfort and energy efficiency?

SBINBEN's design proposal targets under-performing multi-story, glass buildings that do not meet today's energy or aesthetic standards. The project explains the value of adaptable, lightweight building skins and demonstrates how an innovative new process may change the look and feel of our cities in the years to come.

Key Words

Smart Textile, Biomimicry, 3d Printing, 4d Printing, Gaussian Curvature, Developable Surface

Photo of dome prototype exhibiting positive Gaussian curvature

Project description written by the Principal Academic Tutor

Within the present multidisciplinary project, the whole workflow is supposed to be chronologically organized as follows:

1. identify the main challenges that buildings in smart cities have to face;
2. provide a study of the state-of-the-art in the field of adaptive structures and specifically of morphing, kinetic building façades, highlighting the strengths and weaknesses of each approach and the attainable results;
3. propose a novel approach to efficiently actuate and induce the morphing of the façade;
4. quantitatively study the energy efficiency of the proposed solution, through digital models;
5. build a small-scale prototype of the proposed solution, to also discuss relevant technological details.

To frame all the proposed activities, it can be stated that structures have been typically conceived with invariant geometry and mechanical properties to withstand the environmental excitations. To self-adapt under a continuously changing external environment and to also self-monitor their health, bio-mimicking can be considered as a natural development. Accordingly, the goals of making the structures adaptive under variable environmental conditions and of optimizing their behavior are pursued by inducing changes in their configuration, as is typical for the smart structures. To adapt the structure layout for sensing, actuating and possibly energy harvesting and harnessing processes, functional materials and control strategies have to be suitably applied.

A specific focus is proposed on polymeric films, since they allow a significant deformation which might be used to change the system configuration to withstand the variable exciting conditions, while the action they require are conversely limited. Hence, very flexible spatial configurations are envisaged by focusing on lightweight structures, whose capability of self-adapting to variable environmental conditions and interaction with humans is strongly based on an embedded smartness, tailored on customer needs. The technologic goal of this work is to somehow close the gap between the fields of soft stimuli-responsive smart materials and compliant morphing structures, also exploiting parametric design tools.

Team description by skill

Haykaz Poghosyan, from Armenia. He graduated in Architecture (bachelors, masters) at Armenian National University of Architecture & Construction and he is currently enrolled in Architecture Design (masters) at Politecnico di Milano

Isabella Flore, from Italy. She graduated in Architecture (bachelors) at Politecnico di Milano and she pursued her studies in Architecture (masters) at Politecnico di Milano

Mahsa Bohlooli Zamani, from Iran. She graduated in Engineering in Naval Architecture (bachelor) at Amirkabir University of Technology and later in Architecture (bachelors) at Politecnico di Milano. She is currently enrolled in Management of Built Environment (masters) at Politecnico di Milano

Massimo Fontana, from Italy. He is currently enrolled in the 5-year master's degree in Building Engineering / Architecture at Politecnico di Milano

Natalia Antonenko, from Russia. She studied Interior Design (bachelors) at SPbGHPA of Alexander Shtiglitz and she is currently enrolled in Interior Design (masters) at Politecnico di Milano

Nina Romanova, from Ukraine. She graduated in Architecture (bachelors) at Odessa State Academy of Civil Engineering and Architecture and she is currently enrolled in Urban Planning & Policy Design (masters) at Politecnico di Milano

Timothy Liddell, from the United States of America. He studied Architecture (bachelors) at Cornell University and is currently enrolled in Product Design for Innovation (masters) at Politecnico di Milano

Goal

Reflecting on the state-of-the-art, one must acknowledge that the best building envelopes in the world already perform very well from an energy perspective. But their facades are like works of art: singularly designed at great expense to hang on new, pristine walls. They do not, in any substantial way, address the world's energy crisis. Data shows that the most problematic building envelopes are, in fact, those already in existence. Thus, the best shading solution is one that is adaptable and easily applied to existing building enclosures and can pay for itself through energy savings. Thus, it is important to keep material and installation economically viable.

Team Objectives: Facades can perform many quantitative and qualitative functions. For this project, we focus on mediating energy flows incurred from incidental sunlight. Specifically, we consider how shading can reduce unwanted energy gains while maintaining optimal daylighting levels. In terms of energy, this reduces cooling loads within a building and the need for artificial lighting. It improves thermal comfort and reduces glare.

Adaptive skins of plants and animals serve as a source of inspiration, as they have been for builders throughout the course of human history. Today's standard building shell materials resemble the hard, cold surfaces of a cave. We ask ourselves, how might buildings perform if they were covered in soft skins? These considerations led to the team's focus on textiles, and the desire to explore this ancient and rapidly advancing technical material. The digital revolution offers new opportunities as well and it is an aim of this project to show how sensors, processors, and actuators can be deployed alongside smart materials in an autonomous and proactive system.

Starting from the proposed brief and the general research framework on adaptive structures, the team defined key aspects of the project to give a clear, effective answer to current problems. The ability of the structure to adapt does not depend on a single property but on the combination of many features that allow it to respond better to its environment. The team decided to focus on three main criteria: performance of the building, meaning for the community and impact on a global scale.

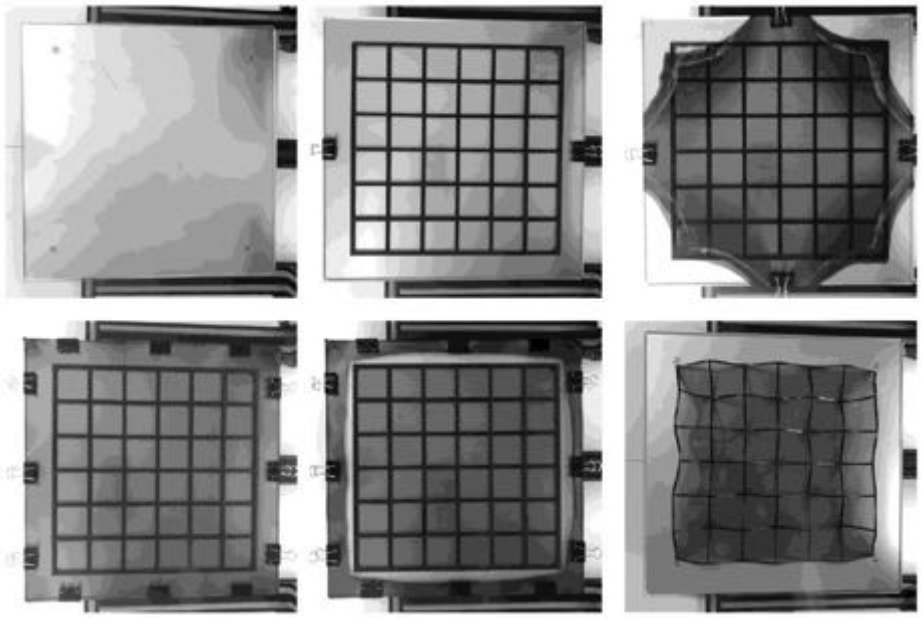
Understanding the problem

Performance, building: The first investigation on the performances of buildings helped us formulate some relevant design features such as responsiveness and adaptiveness, and to highlight the importance of energy saving characteristics. The three main objectives are: (1) regulate energy gain; (2) maximize daylight; (3) reduce glare.

Meaning, community: A second important aspect that the team investigated regards the significance of the project within the urban context and its influence on the community through visual communication. The relevant features are: (1) attractiveness; (2) communication; (3) didactics

Impact, globe: Finally, on a larger scale, a project of adaptive architecture has an impact on the environment, having the opportunity to conserve (and even produce) energy, reduce smog and avoid building waste. Accordingly, additional objectives include: (1) conserve energy, (2) reduce smog; (3) reuse existing buildings.

Target Buildings: The design proposal targets under-performing multistory, glass buildings that do not meet today's energy or aesthetic standards. Many of these structures were built in the post-war period when social and political circumstances called for quantity rather than quality of indoor space. Target buildings include both those built in the Modernist tradition of Mies van der Rohe and those built inside the Communist bloc. In the age of the hanging 'curtain wall', decisions regarding a building's envelope are typically separate from questions of structure. Steel and concrete are almost perfectly interchangeable today in today's high-rise buildings. Yet the SBINBEN project takes a particular interested in rehabilitating reinforced concrete structures that have a high embodied energy, since their demolition constitutes a great material waste.



Steps of SBINBEN's fabrication process: (1) pre-heat bed; (2) print lower layers; (3) stretch and clip fabric; (4) print upper layers; (5) cut excess material away; (6) detach part from printer bed and allow 3d deformation to occur

Four 'Hypar' prototypes after being coated; each exhibits slightly different structural characteristics based on the coating material

Exploring the opportunities

High-Performance 'Skins': In the natural world, skins represent a boundary between external and internal conditions. They mediate energy flows, offer protection, expel waste and create the visual identity of a being. The performance of skin can be attributed to different physical characteristics including shape, movement, color and chemistry. The SBINBEN project is particularly interested in performative shapes, as these can be replicated using the team's hybridized material process. Several biological case studies were explored, serving as inspiration during the team's concept development phase. Architectural case studies were also considered, especially those with high-performance and visually 'performative' building envelopes.

Smart Materials; Smart Systems: The first building skins were literally made of animal skins. Eventually, textiles using animal and plant fibers replaced animal skins and provided new versatility. This early form of biomimicry is considered one of the first examples of human 'technology'. And over the past few centuries, the textile industry has continued to be a driver of innovation - kicking off the Industrial Revolution with mechanized production and anticipating the Digital Age with binary punch cards.

Whereas the history of skins, textiles and buildings stretch back thousands of years, digital technologies represent an abrupt break from the past and an opportunity for new, unprecedented performance. Stated simply, it is now possible to embed intelligence - the ability to dynamically respond to external stimuli - into non-living objects. This goes far beyond simple action-reactions, like a hunter's trap. It enables responsivity with a degree of perception, computational power, and actionability that far exceeds that of human actors.

The field of programmable materials has emerged with the aim of embedding the 'smartness' of our digital world back into the very molecules of material. The SBINBEN team was especially inspired by Lining Yao, who's work at MIT and Carnegie Mellon University has infused materials with life-like, responsive behavior. In just the past few years, other scholars around the world have begun to work at the intersection of smart materials and digital fabrication, achieving extraordinary results.

SBINBEN's contributions: Academic projects to date have had a range of objectives, from theoretical to aesthetic. The SBINBEN project is unique in placing emphasis on real-world building applications. Regarding architecture itself, the SBINBEN team takes a slightly unconventional approach: focusing on the profound need to improve existing buildings at a reasonable cost. It is observed that the best building envelopes in the world already perform very well, reducing and even producing energy. But these facades are costly and complex. The use of smart fabrics with an economic shape-making process could be a game-changing innovation in the world of performance facades.

Generating a solution

A New Way of Shape-Making: The SBINBEN team set out to answer the question: Is it feasible and economically viable to replicate high-performance surface geometries found in nature?

After extensive prototyping, the answer appears to be yes. SBINBEN's process involves 3d printing with thermoplastic (PLA) on stretched textile. The design input is a 2d pattern of plastic ribs and/or tiles, which is printed below and above the fabric layer, locking the fibers symmetrically in their outstretched position. When the textile is released, the printed areas remain elongated, resisting compression and bending. The unprinted areas contract, causing distortion of the entire plane into a 3d form.

To gain a better grasp of the geometric principles at play, a catalogue of shapes was printed using consistent materials and print-settings. The following observations were made:

- The interplay between elongation and contraction generates complex, non-developable, gaussian curvature.
- Depending on the print pattern, the resulting parts will have two or more states of structural equilibrium. When a force is applied, the surface 'pops' from one state of equilibrium to another in a process called snap-buckling.
- Folding may be induced, creating an origami-type effect characteristic of developable surfaces. The SBINBEN team calls these deformed developable surfaces "Def-Dev's"
- New software platforms permit shape prediction based on specific physical inputs, and a reverse workflow from desired 3D shape to 2D input pattern

Interior and exterior renderings of proposed building skin for the Pirelli 39 tower in the Porta Nuova district of Milan, Italy

Scaling up the Idea: There are several advanced manufacturing techniques able to replicate the prototyping process at a large scale. These are discussed in the SBINBEN report in terms of feasibility, cost, and novelty. The most promising process involves 'plotting' material onto a moving sheet of stretched fabric, collected onto a roll, shipped to construction sites and deployed. This strategy reduces the complexity of machines, allows for continuous production and lowers transportation costs.

Several textiles already exist for building applications, with varying degrees of durability. The important thing is that the selected textile has enough elasticity, so it can generate the desired surface deformation. Thin films could be used in place of fabric if necessary in an analogous process. Some of these contract when exposed to heat and could therefore be 'post-contracted' rather than 'pre-stretched'. The interplay of forces within the hybridized material perform similarly regardless of how the tensile and compressive force differential is introduced.

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PRINCIPAL ACADEMIC TUTOR
Carlo de Michele, Dept. of Civil and Environmental Engineering, Politecnico di Milano

ACADEMIC TUTOR
Alberto Bianchi, Dept. of Civil and Environmental Engineering, Politecnico di Milano

Alberto Cina, Dept. of Environment, Land and Infr. Engineering, Politecnico di Torino

Diego Franco, Dept. of Environment, Land and Infr. Engineering, Politecnico di Torino

Alberto Godio, Dept. of Environment, Land and Infr. Engineering, Politecnico di Torino

Paolo Maschio, Dept. of Environment, Land and Infr. Engineering, Politecnico di Torino

Livio Pinto, Dept. of Civil and Environmental Engineering, Politecnico di Milano

Marco Piras, Dept. of Environment, Land and Infr. Engineering, Politecnico di Torino

DREAM 3

DRone tEchnology for wAter resources and hydrologic hazards Monitoring 3

Executive summary

Global warming is an extremely important topic nowadays. Ice melting of glaciers all over the world is proceeding fast in a dangerous way. Many cities are highly dependent on the water resources of glaciers and this is why it is important to analyze, monitor and forecast their change in time.

The DREAM3 project aims at developing new tools for monitoring the glaciers and their evolution in a fast, cheap and safe way. The monitoring consists, in general, in building a 3D model of the surface of the glacier and compare it with the one obtained in the previous years. This strategy relies on the photogrammetry technique, which allows to perform reliable measurements starting from photographs taken by means of drones specifically built for this purpose. The Belvedere glacier, which lies at the base of the east face of Monte Rosa has been chosen as a reference point for conducting the surveys. This choice has been made since this glacier is one of the few Alpine ones not retreating but moving forward. However, the developed tools can be used for any other glacier or surface that requires monitoring. The traditional way of performing photogrammetry to build a 3D model of surfaces relies on the use of helicopters, which are very expensive and dangerous. In the recent years drone technology has attained a huge progression and nowadays they are widely used for replacing helicopters.

DREAM3 is the third step of a 3-years effort: with respect to the previous projects, which started the monitoring of the Belvedere glacier, the main novelty lies in making use of direct photogrammetry. In general, surveys consist in acquiring, together with the pictures taken by the drone, the precise GPS positions of some points on the glacier surface, in order to correctly orient the 3D model in a standard reference system. Normally, in indirect photogrammetry, the acquisition is done manually: this operation is quite dangerous due to frequent prohibitive weather conditions and the continuous sliding of the glacier. In addition, to have a reasonable accuracy, usually a really high number of points are needed. DREAM3 identified direct photogrammetry through drones as the best solution, since, thanks to a GPS system placed on the drone itself, it is possible to know the exact location of the photos at the very moment in which they are taken. This results in a drastic reduction of the number of points to acquire manually on the glacier surface and, consequently, in an increase of the safety and in a reduction of the measurement time.

Solutions relying on drones for direct photogrammetry are already present on the market; however, their cost is relatively high (i.e. more than € 25'000), which make them hardly affordable. The team performed a study in order to find an alternative solution, which led to the creation of a low-cost sensors' kit comprising of an EMLID Reach GNSS (Global Navigation Satellite System) unit, a camera with a hot shoe output, and a suitable antenna. The Reach unit is connected to the camera through a special cable, inserted in the hot shoe output; in this way, a time stamp is created on a GPS log whenever the shutter of the camera is triggered. The kit was mounted on a Parrot Disco UAV, which was purchased due to its performance and price balance, and subsequently heavily modified in order to house all the equipment.

TEAM MEMBERS

Pasquale Walter Agostinelli
Space Engineering
Politecnico di Milano

Alessio Durante
Electrical Engineering
Politecnico di Milano

Davide Rago
Civil Engineering
Politecnico di Milano

Giada Risso
Mathematical Engineering
Politecnico di Torino

Roberto Russo
Electronic Engineering
Politecnico di Torino

Tommaso Verri
Automation Engineering
Politecnico di Torino

Several tests on the above-mentioned kit were done. First of all, the team ensured that the novel idea was working under the weather and surface conditions of the suburbs of Torino. Consequently, a campaign has been done in the Spring of 2018 for testing the new setup of the drone over an avalanche at the feet of Belvedere glacier and demonstrated the effectiveness of the new acquisition system in a concrete application.

Moreover, in parallel to this work, following in the footsteps of the two previous DREAM projects, like every year, data have been collected with the traditional technique to monitor the evolution of the glacier. For this purpose, two campaigns were carried on in the Autumn of 2017 to get the needed data for building an updated 3D model of the surface of the glacier. Beside the fact that the weather conditions had a big influence over the performances of the drones in terms of battery capabilities and stability, the campaigns were always successful. After a long phase of post processing of the images and GPS measurements (performed in the laboratories of Politecnico di Torino) the work gave as a result the latest 3D model of the surface of the glacier.

As an additional element of novelty, for the first time since the DREAM project started, the team decided to investigate on the thickness and morphology of the glacier and of the bottom soil, in order to perform also a hydrological analysis. In this regard, geophysical surveys have been carried out in July 2018. Surveys were conducted by means of geo-electrical and passive seismic methods, but the surface conditions of the glacier were not appropriate. However, referring also to previous geophysical campaigns, it has been possible to employ the collected results in a mathematical model found in literature for approximating the ice mass flow rate sliding downstream.

Since the DREAM project has started, every year the glacier surface and movements are compared and analyzed. DREAM3 is the proof that, with a well-studied combination of new technologies, the behaviour of glaciers can be monitored in an accurate and definitely more safe way.

Key Words

Glacier, Survey, Photogrammetry, UAV

Figure 1- view of the Belvedere glacier

Project description written by the Principal Academic Tutor

Nowadays, expected effects of climate change at local, regional and global scales endanger hydrologic budgets of Alpine regions. An example is the massive shrinkage of mountain glaciers, with the consequent problem of water resources reduction for civil population and ecosystems. Therefore, it is very important to monitor glaciers' evolution, in order to allow an estimation of glaciers' reduction and possible effects on the hydrologic cycle. DREAM3 project aims at investigating new technologies and tools, especially Unmanned Aerial Vehicle (UAVs) for evaluating water resources at different scales. The eastern slopes of Monte Rosa and its glacier tongue (Belvedere glacier) has been used as test site. Research method analysis mainly followed fours steps. Usually, glacier's thickness, area evolution, and glacial motion are monitored using time-consuming field activities, e.g. analysis based on point stratigraphy and mass balances or radar sounding, which do not allow to obtain a continuous-time, detailed and accurate information about surface and volume evolution at fine spatial resolutions. In the first step, we have used commercial UAVs to acquire images, in order to generate a dense DSM (Digital Surface Model). The acquisition was carried out with an ad-hoc field campaign realized in October 2017. Data have been elaborated with different photogrammetric software in order to investigate the ratio quality of the product/time consumption, with respect to hydrological purposes. The DSM obtained has been compared with the ones realized in 2015 and 2016 to estimate the volumes' variations, and the glacial motion in the periods October 2015-October 2016 and October 2016-October 2017. In the second step, we have customized a commercial drone in order to make direct photogrammetry, i.e. acquiring, together with the pictures also the precise GPS positions of some points on the glacier surface, in order to correctly orient the 3D model in a standard reference system. In the third step, we have used the modified drone in an ad-hoc field campaign realized in May 2018 together with commercial drones in order to check the validity and potentiality of the modified drone. In a fourth step geophysical surveys have been carried out in order to retrieve information about glacier thickness which combined to glacier motion could validate glacier dynamics models. Finally, we have been compared the obtained results with the existent literature in alpine areas.

Figure 2 - markers coordinates acquisition

Figure 3 - mounting the modified drone

Team description by skill

Pasquale Walter Agostinelli: contributed in the development of the Mathematical model of the glacier according to literature and participated to the third campaign. Moreover, he was charged of the development of the promotional video of the project.

Alessio Durante: participated to the first and third campaigns, gave its contribution in the post-processing of the GPS data acquired during the campaigns to obtain the markers coordinates, performed the loading tests of the drone and worked on the alternative solution of the flight planner software.

Davide Rago: participated to all the three campaigns and, with knowledge in civil engineering, topography and photogrammetry, worked alongside with Alessio for the post-processing of the GPS data, the loading tests of the drone, and to the investigation of alternative software solutions. Moreover, he was charged of the geophysical part of the project and estimated the amount of melted ice comparing models of previous years.

Giada Risso: partecipated to the first campaing. Building and analyzing the 3D model of the glacier was her responsability. Moreover, she assisted Tommaso Verri at Politecnico di Torino in the hardware development. Particularly she contributed to all the test carried out at Campovolo in Turin and the last test performed with Roberto Russo.

Roberto Russo: was the team controller and took care of the communications with tutors and with the ASP board. He participated to the first and third campaigns, worked on the second phase of modifications on the drone taking care of the post processing of the last GPS data and to the determination of the final sensors' kit after the last test of the solution. He worked on the report structure and writing. Moreover, he took care of the economical part of the project.

Tommaso Verri: participated to all three campaigns and took care of the hardware components of the drone. His work started with the benchmarking of the various available drones, to proceed with the definition of the GPS recording system, together with camera choice and battery modification. All the hardware modifications to the drone itself were supervised and carried out by him in the Politecnico di Torino labs, with the help of Horea Bendea. Furthermore, the loading tests and flight tests carried out at Campovolo in Turin were also his responsibility.

Figure 4 – DREAM3 team members

Goal

The DREAM3 project follows the path traced by the DREAM and DREAM2 groups that, in recent years, have reconstructed a 3D model of the Belvedere glacier (Macugnaga - Monte Rosa) through the use of equipped drones for land mapping: these projects proved the concept that a drone could be used instead of current technologies for surveying, which require the rental of a plane equipped with a camera, significantly reducing costs and increasing the collected data due to easy access to drone technology. While the DREAM project firstly showed the feasibility of drone technology for this purpose and the DREAM2 project investigated the possibilities to develop and build one ad hoc drone, focusing on weight, battery life, payload and camera quality, the aim of DREAM3 is to continue the work on the Belvedere glacier in order to monitor and study its evolution. In particular, the project focuses on collecting updated data for the hydrological analysis of the glacier, on further developing the techniques adopted for their acquisition and on exploring the potential of low-cost UAV technology in environmental engineering applications.

Figure 5 - drone built by DREAM2 project

Understanding the problem

In the last decades, the phenomenon of global warming has increased its relevance: the surge of temperatures, the melting of the glaciers, the rising of the global average sea level and the shifting of the rainfall patterns are phenomena involved in this global climate change. The latter affects mostly regions characterized by fragile equilibrium between the influence of hydrological processes as the Alpine regions, where the relevance of this change is greatly due to the melting of the glaciers that is happening at an alarming rate. This is the result of very complex interacting environmental phenomena that limits the predicting capabilities in case of experimental data shortage. Therefore, the "work on field" had to be extended to detect the rapid changes that are taking place.

Figure 6 - commercial drone used for photo acquisition

For this purpose, photogrammetry techniques have been investigated for the last three editions of the project; in particular the objective is to use photogrammetry to build a 3D digital model of the surface of a glacier, in order to study its evolution along the years. The Belvedere glacier has been chosen as test field to conduct these photogrammetric surveys and the technology being adopted relies on Unmanned Aerial Vehicles (UAV).

Exploring the opportunities

UAV technologies have been already employed in the field of engineering for photogrammetry purposes. They have been substituting since many years the use of helicopters equipped with suitable cameras for performing these kind of surveys. The available solutions typically rely either on quadcopters or fixed-wing drones, more suitable for wider areas.

Figure 7 - SenseFly eBee Plus for direct photogrammetry

As regarding the acquisition method, the majority of the UAV technologies currently employed is based on indirect photogrammetry, a technique requiring a lot of physical effort, since, in order to orient the obtained models in space, it is required to acquire manually the GPS position of a relevant number of points placed on the surface to be modeled. This may not be such an issue in urban contexts, but when it comes to the glacier environment the need of employing safe and fast operations is a must.

In this respect, a suitable solution would be represented by direct photogrammetry. By means of a GPS antenna equipped on the drone, it is possible to acquire the position of the camera in the exact moment in which the picture is taken, in order to heavily reduce the number of needed point to be measured on the ground.

The DREAM3 project identified the direct photogrammetry as the best method to be investigated to improve the data acquisition technique for building the 3D model of the surface of the glacier. Indeed, the most recent UAVs available on the market make use of direct photogrammetry techniques, but their cost is still very high. As a conclusion the DREAM3 team has come out with the objective to find a solution, cheaper to the ones available on the market, to realize direct photogrammetry with the reasonable level of accuracy to make proper hydrological estimations.

Generating a solution

The starting point for the DREAM3 team has been the purchasing of the fixed-wing Parrot Disco drone, since it was identified as the best compromise between cost and performance.

After that, the team performed suitable loading tests on the drone and executed accordingly detailed analyses of the components to be purchased to realize the wanted solution.

Therefore, the drone has been heavily modified to leave space to the additional equipment: a RICOH GR camera, a Tallysman Multi-GNSS and an EMLID Reach board supplied by a lighter and more performing set of batteries (whose cells have been separated for balancing purposes) by means of a DC-DC converter.

Figure 8 - Parrot Disco modifications

Figure 9 - Final solution: balancing test

Figure 10 - Model of the Belvedere glacier

The camera is set in time-lapse mode. In the meantime the EMILD Reach board records continuously the GPS position of the drone measured by the antenna; as soon as the camera takes a picture, the signal coming from the hot shoe is used as trigger to place a marker in the GPS logging data. In this way, it is possible to know the position of the camera in the moment the picture is taken and realize a first solution relying of direct photogrammetry.

The solution is characterized by a cost of about 1300€ and a payload of about 300 g from the Parrot Disco.

The solution has been tested at first on site, surveying an avalanche near the Belvedere glacier on May 2018 and, few weeks later, on the "Volare sui Tetti" aeroclub near Turin, proving its actual effectiveness and providing suitable guidelines for its further improvement.

In addition, in agreement with the path followed by DREAM and DREAM2, the team has been collecting and processing the data coming from two measurements campaigns performed in October and November 2017, to build the updated 3D surface model of the Belvedere Glacier.

After an initial phase consisting in processing of the GPS data of the markers delocalized all over the glacier, the photos taken by the drones have been exploited to realize a 3D model, suitably georeferenced, which describes the surface of the Belvedere glacier with a precision of 2 cm for each of the computed points.

From the comparison between the previous models, it has been estimated that about 4 millions of cubic meters have melted within last year.

Moreover, geophysical measurements have been performed by means of electric and seismic techniques in two relevant section of the glacier, with the objective to estimate its depth.

Finally, the results have been exploited to feed a mathematical model widely used in literature, in order to provide an estimation of the ice flow rate going downstream.

Figure 11 - glacier's sections investigated with geophysical surveys

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PRINCIPAL ACADEMIC TUTOR
Francesco Grimaccia, Dipartimento di Energia, PoliMI

ACADEMIC TUTOR
Sonia Leva, Dipartimento di Energia, PoliMI
Giorgio Guglieri, Dipartimento di Ingegneria Aeronautica e Spaziale, PoliTO
Alessandro Niccolai, Department of Energy, PoliMI

EXTERNAL INSTITUTIONS
Nimbus S.r.l.

EXTERNAL TUTOR
Paolo Bellezza Quarter, CEO, Nimbus S.r.l.

TEAM MEMBERS

Giulio Cantoro, Management Engineering, PoliMI

Raffaele Guido, Aerospace Engineering, PoliTO

Andrea Milanta, Computer Science Engineering, PoliMI

Maurizio Valesani, Aerospace Engineering, PoliTO

Marco Villani, Aerospace Engineering, PoliMI

USES4

Project description

In recent years new trends and challenges are involving photovoltaic (PV) power sector due to a dramatic change of the market. Plant monitoring and O&M is becoming a crucial point in this field: plant owners and operators are requiring higher accuracy and lower costs in the maintenance operations to keep at top the performance of the plant during its whole lifetime. PV modules installed in the last decade recently have shown quite a wide range of defects able to sensibly compromise the performance of the plant. Standard monitoring techniques are based on a completely manual systems where operators take pictures of the PV plant and identify potential defects generally on a visual approach. These procedures have many drawbacks, for example the very long time required, the need of an expert operator which often means subjectivity and the impossibility to perform on most of the roof-top plants. Moreover, this monitoring reduction in the power production not assuring a decision-making preventive strategy.

This project is aimed to integrate a fast monitoring system, based on the Unmanned Aerial Vehicles technology with an appropriate sensor suite, combined to an economical power site analysis. This combination will lead to an optimized technique: while the novelties in the monitoring system will reduce the monitoring time and will increase the effectiveness of acquired information, the economic analysis will find the optimal scheduling of the monitoring and the optimal maintenance strategy in terms of return on investments.
The use of Unmanned Aerial Vehicles helps to speed up the operation and include a new class of plants (namely the roof-top plants) in the monitoring and O&M PV market. This system produces a huge amount of data that can be successfully processed with computational techniques: the results of the project is a complete map of the plant where the defected modules can be easily found with respect to their critical impact on the energy production.
In order to improve the overall system efficiency, a decision-making process has been investigated as well: in particular, an optimized support system can help the operator to identify optimal maintenance strategies, thus it can be applied to a large plant portfolio leading to a growth of the assets' profitability. A potential extension to other Renewable Energy power plants can enhance the impact of the proposed system to other stakeholders like large Energy Companies, Insurances and Investment Funds.

Key Words

Photovoltaics-Monitoring, Photovoltaics-Maintenance, Drone-Inspection, Thermography, Process-Optimization


ALTA SCUOLA
POLITECNICA
Uses 4
USES4
Innovative Unmanned Systems for Supporting Efficient
and Effective PV Plant Maintenance Planning
Cantoro Giulio
Guido Raffaele
Milanta Andrea
Valesani Maurizio
Villani Marco

Team description by skill

Giulio Cantoro: his main activities included market research (photovoltaics in Europe, stakeholders' needs and interaction), state of the art research (photovoltaic plant monitoring), maintenance optimization and forecast model, graphic user interface, business model.

Raffaele Guido: his main activities included market research (UAV applications, photovoltaics in Italy), state of the art research (UAVs in plant monitoring, alternatives to thermography), optimal maintenance intervention algorithm, maintenance forecast optimization algorithm.

Andrea Milanta: his main activities included market research (photovoltaics in the world), state of the art research (image processing for photovoltaic thermal images), image processing, defect recognition.

Maurizio Valesani: his main activities included market research (UAV applications, stakeholders' needs and interaction), state of the art research (UAVs in plant monitoring, alternatives to thermography), picture-sorting algorithm, digital map assembly.

Marco Villani: his main activities included market research (UAV applications, stakeholders' needs and interaction), state of the art research (module defect recognition, defect impact on module performance), module degradation model, automatic report generation.

Abstract

The photovoltaic industry is one of the fastest growing worldwide, also thanks to climate change policies. The same holds true for Italy, which aims at a relevant increase in installed capacity by 2030. Due to its topography, though, this increase must be accompanied by an improvement of plant efficiency. However, residues of the incentives system of 2010-2013 and the inherent complexity of maintenance, together with its over-reliance on manual, time-consuming procedures, often result in plants been neglected with a considerable performance loss, which hinders the needed efficiency increase.

USES4 project sets its root within this need to increase the efficiency level of PV plants and aims at exploiting the industry potential to determine a business opportunity. The route chosen aims at the development of a service based on the automation of inspection, maintenance, data analysis, and decision-making procedures in PV plants, to streamline them and reduce their cost as well as improve plant energy production.

By automatically generating an interactive, digital map of a plant from pictures taken by the drone during an inspection according to a set of ad-hoc defined guidelines, with detailed information on the health status of each single module, and providing a technical report including a set of suggestions on the optimal maintenance intervention based on the maximization of the production and minimization of costs, USES4 team hopes to introduce a drastic innovation in the photo-voltaic maintenance sector. The designed tool has the potentiality to modify the future scenario by optimizing present procedures, fostering a change in maintenance practices leading to a minimization of the profit loss in plant management.

Understanding the problem

The photo-voltaic industry is one of the fastest growing worldwide. With $161 billion of investment (2016) and a CAGR (Compound Average Growth Rate) of over 40%, it holds the top spot in the renewable energy market. Political initiatives aimed at reducing emission and limit fossil fuel consumption are

fostering the sector. Focusing on home turf, Italy's photovoltaic market is just starting to pick-up after a crisis period following the end of the incentives in 2013. At the end of 2017, 19.67 GW were installed in Italy, a figure expected to grow. SEN's (Servizio Energetico Nazionale) objectives for 2030 aim at a yearly PV energy production of 72 TWh and depict a road map that foresees new installations for 33 GW, the re-powering of already installed plants for 2 GW and the revamping of the available 20 GW installed.

This scenario increases the pressure on O&M operators for increasing monitoring and maintenance efficiency. However, residues of the incentives system and the inherent complexity of maintenance often result in plants been neglected with a considerable performance loss. In this context, a need for optimized monitoring and maintenance is becoming apparent. Plant owners and asset managers are looking for a detailed appraisal of the status of a plant, to optimize its production and the profit it generates or to maximize its market value for a transaction. Respectively, plant buyers are looking for an objective representation of the health of a plant before deciding to invest in it. The two categories are linked by O&M operators, in charge of assessing the plants and guaranteeing an agreed upon level of performance. Another key role is played by insurance companies, as circa 25% of a system's annual operating cost consists of premiums, ranging from 0.25% to 0.5% of the total installed cost. Finally, authorities complete the overall picture, source of standards and regulations, as well as interested in statistical data on the performance of installed facilities and the technological progress to define incentives.

All these actors share the need of a quick, affordable, and objective representation of the status of a plant, and would all benefit from an optimization of maintenance intervention aimed at improving plant performance. Current market offers however are still based on manual intervention and cannot provide time and cost-effective solutions, while maintenance interventions are often economically suboptimal.

Exploring the opportunities

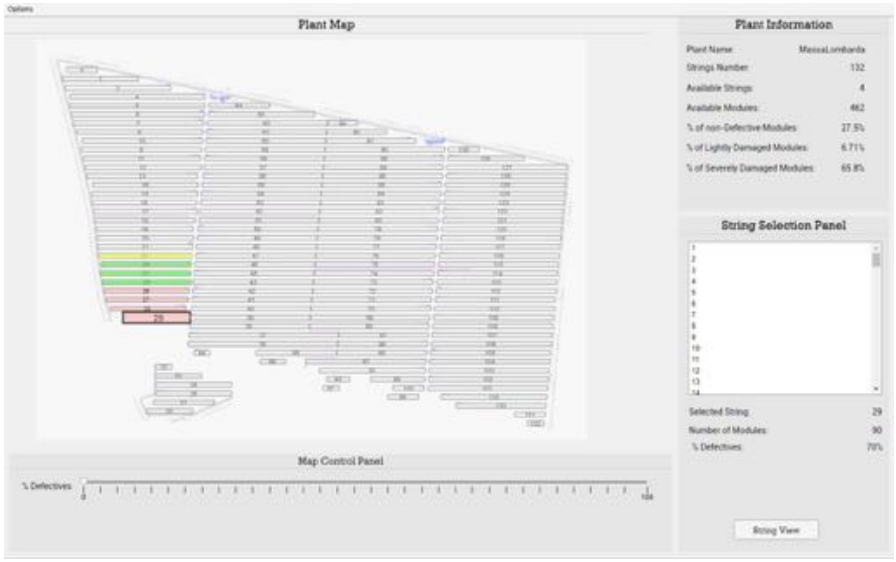
Having identified the market need for an improvement of the overall quality and efficiency of plant monitoring and maintenance planning, different routes have been considered to provide a suitable product or service to the involved stakeholders. Due to the partnership with a drone manufacturer already participating in photovoltaic monitoring and the prevalence of aerospace engineers in the team, efforts were initially focused on understanding whether it was possible to optimize the flight procedure. Automating the flight seemed at first a very promising alternative, with interesting margins for improvement. However, after having spectated an on-the-field example of monitoring procedures, it became apparent how the benefits from a pilot-less flight would have been negligible due to the outstanding inefficiencies hindering the process. Leaving flight automation as a possible future development, focus was shifted to the optimization of existing procedures and the automatic generation of an interactive digital map of the plant, to eliminate the need for manual intervention when unnecessary and minimizing down-times, while at the same time improving output quality.

Moreover, during the concept development phase, a critical point that was faced was the selection of the scope of the service, as two main alternatives presented themselves. On the one hand, limiting the service to the generation of a digital map of a plant would have tackled the need to improve monitoring performance, and it would have meant a stronger focus on defect recognition and classification; however, maintenance planning would have been neglected and left to its underperforming state. On the other had, partially sacrificing output quality in favor of the preliminary design of a maintenance optimization tool would have tackled both the identified issues, and it would have shown the real potentiality of the devised idea. While the first route would have allowed to

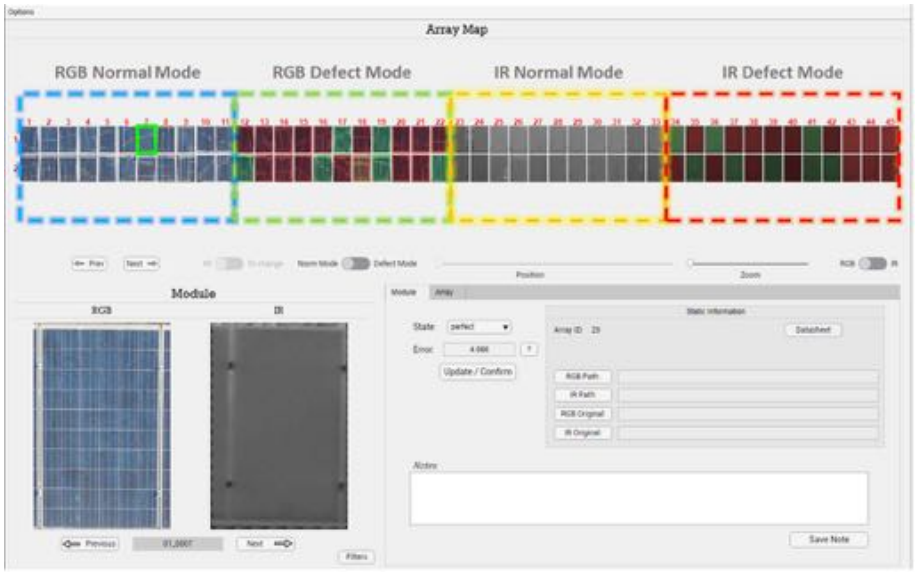
present a complete, market-ready product, the final decision fell on the most ambitious alternative, due to its pervasive innovative aspect and its higher appeal to different stakeholders in the field.

Generating a solution

The outcome of the project aims at alleviating the two most prominent critical aspects identified within the PV monitoring and maintenance subsector: the slowness and low accuracy of manual data gathering and analysis, and the lack of detailed information on the health status of a plant to be used to make informed decisions when planning maintenance operations. Thus, the first step of the service devised by the team consists of an automatic management and sorting of the raw images, both visible and infrared, captured by the drone. Then, data associated to the pictures are further processed to unequivocally identify each module. Defect recognition is automatically performed by an AI algorithm, the precision of which can improve the more data it collects. Then, a digital map of the plant is presented to the user, who can easily access information of each panel in the plant, from its position to its defects.



Main window of the Visualization tool.



Array window with different display alternatives combined.

To make sure the quality of the input images is consistent and sufficient for the software to properly operate, a set of dedicated flight guidelines for drone pilots has been conceived. The goal, however, is to improve the robustness of the code, so as to make it possible to relax said guidelines and limit the service reliance on drone operators. Gathered information is then transmitted to a predictive and evaluative algorithm, tasked to estimate the general status of the plant, suggest the optimal maintenance intervention and predict the optimal moment for the next inspection, with a prediction of the expected magnitude of the intervention itself. Thus, maintenance planning is enhanced, as it can be based on detailed information on the health of each module. Moreover, maintenance operators are provided with more information on their task, which further streamlines their job and limits mistakes by reducing uncertainty. Finally, customized reports are produced, ranging from a purely technical description of the status of the plant to a set of operative guidelines for maintenance optimization, or, as a future development, a detailed financial evaluation of the asset.

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PRINCIPAL ACADEMIC TUTOR
Sara Comai
DEIB, Politecnico di Milano

ACADEMIC TUTORS
Andrea Masciadri, Ph.D.
DEIB, Politecnico di Milano
Matteo Matteucci
DEIB, Politecnico di Milano
Fabio Salice
DEIB, Politecnico di Milano

EXTERNAL INSTITUTIONS
Cooperativa La Meridiana
Empatica S.r.l.

EXTERNAL TUTOR
Alberto Attanasio
Cooperativa La Meridiana

TEAM MEMBERS

Sara Bianchi
[Team Controller]
Management engineering
Politecnico di Milano

Francesco Amato
Management Engineering
Politecnico di Milano

Pietro Crovari
Computer Science Engineering
Politecnico di Milano

Maria Giulia Grillo Pasquarelli
Architecture
Politecnico di Torino

Afnan Imtiaz
Computer Engineering
Politecnico di Torino

Mariê Toldo
Design and Engineering
Politecnico di Milano

Ece Yuyar
Interior Design
Politecnico di Milano

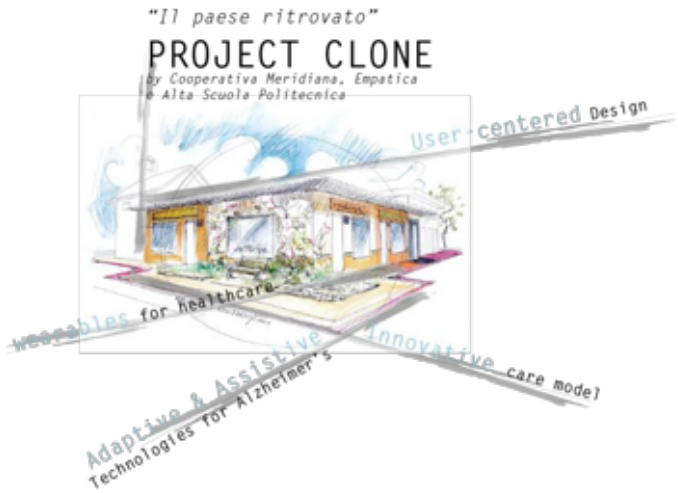
CLONE

Executive summary

Alzheimer's Disease (AD) is the most frequent form of dementia [1] that compromises the main cognitive functions of an individual. The most critical symptoms of Alzheimer's are crises, namely behaviours entailing psychomotor agitation and psychological alterations (such as aggressiveness). The frequency and randomness of crises require patients to be continuously supervised, which affects significantly their quality of life and causes substantial burden to caregivers, who provide physical and emotional support to patients on a daily basis [2]. The necessity of continuous assistance drives families to move their loved ones inside skilled facilities, which, in turn, imposes high costs on national healthcare systems.

This project aims at exploring the application of remote monitoring technologies to detect the onset of crises in patients affected by Alzheimer's. This system would entail the use of a wearable device to measure specific physiological parameters on the patient and would allow to signal the necessity of caregivers' intervention when needed, replacing the need of continuous assistance.

In particular, CLONE project brings two novel contributions towards this direction. On the one hand, it provides the first dataset of physiological parameters measured on Alzheimer's patients, that allows to look for potential relationships between physiological trends and the onset of crises. On the other hand, it proposes the design of a new smart wristband called Eclipse, which is the first wearable device specifically designed to fulfil the peculiar needs and vulnerabilities of Alzheimer's patients and their caregivers.



Caption Example (image dimension: 10,5x7 cm)

Key Words

Alzheimer's, Assistive Technologies, Wearables, Data Analysis, User-centred Design

Project description written by the Principal Academic Tutor

This research work aims at investigating new technologies and tools to facilitate the monitoring of fragile people in the Ambient Assisted Living (AAL) context: in such a context, technologies for indoor localization are typically used to locate people and/or objects inside buildings; wearable devices allow the collection of physiological data of the patients/users; home control devices can be exploited to provide environmental/contextual data.

The CLONE project focuses on Alzheimer's patients, and analysed available technologies and methodologies facilitating their monitoring at "Il Paese Ritrovato", the first Italian village for the treatment of Alzheimer's disease. Il Paese Ritrovato is inspired by the pioneering experience of the care center Hogewey in the Netherlands and is organized as a small village, where patients lead an almost normal life, but in a protected context where they can get the necessary treatment.

In particular, CLONE tackled an important challenge: detecting possible crises of Alzheimer's patients from the analysis of physiological data collected by means of a wearable device. The project has pursued two novel paths towards this direction. On the one hand, the collection of the first dataset of physiological parameters measured on Alzheimer's patients through the use of a wearable device in a controlled environment. On the other hand, the realization of the first wearable device able to monitor those parameters and whose design features are specifically centred on the needs of Alzheimer's patients and people around them.

Team description by skill

DESIGN TEAM

Marie Toldo: Marie analysed the requirements of the users through personas and scenarios. She also participated in the ideation of the new wearable Eclipse and performed the prototyping of the device through an iterative 3D printing process, up to the development of the final concept. Finally, she contributed to the evaluation of the final concept and to the assessment of its technical feasibility.

Ece Yuyar: Ece carefully analysed the users' requirements through personas and scenarios. She also provided an active contribution to the ideation of Eclipse. Finally, she performed detailed research on the most innovative materials for medical wearables and selected the materials for each component of Eclipse.

Maria Giulia Grillo Pasquarelli: Maria Giulia conducted a deep research on Alzheimer's disease and its main symptoms. She also contributed to the definition of personas and scenarios, to the ideation of Eclipse and to its final evaluation.

TECHNICAL TEAM

Pietro Crovari: Pietro drafted the Operative Protocol and the other legal documents for the experimentation. He also participated in the deployment of the IT infrastructure inside Residenza San Pietro. Finally, he carried out a preliminary analysis on the data collected, up to the extraction of a selected set of features.

Afnan Imtiaz: Afnan worked with Pietro to draft all the necessary documents for the experimentation and to deploy the IT infrastructure inside the clinic. After that, he entirely developed the server infrastructure of the system.

MANAGEMENT TEAM

Sara Bianchi: Sara carried out a deep market research on wearable devices, with a particular focus on medical wearables. She evaluated the alternatives and selected the E4 wristband from Empatica as the most suitable device for the experimentation. She also participated in the analysis of the economic feasibility of Eclipse and in its performance assessment.

Francesco Amato: Francesco conducted a detailed research on Alzheimer's and its main symptoms. He also analysed the state of the art for Assistive Technologies, with a focus on monitoring technologies for the treatment dementia. He also contributed to the assessment of the economic feasibility of Eclipse and of its relative performance with respect to other medical wristbands on the market.

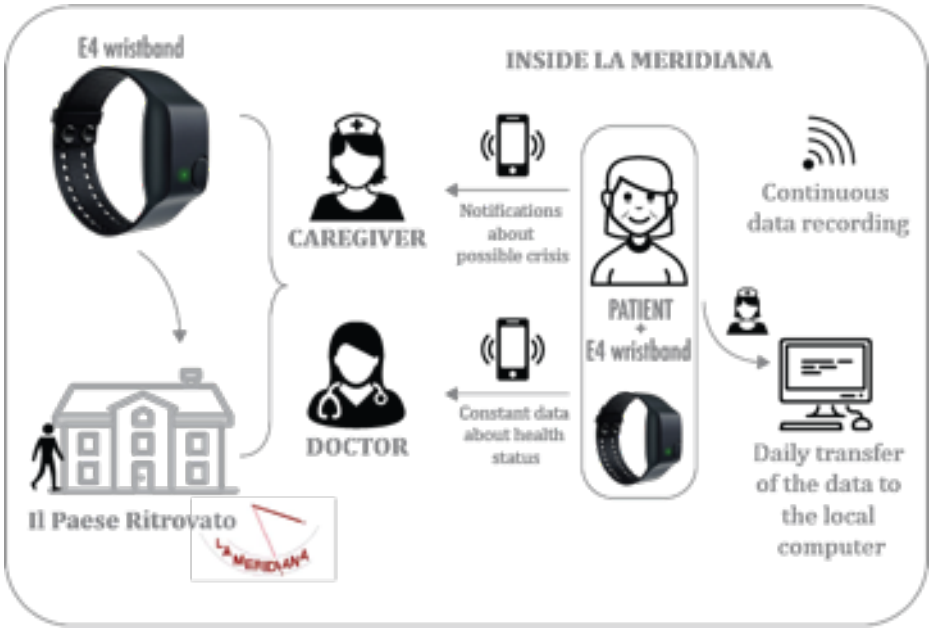
Goal

The main partner of this project is Cooperativa La Meridiana, an association targeted to elderlies that operates with clinics and nursing homes. In particular, in February 2018, La Meridiana inaugurated Il Paese Ritrovato, a pioneering village for the treatment of Alzheimer's disease. Inside Il Paese Ritrovato, non-invasive cutting-edge technologies are implemented for the invisible monitoring of Alzheimer's patients, with the aim of improving their quality of life.

Il Paese Ritrovato – Cooperativa La Meridiana

Inspired by Il Paese Ritrovato, project CLONE focuses on Alzheimer's and aims at investigating how technology can help reshaping the treatment of the disease. Among all the alternative directions of research, this project tackles the problem of crises, namely any behaviour entailing psychomotor agitation or psychological alterations. These are the most burdensome and dangerous Alzheimer's symptoms, as in many instances they are related to an aggressive or hostile behaviour.

In this challenging context, project CLONE aims at exploring the application of remote monitoring technologies able to detect the onset of crises in Alzheimer's patients. worn by the patient.



General Framework of Project CLONE

It aspires to develop a system that remotely detect crises through the analysis of physiological parameters measured by a non-invasive wearable device A system like this would have the potential to alleviate the psychological burden suffered by caregivers, improve clinical knowledge, enhance safety and promote freedom of movements for the patients, all outcomes that are particularly relevant for the future of dementia care. Moreover, if applied in private contexts, monitoring technologies can also guarantee fragile people a longer permanence in their homes, with consequent long-term benefits for both them and their families and lower costs on national healthcare systems.

Understanding the problem

Alzheimer's Disease (AD) is the most frequent form of dementia [2] and can be defined as a severe progressive neurologic pathology in which the main cognitive functions of an individual are compromised. The likelihood of developing Alzheimer's increases significantly with the age. Therefore, the constant ageing of population has led to a much wider diffusion of the disease, which has become one of the biggest challenges of modern society. The World Alzheimer's Report [3] estimated that 46.8 million people worldwide were living with dementia in 2015, number that will almost double every 20 years, to 74.7 million in 2030 and 131.5 million in 2050.

Among all the symptoms of Alzheimer's, crises are considered particularly critical as they often involve aggressive behaviours. Crises become more frequent and random as the disease progresses, compromising the autonomy of the patient who needs to be continuously assisted. The necessity of continuous monitoring and the intensity of these symptoms, causes a strong burden on caregivers. Many studies reveal that they face dramatic increases in emotional stress and depression as AD progresses, which translates in more frequent health problems [4].

The high level of stress suffered by those providing help constitutes the main reason why families decide to move their loved ones inside skilled facilities. The early institutionalizations of the patients and the high number of caregivers needed to assist a single patient imposes significantly high costs on national healthcare systems and will soon become a problem for worldwide economies.

Exploring the opportunities

Assistive Technologies (AT) are considered one of the most promising available solutions for reshaping dementia care [2]. Indeed, they can help in reducing the burden on public finances through the delay or obviation of institutional care for PWD (People With Dementia). AT has also the potential to decrease the psychological burden on caregivers while enhancing quality of care [5] and increasing staff members' satisfaction in their work [6]. The number of publications in literature regarding AT for dementia has been considerably increasing in the past few years, as the disease is one of elderlies' problem most studied in the field of assisted technology care [7].

Wearable devices represent one of the most popular typologies of AT [8]. Indeed, medical wearables already cover a significant share of the overall market and are expected to grow exponentially, reaching more than 17.8 billion US dollars in 2021 [9]. Among the medical devices, some aim at gathering information on specific diseases, such as "Valedo" and "Lumo Lift" for skeletal system diseases, "PIP" for detection of stress level and "Embrace" for epilepsy. However, none of them currently addresses specifically Alzheimer's or other types of dementia.

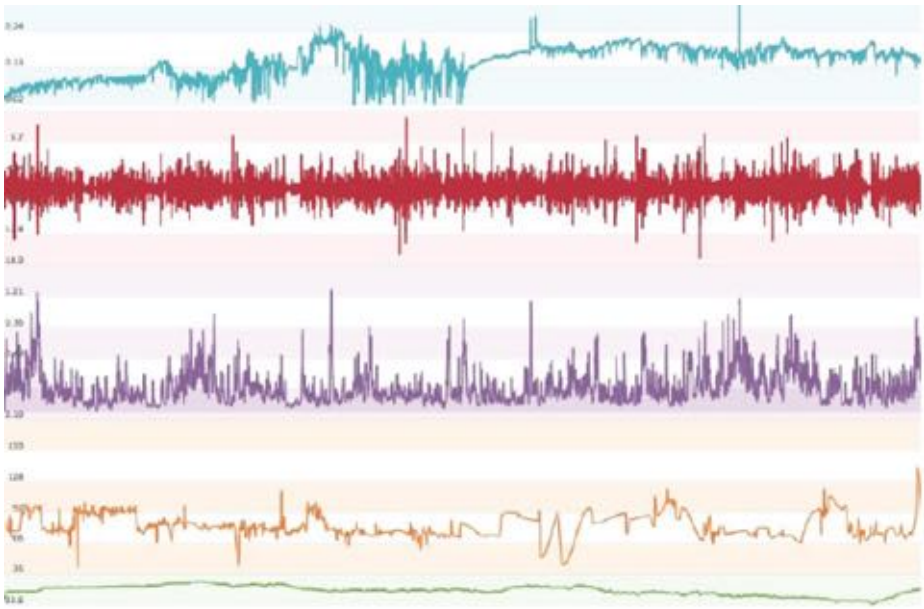
Project CLONE aims at developing a system able to remotely detect the onset of crises through the analysis of physiological parameters measured by a wearable device worn by the patient. However, looking at the state of the art, two main elements are missing. On the one hand, although several parameters have been assessed as relevant for Alzheimer's crises, there are still no evidences in literature about clear relationships between physiological parameters' trends and the onset

of crises. On the other hand, the market lacks a wearable device specifically addressing needs and vulnerabilities of Alzheimer's patients and their caregivers.

Generating a solution

Project CLONE brings two novel contributions to the application of remote monitoring technologies for the treatment of Alzheimer's and, specifically, for the detection of Alzheimer's crises.

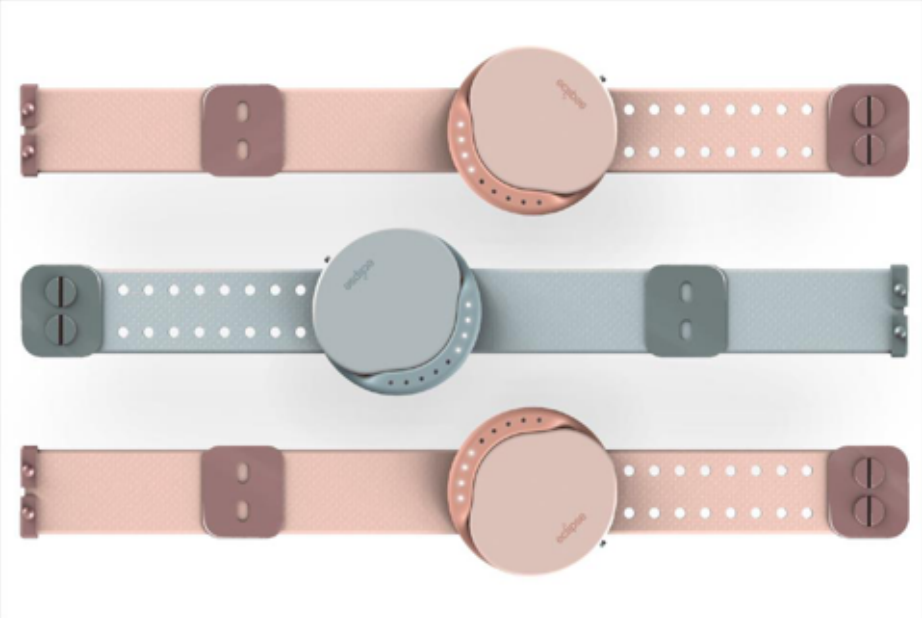
The first contribution consists in the generation of a dataset of physiological parameters measured on elderlies affected by Alzheimer's. The dataset resulted from an experimentation conducted in Residenza San Pietro – a nursing home in Monza – where patients were equipped with a smart wristband, the E4 from Empatica[1]. The data analysis subsequently performed allowed to extract from the data collected a selected set of features. They represent the ideal input for training multiple types of machine learning models, that may allow to look for potential relationships between physiological trends and the onset of crises. No analogous studies are present in literature even though research in this field is considered increasingly essential. The experimentation also showed how the technology is sufficiently mature to be adopted in nursing homes environments and not only in simulations performed in laboratory, in terms of economical cost, reliability and ergonomics, both for the device itself and for the computer interfaces.



Data extracted from the Empatica E4 Wristband during a recording session

On the other hand, the experimentation conducted in the nursing home entailed the interaction of doctors, caregivers and patients with a technologically advanced device. Several aspects regarding their interaction with the E4 wristband emerged as critical, suggesting the necessity of a dedicated product. Eclipse, the second contribution of this project, is the first wearable designed to specifically fulfil needs and vulnerabilities of Alzheimer's patients, compensating for the lack of Alzheimer's specific wearables on the market. It embeds a particularly wide set of sensors while maintaining a non-intrusive design, overcoming the trade-off between features and intrusiveness. Several design features contribute to make the product unique including the attachable battery, that allows charging the device without interrupting the monitoring of the patient. Differently from the majority of AT for dementia [8]. Eclipse is a successful user-centred concept specifically developed inside a context that made evident the needs of the users and their verification.

[1] https://www.empatica.com/research/e4/



Eclipse Final Design

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PRINCIPAL ACADEMIC TUTOR
Patrizia Savi, Dipartimento di Elettronica e Telecomunicazioni Politecnico di Torino

EXTERNAL INSTITUTIONS
E.D.C. S.r.l.

TEAM MEMBERS

Nicolò Bonacina, Politecnico di Milano

Davide Carminati, Politecnico di Milano

Matteo Collura, Politecnico di Torino

Stefano Gabetti, Politecnico di Torino

Massimo Giordano, Politecnico di Torino

Andrea Sottocornola, Politecnico di Milano

Lorenzo Vergari, Politecnico di Milano

PROJECT RaFrBio

Executive summary

Mission Statement

According to recent studies led by the World Health Organization, the number of patients affected by diabetes has been constantly growing at alarming rates since the past few decades, mainly due to population growth and increase in population average age. In order for medicine not to lag behind such an ever-expanding phenomenon, new easy-to-use, low-maintenance glucose meters should be devised. As there is also much interest in abandoning the traditional blood-measuring approach due to its invasiveness, novel sensing techniques are required as well. Radio Frequency (RF) sensors represent an innovative solution in this sense, since their high sensitivity allows them to painlessly measure glycemia from sweat or ocular fluid, where glucose concentrations are typically lower, rather than from blood. Such high sensitivity is achieved by means of substrate functionalization of the antennas, that is a chemical modification process favoring glucose molecules binding to sensors surface. RaFrBio project tackles this issue on a set of already existing RF sensors (patch antennas), employing an avant-garde technology, i.e. graphene-enhanced interaction.

Sensor Functionalization

The biggest challenge faced during the project has been the design of a functionalization procedure which could provide the sensor with both selectivity to glucose only and good sensitivity in terms of resonance frequency shift versus glucose concentration. The starting point was a compact patch antenna of droplet-compatible dimensions, built by Prof. Savi at Politecnico di Torino. Due to its dimensions, such antenna has a resonance frequency in the range of few GHz. A tailor-made functionalization routine has been developed, involving the deposition of a layer of graphene as coupler for the later deposited glucose binding protein (GBP) or glucose oxidase (GOx), molecules that are highly reactive to glucose. A functionalized sample antenna has been sent to the "Istituto Italiano di Tecnologia" (IIT) facilities for validation, with very promising results. In order to allow for a simultaneous characterization of different deposition techniques, a custom multi-channel measurement station has been prototyped: it consists of a portable, user-friendly instrumentation, hosting up to four frequency-measuring electronic boards entirely designed by the team itself. All these electronic devices are highly modular, meaning that they can be deployed for the measurement of other molecules than just glucose with very little effort. Such electronic system has shown to be perfectly compliant with the sensitivity data extracted from the above antenna.

From Lab to Market

To have a firmer grasp on the possible position of the solution within the wide market of biosensors, an exhaustive study regarding state-of-the-art technologies has been led. This, together with a visit at MEDTEC 2018 in Stuttgart, one of the largest expositions of innovative medical devices in Europe, highlighted the lack of a RF approach among the existing sensing methods. As a result of the team's increased awareness of RaFrBio innovation potential, a detailed study about the solution patentability was conducted. Consulting a set of online patent databases, the sensor emerged to be the best candidate, pushing the team into contacting the Technology Transfer office of Politecnico di Torino. A custom-made survey concerning glucose meters was handed to both users and experts of the field in order to select successful drivers for the future product development. The collected results pointed out the demand for features like continuous monitoring, user-friendliness and reduced maintenance. Such features will be surely taken into account for the future development of a market-ready product.

Keywords

Diabetes Radiofrequency Graphene Glucose Sensor

Project description written by the Principal Academic Tutor

The development of RF biosensors for biomolecular detection is a very recent trend and is still in the early stages of definition.

The introduction of carbon-based nanomaterials thin film seems promising not only for the detection of biomolecules but also for the realization of passive biosensors for diagnosis of various cancers (breast, prostate …) as well as routine clinical analysis (detection of glucose levels in the serum or drug detection and monitoring).

Clearly, the realization of RF sensors with high sensitivity and low detection limits requires multidisciplinary research.

The goal of this project is to realize a small size, lightweight, biocompatible and cheap radio-frequency sensor for bio-sensing applications. The performances of the sensor will be improved with the introduction of carbon-based thin films.

In the first part of the project, a specific application and the most promising configuration of the sensor will be chosen. The sensor will then be designed and realized using standard PCB etching techniques. The carbon-based nanomaterials thin film will be deposited on the sensor by means of screen-printed electronics manufacturing technology. In the final part of the project, the sensor prototype will be tested for the chosen bio sensing application.

In this multidisciplinary project students will have the unique opportunity to be involved in a new research field and to give a contribution for future technological and medical advancements.

For the detection of various biomolecules, many invasive techniques such as electro-impedance spectroscopy, enzyme oxidation, time domain reflectometer, and surface plasma resonance exist.

Recently, the use of radio-frequency (RF) biosensors based on passive and/or active devices and circuits has been investigated. The performance of these biosensors can be enhanced by the introduction of nanomaterials.

In this project, we focus on passive RF biosensors (meander lines, interdigital capacitors, or microstrip patch antennas) designed for detection of glucose levels in the serum or other applications. The performances of the printed sensors will be enhanced by the addition of nanomaterials (e.g., carbon nanotubes, graphene oxide, magnetic and gold nanoparticles, etc.) on the surface by a screen-printing technique. In this technique, a mesh is used to transfer ink onto a substrate except in the areas made impermeable to the ink by a blocking stencil. The surface will be properly functionalized.

It has several advantages:

- it works on different substrates (plastic, glass, flexible substrates…).

- it is a low cost and it is easy replicable

- various carbon-based filler can be added to the ink.


ALTA
SCUOLA
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Driving Opportunity and Innovation for the Medical Technology Industry
Lorenzo Vergani
Student
PoliMI
Italy
VISITOR
KOCH
Nicolò Bonacina


ALTA SCUOLA
POLITECNICA
Stefano Gabetti
M.Sc Biomedical Engineering
ALTA SCUOLA
POLITECNICA
Davide Carminati
M.Sc Materials Engineering
and Nanotechnology
+39 345 8552166
davide.carminati@asp-poli.it
linkedin.com/in/carminatidavide

Team description by skill

- Nicolò Bonacina: M.Sc Electronics Engineering, worked on the full-stack development of the hardware electronics.

- Davide Carminati: M.Sc Materials and Nanotechnologies, worked on the materials and chemistry related with the sensor and its functionalization.

- Matteo Collura: M.Sc Nanotechnologies for ICTs, worked on the patentability analysis and the front-end software development.

- Stefano Gabetti: M.Sc Biomedical Engineering, worked on the state of the art research, market analysis and back-end software development.

- Massimo Giordano: M.Sc Nanotechnologies for ICTs, worked on the physics of the sensor and the front-end software development.

- Andrea Sottocornola: M.Sc Electronics Engineering, worked on the full-stack development of the hardware electronics.

- Lorenzo Vergari: M.Sc Nuclear Engineering, worked on the market analysis, the related survey and back-end software development.

Goal

With the number of patients affected by diabetes rising at sustained rhythms, the development of new easy-to-use, low-maintenance glucose meters has become an important topic of research in the biomedical sector. In the light of such a demand for innovation, the aim of this project is to introduce a novel technology for the sensing of biomolecules, with a particular focus on glucose.

Team "RaFrBio" (namely, Radio Frequency Biosensor) decided to approach the world of life sciences to give its contribution in research, with the aim of building a prototype of a (possible) medical instrument.

The scientific research plays an important role in the whole project; however, this is not the only. The reason why most technologies today are successful is not strictly related with the engineering aspects, but rather on the trade-off between progresses in research and marketing campaign, that comes along with product and market analysis.

This is why the team faced the challenge of bringing a purely scientific research activity towards the market, eventually building an instrument capable of measuring the glucose concentration in a fluid.

Driven by the motto From Lab to Market, the team has given a multidisciplinary shape to a deep research activity, following the development of the product from research to production, from patentability to market analysis, with a strict plan of the activities.

Understanding the problem

Diabetes is a chronic disease which develops when the pancreas is unable to produce enough insulin (type 1) or when the body cannot use the insulin produced (type 2). It is one of the most widespread diseases across the globe and it is also among the diseases with the fastest growing rate in number of cases. The WHO estimated that more than 422 million people across the globe had diabetes in 2014, in 2012 1.2 million deaths were caused by diabetes, while other 2.3 million happened because of too high levels of blood glucose. From 1980 the number of cases quadruplicated. For these reasons it has been included in the list of the four priority noncommunicable diseases by the World Health Organization (WHO) [1]. High blood glucose has even a wider impact than diabetes, as 3.7 million deaths are related to it. Consequences of diabetes can include loss of vision, cardiovascular events, end-stage renal diseases and lower limb amputations. Monitoring the levels of blood glucose is therefore of paramount importance for early detection and monitoring of the disease.

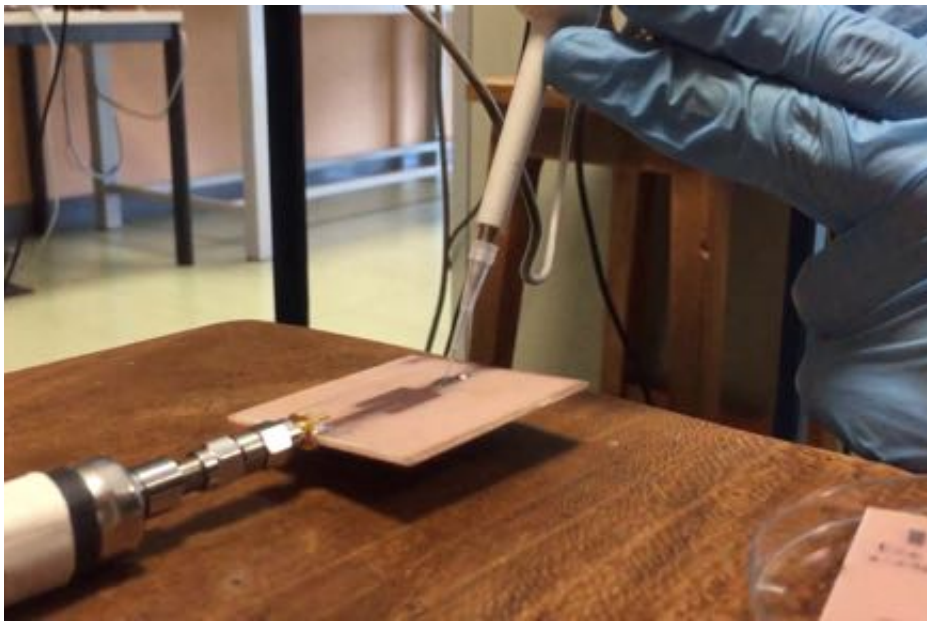
The most widely used self-monitoring method for blood glucose concentration relies on the fingerpricking approach. It involves sampling blood from a finger via pricking, to be analyzed by test strips and an impedance-based glucometer [2], as shown. It needs to be carried out at multiple intervals throughout the day

to help manage elevated glucose levels especially after meals, exercise and dosing of insulin medication. To perform each measurement, the patient is supposed to prick his finger with a needle, allowing the extraction of a small droplet of blood. This may have some drawbacks in the patient life, such as pain, risk of infection of the wound and others.

A possible solution for those issues can be found considering other more accessible biological fluids such as interstitial fluid, ocular fluid, sweat, breath, saliva or urine to perform such kind of measurements.

The main difficulty concerning these alternatives is the lower concentration of glucose to be detected, if compared to blood. To correctly detect the concentration, the sensor requires a lower Limit of Detection (LOD) and higher sensitivity with respect to those implemented for glucose sensing in blood.

According to the standard for evaluating the accuracy of blood glucose meters, called ISO 15197 released in 2013 [3], the accuracy specification for glucose values below 75 mg dl^{-1} requires that the measurement errors lie within ∓15 mg dl^{-1}. Considering that the molar mass of the glucose is 180.16 g mol^{-1}, the minimum detectable variation of concentration must be of 4.16mM. This limits the application of common sensing techniques with other corporal liquids such as sweat or saliva. For this reason, a development of new kind of detectors with higher sensitivity is required to be able to perform non-invasive measurement of glucose concentration in human blood.



Making of the sensor: deposition of the active graphene film.

Exploring the opportunities

Glucose biosensors are devices adopted in multiple contexts and their features must be tuned on the usage required. Indeed, such devices can either be used in a hospital, by qualified professionals (e.g. nurses) on the patients, or by patients themselves at home. While for the former usage the time required for the sensing is a critical parameter, for the latter simplicity of use and portability are more relevant. Having acknowledged that different situations require different designs, the team proceeded to investigate the crucial features for each one and how companies of the sector are having their products evolving in these directions.

The first step of the analysis consists in acknowledging the stakeholders of the sector, to clarify the needs for the project itself and define the features that the device should comprehend.

Testing of the electronic instrumentation.

The first stakeholders of a glucose biosensor are certainly the end-users, i.e. the patients, which can be either active, measuring their own glucose levels, or passive, needing a third individual such as a nurse or a physician for having their glycemia measured.

Due to their participation, also health operators belong to the list of the project stakeholders. Clearly, companies and businesses producing the devices are relevant stakeholders and will manifest different kinds of needs.

To investigate the needs of each of the involved stakeholders, the decision to prepare and distribute a survey was considered. The survey, that was realized in both Italian and English versions to cover a wider audience, is such that a different flow of questions is followed depending on the category the respondent belongs to.

The survey was mostly distributed online to have a heterogeneous group of respondents. More than 120 answers were recorded before the survey was closed for data analysis.

The four different categories of stakeholders expressed different needs towards the device. In particular, active users require the device to be portable, cheap, fast and easy to use, while passive users are more concerned with comfort. When it comes to health operators the most important requirements become accuracy and durability, while producers have mainly to deal with the costs related to the manufacturing of the device.

As it concerns the present market situation, blood glucose monitoring is a standard sector in which all major pharmaceutical companies invest conspicuous resources to obtain a product suitable for the largest slice of customers. As a result, up to now more than 80 different devices are available on the market, with prices ranging from 9 to 150 $ (most of the devices have a price of around 30-40 $).

Leading players in the field are major companies in the health care area, which have launched the products with the broader diffusion.

However, recent studies have evidenced that the low accuracy of these devices is their main weakness. This limit, which is due to the sensing technique implemented, is also the reason why blood is still the reference fluid, even though everyone acknowledges the discomfort deriving from finger-pricking.

Based on this information, it emerges that a new sensing technology providing a higher accuracy and avoiding finger-pricking, has the potentiality to be disrupting.

Dismissing blood sampling and opting for different body fluids, such as tears, sweat or saliva, may constitute a breakthrough for the quality of life of the patients.

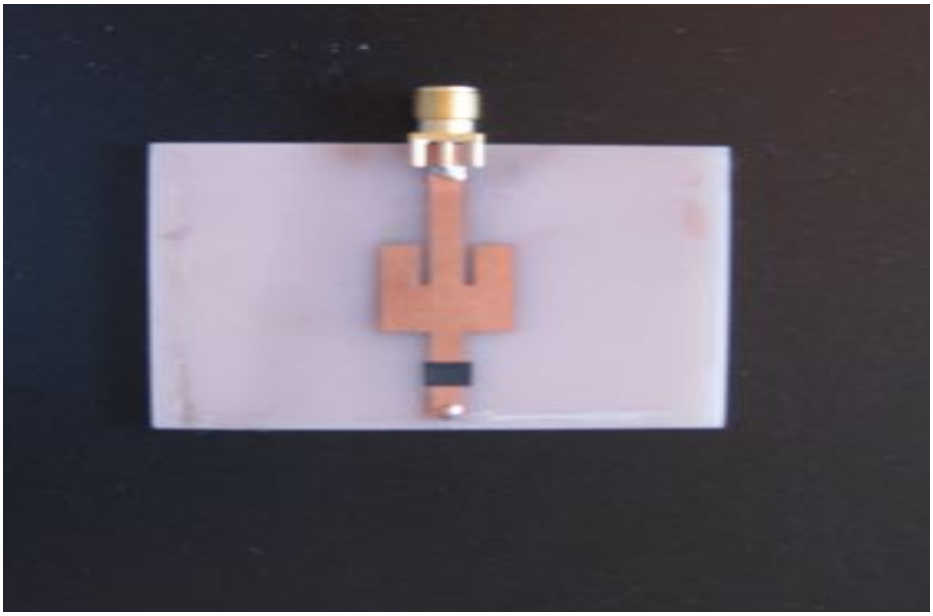
Generating a solution

In recent years, the evolution in research and development in the sector has sparkled and novel designs, with innovative features and materials have been proposed. During the first phase of the project a comprehensive study of the State of the Art in the field of glucose sensing have been performed. Results shows that none of the currently implemented solutions can accomplish all the requirements identified in the previous stage.

Differently, the research lead by Prof. Savi and her research group at Politecnico di Torino on glucose sensors offered a good starting point to create an effective technology to reach the goal of the project. To proceed in the development of the technology, a great effort has been focused on the improvement of the sensor working principle, in particular, the interaction with glucose molecules.

The final sensor design includes a custom-made resonating transducer unit, upon which a functionalized layer of graphene, able to interact with dissolved glucose, is deposited. In particular, the transducing solution is given by a radio frequency resonator (a microstrip patch antenna) able to convert the biorecognition output into a measurable resonance frequency shift. The selected final functionalization strategy is given by a generalized analyte binding approach, where the active biomolecules are GBP (that conformationally binds glucose) or GOx (that catalyzes the oxidation of glucose and is therefore influenced by near-field effects). These molecules are covalently bonded to graphene by means of an optimized binding protocol, which was developed in collaboration with the DISAT Department of Politecnico di Torino.

To qualitatively assess the performances of both setups, a series of equivalent experiments were performed: Raman spectroscopy was executed at Istituto Italiano di Tecnologia (GE) to verify the efficacy of the binding protocol and S11 measurements were carried out at Politecnico di Torino to ascertain the presence and correlation of a frequency shift. Throughout these experiments, the glucose-substrate interactions were mimicked by biomolecules with very similar activity to GBP and GOx.



Top view of the sensor: the microstrip patch antenna is deposed over the square substrate. The dark element on the right is the active graphene film.

During the development of the project, the team has come across the need of a simple way to test the different sensor samples we created. In parallel to the fabrication of the sensing units, RaFrBio team therefore decided to develop a custom testing instrumentation that could allow any user, also those lacking a

proper technical background, to easily read the amount of glucose poured onto the sensing element and perform some simple data processing, either on-board or on a PC. In response to a detailed requirements assessment, a real-time, multi-channel measurement setup was built through a complete in-house manufacturing process, pursuing limited dimensions, maximum modularity and simplified data readability above all.

The beating heart of the whole instrumentation is the readout electronics, able to perform the actual measurement of the frequency. The two critical and conflicting requirements to fulfil for this module consist in achieving a very high resolution and wide operative range. To accomplish both the requirements, has been developed a piece of hardware implementing an innovative technique to measure the frequency, based on periods-counting. Due to the high frequency at which the sensor operates, namely above 500 MHz, its design had been challenging. Thanks to the collaboration with a small electronic manufacturing company, namely EDC S.r.l., the hardware has been effectively built and tested. Such an opportunity allows to publish this part of the work in form of a scientific paper.

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PRINCIPAL ACADEMIC TUTOR
Fabio Alessandro Deorsola,
Applied Science and Technology Department, Politecnico di Torino

ACADEMIC TUTORS
Debora Fino, DISAT Department, Politecnico di Torino
Lidia Castoldi, Energy Department, Politecnico di Milano

EXTERNAL INSTITUTION
Grinp S.r.l.

EXTERNAL TUTOR
Francesco Parisi, Grinp S.r.l.

TEAM MEMBERS

Luna Pratali Maffei,
Chemical Engineering,
Politecnico di Milano

Francesco Cannizzaro,
Chemical Engineering,
Politecnico di Milano

Federico Allocco,
Chemical Engineering,
Politecnico di Milano

Andrea Giuseppe Landella,
Chemical Engineering,
Politecnico di Milano

Rawad Ibrahim,
Petroleum Engineering,
Politecnico di Torino

Lucrezia Maini,
Nanotechnologies for ICT, Politecnico di Torino

SO_3AS

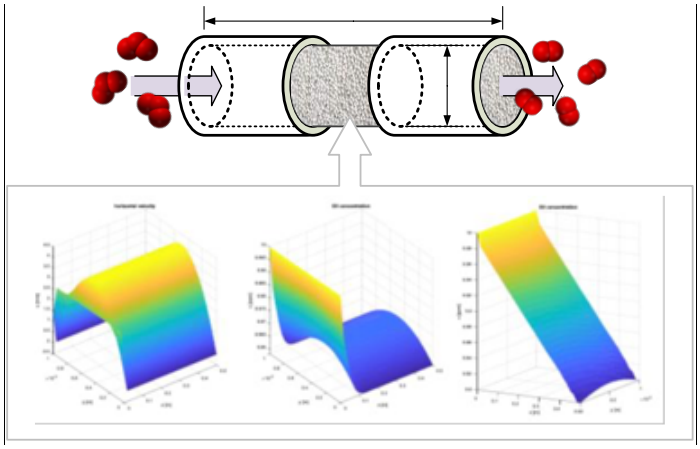
Smart catalytic-based system for abatement of polluting ozone at room temperature

Executive summary

Ground-level ozone badly affects human health, causing both respiratory diseases due to short-term exposure to ozone peaks and lung diseases of even cancer due to long-term exposure. The SO_3AS project aims at reducing indoor ozone concentration to non-harmful levels especially in polluted cities and industrial environments subject to ozone slips. The solution found by the Team is a reactor packed with catalyst for the transformation of ozone to oxygen with high efficiency at room temperature, and be integrated with heating, ventilation, and air conditioning systems (HVAC) in buildings. The ozone abatement system designed deals with low ozone concentrations, and the target outlet concentration was selected according to the regulation standards. The selected catalyst is Carulite®, which converts ozone efficiently at a reasonable price. For the reactor design, the team performed accurate computational fluid dynamics (CFD) simulations in MATLAB. To assess the market viability of the solution, the Team performed a market analysis to find an appropriate customer sector, and northern Italy emerged as viable target. Finally, to investigate the interest of these customer in buying our ozone abatement device, a questionnaire was proposed to almost 600 people. This also tested the awareness and responsiveness to an informative campaign about the ozone problem. Finally, the integration of the device in HVAC systems was studied. An overall feasibility analysis was conducted merging the results of simulations and market analysis, finally converging to the needs of GRINP S.r.l., together with other companies and institutions facing indoor ozone pollution problems.

Key Words

smog; ozone abatement; catalytic device; simulations; cost minimization



One of the principal tasks of the project: study, sizing and optimization of the catalytic system for the ozone conversion reactor (device).

Project description written by the Principal Academic Tutor

In collaboration with GRINP S.r.l., the SO_3AS project aims to study a dedicated catalyst-based system for the reduction to oxygen of ozone with high efficiency at room temperature. The possible end user of this system could be industrial activities but also public municipal entities. Indeed, this system will be a possible solution of the pollution in urban landscape. So, it requires a strong multidisciplinary approach, joining physics and chemistry, as well as chemical engineering, process design and management, environmental awareness and regulations' knowledge.
GRINP S.r.l. is an innovation-driven and knowledge-based Italian Innovative SME, devoted to development, implementation and industrialization of atmospheric plasma technology for different application such as textile products, film treatment and air treatments. Efforts directed under this vision have led it to require the design and realization of a new catalyst-based system: an air pollution control device able to abate ozone with high efficiency and treatment flexibility, overcoming major issues of current technologies about investment and operating costs. As described, the success of this ambitious project will lie on the strict synergy among the different skills and expertise composing the team, coupling technology, science, process management and sustainability. SO3AS will offer to the students the opportunity to learn all about the operation of the system and to explore different aspects of a technological devices driven towards sustainability and environment protection, under the leadership of a very dynamic and innovation-devoted SME aiming at expanding its position in the market. The management of the project, under the coordination the academic tutors, will see several progress meetings (one each 2 months), periodic visit to the Grinp site and dissemination actions through social media.

Within the SO_3AS project, the work to be undertaken might include:

- A literature study about the possible catalysts to be employed in the system, during which the final choice will be driven by availability, cost, handling and environmental-friendship.
- A fluid-dynamic modelling of the catalyst system, emphasizing the distribution of the gaseous feed for the optimization of the reaction.
- A re-think and redesign of the whole system to make it user friendly, safe and homologated (ergonomics, fool-proofing and standardization).
- A study of the possible fields and application scales, considering the company and user's needs, the technical/technological and economic limits.
- A marketing study about the penetration of this system in the market of environment protection, with particular focus on a patent survey and on the actual and future regulation actions.

Team description by skill

Luna Pratali: as the team controller, coordinated the actions and planning of the group, and with her Chemical Engineering knowledge performed the first design concept and simulations for the device. Moreover, she completed the selection of the most feasible solution and collaborated to the final technical analysis.

Francesco Cannizzaro: performed the initial analysis on the ozone problem and air quality, with emphasis on the effects on health. He also organized the sensitization campaign with the mean of a custom questionnaire, with the subsequent results analysis. Moreover, he performed the device manufacturing cost analysis.

Federico Allocco: devised the stakeholder analysis, with the user's requirements and the global industrial/municipality choice analysis. He also completed the full market and financial analysis and evaluation, listing the ozone problem in parts of the world and evaluating the possibilities for the final market choice. Together with Lucrezia and Andrea, he helped with the smart sensor integration.

Andrea Giuseppe Landella: did perform the analysis and dimensioning of HVAC systems, and helped Luna with simulation codes. With his Chemical Engineering knowledge, he also helped with the final reactor (single/modular type) choice and devised the design of experiments for kinetic validation.

Rawad Ibrahim: performed the requirements and constraint analysis for the device, coupled with the catalyst choice and performed the existing solutions' analysis, which helped define the final application of our solution.

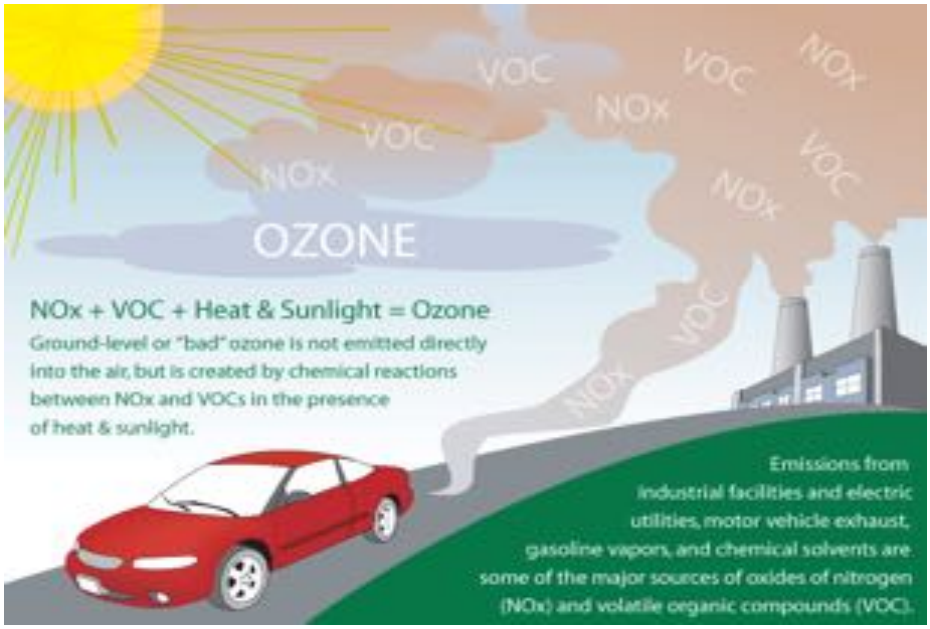
Lucrezia Maini: with her Nanotechnology knowledge, she performed the analysis of the ozone detection sensor, by means of the material, interface and connection to the device in order to make it integrated with the control loop (smart).

Goal

The SO_3AS project aims at reducing indoor ozone concentration to non-harmful levels, especially in polluted cities, industrial environments and offices subject to ozone slips. In collaboration with GRINP S.r.l., the project objective is to study a dedicated catalyst-based system for the reduction to oxygen of ozone with high efficiency at room temperature. The possible end user of this system could be industrial activities but also public municipal entities. Indeed, this system will be a possible solution of the pollution in urban landscape. The main goal of the project is the completion of the innovative system and the development of the business proposal up to commercialization stage.

Understanding the problem

Ozone is found in gas phase as a natural component of the upper stratosphere between about 10 km and 50 km above the Earth's surface. Stratospheric ozone is produced naturally from short-wave ultraviolet rays between 240 nm and 160 nm. The stratospheric ozone layer filters out sunlight wavelengths from about 200 nm to 315 nm. This filtering activity is very useful for life on planet Earth. In fact, ozone absorbs the UV-C and the entire UV-B bands, which are responsible of sunburns in humans and direct DNA damage in living tissues in both animals and plants. Unlike stratospheric ozone, ground-level ozone is both man-made and created by natural emissions, and it is currently considered a pollutant as it is one of the main components of the so-called photochemical smog. Ozone forms when two types of pollutants such as volatile organic compounds (VOCs) and nitrogen oxides (NOx) react in sunlight. For this reason, it is a secondary pollutant. These pollutants come from sources such as vehicles, industries, power plants, and products such as solvents and paints.



Tropospheric ozone generation from manmade emissions and sunlight

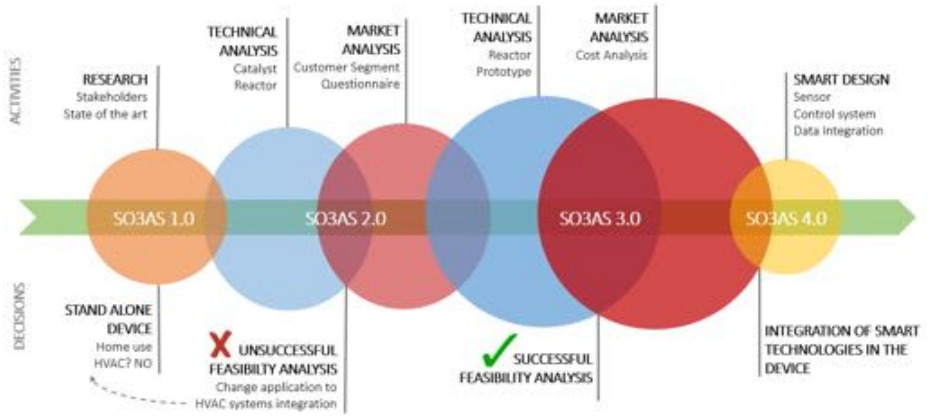
Ozone is also currently used in a wide variety of processes for its good oxidant capacities. As a versatile reactive compound, it can oxidize metals, nitric oxide to nitrogen dioxide, sulphides to sulphates; also, it can oxidatively cleave alkenes to alkanes. Massive usage of ozone as chemical reactant, emissions from industrial facilities in metropolitan areas and increasing global warming, make ozone one of the most widespread pollutants around the world. In addition, its interaction

with sunlight makes it even more dangerous during summer and in geographical areas exposed to intense sun radiation. Local geography also plays a role, as many densely-populated regions show moderate ozone concentration. In Mexico City, mountains to the city's north, east and west act like a natural barricade against gases and particles from distant fires.
As described, ground-level ozone is formed from other pollutants and can react with other substances, in both cases under the action of light. Air can transport ozone over long distances and across borders resulting in increasing the size of pollution from the local scale to the regional scale with concentrations varying depending on season and time of the day (higher in the afternoon). High concentrations of ozone near ground level can be harmful to people, animals, crops, and other materials. Ozone can irritate the respiratory system, causing coughing, irritation in throat, uncomfortable sensation in chest. Ozone can aggravate asthma and can inflame and damage cells that line lungs. Ozone may also aggravate chronic lung diseases and weaken the immune system. Lastly, ozone may cause permanent lung damage. These effects can be worse in children and exercising adults. The problem of ozone pollution and the related effects on human health has raised the concerns of national and international organizations for environmental protection aiming at the definition of air quality standards that can protect people's health, especially if belonging to at-risk categories such as children and elder people.

Exploring the opportunities

The ozone problem is difficult to tackle: in fact, ozone is a secondary pollutant, hence it cannot be abated directly. Some technologies focus on the abatement of its precursors (NOx and VOC), however few solutions are available for abatement of ozone itself. The Team was assigned to build an ozone abatement device and believes that this is the only possibility to reduce indoor ozone levels efficiently and with an immediate effect. In the US, where regulations about ozone levels are more stringent and there is higher awareness about the ozone problem, some companies already produce stand-alone ozone abatement devices for small rooms and laboratories. The current ozone abatement technology is based on catalytic processes, which enhance the speed of the conversion of ozone to oxygen. The widest spread one is Carulite, which is a mixture of Cu/Mn oxides. The Team chose it among a set of catalysts after a full state-of-the-art analysis. In fact, Carulite shows high efficiencies and a wide range of operating conditions, both in terms of temperature and humidity. Furthermore, it is the cheapest catalyst available for ozone abatement. The Team also explored the possibility to investigate the performance of new catalysts such as zeolites, but this option was eventually discarded because too expensive. Hence, the Team focused on designing an ozone abatement device which is flexible, so as to adapt to a wide range of applications, and cheap, namely compatible with the liquidity of the selected customers. Concerning the reactor configurations, both monolith and packed bed reactors were investigated. However, the CFD simulations of the monolith reactor showed that the monolith configuration has a poor efficiency, therefore the packed bed only was investigated in depth when generating the final solution. Concerning instead the application of the device studied, it was first thought about a stand-alone device for abatement in rooms. However, this solution is already available and may not be competitive in the market. Furthermore, it turned out that common citizens are not willing to pay enough money to buy an ozone abatement device for their houses. Therefore, the Team also explored other possibilities, such as the integration of ozone abatement systems in the air circulation ducts (HVAC). This was never done before. To do so, a further technical analysis about the characteristics of air circulation systems was required. To maintain the solution as flexible as possible, it was decided to focus on the development of a code for the design of the device rather than a device with fixed size. Finally, the possibility of commercializing the device was also considered by studying the market opportunities. The attractivity of each market was assessed by evaluating the extent of the ozone problem, the presence of competitors and the regulations about pollution. It turned out that both north America and northern Italy have good market potential in this respect. From what stated above, it is evident that the project was developed as an iterative

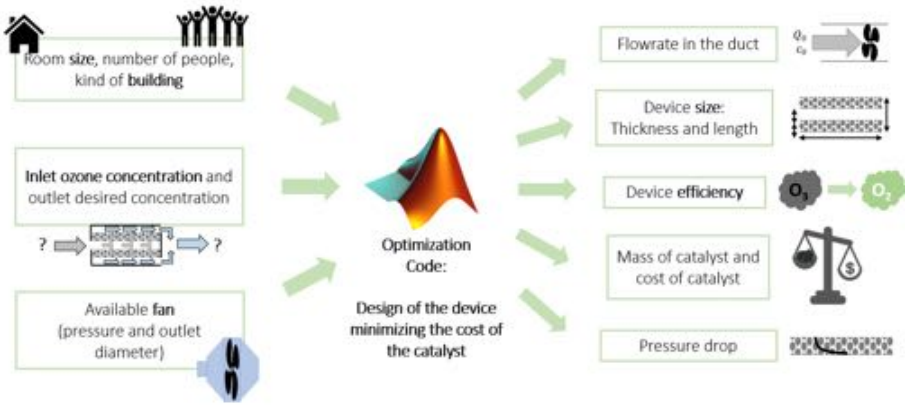
exploration of opportunities, finally selecting the solution, as summarized in the figure below.



Opportunities' exploration turned to a sequential refinement of the brief and solution.

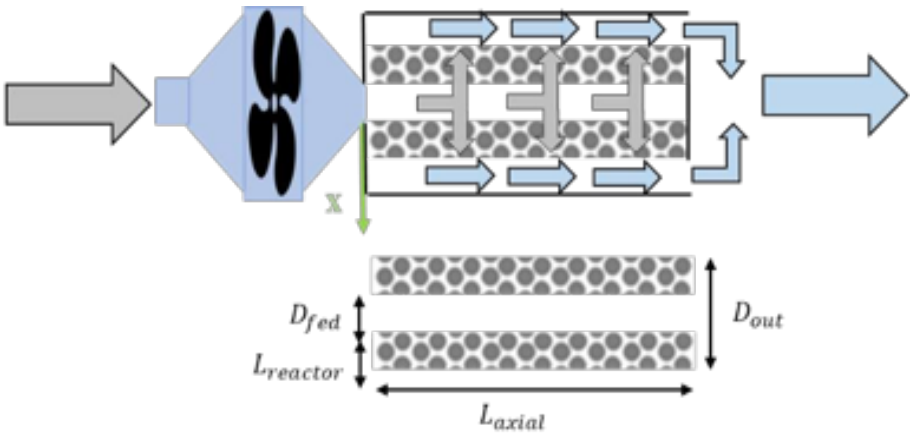
Generating a solution

The designed ozone abatement system deal with low ozone concentration, which are caused by either industrial slips or pollution: the outlet concentration ranges have been selected according to environmental regulation standards. The abatement occurs at room temperature with Carulite®. Concerning the reactor design, the Team chose to rely on highly accurate computational fluid dynamics (CFD) simulations performed on MATLAB:



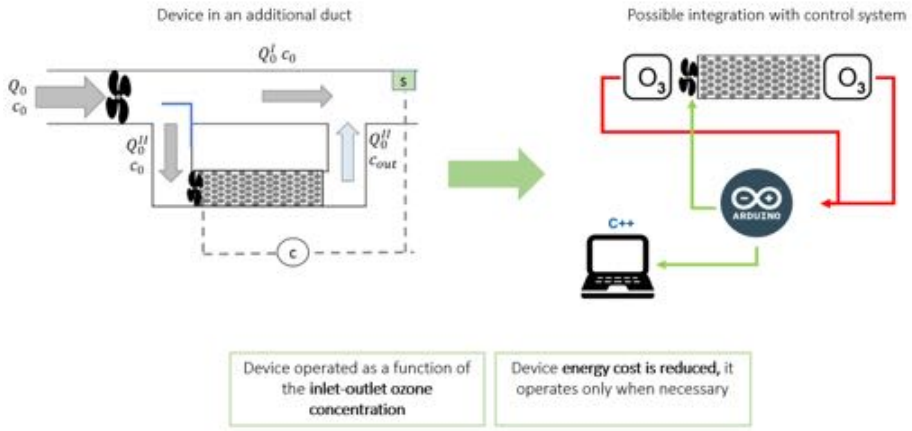
Solution conceptual architecture, with the input and output (optimized) data

Thanks to code flexibility, inlet/outlet concentrations required can be changed with no effort, thus resulting in an easily customizable design, by just tuning or setting such input values. This flexibility does not only regard the reactor itself, but also extends to the HVAC system integration: in fact, the code also performs the sizing of the HVAC duct based on the size of the building and number of people considered. The design proposed for the reactor was a radial reactor, as sketched in detail:



Radial Reactor architecture

The air flow redistributes on a large catalyst surface, achieving small pressure drops, which can be easily overcome by a low energy consumption axial fan, which is already available in HVAC systems. This innovative solution allows also minimizing the amount of catalyst used, and therefore the costs, for a feasible indoor ozone abatement. In addition, the device can be easily integrated with both existing or *new* HVAC ducts, in their design phase.
In addition, a sensor measuring ozone concentration can be installed allowing constant monitoring of the actual inlet and outlet concentrations via a simple user interface. Further implementation of a control system for automatic on/off switching of the fan would even bring to energy savings. These additional features finally allow making the device smart and ready to break through in the context of industry 4.0, which exploits the cyber-physical system shown below:



Solution practical architecture, which works on the given (optimized) data by the code

On the commercial side, even though in California there is an existing market, the team has chosen to focus its attention on northern Italy. In this region the solution proposed would emerge as the first indoor ozone abatement since no market currently exists. Here, the device would enter a market in which people awareness about ozone pollution is not high. Thus, the team performed a questionnaire in order to understand the citizens' awareness about the ozone problem and to sensitize people about pollution. Finally, a full cost analysis accounting for both materials and manufacturing process has been performed. The final price is of the order of few thousands of euros, which is affordable for both public and private institutions such as schools, hospitals, and private companies.
In conclusion, the team thinks that its device can spread thanks to an increase in pollution awareness through sensitization campaign. In fact, in this way it would

be possible to force authority to set more stringent regulations about ozone pollution.

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