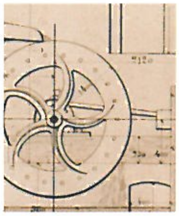
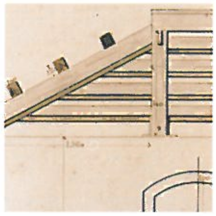
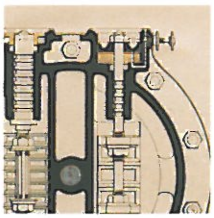
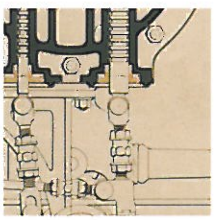


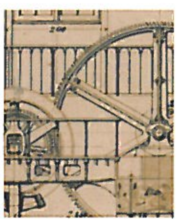
Multidisciplinarity and innovation ASP projects 1

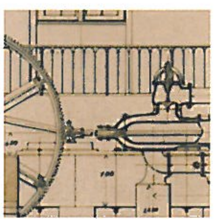


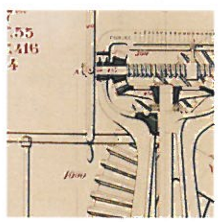


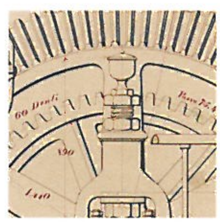


ALTA SCUOLA POLITECNICA



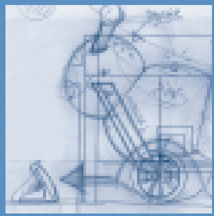


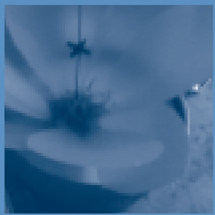




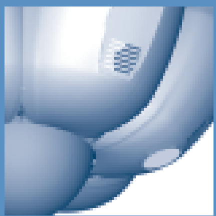
POLITECNICO DI MILANO
POLITECNICO DI TORINO

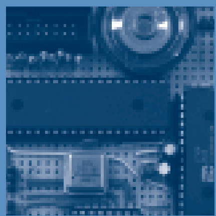
TELESMA
EDIZIONI





PROJECT 1





AmoRoSA

AUTONOMOUS MOBILE ROBOTS FOR SERVICE APPLICATIONS

project 1

Autonomous Mobile Robots for Service Applications. Companies: Microsystems, Itoys. Projects: A sensitive plant, an intelligent toy, a movable ceiling lamp.

AMoRoSA Autonomous Mobile Robots for Service Applications

PRINCIPAL ACADEMIC TUTOR

Marco Maiocchi
InDACo, Politecnico di Milano

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Lucia Rampino
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Massimo Sorli
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Francesco Trabucco
InDACo, Politecnico di Milano

EXTERNAL INSTITUTIONS

Interactive Toys
Microsystems

EXTERNAL TUTORS

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Interactive Toys

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Interactive Toys

Marco Tausel
Microsystems

TEAM A

Francesco Brasacchio [Team controller]
Industrial Design

Ivo Emanuele Francesco Boniolo
Automation Engineering

Marco Garlaschè
Mechanical Engineering

Paolo Giamminonni
Biomedical Engineering

Fabrizio Giordano
Electronic Engineering

Davide Mazza
Computer Engineering

TEAM B

Marco Rossi [Team controller]
Management

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Electronics Engineering,

Luisella Borra
[Project Communication Coordinator]
Environmentally friendly product design

Maria Beatrice Criniti
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Luigi Malagò
Computer Engineering

TEAM C

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Mechanical Engineering

Tatiana Chierici
Interior Design

Luca Frasson
Biomedical Engineering

Diego Quadrelli
Architecture

Claudio Roncuzzi
Materials Engineering

PROJECT DESCRIPTION

The project was oriented towards autonomous mobile robots, that are products of growing interests in the consumer market (surveillance, cleaning, gardening, impaired people support, etc).
In order to achieve the exploitation of the research, strong constraints were defined: the goal was to obtain low-cost products able to satisfy the requirements of the market and not only of niches. In fact, the aim of the project was the implementation of solutions compatible with market requirements through the development of new methodologies and technologies.
Many people took part in this project: three student groups, academic tutors and companies. The three groups of students carried out their activities in different complementary fields, to explore various solutions for a wide market: intelligent furniture complements, intelligent toys and intelligent multipurpose lighting.
The first project, relevant to intelligent furniture complements, concerned a robotic flower, initially intended as a "gadget", capable to react to user gestures and to work also as a barometer, a perfume dispenser and a personal lighting device. The second project focused on cheap, intelligently flexible toys, easy to use and able to evolve; an intelligent toy-car (or caterpillar, or other) that could detect the signals (RFID buttons) arranged by the user and to interact with them, both for moving (turn, stop, speed up, etc.) and for matching goals (collect points, discover clues, etc.). The third project regarded a remotely controlled ceiling lamp, capable of changing from soft light to a directional spot. It could also be programmed to descend from the ceiling, becoming a personal lamp. All three projects required a lot of different skills and a multicultural approach: mechanical elements to be moved; electronics for most of the functions; automation controls apt to define interaction and behaviour; definition of user's scenarios; biological aspects concerning of psychology interaction and human responses; electronics for circuitry and power; information technology necessary to provide proper software controls; design to define roles and to insert semantics into the shapes and, finally, management to maintain production costs adequate for the market.

The aim of the project was to drive ideas, providing also the experience of the problems arising from the real production: the tutors compelled the implementation of demonstrating prototypes for each project. The result was really impressive: in a short period of time the prototypes highlighted problems under several aspects (mechanics, electric power, size, shape, appeal, costs, etc.), fostering solutions and increasing interactions among the various disciplines; prototypes changed heavily and quickly.
Experience went beyond our expectations: during the final stages, the initial goals of modularity and flexibility forced us to interact with other companies (not competing with the official ones), in order to obtain support and materials for further experimentations and improvements in different fields. Legoled, provided diode lamps for the lighting aspects in more than one project and Oikos, supplied advanced electronically controlled perfume dispensers. Their unrequested interest and availability, as well as the regular and effective presence of the official companies, clearly testify the significance of the projects in opening new market areas.

project 1A

FLOrobot

TASKS & SKILLS

Ivo Boniolo, experienced in automation engineering, was responsible for managing movement and control frame components choice. He worked on the prototype together with Francesco Brasacchio and Marco Garlaschè.
Francesco Brasacchio, took care of the project usability, scenario settings, materials and prototyping. He was responsible for project visualization and presentation.
Marco Garlaschè, was responsible for the mechanical analysis in the project and carried out the prototype.
Paolo Giamminonni, managed the Zigbee wireless communication protocol and controller interfacing.
Fabrizio Giordano, took care of sensor frame and controller interfacing for the robot.
Davide Mazza, managed the software for the controller programming in the project.

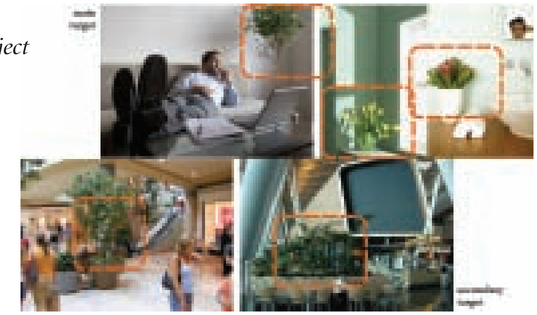
ABSTRACT

The main purpose of FLOrobot project is to develop a system targeted at the entertainment world. The secondary aim is the creation of a sort of weather station. These refer to the collective imaginary of a fantasy world, where plants and flowers show extraordinary features and are endowed with their own behaviour.
An analysis of the problem was performed in order to determine possible market areas concerning to different customers' needs.
An autonomous system, suitable for simulating the main features of a plant lifecycle is not yet available on the market. Therefore, the purpose of this research is to study a way to create an autonomous plant able to react to environmental conditions and interact with the user.
The potential scenarios for the product positioning on the market change depending on the different functions that could be implemented. It could be seen as:

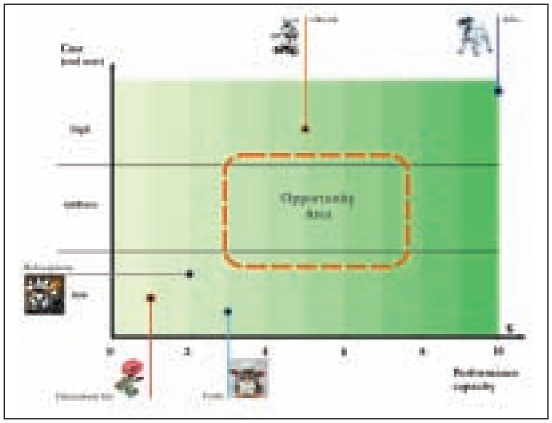
- a furniture complement able to create a relaxing atmosphere;
- a game toy for people looking for interaction with a plant and willing to take care of it as if it was real;
- a weather station: external sensors transmit to the plant informations on atmospheric pressure and temperature and the plant displays them to the user in a behavioural manner according to the specific weather conditions.

The following section focuses on the state-of-the-art in the entertainment robot world. Then the description of feasible and innovative solutions is provided, along with the main features of the robot and the general construction issues.

1 *Partner companies participating in the project*



2 *Target of the project*



3 *Opportunity area of FLOrobot project*

UNDERSTANDING THE PROBLEM

TThe A.Mo.Ro.S.A. project includes different fields of application, e.g. surveillance, cleaning, gardening, impaired people support as well as entertainment.

In the last few years the market for robotic entertainment has rapidly grown and the rising trend is expected to remain constant in the near future, going from one million present units to estimated 2.5 millions by the end of 2009. The sales value is estimated to be over $4.4 billion (source: IFR Statistic Department 2005).

As the the field is so promising, we opted for the development of an autonomous entertainment system. Of all the existing concept ideas, FLOrobot stuck out as the best idea for technological innovation and possible market broadness.

Thanks to its numerous functions, FLOrobot is addressed to several groups of users, such as those who desire an alternative to traditional barometers and prefer an entertainment and furniture product. It could also be an appealing environmental enhancer in public places (hotel halls, airports, etc.).

EXPLORING THE OPPORTUNITIES

Based on a consumer market analysis, the entertainment robots segment can be divided into two main groups. The first consists of low-cost educational kits and toys, all with limited performance capacity, such as Furby® by Hasbro®. The second group consists of hi-tech toys characterized by high performance and high cost, such as Aibo® by Sony®. FLOrobot is an in-between product, providing good performance at a reasonable price. Through the implementation of new features allowed by its modularity, FLOrobot has the possibility of reaching higher market levels as well.

The choices we made especially concern the customer's target and the number and type of features, which added a series of constraints to the project:

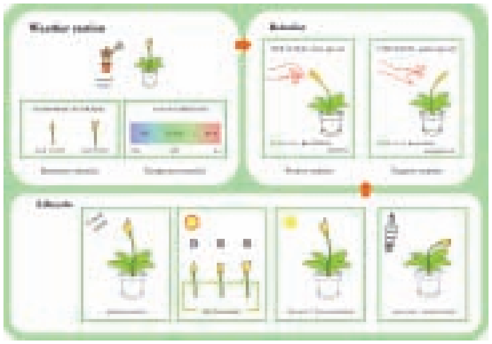
- weight and dimensions of the structure should be similar to those of a real flower
- easy mechanical solutions
- dramatically reduced number of sensors and actuators
- continuous fluid movement.

These constraints represent a challenge, specifically for what concerns the stem and the flower movement, the input-output control devices and their interfaces.

GENERATING A SOLUTION

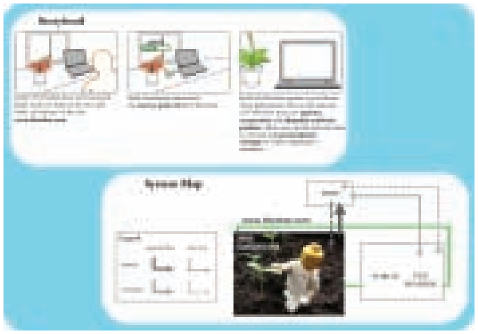
The robot unit behaves like a typical apartment plant with its requirements and lifecycle. The common requirements of a plant are: light, water and user's care. The water demand is simulated through the progressive exhaustion of the batteries and the consequent electricity requirement, while the lifecycle is represented by the daily blossoming and withering of the flower.

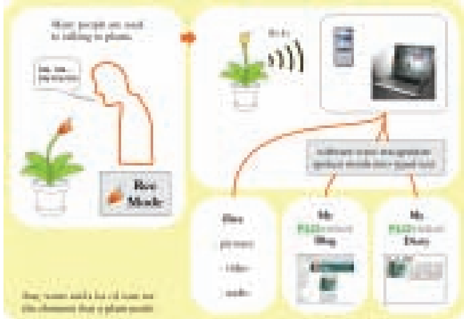
As the system gets started, the plant shows a positive state by seeking



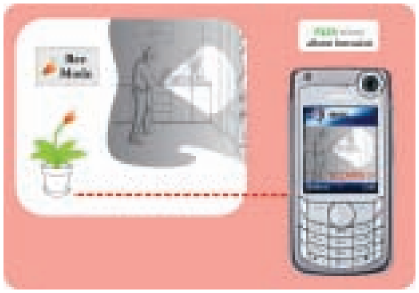
4 *Tamagotchi FLOrobot and weather station*

5 *FLOrobot Community*





7 *FLOrobot MomentKeeper*



6 *FLOrobot Indoor Surveillance*

contact with the user, who in turn can interact with it both through touch and voice. If it is neglected, a negative mode becomes increasingly apparent: the plant lowers its leaves, closes petals and turns to a specific colour. In order to get the plant back to a positive mode, the user must show more affection, taking care of its primary needs, talking to it and approaching it slowly. In fact, approaching it slowly, the user will make the plant to be attracted by him/her. If, on the other hand, the plant is approached too quickly it will react as if threatened and will try to avoid the user, moving away from him/her. After a defined lapse of time during which the plant remains in the negative mode, a terminal state is reached: FLOrobot virtually dies and will remain in this state until the user resets it. Moreover, all the results of the user-plant interactions are influenced by the weather conditions: if the weather is fine the positive mode will last longer and will be easier to reach. On the contrary, if the weather is bad, this will act as an obstacle for the user trying to make the plant reach its positive mode.

As to the weather forecast, the basic variables evaluated by FLOrobot are external temperature and pressure (barometric function), that are expressed by the plant's behaviour through the leaves inclination (high, medium, low) and colour, the blossoming level of the flower and the stem position.

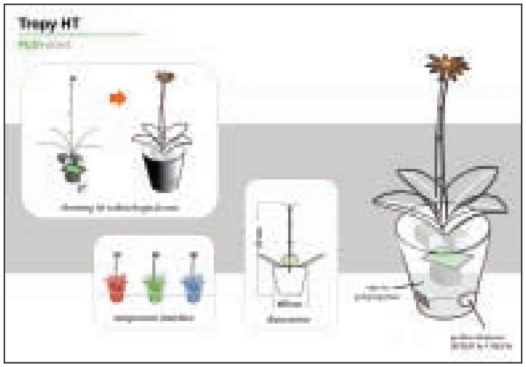
The robot main elements are: sensors, actuators and central computing unit.

Sensors

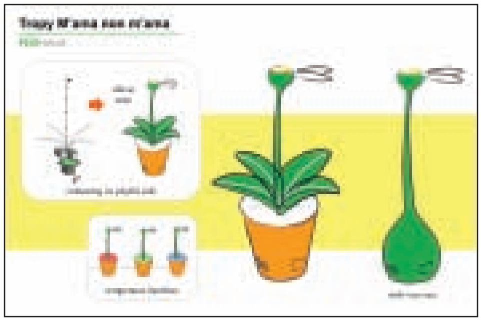
- Capacitive proximity sensors. The value of the capacity changes according to the variation of distance between the sensor and the incoming object.
- Luminosity sensors, set to detect the luminosity of the surrounding environment.
- Acoustic sensors, microphones used to determine the presence of music or voices.
- Temperature and pressure sensors, used to discern the different weather conditions.

Actuators The leaves, the stem and the flower are the moving parts of the device. The actuators that will be employed are the folowing:

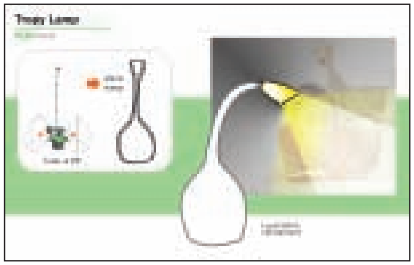
- Tie rods for the stem. The stem movement is obtained by flexing its upper end thanks to the presence of four connecting rods that run in parallel with the main structure.
- Tie rods for the leaves. The movement is obtained by traction and release of the leaves, following a procedure similar to the one described for the stem.
- Flower motor. The opening and closing of the flower is obtained through two additional motors in the bulb.



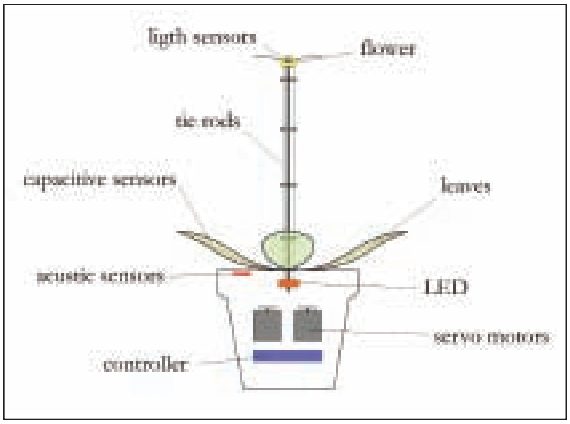
8 *A product development: TROPY HT*



9 *A product development: TROPY M'ama non m'ama*



10 *A product development: TROPY Lamp*



11 *Section of the robot*

Additional elements:

Light A series of LegoLED® FlexiLED® strips and RGB Led by Crosspoint, positioned inside the flower and under the leaves, assure the capacity to implement the play of light linked to both the charging mode and the different weather induced behaviours.

Perfume The air freshener by Oikos Fragrances, based on SFR® patent (Solid Fragrance Release), will be inserted in the plant too, enabling FLOrobot to release perfume according to a standard routine and the user's interaction.

FUTURE DEVELOPMENT

Different products through flexibility Due to the innovative modularity, three different products can be developed starting from the same core:

- Tropy HT: the internal structure of the device is displayed.
- Tropy LAMP: thanks to a high luminosity led the plant becomes a mobile lamp.
- Tropy 'M'ama non M'ama': emphasizes the playful side of the robot.

Scenarios:

- Tamagotchi FLOrobot and Weather Station
- FLOrobot Community
- FLOrobot Moment Keeper
- FLOrobot Indoor Surveillance

Central Computing Unit The plant's biorhythm (blossoming, withering) is modelled through finite state automata. The movement of the plant , according to the user's actions, is regulated by an algorithm. It allows the identification of the "intruder's" position through the sensors and the transmission of a series of commands to the actuators, in order to generate movements following a specific pattern. A PIC processor is enough to execute the required algorithm.
For what concerns the weather forecasting function, the outdoor sensors transmit their values to the plant through a wireless connection. Weather conditions are communicated to the user through the colours and positions that the plant takes.

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project
1B

IERoKi
Innovative Entertainment Robot for Kids

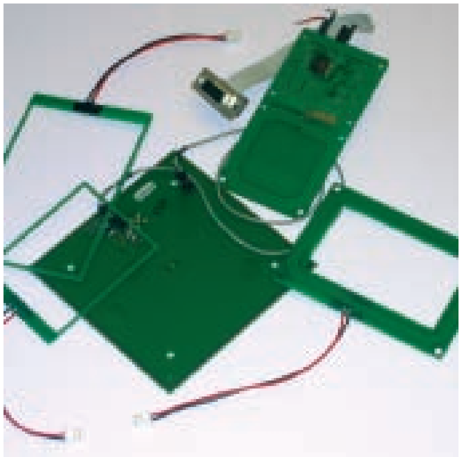
TASKS & SKILLS

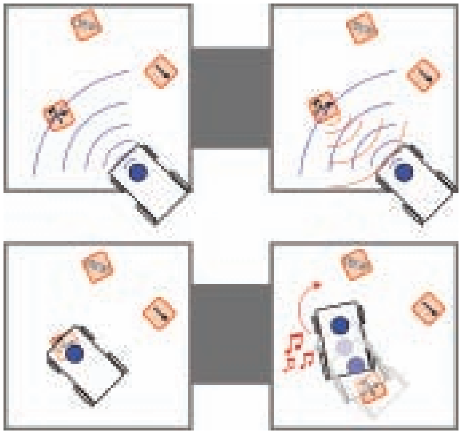
Raouf Barboza was responsible for all the hardware components of the project, optimizing problems related to the interfacing among the different electronic devices.
Luisella Borra took care of product ergonomics and usability, designed the mechanical structure and the external shell of the toy.
Maria Beatrice Criniti gathered information about the state of the art and legal discipline relevant to the technologies adopted in the project, moreover she supervised almost all the components buying activities.
Luigi Malagò designed and implemented the firmware for the microcontroller and defined the overall software and hardware architecture of the toy.
Marco Rossi was responsible for internal coordination, economic project analysis and document editing.

ABSTRACT

With this project we entered for the first time in the world of entertainment with a different perspective, that is not as customers, but as creative designers and engineers. We proposed and realized a new toy, that we expect to become a success among young kids. For this reason, we decided to write this article in a different way, compared to the engineering books we have studied so far in our university courses. It is Christmas morning and a child is opening his presents. His eyes shine discovering that he received the toy he has desired for so long: caterBOT, his favourite character from the IERoKi series. It looks like a thirty-centimetre long caterpillar, with a green plastic body and four wheels fixed to the base.
The packaging contains some green plastic leaves too. In less than a minute the child places them on the floor next to the caterBOT and turns it on. The toy starts moving towards the closest leaf, passes over it and turns left. After detecting the second one, the caterpillar changes its direction and once it has reached the new leaf, it lights up. Leaves act as signals and can be placed freely on the floor. Their position can be changed also while the caterpillar is moving. Not only the toy looks nice, but it also shows many nice features: it can play sounds, switch its colourful lights on, and, of course, follow the instructions it receives from the child through the signals. It can turn right and left; it can speed up and even stop as long as the button placed on the rear is kept pushed. The toy name is IERoKi, an acronym for Innovative Entertainment Robot for Kids. The toy presents autonomous behaviours – no external direct command is needed: it moves on the floor as if an invisible hand guides it!
All this is possible thanks to the use of RFID, a wireless technology that enables the identification of a tag through the use of electromagnetic waves. In fact, the caterpillar shell hides an antenna beneath it, which can detect the so-called RFID tags contained in the leaves. Tags have been previously endowed with an identification code, so that after they are activated by the electromagnetic field of the reader antenna, the toy can identify them. This information is processed by a microcontroller, which commands accordingly the movement, the lights and the loudspeaker of the toy.

1 *Concept scenario*


2 *RFID antenna and transponders*


3 *Description of the robot functionalities*

UNDERSTANDING THE PROBLEM

Imagine five students taking part in an adventure. They don't know each other, speak different languages and even come from different continents. It is not a pleasure holiday on a Caribbean island, but a two-year long trip bristling with troubles, difficulties and problems students have to face.

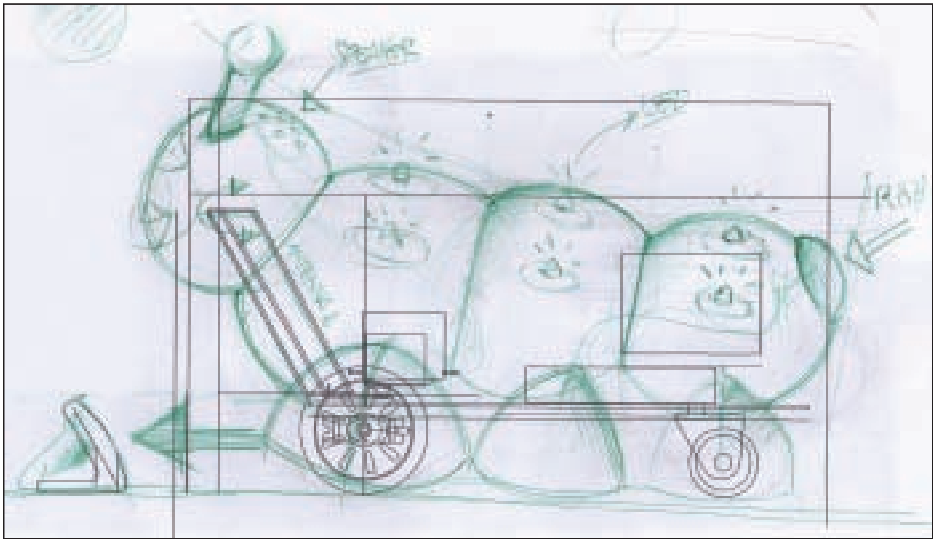
We love this comparison because it best reflects our experience in this project. We had to realize an autonomous mobile robot for services applications, summarized by the acronym AmoRoSA, which was the name of our project. We were even given a series of constraints our robot had to respect, in particular flexibility, modularity, usability, market orientation and, last but not least, innovation: our robot would have to be different from already existing devices, in terms of functionalities and technologies.

After having understood the meaning of all these concepts, we organized several brainstorming sessions. Once a sufficiently rich list of ideas was obtained, we assessed them with our tutor's support. Finally, we set the field of our project: children entertainment.

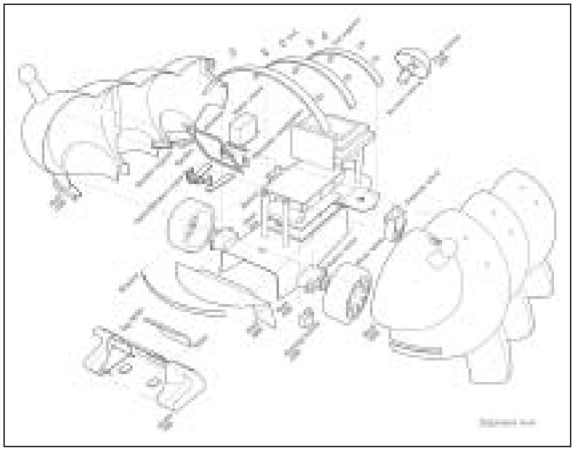
EXPLORING THE ALTERNATIVES

We conducted a market analysis to realize which technologies, strategic positioning and tendencies characterized the existing products. At first we tried to understand how entertainment robotics evolved in the last decades. Through many researches on the Internet and product catalogues released by entertainment companies, we identified today's most successful products. We tried to assess them based on two variables: selling price and performances. After mapping this information in a simple performance-price chart, we identified the market segments and products positioning. This state-of the-art analysis concluded with the study of market trends, in order to judge the profitability of the field we were about to enter. We analyzed entertainment robot market past trends in terms of value and units sold, considering in the end experts' expectations about the future evolution.

Basically, we wanted to provide children with a toy that could possibly fulfill their expectations, and attract their attention as long as possible. In order to achieve this goal we adopted a sort of stage-gate approach. Actually our project evolution was not as linear as it appears from the previous description. In fact it was characterized by several loops arising from unexpected troubles and even from the



4 *First drawing of the external shell*



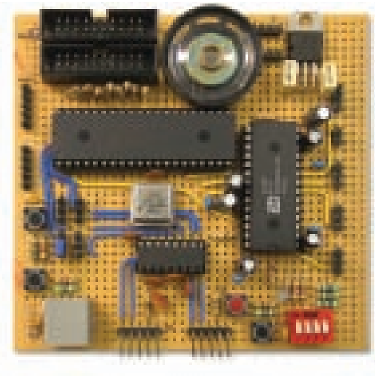
5 *Exploded view of the toy*

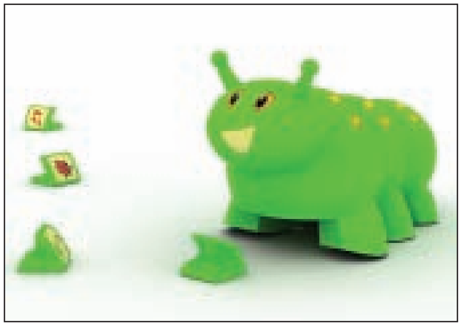
better understanding of aspects related to children behavior. Another great issue was related to the impossibility of implementing some chosen technologies, owing to the lack of specific competencies of the team. During the early project stages, for example, we decided, for several reasons, to change repeatedly the size of the toy and the technologies to be used in order to better interact with the external environment.

GENERATING A SOLUTION

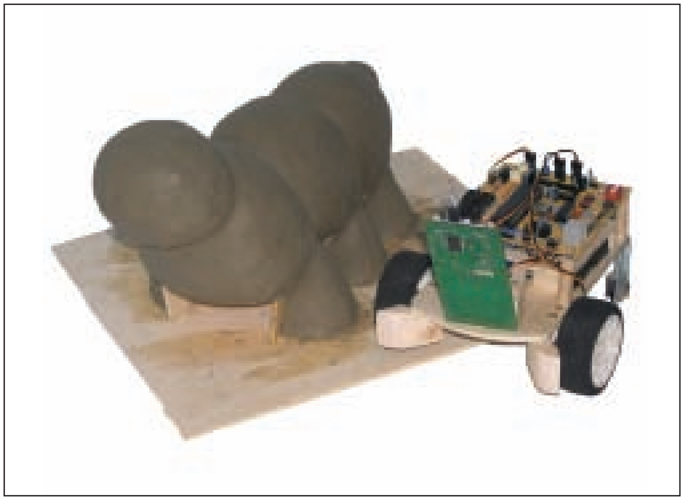
We decided to explore and bring forward two different solutions, which seemed to be equally interesting. The first one was an autonomous racing car moving along a circuit build up in a domestic room with standard modules to be assembled by the child. In our scenario the car would be able to follow the path thanks to the on-board sensors, register it and then compete in the same circuit against another racing car guided by a child through a radio controller.
In our mind this toy fulfilled many of the project requirements such as flexibility, innovation and, of course, autonomy. On the other hand we identified some problems, in particular those concerning technological aspects of the robotic device. Besides the technological difficulties related to the significant speed the car was required to sustain, there was the threat that some potential consumers could be prevented from buying it owing to limited indoor available spaces.
The second best solution consisted in a sort of small train able to follow a line freely drawn by the child on a floor or on other surfaces. This idea was characterized by a lower speed compared to the previous one; as a consequence, the toy resulted more suitable for younger users. The child could paint some signals along the path to be recognized by the toy. We were able to identify some difficulties related to the choice of the support on which drawing the line or to the correct identification of the signals.
Owing to these critical and serious aspects common to both solutions, we decided to interface directly with the children world. We organized a meeting with two experts in the field of youth entertainment, in order to integrate information we collected previously from books and manuals. One of the most important contributions they gave us concerned the limits associated with a two-dimensional game environment. They provided enough information for us to conclude that the toy train was not completely able to represent a good source

6 *Electronic components on the control board*





7 *Final rendering of caterBOT with external markers*



8 *Prototype of the robotic base with the RFID antenna and model of shell*

of fun for our target users. We decided also to discard even the racing car toy because, after having consulted our academic and external tutors, we realized that the technological problems we would have to face were far beyond the reach of this project.

In order to change our approach towards a three-dimensional game we needed a technology that could let our toy identify an object in a three dimensional space. We chose RFID, a technology widely used but rarely applied in the entertainment field.

The game standard scenario is very simple and will be now briefly described. The toy moves in a domestic environment thanks to two driving wheels. While moving, it is able to use a RFID antenna as a kind of radar, in order to detect tags in the nearby. Tags are contained in signals that can be freely placed by the child on the floor, for example forming a path along which the toy will move. To each RFID tag a specific identification code is associated, so that when the toy recognizes it, this will behave accordingly. The toy is able to perform some basic actions: it turns left/right, plays sounds, and so on.

Moreover, the toy can implement several higher level behaviors: most of them will depend on the specific external shape that will be delivered. Besides caterBOT, different versions of the toy have been conceived. For example, the same device could be easily adapted to behave as learnBOT, the personal teacher helping children to learn a foreign language or fableBOT, a friend telling a new story according to the sequence of the events created by the child with the markers.

The software and hardware architecture of the toy have been designed in order to be as much modular as possible: for this reason, not only different behaviors can be easily implemented, but also can be extended to other types of toys.

Finally, we also prepared a business plan like we had gotten into partnership with our project tutors. Due to a series of economic reasons, we supposed to sell our robot to kindergartens with the help of a couple of agents and through a web site. We considered lot of aspects: production site choice, production techniques, delivery strategy, cost analysis and marketing strategy. After computing the best selling price through benchmarking and mark up techniques, we supported qualitative considerations with an estimation of cash flows. For what concerns the first three years, with our given assumptions we estimated a positive profit since the second half of the second year.

project 1C

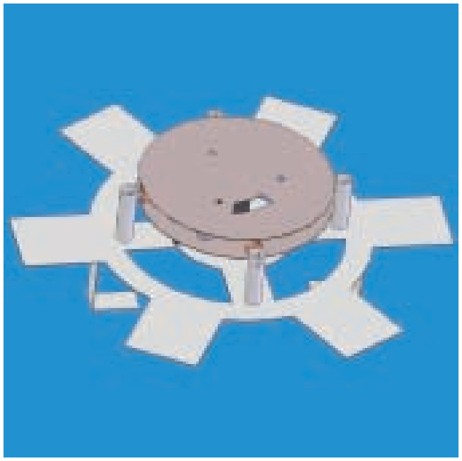
Flobe
A veritable robotic lamp

TASKS & SKILLS

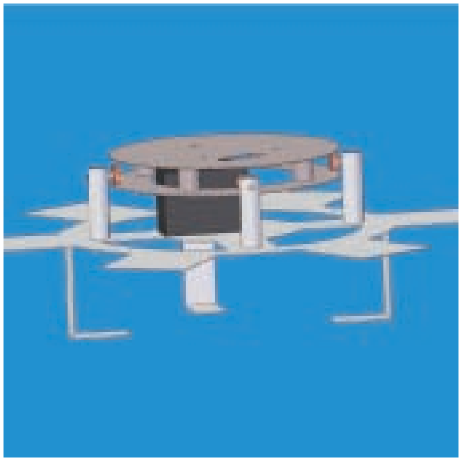
Claudio Roncuzzi, experienced in materials, took care of the selection of adequate materials.
Carlo Ballerini competence lies in two fields of research: automotive industry and renewable energies. He worked on lamp architecture and actuation components.
Luca Frasson, interested in development of strategies and devices for rehabilitation, focused on technical aspects and user's requirements.
Tatiana Chierici was responsible for the state-of-the-art, metaproject, project scenery and ergonomic components.
Diego Quadrelli was responsible for design, light characteristics, dialog between lamp and room and coordination of the prototype.

ABSTRACT

Light is a complete sensorial experience that brings man to acquire a continuous new perception of the surrounding world. Light is an element in motion: difficult to describe, it is partly natural and partly man made.
Let's try to imagine to enter in a very dark room that is like a black cube that chokes and oppresses us, concealing its perception. Suddenly a metal rustle signals us the presence of a fast rotation movement. After this, a second noise arises: something is moving. LIGHT. The cube is shining with an ivory light, a pure and clean light that surrounds us and draws our attention to its point of origin. In the middle of the ceiling there's a strange object shaped like a flower. It's our lamp. The robot-lamp is formed by six petals and a central bulb able to sense the lightness condition of the room and adequate its intensity and light direction according to the user's needs. However, due to the nature of the light, the lamp mutates continuously just like a real robot that develops its potential to help its master. The central bulb, the eye of Medusa that turns everything into stone, with its well-balanced light intensity, is vertically moving to the bottom. A sphere made up with two materials, hanging from three cables, falls into the master's hands waiting for it. With a fluid movement it detaches from the mother that gave birth to it. Now the game starts. Half of this little portable sphere is made up with a material that can be manipulated, assuring an adequate volume of the sphere in any condition. Its lightness, dimensions and tactility tempt the user to play with it and to bring it with him/herself. The sphere is a three leds lamp that is autonomous and can be placed in the main lamp at user's will.
The dream we want to give is based on the simplicity of managing - by ourselves and by the robot - the light that follows our day. Sometimes the lamp lights correctly the cube, other times we take the lighting sphere in our hands…



1 *The internal chassis of the lamp consists in two main parts. The brown one is fixed to the ceiling, while the white one can rotate along with all the lamp. Its function is supporting all the internal components such as LEDs, servomotors, PICAXE, thanks to its six external appendixes, one for each petal of the lamp*



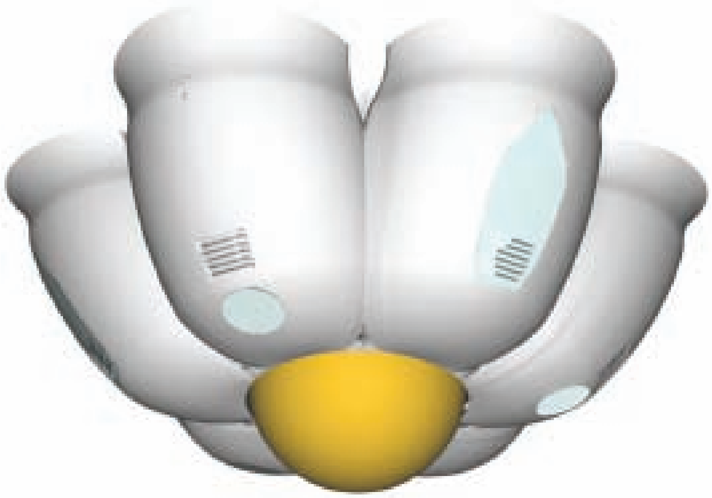
2 *A side view of the chassis. The black element visible inside is the servomotor which makes the lamp rotate around a vertical axe. In doing so it is assisted by four small wheels (orange-coloured in the picture), rolling on the bottom ring of the brown element. The three consoles on the bottom of the rotating part support servomotors which make the sphere go up and down to/from the celing from/to the user*

3 *Some of the components of the robo-lamp. On the bottom the microcontroller PICAXE is recognisable: it is the real "brain" of the robot. This element receives data from light sensors and drives all the servomotors to achieve the required performances*

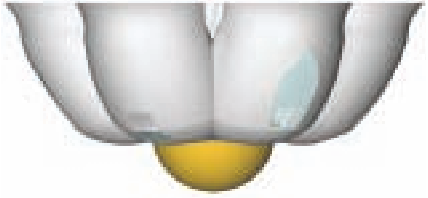
FEATURES AND USE

A typical object necessary for our lives is revised from an innovative and imaginative perspective: a lamp, a robotic lamp.
This lamp lives in the house, in the middle of the living-room ceiling. It interprets and determines the surrounding environment in an autonomous and intelligent way. This lamp is able to understand what happens in the room: if someone enters the room or if the room is empty, if it is becoming dark or there is too much light. It learns and knows the habits of the people living in the house and interacts with them singing and lighting when required. The robo-lamp can also give birth to another portable and fun spherical lamp which can be placed wherever the user desires to light up the room around it.
This robo-lamp can be used in different kinds of room and with different kinds of furniture; it will fascinate any perspective buyer, but its target user is a sophisticated consumer, really interested in high and refined technology and passionately fond of curious technical and intelligent objects. This robo-lamp would become a 'status symbol' because of its particular oddity and its strong impact.
The robo-lamp has, under certain aspects, the appearance of a flower, with six petals including leds, sensors and speakers. It is able to move to light up the place where people stand or where there's no or scarce light. In the middle of the flower there is the spherical lamp, which, when required, can descend from the ceiling to welcome with light and music everyone enters the room and can be also taken off to be manipulated and placed somewhere else.
We decided to develop the idea of this lamp, because we thought that a smart element at the core of the house was needed: the oven is intelligent, the fridge is intelligent, the shower is intelligent and now also the lamp is. Moreover, this idea match the interests of Microsystem and Interactive Toys, the two companies joined in the Amorosa

4 *The robo-lamp has several light sources, both in the part fixed on the ceiling and in the spherical lamp. Here some of the LEDs used are shown: their colours can vary, depending on user's requirements. In general, white and amber lights dominate, but in spherical lamp other colours can be applied as well*

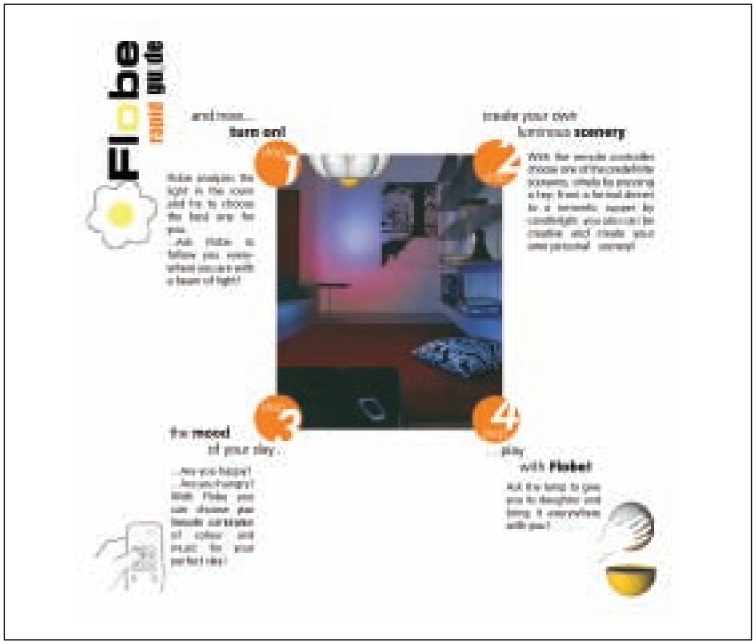


5 *The lamp cover, whose shape aims to remind of a flower, with its six petals. The lamp, here shown as a daisy, has two different light sources for each petal. The first is located on the bottom and has a round shape, while the second one ha a drop-like shape. This light source can be freely oriented to illuminate the room better and concentrate the light where necessary*



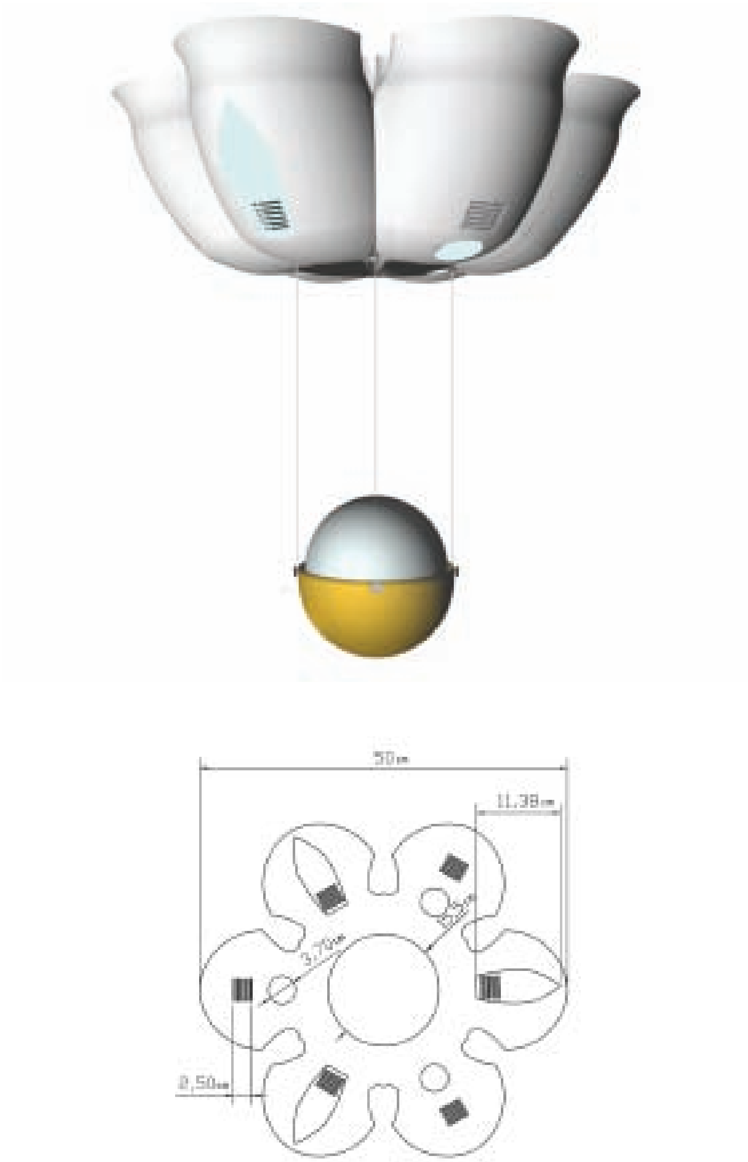
6 *This side view of the cover highlights the position of the two different light sources and shows also the spherical central component of the lamp. Its function is including the mobile part, which represents the ludic and more versatile aspect of the robot. Even though the robot is not too small, its impact in the interior is quite soft, because it seems a flower rising from the ceiling*

project, in the development of new intelligent ad useful products which can also be appreciated for their usability and sophisticated design.
The lamp, being also a robot, has different sensors for the detection of ambient light (photo diodes) and infrared sensors for the detection of human presence in the room; these sensor are cheaper compared with video systems though, with an adequate image processing, the video system can better understand what happens in the room.
Light is assured by small moving leds, with different colours and with different angles of lighting; leds are very small and powerful, if compared with incandescent light bulb, and they also show low power consumption.
The robo-lamp can rotate on its own axis and can push one of its petals far from the centre of the room, being able to light with narrow beams the place where, for example, a person is reading. Also the spherical lamp can move and, in this way, it expresses emotions with its movements of light.
The robo-lamp can also be controlled by an infrared remote control that can be used as a joystick to move the beams of the lamp, and also as a computer for the programming of some behaviours of the lamp: actually it is possible to configure different settings of illumination for different contexts (for instance while watching a film, reading, dining with the fiancée, lunching with friends…) and to save them in the memory of the intelligent part of the lamp. The lamp can also remember particular dates, such as birthdays, playing music for the



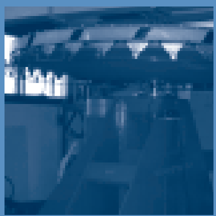
7 *Flobe rapid guide*

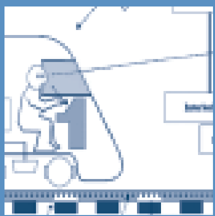
8 *Here the two parts of the robo-lamp are shown. The spherical lamp is able to get up and down to/from the part fixed to the ceiling. The user can take and bring it wherever he desires in the room. Because of the peculiar material it is made of, the spherical lamp can be manipulated to be placed on any surface (desk, floor, bedside table, the back of an armchair, etc).*

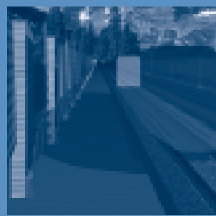


person who is to be celebrated. Music can be loaded in the lamp in mp3 format.
The intelligence of the robo-lamp is achieved through powerful microcontrollers able to process all the different data coming from the remote control, the sensors and the inner calendar, in order to answer to these inputs with suitable different illuminations, movements and music, creating different atmospheres.
The robo-lamp needs to be programmed the first time it is used with a personal computer that, thanks to a particular software, is able to set up the best settings for the particular room where the lamp is installed. The software can also be used for further setting changes that are not very simple to carry out with the remote control, for example when the user decides to move the furniture.

PROJECT 2







I-TRAILS

ITALIAN HIGH SPEED RAILWAYS

project 2

I-TRAILS - Italian High Speed Railways

Impact assessment of new technologies on the High Speed/High Capacity network, currently under construction and partially operating

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Mechanics, Politecnico di Milano

ACADEMIC TUTORS

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Transport and Civil Infrastructures, Politecnico di Torino

Renato Manigrasso
Mechanics, Politecnico di Milano

EXTERNAL INSTITUTIONS

Gruppo FS - Ferrovie dello Stato
RFI - Rete Ferroviaria Italiana
Trenitalia

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Umberto Foschi
Luigi Debertol
Chiara Iommazzo
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Marta Stellin

EXTERNAL TUTORS [TEAM B]

Giovanni Costa [principal]
Lucia Coa

EXTERNAL TUTORS [TEAM C]

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Aerospace Engineering

Christian Burrows
Computer Engineering

Gianmarco Gaviglio
Telecommunication Engineering

Tommaso Mandorino
Telecommunications

TEAM B

Daniele Tosi [Team controller]
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Francesco Polidoro
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Alessandro Zurlo
Civil Engineering

TEAM C

Francesco Fumarola [Team controller]
Mechanical Engineering

Emmanuela Confalonieri
Mechanical Engineering

Daniel Tiago Guzzafame
Aerospace Engineering

Matteo Lombardi
Mathematical Engineering

Francesco Secondino
Electrical Engineering

PROJECT DESCRIPTION

THE CHALLENGE

The general aim of this project is challenging our teams with the application of some of the main concepts treated by ASP like, for instance, the management of complex systems, the theory of decision, the technical design of a High Speed (HS) line and network. The project is carried out under the tutorship of engineers and professionals working for the "FS" Group (the main Italian Railway company). A railway network – especially a HS one – is by nature a complex and multidisciplinary system where the evaluation and optimisation of safety, quality, performance and cost efficiency involves a variety of disciplines, such as: mechanical, electric and aerospace engineering for the train design; telecommunications and computer engineering for the signalling systems; civil engineering for the infrastructure design. Moreover, economic and management skills are required to achieve significant results.

THE TEAMS

Three teams formed by ASP students – each one focusing on a specific theme – dealt with the topics mentioned above.

Team A was assigned with the theme 'Safety and quality of the signalling systems'. Specific task of the team was to carry out a cost-benefit analysis of several technological options (ERTMS/ETCS Level 1 with or without infill, Level 2 and Level 3) for the signalling system of the Direttissima HS line connecting Rome to Florence.

Team B dealt with the economic, environmental and public impact of the Mi-To HS line, including also the technical features (sleepers) and a comparison with an alternative option consisting in building a railway line mainly dedicated to freight transport instead of a HS line, as sometimes part of the public suggests.

Team C focused on the rolling stock, with specific reference to general vehicle architecture, the electric traction equipment, the mechanical performances and economical issues, such as the cost per passenger and per km travelled. Alternative HS train architectures, like those currently adopted in Italy, in France, in Germany and Spain were compared too.

THE RESULTS

The students achieved a thorough understanding of the HS as a whole: its strong and weak points, the critical role played by some disciplines and know-how and the potential of several enabling technologies. Furthermore all the evaluations, comparisons and cost benefit analysis performed by the teams offered a new and original point of view over these subjects, and thus they were highly appreciated by the FS group that ordered the project.

The Team A demonstrated on solid grounds that the ETCS Level 1 with double infill solution is able to provide good performances and, most important, to satisfy interoperability requirements with reduced costs. The Team B provided a detailed study of structure, acoustic and electromagnetic issues and proposed interesting solutions. The Team C completed a thorough overview and analysis of the existing and future HS trains and put forward strong arguments supporting the solutions for the train configurations that best suite the Italian HS Railways.

project 2A

Interoperable signalling system on the Direttissima Roma-Firenze

ABSTRACT

When dealing with railways, the most important aspect to be considered is safety. Signalling systems have been created exactly for this purpose: they communicate the drivers that the way is clear and alert them if obstacles are approaching so that they have all the time and space needed to brake. In particular, trains running at 250 km/h may require more than 5 km to stop, therefore drivers cannot rely merely on their sight to detect obstacles. The Direttissima is a high speed railway connecting Rome to Florence; it uses a domestic proprietary signalling system, so foreign trains are not equipped for travelling on it. In order to allow transport of people and goods through international corridors, a standardized European signalling system – known as ERTMS/ETCS – has been developed, but several levels of implementation exist. The main task of the team is to compare these levels of implementation and understand which one best enhance the Direttissima. Two levels of implementation are taken into account: level 2 (L2) and level 1 (L1) with radio infill. The choice is based on the following analysis: performance, norms, telecommunications, technology and economics. A great importance is given to the performance analysis, carried out with qualitative, theoretical and simulative approaches, that employs also a numerical train simulator developed by the team. The ultimate solution is L1 with radio infill, because its only negative aspect concerns to the standards. Finally, the report indicates how the system can be concretely applied to the Direttissima.

TASKS & SKILLS

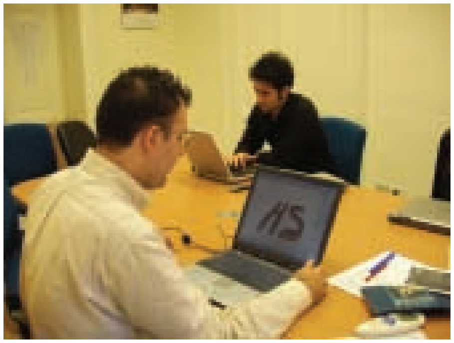
Andrea Maria Antigone Barbera programmed the capacity simulator and was the group budget manager.

Christian Burrows was responsible for Signalling and Technology along with Gianmarco Gaviglio. He took care of the theoretical aspects of line capacity and studied in depth the current Rome-Florence railway line.

Gianmarco Gaviglio was responsible, along Christian Burrows, for Signalling and Technology. Moreover, he studied toroughfully ERTMS/ETCS and took charge of the economical analysis.

Tommaso Mandorino, experienced in telecommunications engineering, contributed to the compiling aspects related to the technical norms of the project.

1 *Front view of an ETR 500, the most famous interoperable train running on Italian High Speed Railways*



2 *Andrea Barbera and Tommaso Mandorino at work in the central RFI offices in Rome, at the Ministero dei Trasporti.*

UNDERSTANDING THE PROBLEM

When dealing with railways, the most important aspect to be considered is safety. Signalling systems have been created exactly for this purpose: they communicate the drivers that the way is clear and alert them if obstacles are approaching so that they have all the time and space needed to brake. In particular, trains running at 250 km/h may require more than 5 km to stop, therefore drivers cannot rely merely on their sight to detect obstacles. The Direttissima is a high speed railway connecting Rome to Florence, that was completed about 20 years ago. It allows trains to run at speeds up to 250 Km/h, but it uses a domestic proprietary signalling system known as BAcc (with the addition of SCMT), so foreign trains, not equipped with the required onboard hardware, cannot travel on the line.

Since 1992 Maastricht Treaty, the European Union has been promoting interoperability to allow transport of people and goods through international corridors; for this purpose a standardized European signalling system has been developed. This system is known as ERTMS/ETCS (European Rail Traffic Management System / European Train Control System), but several technological level of implementation exist (Levels 1 to 3, abbreviated in L1 to L3). Our project work consists mainly in comparing these levels of implementation and understand which one would best suite the Direttissima. Note that the new Direttissima should be able to support trains equipped with either BACC/SCMT and/or ERTMS/ETCS, i.e. the new interoperable signalling system should coexist with the old one.

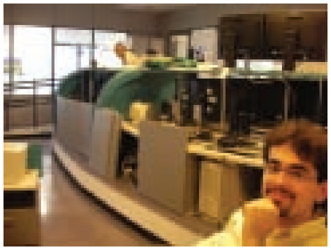
EXPLORING THE OPPORTUNITIES

ERTMS/ETCS employs both onboard interfaces and external trackside equipment, which communicate in different ways.

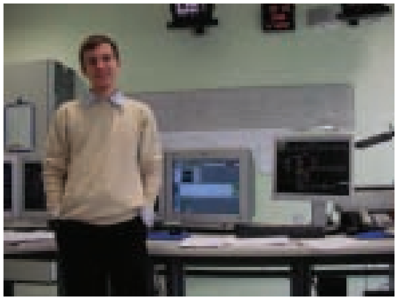
For L1 this communication occurs through antennas, known as *balises*, positioned along the track between the rails. As balises are positioned at a certain distance from each other (for example 1350 m) the information stream towards the train is not continuous. According to Italian standards, it is not safe to allow a train driver to rely only on the information displayed onboard, so he/she has to look also at the trackside signals (lights and signs), that must be present. Due to this fact and to normative constraints, trains equipped with L1 cannot safely reach the highest speeds the Direttissima was designed for, being limited to 150 km/h. As a consequence, plain L1 was immediately discarded from the available options.

Balises information may be however integrated with continuous information, thereby making lineside signals optional and allowing trains to run at higher speed. This integration is called 'infill' and can be sent through radio waves (Euroradio), a codified electric current through the track (Euroloop), or additional infill balises positioned between the main balises (in this case infill is only semi-continuous).

As to the choice of the infill to adopt in case of L1, we can say that it is a simple task, because Euroloop has a good chance of interfering with the existing signalling system and a radio coverage on the Di-



3 *Gianmarco Gaviglio in the central control room in Roma Termini station, where the entire High Speed Rome-Naples Railway is supervised*



4 *Christian Burrows in front of the monitors of an interlocking*

5 *The cockpit of an ETR 500 during our educational run of the Turin-Novara High Speed Railway*

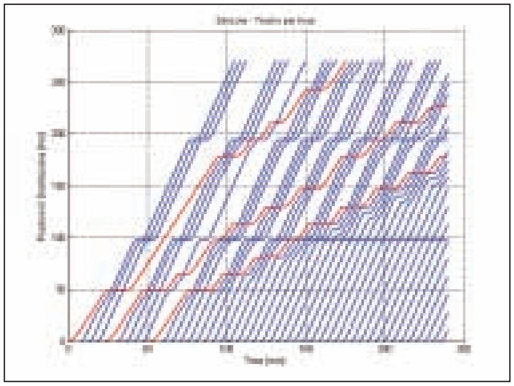
rettissima is already present, while the semi-continuous infill given by additional balises is inadequate to allow high speeds according to Italian regulations. The most reasonable option is then the employment of Euroradio Infill.

L2 also uses balises along the track, but these have a minor role, since most data are transferred through GSM-R, a centralized telecommunication system, based on the GSM wireless communication technology. This allows a continuous trains supervision.

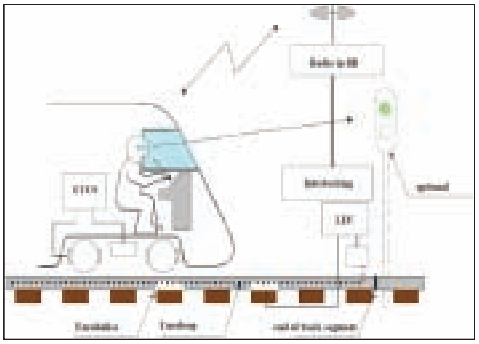
Although ERTMS L3 significantly differs from previous levels and greatly increases the line capacity through the so called "mobile block", it is not a viable option at the moment, because of the huge costs that would be involved to warrant not only adequate safety but also technological and normative changes. It is important to understand that for RFI safety always comes first, so the least changed the better, especially to assure that the strictest safety levels are observed.

Finally, between L1 with radio infill and L2 we chose ERTMS/ETCS L1 with radio infill, after having carried out an accurate analysis of some important aspects reported below.

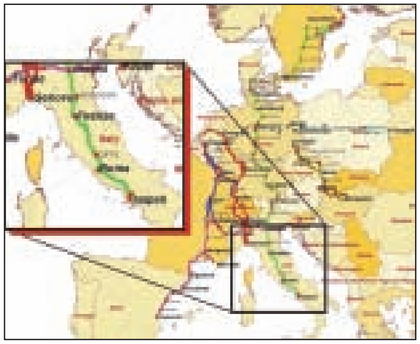
- **Performance** We estimated it by qualitative, theoretical and simulative analysis. As far as theoretical analysis is concerned, it is interesting to note that our results are quite different from those reported previuosly in literature, as we do not agree with many simplistic assumptions made in the past. Quantitative performance evaluation was undertaken by a numerical simulator (SimLine) written by the team to model practical situations over the Direttissima as a whole, including both cargo and passenger trains. These three evaluation methods gave adequately coherent results: L1 with radio-infill guarantees a performance very similar to that of L2, at least in a standard situation. L1 and L2 differ substantially in case of degradation: if the radio resource (Euroradio) is unavailable, L2 cannot work at all, dramatically impacting on traffic circulation since trains must run at speeds of 30 km/h or less, if they cannot resort to other alternative traditional signalling systems. On the other hand, L1 with infill can work even if infill is temporarily unavailable, although speed is limited to 150 km/h.
- **Standards**: this is the only negative aspect. Norms have been already written for L2 but not for L1 yet, so it is necessary to write them starting from scratch. However, it is possible to exploit the experience made in writing L2 standards to shorten the whole work. Note that for level 2 a significant problem is the possible discordance of the existing trackside signalling from the information displayed on the train. We indicated several solutions to this problem even though not in details, because this was not the level we decided to examine.
- **Telecommunications and technology**: balises currently installed on



6 *An output graph of our simulator SimLine, with time traces of freight (in red) and passenger trains (in blue)*



7 *Scheme of the European Rail Traffic Managment System / European Train Control System Level 1 with radio infill, our selected interoperable signalling system for the Direttissima Roma-Firenze*



8 *The Direttissima Rome-Florence Railway as a part of the European interoperable network*

the Direttissima for the SCMT signalling system can be reused for both L1 and L2. The current radio coverage is sufficient for L1 with infill but not for L2. On the other hand, L2 has already been tested and applied on other Italian High Speed lines, such as the “Roma-Napoli” and the “Torino-Novara”, while it would be the first application of L1.

- **Economics**: installation and maintenance costs estimate. It must be noted that this project involves large amounts of money, close to national financial acts. Global costs, including installation process and 20-years maintenance, are much lower for L1 with radio infill: 90 M€ versus 138 M€ for L2.

A further comparison concerns slowdowns. While with L1, even with infill, it is necessary to send a maintenance team onto the track to position signals or balises that alert incoming trains of the presence of slowdowns, for L2 all slowdowns can be remotely set up from the central station as soon as they are needed, and can be removed as quickly. We thought of an alternative solution that employs additional permanent balises, connected to a dedicated central apparatus, to offer a performance similar to L2, but it is too complex and costly to be a viable slowdowns management system.

GENERATING A SOLUTION

The last part of our project focused on the migration strategy required to adopt the new signalling system, exposing in details, from a technical point of view, what can be kept and what needs to be changed.

- **To be changed/new**: radio infill units.
- **Not to be modified**: telecommunication system, central apparatuses, thermal survey equipment and trackside signalling.
- **Might be varied**: balises and power supply.

We then proposed how to write dispositions and technical specifications for L1 with radio infill, based on the existing norms for L2. The number of norms is titanic but we focused only on those that needed to be modified. Where possible, we suggested modular parts in order to exploit them also for other uses.
Finally, we used our SimLine software to find the best strategy for cargo transport, and closed the report with our conclusions.

project 2B

The impact

TASKS & SKILLS

Daniele Andreola dealt with the socio-economic impact of the AV/AC and with the noise pollution perception and its countermeasures.

Francesco Polidoro designed, simulated and characterized our high-quality noise barriers and assessed a cost-benefit analysis for environmental impact.

Daniele Tosi investigated the electromagnetic interference of AV/AC system and subsystems, and studied the social benefits and the catchment area of the infrastructure.

Alessandro Zurlo dealt with the structural problems of the railway line and analyzed the environmental noise impact.

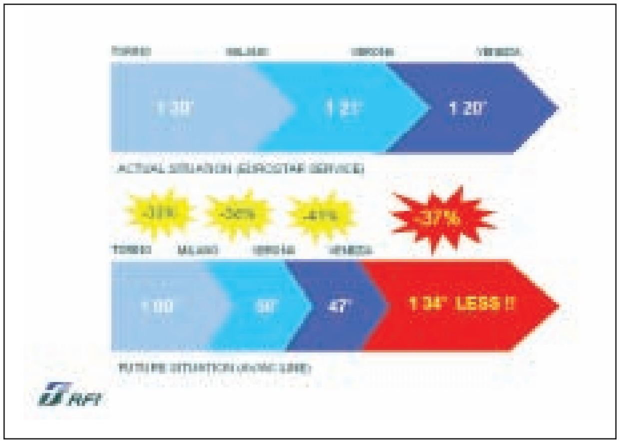
ABSTRACT

In the recent years, high Speed Railway Lines has represented one of the most important technological and socio-economical challenge. Considering the European background, the realization of the Lisbon-Kiev Corridor V - a fast transportation track interconnected with all the principal poles through an efficient mobility network - requires the integration of the Italian railway system with a new High-Speed/High-Capacity line across the Turin-Milan-Venice route, the AV/AC – Alta Velocità/Alta Capacità. The aim of this project is to perform a feasibility analysis of the Turin-Milan AV/AC railway line, from the social, economical and environmental impact point of view.

Firstly, considering the reduction of travel durations along the route (-33%) and the increased capacity of the transportation system, we outlined a new scenario including the transportation improvements due to the High Speed railway introduction. Hence, we were able to determine the social and economical effects, both in short and long time, on the Turin-Milan bipole and the surrounding territories: the AV/AC allows a large scale rearrangement of the mobility network, paves the way for a more efficient exploitation of people's services and raise the competitiveness of Italian industries by speeding up goods transportations.

Then, we focused on the environmental impact of the AV/AC, investigating the nature of acoustic noise and the sources of vibration, and designing a set of specific countermeasures to minimize its impact. Our goal was to jointly optimize several aspects (noise barriers, anti-vibration sleepers, noise reduction on the rolling stock) by analyzing the cost related to every component and their impact on the overall noise reduction. In particular, this analysis relies on the design of a new kind of noise barrier, allowing an excellent noise reduction with a low aesthetic impact. We were then able to define an intervention strategy to be applied for minimizing the environmental impact of the High Speed railway line.

1 *Corridor V from Lisbon to Kiev*



SOURCE: RFI

2 *Reduction in time thanks to the AV/AC railway line*

THE AV/AC SOCIO-ECONOMICAL IMPACT

The considerable reduction in travelling time is the most evident aspect related to the AV/AC railway line infrastructure. The actual Eurostar service requires about 4 h 10' for going from Turin to Venice – 1 h 30' from Turin to Milan – and the introduction of the High Speed service would save approximately 1 h 30', i.e. the 37% of the whole travelling time – from Turin to Milan the reduction is about 30' (–33%). Yet, the other peculiar feature is the High Capacity of the infrastructure both for passenger and goods transportation. The introduction of the 25 kV line, as a matter of fact, allows the creation of a more powerful system that makes possible the use of a greater number of trains with a larger towed weight that can go all over Europe thanks to the interoperability of the new system of transportation.
As a result, the decrease of travel duration and the increase of line capacity, that reduces the average waiting time, allow to achieve a very fast transportation vector between the Milan-Turin bipole. The availability of an efficient mean of transport yields also an enlargement of the railway catchment area. Furthermore, as the train-traveller number will increase, the transportation by road and by air will gain efficiency, leading to a global equilibrium of the transportation network. Since Turin and Milan represent two of the most advanced poles, the enhancement of mobility network constitutes a necessary support for further internal development. Moreover, considering long spans, High Speed lines allow to dramatically cut travel duration down, offering a valuable alternative to air transportation. The High-Speed line supports also a better accessibility to services, enhancing the attractiveness of the territory and making it a tourism resource. Our analysis documents how the implementation of the AV/AC line will contribute to social improvements in the involved region, raising the competitiveness of Italian industries as well.

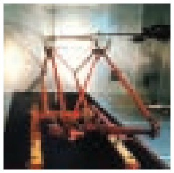
ACOUSTIC IMPACT AND COUNTERMEASURES

Acoustic noise is probably the most critical factor in the analysis of the environmental impact of High Speed railway lines. While European normative provides emission limits regulating the acoustic impact, the goal is to define an intervention strategy capable of attenuating the overall noise so that it undergoes the limitations.
Dealing with noise emission requires particular attention to the physical phenomena involved and how countermeasures work. Noise reduction could be applied on rolling stock, by reducing the noise generated by wheels and the aerodynamic noise of the pantograph, on structural elements of the line, by attenuating vibrations of the sleepers, and on fixed installations outside the line - the noise barriers. Each of these interventions implies variable costs, depending on the number of trains, the number of residents within the noise crit-

3 *The AV/AC line benefits the long range travels, goods transportation and commuters*

4 *Device used for testing ATR95 pantograph*

5 *The ATR95 pantograph*



6 *Shielded room for testing electromagnetic interference related to the pantograph*

7 *50 Hz filter used for reducing induced EMI in 3 KVcc railway lines*

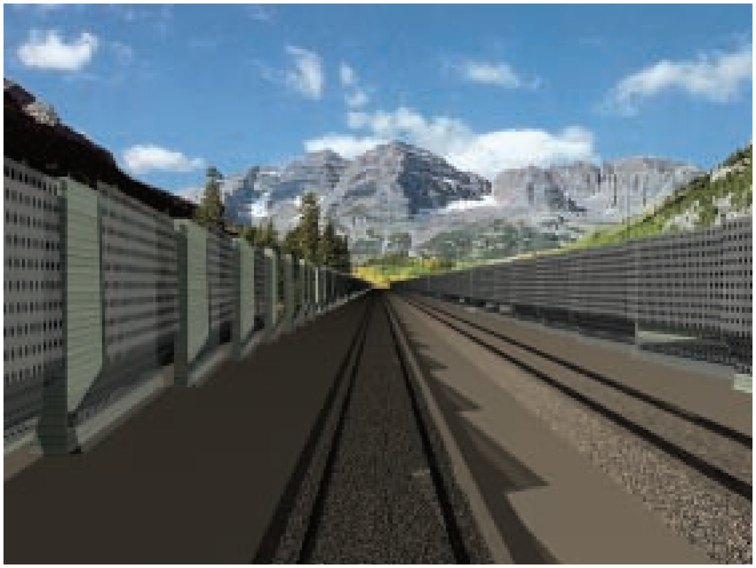
ical range (±250m across the railway line) and the extension of the critical zones along the line. The combined employment of these interventions requires a process of optimization that reduces the overall costs and assures the observance of the limitations; our proposal is based on the design of innovative noise barriers.

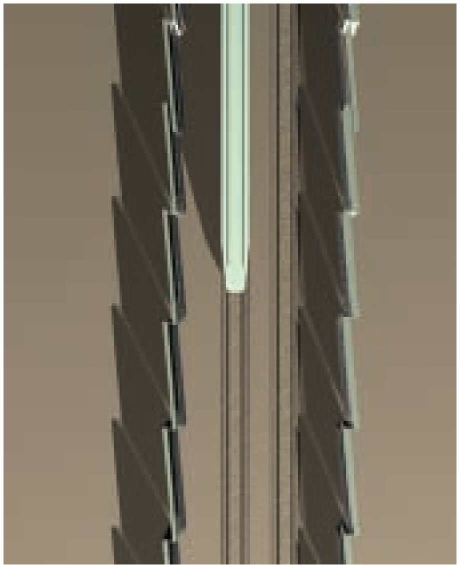
DESIGN OF INNOVATIVE NOISE BARRIERS

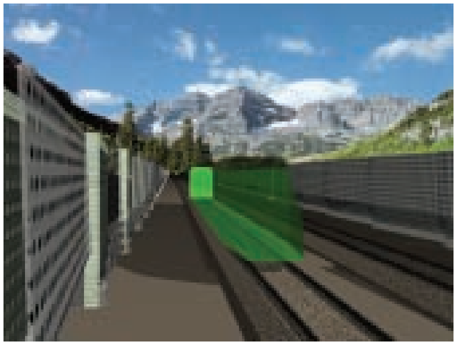
Our intervention strategy for reducing the invasiveness of the High-Speed line on the surrounding territory relies on the project of innovative top-quality noise barriers, that combine a strong noise attenuation with a low aesthetic impact for travellers. This project follows the guidelines based on the most recent scientific articles on this problem and on the experiences of our partner RFI – Rete Ferroviaria Italiana; the shape of the barriers has to be designed following a deep analysis on the nature, according to the intensity and the position of the different noise sources and considering the structural strength problem.

The project, developed in compliace with these guidelines, led to the preliminary design of a holed panel that can be simply added to the barriers already built. The convex shape of these additional barriers has been chosen to maximize the reduction of the noise coming from the wheels and the lower part of the train, while the holes reduce aerodynamic noise at low frequencies. The room between the panel and the barriers helps to reduce the noise level acting as the double glasses of the windows of our houses.

The panels are less afflicted by structural problems both because they







8 *overwiews and details of the preliminary project concerning the acoustic barriers on the AC/AV railway line*

can rotate on their longitudinal axis, which link them to the old barriers, and the pressure load is decreased by the holed surface. The movement of the panels is smoothed and limited by a dumper on the longitudinal axis and by the pressure losses through the holes.

COMPARING DIFFERENT SOLUTIONS

Our cost-benefit analysis clearly shows that the employment of the top-quality noise barriers that we have designed, exhibiting excellent performances in terms of noise reduction and minimize aesthetic impact, is the best way to achieve the project goal. Even though these components have higher costs compared to the standard barriers, they are particularly suitable for our proposal, because these barriers yield such a strong noise-reduction that they don't need further interventions on the other elements of the railway infrastructure, allowing to reduce the overall cost. Fostering the development and application of fixed components, that not only usually require less maintenance and adaptation costs but also can be flexibly employed, avoids difficult and time-consuming interventions on rolling stock and tracks to be performed. Moreover, this intervention strategy is based on the development of a high technological component, and follows the path to innovation and high-quality that the realization of AV/AC should undertake.

project 2C

Innovative Architectures of High Speed Trains

_I-TRAILS_Italian High Speed Railways

ABSTRACT

The aim of the project was assessing the problem relevant to the selection of a high speed (HS) train configuration for the future HS railways (HSRs) in Italy. The performed analyses, dealing with the most important and influencing aspects, can be considered as an overview of the problem as a whole. For some cases, the study is more detailed, in order to give an accurate idea of the way it could be developed. Because of the particular characteristics of the Italian HSR and the new European requirements, a general introduction over these subjects (basically the TSI) was mandatory. Six HS trains configurations were selected and a general comparison on their basic characteristics was done, e.g. TSI requirements fulfilment, weights and composition, traction characteristics, number of seats, etc. The configurations were then compared on the basis of their traction performances (travel duration, speed, acceleration, etc) on the Milano-Napoli HS line. The Simtre program developed by Trenitalia was used for this purpose. The trains were modelled according to the constructors' data. The comparison also provides some considerations on the adhesion limits and on the running in degraded conditions – thus accounting for a traction failure. An algorithm for the energy consumption optimization was also proposed. A specific analysis of the electric tension and a thermal study of the engine were performed for the current Italian HS train (the ETR 500) in a critical working point along the HS railway. An on-purpose developed program was used. The train configurations' benchmark concluded with a Life Cycle Cost (LCC) of the different options. On the basis of all the examined factors, some conclusions were drawn and the most fitting train configuration for the Italian HSR was identified. Finally, the HSR solution was compared with other transportation systems (both on-ground and on-air). The focus was on the advantages and disadvantages of the options, basically the travel duration, the costs per passenger and the environmental issues. Social consequences and transformations are briefly discussed too.

TASKS & SKILLS

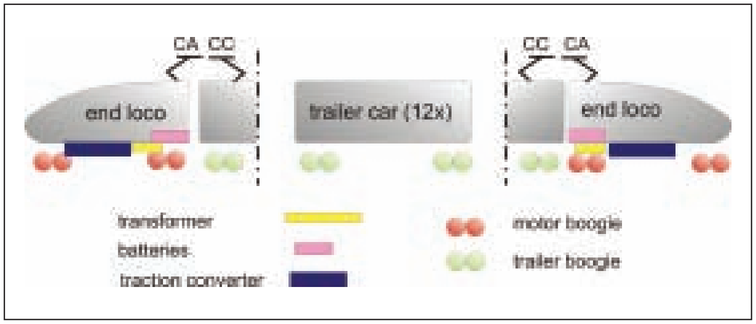
Emmanuela Confalonieri was responsible for the individuation of the critical working point for the traction system of the ETR 500 configuration. She took care of Technical Specifications for the Interoperability (TSI) requirements analysis.

Francesco Fumarola collected HS trains data, selected the configuration to be analyzed and carried out the Life cycle cost analysis.

Daniel Tiago Guzzafame developed the train models and Traction performance analysis as well as the comparison of the HS railway with other transportation systems.

Matteo Lombardi was responsible for the energy consumption optimization algorithm and the development of the dedicated code; he assessed the influences of energy consumption on the life cycle cost as well.

Francesco Secondino performed a detailed analysis of the electric voltage and current of the electric drive; he carried also out a thermal study of the engine as well as the development of the dedicated codes.



1 *The ETR 500 simplified configuration used for the analyses*

HOW WE PERCEIVE THE PROBLEM

The characteristics of interoperability for the new generation HS trains are defined by the TSI. The first approach to the problem was the understanding of the requirements that affect the train's configuration. In order to come to a choice among the different configurations, we identified the following parameters:

- Interoperability, reliability and safety (TSI and UIC/EN standards)
- Technical performances
- Comfort and travel duration, seating capacity
- Life cycle cost
- Train image (speed, brilliance, comfort, beauty, etc.) and flexibility according to client's exigencies.

Today the Italian railway network is mainly based on 3 kV DC power supply. Because of the speed limitations posed by this system, the new dedicated HS lines are built using the 25 kVAC power supply system. Due to lines interaction, the train must be able to run also on the 3 kV DC system. A technical evaluation of the proposed configurations was based on the traction performances analysis and a data collection concerning speed, power, travel duration, resistance, adhesion limits, etc. The energy consumption optimisation during the execution of a certain task was also of interest: the train speed can be lowered if the train is running early. The question was how to save the maximum amount of energy, and which train configuration performed best. We decided to undertake a specific analysis of thermal and electric performances of the current Italian HS train – the ETR 500 – using a dedicated program. The benchmark of the different configurations was completed with a life cycle cost (LCC) study. Finally, an analysis of other means of transportation was included and some considerations about the impact of a new HS railway (HSR), considering environmental, economic and social issues, were added as well.

OUR PROSPECT

HS trains can be distinguished based on their general design:

- concentrated traction, with one or two end power locos, or distributed traction, with the technical equipments under the car bodies
- conventional train, with two bogies per car, or articulated train, with bogies shared between every two cars
- tilting train (with active or natural tilting systems) and variable gauge trains

The distributed traction is characterized by:

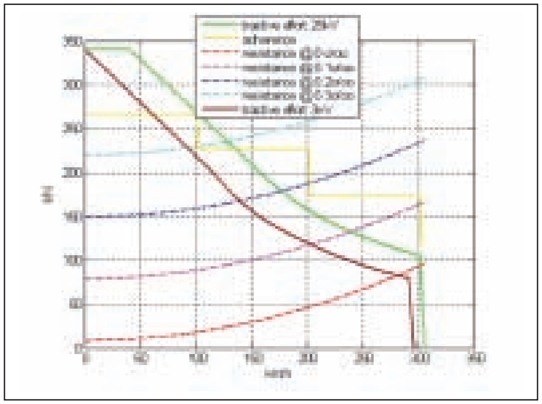
- higher passenger capacity per fixed length
- higher number of driving axles and hence higher acceleration and better adhesion
- possibility of installing a higher traction power and of maintaining the same commercial speed independently from the length of the train

The concentrated traction is characterized by:

- increase of trains availability, separating locomotives maintenance from cars' one
- areas for energy conversion and utilization separated from those assigned to passengers
- better performance in cross wind conditions, due to the higher weight of the leading vehicle.

Six HS trains were considered: five with distributed traction (two conventional configuration (DTCC), one articulated configuration (DTAC), two HS conventional configuration with max speed at 250km/h (DTCC_250), and the ETR 500, with concentrated trac-

2 *The ETR 500 in the new "Alta Velocità" design*

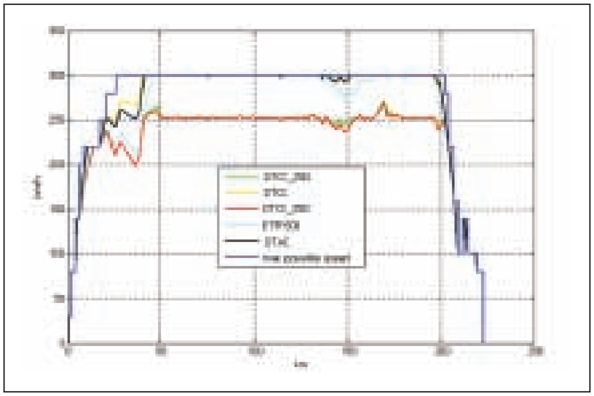


3 *ETR 500 traction characteristics and adhesion curves examples*

tion and conventional configuration (CTCC). They were compared on the same task profile (Milano-Napoli) in terms of traction performances using Simtre, a dedicated code implemented in C++ /Matlab by Trenitalia. Its usage implied some previous analyses:

- task profile features (Trenitalia source)
- settings for the simulation
- trainmodelling:
  - composition
  - weight estimate of composition, number of passengers and rotating mass
  - traction characteristics and breaking effort of each motor car/loco
  - different adhesion test-sets, taking into account different meteorological and wheel conditions
  - resistance to vehicle motion, both of mechanical and aerodynamic nature.

The trains were compared based on traction / resistance curves, travel duration, speed and required power. A proper algorithm was developed for the energy consumption optimisation, with the aim of decreasing the traction when the maximum loss of energy occurs. Then the study case of the ETR 500 was considered, analyzing the motors traction drive performances over a stage. The simulation program, realized in Matlab Simulink, takes as inputs the train speed and power given to motors axis. The program evaluates the steady state point of the converter and the motor, the phase voltages and the phase currents instantaneous values, the latter corresponding to the traction inverter output currents. Outputs are also the stator chopper and the stator steel losses: another thermal model of the motor stator gives the windings and the steel temperatures over a stage. The outputs of the thermal model define the admissibility and the safety criteria of the traction motor. The LCC study considered the overall costs related to the product during its life time, including manufacturing (train price), operation (energy, staff, cleaning), maintenance and disposal costs. It was possible to identify the driving costs influencing the different train architectures. For what concerns other transportation systems, the advantages and disadvantages of airplane and highway with respect to HSRs were considered, mainly focusing on travel duration, costs per passenger/km and environmental issues.



4 *Speed comparison on the route Rm-Na (25 kV)*

OUR SOLUTIONS

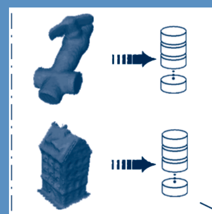
The DTCC resulted to be the most suitable configuration in terms of general characteristics (weight, seats,TSI requirements, comfort, reliability) for the Italian HS railways. As to the traction performances analysis, the achieved results are the following:

- Travel duration and speed performances:
  - the DTCC_250 configurations show almost no difference relative to the other HS trains on a 25 kV line with max imposed speed of 250 km/h (Fi-Rm)
  - ETR 500: on the 3 kV line performances comparable to the other HS configurations. Worse performances on the 25 kV line
  - best performing is the DTCC, small differences with DTAC.
- Power consumption:
  - DTCC_250 configurations apart, the power of which is limited to 5.5 MW, DTCC trains are the least consuming, closely followed by DTAC.
- Adhesion limits on the theoretically achievable traction: the train configurations can react differently in terms of maximum performed acceleration on a certain slope. Our tests resulted in the expected successful performances of a distributed traction configuration.
- Breakdowns: because of the different compositions, the configurations show different sensitivity to a defined fault. The entire task profile can be completed by any of the trains with only 50% of their power.
- TSI / terms of contract requirements:
- Exceptional conditions: with 75% of their power DTCCs and DTACs are able to start on a slope of 3.2% and reach a speed of at least 30 km/h in the first 800m.
- TSI: all trains fulfil the TSI requirement of minimum speed and acceleration with a traction module out of order on the maximum railway slope (2.1%).

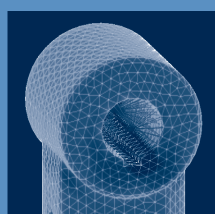
The energy consumption optimization confirmed that the best way to operate is decreasing the traction in presence of the maximum passive resistance, reducing the maximum achieved speed. The thermal and electric analyses for the ETR 500 were performed in a critical point of the Rm-Na, at 280 km/h and with a power of 8.8MW. The nominal values were observed. The LCC study demonstrated that a DTCC is less costly over its life time.
In the light of all the requirements and the needs that were enucleated, and taking into account all the approximations done in the different analyses , our team came to a double conclusion:

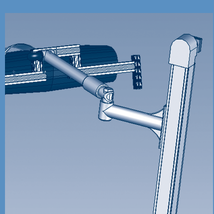
1 The most suitable option for the ItalianHSRs is a train with distributed traction and conventional configuration
2 The team deems one of the DTCC_250 options appropriate for the integration of the HS trains Italian fleet.
The comparison with other transportation systems showed:

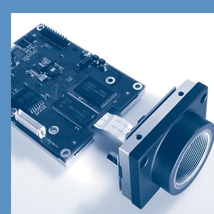
- Environment: HS trains are more environmental friendly than cars and planes.
- Costs: the internal monetary costs for infrastructure, carrier, and vehicle operating costs are the highest for HSR, but social costs – congestion, air pollution, noise, accidents are the lowest.
- Comfort and better time usage: HS trains provide excellent travel duration for short/medium distances.

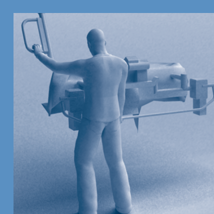


PROJECT 3









IRoPA

INTELLIGENT ROBOTIC PARTNER

project **3**

IRoPA
Intelligent Robotic Partner

Development of an innovative robotic architecture to create intelligent partners on production lines

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EXTERNAL INSTITUTIONS

Centro Ricerche FIAT

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PROJECT DESCRIPTION

The IRoPa project, ordered by the Centro Ricerche Fiat, is dictated by the automotive sector need not only to enhance the flexibility of the production lines but also to allow high product diversification and quick line conversions. The purpose of this project is the implementation of a feasibility analysis – with its relevant preliminary plan – of an "intelligent manipulator" which can comply with these flexibility requirements: in particular, this "intelligent manipulator" has to be able to carry out both the implementation of bodywork (through spot-welding) and the components installation (i.e. dashboard) into the cockpit. The execution of so different tasks requires the design to be significantly modified: in fact, a working cell planned with this method should also allow, with a simple reprogramming, the execution of operations it wasn't initially conceived for.
Firstly, we had to develop an innovative structure, with six degrees of freedom, able to guarantee handling and welding operations to be smoothly completed. Moreover, the robotic partner would have to include also an onboard intelligence system, able to manage moving and positioning stages of the components, employing a vision or sensorial system and optimizing both the operations to be carried out and the path to be followed. Other requirements involve the use of wireless technology, to allow the reduction of both setup costs and reconfiguration time, and an ergonomic analysis of both the current and the future working station, to better understand how the operators' health and the safety conditions could be warranted and observed under any circumstance.

The students' group split into two teams, so as to allocate the individual skills as evenly as possible. This was done mainly to allow each team to be multidisciplinary and able to work independently on almost every aspect of the project. At the same time, however, the teams maintained an overall cooperative approach, to focus on the best solutions and sharing the most complex parts of the work: in particular, team A dealt with the innovative mechanical project of the robot – thanks to a detailed analysis of the existing working cell – while team B worked on the robot guidance system and the wireless communication setup for data transfer.

Both teams achieved excellent results in their own field of competence, respectively. Their work paved the way to the prototyping of the robot, providing a number of advantages compared to the original, low-tech partner: the automation of the working cell increases productivity and quality by reducing duty cycle and allowing for more repeatability and precision. Further, the new robot not only is more flexible, as it is easily adaptable to different operations or line reconfiguration, but is also compliant with ergonomic principles: the improvement of the working conditions and the reduction of human interventions will surely have a positive impact on the workers both in terms of daily work reduction and job quality enhancement.

project 3A

TeMATIC
Telescopic Manipulator with Automation Technologies and Intelligent Control

_IRoPA_Intelligent Robotic Partner

ABSTRACT

The first task our team accomplished was the ergonomic analysis of the existing, low-tech mechanical partner [fig. **1**] which aids the worker in the dashboard installation process: this study highlighted several problems as ones concerning to inefficiency and the workers' health and safety conditions. We then moved on to the design of an automated solution which could solve these problems. In selecting the structure for the robotic arm, we decided to go for an optimum combination of "tested and tried" and innovative ideas: our robot is basically a standard 6 degrees of freedom arm [fig. **2**], with the innovative addition of a telescopic component, which suits well the insertion operation the robot must perform. Moreover, we studied the interface between the end effector and the interchangeable tools to minimize the set-up time and to comply with the project guidelines requiring not only the robot being able to handle dashboards of different kind and size, but also to carry out welding operations.

The computer vision system, the task of which is monitoring all the operations through a mounted camera, is supposed to be able to detect a generic, textureless, three-dimensional object (i.e., any part of the car body) and calculate its distance from the robotic arm in real-time. As these features are currently the subject of several researches in the computer vision field, it was unlikely that we could reach the prototypal stage. For this reason we decided to work on a feasibility study of an advanced algorithm, simultaneously implementing two simpler yet working solutions, so as to obtain some tangible results. In particular, our first prototype is a simple two-dimensional template matching algorithm, while the second one is able to detect a specific black and white marker in a three dimensional space.

The conclusive stages of our work included an ergonomic study of our new robotic partner to assess the improvements and benefits achieved.

TASKS & SKILLS

Marco Cavallaro, specialized in technology and factory planning, worked on the ergonomic analysis of the installation operation, both for the current and the advanced solutions, in a digital factory specifically designed for the project.

Davide Devescovi, interested in artificial intelligence and software engineering, worked on the computer vision system controlling the robotic arm movements, focusing on the development of the two different software solutions for position detection.

Maria Elena Innocenti analyzed the ergonomics of the current station, studying its impact on the workers and the available opportunities to increase the level of automation.

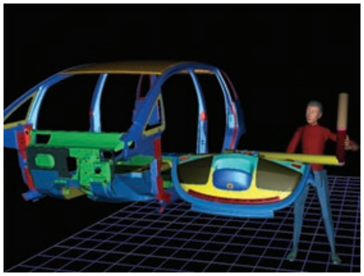
Nicola Rossi, specialized in transport systems, worked on the dynamic simulation of the robot, verifying the sizing of the structure and servomotors and analyzing the trajectories of the dashboard insertion.

Cristian Taibi, particularly interested in engines and gears, worked on the innovative robot structure defining servomotors and transmissions and providing a FEM analysis for the most loaded joint.

Mario Torello, interested in digital image processing, dealt with the feasibility study of an advanced computer vision system for the detection of the robot position through an image-to-model mapping system.

1 *An example of an industrial partner for the dashboard insertion operation*

2 *A sketch showing the concept of our "intelligent manipulator"*



3 *The assessment of ergonomic indices we performed in a virtual digital factory environment*

UNDERSTANDING THE PROBLEM

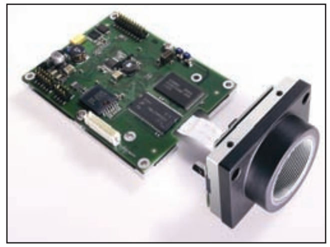
First of all, we had to examine the currently employed mechanical partner, which is manually operated and merely reduces the workers' physical work. According to our analysis, this solution is absolutely inefficient [fig. **3**], because it requires two workers for each mechanical partner and the operation completion is quite slow and error-prone; further, ergonomic principles are not observed, especially in the insertion process, putting the workers' safety at risk.
In order to find a remedy for this situation, we had to design a fully automated robot or, at least, a robotic partner requiring less operations to be performed and easy to manage by the workers, thus increasing productivity while observing ergonomic guidelines. As a result, the two main aspects we had to focus our research on were the definition of the mechanical structure and the development of an intelligent guiding system.

EXPLORING THE OPPORTUNITIES

The first step was to choose the arm structure [fig. **4**]. We thoroughfully studied the state-of-the-art in robot design, so as to understand advantages and drawbacks of the different available options, mainly focusing on the two most commonly used structures: anthropomorphic and Cartesian.

The anthropomorphic structure is characterized by high flexibility – which allows for welding operations but unfortunately also by an insufficient workspace for dashboard insertion process. On the contrary, the Cartesian structure guarantees a wide workspace and a simple control, although its application in an industrial context is rather difficult because of the cumbersome protections required by the safety rules.
Secondarily, we had to select the motors and the reducers to be mounted on the robot. Pneumatic servo-motors aren't widely adopted in robotic applications due to their low accuracy; other options include hydraulic and electric motors, showing comparable performances but also significant differences: the electric motors are usually cheaper and more efficient, while the hydraulic ones don't pose overheating risks and are more capable of handling heavy loads.
When we chose the reducers we examined the two most common types. Harmonic reducers are very accurate in positioning and re-

4 *The range of movements our robot is able to perform*



5 *An example of a commercial smart camera, able to carry out onboard processing*

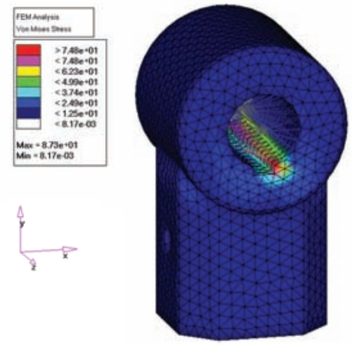
6 *The dashboard insertion step, performed by our robot*

peatability, and can also boast a very low weight; on the contrary, they can cost twice as much and be less efficient than epicyclic reducers.
We had then to evaluate several aspects concerning the intelligence system. First of all we had to choose the best hardware allowing the robot to detect its own position regarding its target. A simple video camera mounted on the arm is generally not sufficient, because it lacks the ability to measure distances and scales; a common solution consists in the employment of a pair of cameras in a *stereoscopic rig* allowing for depth perception, as it happens with human eyes.
Scaling and distance measurements can be obtained using a single camera with some expedients as well. For example, an experimental technique, called 'depth from defocus', is able to estimate the distance of an object from the camera comparing the recorded images as the camera focus varies; alternatively, the camera can be coupled with a laser telemeter which can provide depth data. Other options include the use of *multiview geometry*, a technique which can extrapolate additional information about an object from two or more images taken from different viewpoints, or more advanced 3D shape-based recognition algorithms.
A second aspect we had to consider was the positioning of the processing unit: several commercial solutions adopt a *smart camera* [fig. **5**] approach, where the CPU and the relevant algorithms are all stored in the camera onboard; in this case the camera can be remotely configured and monitored, being able to independently process images and control the robot with no further communication. A more flexible yet complex approach delegates the processing to a remote computer station, connected to the robot both to receive all the recorded images in real time and to send motion commands to the arm.
For what concerns the specific algorithm we should use to detect the object, we reviewed several options, ranging from a simple template matching approach, to a marker detection algorithm, to more complex solutions like main component analysis and surface matching technique.

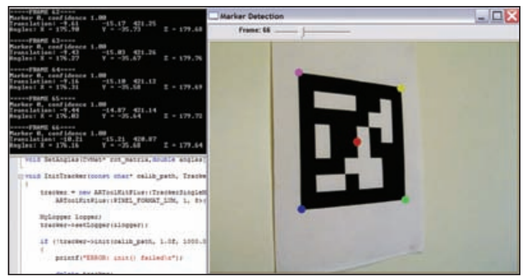
GENERATING A SOLUTION

The final solution [fig. **6**] consisted of a 6 degrees of freedom robot with a telescopic arm connected to the base, able to provide flexibility and a wide workspace while limiting its size. This was possible thanks to the relatively light payload the arm is required to support, also allowing us to conceive a hollow structure: cables can be placed

inside it to increase reliability and reduce operating costs.
We then chose brushless motors, a particular kind of electrical motors often used in robotics because they are easy to control and maintain; the moderate loads our robot will have to hold wouldn't justify the choice of hydraulic motors. We employed harmonic and epicyclic reducers, choosing the most appropriate for each joint of the arm: in this way we managed to reduce the weight resting on the most critical joints [fig. **7**], while holding down the costs by using epicyclic reducers where weight was not a problem.
In order to guide the movements of the robotic arm we adopted a mixed solution. First, a CAD/CAM system pushes the arm relatively near its target; thanks to the knowledge of the car CAD model and the aid of radar sensors, collisions are prevented if the car is not in the expected position. The actual approach and precision positioning are performed by the vision system, for which we decided to adopt a single camera: two cameras, or a single camera coupled with another sensor, didn't yield significant advantages, as some of the advanced algorithms we considered can be as powerful as stereoscopy in terms of collectable information. Moreover, a single camera takes up less room on the arm.
The specific algorithm we focused our feasibility study on, is a surface matching algorithm, which uses *spin images* to perform the match. A spin image is a particular surface transformation that makes the comparison straightforward, reducing the complexity of a surface-to-surface match. Given the 3D models of the objects to be detected, the algorithm can compare the spin images of surfaces in the scene with the stored spin images of models, even in presence of noise or partial occlusions; unfortunately, obtaining real time performances with this method is not easy.
Considering the complexity of the chosen approach, the best way to handle the computation was using a remote PC station; the wireless connection used to make it communicate with the robot was studied by Team B.
Besides the feasibility study of the advanced algorithm undertaken in cooperation with Team B, we coded two much simpler yet working prototypical algorithms. The first one performs a simple template matching operation comparing a known template of an object, on a pixel by pixel basis, with the currently acquired image, detecting the object in the scene; this approach, however, requires a perfectly perpendicular point of view, basically limiting us to a 2D image. The second one [fig. **8**] doesn't show this limit, as it can recognize a specific binary marker from any perspective; unfortunately, this means that the marker has to be accurately placed, can't be occluded by any object and has to be removed afterwards: in our situation, all these conditions weren't easy to comply with.
The final step of our work consisted in the ergonomic analysis of our new "intelligent partner", performed in a virtual, digital factory environment, which allowed a detailed analysis and, in particular, a study of the suggested solution. This study showed that the workers' conditions had dramatically improved for what concerned both safety and health-related factors; moreover, the robot allowed the job to be completed in a faster, more efficient and flexible way.



7 *Tension distribution on the most loaded joint of the structure*



8 *Our marker detection prototype program at work* project 3B

_IRoPA_Intelligent Robotic Partner

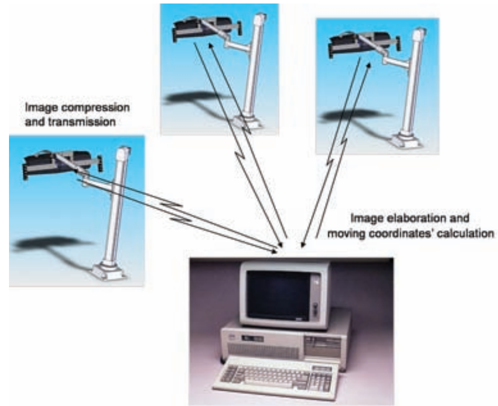
The AntroCart Wireless robot

TASKS & SKILLS

Xenia Fiorentini, specialized in technology and factory planning, dealt with the general cell configuration and the examination ergonomic aspects of the proposed solution.
Lorenzo Guidi, specialized in production and manufacturing processes, worked on the ideation of an innovative structure for the robot and the end-effectors, and performed a preliminary measuring of the arms.
Francesco Monti, specialized in chassis design, performed the simulations needed to size the partner structure and the mechanical components with FEM analysis and dynamic simulations.
Marianna Pepe, particularly interested in source coding and signal elaboration, worked on the wireless communication system and the image compression algorithm.
Federico Sarzotti, specialized in computer graphics, led a feasibility study of an advanced computer vision system for the detection of the robot position in a 3D environment.
Iacopo Gambino, specialized in technology and factory planning, worked with Xenia Fiorentini on the general definition of the system, taking care of the cost-benefits analysis of the project.

ABSTRACT

The work-cell currently employed for the dashboard insertion uses a mechanical framework to aid the operator in moving and positioning the components; this solution not only proved to be problematic from an ergonomic point of view, but also offered limited performances. As a result, the idea we developed was the replacement of the current cell with a fully automated robotic partner.
We began our work designing an innovative structure, adopting as guidelines principles the simplicity of the framework, the adaptability to different operations and the least expensive solution. Additional goals were also the small volume for a limited room occupation and a wide workspace at arm reach. We conceived a robot with 6 degrees of freedom, five rotational axes and a translational one, and an equipment designed taking into account the possibility of a line reconfiguration. The feasibility study concluded with an executive project of some elements: a FEM analysis and a dynamic simulation gave us crucial information about the sizing of the critical joints and the best servomotors to choose.
In order to control the movements of the robot we chose a mix of CAD/CAM and a vision system: the robot moves along trajectories previously defined on the base of a CAD scheme; then, once the car door is reached, an accurate positioning can be obtained thanks to a 3D video camera. To complete this operation, the computer system needs to be able to recognize a generic 3D object and to calculate the distance from the robot so that it can identify the arm position in real-time.
The images acquired on board are compressed, using the wavelet transform of the signal, and sent, through a WiFi protocol, to a remote terminal where the current computation occurs. The new cell was designed taking in consideration ergonomic principles to overcome the ergonomic inefficiencies of the previous system. The final solution granted a significant improvement of the work conditions. Furthermore, the decisions regarding materials, configurations and technological solutions were always taken in consideration of the trade off between performances and costs. This approach allowed an easy development of the costs-benefits analysis.



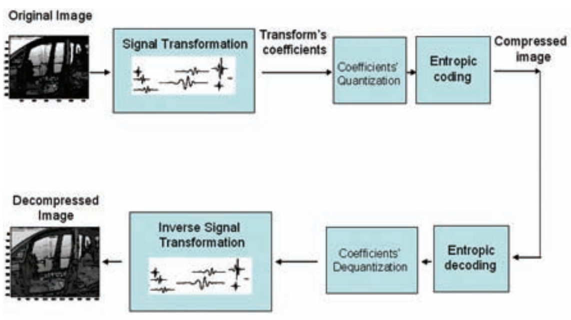
1 *Description of the chosen architecture for the wireless network*

UNDERSTANDING THE PROBLEM

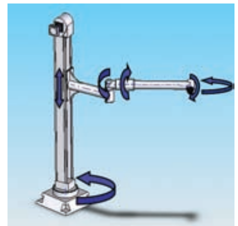
After having analyzed the current work-cell, in which the operator uses a simple mechanical partner, we immediately realized that the dashboard insertion and spot welding processes require lot of efforts by the workers. We decided then to exclude the human operator, who remains only a supervisor, and to create a completely automated work-cell, able to operate with different types of vehicle, automatically recognizing which one is currently being processed. Actually we also took into consideration the possibility of a dashboard model – and maybe also the end-effectors equipment – change, considering a random arrival sequence of vehicles. Throughout the project, our group always adopted a general-purpose approach in facing the problems and considered flexibility as the most important requirement. Finding the most inexpensive solution was the other fundamental goal: as there already existed many different robots on the market, our solution would have to be cheaper but just as effective as those ones.

EXPLORING THE OPPORTUNITIES

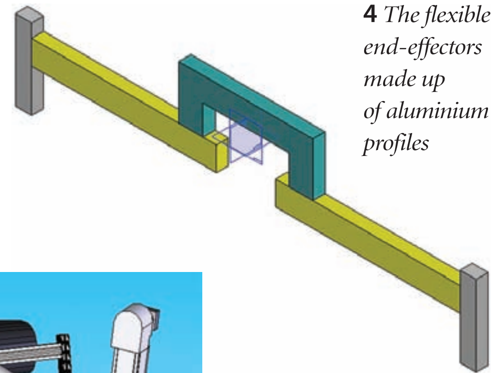
The first stage of the project consisted in the analysis of the movements the robot should be able to perform, particularly focusing on two different movements: the handling of the spot welding gun and the insertion of the dashboard in the vehicle. The second movement showed the need for a flexible structure: this compelled us to conceive a solution with six degrees of freedom. We evaluated current commercial products developed by leader companies in this field to find out which positive and negative aspects characterize the most important solutions. The main typologies of six-degree of freedom robot are Cartesian and anthropomorphic robots. The first one presents the advantage of a simple and economic structure, but the floor supports it requires can be quite encumbering. On the contrary, the anthropomorphic solution is very flexible and can reach wide workspaces, although the structure occupies a limited room, but the negative aspect is represented by its more complex structure; the latter solution is the most widespread in the industrial field. Almost all the robots we found showed high performances we judged unnecessary for our application: the reduction of the costs by achieving lower performances was a fundamental assumption in generating the solution.
As to the vision system, we noticed that mounting the dashboard on the car is a critical operation, since the algorithm has to recognize an object the image of which, in accordance with the position of the robot arm in the cockpit, could be rotated and translated compared to our model. Therefore we reviewed several possibilities, ranging from a simple template matching approach, to a marker detection algorithm, to more complex solutions using a surface mesh as representation for 3D shapes.
As regards the wireless transmission, we first evaluated the option of an onboard elaboration: in this way only the coordinates obtained from the vision algorithm and those calculated from the cad scheme would need to be transmitted from and to the robot; most important, no image compression would be necessary. However, an elaboration unit near the video camera would be indispensable, but that could hamper the arm movements.
The alternative option was compressing the image and sending it to the remote terminal attending to the elaboration [fig. **1**]. The compression algorithm works through a series of steps: the image is first transformed as the weighted sum of simple waveforms, so that the quantization step can be efficiently implemented, then the quantized weights are codified to reduce source entropy [fig. **2**]. We examined



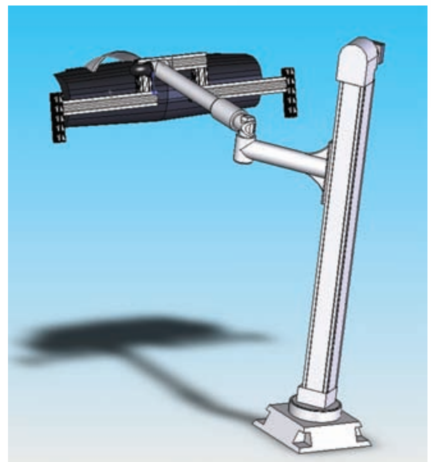
2 *Image compression and decompression scheme*



3 *Robot structure and disposal of the six degrees of freedom*



4 *The flexible end-effectors made up of aluminium profiles*

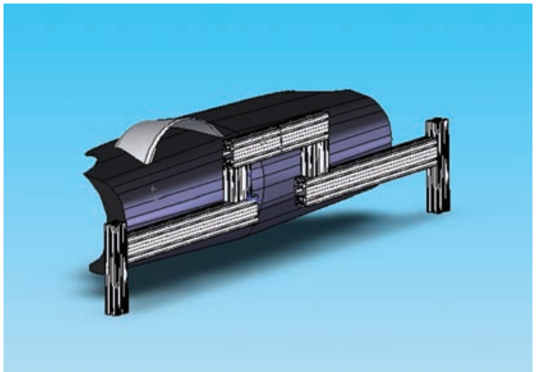


5 *Manipulation of the dashboard by the robot*

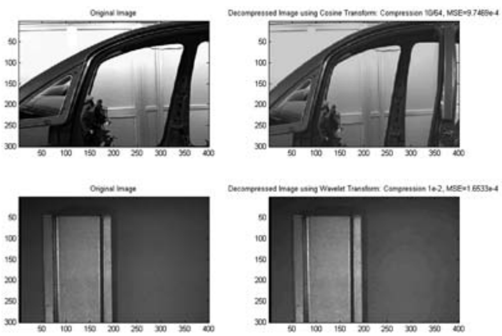
two possible kinds of algorithms: lossless and lossy. The lossless ones give a quite low compression factor, but they definitively succeed in accurately reconstructing the image; lossy algorithms cause a fidelity loss in the decompressed image, but allow for higher compression factors compared to the lossless ones. Two important factors influenced our choice: we used image compression to achieve wireless system better performances, so we looked for a high compressing factor, guaranteed by a lossy algorithm; on the other hand the acknowledgment algorithm had to work also with the decompressed image which, using a lossy technique, is degraded compared to the original one. So the solution had to be a compromise between these two contrasting requirements.
Finally, we considered the wireless communication system: W-PANs (802.15), that have a short-range (about a meter) and can reach a bit rate of 1 Mb/s, and W-LANs (802.11), that reach distances up to 100 meters and allow for a bit rate of 10 Mb/s.

GENERATING A SOLUTION

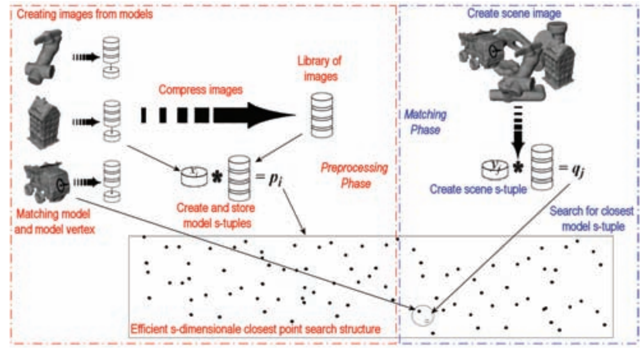
The solution we put forward is a compromise between a Cartesian and an anthropomorphic structure - that's why we named this robot AntroCart. We adopted a robot with 6 degrees of freedom, 5 rotational axis and 1 vertical translational axis, able to reach a wide workspace occupying limited room in the plant [fig. **3**]. We designed the end-effectors to handle the dashboard and to fix it within the vehicle, adopting a modular structure made up by commercial aluminium profiles allowing the creation of an economical and flexible equipment, able to keep dashboards of different sizes [fig. **4**].
For what concerns the servomotors, we selected electrical brushless motors. Other typologies (pneumatic or hydraulic) weren't suitable for our specific needs: the first doesn't allow an accurate movements control, while the second is usually appropriate for high torque. As to the reducers, however, we chose a harmonic driver transmission because of the operating principle and flexible design that make them perfect for industrial robots. The main qualities of these reducers consist in their compact size and light weight, high reduction ratios in a single stage and high torque capacity with high precision performances. The size of some critical joints was tested out through FEM analysis and, through a dynamic simulation software, we checked the correct performance required by the servomotors [fig. **5**, **6**].



6 *Fixing of the dashboard to the designed end-effectors*



7 *Comparison between the original image and the decompressed one obtained through two different algorithms*



8 *Surface-matching vision algorithm using spin images*

We implemented two different image compression algorithms. They both belong to the lossy class but they use two different transformations. We took two parameters into account: Mean Square Error (MSE) between the original image and the decompressed one, and the ratio between original image size and decompressed image size (compression factor). We chose the algorithm providing the highest compression factor, although it provides also a higher MSE, because it allows the vision algorithm to work correctly [fig. **7**].
The chosen communication protocol is 802.11b. We carried out some tests, but not in an industrial environment: since this system works with a central frequency of 2.4 GHz, which is not licensed and undergo a lot of interferences, its use in complex environments could involve problems we didn't considered in our work.

Both teams studied the 3D vision algorithm in cooperation, carrying out a feasibility study of a surface-matching algorithm. It works by comparing spin images, which are a particular kind of surface representation reducing the complexity of a surface-to-surface comparison [fig. **8**]. When two spin images are highly correlated, a point correspondence between the two surfaces is established. More specifically, before the matching phase, all the spin images from one surface (the model) are constructed and stored in a stack. Then the algorithm selects a random vertex from the other surface (the scene seen by the camera) and computes its spin image. Point correspondences are then established between the selected point and the points with best spin images matching on the other surface. The use of surface mesh as representations for 3D shapes was avoided in the past because of its computational cost: however, nowadays processing power improvements make this technique feasible.
The final result of our activities is a work-cell equipped with a robotic system characterized by high flexibility and reconfigurability, and a distinctive amount of installed intelligence (visors, positions sensors, anti-collision sensors). This goal is achieved with a cell that only employs quite simple and common solutions, allowing a dramatic cost reduction and offering the operators a significant improvement of their working conditions.

project 4

R (UE)²
Rational and sustainable use of energy in urban environments

Analysis of different energetic scenarios in urban areas based on cogeneration and trigeneration technologies

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project 5

ICOSA
Inter-vehicular Communications for Traffic Control and Safety Applications

Study for the effective exploitation of wireless communications to obtain innovative systems and services for vehicular traffic control and safety support

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project 6

DaGoGò
Goods Tracking and Risk Management

Dangerous goods governance framework from strategic, management and operative point of view.

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project 7

DESIGN JUNCTION

Supporting Cultural Capital Competitiveness

Supporting global competitiveness of Italian cultural capitals: Milano and Torino as poles for exploring new cultural strategies driven by design

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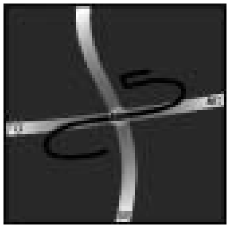
project 8



Corridor V
Territorial Policies and Local Development

The Project develops the idea of Corridor as a backbone rather than just physical infrastructure: to what extent Corridor policies sustain local development?

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project 9

COMPITO
Monitoring Territorial Effects due to Commercial Polarities along the Milan-Turin Connection

The project aims at setting up a methodology for evaluating effects of large-sized shopping centers and at defining visions to improve territorial development.

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project **10**

Pil-Sim
Simulation of Scenarios for the Lombardia-Piemonte Macro-region

PiL-Sim experiments microsimulation of the Lombardia-Piemonte for next decades scenarios of system-environment dynamics in transport, business, work and housing

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Sergio Gabriele Maria Sereno
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project 11

Domestic Technology Evolution
Environmental and Behavioural Changes in People's Life

DO.TE.E aims to build scenarios for future developments of home automation, staring from a user-centred analysis of changes in people's life

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project **12**

BioFluor
Intelligent Diagnostic Tools and Smart Drug Delivery: Biomedical Applications of Fluorinated Fluids

The mission of project 12 is finding new opportunities for the exploitation of perfluorinated fluids in biomedicine, for diagnostic and drug delivery purposes

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