uFactory

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Executive Summary

The COVID-19 pandemic significantly disrupted global supply chains, leading to factory closures and skyrocketing transportation costs, which persisted due to geopolitical instability and increased insurance costs. Additionally, international shipping's growing contribution to greenhouse gas emissions and shifting consumer demand toward personalized products have fueled interest in more resilient, localized production models.

In response, uFactory partnered with Dutch startup Industrio to establish urban-based mini-factories, focusing on personalized manufacturing. The project emphasized selecting urban locations with minimal disruption, producing custom orthopedic insoles for the healthcare and sports sectors, and designing a fully automated additive manufacturing pipeline.

Key contributions included the integration of Direct Ink Writing (DIW) technology to print sensors onto insoles and the programming of robots for automated production. A strategic partnership with the Italian healthcare network Santagostino validated the project's commercial potential, while the production model's modularity supports its application across various wearable products.

The uFactory approach not only reduces reliance on global supply chains and lowers transport emissions but also responds to growing market demands for customization, fostering sustainable urban manufacturing ecosystems.

Key Words

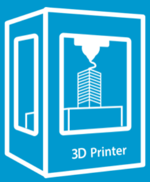
Urban Factory, Additive Manufacturing (AM), Mass Personalization, Supply Chain Resilience

Do you have a wearable product requirement or idea?

With uFactory your customers can design it by themselves!

1. We collect customers' measurements to ensure the right fit

2. We gather their preferences



3. We print the product and deliver it to customers in minutes

All of this inside your store!

Project Description Written by the Principal Academic Tutor

In the globalised market, companies have tried to remain competitive through the adoption of a strategy where high quantity production of goods was the leverage to reduce costs. This approach is not always the most effective and efficient way. Now that the entire supply chain has been affected by pandemic and war events, more than before. Additive Manufacturing is a consolidated technology that could change the way how certain products can be designed and manufactured. Its advantages are well-known, however its use in industrial contexts needs additional development to be considered competitive in production time and costs. Industrio would like to bridge this existing gap and make 3D printers industrial, realiable, repeteable and easy-to-use. Industrio alternatively proposes the "Mini-factories" concept, which is conceived to be an innovative solution for most of the actors involved in the whole supply chain. Industrio would like to contribute in the revolution to move back the manufacturing model from centralised to locally distributed. This high-level concept can be applied focusing on need-driven products, and different levels of manufacturing solutions which can be placed:

- at RETAIL environment, to manufacture simple products with minor assembly required;
- at DISTRICT or URBAN level when the products are complex and the manufacturing procedures cannot be scaled at local level.

Consumers demand for personalised, comfortable, safe-healthy and sustainable products is growing. The high capability to track performances as well as biometric data via affordable wearable technologies is making it possible the design of individual and personalised products. The bottleneck for such paradigm to industrially happen is the manufacturing and related business models to be applied. Industrio proposes different solutions that guarantee mass market production at high volume with the magics that products are all different and individually fabricated as per personal need.

Team Description

uFactory project required a multidisciplinary team to tackle the complexities of shifting from centralized to local manufacturing, and to handle the multifaceted design of product and process. The team comprised students with expertise in automation, physics engineering, management, and biomedical engineering. This diverse expertise ensured that the project could address the broad challenges of the new manufacturing paradigm effectively.

- Michele Sbacco has been responsible for the section of the project regarding the production pipeline. He developed the strategy for the robot to be used inside the production pipeline and wrote the code to simulate the behavior of the robot.

- Berna Esmer was tasked with selecting materials for the proof-of-concept. Her role involved participating in the sensor printing process, including selecting and modifying inks as needed for optimal printing.

- Bogdan Tofan played a key role in forming the strategic partnership between Santagostino and Industrio. He also contributed to developing the urban factory paradigm and engaging key stakeholders.

- Alberto Pettenella was responsible for the selection of candidate products for the urban factory and the integration of electronics. He also contributed to the development and testing of sensors, ensuring their functionality.

Understanding the Problem

The fragility of global supply chains, already stressed by the COVID-19 pandemic and escalating geopolitical tensions in the Red Sea, has exposed the inadequacies of traditional high-volume production strategies, given the increasing fragility of global supply chains. Moreover, these challenges have been further exacerbated by current geopolitical instability, leading to tripling of the shipping costs since January 2020, with many ships, particularly those on Western trade routes from Southeast Asia to Europe, to reroute around the Cape of Good Hope. This detour adds over 11,000 miles and up to two weeks to each voyage, with additional fuel costs of about $1 million each way. Furthermore, insurance premiums for these routes have surged by 1,000 percent. Additionally, the shipping industry, a significant contributor to global greenhouse gas emissions, faces projections of increased emissions if the slow pace of decarbonization persists. Moreover, the shift towards personalized products challenges the conventional mass production methods, demanding a more agile manufacturing approach.

In response, Additive Manufacturing emerges as a transformative solution, offering a way to design and produce goods that align with the growing consumer demand for personalized, comfortable, safe, and sustainable products. Despite its advantages, Additive Manufacturing requires further development to compete effectively in terms of production time and costs in industrial contexts. The integration of Additive Manufacturing in industrial processes could revolutionize the supply chain, making it possible to create individually tailored products without the high delivery lead times associated with traditional supply chains of mass production methods and the high costs associated with artisan production.

Conventional mass production methods lack the flexibility of technologies such as Additive Manufacturing, which can ensure each product to be customized to individual needs without sacrificing efficiency, cost, or quality, aligning at the same time with the increasing emphasis on sustainability and reduced greenhouse gas emissions.

To redefine competitiveness in a globalized market, a shift to a more resilient and responsive supply chain model is therefore needed.

Goals

The project envisions a new manufacturing paradigm where production of goods does not only happen in a centralized way in big factories, mainly located in East Asia. Instead, production could -and should- also take place in a decentralized way, and near the final customer. The core vision is to seemlessly integrate production units into urban environments, in a way that makes them publicly accepted and beneficial to the local communities. One aim of the project is to identify a way to make production of personalized goods more automatic and affordable, so that it can be ”local” again. The decentralized manufacturing cells should exhibit specific qualities such as flexibility, modularity and scalability to facilitate reconfiguration of production settings. All of this while respecting strict noise and emission regulations, to align with sustainability goals and to respect the needs of the citizens.

The healthcare sector was selected as the entry market to expedite the adoption of the solution, as the demand is driven by necessity rather than desire. For this purpose, a strategic marketing initiative is launched to secure partnerships with orthotic clinics, later to be extended to sports retailers, and technology providers. These partnerships would not only facilitate the proliferation of the mini-factories in cities, but they would also play a critical role in ensuring the long-term sustainability and success of the project.

On the product side, the focus is on developing personalized smart orthotic insoles due to their relatively short production time and the growing need for sensorized versions to monitor the progress of both orthotic users and athletes. Insoles are designed in a customized way to address the specific needs and anatomy of the user, then they are crafted leveraging 3D printing techniques. These same techniques also enable the integration of sensors within the insoles to monitor gait cycle and store the related data.

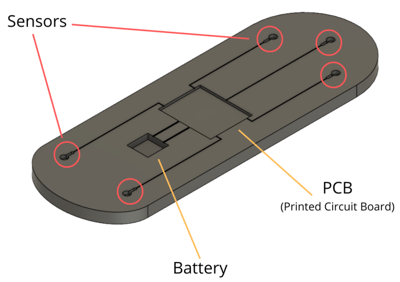
Data can then be used both for sports performance optimization and for clinical applications, making the product versatile and high-value in both healthcare and athletic markets.
The final goal also includes a strategic marketing initiative to secure partnerships with orthotic clinics, sports retailers, and technology providers. These partnerships would not only facilitate the proliferation of the mini-factories in cities, but they would also play a critical role in ensuring the long-term sustainability and success of the project.

Exploring the Opportunities

The uFactory project presents an innovative vision for how we produce and deliver personalizable goods, especially for sports and healthcare. By embracing decentralized, local mini-factories, this initiative offers a cutting-edge solution to the inefficiencies of traditional mass manufacturing, where long supply chains and environmental impact are significant issues and product personalization is not feasible.
This project is the first step towards a future where mass personalization becomes the norm, and customized products are designed and crafted on demand, near the final customer, without sacrificing affordability. Retail stores could attract more clients by exploiting unique in-store experiences, such as the possibility to co-create personalized products with customers. This would give them a competitive edge in their battle against e-commerce platforms by offering unique, hands-on customization that online stores cannot match.

Key technological choices have made this vision possible.

- Selective Laser Sintering (SLS) is used to 3D print high-quality, flexible insoles, while Direct Ink Writing (DIW) integrates electronics directly in the products. These technologies ensure that the products are not only customized but also feature ”smart” functionalities.
- A thoughtful selection of conductive inks for direct ink writing makes sure that the printed sensors achieve their desired properties. These inks are chosen for their ability to maintain strong adhesion to the materials used in the insole’s fabrication, and for the precision and ease of the printing process.
- The integration and fusion of many cutting-edge techologies like robotics, vision systems, 3D printing and innovative assembly lines, makes the production pipeline fully automated, flexible, scalable and modular.
- The choice of the smart insole as the proof-of-concept for this project was strategic, providing a valuable application for healthcare and sports sectors. Custom orthotic insoles address the need for personalized medical solutions while demonstrating the feasibility of integrating sensors into everyday wearables. This product showcases the potential of the uFactory model to offer tailored, functional, and high-tech goods on demand.



Proposed product: personalized insole with embedded sensors and electronics.

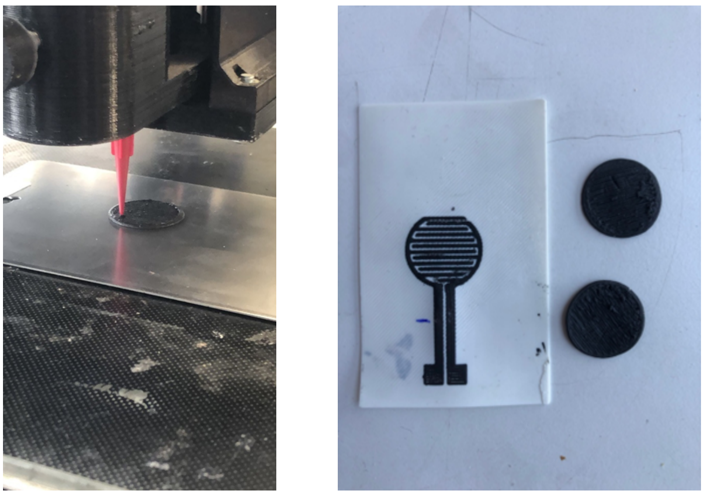
Generating a Solution

Building on the partnership with Industrio and considering uFactory's aim to establish "mini-factories" that could be seamlessly integrated into urban settings, we focused on three essential pillars.

1) Integration of the Factory in the City: The project prioritized selecting urban partners and sought partnerships with the private sector to find optimal locations for the mini-factories with minimal impact on local residents and close proximity to points of sales. From a business collaboration point of view a strategic partnership with Santagostino, a leading network of specialized polyclinics in Italy, was secured. This collaboration underscores the commercial viability of the uFactory model, particularly within the healthcare sector, where there is a strong demand for customized, high-quality orthotic devices.

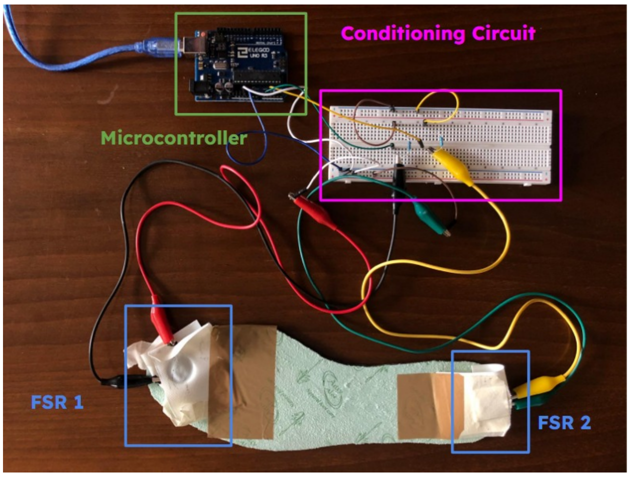
Envisioned user experience: in-clinics and in-store production of insoles.

2) Selection of Candidate Products and Proof of Concept: To identify products with demand for personalization, the team conducted a survey focusing on the sports sector. This research also extended to healthcare, leading to the selection of customized orthopedic insoles as a key product offering, based on the requirements of our end users, orthotic users, and the requirements of Santagostino's Chief Technology Officer. The project successfully demonstrated the ability to print pressure sensors directly onto thermoplastic polyurethane using DIW retaining the conductive and sensing properties of specifically chosen inks.

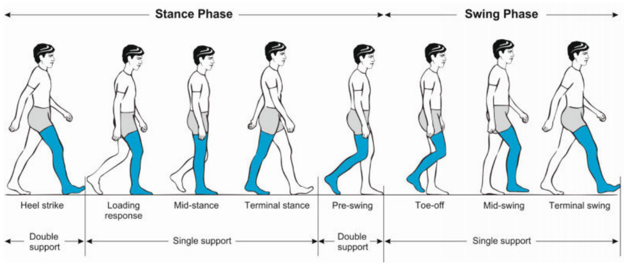


DIW printing setup (left image), sensor printed with DIW (right image)

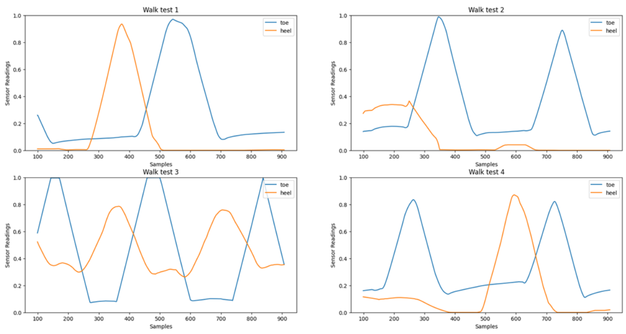
A proof-of-concept insole was then built, and the printed sensor topologies (shunt mode and thru mode) were able to differentiate between various phases of a user's gait cycle.



Overview of the setup for the prototype insole.



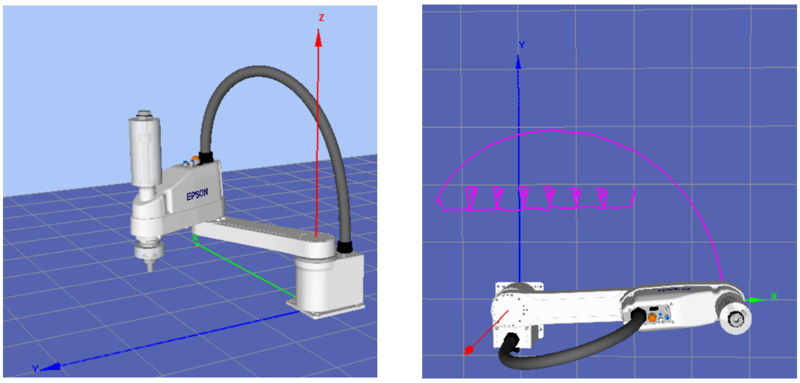
Phases of normal gait cycle.



Gait cycle analysis with the sensors of the prototype: normalized and filtered toe and heel signals

3) Design of the Production Process: Leveraging Industrio's intellectual property and their achievements in Selective Laser Sintering (SLS), the project envisioned a fully automated additive manufacturing (AM) pipeline. This approach included the design of a fully automated and flexible pipeline using robots alongside AM machines, and the introduction of Direct Ink Writing (DIW) technology to print electronic sensors on foot insoles. The team designed an additive manufacturing production pipeline small enough to be integrated into existing businesses, with full automation to enable real-time product customization with customers. Moreover, its modularity makes it suitable for a variety of wearable products besides insoles, ultimately reducing the reliance of retailers and clinics on centralized production from Asia.

Finally, the integration of a robot in the production process has been arranged and simulated. This procedure is needed to clean workpieces from excess powder and prepare them for the DIW process, and includes the use of a camera and a vision system to enable the robot to follow the insoles and operate on them -even while they are moving.



Robot in Epson's simulation environment (left image) and final trajectory followed by the robot (right image, in pink)

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