



variability in extraction strategies. For this, INESCOP, together with an industrial partner Platinher Urban, chose a selection of models that were representative of the different requirements involved in the task and addressed the challenge of automating them.

## DEMOULDING INJECTED OUTSOLES

Demoulding injected soles has many features that make its robotisation as attractive from a technological research point of view as much as it is necessary from an industrial one. One of the main reasons that led us to face this challenge was to seek an improvement in the impact of the ergonomics of this task on the daily life of production operators. Typically, an operator attaches various decorations, technical parts or brand inserts, after which the machine cycle begins. After injection and once the injected material has cured, the operator must remove the sole from its mould, which requires the use of considerable force and risky unergonomic body postures. If we add to this the repetitiveness of the task, the possibility of injury to the operator in both the medium and long term increases exponentially. Changing the method of extracting the soles from manual to one using an automatic system supervised by the operator therefore needed to be considered.

However, not just an ability to exert a high degree of force is needed to demould injected soles. In actual fact, the manual dexterity applied to the demoulding path is even more important, as has been stated by operators themselves. The integration of many different active and appealing robotic research areas, such as manipulation, human-robot interaction and artificial intelligence for robotics has therefore been required in order to successfully automate the task.

## MANIPULATION

As stated, the handling of flexible and deformable objects is the main objective of the project; therefore, correctly gripping and manipulating the injected sole in order to demould it, is still a challenging task. To this end and working jointly with Platinher Urban, 12 models were identified which most represented the peculiarities of the

demoulding process in terms of materials, flexibility, grip, force required and dexterity of the path needed to demould the sole and more.

A UR10e collaborative robot has been used, as well as two different robotic grippers which are being developed by Zimmer, another technology partner in the project, to cover the different extraction needs. The gripper to be used in each case has largely depended on the difficulty of the extraction involved and the available surface area of the individual soles to be grasped when the mould is opened.

On the one hand, a Zimmer electric gripper which, among other things, offers a controllable stroke and grip strength, has been used when the surface of the sole available for gripping is the outer and visible part of the finished shoe. Such electric grippers are equipped with soft fingers designed not only to optimise the grip but also to avoid damaging or scratching the soles. On the other hand, a stronger Zimmer pneumatic gripper has been chosen when the surface of the sole available to be gripped is the inner part which is not visible when the shoe is crafted. This kind of extraction is usually the most challenging as the sole is embedded inside the mould so that the friction is very high. This pneumatic gripper is equipped with fingers designed to resemble the pliers that operators use to grasp deep inside the cavities of the injected sole before pulling with dexterity and strength to demould it without deformation or breakage of the final product.

An intensive and active research programme is being conducted by the different projects' technological partners (SIGMA, STAM, SORBONE) to integrate tactile sensors into the gripper fingers as they will be able to provide valuable information in order to contextualise the status of the contact between gripper and sole, and so help to prevent errors such as slippage, scratches or breakage due to bad grip.

## AI FOR ROBOTICS

What makes humans expert manipulators is the connection between the brain and hands. As humans, we are capable of precisely controlling movements and integrating different sources of information such as visual or tactile, to plan and react almost

unconsciously. In an effort to replicate human behaviour, many different AI techniques are being applied. To this end, the robot end-effector is equipped with a 3D camera to provide the system with visual perception. Such visual information is forwarded through a deep neural network trained to estimate which is the best gripping point of the injected sole. Once the sole has been gripped, the decision-making module responsible for the pulling path will approximate a human operator's expert behaviour. This point is still under development and is one of the most innovative bits to solve the proposed problem.

## HUMAN-ROBOT INTERACTION

In the context of the SoftManBot project, human-robot interaction (HRI) plays a fundamental role as the robotic solution will coexist and share the workspace with humans while working in a sequence. The development of the solution has considered the expectations and opinions of people with different profiles in the manufacturing workplace, such as operators, supervisors or managers, through interviews and questionnaires. An ongoing research line of the project focuses on the social interaction between the robot and the operator so that the latter feels safe and trusts and accepts the system.

To this end, the task will be performed by UR cobots, which are a new kind of robot designed to be collaborative. Moreover, the robotic system will count on different sensors to detect and contextualise humans around it and react accordingly, always putting security first. The robotisation of traditional manufacturing sectors such as footwear or toys is an important challenge necessary for their modernisation and improving their competitiveness and quality standards. However, it is not a trivial task and will only reach real solutions when based on a thorough knowledge of their peculiarities and applying the tools that new technologies offer us. 

*This work is part of the SoftManBot project which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 869855.*