2020-2021 Awardee

***Florent Pastorelli** is currently completing his master's degree in mechanical engineering at Université Laval in Québec City, QC,Canada. Originally from France, where he trained as a mechanical engineer at the Arts & Métiers school, Florent decided to pursue his education in Québec City in the field of robotic engineering. His research project focuses on the automation and optimization of shotcrete placement by the use of a computer controlled robotic arm. This project is part of a larger project developed by Marc Jolin's Shotcrete Research Team, the SPARO project (Shotcrete Placement Automated by Robot).*

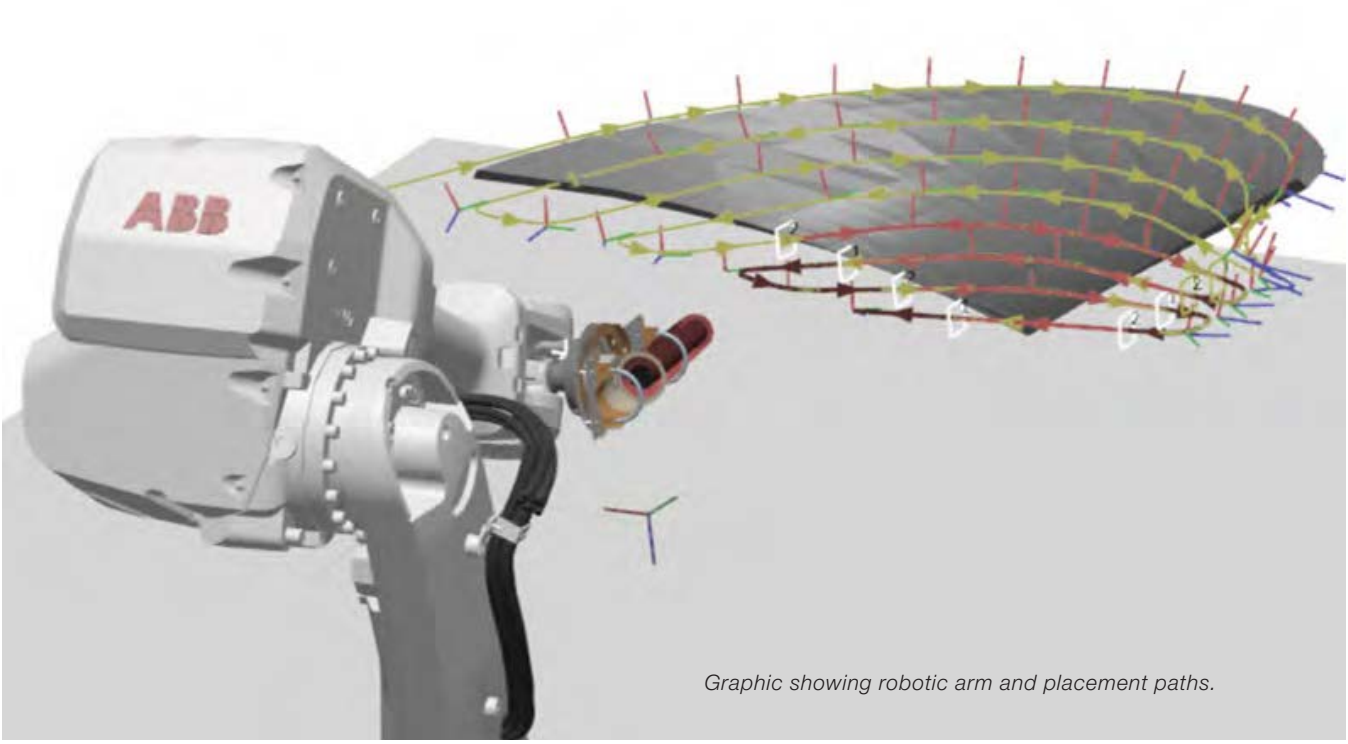
PASTORELLIE'S M.SC. RESEARCH PROJECT

Automation and Optimization of Shotcrete Placement by the Use of a Computer Controlled Robotic Arm

Civil engineering, and particularly construction, is experiencing technological advances with the advent of the so-called Industry 4.0, and shotcrete should be no exception. In many ways, shotcrete is the pioneering process of 3D-concrete printing and fits perfectly in this technological revolution, which is why it is clearly obvious to us to advance the automation of this process. Moreover, the development of automation in shotcrete will allow for a more thorough understanding of pneumatic placement of fresh concrete, and thus open the door to further optimization.

From an environmental and economic perspective, the reduction of rebound (and therefore concrete material loss) is one of the main challenges of process optimization. The knowledge acquired in the Shotcrete Laboratory at Université Laval over the years has shown that the placement technique has a great influence on rebound. We therefore conducted various tests using a robotic arm, enabling us to observe highly precise adjustments repeatedly. This showed us that optimal values of spraying parameters can be found for trajectories, angles or speeds to reduce the quantity of rebound and improve the quality of the production-placed concrete, fulfilling one objective to determine the best possible set of spraying parameters. However, this also led us to relevant interpretations of the placement process to better understand and describe the mechanisms involved in quality pneumatic placement of concrete.

This particular M.Sc. project implemented automation procedures to fill a conventional ACI nozzleman certification panel using the robotic arm. This task choice provided



Graphic showing robotic arm and placement paths.

an opportunity to address complex elements such as the presence of reinforcing bars and panel boundaries. Trajectory and handling techniques will be manipulated to ensure encapsulation of the reinforcement bars and fill the corners and edges of the panel. This allowed us to learn more about optimal spraying techniques.

An associated aspect of this project focused on 3D mapping methods. The goal is for the system to resolve all aspects of its specific working area, and develop a prototype for a visual digital system specifically for sprayed concrete applications. The robot should be able to evaluate the position of the certification panel and its reinforcing bars to automatically generate the required spraying trajectories.

Finally, the increasing complexity of shapes and optimally designed structures in architecture is pushing manufacturing methods to improve their technology. This project hopes to highlight the advantages of automated shotcrete, especially when compared to conventional 3D-concrete printing techniques. Indeed, shotcrete has tremendous advantages as it allows the use of conventional reinforcement with proven concrete design and facilitates the production of double-curvature elements. Moreover, shotcrete is a method particularly well adapted for high-performance concrete materials.

Robotic arm with shotcrete nozzle in the lab

This master's project therefore strives to optimize the efficiency of fresh concrete placement by optimizing the spraying parameters and automating these spraying methods. To do so, it relies on the development of a robotic arm system integrating 3D visualization technologies. The performance of automated sprayed concrete is opening up exciting prospects for the future in terms of reducing the use of materials and facilitating complex architectural possibilities.