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Printing of Use-cases by Direct-to-shape Inkjet Printing with Industrial Robot

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Abstract

In the initial phase of this project, a single-colour printing system was developed to perform printing tests on 2D surfaces in different orientations and robot workspaces. These test prints were scanned by a microscope and treated by an image processing software, which allowed the statistical characterisation of the drop placement error and its different parameters. An active ink pressure control system was developed, implemented and tested to mitigate the pressure fluctuations caused by the dynamics that occur within the system. Using high-precision distance sensors, a correlation between drop placement error and robot path accuracy was proven, confirming the effectiveness of the ink pressure control. In the second phase, a four-colour printing system was developed to test high quality graphic printing and selective coating on an automotive part. This phase involved several considerations, including path generation, correcting positioning errors, ensuring stitching quality, achieving coating uniformity and implementing UV curing on 3D surfaces. The DTS workflow developed in this project was tested and improved on various use cases including automotive parts and furniture.

Introduction

Known for its adaptability, speed and accuracy, digital inkjet printing has become increasingly popular for graphic printing and coating applications. It supports a wide range of materials, including aqueous and solvent-based inks, UV-curable inks and functional substances such as conductive inks and adhesives. The technology provides precise control over coating deposition, enabling selective applications without the need for masking and facilitating the creation of intricate patterns and textures.

Digital inkjet printing has found a wide range of applications in industries such as packaging, textiles, ceramics and electronics due to its ability to produce high quality, customisable graphic prints and coatings while minimising waste and costs.

Direct-to-shape (DTS) printing takes digital printing a step further by enabling images or coatings to be printed directly onto three-dimensional surfaces such as bottles, cups and automotive parts. Typically, DTS printing uses customised printers that are designed to fit the unique shape of the object. These systems often rely on a static printing setup that moves the object to be printed and are therefore limited in their flexibility and their ability to print on large or heavy objects.

By taking the opposite approach and moving the printing system around a static object, iPrint has collaborated with MABI Robotic AG and Polytype AG to integrate a printing system with a large industrial robot and further develop their DTS workflow to improve the ability to print on large and heavy objects and to achieve a more flexible process.

Figure 1 *DTS printing system concept [1]*

Procedure

In the first phase of this study, a single-colour printing system was developed to print on a two-dimensional surface in different orientations and robot working spaces. An active ink pressure regulation system has been developed to compensate for the pressure variations caused by the dynamics to which the printing system is subjected when moved by the robot. The different samples were scanned by a microscope to determine the relative drop position errors by image processing and to show the capability of the Mabi MAX-100 robot for DTS applications. High-precision distance sensors built into the printing system provided further data on the robot's path accuracy and repeatability.

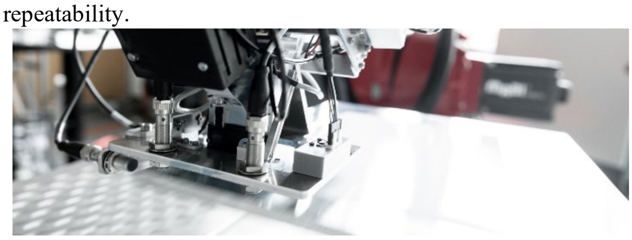

Figure 2 *single-colour printing system*

In a second phase, a four-colour printing system was developed to test the feasibility of high-quality graphic printing and selective coatings in a use-case with an automotive part. In the process, aspects such as path & image generation, position error correction, stitching quality, coating homogeneity and UV curing on 3-dimensional surfaces were addressed.

Results

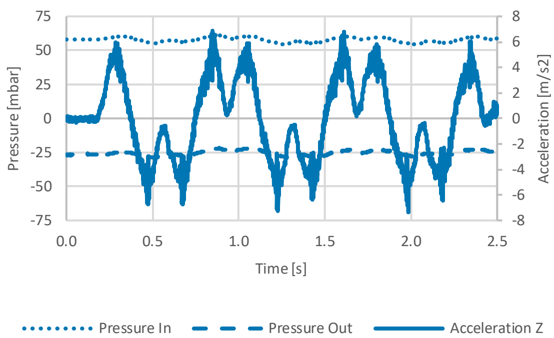

Figure 3 *Pressure and Acceleration data*

The pressure regulation tests showed a maximum deviation of 4.16 mbar in the differential pressure between the inlet and outlet of the print head at an acceleration of 7.36 m/s2. In addition, further print tests performed immediately after the accelerations showed that the additional qualitative criteria of no ink leakage on the nozzle plate and no air intake into the print head were met, thus validating the performance of the system.

Statistical analysis of the large-scale test data characterised the drop placement errors. A high correlation between the drop placement error detected by image processing and the position data generated by the laser distance sensors confirmed that the inaccuracy of the robot trajectory was the main cause of the positioning errors rather than the printing system. With the optimum parameters, an accuracy of 8 ±7.5 µm and a repeatability of ≤ 5 µm were achieved on 2D surfaces.

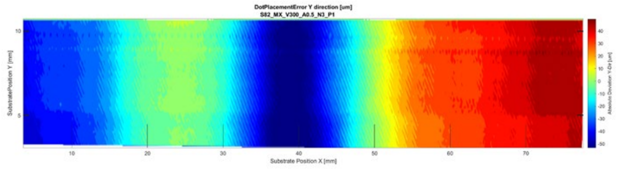

Figure 4 *Example of a contour plot of the drop placement error in Y-direction*

A prototype software was tested to generate both, path and image, and was continually improved by analysing the results. Initial printing tests on the real part, however, revealed printing errors attributable to an unacceptable deviation between the path and the real part. Manual measurements showed that the position of the real part deviated significantly from the position of the digital model. To overcome this problem, a point cloud of the real part was generated by scanning the part with a laser distance sensor built into the print module. This point cloud was then used to generate a new shape in CAD software, and the path and image generation was repeated. This significantly improved the printing results.

A further test, in which lines printed on the 3D surface were scanned, the error of these lines measured and then applied as a correction, resulted in an improvement in accuracy from +/- 140 to +/- 80 um.

Although there is room for improvement, the print quality achieved is very satisfactory for the first tests. The prototype system has proven its ability to perform the first practical applications.

Outlook

The overall results achieved in this project are very promising. A key topic for the future is to further optimise the path and image generation process towards an industrialisable solution. Furthermore, a solution for measuring the real part and correcting the path and image is needed. Finally, pre- and post-processing on the 3D surface needs to be further investigated and optimised.

References

[1] A. Balogh, Mabi Robotic AG, Inkjet printing –Challenges in Robotics (2023)

Author Biography

Philip Kessler studied mechanical engineering, specialising in plastics technology and lightweight construction, at the University of Applied Sciences of Western Switzerland in Fribourg. He is currently writing his thesis as part of the Master of Advanced Studies in Industry 4.0 at the Zurich University of Applied Sciences. He has worked for the iPrint Institute for 5 years and is responsible for mechanical engineering, platform development and management of industrial projects