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INTRODUCTION TO ADAPTIVE ROBOTICS

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Abstract

This introductory paper aims to demonstrate how adding a degree of adaptability in a robotics process can reduce disruptions and increase quality. The concept is presented through a machine tending example.

Introduction

Robotics and automation have been largely deployed in factories and monitored environments since the 20th century. With the advent of technological advances and increased needs for more flexibility, new generations of robots and programming methods have been emerging in the last decade. Now, robotics system can in some cases be safely deployed without safeguards and programmed via teaching and hand-guiding.

However, robot systems in manufacturing often lacks the required sensorisation and decision-making in order to have the same capabilities as humans - who are experts in coping with complex situations and in reacting to unexpected events. Robots, by design, are programmed to perform pre-set tasks, thus leading to a certain rigidity of the system. This leads to robot systems repeatedly executing their pre-defined tasks but unable to react to unexpected events, which often leads to interruption of the production. Other fields of robotics, such as service robotics or bio-robotics, uphold higher flexibility and adaptability in their design, which comes however at a cost of large complexity. There is a need to enable manufacturing robot systems to adapt to changes, either desired or unexpected, while limiting their complexity. This paper aims at demonstrating a simple concept that has potential to bring value in manufacturing robotics.

Value of Adaptive Robotics

Practical Example

IMR has developed a modular production line for testing both concepts and technologies in partnership with innovative companies. The modular line is composed of different interchangeable cells with various capabilities. One of these cells is a wash station for 3D printed parts and is comprised of a collaborative robot UR5, an automated washer, and an input and output jig (Figure 1).

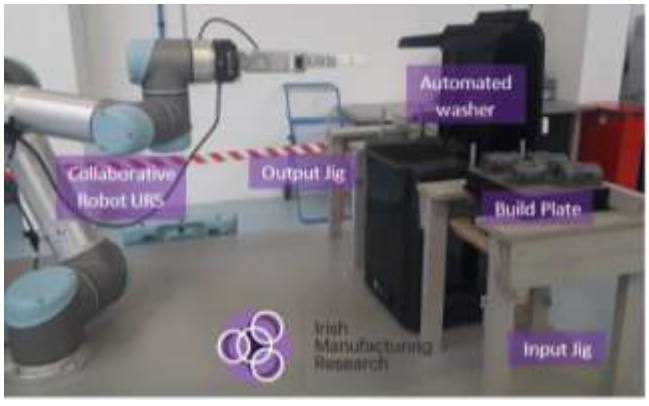

Figure 1 - Cell Setup

The automated process takes on the repetitive and strenuous manual process of plunging the parts up and down in the IPA solution and consists of the following tasks:

1. A mobile robot transports the 3D printed parts on their build plate to the wash station;
2. The build plate is placed onto the input jig;
3. The robot system picks the build plate and places it on the holding rails of the washer;
4. At the start of the washing cycle, the rails lower down to plunge the parts in IPA solution;
5. When the parts are rinsed, the rails ascend;
6. The robot system picks the build plate from the rails and places it on the output jig for collection.

Why the need of adaptability?

While the variability in this process is low as the positions of the different objects are mechanically limited, this process appeared to be an excellent example of how adaptability in robotics process can be beneficial.

Indeed, while the washer rails are deployed to the same height every time the door opens, the action of unplugging and re-plugging the power cable of the washer, which can happen during cable securing or maintenance, causes the rails to lower down. As a consequence, the robot system drops the build plate at the predefined placement zone, where the rails are no longer deployed, causing the build platform to fall from the cell.

While the consequences of this incident only led to product damages and interruption of the cycle process, this situation can happen easily and from different sources (maintenance, continuous improvement actions, etc.). This incident happened on this specific process, yet it can be easy to conjecture that a majority of robotics cells are exposed to incidents of similar type. A such, the robot system had a task - picking and placing the build plate into a preset location - and the task was performed as expected. However, this highlights the fact that there is a need for the robot system to cope with different situations. This can be done on different levels, easily or in a more complex manner, adapting to either foreseeable situations or to any situation at all.

In this case, the height of the wash station rails does not alter with the quality of the output and can therefore be accommodated within the process cycle. While the situation is not critical, this represents a good opportunity to implement the concept of simple robotic adaptability into the production line.

Adding a degree of adaptability

For the robot system to adapt to the height of the rails, it has to sense its environment. While a vision system would provide with a lot of information about the surroundings of the robot system, the vision implementation and data processing is also highly complex. In order to simplify the concept, the choice has been made to equip the robot system with a force and torque sensor, enabling the system to detect forces applied on the end-of-arm tooling.

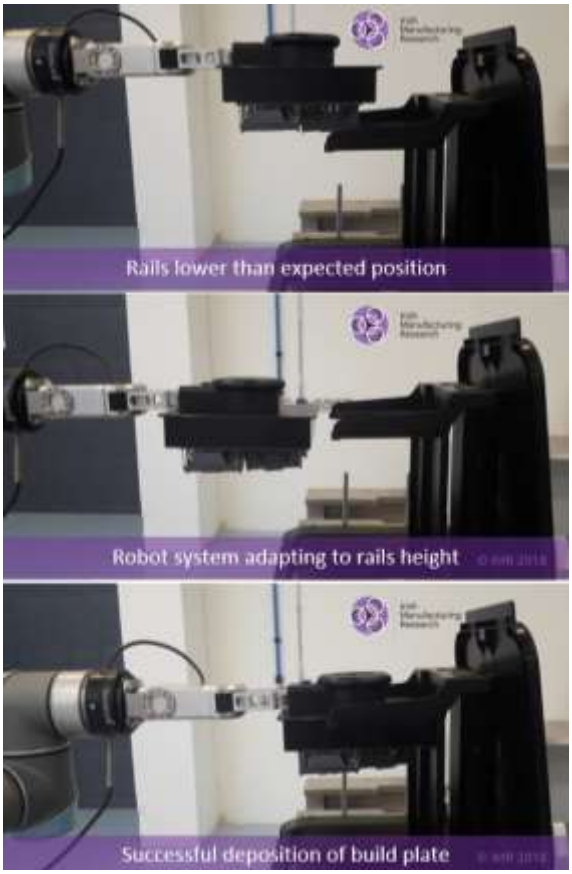

Figure 2 - Adaptation to rails height

With the ability to sense the environment by "touch", the robot system can now detect any objects in its trajectory. The force feedback is therefore used to perceive whether the rails presented a resistance to the robot arm during the placing approach. If the pre-set force threshold is not detected at the full extended height, the robot arm would then lower itself and seek to find the rails. With this cycle of lowering until detection of the force threshold, the

robot system is able to place the build plate exactly on the location of the rails (Figure 2).

The demonstration of the concept presented above offers great value in reducing time waste and defects on the production cell, while using a simple method, both in terms of programming complexity and implementation time.

Impact of adaptability

The ability of the adaptive program to successfully place the build plate onto the rails has been tested over 90 runs at 3 different rails heights. This led to the conclusion that with 95% confidence, the success rate of build plate placement at different rail heights is above 90.5%. Repeatable success in the placement of the build plate limits disruption in the production, product damages, and leads to less operator input needed for process recovery, reducing therefore health & safety risks related to the exposure of operators to robot systems. While the impact of the disruption taken as example for the concept presented in this whitepaper is not highly critical, other similar situations in a manufacturing environment can have damaging consequences.

Further applications of the concept

The concept introduced in this whitepaper aims at demonstrating the high value that simple adaptive robotics can bring in a manufacturing process. While straightforward, this concept can act as a first step towards a highly adaptive line.

To fully extend the adaptability of robotics systems, more complex solutions have to be put in place. A valuable approach for wide adaptation is to use reinforcement learning for robotics, where the robot system is given a goal and rewards depending on its actions. The robot system then learns via trial and error how to achieve the given goal. Examples of deep learning for robotics show how robot systems can adapt to any situations using reinforcement learning given enough training.

Force feedback and deep learning are on both ends of the scope of adaptive robotics solutions and many other possibilities can be applied to increase flexibility in automated processes.

In the same way that significant progress has been made from early industrial robots to the intelligent robot systems that have appeared in the last decades, there is a long way to go to reach the wide deployment of fully adaptive robotics. IMR's mission is to help pave to way for Irish companies to reach this ambitious goal.

For more information visit imr.ie.