Chapter 2

Developing a Cyber–Physical System for Hybrid Manufacturing in an Internet–of–Things Context

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ABSTRACT

This chapter describes design and development of the HORSE system for process-oriented hybrid manufacturing that seamlessly integrates human and robotics actors in vertical manufacturing cells that are horizontally coupled in end-to-end manufacturing processes. The HORSE system supports advanced dynamic actor allocation to work cells, direct robot control and human actor instruction, closed-loop local event processing, and near-real-time global event processing. The system handles abstract process definitions and status information on the one hand and directly interfaces to industrial sensors and actuators on the other hand, making it a system with a strong cyber-physical character. The physical side of the system is deployed in an internet-of-things context, where the things are the industrial robots controlled by the HORSE system, the sensors feeding data to the system, and the products being manufactured in the industrial process managed by the system. The system will be deployed in real-world, industrial pilot scenarios in a European Horizon 2020 project.

INTRODUCTION

The use of advanced robots in manufacturing is becoming more and more commonplace in industry. This is for instance very evident in the German Industrie 4.0 initiative towards smart manufacturing (Germany Trade & Invest, 2014). Where robots used to be applied mainly in large, high-tech manufacturing plants, their application becomes increasingly accessible for a diverse range of manufacturing companies, even if they are small or medium enterprises (SME organizations) or not in a high-tech environment. Robots are used for highly repetitive tasks (such as making large numbers of spot welds), tasks that require strong force (such as lifting of heavy objects) and tasks that are unhealthy or dangerous to human workers (such as working in hazardous atmospheric conditions).

The use of robots in manufacturing is, however, not always very flexible and efficient. Firstly, this is caused by the safety requirements: if robots are not equipped with the right technological context, their use may present a safety hazard for human workers in the same physical space. Consequently, spaces where robots work and spaces where humans work are often physically separated, possibly leading to inflexibility and inefficiency. Secondly, the inflexibility is also caused by the work allocation specification: robots have their specific tasks and human workers too - it is not easy to transfer tasks from one class to the other. In other words: dynamic actor allocation in manufacturing cannot easily cross the human/robot boundary. This may lead to inefficiency where it comes to optimal resource usage. Thirdly, robot control processes are often poorly integrated in overall, end-to-end manufacturing processes. Robot control processes often follow a vertical orientation, focused on the operation within individual manufacturing work cells. End-to-end processes follow a horizontal orientation, focused on the operation across work cells and in the context of enterprise information processing.

The HORSE project is set up to address the three issues identified above. HORSE is a European Research and Innovation Project in the European Union (EU) Horizon 2020 Framework. HORSE runs from 2015 to 2020 and brings together 15 organizations, among which research institutes, technology providers, and manufacturing organizations (see http://www.horse-project.eu/ for more details). HORSE aims at designing, developing and testing an integrated software environment that explicitly supports (1) safe collaboration of human and robotic workers in the same physical environment, (2) flexible, dynamic allocation of manufacturing tasks to robotic workers, human workers, and hybrid teams of both, and (3) integration of vertical, within-cell manufacturing processes with horizontal, across-cell processes and linkage of these to enterprise-wide business processes.

In addressing the three issues above, HORSE integrates the ‘cyber’ aspect of business information processing with the ‘physical’ aspect of robotics, arriving
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