Editorial

Special issue on industrial robot agility

This special issue of the *Industrial Robot* journal is focused on industrial robot agility with co-guest editors Craig Schlenoff (National Institute of Standards and Technology), Stephen Balakirsky (Georgia Tech Research institute) and Murad Kurwa (Flex).

Advances in automation have provided for sustained productivity increase and manufacturing growth over the past decade. Continued sustainment of this growth will require automation to become more agile and flexible, enabling the automation of tasks that require a high degree of human dexterity and the ability to react to unforeseen circumstances. Applying robots is one promising approach, but their traditional program-by-teaching model takes considerable time, requires extensive expertise and does not lend itself to tasks that require adaptability. This has kept robots in high-volume, repetitive operations and precluded them from low-volume, time-critical and flexible projects. Off-line programming of robots is possible, similar to the computer-aided manufacturing method widely used for machine tools. However, the poor accuracy of robots compared with machine tools limits them to jobs with undemanding tolerance requirements or requires additional methods such as calibration, modeling and external sensing to improve their accuracy. These methods increase the upfront cost of a robotic system. However, advances and cost reduction in sensing technologies (especially laser scanning) have brought robot systems into the price range of even small-to-medium enterprises. In addition, use of end-of-arm-tool has given integrators the ability to provide faster turnaround time and utilize the same infrastructure in a high-mix, low-volume environment.

The robotic systems of tomorrow need to be capable, flexible and agile. These systems need to perform their duties at least as well as human counterparts, be quickly re-tasked to other operations and cope with a wide variety of unexpected environmental and operational changes. To be successful, these systems need to combine domain expertise, knowledge of their own skills and limitations and both semantic and geometric information. Papers in this special issue will highlight advances in these areas.

Papers for this journal special issue were solicited in the areas of:

- robot agility through knowledge-based approaches;
- human–robot and robot-robot collaboration;
- hardware approaches to allow for robot agility;
- planning approaches to enable robot agility;
- knowledge-based robot control;
- artificial intelligence techniques;
- test methods to measure robot agility;
- robot agility metrics; and
- advanced robot simulations.

Over 50 papers were submitted, with only a small subset of them accepted and published in this special issue. Robot agility involves many aspects, such as the bullets listed above; therefore, we attempted to include a cross section of papers that addressed various aspects.

We start the issue with three papers addressing representation aspects of agility. The first paper, "Requirements for Building an Ontology for Autonomous Robots", describes the autonomous robotics subgroup of the IEEE ontologies for robotics and automation working group and describes their work in specializing the Core Ontology for Robotics and Automation standard to focus on more specific concepts and axioms that are commonly used in autonomous robots. The second paper, "Industrial Robot Capability Models for Agile Manufacturing", describes the representation of a capability model for industrial robots as they pertain to assembly tasks. The third paper, "The Canonical Robot Command Language", describes an information model which provides a high-level description of robot tasks and associated control and status information.

The next set of four papers focuses on planning, learning and control. "An Agile Robot Taping System - Modeling, Tool Design, Planning and Execution" describes an automatic agile robotic systems and corresponding algorithm to perform surface taping. The corresponding path planning takes into account the mathematical model of the taping process. The next paper, "Trajectory Planning for a Planar Macro-Micro Manipulator of a Laser-Cutting Machine", explores the development of a trajectory planner that may be integrated with industrial computer numerical control systems to resolve kinematic redundancy for task duration minimization. Learning is explored in the next paper, "Learning of assembly constraints by demonstration and active exploration", where a new approach for learning assembly constraints based on programming by demonstration and active robot exploration to reduce the computational complexity of the underlying search problems is proposed. The last paper in this section, "A review on the Evolvement Trend of Robotic Interaction Control", aims to address and analyze the state of the art on robotic interaction control which reveals that both practical and theoretical issues have to be faced when designing a controller.

The last three papers look at a plethora of additional topics related to robot agility. The first paper in this section, "A Comparison of Industrial Robots Interface: Force Guidance System and Teach Pendant Operation", proposes an evaluation method to compare two different human–robot interaction solutions that can be used for on-line programming in an industrial context: a force guidance system and the traditional teach pendant operation. The second paper, "Test Methods for Robot Agility in Manufacturing", defines and describes test methods and metrics to assess system efficiency and effectiveness which can then be used for the assessment of industrial robot system agility in both simulation and in reality. The final paper "Robots Collaboration for Wearable Products Lifetime Testing" explores a practical application of robot agility for wearables by using robot simulation based on associated mathematical models to represent the motion of humans wearing a wrist band to test the product's predicted life span.

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