WP1 Robust and Adaptive Manufacturing Systems

The factory of the future has to at least expose two fundamental properties that are seldom found on a broad scale in contemporary manufacturing:

- **Reconfigurable machine tools and support equipment**
- **Open architecture shop floor control systems**

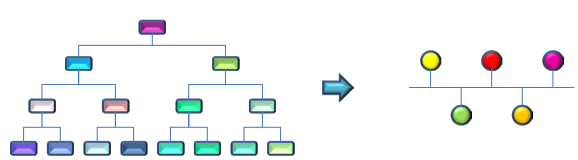
The reason for this is the expectations of even shorter product life cycles than we see today. This is due to a sharpened focus on continuous product development as an important factor of competitiveness and customer demands for individualized product features. The two basic requirements are fundamental to what is known as Reconfigurable Manufacturing Systems (RMS) which exposes six core characteristics: *Modularity*, *integrability*, *customization*, *convertibility*, *scalability*, and *diagnosability*.

Achieving reconfigurability

Based on initial studies of the literature on RMS, the research activities of WP1 were soon dedicated to answering the crucial question of *how open architecture shop floor control systems can facilitate reconfigurable manufacturing*. Perhaps the most obvious contribution of open architecture control is to the characteristic of *integrability*. Many control functions found in any manufacturing system are proprietary and considered as vendor specific 'black boxes'. Although more and more control devices come with an Ethernet interface, there is still a need for a "neutral" wrapping of the associated controllers in order to make them communicate efficiently over a network. This kind of controller wrapping is the key to integrability. Open architectures and *modular design* can be considered as two sides of the same coin. Achieving one without the other is intrinsically difficult so open architecture control also contributes to *modularity*. *Diagnosability* is a feature which is supported by open architecture and modular control systems because fault detection is generally made more easily when the functional units are modular.

Holonic Manufacturing Systems

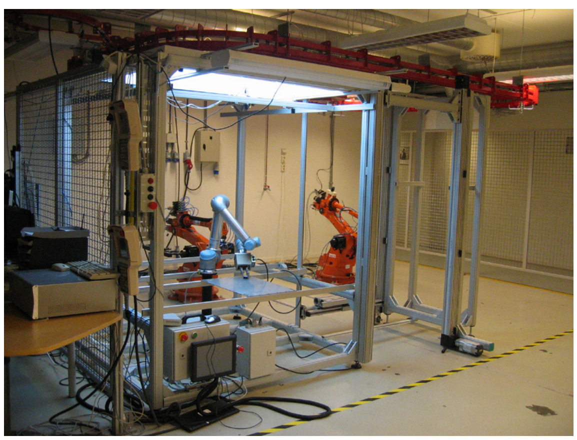
A major source of inspiration to the research activity has been the work of Hendrik Van Brussel on *holonic manufacturing systems* (HMS). The dual role of holons operating in a delimited system context is a key to achieving non-hierarchical, dynamic control systems. The role duality comes from the observation that although it is easy to identify sub-wholes or parts, '*wholes*' and '*parts*' in an absolute sense, do not exist anywhere. From this observation holons are simultaneously self-contained wholes to their subordinated parts, and dependent parts when seen from the inverse direction. The concepts of holons, autonomy, cooperation and holarchy are fundamental to HMS.



APROX framework and test applications

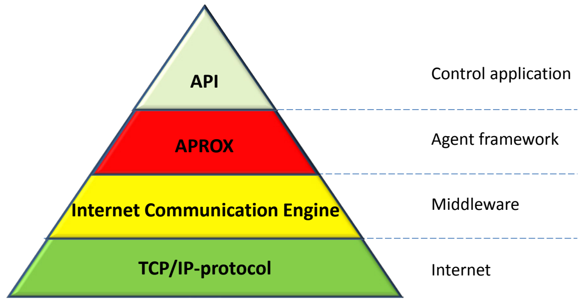
The research activity has been concentrated on constructing a software framework for developing distributed, modular control systems based on RMS characteristics and some fundamentals of HMS. More specifically, a toolbox supporting an integrated development environment for reconfigurable control systems (IDE for RCS) has gradually been filled with design and implementation tools. These tools include diagramming of multilateral agent interaction and individual agent behavior, resulting in automated production of code skeletons for each individual agent preserving the interaction patterns and facilitating state machine implementation.

The framework and the associated IDE for RCS (APROX[1]) have successfully been applied to industrial test cases, primarily in order to obtain a proof of concept. APROX-based control of a laboratory setup for assembly of damping systems at Sandvik Teeness has been demonstrated. In addition, APROX-controlled



assembly of airbrake couplings at Kongsberg Automotive has been simulated. The APROX design approach has been proposed to Volvo Aero Norway for redesign of their production lines for jet motor vanes. Sandvik Teeness is about to build an industrialized version of the assembly cell and considers seriously an APROX-based control solution.

Even though the APROX framework exposes promising qualities, some of its associated methods are not aligned with the



basic principles of non-hierarchical structures of autonomous actors (controllers, holons, agents, etc.). These deficiencies will be addressed in the future research activities. The scope will be set by studying basic *agent-oriented* design methods for manufacturing control and especially by focusing on how to identify agents in a true bottom-up guided analysis and design process.

Agent-oriented design

Applying top-down analysis and design methods in order to obtain non-hierarchical agent structures will inevitably sooner or later result in top-down oriented control agents in bottom-up disguise. Hence, the IDE for RCS toolbox must provide alternatives to these traditional and well-proven top-down methods. All aspects of agent-oriented design will be taken into consideration in search for these alternatives. The overall objective is to furnish the toolbox with methods and tools that fundamentally support reconfigurable manufacturing control with modularity, integrability and diagnosability.

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[1] Agent-based Product-Resource-Order eXecution