Adaptation and Evolution in Machining Systems Design

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Parallel Machine Flexible Mfg. Systems

Shared mirror type tool magazine:
- Super tool: 291-999
- Number of tools HSK-A100: 343-2258
- Tool registration with buffer: 12 x
- Washing + tool check: 34-100
- Number of pallets: 34-100

Pallets automation on 3 different levels
Traditional Flexible Manufacturing Solutions

- Over sizing
  - Capacity
  - Flexibility
  - Precision
- Advantages
  - High saturation in highly chaotic shop floors
  - High residual end of life value
  - Short time advantage for machine tool builders
- Drawbacks:
  - Increasing costs
  - Reduced productivity
  - Reduced competitiveness in the global market

Focused Flexibility Mfg.
Plant

- Designed to deal with a specific production problem
- Configured to provide the exact amount of flexibility
- Re-configured to adapt to changing requirements
Re-configurability

- Multi-step installation of complex systems
- Adding new machines to an existing system
- Substituting an old machine with a new one
- Integrating new high performance components
- Modifying automation to adapt to a new part mix
- Re-arranging the manufacturing plant layout
- Integrating new processes and services

Evolution in Focused Flexibility
Mfg. Plants
Multi-purpose Robotized Material Handling

Re-Configurable 5-Axis Machining Modules
Extensible Autonomous Machining Cells

Issues in designing extensible autonomous manufacturing systems

- Mechanical Design
  - What are the right modules to build?
- Control Design
  - How to cope with complexity introduced by extended manufacturing systems life cycle?
Design of modular production system:
Integrated Design Methodology

Bottom-Up Approach

Top-Down Approach

Functional decomposition

Control design

Integrated Design Methodology

Groups

Elementary components

Components Aggregation

Mechanical Design

An object framework for production system modeling
Adaptation to the environment

*ad aptare* → to fit to

“Any process whereby a system is progressively modified to give better performance in its environment”

[Holland ‘92]

- **Environmental Niches**: A set of features of the environment which can be exploited by an appropriate organization of the system.
- **Schema**: A co-adapted set of capabilities which together significantly augment the performance of the corresponding system.

Adaptation in Manufacturing Systems

- A manufacturing system evolves through various reconfiguration steps to adapt to a dynamic manufacturing environment.
- A manufacturing system family (a species) evolve to improve its performance in a manufacturing niche.
- The overall capacity of a manufacturing systems builder evolves to improve its performance in an high competitive market.
Re-configuration, re-factoring, re-shaping

- Re-configuration of an individual system
  - Selection and combination of different concrete variants to improve performance
  - Introduction of some new concrete variants
- Re-factoring of a species
  - Modify old abstraction to improve re-use of existing variants
  - Introduce new abstractions to enable re-use of new variants
- Re-shaping of a genre
  - Monitor the market for emerging niche
  - Develop new specific modules directly addressing market niche specific features
  - Develop new schema of co-adapted features to address niche specificity

Distribute control for evolvable automation

- Availability of embedded processor
- Time frame not compatible with network latency
- Performance enhancement through parallelism
- Simplified realization, maintenance and evolution through parallelism and plug 'n operate approach
- Cost reduction through components reuse
- Legacy system integration
Model Driven Architecture: Application to automation control

- Everything is derived from the model.
- Model of the control system.
  - Platform independent
  - Knows nothing about classes, functions, variables, types, …
  - Concerned with devices, sensors, actuators, transport missions, …
- Platform Specific Model
  - Model of the software.
  - Different for specific PLC, Robot Controller, CNC …
- Both can be described using UML

Diagnostics for evolvable mfg. systems
MCM Strategic Innovation and Research Projects

  - New MODular production system architecture to combine FLEXibility and PRODucity

  - Innovative methodologies to realize mechanical machining stations

  - Total life cycle web-integrated control- design-architecture for distributed control systems

  - Virtual Research Lab for a Knowledge Community in Production

  - PABADIS based Product Oriented Manufacturing Systems for Reconfigurable Enterprises

  - Virtual Automation Networks

Conclusions

- The development of evolvable autonomous manufacturing systems requires integration between plant and control design:
  - To realize an adaptation process that support discovering of the “right” abstractions (components) and configurations (schema) in relation with emerging manufacturing niches

- Model driven development could provide a cost effective method to cope with higher level of complexity of such systems:
  - enabling component based re-use along various life cycles with different time frames for individuals, species and genre.