Modeling the Engineering Process of an Agent-based Production System: An Exemplar Study

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Context

Agent-based smart CPS are a novel class of complex systems:
Autonomous.
Intelligent entities (software agents).
Interact with the underlying CPS to orchestrate, optimize, and control the overall behavior.

Cyber-Physical Production Systems:
Cyber-physical production systems (CPPS) apply CPS principles onto production systems, augmenting these systems with capabilities to increase the product quality and distribution time.

Multi-Agent Systems for CPPS:
Multi-Agent Systems (MAS) accommodate multiple autonomous agents.
Integrates collaborative features into system.
This enables solving problems in a joint effort by multiple agents, that cannot be achieved by a single agent.
What is proposed?

- Application of the FTG+PM in the engineering of an agent-based production system (ABPS).

- We have developed a simplified cyber-physical demonstrator.

- It represents many characteristics of real ABPS. Specifically, an agent-based smart CPS.
Engineering Of A Smart Production System Demonstrator

The demonstrator emulates the behavior of industrial classes of ABPS, but simplifies their cyber and physical parts to the degree that enables experimentation and analysis for developing our approach.
Multi-paradigm Modelling

Multi-formalism:
It is motivated by the required interplay between the architectural, mechanical, control, and agent-based engineering domains.

Multi-components:
• The actual physical platform of the demonstrator is built from specialized LEGO bricks.
• It is augmented with motors, sensors, buttons and embedded devices, such as a Raspberry PI 3 and a BrickPI.
FTG+PM

Fig. 8: The FTG of the process model.
FTG+PM
Nested Activities

Fig. 7: The sub-processes for compound activities in the main process model.
Discussion

Architectural models as first-class elements:

- We found it cumbersome to reason about the engineering of the system by just looking at the FTG and the PMs.
- Our experience motivates augmenting the FTG+PM with architectural descriptive capabilities as first class citizens.
- We suggest the development of front-end tools that can make use of a continuously evolving FTG via the mechanisms of bootstrapping and incremental compilation.

Formal description of engineering patterns of agent-based CPS:

- The semantically unified cyber and physical parts of the engineering process enable reasoning about the complex cyber-physical engineering patterns of CPS.
- But the notion of components, and the incorporation of physical types is not properly addressed.
- The ability to describe engineering patterns in appropriate depths further enables the construction of pattern libraries. So, the engineering patterns tend to become complex as well.
- Extensible libraries offer a suitable way of reducing the costs and errors stemming from this complexity.
Discussion

Abstraction of the FTG:

• The most appropriate formalisms should be used to capture the dynamics of an engineering endeavor.
• Our process could make use of types, such as "Physical Component", and relationships, such as "partOf".
• Cyber and physical parts are blended,
• For physical part the notion of "formalism" does not provide an appropriate typing primitive.
• Push motor, press motor etc. abstracted into a physical component called "motor".
• There is an opportunity in extending the FTG to a Class-Relationship Graph.

Optimization of re-engineering cycles:

• Re-engineering cycles and iterations are modeled with decision-merge pairs.
• As the complexity and size of the engineering case grows, decision-merge leads to over-usage of the control edges, while the comprehensibility and maintainability of the model severely degrades.
• Therefore, developing advanced enactment-execution semantics of the PM is required As the first step, the van der Aalst workflow pattern catalog should be
Discussion

- **Advanced run-time adaptation semantics in CPS:**

The FTG+PM is traditionally employed in the design phase.
Extension to the scope of the FTG+PM to the run-time phase.
Establishing advanced enactment/execution semantics.
This opens up the opportunity to employ the FTG+PM as a Digital Twin of the running system, and control its behavior based on advanced real-time simulations.
For this purpose, DEVS can be employed.
Thank you for your attention