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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.

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Engineering Of A Smart Production System Demonstrator

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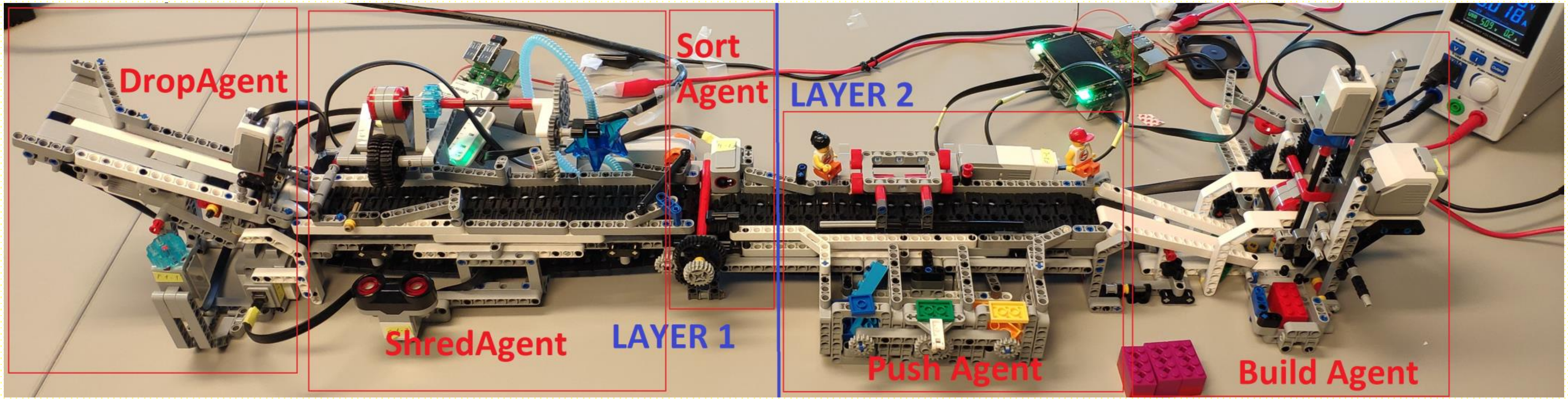
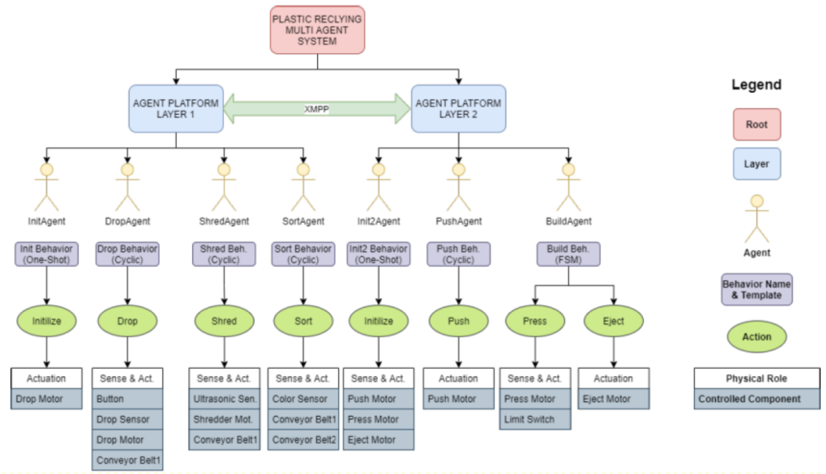
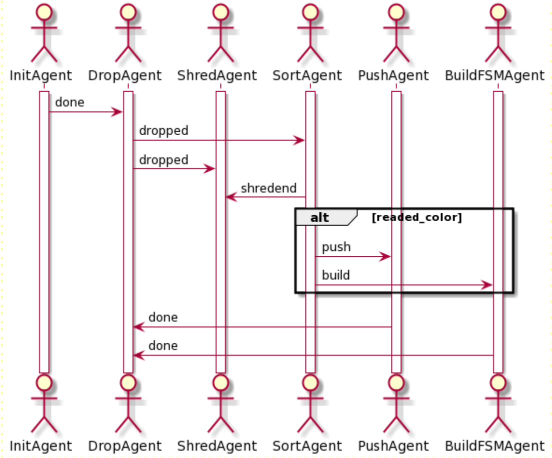
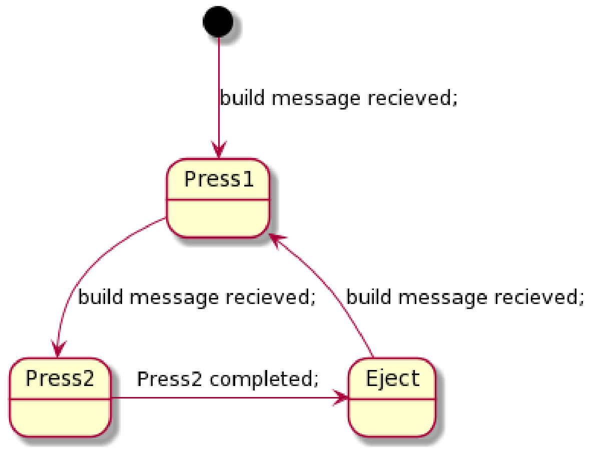
The demonstrator emulates the behavior of industrial classes of ABPS, but simplifies their cyber and physical parts to the degree that enables experimentation and analysis for developing our









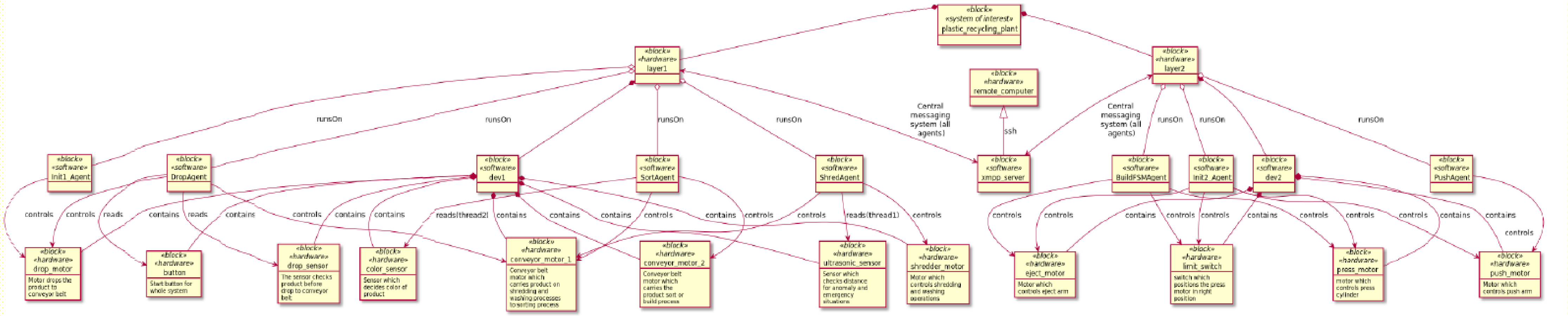
Multi-paradigm Modelling

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.



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FTG+PM

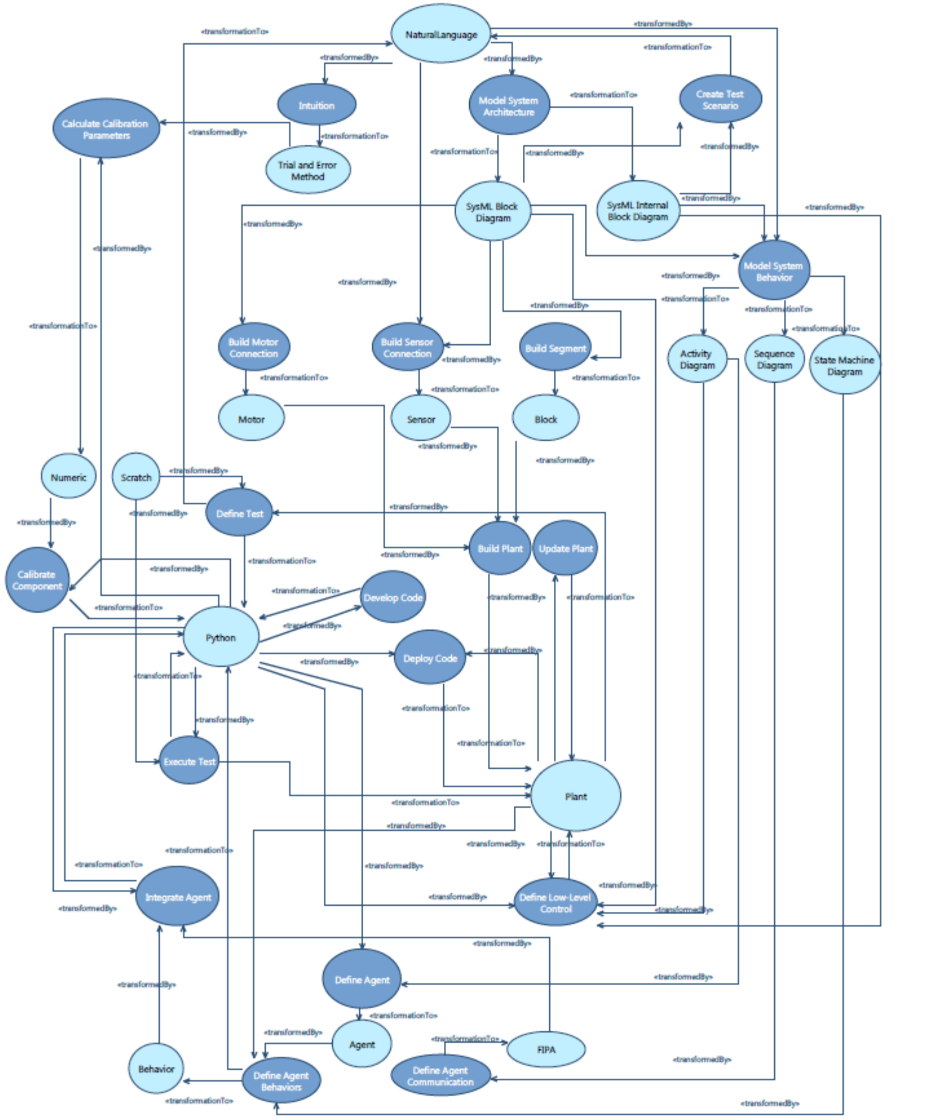
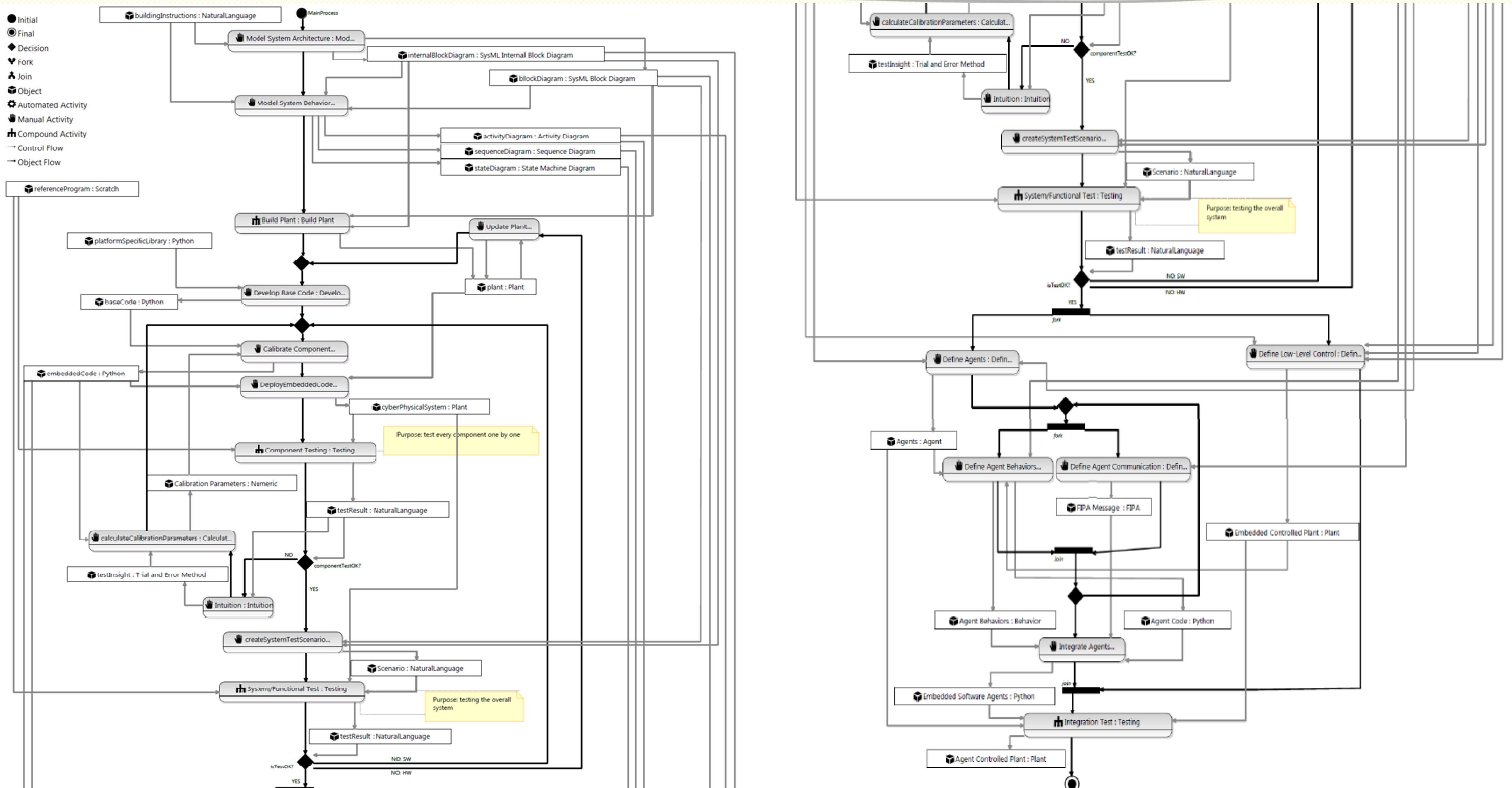


Fig. 8: The FTG of the processmodel.

FTG+PM



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Nested Activities

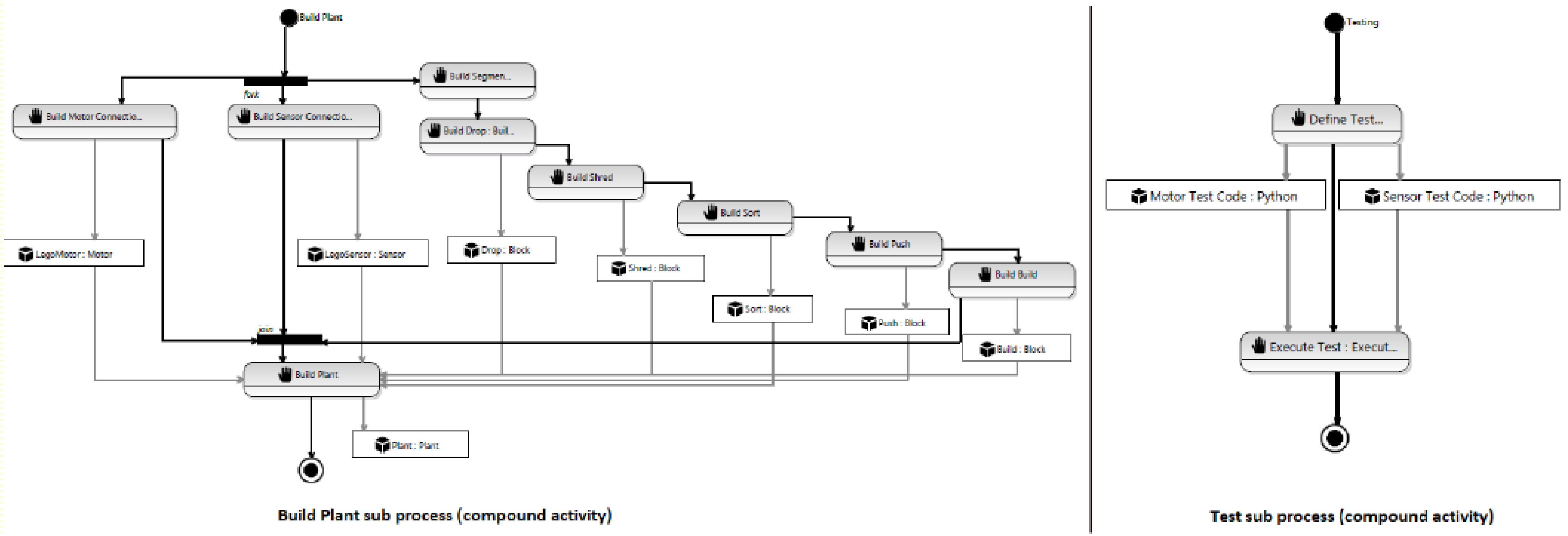

Fig. 7: The sub-processes for compound activities in the main process model.

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

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