Short Term Scientific Mission (STSM)
Scientific Report for COST Action IC1404
MPM4CPS

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STSM Title: Multi-view modeling and model-driven development of A Cyber-Physical System: Formalism Transformations for the Fire Detection Use Case
Working Group: WG4 (Education and Dissemination)
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1. Initial purpose of the visit

The development of a Cyber-Physical System (based on WSN and IoT elements) is a complex task as it usually consists of several components for: communication, control, and computation. It becomes even more complex when we consider heterogeneous types of embedded devices. To manage this complexity, in this STSM, the possible model transformations is analyzed to transform a formalism to other formalisms/artifacts. These transformations helps the developer to automate part of the development in its different phases. The proposed approach will be applied on a use case called Fire Detection System. A multi-view models will be proposed (to model the process and transformations) for this domain to increase the performance and quality of developing these systems. To this end, FTG+PM framework will be used to provide the process model and formalism transformation graph to make the development of these systems more efficient.

2. Description of the work carried out during the STSM

In this STSM, we focused on extracting the general process model for developing CPSs and discovering the formalisms which can be used in this process model. Different steps of developing an CPS/IoT are discussed in this process model. Also, we worked on finding the possible transformations between these

formalisms. To present these series of transformations as a graph the FTG+PM framework is adopted. As a result, two models are presented according to the FTG+PM framework: Formalism Transformation Graph (FTG) and Process Model (PM). These models are demonstrated in a use case called fire detection system.

FTG+PM framework is used to define all relations between different formalisms using transformations, to build a process model next to this and to enact this process based on these languages and transformations. Experiences from the megamodelling, process modelling and transformation chaining communities are used to construct the FTG+PM.

The framework used to define FTG+PM consists of two sublanguages:

- Formalism Transformation Graph (FTG) language: This language allows declaring a set of languages that can be used to model within a given domain, as well as the transformations between these different languages. This corresponds to a megamodel.

- Process Model (PM) language: is used to describe the control and data flow between MDE activities. A subset of the UML 2.0 activity diagrams is used for this.

The Development Process Model:

This section discusses the development process of a CPS/IoT based on WSN systems and WiFi components. The system analysis and design are generally based on SysML principles. The development process includes the hardware, software, and networking parts of the system and covers the entire process starting from analysis to testing.

The activities constituting this process and their order are described below:

- System analysis
  - Defining the systems functional and non-functional requirements.
  - Providing use case diagrams describing the important scenarios for the system. Use case specification elaborates the events and flows of the system including normal flows, alternative flows, and exception flows.

- System design
  - For the architectural design, the Package Diagram (PD) and Block Definition Diagram (BDD) can be used based on SysML principles.
  - The detailed design can be realized by providing Internal Block Diagrams (IBD) based on SysML principles. The BDD and IBD can provide the required structural modeling of the system. However, the other SysML diagrams such as parametric diagram can also be applied.

  - State machine diagram and activity diagram can be provided to model the system behaviour. These diagrams can be developed using the flows provided in the analysis phase. In addition to this diagram, the other behavioural diagrams of SysML can be used, such as sequence diagram, depending on the needs of the system under development (SUD).

- System modeling and simulation: As a CPS or IoT system is composed of several hardware, network and software components, a bottom-up approach can be a useful way to develop the system. To realize the system modeling and simulation, the following steps can be applied:
  - The system modeling can start with the physical model of the system where the hardware has interaction with mechanical or physical components. For example, a CPS with a servo motor component used for lifting a weight can be modeled by physical rules to be used later in the implementation phase.
  - The setup model for configuration of sensors and actuators with micro-controllers or development boards. This can be realized in different hardware modeling environments depending on the level of modeling, such as Proteus.
  - WSN setup model can be done in a modeling environment such as Cooja in which you can also simulate the WSN to check its functionality.
  - Software model: the software model can be provided using UML diagrams such as class diagram, object diagram, interaction diagram and so on to model the structural and behavioural aspects of the system software. These diagrams can used to model the software components of the CPS systems such as web-based application, database, gateway program, or embedded software on the devices.

- Implementation
  - Networking setup
  - Hardware setup and wiring for actuators and sensors with their computation devices such as development boards.
  - Software generation: the software can be partially generated depending on the DSML which is used and its generative capability. Usually this code is an template or architectural code and needs to add delta codes to have fully functional code.
  - Software development: For those software components which are not generated via DSMLs, the manual development has to be done based on the design models which are already provided.

- System test and verification

– Hardware, network, and software components can be tested separately and integration test can be done via test cases as posting events to monitor the results.

The Development Formalism Transformation Graph:

Based on the proposed process model, different formalisms and transformations between these formalisms can be used in the development of WSN and Internet based CPS and IoT systems, from the requirement engineering to the testing. The transformation between these formalisms can be manual or automatic. These transformations are used/instantiated in the Process Model. In our FTG model, the transformations and their input and output languages are discussed.

3. Description of the main results obtained

The main result of this STSM is a general process model including the control flow and data flow for developing the CPS and IoT systems based on WSNs and Internet connectivity modules. Also, the formalisms and languages which are used in this process as well as the possible transformations (manual or automatic) between these formalisms are defined in a formalism transformation graph for the development of thes CPS/IoT systems. These two models are presented in the FTG+PM framework and demonstrated on fire detection system.

The result can be used in the development of the other use cases. Also the common patterns can be investigate among FTG models of different use cases to find out the commonality and variability of developing these kinds of CPSs. This can be used for further MDE of CPSs to improve their development.

4. Future collaboration with the host institution (if applicable)

The collaboration will continue and the proposed development models will be extended by solving the issues discussed in item 3 and results will be reported as a publication.

5. Foreseen publications/articles and other contributions

In this short report, we summarize the results. The details of the results including the details of the process model and the formalism transformation graph are planned to be published in an academic event.