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COMPOSABLE MODELS AND SOFTWARE FOR ROBOTICS SYSTEMS

DELIVERABLE 5.6: PROGRESS REPORT ON OPEN CALL I EXPERIMENTS

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Content

Executive Summary

This document presents the mid-term progress review of the six Integrated Technical Projects (ITPs) selected in the first RobMoSys Open Call over the first reporting period (6 out of 12 months progress). This deliverable reports the progress of work package WP5 "Open Call" of the RobMoSys Project, related to task T5.5: "Monitoring and review".

The main topics of this report are:

- Background on ITP management and expected objectives.
- Preliminary global progress assessment in terms of performed activities and achievements.
- Preliminary individual ITP progress reports and assessment, as well as adjustment actions to achieve the proposed objectives.

This interim report is focused on evaluating the conceptual understanding and preliminary tooling developments by the six ITPs. This scope will be extended in the final report by adding the measurements of Key Performance Indicators (KPIs) and success stories related to ITP contributions to the RobMoSys ecosystem.

Conclusions of this deliverable are:

- In general, the experiments follow the planned schedule and development plan, therefore the second and last reporting period should be successfully completed.
- Some issues have been noticed, mostly related to difficulties of aligning the existing solutions with RobMoSys paradigm and difficulties in adoption to the new toolchains. This was to be expected and is due to the fact that RobMoSys is a paradigm shift and not all impacts were to foresee during writing the ITP proposals.
- The key insight after this period is related to the crucial role of individualized coaching by RobMoSys core partners. Coaches play a particular role to ensure the integration of the ITP contributions already while they are being developed and to assist the ITPs in lowering the entry hurdle that comes with a paradigm-shifting approach such as RobMoSys.
- According to the general feedback given by ITPs, the coaching is perceived very well and beneficial. This contributes to a constructive mood and atmosphere in the close collaboration between ITPs and RobMoSys: the integration of ITPs was successful and is a valuable contribution to community building.
- Therefore, the coaching approach is considered a mandatory success factor for Second Open Call. It must be reinforced during the Second RobMoSys Open Call and must be considered for further refinement in order to improve ITP productivity.

1 Introduction

RobMoSys's main goal is to create and consolidate an EU Digital Industrial Platform for Robotics to establish a common methodology for software development, improve tools and foster interoperability by model interchange and composability. The RobMoSys approach aims at solving critical issues observed in industry and will draw a migration path for a stepwise adoption of existing systems for interested early adopters. It will consist of specialized set of players with both vertical and horizontal interaction levels, providing both widely applicable software products and software-related services. This ecosystem will be able to rapidly address new functions and domains at a fraction of today's development costs.

The RobMoSys Open Calls are an essential means to achieve this goal. The First RobMoSys Open Call, which was open from July 2017 to October 2017, has funded six Integrated Technical Projects (ITPs) with a focus on strengthening the RobMoSys platform with better metamodels, tools and models. They cover core technical aspects of the RobMoSys ecosystem, including behaviour modelling, Quality of Service (QoS) management, functional safety, communication and control, and robotics performance benchmarking.

This report covers the evaluation of the progress made by the ITPs of RobMoSys during the first six months of the experiments. The ITPs are six teams which were selected during the First Open Call for RobMoSys, with competences in tooling, development of models and generation of associated software (implementations that realise the models, and that are created/configured by the tooling) demonstrated on system-level prototypical scenarios e.g., navigation and manipulation. All the outcome of those ITPs will be made publicly available and will serve to the industrial experiments as well as be available in the baseline of the Second Open Call.

This deliverable reports the progress of work package WP5 "Open Call" of the RobMoSys Project, related to task T5.5: "Monitoring and review". The description of first open call is provided in the deliverable 5.1: Open Call I Preparation Documents, whereas the selection process is covered in deliverable 5.4: Open Call I Evaluation and Selection.

1.1 Scope

This interim report is focused on evaluating the conceptual understanding and preliminary tooling developments by the six ITPs. This scope will be extended in the final report by adding the measurements of Key Performance Indicators (KPIs) and success stories related to ITP contributions to the RobMoSys ecosystem.

1.2 Document Structure

The remaining of this document is organised as follows:

- Section 2 provides background on ITP management and expected objectives, as well as a preliminary global progress assessment in terms of performed activities and achievements.
- In Section 3, we present preliminary individual ITP progress reports and assessment, as well as adjustment actions to achieve the proposed objectives.
- The next steps and conclusions are discussed in Section 4.

2 Overall Activities and Achievements

2.1 ITP Management

The consortium ambition is to integrate not just the ITPs contributions into the body of knowledge of RobMoSys, but also the ITP teams themselves into the RobMoSys community. To meet this goal, an important condition is to achieve a close and meaningful interaction between these ITP teams and the RobMoSys consortium, beyond the pure monitoring of their progress.

In order to guarantee and maintain the strong integration of ITPs with RobMoSys activities, three mechanisms have been effectively set:

(1) fluid communication,
(2) active coaching,
(3) agile reporting.

Fluid communication with ITPs has been supported by an infrastructure composed of a Discourse forum, and a Tuleap repository and wiki. Such a communication configuration is used as a first proof of concept for the fully open communication infrastructure that will be released for the upcoming RobMoSys community.

An **active coaching** strategy has been developed from work package WP5 according to which individual members of the consortium have been assigned to each ITP. These so called "coaches" are actively involved in the technical development of the ITPs taking the monitoring process a step beyond pure tracking of the project progress.

In order to achieve **agile reporting**, a monitoring digital platform was set up by TUM. This platform allows to store project deliverables, bimonthly reports and keep track of milestones as well as offering a space for discussion about the project progress between the ITP members and the assigned coach. This platform was designed to ease the coaches' work in keeping track of their project progress and reporting.

2.2 Meetings and workshops

The **Kick-off ITP Workshop** for the ITPs selected in the first open call happened on 5th March, 2018 in Barcelona, Spain. A two-day event was organized with workshops towards having a first interaction between coaches and project teams. Presentations were made to share details on the RobMoSys approach and to explain the monitoring process. Each project was given the possibility of presenting their proposal so all the teams involved would have a global perspective of the topics being carried on in the first open call. This was thought to be important since such a meeting leverages synergies and allows avoiding double work, especially if several projects share common topics (e.g., Behavioural trees). This approach has already proven to be fruitful since collaborations between projects have emerged.

A **Virtual ITP Workshop** for all the projects and the coaches was held on 27th June, 2018 organized by CEA. In this workshop the ITPs had the opportunity of enquiring the consortium about technical or non-technical issues in the implementation of their proposals and each of them were asked to elaborate on questions regarding: technical details on the implementation of their proposal and details on the connection between their contributions and the existing RobMoSys meta-models.

The event was very productive toward aligning views across different projects and to prepare the ground for the **RobMoSys Community and ITP Workshop**, which was hosted by KUL on 14th and 15th September, 2018 in Leuven, Belgium. Around 40 roboticists, representatives of the robotics and software engineering community and beneficiaries of the first set of ITPs discussed the challenges of RobMoSys. A structured dialogue and discussion with the audience about the challenges from the point of view of the robotics domain, the pain points from a robotics perspective and the views of the participants was valuable input for the ongoing work within the project, on its way to provide a tooling and software ecosystem towards an EU digital industrial platform for robotics.

Individual ITP coaching workshops (virtual and on-site) between coaches and ITPs have been set up per ITP. To ramp-up and foster the collaboration between coach and ITP and to ensure the integration of the technical projects in RobMoSys.

2.3 ITP Coaching

As part of the efforts towards integrating not just the ITP contributions into the body of knowledge of RobMoSys but as well the ITP members into the RobMoSys community, each of the ITPs are being individually coached by an assigned partner of the RobMoSys consortium. Concretely:

- EG-IPC – Herman Bruyninckx (KUL)
- MOOD2BE – Dennis Stampfer (HSU)
- CARVE – Matteo Morelli (CEA), with technical assistance by Dennis Stampfer (HSU) due to use of tooling provided by HSU
- RoQME – Dennis Stampfer (HSU)
- eITUS – Huascar Espinoza/Ansgar Radermacher (CEA)
- Plug&Bench – Eloy Retamino (TUM)/ Enea Scioni (KUL) , with technical assistance by Dennis Stampfer (HSU) due to use of tooling provided by HSU
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Overall coaching (master coach) coordination was performed by Huascar Espinoza (CEA).

The duties of these coaches include: active involvement in the technical development of their assigned ITP; aligning with RobMoSys background and to contribute in a consistent way; to be an external partner for discussions with a strong background in the RobMoSys methodology; to serve as main link between the ITP the RobMoSys consortium for questions, requests or to trigger potential collaborations or interactions between ITPs.

Coaches worked closely with ITPs in conference calls and ad-hoc face-to-face meetings. Some of the meetings have been organized as hands-on meetings of up one week duration. The goal of these meetings is to get strong alignment with the RobMoSys approach and ensure of a common technical understanding of the expected ITP outcomes. As a result, early ITP outcomes using RobMoSys pilots have been already published on a dedicated corner of the RobMoSys wiki (see Community Corner at the end of page https://robmosys.eu/wiki/community:start).

2.4 Overall Progress Assessment

The work plans of the six ITPs for the first semester focused on the following technical objectives:

- Conceptual detailed specification of the technical work.
- Development of metamodels, aligned to the RobMoSys metamodels, covering their technical areas.
- Specification of case studies and user stories.
- Early tool prototyping as a proof of the proposed model-based concepts.

During this period, the ITP consortia have pro-actively participated in the creation of the RobMoSys ecosystem and have achieved the following results:

a) ITP approach alignment with RobMoSys

ITPs proposed relevant contributions to the RobMoSys ecosystem as part of their submissions to the Open Call. However, the technical effort to align their conceptual approaches, implementation technologies and expected results was significant. During the very early phase of each ITP, the detailed specifications were released as result of: (i) intensive interaction with the RobMoSys consortium, (ii) coordination meetings with coaches and (iii) a set of core technical decisions to align their ITP plans to the RobMoSys principles and technologies. This includes terminology alignment, common understanding of software execution semantics, ITP metamodels preparation connected to RobMoSys metamodels, and implementation interfacing of ITP tools with RobMoSys toolchains.

b) Seamless link of RobMoSys with state-of-the-art middleware

As part of the alignment and integration of different execution platforms/middlewares with RobMoSys semantics, new mechanisms were proposed to allow technologies for a seamless interfacing. One concrete example is the link of RobMoSys component with YARP components in the context of the CARVE ITP. In a preliminary proof-of-concept demonstration, CARVE partners and RobMoSys partners used the so-called "Mixed-Port Component" concept to illustrate how the structures of RobMoSys can connect with YARP existing software components to ensure interoperability. Further information of this example can be found at: https://robmosys.eu/wiki/community:yarp-with-robmosys:start.

c) Development of solid user stories of RobMoSys usage scenarios

ITPs specified and developed user stories, describing specific user goals, tools usage procedure, and expected measures of success. The user stories were defined by ITPs but discussed with RobMoSys partners. The adoption of user stories has been an effective instrument to balance concreteness and technical focus in the light of concrete industrial usage of the RobMoSys platform. Some of these user stories were already demonstrated with the early prototype as described in the Community Corner of the RobMoSys wiki: https://robmosys.eu/wiki/community:start with links to the RobMoSys YouTube channel:

https://www.youtube.com/channel/UCURqFtHgAPsXl9mB_QgbBow

d) Cross-fertilisation and openness of ITP results

ITP workshops helped to identify excellent opportunities of cross-ITP collaboration, which were boosted by the open source approach in RobMoSys. Among the collaboration opportunities in current exploitation are: (i) the use of the MOOD2BE tools for behavioural tree modelling by the CARVE project, (ii) the use of the contract-based approach for safety constraints between eITUS and CARVE, (iii) implementation of the runtime monitors between the RoQME and CARVE projects. This is also true for the development of the RobMoSys Pilots (managed by RobMoSys industrial partners, HSU, and CEA), which were aligned to ITP plans and results. Examples are the CEA Pilot on Safety Analysis, which has been integrated with the eITUS ITP user story and the HSU Industry 4.0/Intralogistics Pilot, which was used as a test-bed and demonstration baseline for MOOD2Be, RoQME and CARVE have developed demonstrations based on the HSU Industry 4.0/Intralogistics Pilot.

e) Community building in a coaching-oriented environment

The ITPs actively participated in the RobMoSys Discourse forum (https://discourse.robmosys.eu/), open community workshop (Leuven, September, 2018) and provided useful feedback to refine the communication channels and community infrastructure in RobMoSys. This has been reinforced by the Coaching approach in RobMoSys, which helped to guide ITP partners in using the communication channels, provided a lively environment in Discourse and accelerated the information exchange; between ITP and RobMoSys partners.

f) Early results dissemination and publication

Some ITP partners were very active in publication of early results. Some publications are joint work with RobMoSys core partners, which is an example of the tight and constructive integration of ITPs in RobMoSys.One of these is the RoQME ITP with at least 5 papers already published, as described below:

- "Managing Variability as a Means to Promote Composability: A Robotics Perspective" (Lutz, et al., 2018), New Perspectives on Information System Modeling and Design, by IGI-Global.
- "RoQME: Dealing with Non-Functional Properties through Global Robot QoS Metrics" (Vicente-Chicote, et al., 2018), Model-Driven Software Engineering Track of the XXIII Jornadas de Ingeniería del Software y Bases de Datos (JISBD 2018)
- "A Component-Based and Model-Driven Approach to Deal with Non-Functional Properties through Global QoS Metrics" (Vicente-Chicote, et al., 2018), The 5th International Workshop on Interplay of Model-Driven and Component-Based Software Engineering (ModComp 2018)
- "Towards the use of Quality-of-Service Metrics in Reinforcement Learning: A robotics example" (Inglés-Romero, Espín López, Jiménez-Andreu, Font, & Vicente-Chicote, 2018), The 5th International Workshop on Model-Driven Robot Software Engineering (MORSE 2018)
- "Towards the Application of Global Quality-of-Service Metrics in Biometric Systems" (Espín, Font, Inglés-Romero, & Vicente-Chicote, 2018) IberSPEECH 2018 Conference

Another example is the CARVE ITP which results were submitted to international conferences:

- Colledanchise, M., and Natale, L., Improving the Parallel Execution of Behavior Trees, in Proc. IEEE/RSJ International Conference on Intelligent Robots and Systems, Madrid, Spain, 2018.
- Giunchiglia, E., Colledanchise, M., Natale, L. and Tacchella A., Conditional Behavior Trees: Definition, Executability, Applications, submitted to ICRA 2019.

3 Individual ITP Progress

The Integrated Technology Projects (ITPs) of RobMoSys are scheduled for a period of one year starting in March 2018. The progress of each ITP presented below refers to the first half of the project duration, corresponding to months M01-M06. The aforementioned progress reports are based on the mid-term reports provided by each of the experiments and the recommendations of the ITPs coaches provided as a tool for better comprehension of potential risks in each experiment.

3.1 EG-IPC

The EG-IPC (EG- IPC - Architecture and Components for Reliable Control over Networks, using Intrinsic Passivity Control) project is conducted by Universiteit Twente and Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderoek (TNO). The coach assigned to the project by RobMoSys is Herman Bruyninckx (KU Leuven).

Project objectives

Main goal of the project is the development all-time stable loop control components using Energy Guarded Intrinsically Passive Controllers. For the structure of these EG-IPC blocks, the development of metamodels that conform to RobMoSys is required. This entails formalisation of the generic IPC structure and adding energy guards on the interfaces of the components where needed as well as additional interfaces to communicate and synchronise the energetic state.

The specific objectives of the reporting period are as follows:

1. Development the required metamodels:

- Formulation of a metamodel that describes the bond graph modeling language : Required to formalize the power port and power bond entities and energy exchange mechanisms among components of robotic applications.
- Formulation of an IPC metamodel that conforms to bond graph and the RobMoSys' component architecture : Required to define the policies, mechanisms and constraints of the IPC component architecture.
- Extend the IPC metamodel to incorporate passivity layers. Required to formalize the EG-IPC component architecture.

2. Design of the EG-IPC component architecture :

- Realization of the EG-IPC component architecture based on the previously formulated metamodels and the RobMoSys Component- Definition metamodel.

3. Development of the industrial-linked user story :

- Definition and development of the user story in the role of system developer to evaluate the usability of the EG- IPC model.

4. Dissemination:

- Ensure the RobMoSys community is aware of the efforts, potentials and results of the project.

Reported progress

1. Development the required metamodels:

The formulation of a metamodel that describes the bond graph modelling language has been performed and will be disseminated as conference paper.

The Intrinsically Passive Control metamodel has been successfully developed. As an IPC is a controller which behaves as a physical system, it conforms to bond graph and feedback control. By definition of the passivity property, an IPC has a constraint that indicates that the energy extracted from the system cannot be greater than the energy introduced to the system. In robotic applications, the stability property of passive systems is of particular interest when dealing with unknown environments. In order to overcome the loss of passivity due to delays, the role of Passivity

Layers (PL) come into play to enforce stability. Besides the metamodel, a pair of example datasheets of IPC components were generated. The datasheets are intended to provide diverse representations of the controller and information regarding its properties and parameters.

The Energy-guarded IPC metamodel is still under development. The EG-IPC metamodel makes use of the Bond Graph and IPC metamodels to simplify the definition of its entities. In addition, the EG-IPC metamodel also conforms-to the block-port-connector metamodel, fitting into the RobMoSys ideology. The Passivity Layer component monitors the energy entering and exiting the system, guaranteeing the passivity (and stability) by bounding the extracted energy.

2. Design of the EG-IPC component architecture:

The EG-IPC component architecture is still under development. The architecture in question is composed by entities defined in the bond graph and IPC metamodels. The definition of the Passivity Layers component is concerned to the EG-IPC metamodel. The proposed structure ensures the passivity of the block, regardless of the properties of the component between the passivity layers. A potential contribution of the EG-IPC component architecture to the SmartSoft environment has been identified. In order to achieve this incorporation, the toolchain requires the implementation of the bond graph and EG-IPC metamodels to define power ports, power bonds, passivity layer and other elements of the EG-component architecture.

3. Development of the industrial-linked user story:

The user stories are still in draft since they have to be adapted to developments in modeling and vice versa. To connect the developed models and metamodels to a real-world application, and thereby validate their usefulness, two user stories have been initially proposed. The user stories strive to demonstrate the composability, reusability and stability of the EG-IPC components based on the metamodels. To limit the implementation effort, the two user stories are very similar. The first one features transparent bilateral teleoperation of a robotic arm by manipulating an identical arm. In the second user story the same components are connected in a different way, and two robot arms will be controlled by a single haptic controller, also taking into account the interaction between the two robot arms when pinching an object.

4. Dissemination:

A paper aimed at major conferences is currently under development. In the paper a formalized metamodel for the bond graph language that captures the features of the energy-based modelling and control and relates them to the Block-Port-Connector paradigm is to be presented. Also, the identification of the entities, relations, and properties of the bond graph language will be tackled. The definition of these entities is critical to describe the power exchange between components under the energy-guarded component architecture.

During this period the consortium encountered following issues :

1. Delay in IPC metamodels preparation – due to insufficiency of the The Web Ontology Language 2, other tools had to be incorporated into metamodels preparation which caused additional delays.

2. Delay in EG-IPC metamodels preparation - due to strong dependency of EG-IPC metamodels on the completeness of the bond graph and IPC metamodels a delay occurred.

3. Delay in the definition of user stories - due to the rapid progression of insights and the interplay with the developing metamodels, the user stories deliverable could not be completed on time. Therefore, the deliverable was transformed into living document which will be updated according to the development to the (meta)modelling work.

4. Change in approach for user story implementation to realize it with RobMoSys tooling (SmartMDSD Toolchain). Additional time is required to adapt the user story. It is hard to estimate the magnitude of the delay as the comprehensive knowledge of the tool is necessary.

5. Delay in delivery of hardware - the delivery of required robot systems has suffered delay, but since implementation was not planned to start, this has had no impact on the ITP so far.

6. The completeness of the metamodel is limited by the user story and vice versa- the metamodels can only be assessed by implementing them in the user story. Due to this dependency, the aforementioned delays in the user stories impacts the progress on the metamodels. In a similar way, the implementation of the user stories requires the metamodels to be sufficiently descriptive of the elements they define. In order to avoid any further delay, the development of the metamodels and the implementation of the user story are done in parallel (iteratively).

The ITP consortium foresees that it can face the additional obstacles that will hinder implementation of the user stories in the future.

Coach's perspective

The coach's perspective is in overall positive. However, there are some suggestions for the ITPs to improve their progress regarding:

- conversion towards RobMoSys semantics and
- focusing on maturing those modelling aspects that are needed at the "component data sheet" level (and less on the internal details),
- creating software for the demonstrator where IPC control components can be coupled with "legacy" components.

Coaching was crucial especially in the initial phase of the project to align it with RobMoSys paradigm. The experimenters were very responsive to the coach's suggestions and followed his advice. However, a lot of additional effort is needed to address the energy-exchanging physical system. During the implementation the focus switched to concrete user stories. The team has come up with a satisfying initial draft of the modelling process. Despite the initial delays, at the end of the monitoring period, the team has fulfilled all the requirements to proceed to the next stage of the project. The coach is optimistic about the project results.

3.2 MOOD2Be

The MOOD2Be (Models and tOOls Development for BEhavior design) project is conducted by Eurecat, Centro Tecnologico de Catalanya. The coach assigned to the project by RobMoSys is Dennis Stampfer (HS Ulm).

Project objectives

MOOD2Be project focuses on a very specific problem in the domain of Model Driven Software Development - the Concern of Coordination and the Role of the Behavior Developer, as defined in the RobMoSys Wiki. This includes the definition of a comprehensive meta-model, compliant with the RobMoSys one, and the implementation of a specific set of tools and run-times which streamline the adoption of this models in real-world applications. One of the core objectives of MOOD2Be, fitting the overarching goals of RobMoSys, is the development of industrial-grade software tools which shall be easy to learn, to use and to integrate into legacy code bases.

According to the proposal, in this reporting period, the detailed objectives were as follows:

1. Definition of a harmonized metamodel that is consistent with Behaviour Trees, Hierarchical Finite State Machines and SmartTCL.

2. Implementation of the software beta. It is planned to present this software package to the robotics community to receive feedback (ongoing task).

3. Verification of the effectiveness of the proposed metamodels and software tools, based on real-world user story. This is an iterative effort, as the task (ongoing), follows agile approach.

4. Administrative coordination and dissemination (ongoing task).

Reported progress

1. 2. 3. According to the report, the metamodels and software have been developed and made available via a public repository at: https://behaviortree.github.io/BehaviorTree.CPP/ and https://github.com/BehaviorTree/Groot.

4. The open source software has been promoted to the community via the platform GitHub. It allowed to monitor interest in the repository, number of downloads, feedback on improvements and bug correction. As the "impact in the community" is one of the key performance indicators of MOOD2Be community building activities are crucial for the project. The team has strong belief that this goal is going to be achieved on time.

The collaboration with ROS2 developers has been started in order to build the "next generation Navigation stack". It resulted in incorporation of parts of the MOOD2Be software in the ROS2 framework which underlines the need of this well-established community for more flexible way to configure "recovery behaviours".

Coach's perspective

The coach's perspective is positive. Below comments from the coach:

The ITP is making progress with respect to the technical implementations. The ITP is continuously publishing software open source. In the current progress, it seems likely that all foreseen technical goals will be achieved. The report elaborates on the current state of the project and describes the main contributions of MOOD2Be: 1) Groot, a GUI-enabled tooling to create and edit behavior trees by the behavior developer. 2) Behaviortree.CPP, a library that executes behavior trees in a robot. With the M6 technical report, the general workflow and connection of the MOOD2Be technical results with the core RobMoSys approach are established.

Besides tooling for the behavior developer and the behavior tree execution engine, the main achievements of MOOD2Be with respect to RobMoSys are the alignment of the MOOD2Be structures and workflow with the RobMoSys composition structures. More specifically, the usability of the MOOD2Be approach with the coordination interface of a RobMoSys software component has been tested. This has been realized practically and was demonstrated with the SmartMDSD Toolchain using the RobMoSys "Intralogistics Industry 4.0 Robot Fleet" Pilot.

The ITP did not formally provide deliverable D2.1 as a report. Instead, in agreement with the coach, the software is published as open source via GitHub: https://github.com/BehaviorTree. The ITP is advised to put a stronger focus on tutorials and documentation on how to use the MOOD2Be software with the existing RobMoSys software baseline. At the moment, MOOD2Be is conceptually well connected to RobMoSys methodology. The usage of MOOD2Be results together with RobMoSys tooling is not yet well documented and at the moment it is still hard to use MOOD2Be outcomes with RobMoSys. The ITP plans to put focus on this in a later project stage.

3.3 CARVE

The CARVE project is conducted by Fondazione Istituto Italiano di Tecnologia, Universitá degli Studi di Genova and United Technologies Research Center (UTRC). The coach assigned to the project by RobMoSys is Matteo Morelli (CEA). The technical assistance was provided by Dennis Stampfer (HSU) with respect to the RobMoSys Communication Patterns and Mixed-Port-Component (RobMoSys-YARP Bridge).

Project objectives

The main goal of CARVE is to contribute to the development of the RobMoSys ecosystem by fostering its adoption in the research community and by contributing the Behavior Trees formalism and tools for code verification and monitoring that leverage on and extend the RobMoSys component model.

The specific objectives of the reported period are as follows:

1. Integration of Behavior Trees in the RobMoSys ecosystem and the interoperability of the YARP Framework with the RobMoSys ecosystem.

2. Specifications of the user stories.

Reported progress

1. The project concept has been refined by the team and ultimately has the following form:

- The user designs a behavior using BTs. Syntax and operational semantics for BTs have been defined by the ITP consortium.

- Using an automatic tool, the BTs can be compiled into executable code (BT execution engine). This engine is generated using the Coq proof assistant starting from the BT description and a well-defined BT operational semantic.
- Aformentioned engine is then loaded and executed as a RobMoSys component to orchestrate RobMoSys or YARP components.

Also, the incorporation of the off-the-shelf verification tools (OCRA) to statically verify correct execution of the BT is suggested.

For the integration of the BT execution engine in RobMoSys a dedicated component which can execute the code extracted from the Coq proof assistant has been developed. Moreover, the interoperability between the SmartMDSD Toolchain and YARP (the middleware used on the R1 robot) has been achieved. To present the interoperability using the Gazebo simulator, the demonstration of the navigation of R1 using the RobMoSys "flexible navigation stack" was performed.

In order to improve the interoperability between YARP and RobMoSys, the RobMoSys communication patterns were mapped into their YARP equivalent. Current work focuses on automatic generation of bridges in the form of mixed port components in tight collaboration with HSU.

2. Three user stories have been defined to validate the CARVE methodology and tools. In all of them, the robot is presenting "fetch" behaviour, with some deviations:

- scenario 1: robot has to navigate to a given room, search for an object, pick it up and bring it back to the user.
- scenario 2: robot may ask the user to show the location of the room and follow him, if the room is not in the map (adding a human following behavior).
- Scenario 3: task involves picking up a bottle, a glass, and pouring a drink to add a safety constraint to the task.

Although the dissemination (T1) was not limited only to the first period of the project, two publications were already submitted:

- Colledanchise, M., and Natale, L., Improving the Parallel Execution of Behavior Trees, in Proc. IEEE/RSJ International Conference on Intelligent Robots and Systems, Madrid, Spain, 2018.
- Giunchiglia, E., Colledanchise, M., Natale, L. and Tacchella A., Conditional Behavior Trees: Definition, Executability, Applications, submitted to ICRA 2019.

During this period the CARVE consortium encountered the following issues :

1. The interoperability between YARP and RobMoSys turned out to be more complex than expected. This issue was addressed in collaboration with HSU and the solution focuses on the implementation of bridge components between the two middlewares, by relying on mixed port RobMoSys components.

2. With respect to the initial plan, the translation of the BT into Hierarchical Finite State Machine is performed only for verification purposes while relying on a BT interpreter for runtime execution. The reason for this is that it is possible to extract adequate executable code from BT interpreter. However, it requires an additional step to verify that the execution of the BT in the interpreter generates the same computations encoded by the Hierarchical Finite State Machine used for static verification. For this reasons, D5.1 has been delayed from M06 to M09. This deviation with respect to the workplan has been agreed with the CARVE coach and does not have negative impact on the project.

Coach's perspective

The coach's general evaluation is positive. The timely management of small deviations with respect to the original workplan has been highlighted.

According to coach report, all activities were performed smoothly and on time. Synergies with other ITPs (MOOD2BE, eITUS) have been identified. Deliverable 5.1 has been postponed from M06 to M09 without negative impact on the project. The coach is optimistic about the project results.

3.4 RoQME

The RoQME (Dealing with Non-Functional Properties through Global Robot QoS Metrics) project is conducted by Universidad de Extremadura (UEX), Universidad de Málaga (UMA) and Biometric Vox (BV). The coach assigned to the project by RobMoSys is Dennis Stampfer (HS Ulm).

Project objectives

RoQME wants to contribute to RobMoSys model-based framework for dealing with system-level non-functional properties, enabling the specification of global robot Quality of Service (QoS) metrics defined in terms of the (internal and external) contextual information available. The RoQME toolchain is intended to support the role of QoS Engineers, providing them with a specific QoS view. This view will allow them to model system-level robot QoS metrics according to the new RoQME meta-model. The concepts included in the RoQME meta-model will be linked to those already available in the RobMoSys meta-model (defined by other roles in different views). In order to guarantee the correct alignment and harmonization of the new role, view and meta-model with those of RobMoSys, a RoQME-to-RobMoSys meta-model mapping, linking both worlds, will also be defined. This mapping aims at promoting high cohesion and loose coupling among the different RobMoSys views, providing a non-intrusive way of extending the RobMoSys meta-model, i.e., modifying the RoQME meta-model would only imply adapting the mapping to RobMoSys (but not modifying the RobMoSys meta-model itself), and vice versa.

The detailed objectives of first project period are as follows:

1. RoQME meta-models and RoQME-RobMoSys harmonization.

2.RoQME support software development (ongoing task).

3. Dissemination of the project's results (ongoing task).

Reported progress

1. The following meta-models, implemented using the Eclipse Modeling Framework, have been developed:

- An Ecore-based RoQME meta-model enabling the specification of global robot QoS metrics on Non-Functional Properties (NFP). These metrics are specified in terms of reinforcing/undermining Observations based on Context Patterns; and
- An Ecore-based RoQME-to-RobMoSys mapping meta-model, linking the concepts in the RoQME meta-model to those available in other RobMoSys meta-models.

In order to achieve the desired harmonisation between the RoQME and the RobMoSys metamodels, a visit to HS Ulm has been scheduled. This event allowed RoQME team to validate and complete the RoQME-to-RobMoSys mapping metamodel and outline an example scenario which aligns to HS Ulm work.

2. The Java implementation of the RoqmeDDS library, together with a document explaining how to install and use it has been developed. However, the supplementing libraries for Complex Event Processing and Probabilistic Reasoning are still under development which implicates its postponed delivery, by the end of M09 (deadline for Task 2).

Additional efforts have been made focusing on the implementation of modules for :

- automatically generating validation tests out of the RoQME model specifications,
- visualizing the resulting QoS metrics (outputs) in terms of the context variable evolution (inputs).

Even if this work caused slight time delay, it was essential to provide this kind of mechanisms for validating the correctness of the implemented software, in particular, when actual robots were not always available for testing the developed solutions.

3. Regarding raising community awareness of RoQME results, several channels of communication have been established including LinkedIn, ResearchGate and Twitter. The diversity of those means of dissemination ensures the coverage of different groups of target audience.

Furthermore, a paper entitled "How well does my robot work? --RoQME: A project aimed at measuring quality of service in robotics" has been released in medium.com.

Moreover, the results of conducted work have been presented during conferences or workshops as follows:

- "Managing Variability as a Means to Promote Composability: A Robotics Perspective" (Lutz, et al., 2018) was submitted and approved for its inclusion as part of a book entitled: New Perspectives on Information System Modeling and Design, by IGI-Global. This book chapter is an extension of (Lotz, et al., 2014) and it was also written in collaboration with the RobMoSys HSU team. The main extensions included in this manuscript relate to the concepts at the core of both the RobMoSys Project and the RoQME ITP. Currently the book is in press and will be soon available.
- "RoQME: Dealing with Non-Functional Properties through Global Robot QoS Metrics" (Vicente-Chicote, et al., 2018) was submitted to the Model-Driven Software Engineering Track of the XXIII Jornadas de Ingeniería del Software y Bases de Datos (JISBD 2018), to be held in conjunction with SISTEDES 2018 on 17th-19th September 2018 in Seville (Spain). This contribution was accepted and is already available in open-access both through the SISTEDES website (https://biblioteca.sistedes.es/articulo/roqme-dealing-with-non-functional-properties-through-global-robot-qos-metrics/) and via ResearchGate at: https://www.researchgate.net/publication/327239527.
- "A Component-Based and Model-Driven Approach to Deal with Non-Functional Properties through Global QoS Metrics" (Vicente-Chicote, et al., 2018) was submitted to the 5th International Workshop on Interplay of Model-Driven and Component-Based Software Engineering (ModComp 2018), to be held in conjunction with MODELS 2018 on 14th October 2018 in Copenhagen (Denmark). This contribution was accepted and will be shortly available in open-access through CEUR-WS.org (ISSN: 1613-0073). The camera-ready version of the paper is already accessible via ResearchGate at: https://www.researchgate.net/publication/328102310.
- "Towards the use of Quality-of-Service Metrics in Reinforcement Learning: A robotics example" (Inglés-Romero, Espín López, Jiménez-Andreu, Font, & Vicente-Chicote, 2018) was submitted to the 5th International Workshop on Model-Driven Robot Software Engineering (MORSE 2018), to be held in conjunction with MODELS 2018 on 15th October 2018 in Copenhagen (Denmark). This contribution was accepted and will be shortly available in open-access through CEUR-WS.org (ISSN: 1613-0073). The camera-ready version of the paper is already accessible via ResearchGate at: https://www.researchgate.net/publication/327243001.
- "Towards the Application of Global Quality-of-Service Metrics in Biometric Systems" (Espín, Font, Inglés-Romero, & Vicente-Chicote, 2018) has been submitted to the IberSPEECH 2018 Conference, to be held in Barcelona on 21-23 November 2018. If the paper is accepted, it will be presented as part of the IberSPEECH Projects Session and will be included in the online conference proceedings.

Coach's perspective

Overall coach's perspective is positive. An issue regarding reporting the state of the art by the ITP has been quickly solved by scheduling a research stay. The mid-term report provided by ITP team is evaluated as detailed and aligning with the coach's insights.

The active dissemination is well appreciated. Also, connection to and taking up of the RobMoSys methodology and vision has been underlined. Other minor issues, that have arisen during the period, have been swiftly dealt with, those included:

- initial understaffing,
- lack of definition of user story,
- team reports focused mostly on future work instead of current progress.

In general, the coach is very optimistic about future collaboration and it is very likely that the project will achieve all goals.

3.5 eITUS

The eITUS (Experimental Infrastructure Towards Ubiquitously Safe Robotic System using RobMoSys project) is conducted by AKEOPLUS (AKEO) and Tecnalia Research & Innovation (TEC). The coach assigned to the project by RobMoSys is Ansgar Radermacher (CEA).

Project objectives

The eITUS project aims at creating a basic experimental infrastructure (models, software and tools) that enables robotic development stakeholders to assure system safety both at design time, using analysis and simulation-based techniques, and at run time, using safety monitoring algorithms.

The main objectives of the reporting period are as follows:

1. Establishing the basis of the project by assigning all responsibilities.

2. Definition of the specification of the eITUS infrastructure.

3. Elaboration of the Dissemination plan and the Benchmarking plan.

4. Start the development of the eITUS experimental infrastructure (metamodels, interfaces and tools for software generation and safety validation) and the integration with the RobMoSys tools.

Reported progress

1. The project has started by assigning all responsibilities.

2. The methodology and conceptual approach of the eITUS project has been defined and is available in RobMoSys internal repository

3. Both the dissemination and benchmarking plans were elaborated and placed in the RobMoSys internal repository .

4. The development of eITUS experimental infrastructure and the integration with the RobMoSys tools have been started. However, several issues have arisen during the implementation tasks, therefore the eITUS consortium considers necessity of deadline extension for several related tasks.

The encountered issues are as follows:

1. Integration of RobMoSys and the safety view with the safety validation framework:

- The Sabotage fault injection framework was originally developed for performing fault injection simulations on Simulink-based designs. Sabotage was developed to configure, run and execute fault injection experiments on Simulink models. The fact of not performing model transformations to Simulink means that it is needed to adapt part of the Sabotage framework.

- The Sabotage editor is Ecore based while RobMoSys and safety concepts are applied via a profile implemented solution (Papyrus4Robotics), which uses UML/SysML as the underlying realization technology. The platform uses the UML profile mechanism to enable the implementation of Domain-Specific Languages (DSLs) that assist RobMoSys's ecosystem users in designing robotics systems.

2. Capitalising on and adaption of the P-RC2 controller models and OROCOS code generators to RobMoSys:

- The main concepts of the P-RC2 metamodel have been transposed to RobMoSys artefacts. However additional work is required to align some remaining P-RC2 concepts to RobMoSys.

3. Integrating the AMASS contract-based approach and tools to perform formal specification, validation and refinement of assumptions and guarantees under the compositional paradigm:

- During this reporting period, other actions have been prioritised such as the safety view or the generation of safe-aware robotics systems. The partners are aware that solutions for contract-based approach are available in the market and possible integrations with the RobMoSys platform might be investigated within the next period.

4. Integrating a safety monitoring component in the robotics platform. It will gather information from subsystems to correctly describe the environment and increase safety awareness. Supported on state observation (perception) and combined with prediction of future states of the system, it will allow the robot to make later decisions for diminish safety risks.

- During the first reporting period, the eITUS partners together with their coaching team have decided to prioritise other topics such as the safety profile, RobMoSys-P-RC2 metamodels alignment and code generators adaptation, and the safety validation platform. However, during the second reporting period, the eITUS partners and their CEA coaching team will agree on the definition, orientation and scope for this topic according to the current findings of the project.

5. Integrating safety analysis tools with RobMoSys models by using the proposed safety view. The licensing schemes will be evaluated to use either Papyrus/Sophia or other tools available by means of the AMASS project (e.g. Ansys Medini).

- At proposal time and during the first period of the project, Sophia was going to be used and integrated in RobMoSys. However, due to external decisions and policies, the eITUS consortium needed to look for other alternative solutions. This led to a delay on the implementation side when talking about the safety view and the related model-based safety analysis solutions. To overcome this issue, the consortium looked for alternative solutions which have increased the time planned for implementation.

Coach's perspective

The coach's perspective on project progress is positive. The detailed and exhaustive character of the technical report has been highlighted. It was underlined at the beginning of the experiment that the eITUS team fulfilled its obligations in terms of activity, deliverables and achievements. Unfortunately, complexity of the proposed technologies requires more time than planned. Therefore, the team has to accelerate in solution development.

3.6 Plug&Bench

The Plug&Bench project is conducted by Politecnico di Milano (POLIMI) and Fraunhofer Institute for Manufacturing Engineering and Automation (IPA). The project coach initially assigned to the project by RobMoSys was Eloy Retamino (TUM), who from M21 (November 2018) was replaced by Enea Scioni (KU Leuven). The technical assistance was provided by Dennis Stampfer (HSU) with respect to meta-modeling and RobMoSys Tooling.

Project objectives

The main objective of the Plug&Bench is to provide easy to use performance benchmarks. Benchmarks defined using Plug&Bench models and tools will, in turn, allow meaningful comparisons between components offering the same functionality, and act as a foundation for the benchmarking of complete robot systems.

Two separate tasks were assigned to the first reporting period:

1. Definition of the methodological foundations for the work of the project.

2. Development of the Plug&Bench Benchmark Metamodel (P&B-BM) and its description on the RobMoSys Wiki.

Reported progress

1. Although the proposal does not tie results of this task to a particular form of reporting, two initial documents supporting the Plug&Bench Benchmark Metamodel were written:

- "Methodological Foundations for the Benchmark Metamodel", describing the methodological background of the results of Plug&Bench.
- "The Plug&Bench Benchmark Metamodel as part of the RobMoSys Ecosystem", describing the connections between the P&B-BM and the elements of the RobMoSys Ecosystem.

2. The Benchmark Metamodel has been successfully developed and uploaded via RobMoSys' reporting platform.
A first contribution to the RobMoSys wiki has been made publicly available, resuming the goals of the projects and links to both meta-models and software product.
One additional outcome was achieved on top of what was foreseen in the project proposal: The improvement concerns the fact that the metamodel covers all 3 types of benchmark (dataset-based, simulation-based, physical) instead of the 2 considered by the proposal. This is a consequence of the fact that the P&B-BM incorporates in itself the elements required to model the different benchmark types, without need for separate extensions (as hypothesized in the proposal).
3. In the context of the Plug&Bench project, a new role in RobMoSys has been proposed and introduced: **the benchmark developer**. The benchmark developer plays the important role of developing benchmark scenarios and various metrics to test different functionalities.

During this period the consortium reported the following issues:

- According to the workplan, the use of one of the tools provided by the RobMoSys core consortium (SmartSoft, Papyrus4Robotics) was planned in order to ease the automatic code generation of the benchmarking modules. The code generation procedure has to take into account also the possibility of benchmarking ROS modules: for this, it has to support natively the integration of ROS implemented components in the Plug&Bench pipeline. However, during the reporting period some of the tools considered for this work were still under intense development. Therefore, in accordance with the coach, the selection of the final tool for the benchmark models' implementation has been deferred to the beginning of the second period of Plug&Bench. In the meantime, the ITP consortium has considered the adoption of several other tools. Nevertheless, it is to notice that the Plug&Bench partners have spent reasonable efforts in the integration of the Plug&Bench pipeline within the RobMoSys software baseline.
- The release of public material in the RobMoSys wiki has been delayed due to the lack of clear procedures in the process. This aspect should be improved in future open calls. Some difficulties and delays are due to the alpha status of the RobMoSys software baseline, e.g., lack of documentation and non-clear procedure on how to integrate the Plug&Bench tool with the RobMoSys tooling baseline. However, many limitations have been addressed already and the ITP plans to switch to the SmartMDSD Toolchain and is in close contact and exchange with HSU.

Coach's perspective

The coaches admit that a significant effort has been made towards achieving Plug&Bench objectives. However, there is clear indication that not all encountered risks have been mentioned by the Plug&Bench team. Even if there is a clear view on how the benchmarking metamodel is integrated in the RobMoSys structure, there might be a gap between the component described and their realisation. There is also a suggestion on how to effectively overcome this issue in the second half of the project.

Initial concern regarding the communication with PoliMi has been solved quickly.

Several both theoretical and technical issues were raised and not all of them were solved by M06, but addressed later. Deliverable 1 was originally insufficient regarding the content, but based on collected feedback, an improved version has been submitted. However, as a consequence, addressing those criticisms introduced further delays on the subsequent milestones. Plug&Bench interacted actively with the RobMoSys core consortium regarding integrating the developed pipeline, especially with HSU regarding the integration with SmartMDSD Toolchain. More interactions are expected to come in the remaining time of the project. Finally, there is a concrete risk that, due several delays, the realisation of the envisioned scenario may be too simple to proof the generalisation of the overall approach. However, the coaches emphasize the great experience of the Plug&Bench team in benchmarking which ensures that the consortium is capable of achieving the project's objectives.

3.7 Summary of Adjustment Actions per ITP

Table 1 summarizes the main actions per ITP to improve their technical development and impact through the user stories. Most of these actions are a result of coaches' recommendations, as reflected in the previous sections.

Table 1: Main next actions per ITP related to technical and impact goals

ITP	Actions to Improve Technical Development	Action to Improve Success Stories and Impact
EG-IPC	• Conversion towards RobMoSys semantics • Focus on maturing datasheets for components exposure	• Creating software for demonstrator and publish user story • Ensure IPC control components can be coupled with "legacy" components
MOOD2BE	• The ITP shall put a stronger focus on RobMoSys in their tutorials and documentation	• Align the final documentation more to the RobMoSys context and available tooling
CARVE	• The cross-ITP collaboration opportunities must be followed to be concretised in the next period	• Publication of the user stories and industrial application must be envisaged since there are many good technical results
RoQME	• Good technical progress.	• Very good dissemination of results. Should be used as an example for the other members of RobMoSys community. • Make sure to provide tutorials and user-level documentation for accessibility once the tooling is available (planned for second half of ITP)
eITUS	• Reduce technical expectations and focus on agile generation of fault-injection experiments • Favour open-source outcomes with well documented manuals	• Focus success story on fully available robotics system models • Draw a first video to demonstrate the main usage scenarios
Plug&Bench	• Ensure the ITP metamodels can be integrated with RobMoSys metamodels • Considering to introduce Tier-2 (domain-specific) models in the benchmarking scenario.	• Publish demonstrator of the related user stories

4 Conclusions

The general outcome of the first monitoring period is positive. All the ITP teams have advanced their projects and the RobMoSys coaches are optimistic about their final outcome.

Several issues have arisen during this period, with most of them related to the adaptation of the prepared solutions into the RobMoSys framework. Some project also experienced delays caused by unforeseen complexity of the goals presented in the original proposals. Most of the issues have been however solved due to involvement of coaches and their individualized approach to the ITPs.

The crucial role of individualized coaching provided by the experts of the RobMoSys core scientific members (described in section 2) is the most important insight of this period. Following the RobMoSys approach is a paradigm shift and requires deep understanding of the underlying RobMoSys concepts. Most of the ITPs teams did not have (and could not have) such an understanding during the proposal preparation. This was to be expected and the coaching instrument successfully minimized the negative impact due to the (initial) lack of understanding. Further effort to increase the accessibility of the RobMoSys approach and to lower the entry barriers is needed.

In order to facilitate future proliferation of the RobMoSys approach it is necessary to increase the awareness and understanding within the wider audience. Coaching turned out to be a very successful and important instrument. However, the resources available for coaching are limited. Therefore, the second open call has been shaped in a different way to take into account both the limited coaching capacity also its importance as a success factor of the open call. New instruments facilitating easy adoption have been defined.

This realization led to shaping the second open call of RobMoSys in a different way – providing focused ITP areas and introducing new instruments. Those new instruments will enhance the RobMoSys consortium's capabilities in medialization of the results and training of new coaches.

The implementation, monitoring and coaching of the ITPs will continue throughout the next period. Their final results will be presented in the upcoming deliverable D5.7. During the next implementation period the second open call will be launched (in February 2019) with new projects starting just after the original cohort of ITPs finishes their projects.