Modeling and Tooling for Robotics Software Development

The RobMoSys Consortium

ROS-Industrial Conference 2019
Dec. 10-12 2019, Stuttgart, Germany
About

• **The Speaker:** Dennis Stampfer
  - 10+ years into robotics software engineering for service robotics
  - Focus: Tooling via Model-Driven Software Engineering
  - THU takes role of the Technical Lead in RobMoSys

• **The Project:** RobMoSys H2020 Innovation Action:
  - Composable Models and Software for Robotic Systems
  - 4 Years, 01/2017-12/2020, Budget 8M, where 4 M for Open-Calls
  - EU Digital Industrial Platform for Robotics, together with ROSIN
  - http://robmosys.eu/

• **The Relations:** (here @ ROS Industrial Conference)
  - SeRoNet (Next Talk, Björn Kahl)
  - MROS: Metacontrol for ROS2 (RobMoSys ITP/“Sub-Project”: Carlos Hernandez Corbato)
  - ROS Model (Day 2, Nadia Hammoudeh Garcia)
  - Eclipse Foundation (Day 3, Philippe Krief)
Outline

- Challenges in robotics
- Tooling & Industry use-case(s)
Challenges in robotics software development
(to provide some context)
Challenges in Robotics Software Development: Integration (at least one of them)

Building Blocks

Structures and their Implementations
(Read: Methodology, Frameworks, Tools)

People

Key Requirement:
Composition & Separation of Roles
RobMoSys Roadmap – The Big Picture

Model-driven engineering as key enabler for
• complex software and system integration
• integrating existing technologies

Results
• consolidated best practices
• tooling for correct-by-construction composition and code generation
• open-source software and tools

4M € to third party via open calls:

Open Call 1
6 projects running

Open Call 2:
11 Projects Running

EU Digital Industrial Platform for Robotics

ROS-Industrial Conference, December 2019, Stuttgart, Germany -- Dennis Stampfer
Model-Driven Development with the Digital Data Sheet

(Software) Artefact
represents
Data Sheet ("Need to know")

Descriptive Part
Semantic Information, e.g.
- application domain
- performance attributes
- restrictions

Technical Part
Derived from models
- component model
- communication means
- variation points

... but people are developers! -- Did someone mention tooling?
Tooling for Robotics Software Development: Industry Use-Case
Tooling + Industry Use-Case

- TIAGo Base @ Intralogistics
- High flexibility required, depending on customer's needs:
  - Different sensors
  - Different software
- Tooling (IDE) is key for quick developer response: SmartMDSD Toolchain
Part I: The Navigation Stack

TIAGo Base: 100% ROS-based

Corridor-based fleet Navigation: 100% SmartSoft-based

... or not?
Part I: The Navigation Stack

RobMoSys tooling in TIAGo robot

https://www.youtube.com/watch?v=FCvK9dAZXPo
Part II: OPC UA

„There Is No Industry 4.0 without OPC UA“
Stefan Hoppe, Global Vice President, OPC Foundation

... that holds true for: Robots, Devices, Software Building Blocks
Part II: OPC UA

SmartMDSD Toolchain - The effortless use of OPC UA enabled devices with software components

https://www.youtube.com/watch?v=Xi7Irjk8Kyw
Part III: Replacement of Components
Part III: Replacement of Components

https://www.youtube.com/watch?v=RHvvb6lTHG4
Part IV: Middleware Agnostic Modeling
Part V: Tooling Interoperability
Digital Data Sheet as means to enable tooling interoperability.
Here: Behavior Tree Editor + Robotics IDE

Tasks: Deliver Euro-Container from A to B

Component Architecture: Delivery Robot

SmartMDSD Toolchain with:
- Groot
- SmartTCL
- SmartSoft
- OPC UA
- ROS
- Eclipse
Part V: Tooling Interoperability

https://www.youtube.com/watch?v=54_skOuHsds
Why does that work?

- Thanks to Modeling, Best-Practices for Composition, Digital Data Sheet, ...
- **Accessible via tooling**
- No need for developers to learn+understand all details!
How to do it? With the SmartMDSD Toolchain!

- The SmartMDSD Toolchain is an Integrated Development Environment (IDE) for robotics software to support system composition.

- For **real systems development**, not for “just drawing”

- **It supports ROS!**

- Conform to RobMoSys & SeRoNet

- 10+ years, very **mature**, used in commercial products

- **100% Open-Source** @ Eclipse Foundation
Establishment of Stewardship as concept and process within euRobotics:

A general approach

- Steward and host for a consolidated Body of Knowledge
- Elected for de-facto standard
- Supported by according Topic Group
- Moderation
- Strategy and roadmapping
- Shaping, pushing and disseminating the joint vision

Tier 1: euRobotics Stewardship (industry & academia)

Propose what to harmonize
Push consolidated work upwards to tier 1

Tier 2: Horizontal Structured Dialog (industry & academia)
- horizontal interaction
- exchange for convergence of concepts and exploitation of synergies

Activity 1
Activity 2
...

Propose concepts and solutions
Align discussions, research and realize identified needs

Tier 3: Individual activities (industry & academia)

- Carry out research
- Implement Software
- Make Business

Publicly funded research project
Open Source Activity
Industrial Implementation
Commercial Product

16.08.2019
Christian Schlegel, Dennis Stampfer, Reinhard Lafrenz
Conclusion & Take-Away

- ROS is great -- Let's not limit it by technology barriers: Applications should not need to care about packaging of building blocks.

- We need more IDEs to increase developers productivity: The SmartMDSD Toolchain is a framework-agnostic and mature IDE; it loves ROS.

- RobMoSys is:
  - a movement towards a new way of software engineering (via models)
  - a community moderation activity on model-driven engineering
  - more than just this talk.
  - Check out the ITPs (“sub-projects”): robmosys.eu/wiki

Opinions? Want to get in touch?
Dennis Stampfer <stampfer@hs-ulm.de> at the conference and discourse.robmosys.eu any time
Further information

- **RobMoSys**:  
  - http://www.robmosys.eu/wiki  
  - http://discourse.robmosys.eu

- **SeRoNet**:  
  - http://www.seronet-projekt.de

- **SmartMDSD Toolchain**:  
  - https://wiki.servicerobotik-ulm.de/smartmdsd-toolchain:start

Opinions? Want to get in touch?  
Dennis Stampfer <stampfer@hs-ulm.de> at the conference and discourse.robmosys.eu any time
Appendix: Additional Information
Where to get the SmartMDSD Toolchain

- **SmartMDSD Toolchain easy entry:**
  - Available as *pre-installed/ready-to-go virtual machine image!*
  - https://wiki.servicerobotik-ulm.de/smartmdsd-toolchain:start

- **Tutorials**
  - https://wiki.servicerobotik-ulm.de/tutorials:start
  - https://wiki.servicerobotik-ulm.de/how-tos:start
**AMBITION**

RobMoSys will coordinate the whole community’s best and consorted efforts to realize a step-change towards an industry-grade software development European ecosystem

- open
- sustainable
- industrial quality

RobMoSys part of the effort on Digital Industrial Platforms for Robotics (together with ROSIN)
What is the aim of RobMoSys?


- **RobMoSys** envisions an integrated approach built on top of the current code-centric robotic platforms, by applying model-driven methods and tools.
- **RobMoSys** will enable the management of the interfaces between different robotics-related domains in an efficient and systematic way according to each system’s needs.
- **RobMoSys** aims to establish Quality-of-Service properties, enabling a composition-oriented approach while preserving modularity.
- **RobMoSys** will drive the non-competitive part of building a professional quality ecosystem by encouraging the community involvement.
- **RobMoSys** will elaborate many of the common robot functionalities based on broad involvement of the community via two Open Calls.

**Better models, as the basis for better tools and better software, which then allow to build better robotic systems**

The project is open for constructive suggestions from the community, as long as "platform", "composability" and "model-tool-code" are first-class citizens of those suggestions.
Ecosystem, Separation of Roles, Composition

- RobMoSys enables the composition of robotics applications with managed, assured and maintained system-level properties via model-driven techniques

- RobMoSys enables **communication of design intent**, analysis of system design before it is being built and understanding of design change impacts

- RobMoSys enables systems **correct by construction**

- RobMoSys supports management (design, assurance, traceability) of **(extra-functional) system properties** (e.g. resources, safety, QoS, accuracy, adequateness, etc.) in all development phases and at run-time:
  - deliver goods in time
  - trade-off energy consumption, speed, safety, etc.
EU H2020 RobMoSys, German BMWi PAiCE SeRoNet

- Meta-Model: domain-independent
- Model: domain-specific (mobile robots, intralogistics, manipulation, ...)
- Implementation: components and systems

SeRoNet is conform to superordinated structures consolidated at the European level via RobMoSys

SeRoNet Consortium as driver
Involving external experts, professional associations, ...

SeRoNet User component providers, system builders, end users, ...

EU Digital Industrial Platform for Robotics

Companion Specifications

RobMoSys

Tier 1
Ecosystem Drivers

Tier 2
Domain Experts

Tier 3
Ecosystem Users

Technical Implementation with industry standard OPC UA - brokerage platform
Become Part of RobMoSys...

- **RobMoSys Web Page =>** [https://www.robmosys.eu](https://www.robmosys.eu)
  - access point which guides you to more information according to your role and interest
  - role-specific entry points will be improved with respect to Open Call 2

- **Subscribe to Newsletter**
  - easiest way to follow at a high level of abstraction
  - be kept informed about major milestones and activities

  - first reference for in-depth information about the approach etc.
  - additional content to reflect the current state of the overall big picture and the according available baseline follows during the course of the preparation of the Open Call 2
  - additional content will also make it easier to find role specific / interest specific information

- **Discourse Platform =>** [https://discourse.robmosys.eu](https://discourse.robmosys.eu)
  - the community platform to talk about models, tools, software for robotics, just get involved

- **Try it out**
  - tooling, building blocks, simulation, real robots, ..
RobMoSys Modeling Directory

https://robmosys.eu/wiki/model-directory:start

RobMoSys Model Directory

A list of domain models, software components and systems for use with RobMoSys Tooling. Please see end of page for a legend.

Tier 2 Domain Models

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CommBasicObjects</td>
<td>A collection of very basic communication objects for robotics system.</td>
</tr>
<tr>
<td>CommNavigationObjects</td>
<td>A collection of domain models for navigation.</td>
</tr>
<tr>
<td>CommRobotinoObjects</td>
<td>A collection of domain models for Robotino robot.</td>
</tr>
<tr>
<td>CommLocalizationObjects</td>
<td>A collection of domain models for localization.</td>
</tr>
<tr>
<td>CommManipulationPlannerObjects</td>
<td>A collection of domain models for manipulation planning.</td>
</tr>
<tr>
<td>CommManipulatorObjects</td>
<td>A collection of domain models for manipulation.</td>
</tr>
<tr>
<td>CommObjectRecognitionObjects</td>
<td>A collection of domain models for object recognition.</td>
</tr>
</tbody>
</table>

Tier 3 Component Models

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SystemTiagoNavigation</td>
<td>A pilot skeleton that covers the navigation aspect of the Inralogistics Industry 4.0 Robot Fleet Pilot and Assistive Mobile Manipulation Pilot. This system covers the TiAgro Robot in simulation/Gazebo.</td>
</tr>
<tr>
<td>ComponentSymbolicPlanner</td>
<td>Implements the Curvature Distance Lookup (CDL) algorithm for fast local obstacle avoidance. It considers the dynamics and kinematics of the robot.</td>
</tr>
</tbody>
</table>

Tier 3 Systems

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SystemTiagoNavigation</td>
<td>A pilot skeleton that covers the navigation aspect of the Inralogistics Industry 4.0 Robot Fleet Pilot and Assistive Mobile Manipulation Pilot. This system covers the TiAgro Robot in simulation/Gazebo.</td>
</tr>
</tbody>
</table>
Mixed-Port Components

RobMoSys System
Builder role
Composing RobMoSys-conformant components

RobMoSys Component for composition.
Encapsulated building blocks of the specific frameworks.

RobMoSys Supplier role

Legend:
- RobMoSys Port
- Plain YARP Port
- Plain ROS Port
- Plain OPC UA Port
- (unstructured OPC UA)

RobMoSys Ports
- ROBARTYARP
- ROBARTROS
- ROBARTOPC

Plain YARP Port
Plain ROS Port
Plain OPC UA Port

YARP Component
ROS Component
OPC UA Component

XML

Hochschule Ulm
CEA
KU LEUVEN
TUM
Comau
PAL Robotics
SIEMENS
EUniedt Robotics & European Robotics Association
Eclipse
RobMoSys Ecosystem Organization: Analogy with the PC Domain

Examples of the PC Analogy:
- e.g. Semiconductor standards, computer architecture, USB, PCIe, modern use of ethernet, etc.
- e.g. laptop PC, desktop PC, industry PC, ATX, ITX, Mini-ITX, VGA, HDMI, SATA, IDE, CPU socket, GPU socket, etc.
- e.g. graphics card, CPU, TPM, Memory, power supply, etc.

Examples of Robotics:
- e.g. robotics architectural patterns and robotics composition structures (service-oriented software component model, robotics task models etc.)
- e.g. Flexible Navigation Stack, Active Object Recognition, Motion Stack, Perception Stack etc.
- e.g. robotics software components (Motion Planning, SLAM, Object Recognition), robotics functional libraries (MRPT, OpenCV, PCL), applications (Pilots, Logistics Fleet, Production Cell, Healthcare Servicerobot), etc.
RobMoSys envisions a robotics business ecosystem in which a large number of loosely interconnected participants depend on each other for their mutual effectiveness and individual success. The modeling foundation guidelines and the meta-* model structures are driven by the needs of the typical tiers of an ecosystem and the needs of their stakeholders. The different tiers are arranged along levels of abstractions.

RobMoSys Ecosystem Organization

- **Tier 1:** structures the ecosystem in general for robotics. It is shaped by the drivers of the ecosystem that define an overall composition structure which enables composition and which the lower tiers conform to (similar to, for example, the ecosystem of the Debian GNU/Linux OS and its structures). Tier 1 is shaped by few representative experts for ecosystems and composition. This is kick-started by the RobMoSys project.
  - Structures defined on Tier 1 can be compared to structures that are defined for the PC industry. The personal computer market is based on stable interfaces that change only slowly but allow for parts changing rapidly since the way parts interact can last longer than the parts themselves and there is a huge amount of cooperating and competing players involved. This resulted in a tremendous offer of composable systems and components.

- **Tier 2:** conforms to these foundations, structuring the particular domains within robotics and is shaped by the experts of these domains, for example, object recognition, manipulation, or SLAM. Tier 2 is shaped by representatives of the individual sub-domains in robotics.

- **Tier 3** conforms to the domain-structures of Tier 2 to supply and to use content. Here are the main "users" of the ecosystem, for example component suppliers and system builders. The number of users and contributors is significantly larger than on the above tiers as everyone contributing or using a building block is located at this tier.
Digital Data Sheet

Software Building Block (e.g. Component)

- Software Artefact
- Digital Data Sheet

compatible to industry 4.0 asset administration shell

Descriptive Part:
Manual annotations
Semantic modeling, focus on
searching and selection:
- Application domain
- Performance attributes
- Common speech in domain
- Restrictions

Technical Part:
Generated from Models
Technical modeling, focus on
composition:
- Component Model,
- Communication Patterns
- Variation Points
- Resource Constraints

conformant to RobMoSys

RobMoSys

utors of the joint research project RobMoSys:

CEA
HU Leuven
TUM
COMAU
EU Robotics
SIEMENS
Eclipse
Support of the SmartMDSD Toolchain:

Definition of Skills - Tier 2

(e.g. ecore meta-model for Component definition)
Support of the SmartMDSD Toolchain:
Support of the SmartMDSD Toolchain:

```
package model;

public class CommLocationObject {
  public enum Location {
    INITIAL, TRAVERSING, DESTINATION
  }

  private Location location;

  public Location getLocation() {
    return location;
  }

  public void setLocation(Location location) {
    this.location = location;
  }
}
```

```
package model:

public class CommNavigationObjects {
  public enum NavigationMode {
    NAVIGATE, TRAVERSE, STATIONARY
  }

  private NavigationMode mode;

  public NavigationMode getMode() {
    return mode;
  }

  public void setMode(NavigationMode mode) {
    this.mode = mode;
  }
}
```

```
package model:

public class CommNavigationObjects {
  public enum Service {
    NFC, RFID, GPS
  }

  private Service service;

  public Service getService() {
    return service;
  }

  public void setService(Service service) {
    this.service = service;
  }
}
```

```
package model:

public class CommNavigationObjects {
  public enum Parameter {
    LOCATION, SPEED, DIRECTION
  }

  private Parameter parameter;

  public Parameter getParameter() {
    return parameter;
  }

  public void setParameter(Parameter parameter) {
    this.parameter = parameter;
  }
}
```

```
package model:

public class CommNavigationObjects {
  public enum Mode {
    NAVIGATE, TRAVERSE, STATIONARY
  }

  private Mode mode;

  public Mode getMode() {
    return mode;
  }

  public void setMode(Mode mode) {
    this.mode = mode;
  }
}
```

```
package model:

public class CommNavigationObjects {
  public enum Parameter {
    LOCATION, SPEED, DIRECTION
  }

  private Parameter parameter;

  public Parameter getParameter() {
    return parameter;
  }

  public void setParameter(Parameter parameter) {
    this.parameter = parameter;
  }
}
```

```
package model:

public class CommNavigationObjects {
  public enum Mode {
    NAVIGATE, TRAVERSE, STATIONARY
  }

  private Mode mode;

  public Mode getMode() {
    return mode;
  }

  public void setMode(Mode mode) {
    this.mode = mode;
  }
}
```

```
package model:

public class CommNavigationObjects {
  public enum Parameter {
    LOCATION, SPEED, DIRECTION
  }

  private Parameter parameter;

  public Parameter getParameter() {
    return parameter;
  }

  public void setParameter(Parameter parameter) {
    this.parameter = parameter;
  }
}
```
Support of the SmartMDSD Toolchain:

Skills - Tier 2

- Tier 1: Ecosystem Drivers
- Tier 2: Domain Experts
- Tier 3: Ecosystem Users
Support of the SmartMDSD Toolchain:

Realization of Skills Tier 3 (Component Developer)
Support of the SmartMDSD Toolchain:
Support of the SmartMDSD Toolchain: