

From service to assistive robotics with EARL based system engineering

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1 RPMPG SCIENTIFIC TEAM

2 EARL MODEL

3 EARL APPLICATIONS

4 CONCLUSIONS

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Robot Programming and Machine Perception group – www page [6]

HOME

TEAM

PROJECTS

ROBOTS

PUBLICATIONS

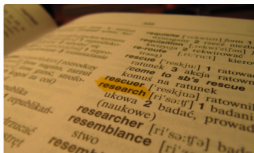
THESES

BIONIK

CONTACT



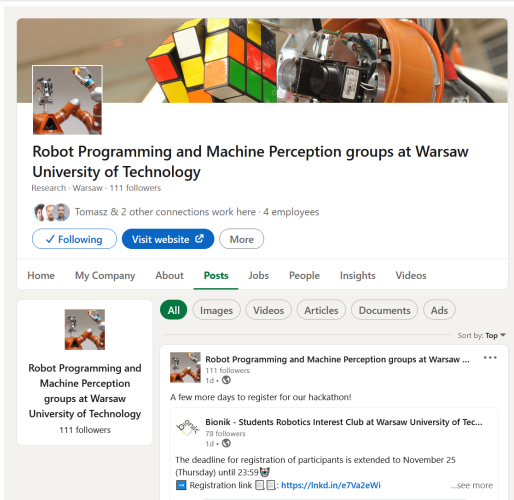
Robot Programming and
Machine Perception groups



[6]

Robot Programming and Machine Perception group – www page. URL:
<https://www.robotyka.ia.pw.edu.pl/>.

Robot Programming and Machine Perception group – LinkedIn [5]

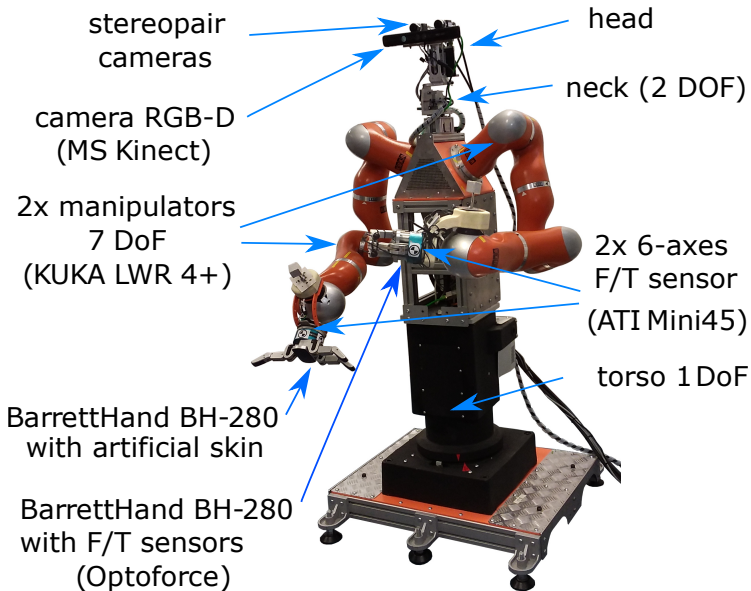


The screenshot shows the LinkedIn profile page for the group. The header features a banner image of a robot arm and a Rubik's cube. The profile name is 'Robot Programming and Machine Perception groups at Warsaw University of Technology', with 'Research · Warsaw · 111 followers'. Below the name, it says 'Tomasz & 2 other connections work here · 4 employees'. There are buttons for 'Following', 'Visit website', and 'More'. The navigation bar includes 'Home', 'My Company', 'About', 'Posts', 'Jobs', 'People', 'Insights', and 'Videos'. The 'Posts' tab is active, showing a post from the group: 'A few more days to register for our hackathon!'. Below this is a post from 'Bionik - Students Robotics Interest Club at Warsaw University of Tec...' with the text: 'The deadline for registration of participants is extended to November 25 (Thursday) until 23:59'. A registration link is provided: <https://lnkd.in/e7Va2eWI>.

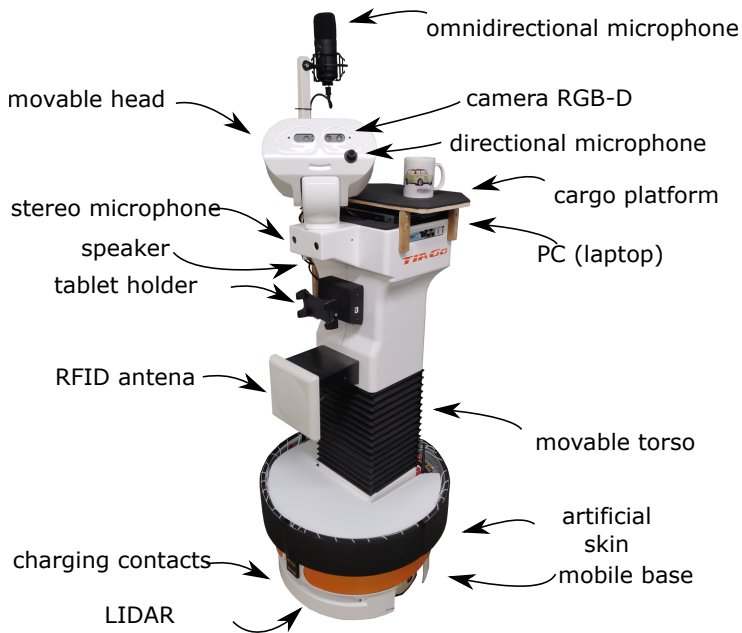
[5]

Robot Programming and Machine Perception group – LinkedIn. URL: <https://www.linkedin.com/company/robot-programming-and-machine-perceptions-groups-warsaw-university-of-technology/>.

Velma service robot



Rico (modified TIAGo) assistive robot



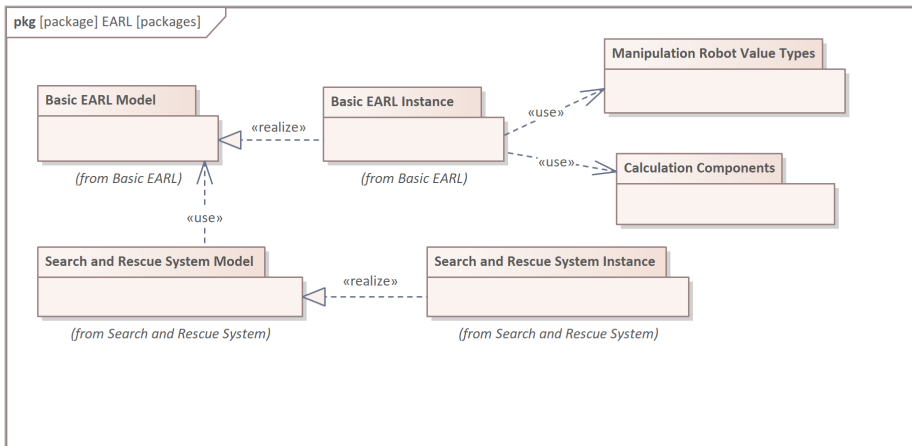
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EARL [1, 10] – Embodied Agent-Based Robot Control Systems Modelling Language based on:

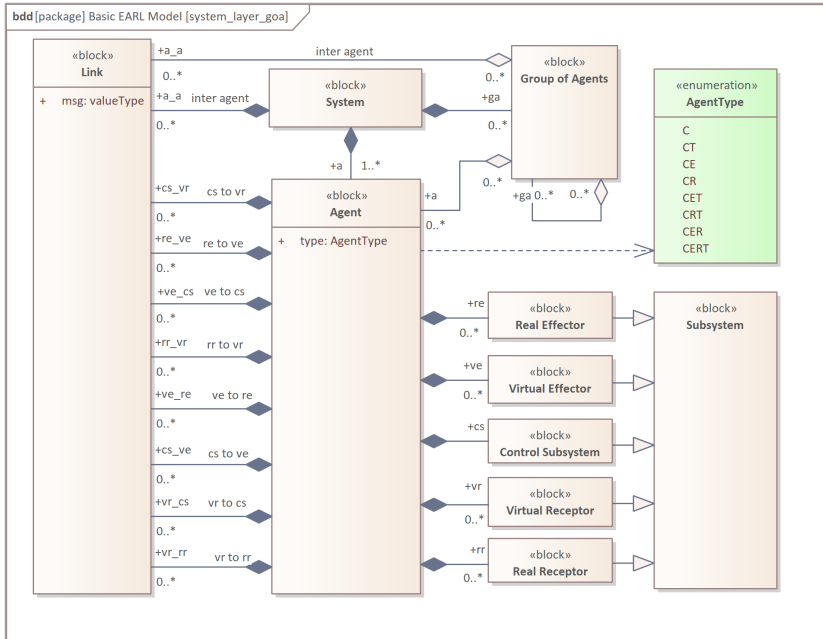
- SysML [4],
- Embodied Agent Theory of Warsaw school of prof. Cezary Zieliński [3].

- [1] *EARL – Embodied Agent-Based Robot Control Systems Modelling Language - reference manual*. Mar. 2022. URL: <https://www.robotyka.ia.pw.edu.pl/projects/earl/>.
- [3] T. Kornuta, C. Zieliński, and T. Winiarski. “A universal architectural pattern and specification method for robot control system design”. In: *Bulletin of the Polish Academy of Sciences: Technical Sciences* 68.1 (2020), pages 3–29. DOI: 10.24425/bpasts.2020.131827. URL: http://journals.pan.pl/Content/115154/PDF/01_03-29_01163_Bpast.No.68-1_28.02.20_K_OK_TeX.pdf.
- [4] *OMG Systems Modeling Language - Version 1.6*. accessed on 4 April 2020. Open Management Group. Dec. 2019. URL: <https://www.omg.org/spec/SysML/1.6/>.
- [10] T. Winiarski et al. “EARL – Embodied Agent-Based Robot Control Systems Modelling Language”. In: *Electronics* 9.2 (2020), page 379. DOI: 10.3390/electronics9020379. URL: <https://www.mdpi.com/2079-9292/9/2/379>.

EARL a SysML packages



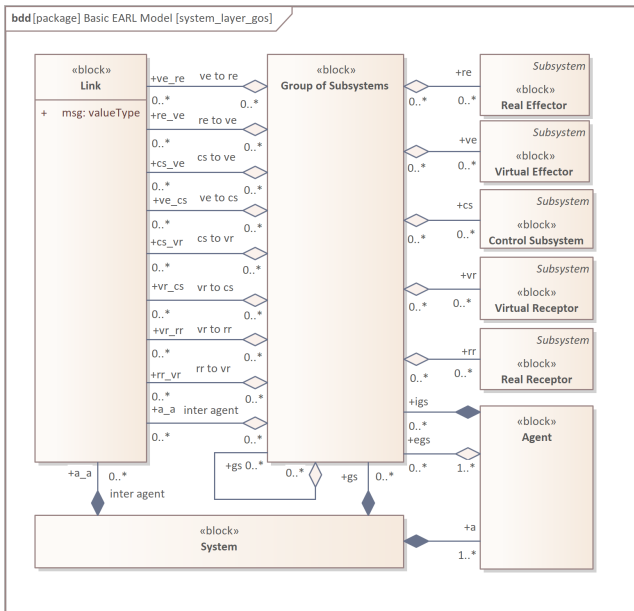
System layer



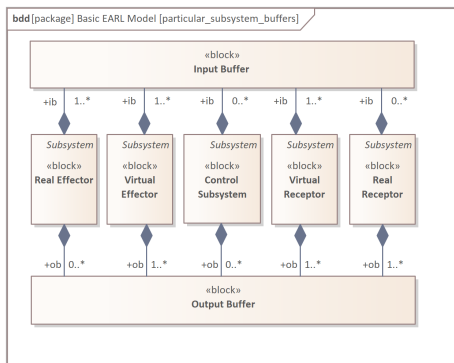
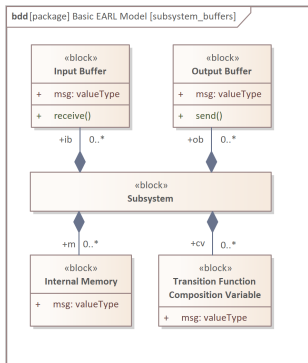
It is not trivial in SysML to add constraints like the following in the mathematical notations. EARL comprises it.

$$|vr| \geq 1 \iff |rr| \geq 1, \quad |ve| \geq 1 \iff |re| \geq 1. \quad (1)$$

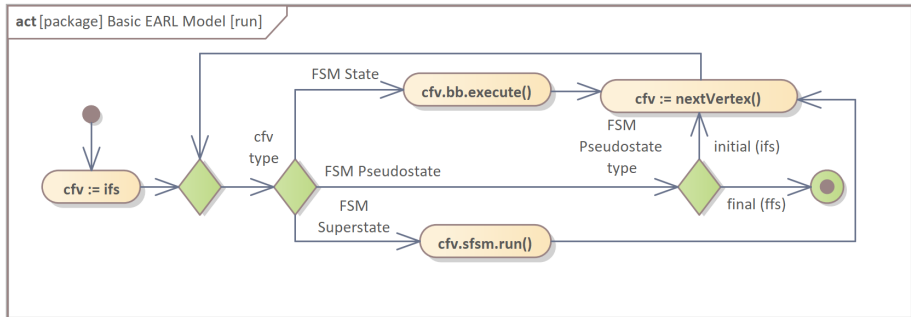
Groups of Subsystems



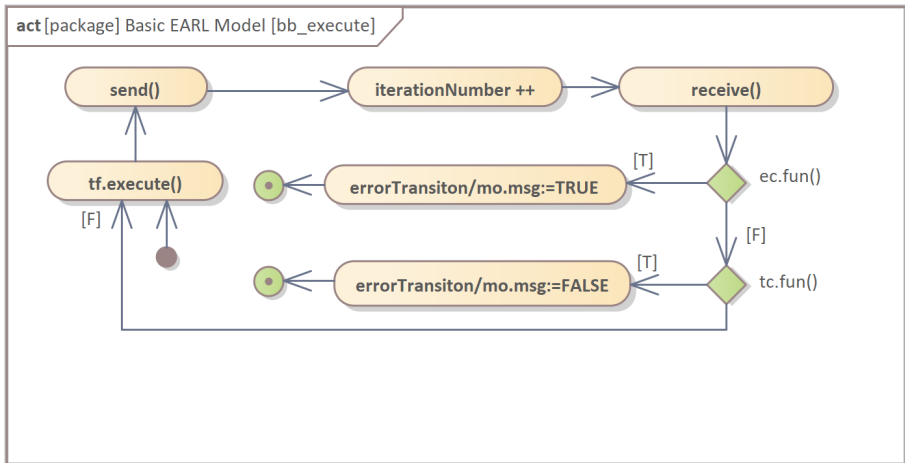
Buffers and Subsystems



Subsystem – operation FSM.run()

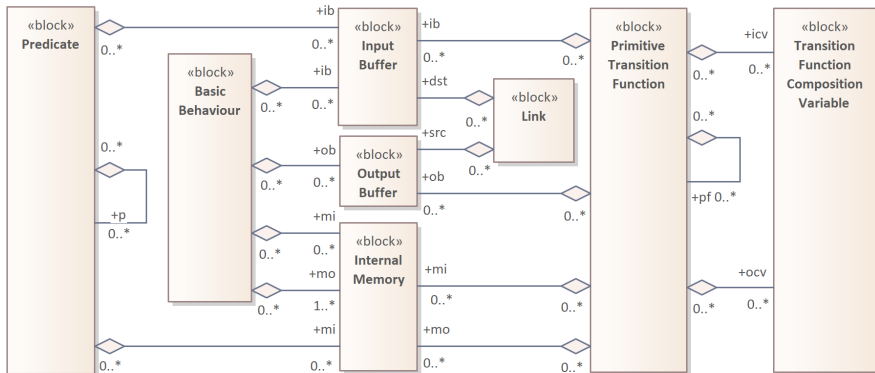


Subsystem – operation Basic Behaviour.execute()



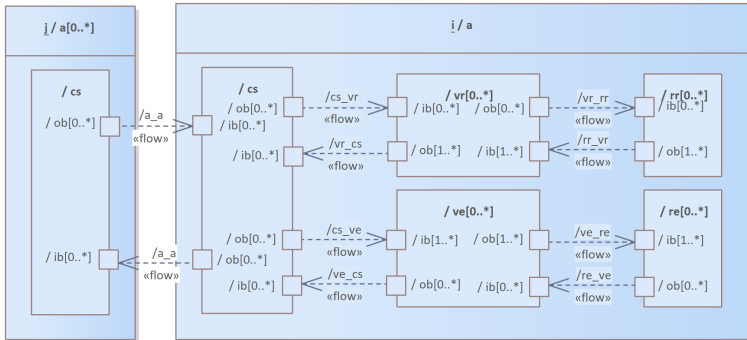
Subsystem – Buffers, Predicates, Primitive Transition Functions

bdd[package] Basic EARL Model [buffers_usage]



Model – communication constraints

ibid[package] Basic EARL Model [communication_constraints]



Some aspects of notation

The same Block can be presented in various context:

In Subsystem:

$$\textit{manip/a.cs.jointMotion/bb} \quad (2)$$

In FSM state: *fsm.firstMotion/s*:

$$\textit{manip/a.cs.fsm.firstMotion/s.jointMotion/bb} \quad (3)$$

If only one element exists, there is no need to specify particular name:

$$\textit{manip/a.cs.fsm.firstMotion/s.bb} \quad (4)$$

If there are many elements, the lack of name denotes all of the elements - the whole set:

$$\textit{manip/a.cs.bb} \quad (5)$$

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Gravity compensation in impedance robot control [8] – robot Velma in experiments



(a)



(b)



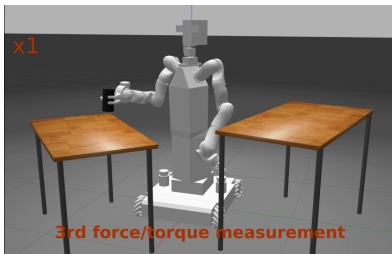
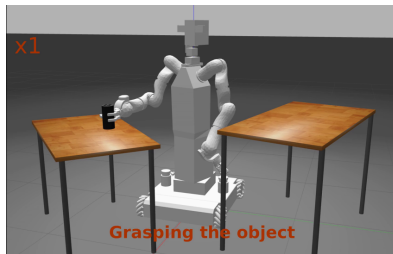
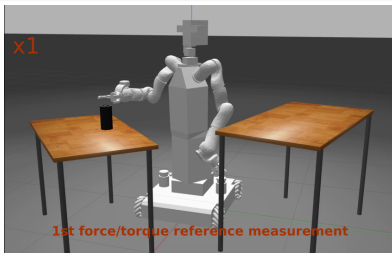
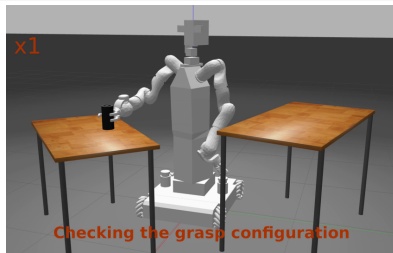
(c)



(d)

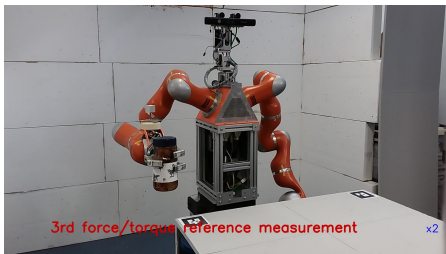
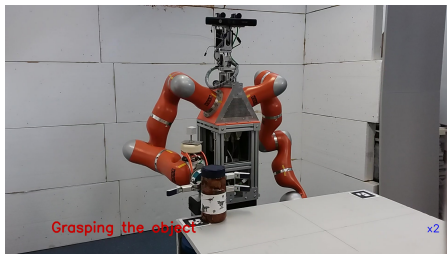
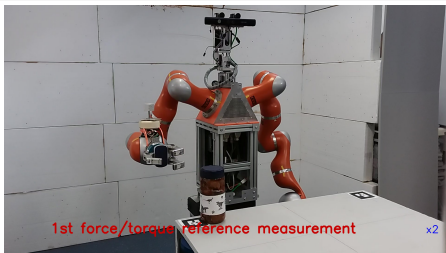
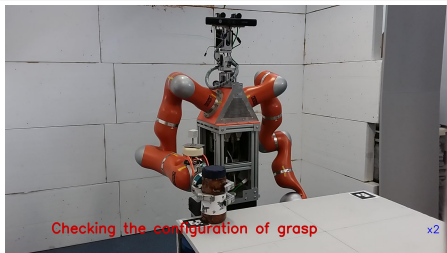
- [8] T. Winiarski, S. Jarocki, and D. Seredyński. “Grasped Object Weight Compensation in Reference to Impedance Controlled Robots”. In: *Energies* 14.20 (2021), page 6693. ISSN: 1996-1073. DOI: 10.3390/en14206693. URL: <https://www.mdpi.com/1996-1073/14/20/6693>.

Gravity compensation in impedance robot control – simulation



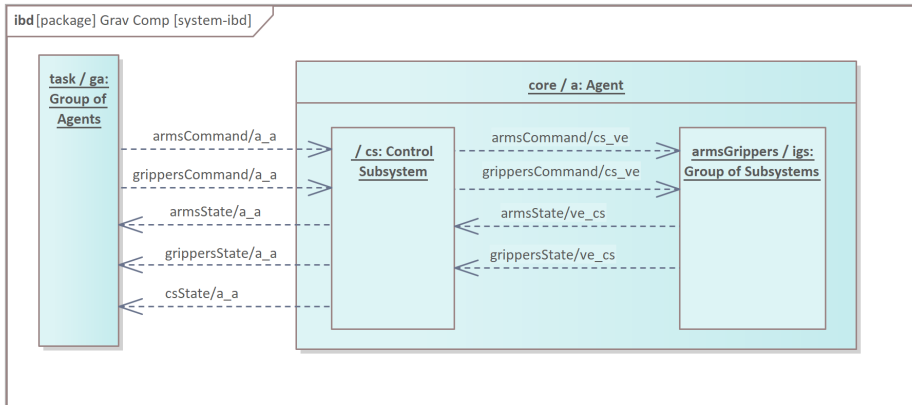
- [ownCloud/rpmpg_movies/team/velma/Grasped object weight compensation in simulation.mp4](https://ownCloud/rpmpg_movies/team/velma/Grasped%20object%20weight%20compensation%20in%20simulation.mp4)
- <https://vimeo.com/397214388>

Gravity compensation in impedance robot control – experiments with hardware



- [ownCloud/rmpmg_movies/team/velma/Grasped object weight compensation with hardware.mp4](https://ownCloud/rmpmg_movies/team/velma/Grasped%20object%20weight%20compensation%20with%20hardware.mp4)
- <https://vimeo.com/618941465>

Gravity compensation in impedance robot control – controller structure



Full (self-descriptive) notation of Agents names that bases on instances.

Rico – mobile assistive robot – execution of user commands [9] – the robot



- [9] T. Winiarski et al. "An intent-based approach for creating assistive robots' control systems". In: *arXiv preprint arXiv:2005.12106* (2020). URL: <http://arxiv.org/abs/2005.12106>.

Rico – transportation attendance with hazard detection [7]



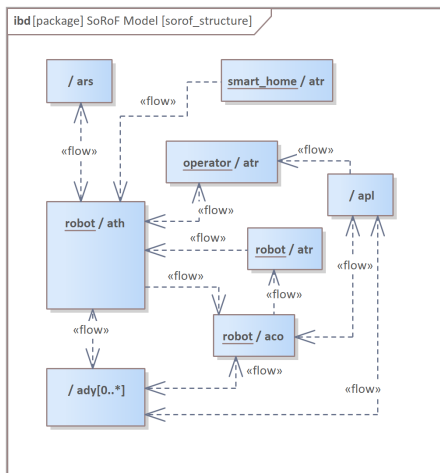
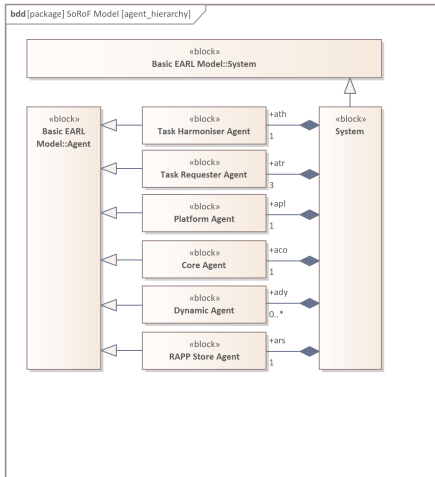
- ownCloud/rmpmg_movies/team/rico/20220120_uwiniara/rico-tea-home.m4v
- <https://vimeo.com/670252925>

Rico – reaction to a human fall [7]



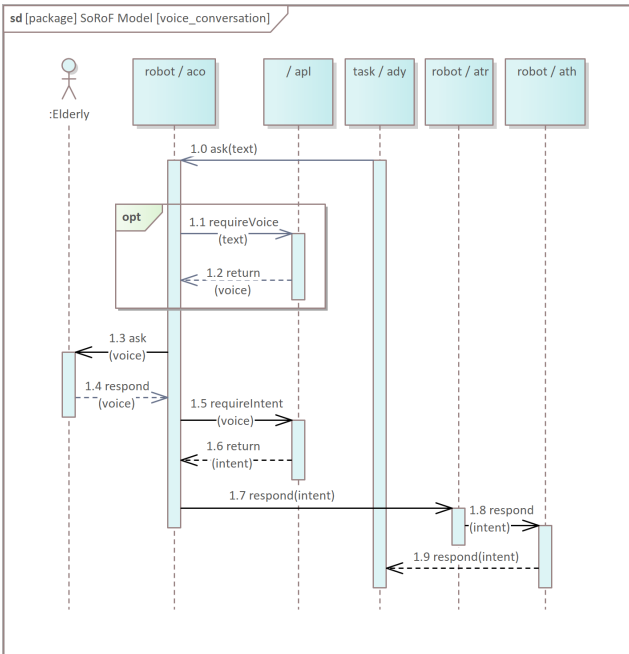
- ownCloud/rmpmg_movies/team/rico/20220120_uwiniara/rico-human-fall-home.m4v
- <https://vimeo.com/670246589>

Rico – controller structure

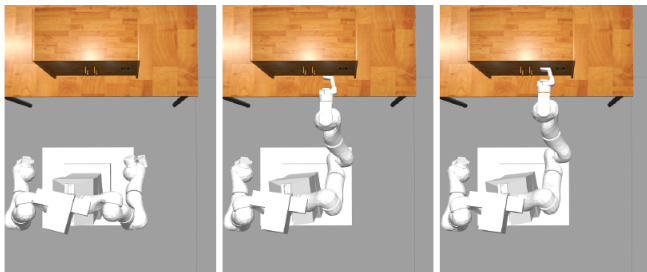


Short notation of Agents' names that bases on parts.

Rico – controller behaviour



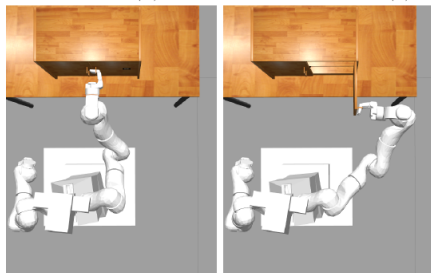
Velma – safety assurance



(a) point A

(b) before the door

(c) point C

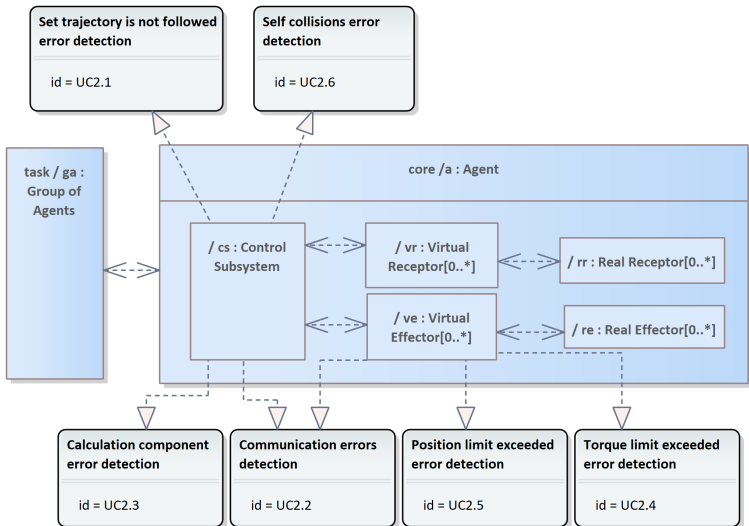


(d) point D

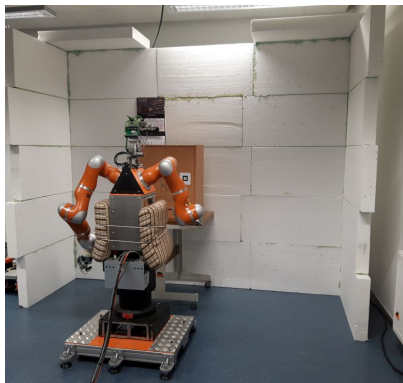
(e) point E

Velma – safety assurance – controller structure

ibd [package] Safety [general_system_structure]

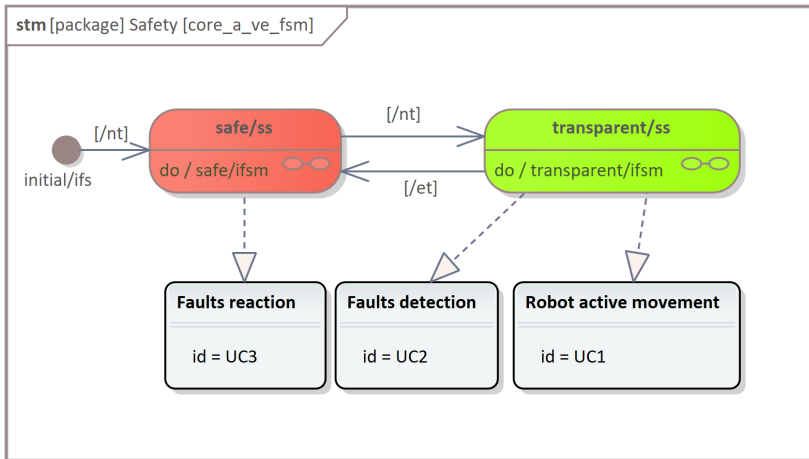


Velma – safety assurance – experiments [6]

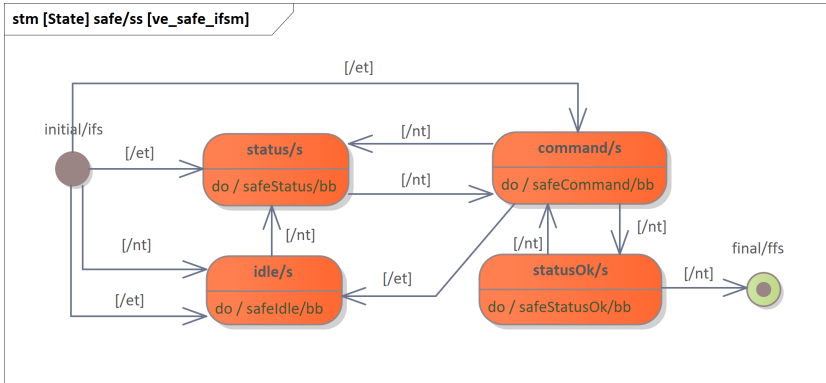


- ownCloud/rmpg_movies/team/velma/velma_safe_door_hq.mp4
- <https://vimeo.com/266285125>

Velma – safety assurance – hierarchical FSM of controller (1/2)



Velma – safety assurance – hierarchical FSM of controller (2/2)



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EARL has answered some issues stated within discussion on INCOSE 31st Annual International Symposium 2021 – Panel: The Journey from SysML 1.7 to 2.0 [2]:

- 1 the paradigm of using SysML to model robot controllers and cyber-physical systems,
- 2 the way to connect structural and behavioural diagrams,
- 3 text and graphic notations correlation.

[2] *INCOSE 31st Annual International Symposium 2021*. URL:
<https://www.incose.org/symp2021/home>.