From service to assistive robotics with EARL based system engineering

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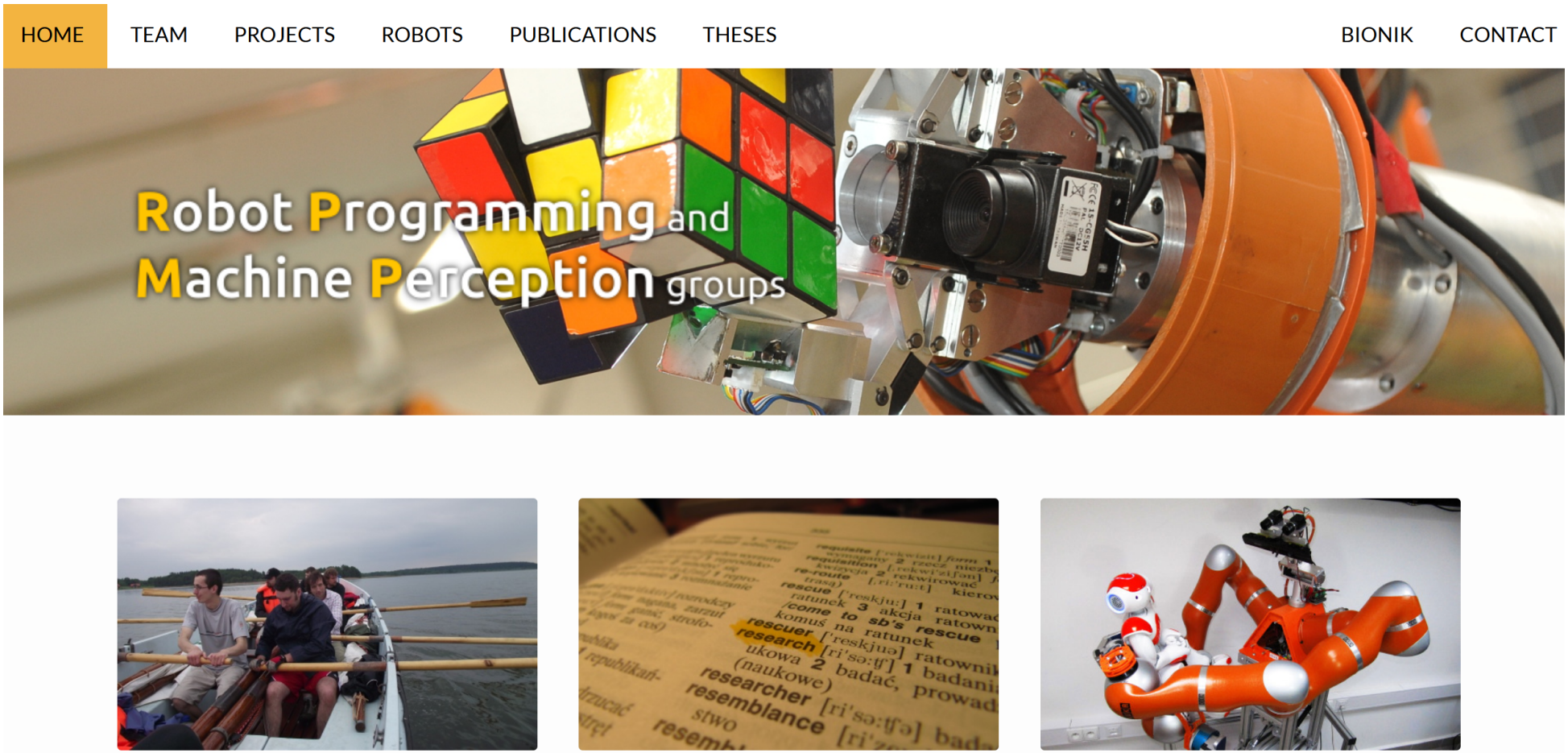
FIT Europe Bucharest seminar, 24 March 2022

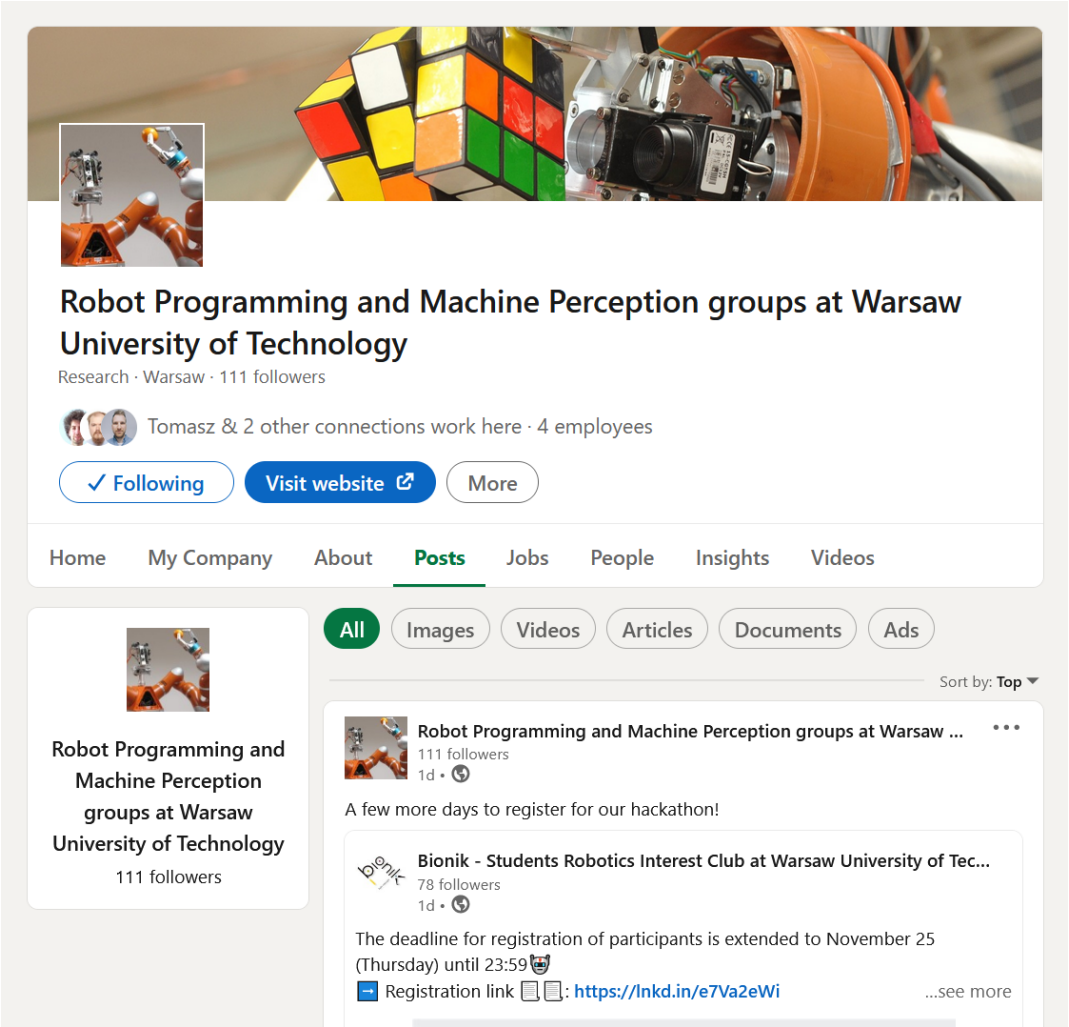
Plan

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



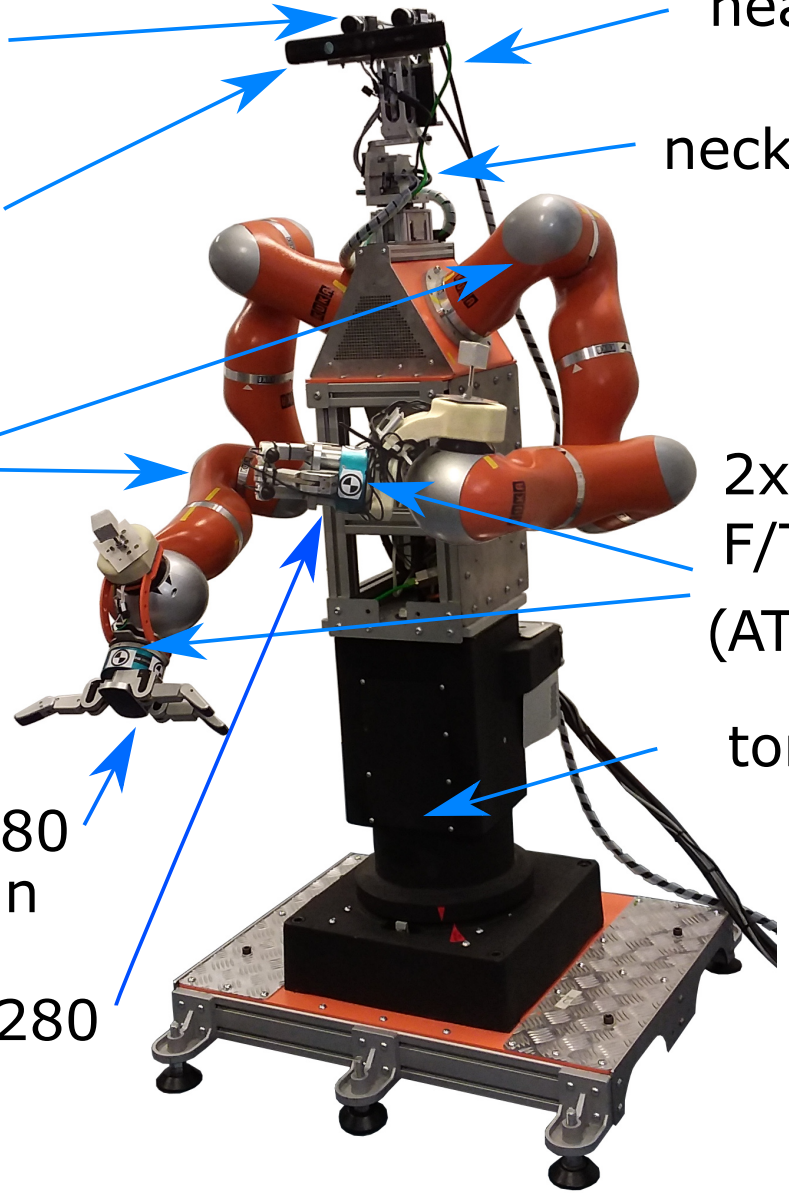
[6] *Robot Programming and Machine Perception group – www page*. URL: https://www.robotyka.ia.pw.edu.pl/.

Robot Programming and Machine Perception group – LinkedIN [5]

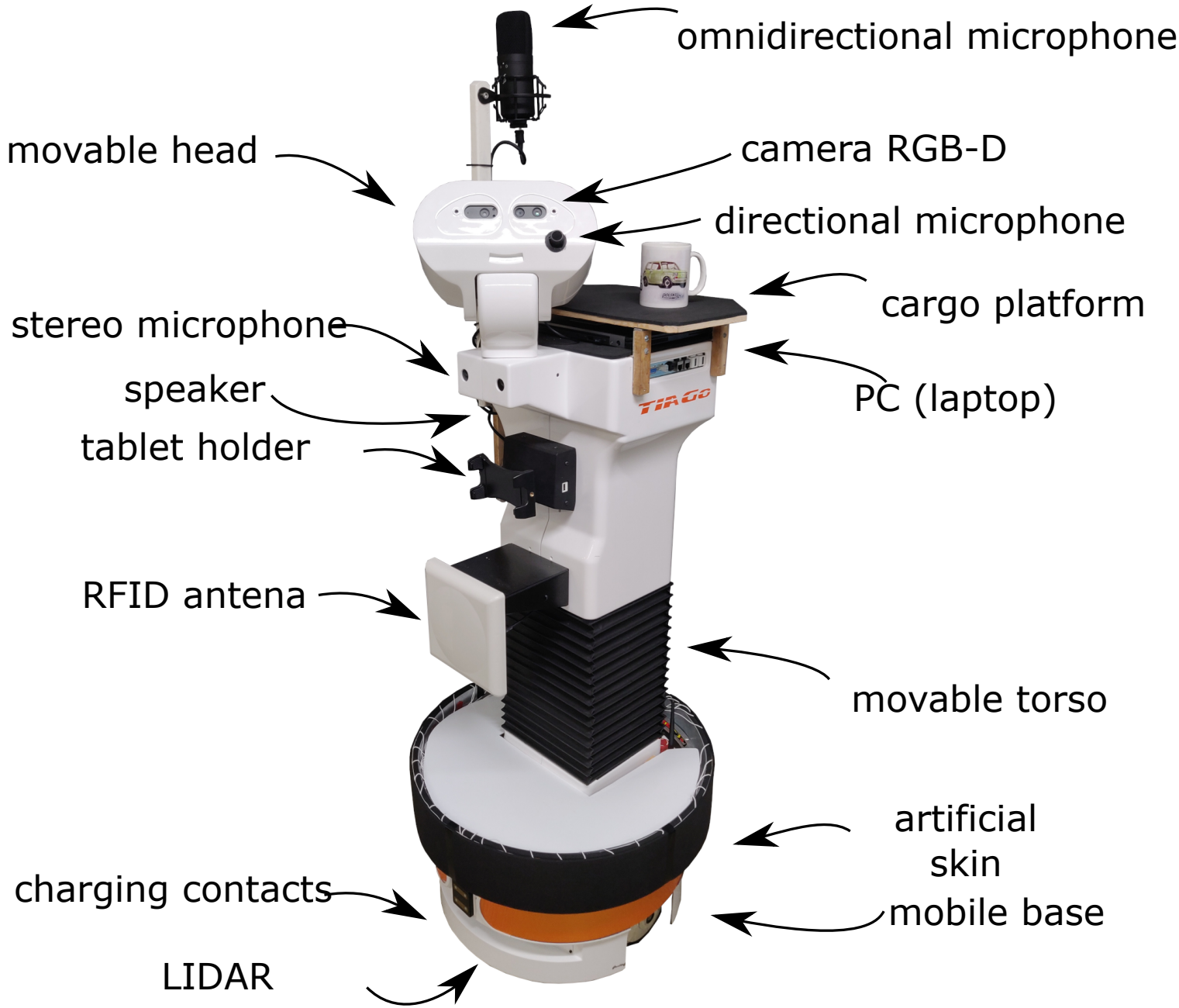


[5] *Robot Programming and Machine Perception group – LinkedIn*. URL: https://www.linkedin.com/company/robot-programming-and-machine-perceptions-groups-warsaw-university-of-technology/.

Velma service robot



Rico (modified TIAGo) assistive robot



Plan

EARL idea

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].

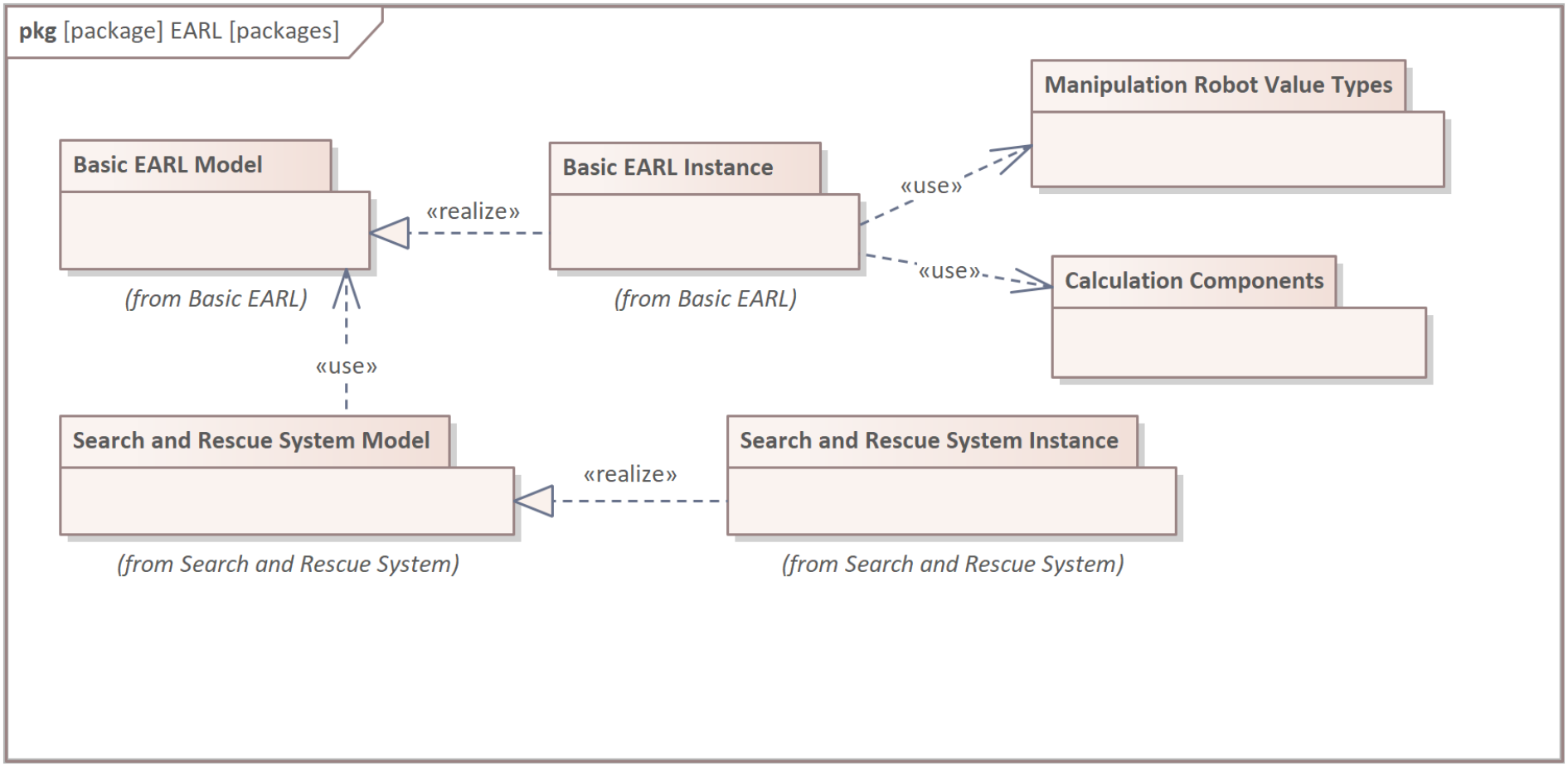
[1] *EARL – Embodied Agent-Based Robot Control Systems Modelling Language - reference manual*. Mar. 2022. URL: https://www.robotyka.ia.pw.edu.pl/projects/earl/.

[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.

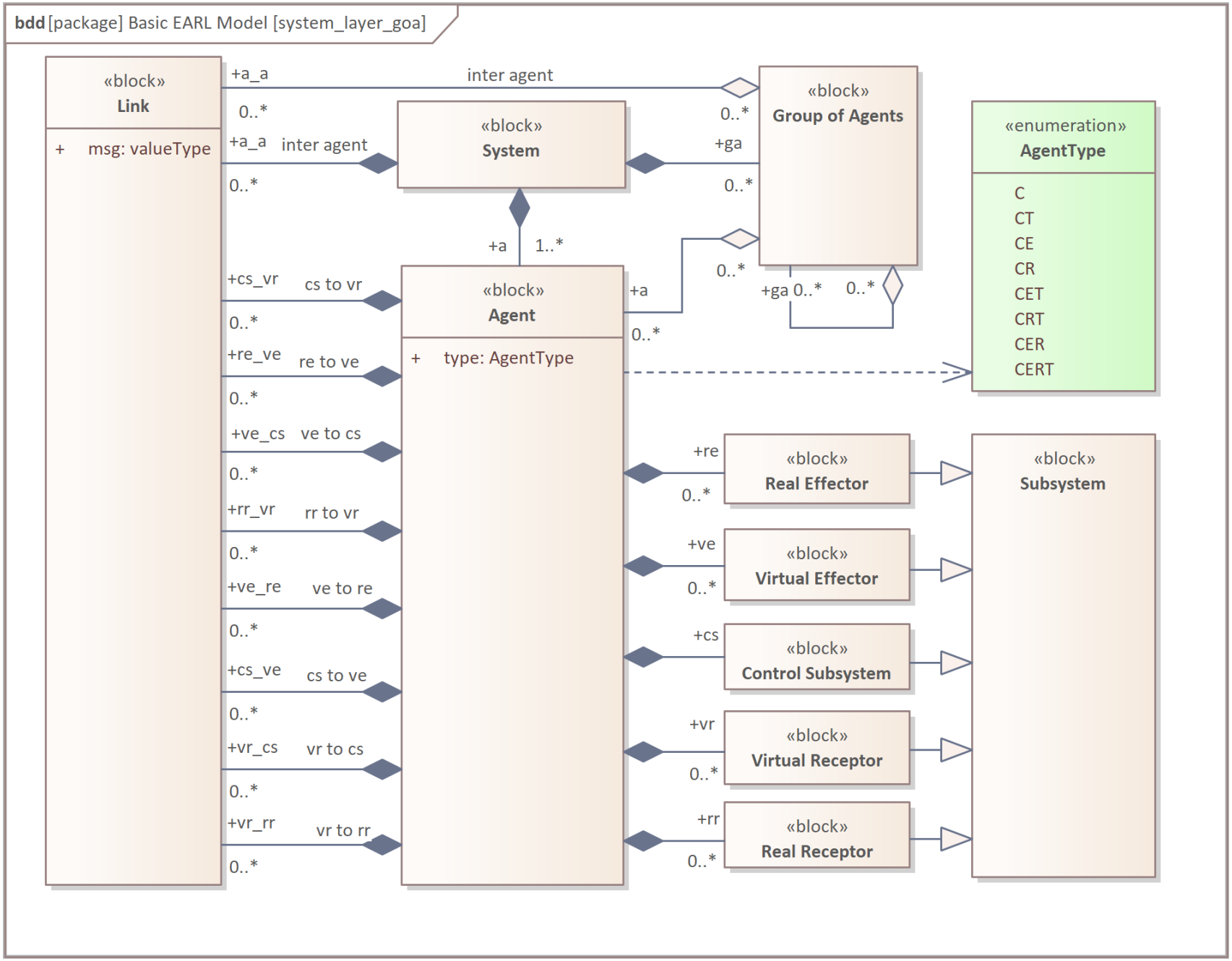
[4] *OMG Systems Modeling Language - Version 1.6*. accessed on 4 April 2020. Open Management Group. Dec. 2019. URL: https://www.omg.org/spec/SysML/1.6/.

[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

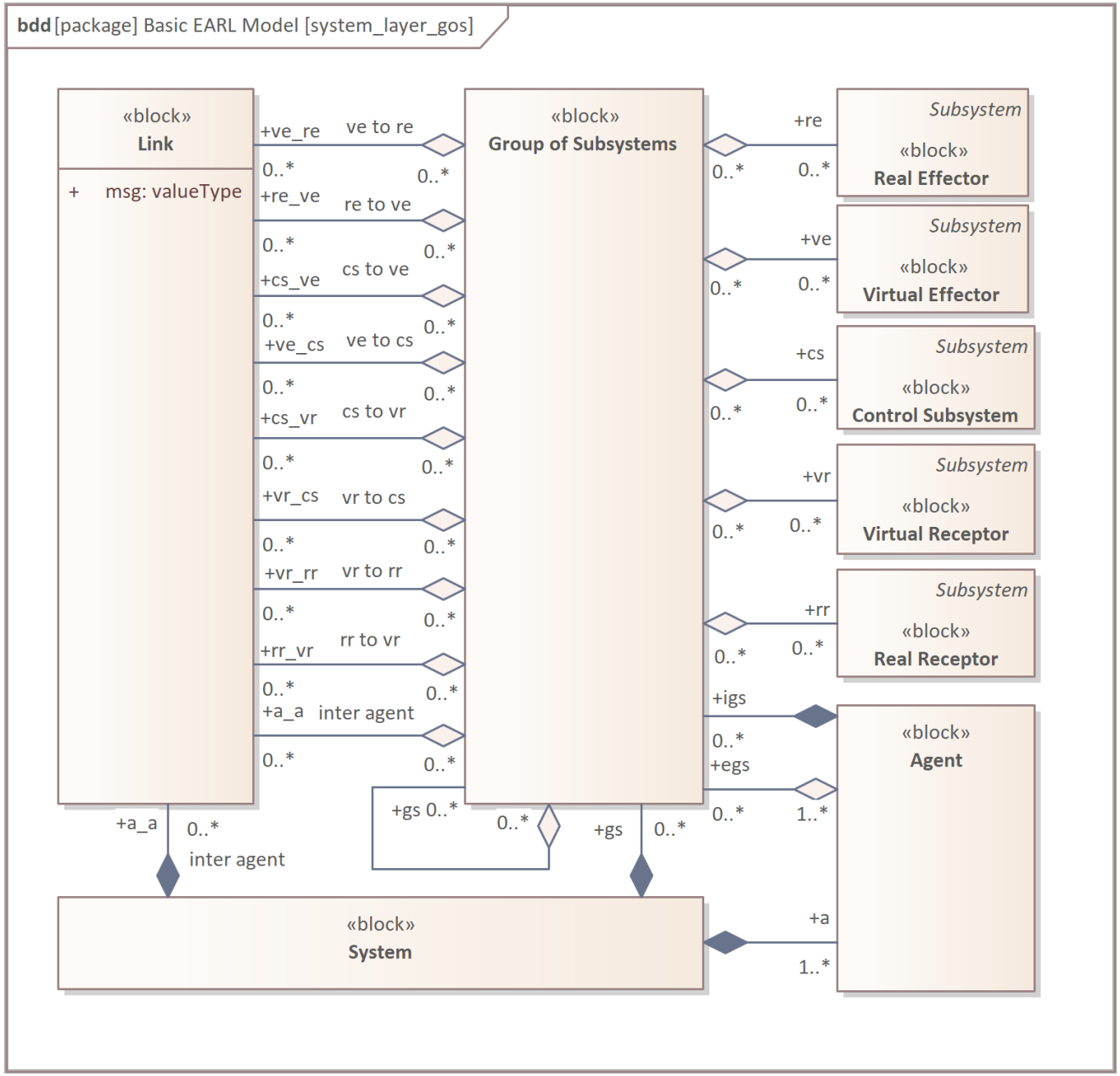


Metamodel - System layer - cardinality of Subsystems

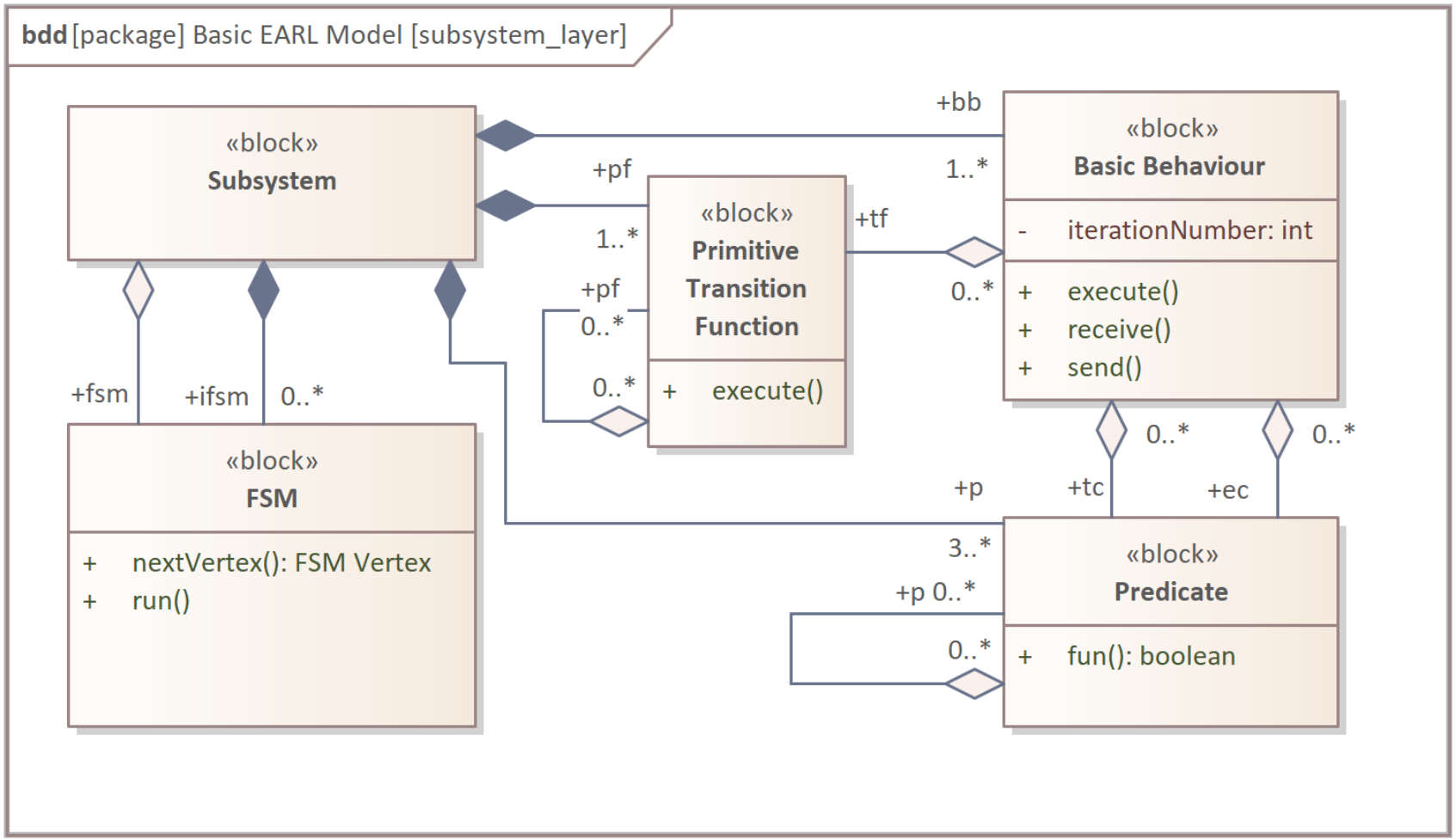
It is not trivial in SysML to add constraints like the following in the mathematical notations. EARL comprises it.

$$|vr| \geqslant 1 \iff |rr| \geqslant 1, \quad |ve| \geqslant 1 \iff |re| \geqslant 1. \tag{1}$$

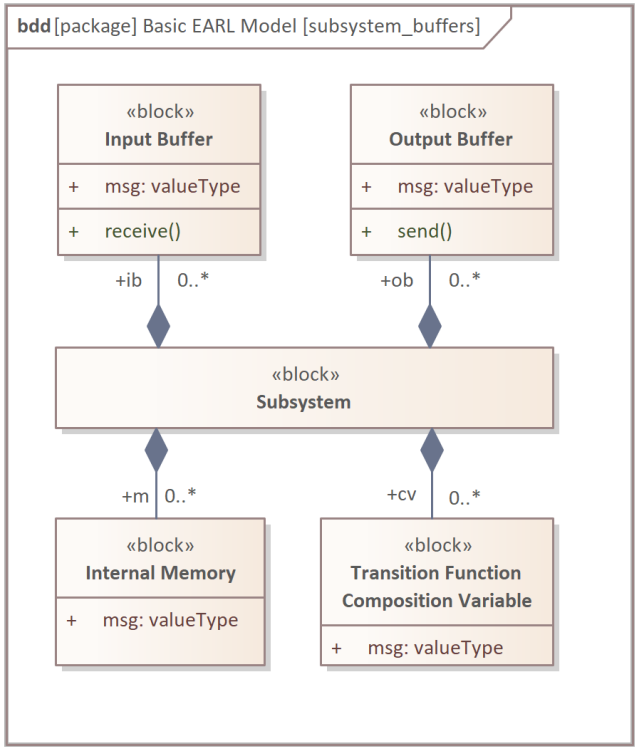
Groups of Subsystems

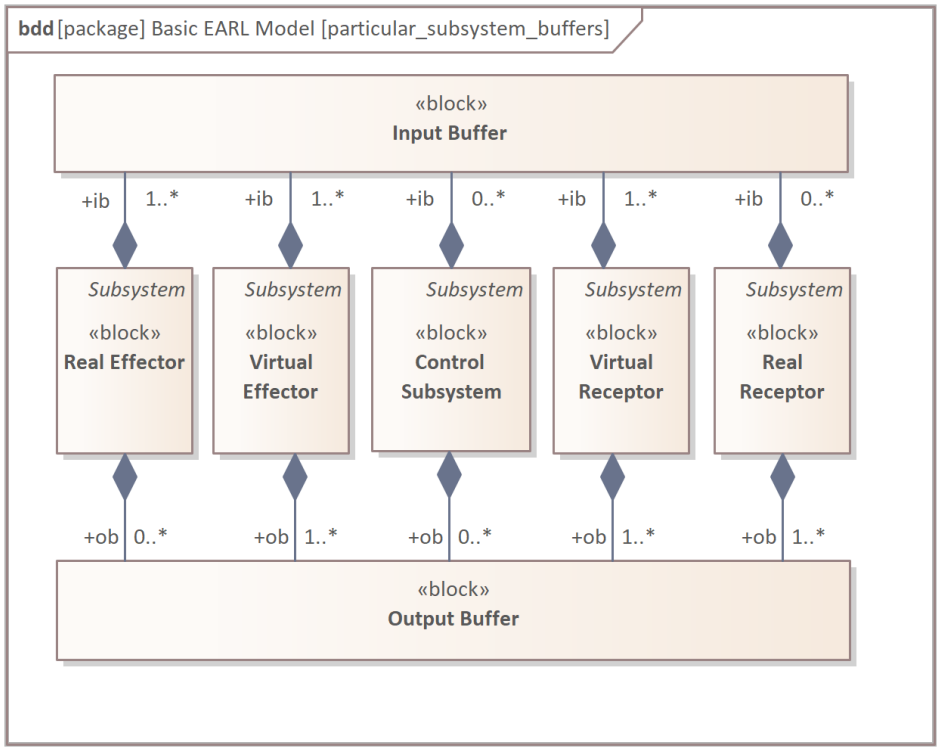


Subsystem layer

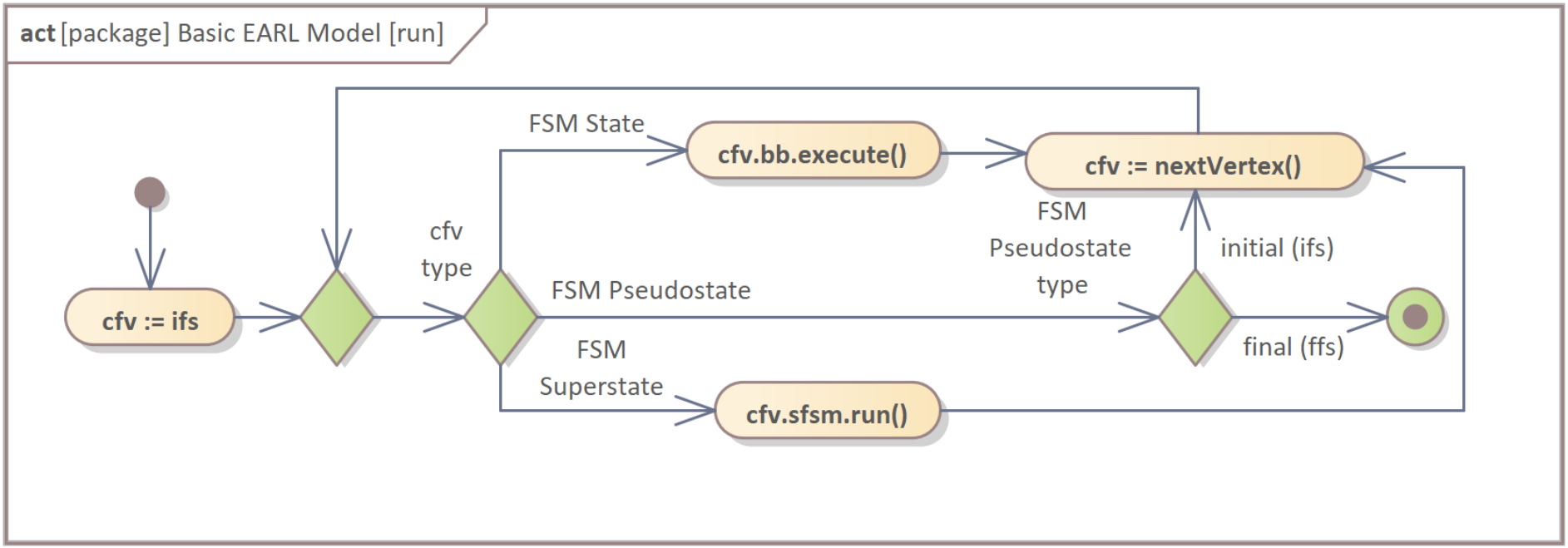


Buffers and Subsystems

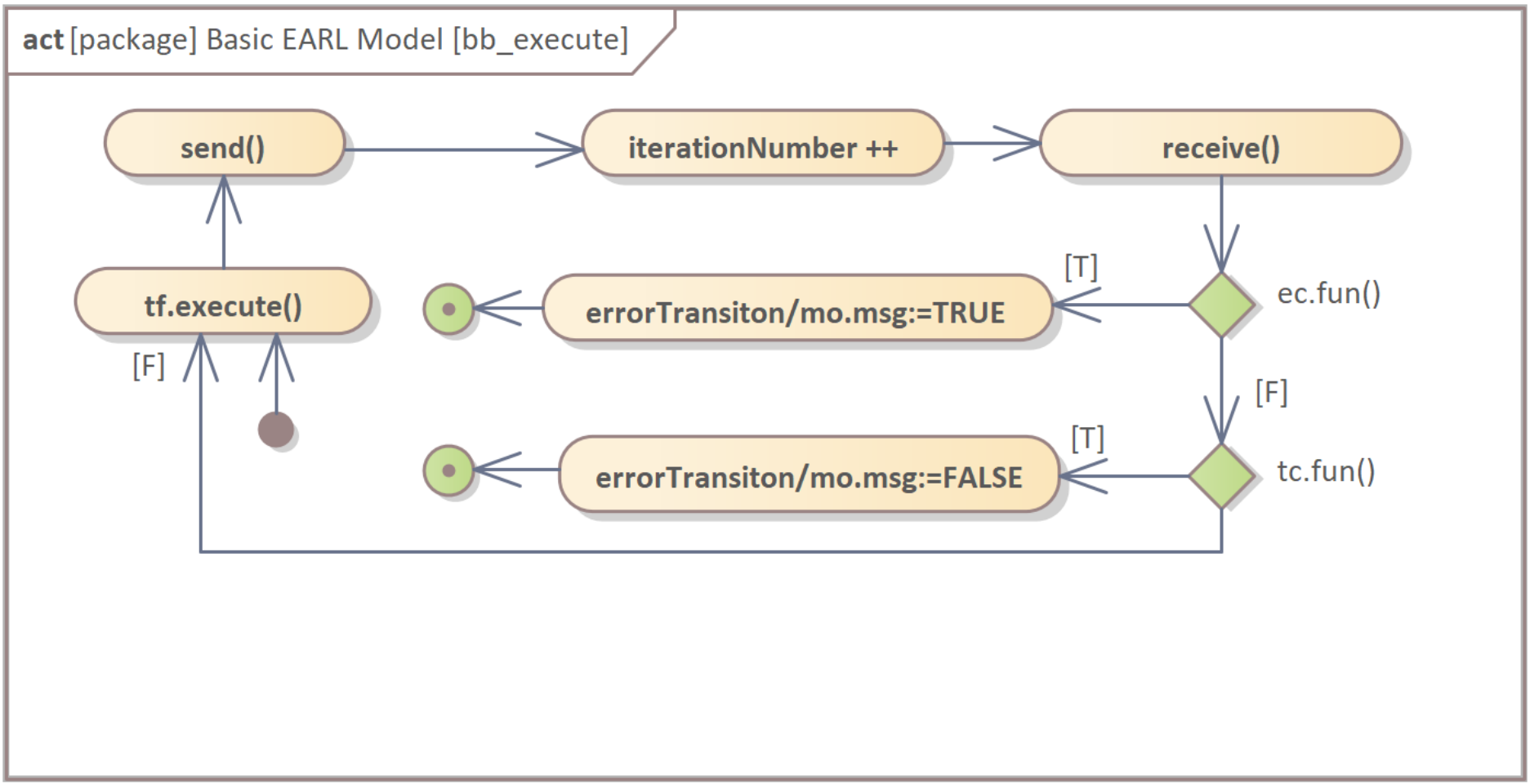




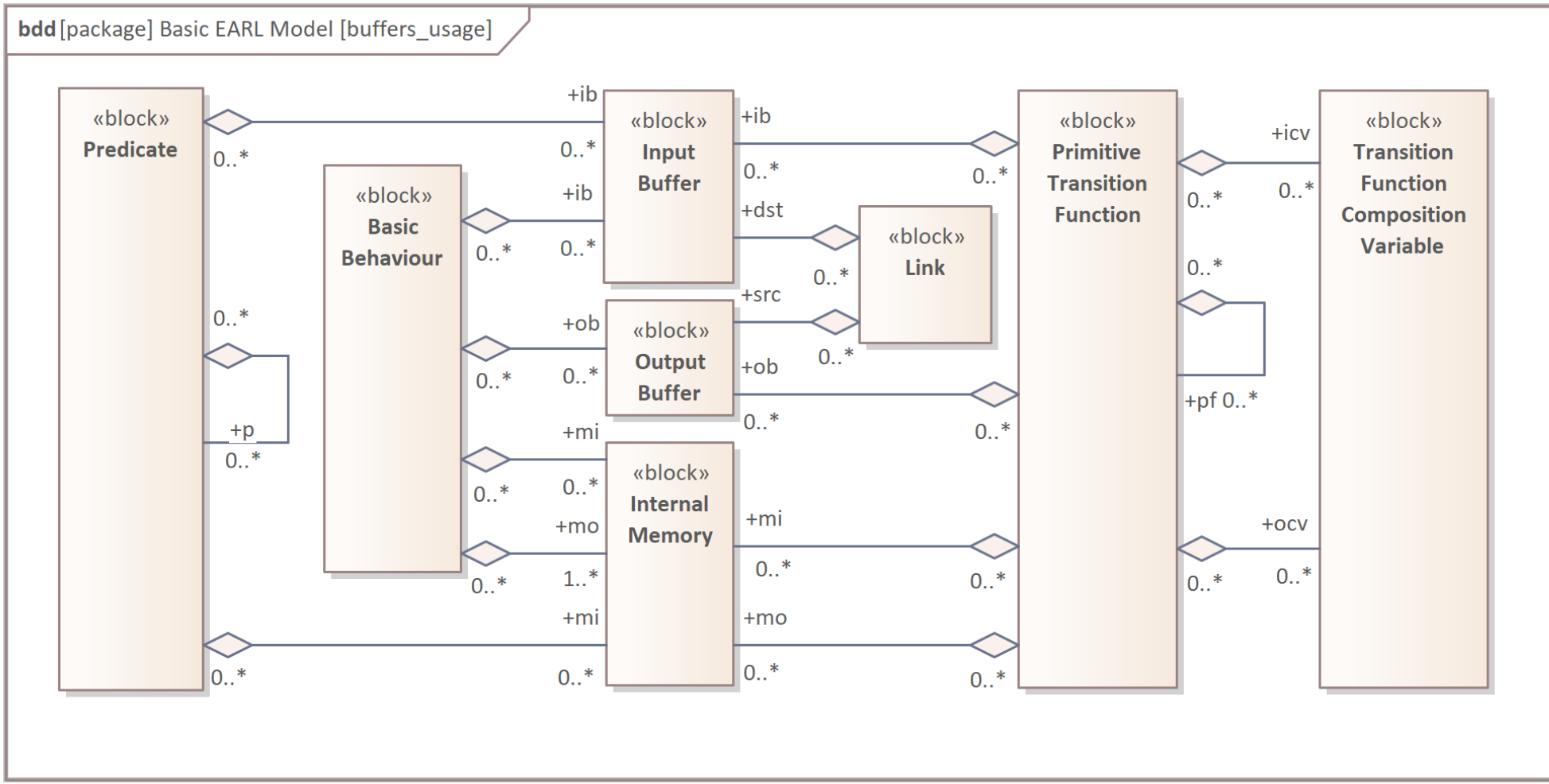
Subsystem – operation FSM.run()



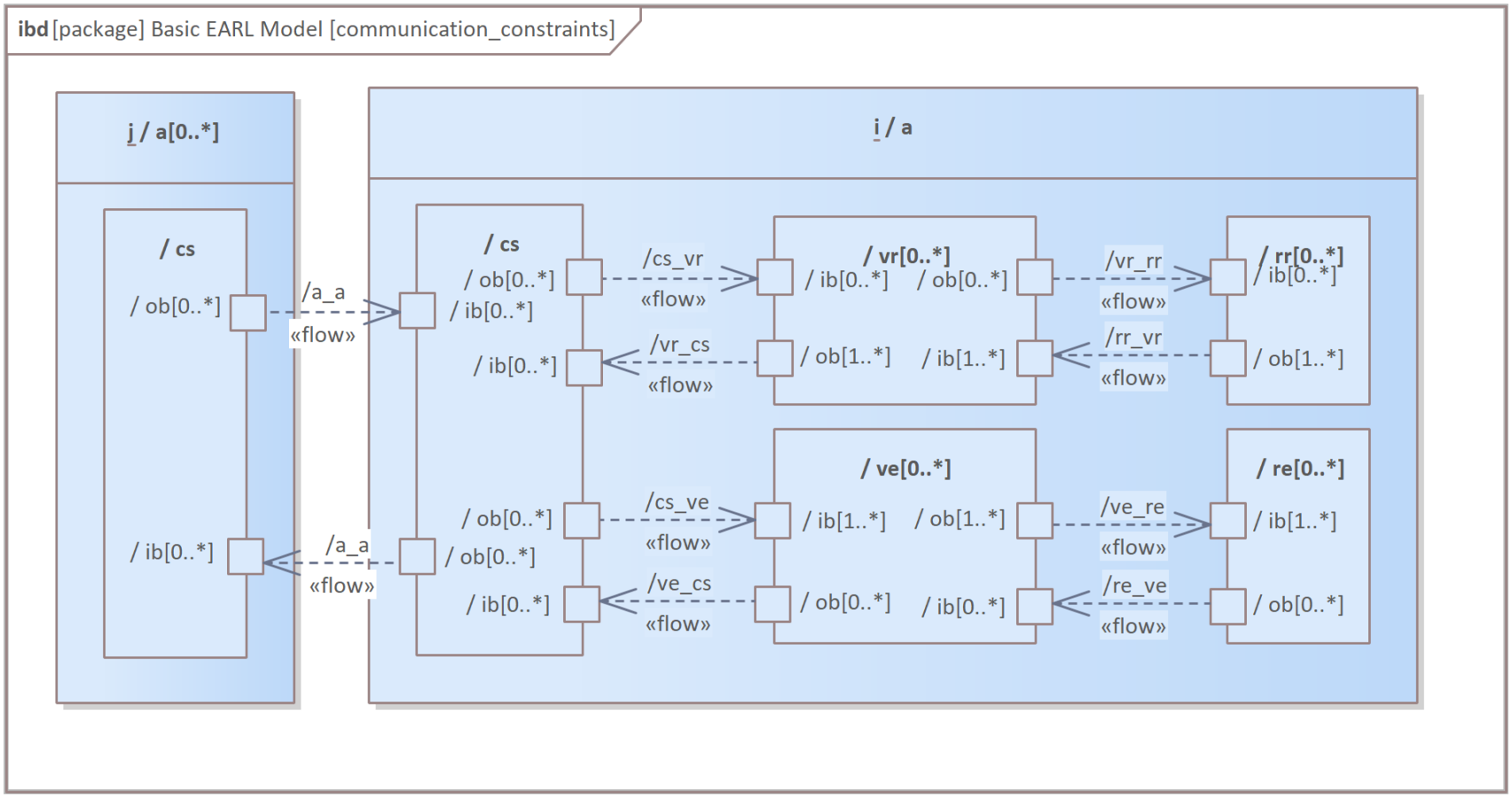
Subsystem – operation Basic Behaviour.execute()



Subsystem – Buffers, Predicates, Primitive Transition Functions



Model – communication constraints



Some aspects of notation

The same Block can be presented in various context:
In Subsystem:

$$manip/a.cs.jointMotion/bb \tag{2}$$

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

$$manip/a.cs.fsm.firstMotion/s.jointMotion/bb \tag{3}$$

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

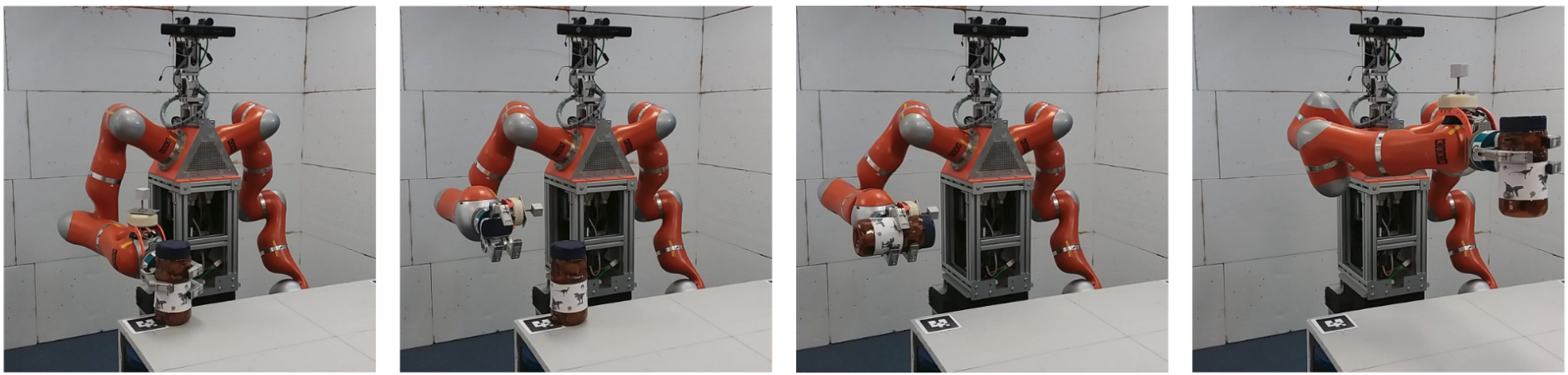
$$manip/a.cs.fsm.firstMotion/s.bb \tag{4}$$

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

$$manip/a.cs.bb \tag{5}$$

Plan

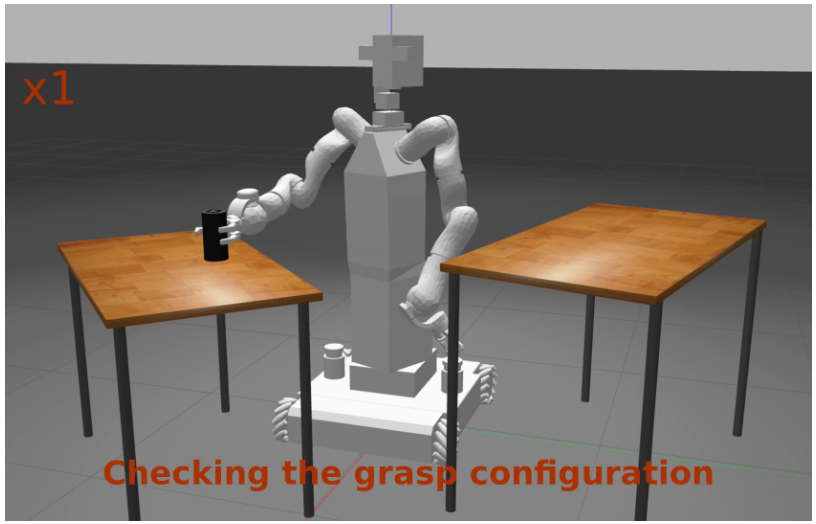
Gravity compensation in impedance robot control [8] – robot Velma in experiments

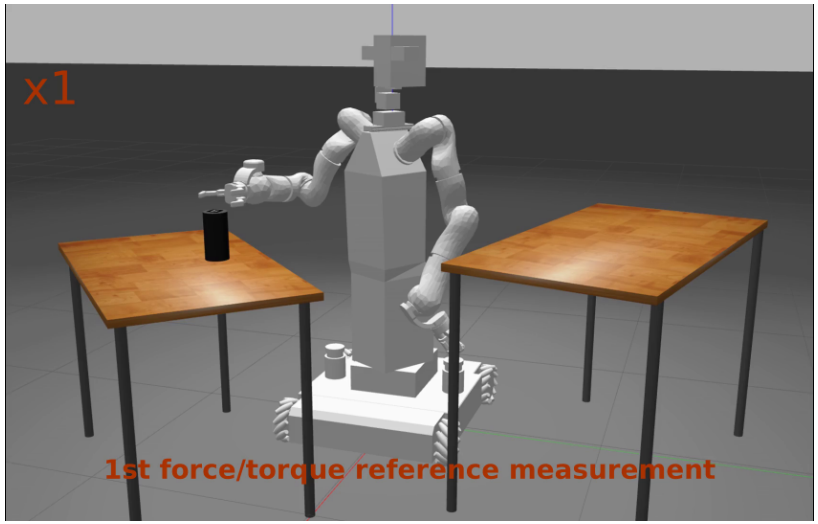


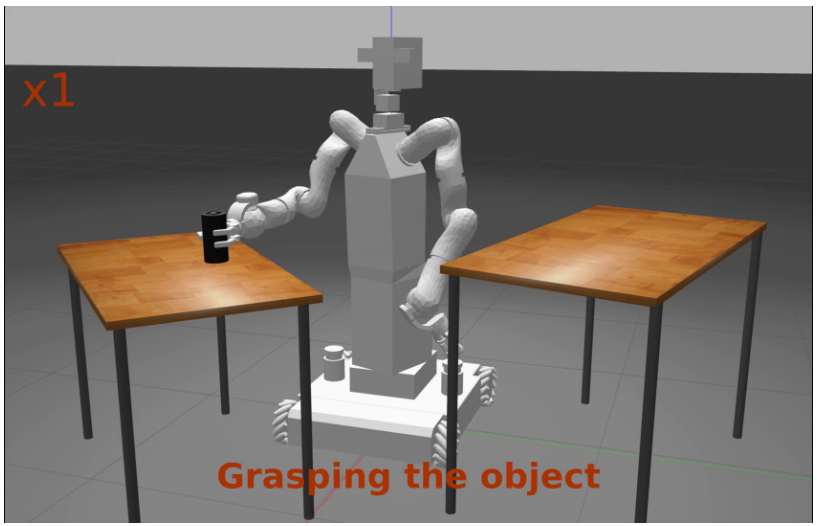
(a) **(b)** **(c)** **(d)**

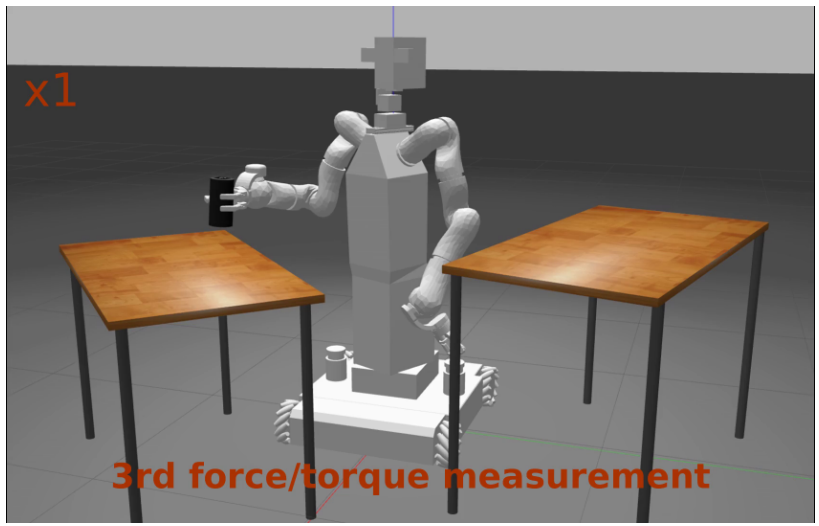
[8] T. Winiarski, S. Jarocki, and D. Seredyński. "Grasped Object Weight Compensation in Reference to Impedance Controlled Robots". In: *Energies* 14.20 (2021), page 6693. ISSN: 1996-1073. DOI: 10.3390/en14206693. URL: https://www.mdpi.com/1996-1073/14/20/6693.

Gravity compensation in impedance robot control – simulation



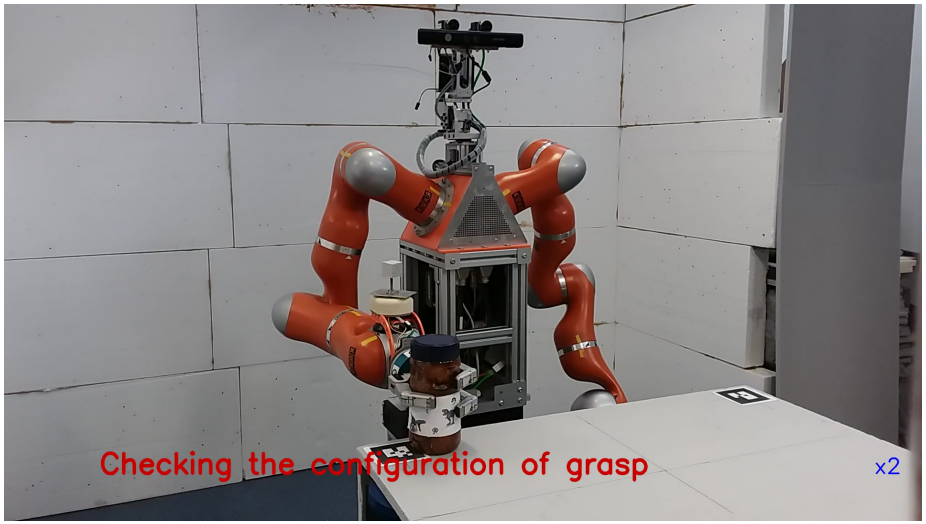


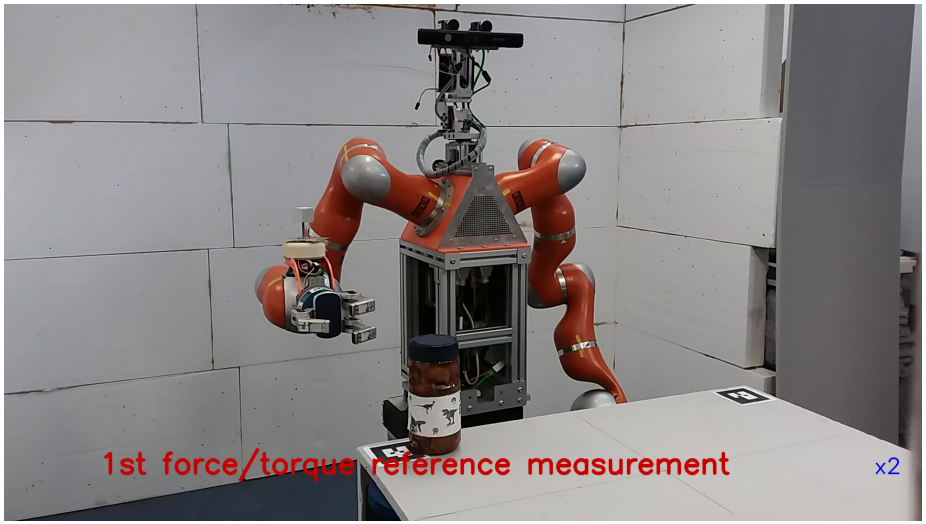


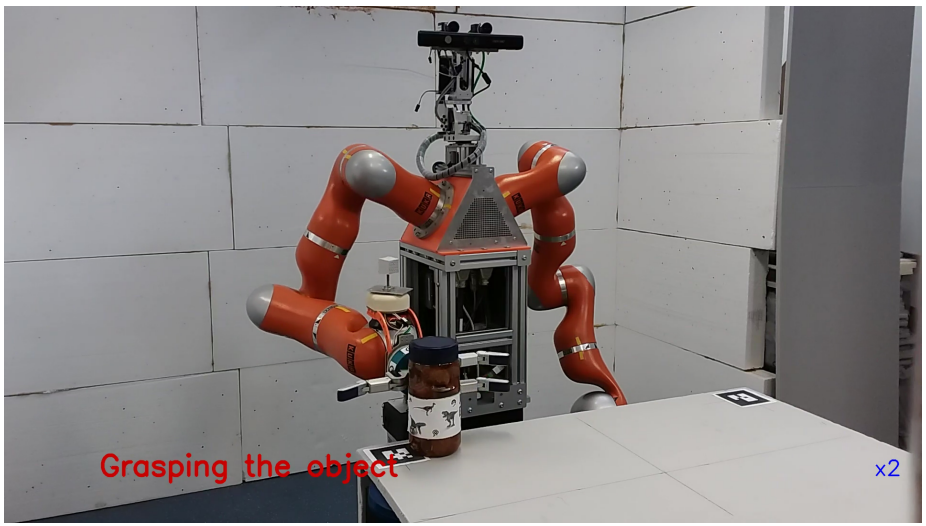


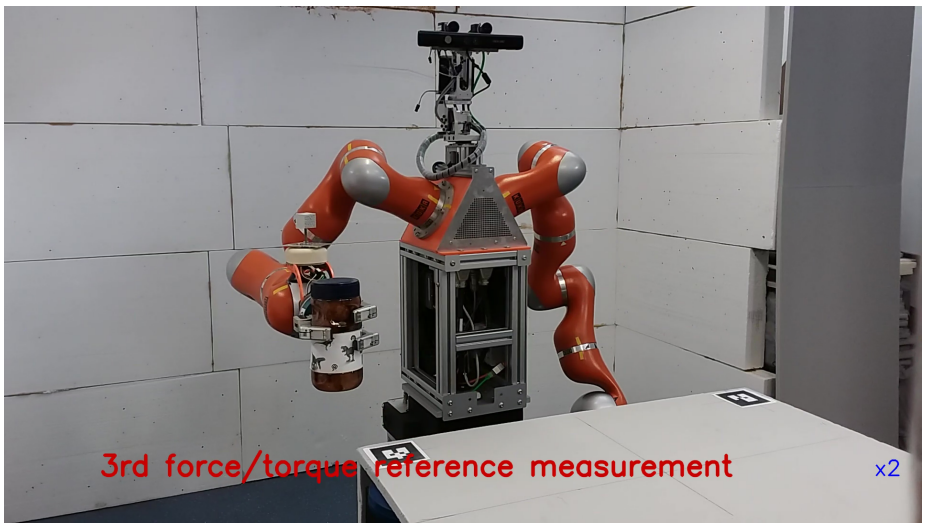
- ownCloud/rpmpg_movies/team/velma/Grasped object weight compensation in simulation.mp4
- `https://vimeo.com/397214388`

Gravity compensation in impedance robot control – experiments with hardware



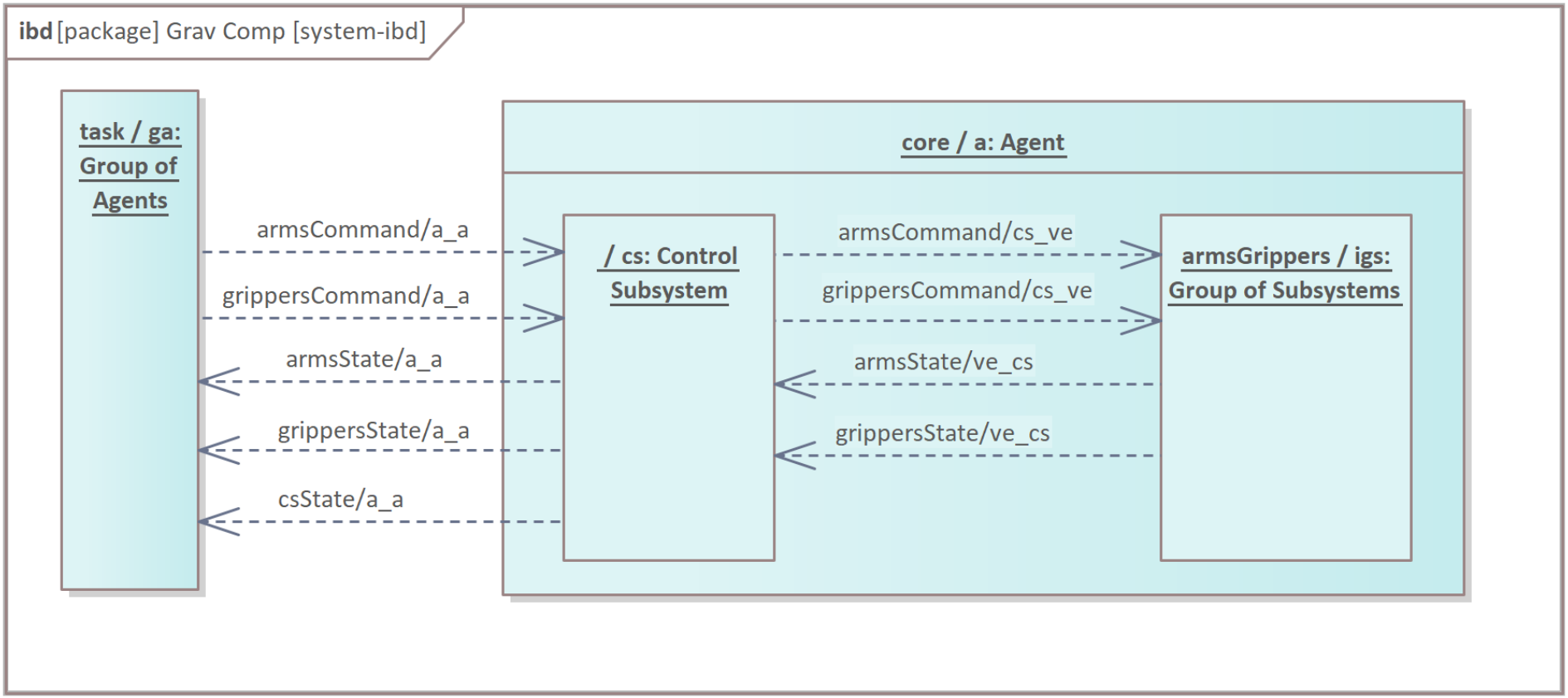






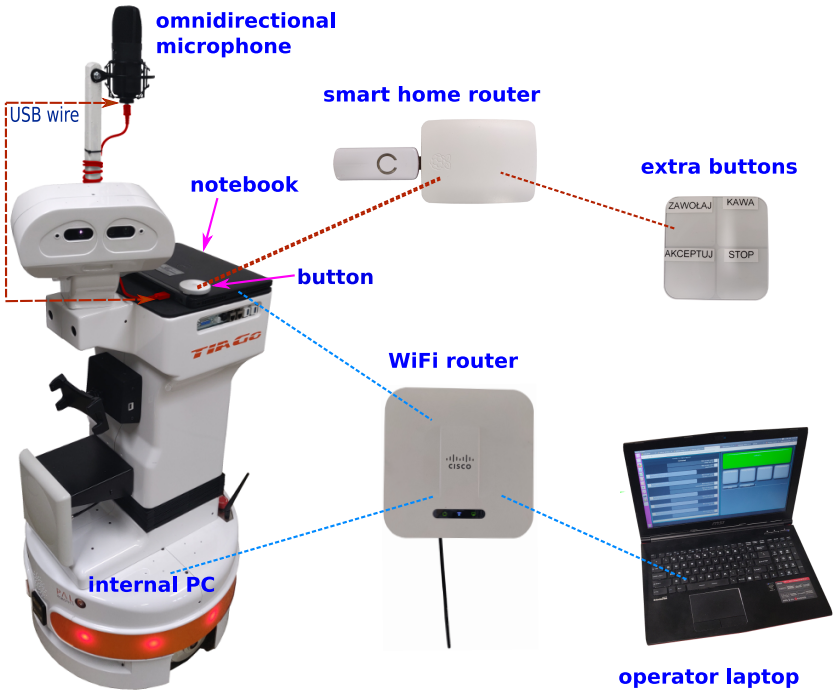
- ownCloud/rpmpg_movies/team/velma/Grasped object weight compensation with hardware.mp4
- `https://vimeo.com/618941465`

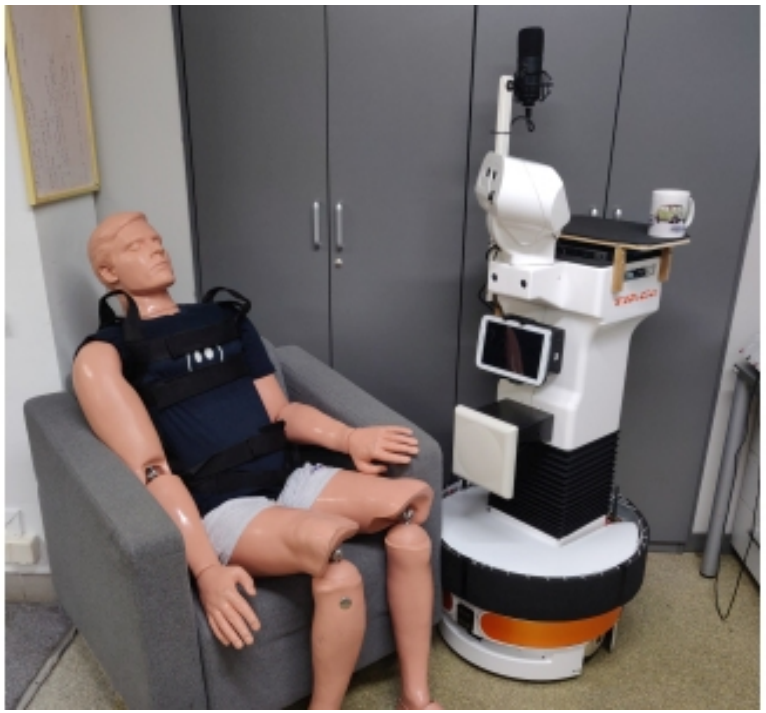
Gravity compensation in impedance robot control – controller structure



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.

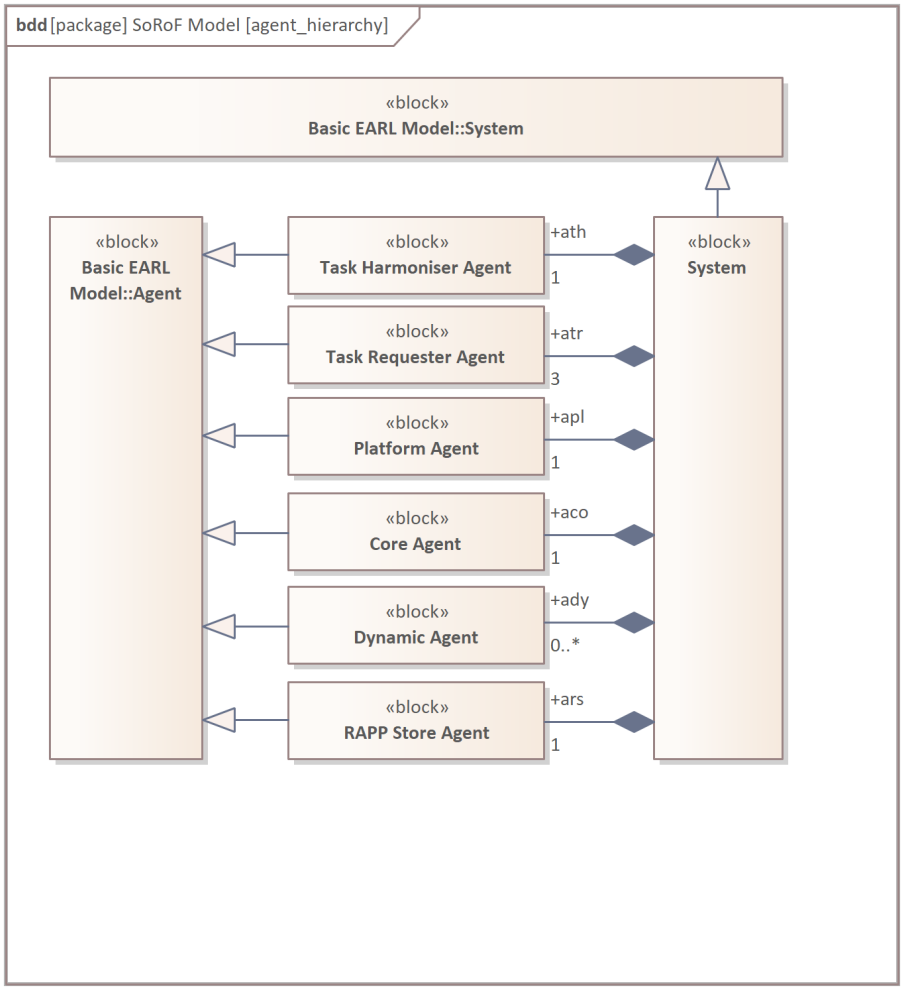
Rico – transportation attendance with hazard detection [7]

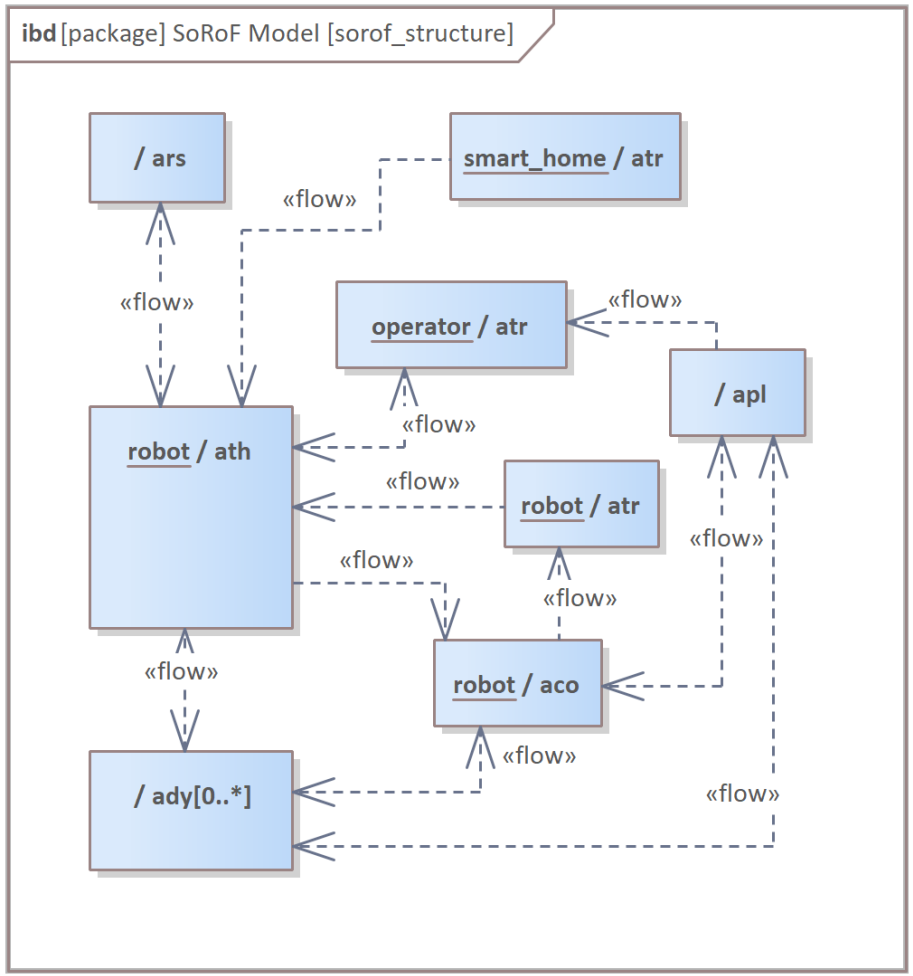
- ownCloud/rpmpg_movies/team/rico/20220120_uwiniara/rico-tea-home.m4v
- `https://vimeo.com/670252925`

Rico – reaction to a human fall [7]

- ownCloud/rpmpg_movies/team/rico/20220120_uwiniara/rico-human-fall-home.m4v
- `https://vimeo.com/670246589`

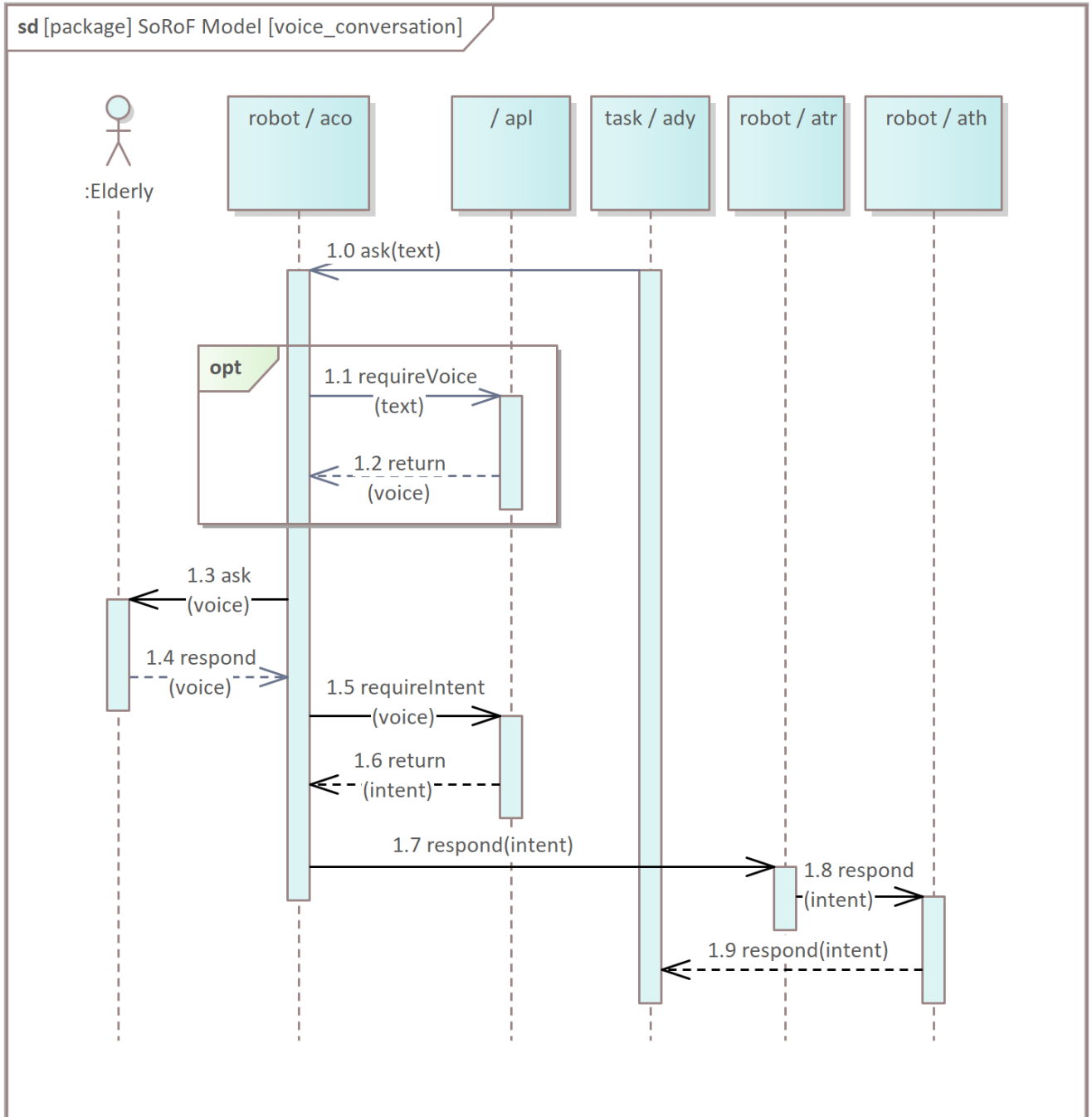
Rico – controller structure



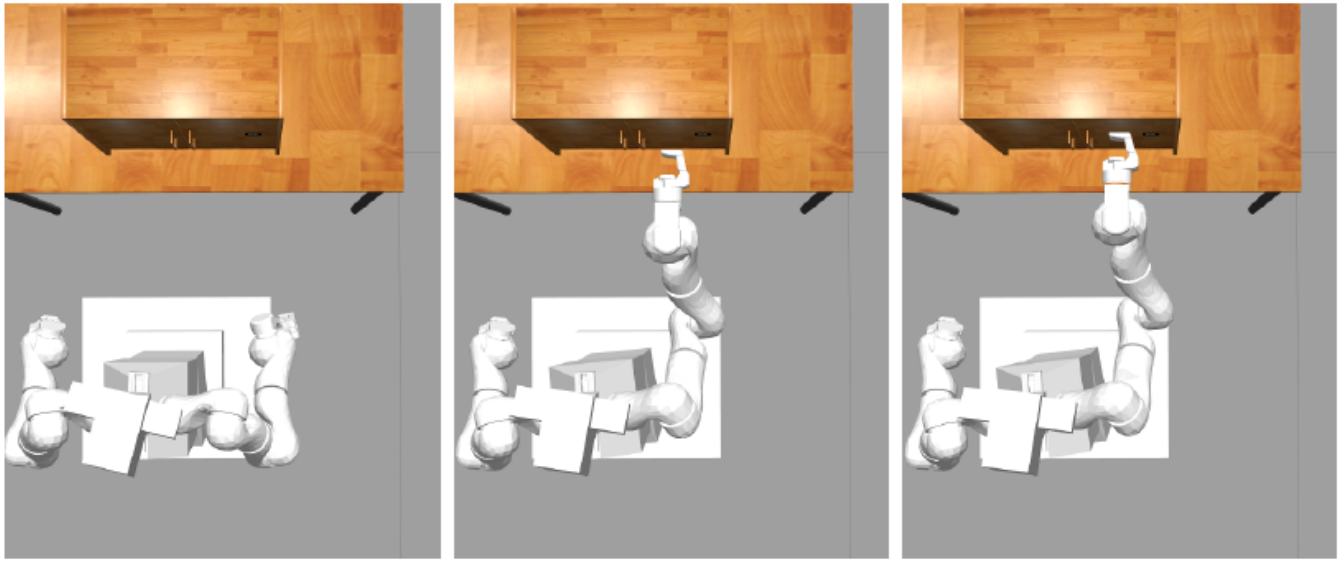


Short notation of Agents' names that bases on parts.

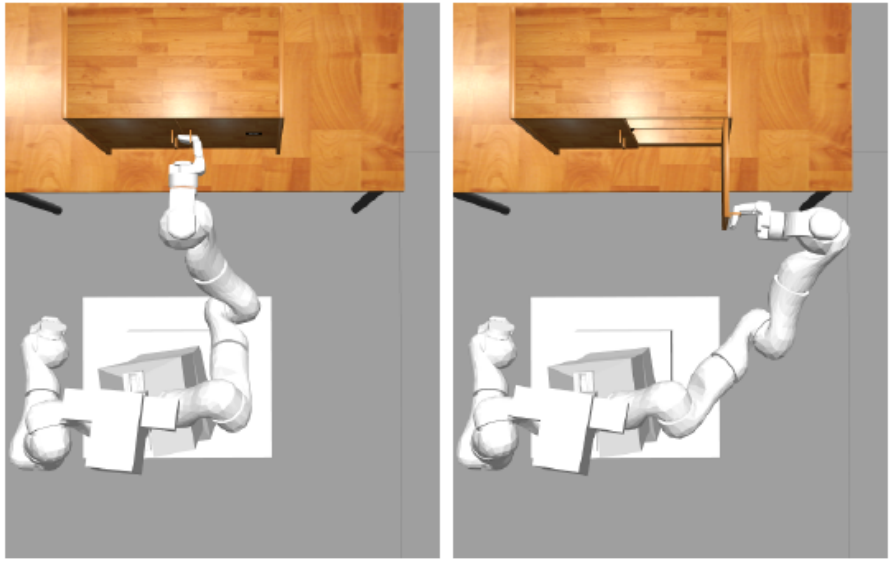
Rico – controller behaviour



Velma – safety assurance



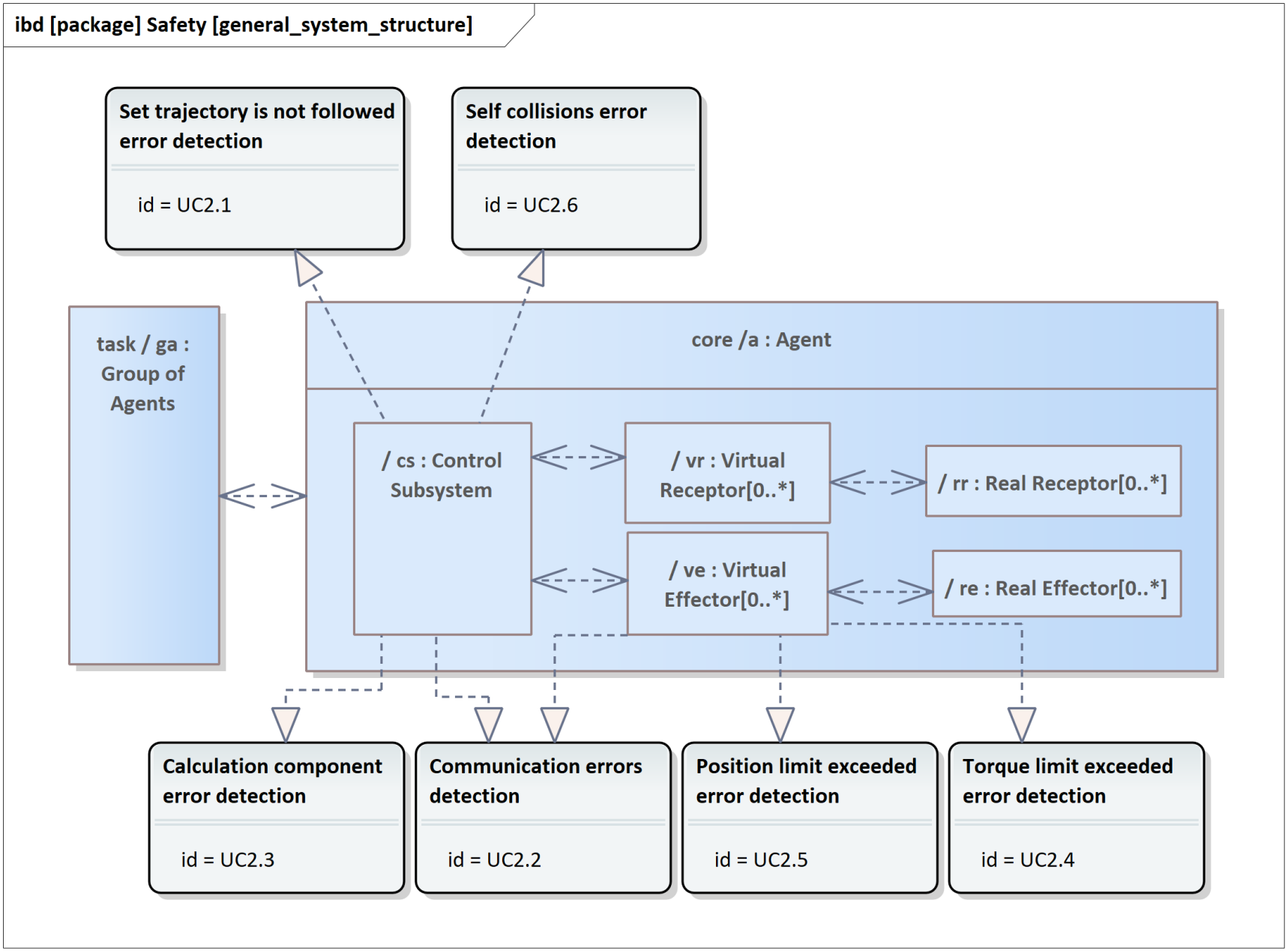
(a) point A (b) before the door (c) point C



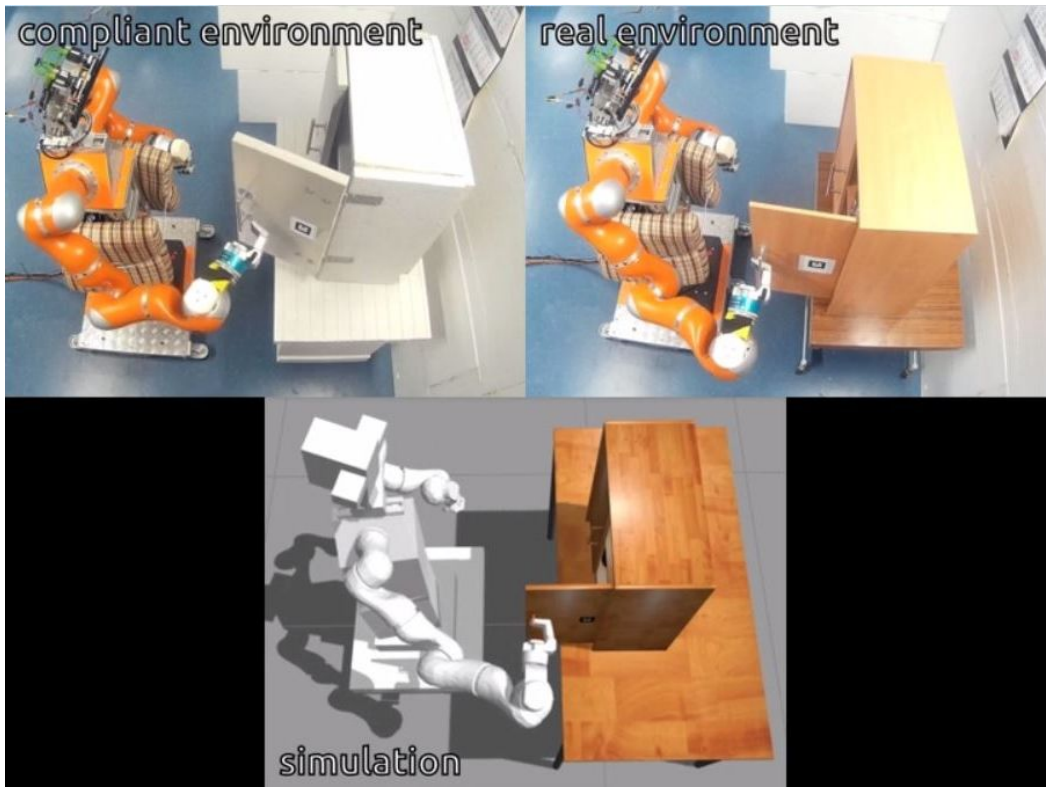
(d) point D (e) point E

Publication in progress

Velma – safety assurance – controller structure

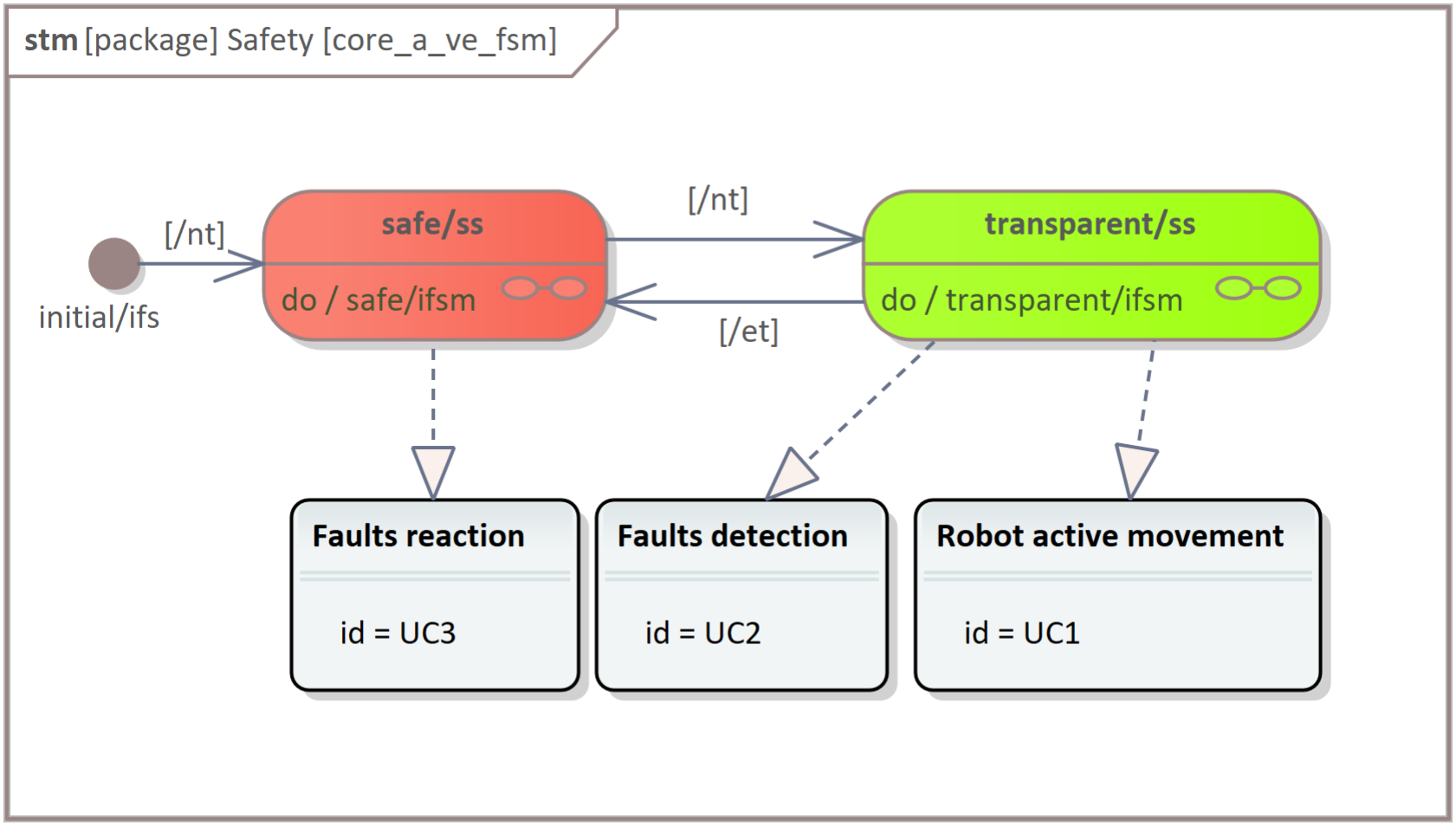


Velma – safety assurance – experiments [6]

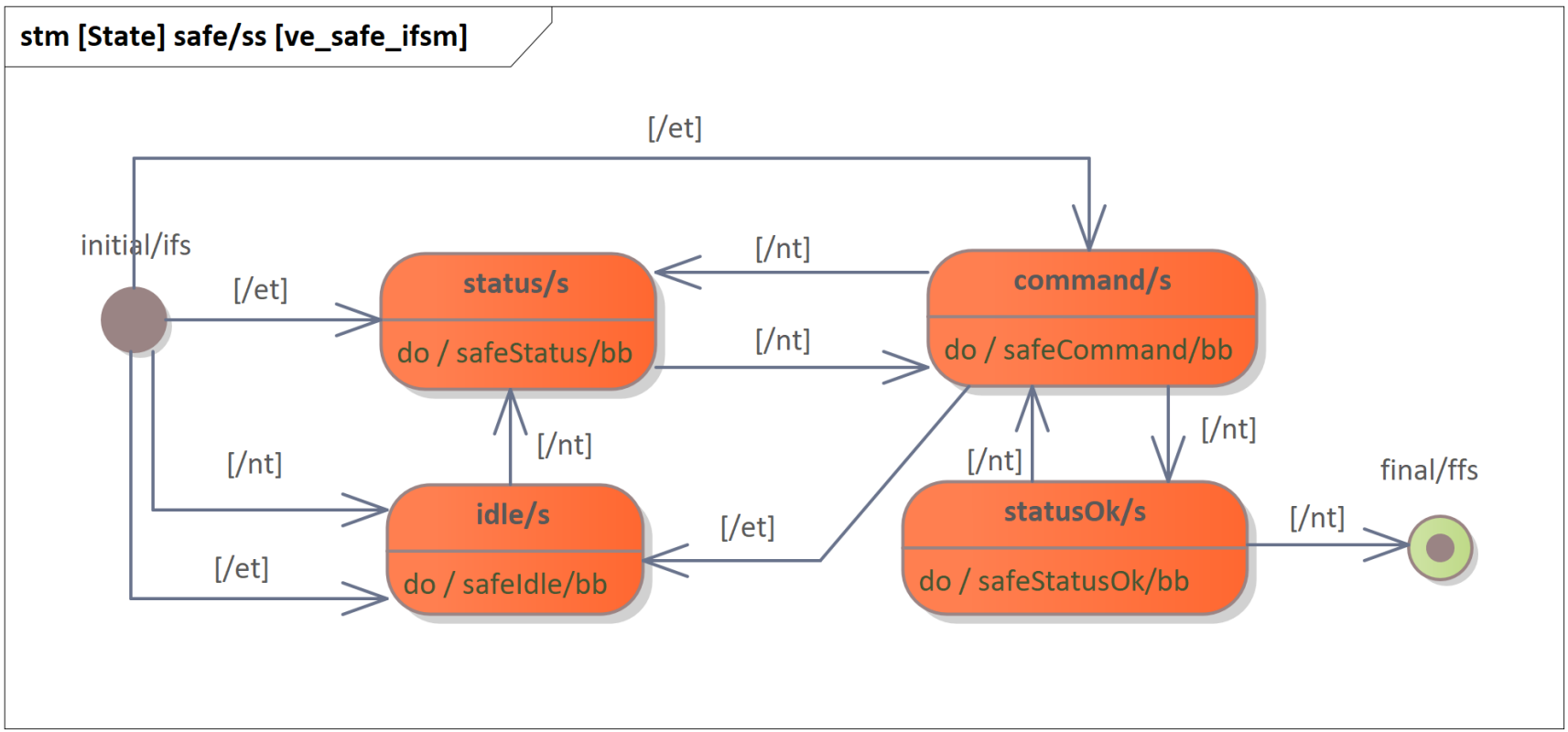


- ownCloud/rpmpg_movies/team/velma/velma_safe_door_hq.mp4
- `https://vimeo.com/266285125`

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



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



Plan

EARL – SysML 1.7 issues

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.