# Logic and Constraint Programming

Course Introduction

Prof. Fabrizio Fornari - Prof. Lorenzo Rossi

March 9, 2022

# About us

**Fabrizio Fornari**

Research fellow @ Unicam
Computer Science dpt.

*fabrizio.fornari@unicam.it*

**Lorenzo Rossi**

Post-doc researcher @ Unicam
Computer Science dpt.

*lorenzo.rossi@unicam.it*

**Professors for the Logic and Constraint Programming course**

# Who is Fabrizio Fornari?

**2022** Research fellow in Computer Science at UNICAM

**2020** Postdoc in Computer Science at UNICAM

**2018** PhD title in Computer Science at UNICAM. 3 months in Brisbane Queensland University of Technology (Australia)

**2012-2013** Master's degree in Computer Science at UNICAM and University of Reykjavik (Iceland)

**2010-2011** Bachelor degree in Computer Science at UNICAM

# Teaching Activities

- **Logic and Constraint Programming** at "University of Camerino", Department of Computer Science 2021/2022

- **Software Project Management Laboratory** at "University of Camerino", Department of Computer Science 2018/2019, 2020/2021, 2021/2022

- **Computer Science** at "Università di Macerata", Faculty of "Economia e diritto" 2018/2019, 2019/2020

# Who is Lorenzo Rossi?



**2020** Postdoc in Computer Science at UNICAM

**2020** PhD title in Computer Science at UNICAM. 3 months in Technical University of Denmark (Denmark) collaborating with Prof. Burattin

**2016** Master's degree in Computer Science at UNICAM

**2014** Bachelor degree in Computer Science at UNICAM

# Teaching Activities



- **Logic and Constraint Programming** at "University of Camerino", Department of Computer Science 2021/2022

- **Web Programming** at "University of Camerino", Master in Digital Solution Manager 2020/2021
-
- **Computer Science** at "Università di Macerata", Faculty of "Economia e diritto" 2020/2021

# PROS Lab Members

**Flavio Corradini**
FULL PROFESSOR

**Andrea Polini**
ASSOCIATE PROFESSOR

**Barbara Re**
ASSOCIATE PROFESSOR

**Francesco Tiezzi**
ASSOCIATE PROFESSOR

**Andrea Morichetta**
RESEARCH FELLOW

**Fabrizio Fornari**
POSTDOCTORAL RESEARCHER

**Lorenzo Rossi**
POSTDOCTORAL RESEARCHER

**Marco Piangerelli**
POSTDOCTORAL RESEARCHER

**Alessandro Marcelletti**
PHD STUDENT

**Caterina Luciani**
PHD STUDENT

**Khalid Bourr**
PHD STUDENT

**Ivan Compagnucci**
PHD STUDENT

**Sara Pettinari**
PHD STUDENT

**Arianna Fedeli**
PHD STUDENT

and…
- Morena Barboni
- Vincenzo Nucci
- Ahmad Ronaghikhameneh
- Umair Qureshi

https://pros.unicam.it/members

# PROcesses and Services Lab

Our **mission** is to promote the usage of **formal methods** and **automatic tools** for the **development of high-quality software** having care of hiding the complexity of formal methods to the final user

## HOW?

By developing:

- **Languages** and **techniques** for the *modelling* and *analysis* of systems
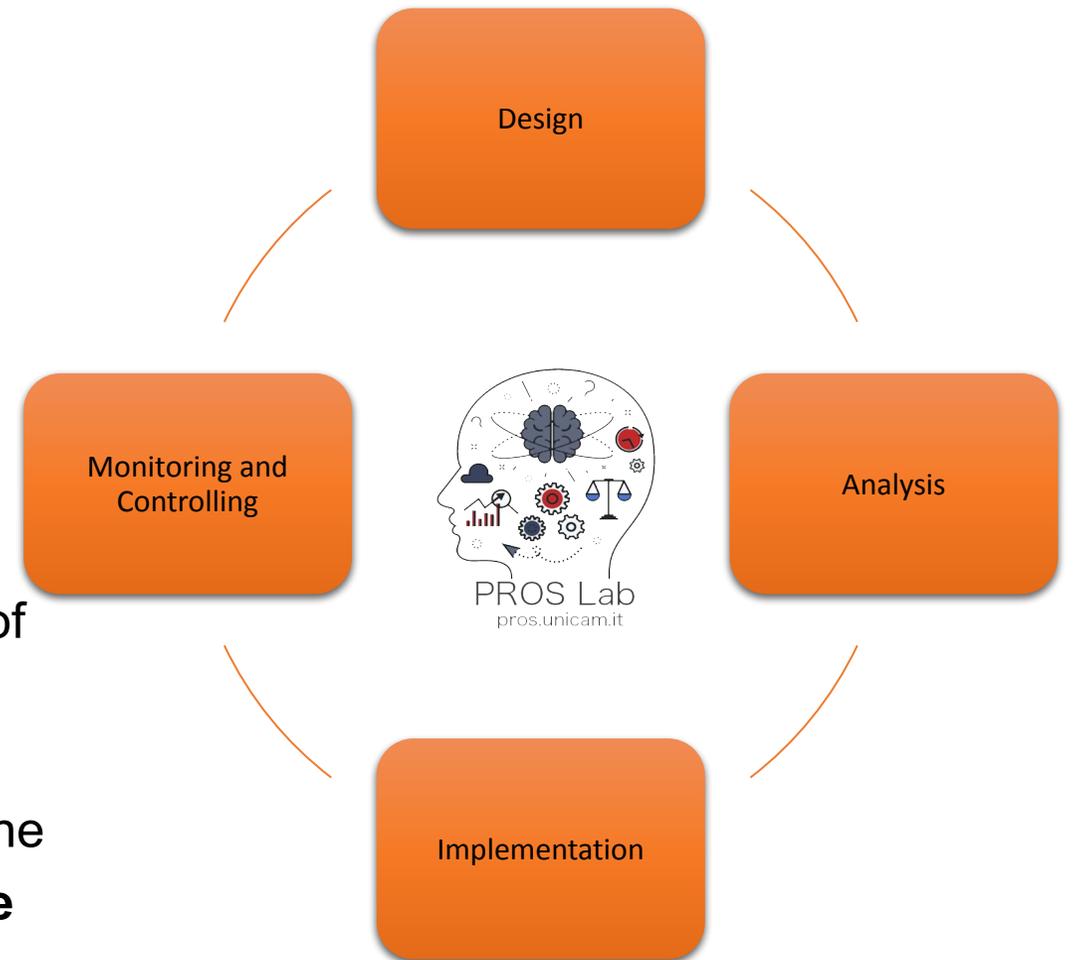- Complex systems based on **process-** and on **service-oriented applications**

# What we do?
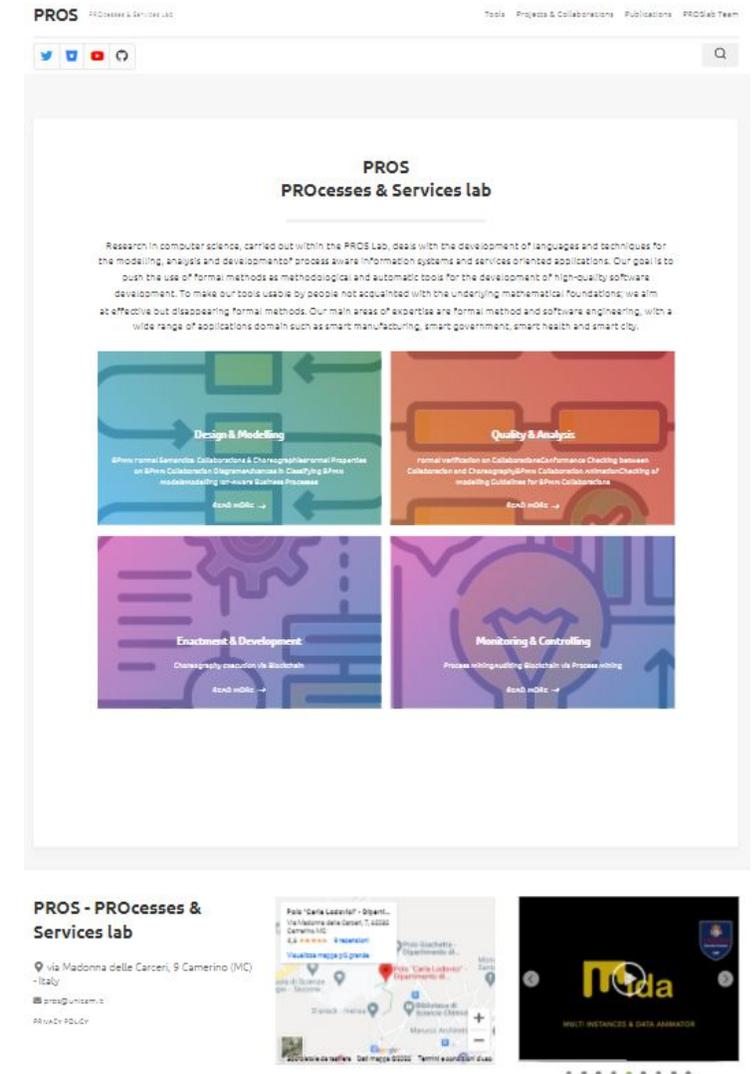
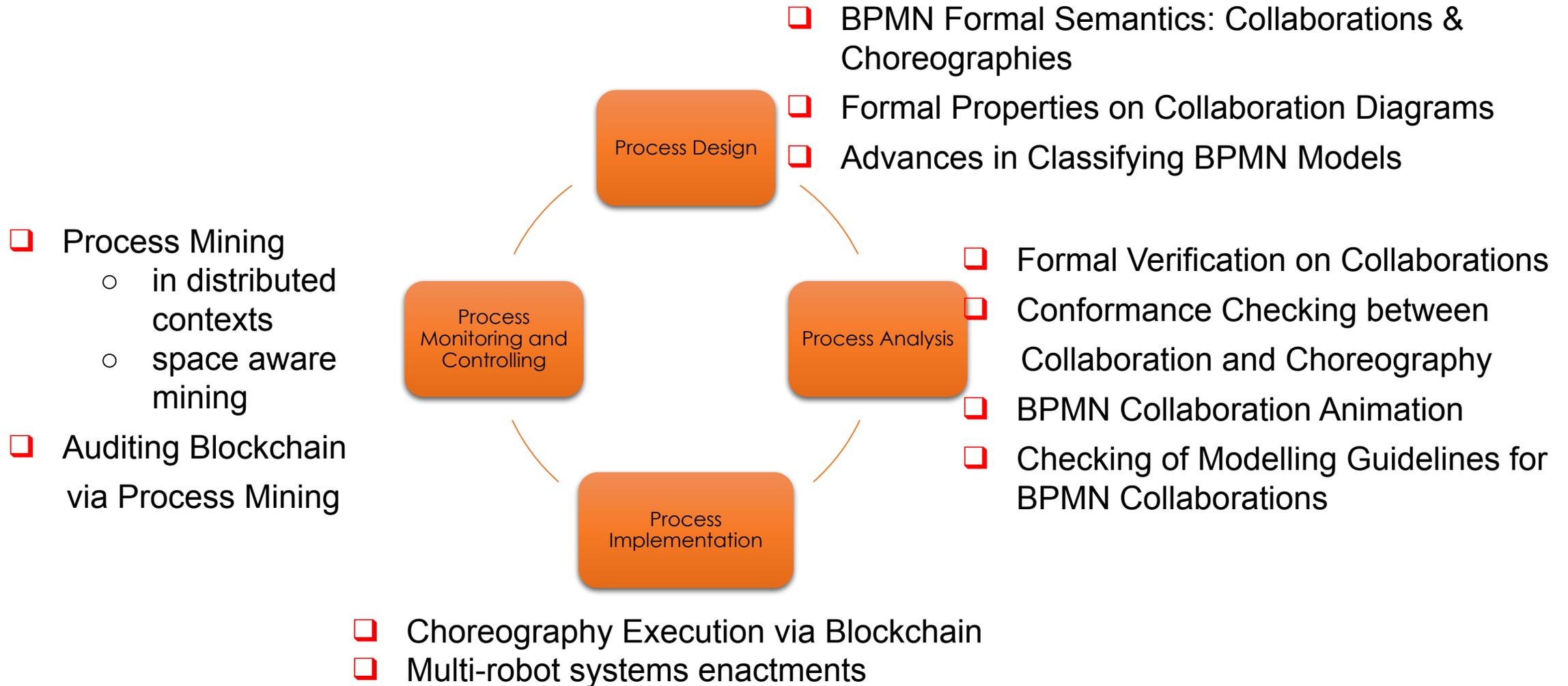Research carried out within the PROS Lab deals with:

- ❏ The development of **languages** and **techniques** for systems **modelling and analysis**

- ❏ The development of **process aware information systems** and **services oriented applications**

Our goal is to push the use of **formal methods** as <u>methodological</u> and <u>automatic tools</u> for the development of high-quality software

To make our tools usable by people not acquainted with the underlying mathematical foundations; **we aim at effective but disappearing formal methods**

Design

Analysis

Implementation

Monitoring and Controlling

PROS Lab
pros.unicam.it

# Main Topics and Contributions



- BPMN Formal Semantics: Collaborations & Choreographies
- Formal Properties on Collaboration Diagrams
- Advances in Classifying BPMN Models

- Formal Verification on Collaborations
- Conformance Checking between Collaboration and Choreography
- BPMN Collaboration Animation
- Checking of Modelling Guidelines for BPMN Collaborations

- Process Mining
  - in distributed contexts
  - space aware mining
- Auditing Blockchain via Process Mining

- Choreography Execution via Blockchain
- Multi-robot systems enactments

Process Design
Process Analysis
Process Implementation
Process Monitoring and Controlling

# Business Processes execution semantics

## Textual semantic

$$\frac{\langle T, \sigma_e, \sigma_d, \sigma_t, \sigma_c \rangle \xrightarrow{\ell} \langle \sigma'_e, \sigma'_d, \sigma'_t, \sigma'_c \rangle}{mipTask(e, exp, T, c, exp', e') \xrightarrow{\ell} \langle \sigma'_e, \sigma'_d, \sigma'_t, \sigma'_c \rangle} \quad (P\text{-}MipTask_3)$$

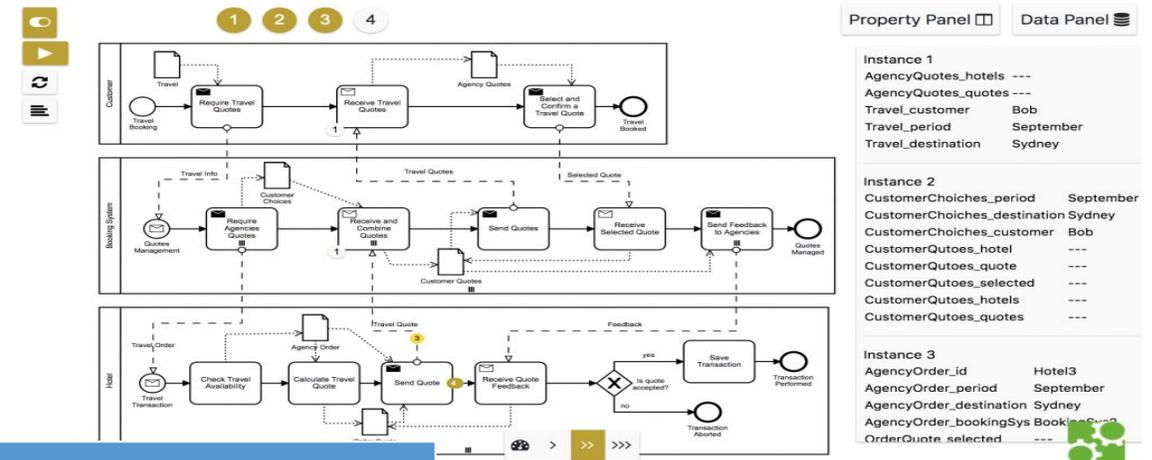$$mipTask(e, exp, T, c, exp', e') \xrightarrow{\epsilon} \langle inc(reset(\sigma_e, edges(T)), e'), reset(\sigma_c, c) \rangle \quad \begin{array}{l} \sigma_e(out(T)) = \sigma_c(c) \vee \\ eval(exp', \sigma_d, true) \end{array} \quad (P\text{-}MipTask_4)$$

$$misTask(e, exp, T, c, exp', e') \xrightarrow{\epsilon} \langle inc(dec(\sigma_e, e), in(T)), set(\sigma_c, c, h) \rangle \quad \begin{array}{l} \sigma_e(e) > 0, \\ \sigma_c(c) = 0, \\ eval(exp, \sigma_d, h) \\ \text{with } h > 0 \end{array} \quad (P\text{-}MisTask_1)$$

## Animation
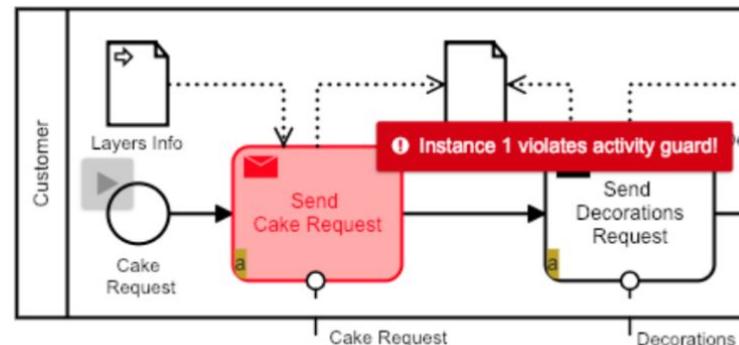


## Behavioral model



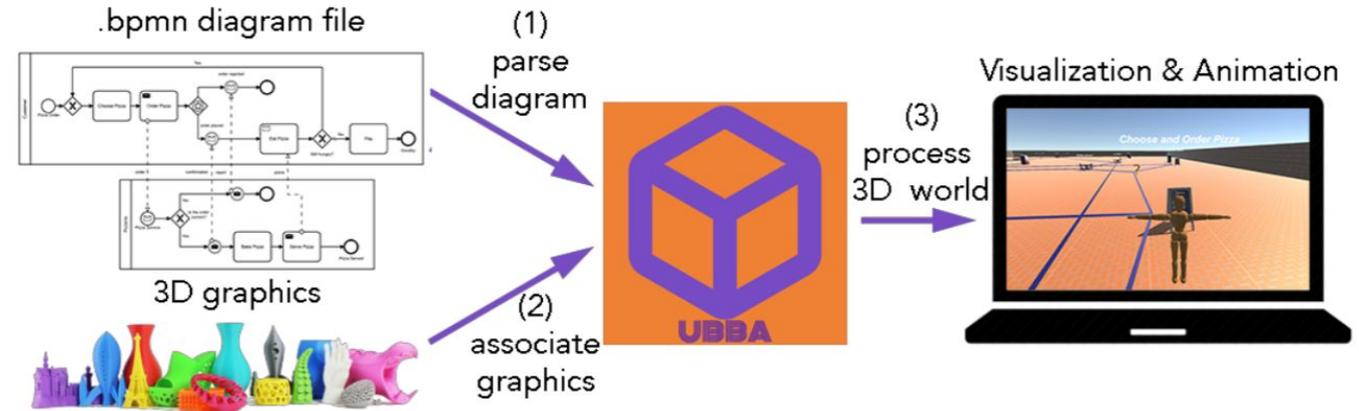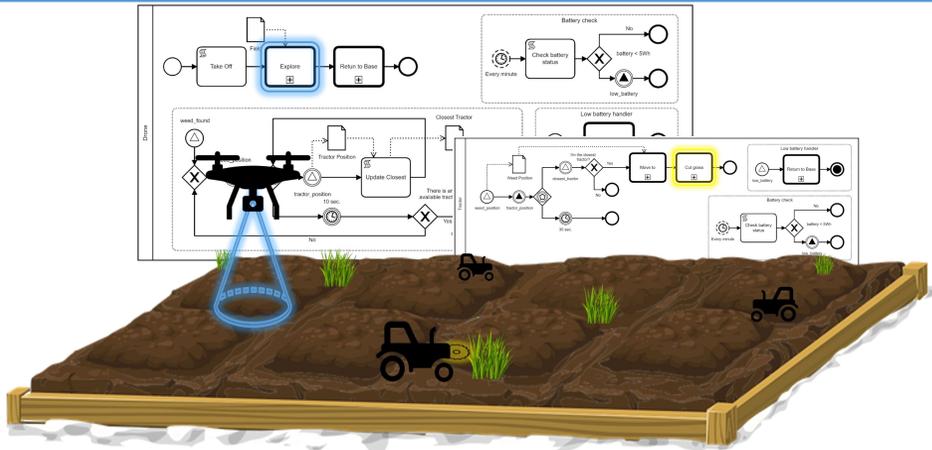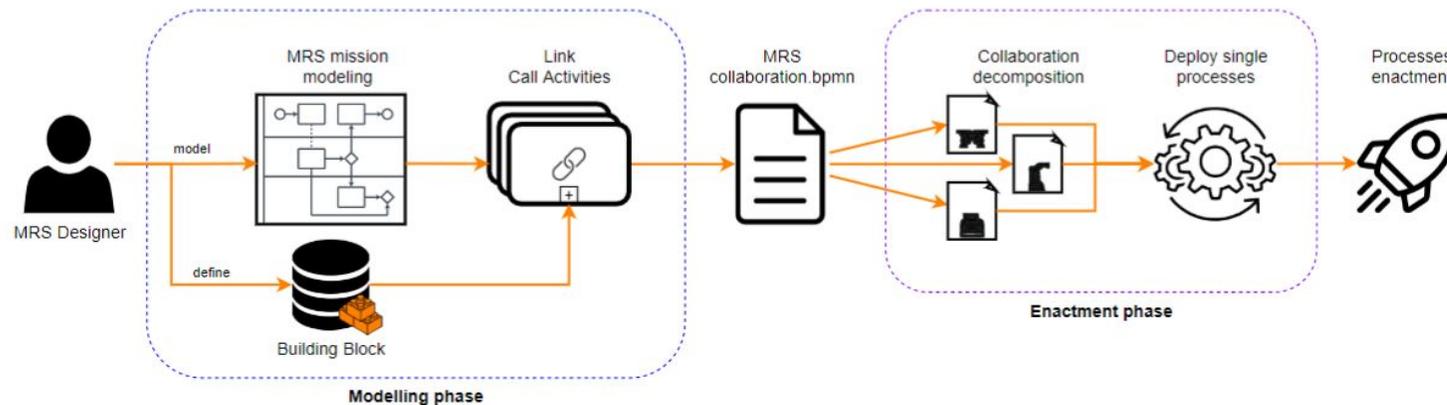## Analysis



11
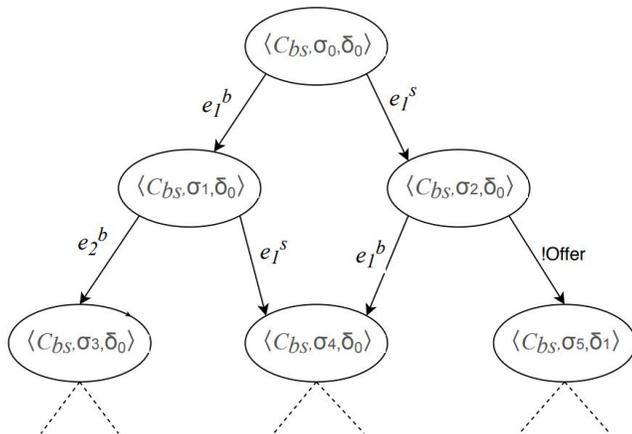
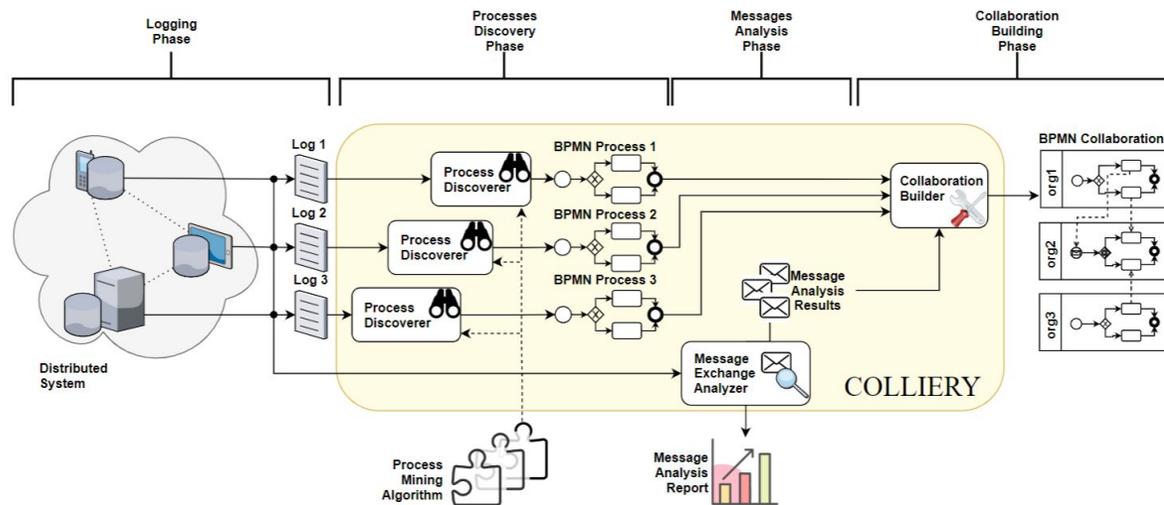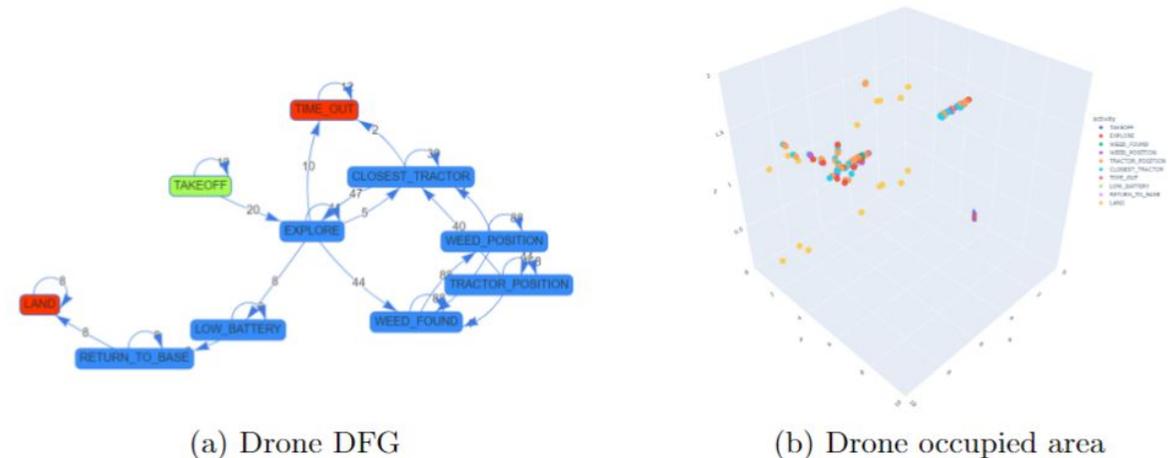# Business Process and MDE



**Multi-robot systems**

**3D environments**

# Process models and data mining



**Collaborative process mining**

**Space-aware process mining**

(a) Drone DFG
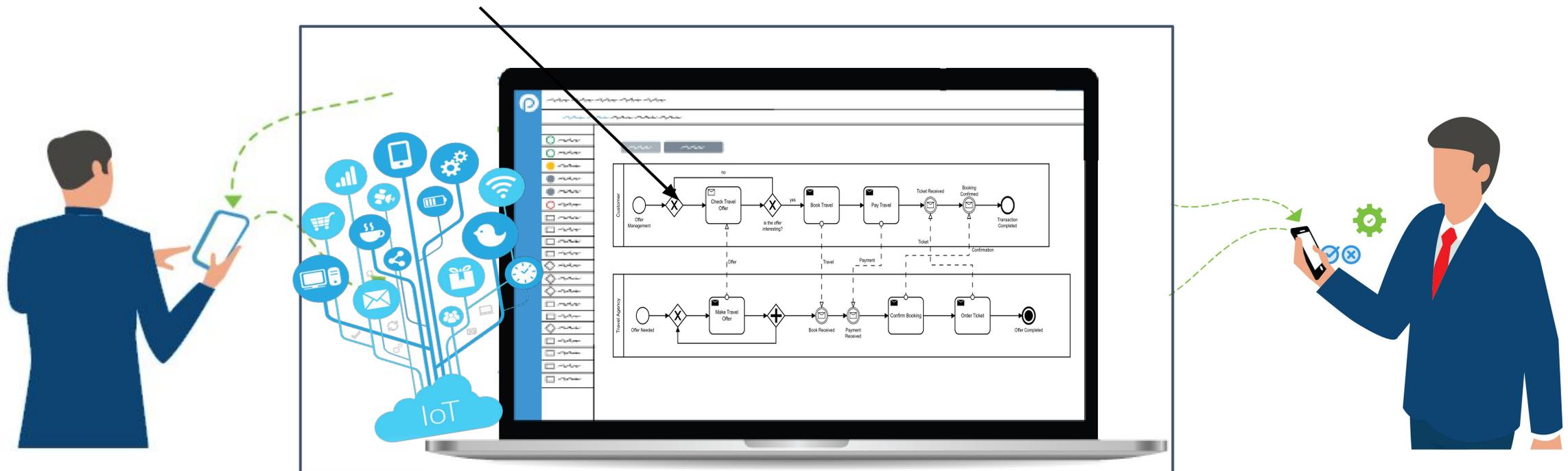
(b) Drone occupied area

# Business Processes & Internet of Things

## Business Processes

A set of activities, tasks or actions to carry out a specific organizational goal such as a service or a product
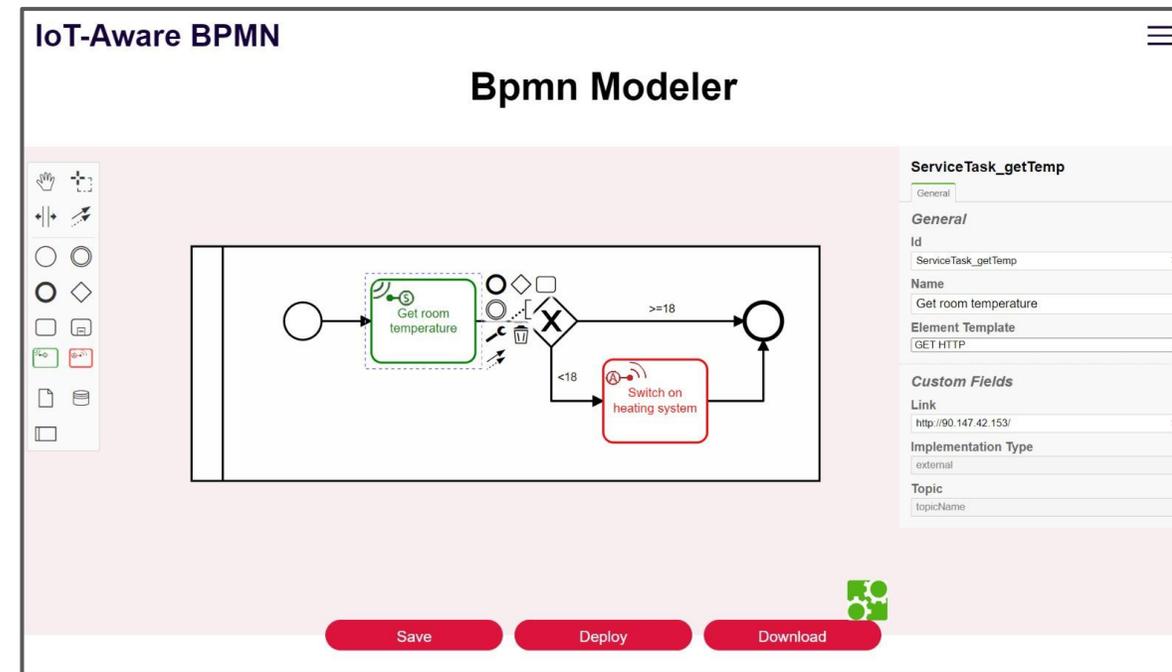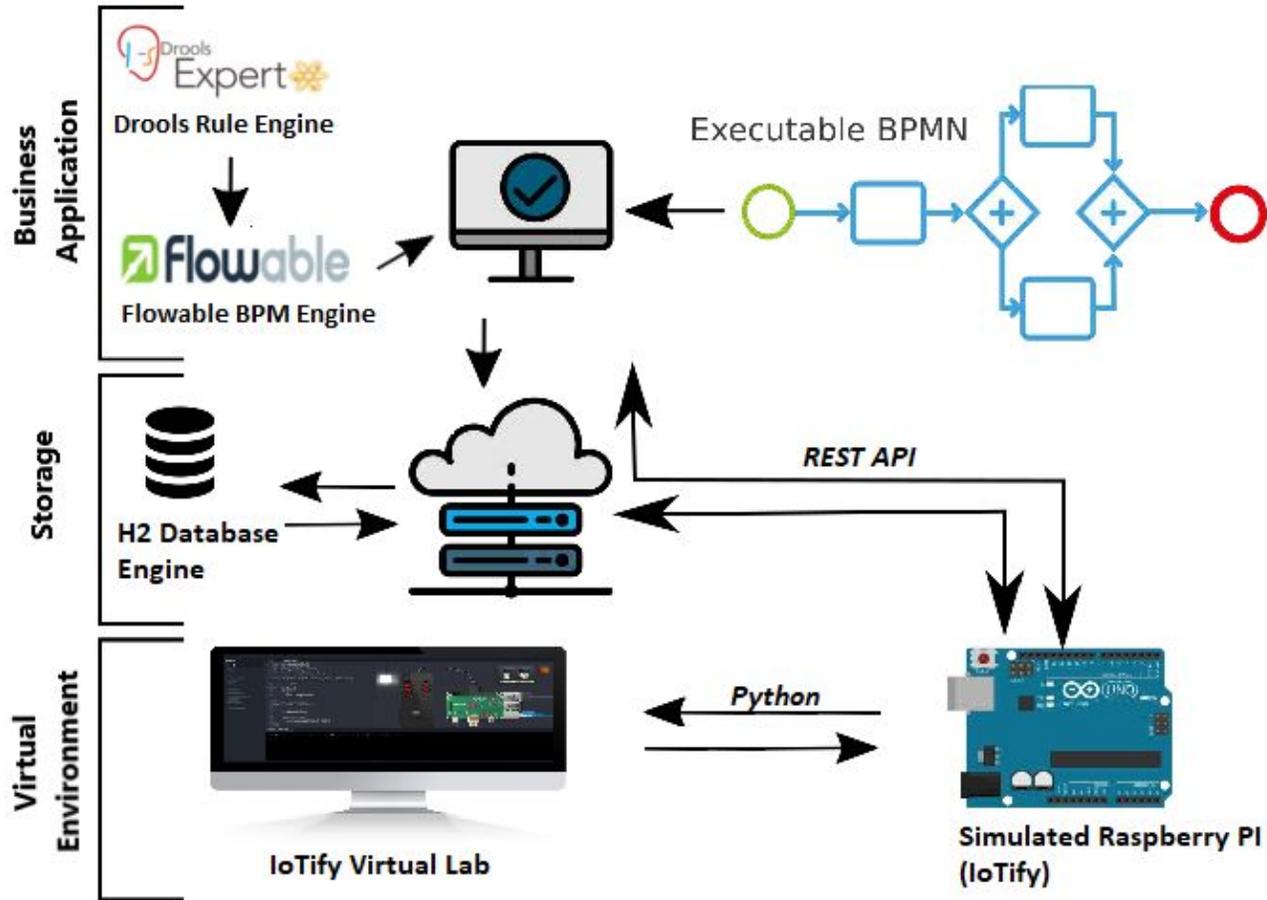
### BPMN

## Internet of Things

Network of interconnected devices that collect and exchange data to monitor, control or transfer relevant information so as to be able to perform consequent intelligent actions
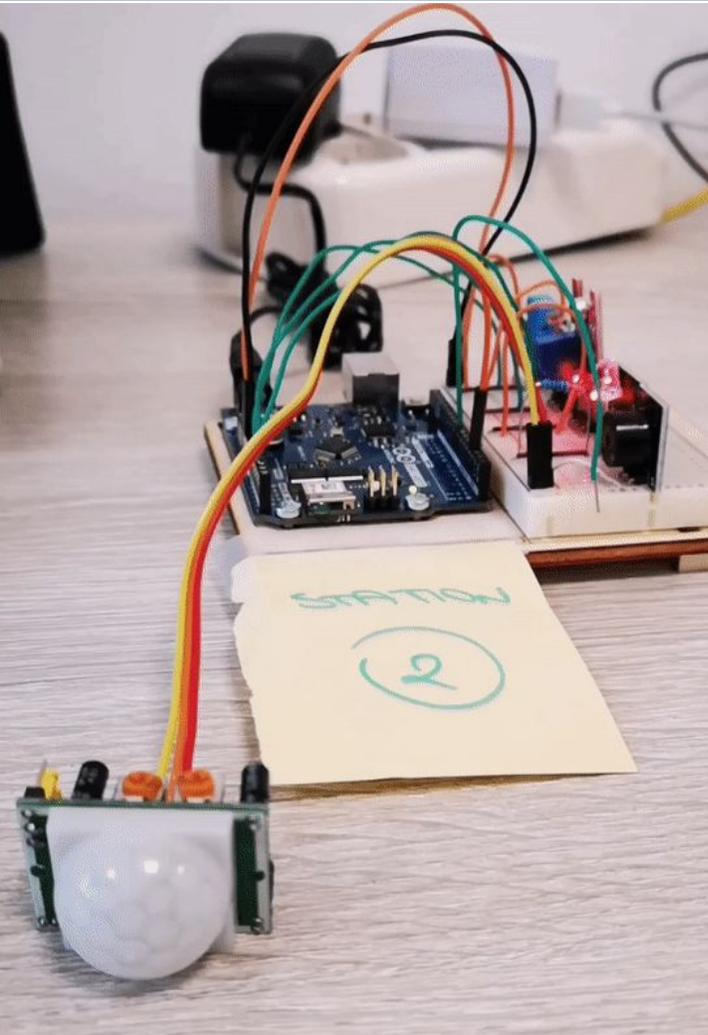


C. Janiesch *et al*., "The Internet of Things Meets Business Process Management: A Manifesto," in *IEEE Systems, Man, and Cybernetics Magazine*, vol. 6, no. 4, pp. 34-44, Oct. 2020, doi: 10.1109/MSMC.2020.3003135.
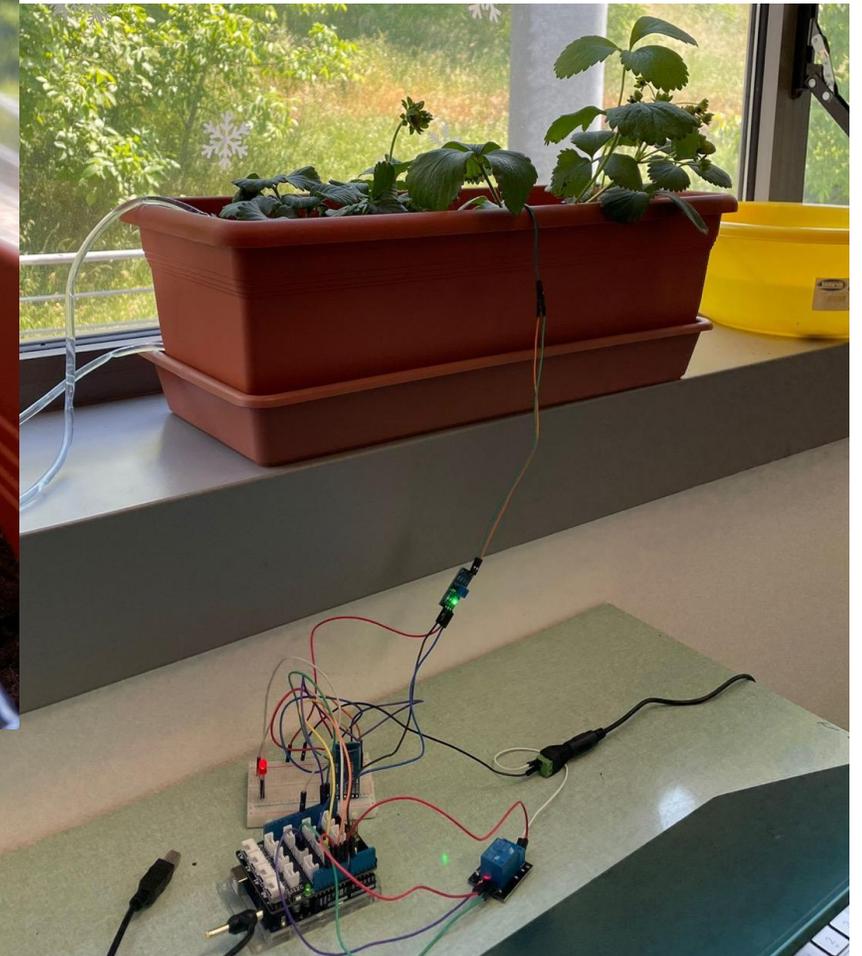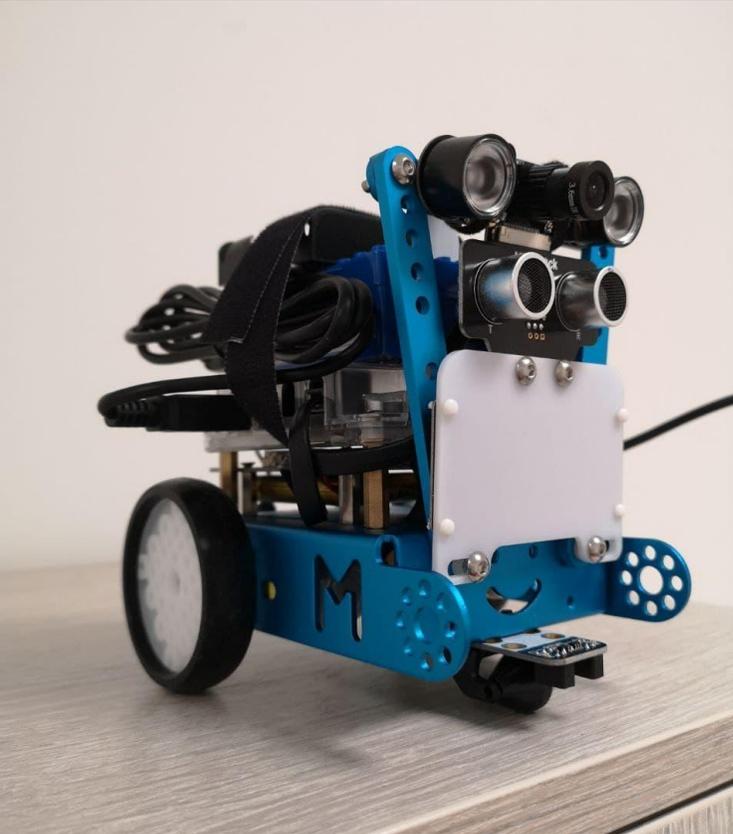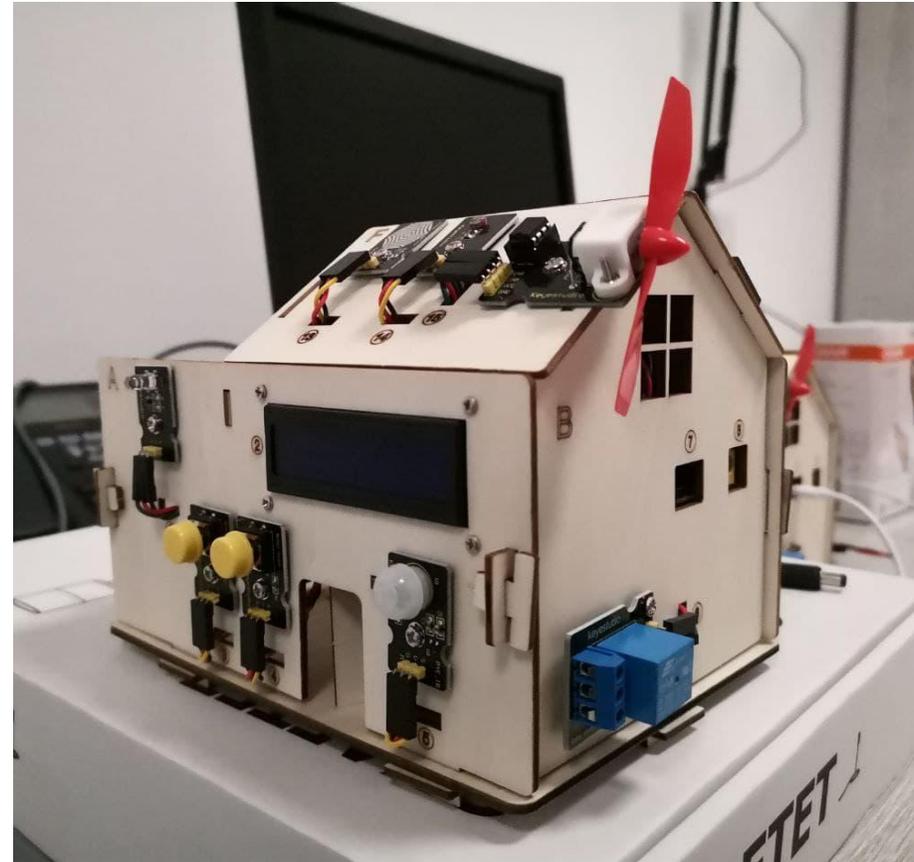
# BPMN & IoT
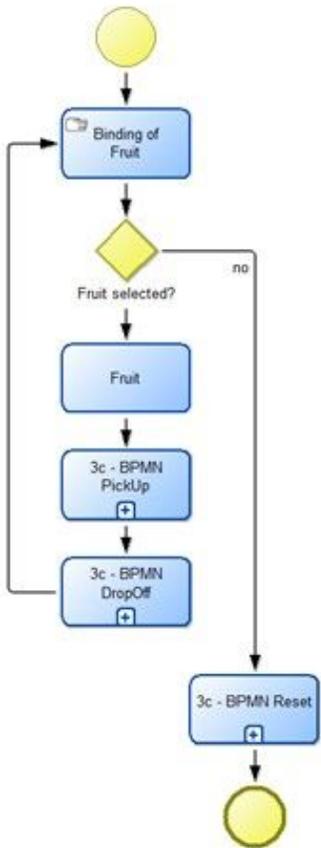
Smart Garden

Environmental Monitoring Station

Automatic Car



Smart Home
prototype

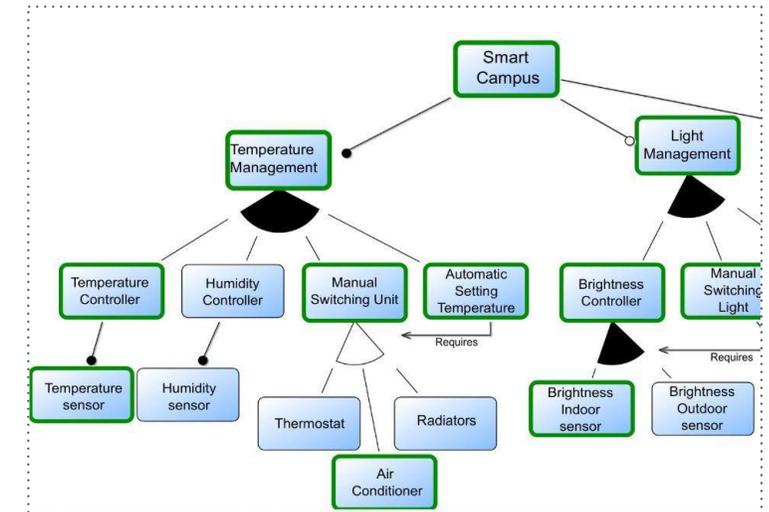Robotic Arm

# Smart Workflows for the Robotic Arm
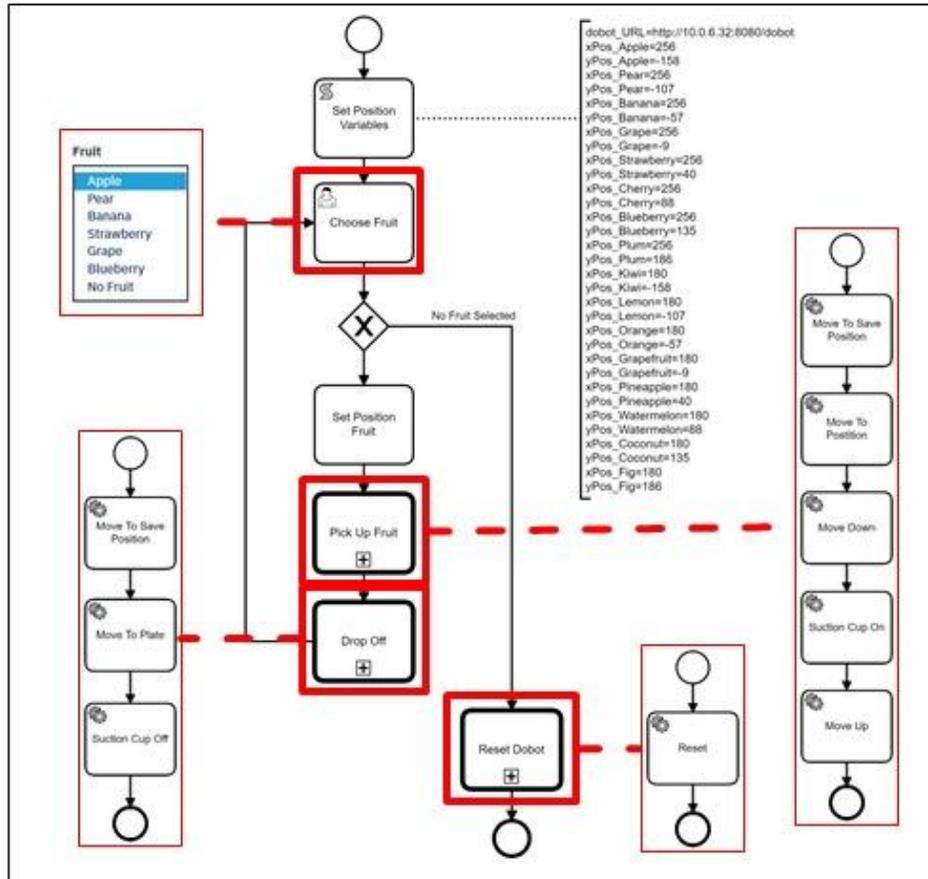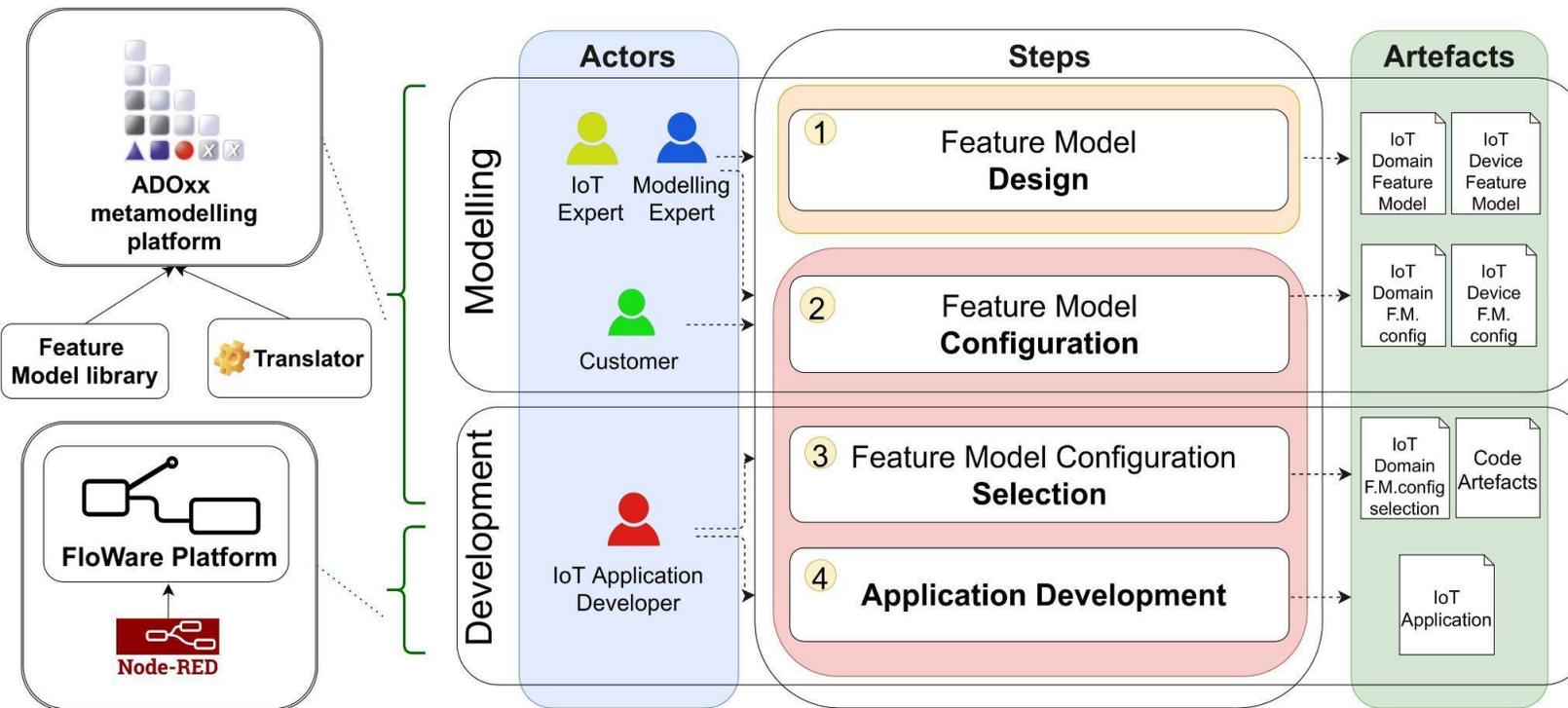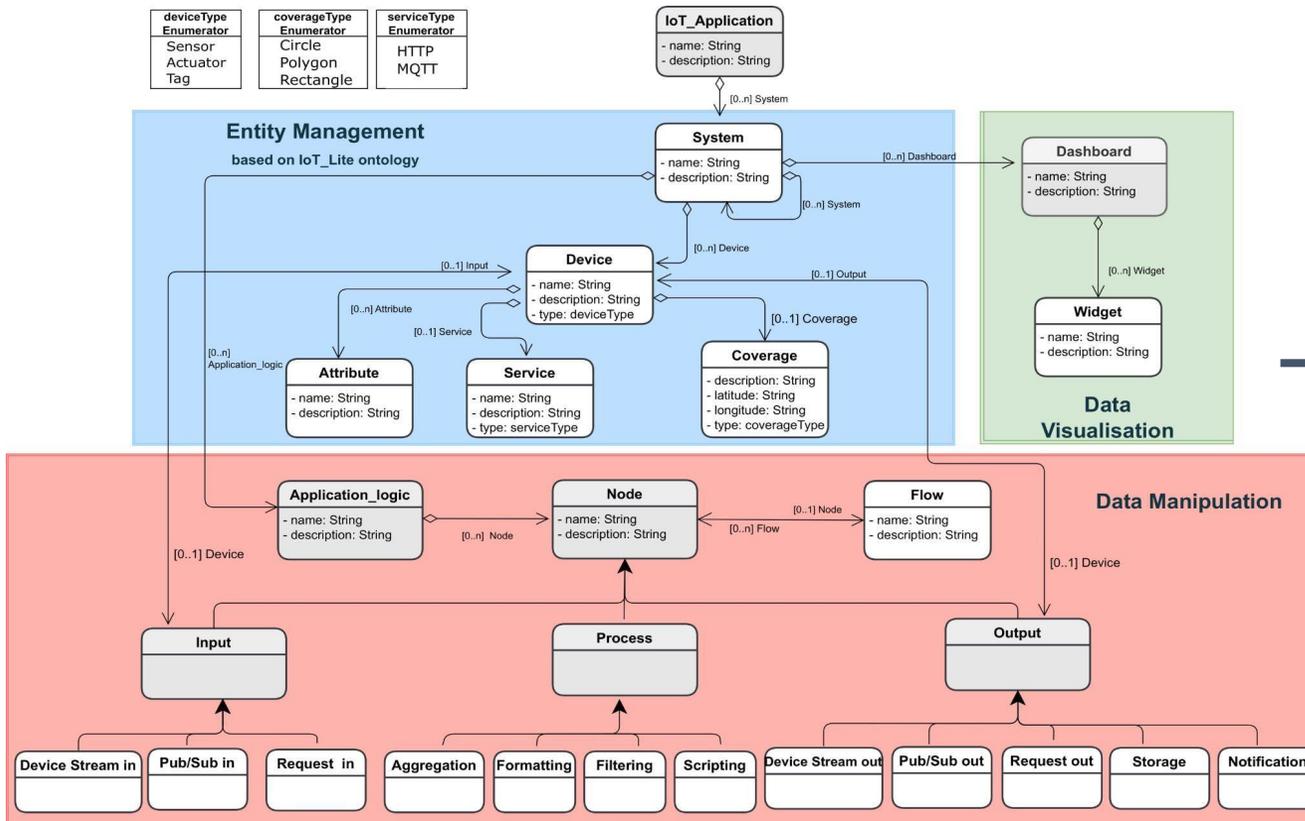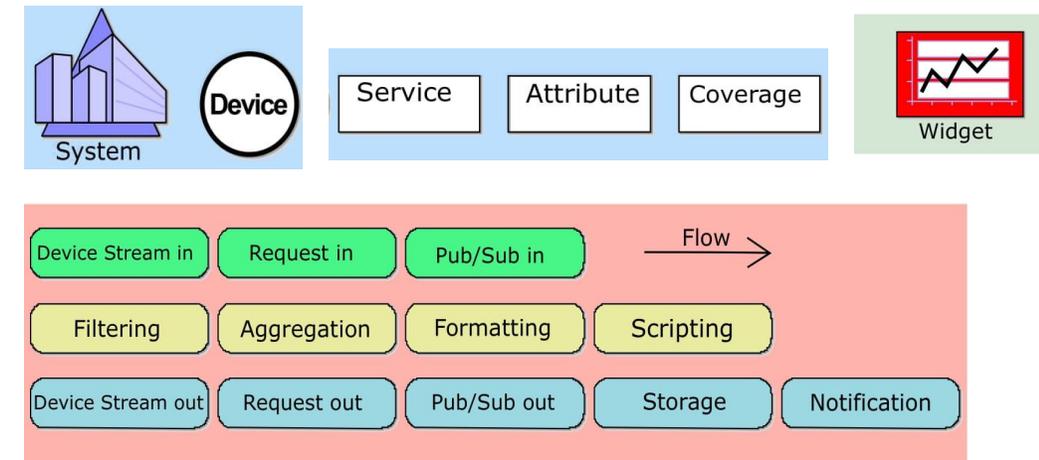
# Model Driven Engineering for IoT



- Feature Models
- ADOxx  metamodelling Platform
- Node-RED, ThingsBoard, Losant
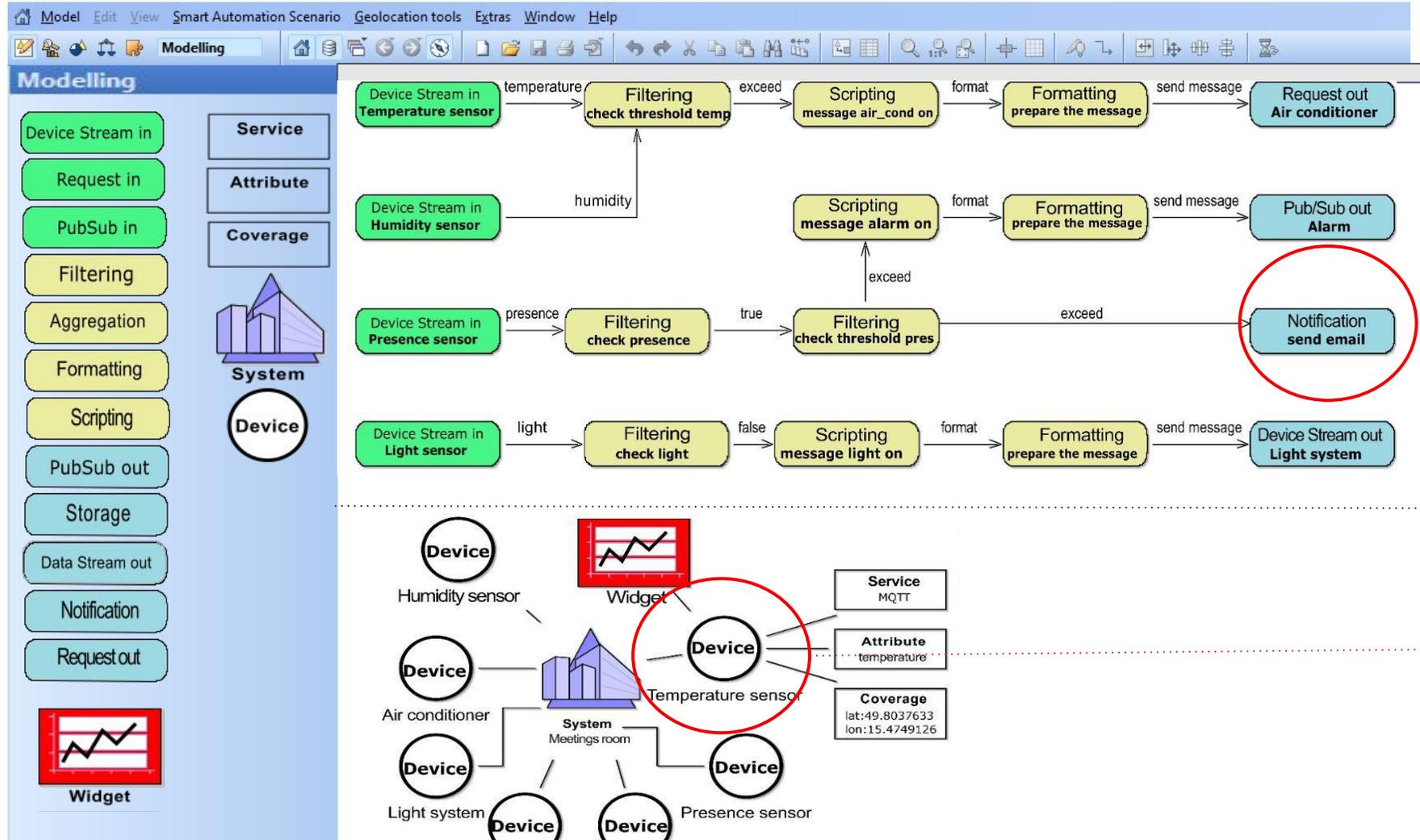
# Domain Specific Modeling Languages

**Meta-Model**

**Graphical Notation**

# Domain Specific Modeling Languages

# Cross-platform IoT Application

**ThingsBoard**

**Losant**
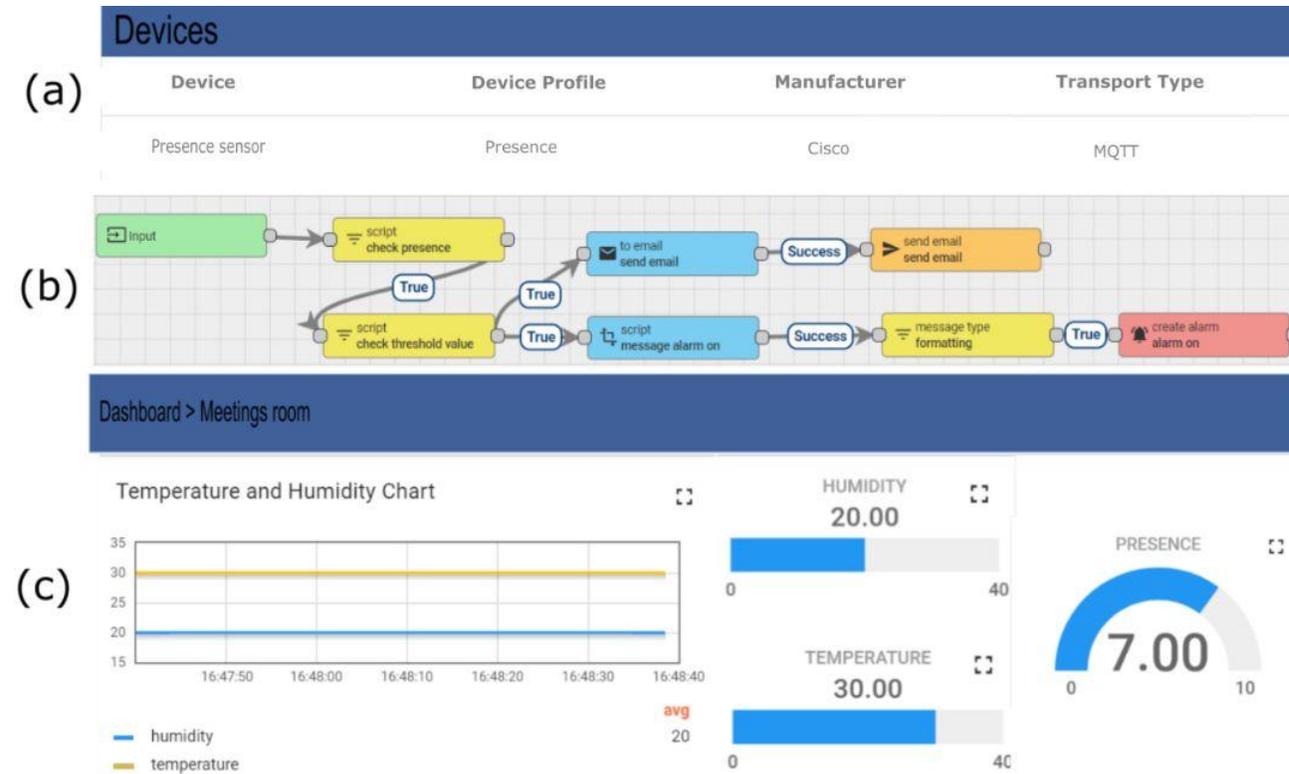
# PROS Research Projects & Collaborations

**PROJECTS**

**SEDUCE**

Designing Spatially Distributed Cyber-Physical Systems under Uncertainty (MIUR-PRIN 2017) These systems are, and will be more and more, pervasive and ubiquitous,...

READ MORE →

**PROJECTS**

**Odeco**

ODECO is a 4-year Horizon 2020 Marie Skłodowska-Curie Innovative Training Network initiative (H2020-MSCA-ITN-2020, grant agreement 955569). The central aim of the...

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**PROJECTS**

**LearnPAd**

Model-Based Social Learning for Public Administrations, EU-FP7-ICT In modern society public administrations (PAs) are undergoing a transformation of their perceived...

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**COLLABORATIONS**

**Fachhochschule Nordwestschweiz**

In collaboration with Prof. Knut Hinkelmann, since 2007, a Double Degree Program between Master of Science in Business Information Systems @ FHNW...

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**COLLABORATIONS**

**Apromore**

In collaboration with Prof. Marcello La Rosa, @UniCam we hosted a local node of the Apromore Platform.

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**PROJECTS**

**Fluidware**

PRIN PROJECT FLUIDWARE FUNDED BY ITALIAN GOVERNMENT (MIUR) N. 2017KRC7KT The objective of the project is to develop a novel...

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**PROJECTS**

**Choreos**

Large Scale Choreographies for Future Internet, EU-FP7-ICT The CHOReOS project positions itself in the context of the Ultra-Large-Scale (ULS) Future...

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**Regional Projects:** Miracle

**National Projects:** SAFE, Fluidware, SEDUCE

**European Projects**: LearnPAd, ODECO

**Internal Projects**: Group Projects and Thesis can be carried out within the PROS Lab

# LCP course information

# Content of the Course

**Constraint programming**: basic concepts and Minizinc, OR-tools

**Rule-based programming**: basic concepts and Drools

**Logic programming**: basic concepts and Prolog language

# Constraint Programming

**Minizinc** is a constraint modeling language that can be used to model constraint satisfaction and optimization problems in a high-level, solver-independent way.
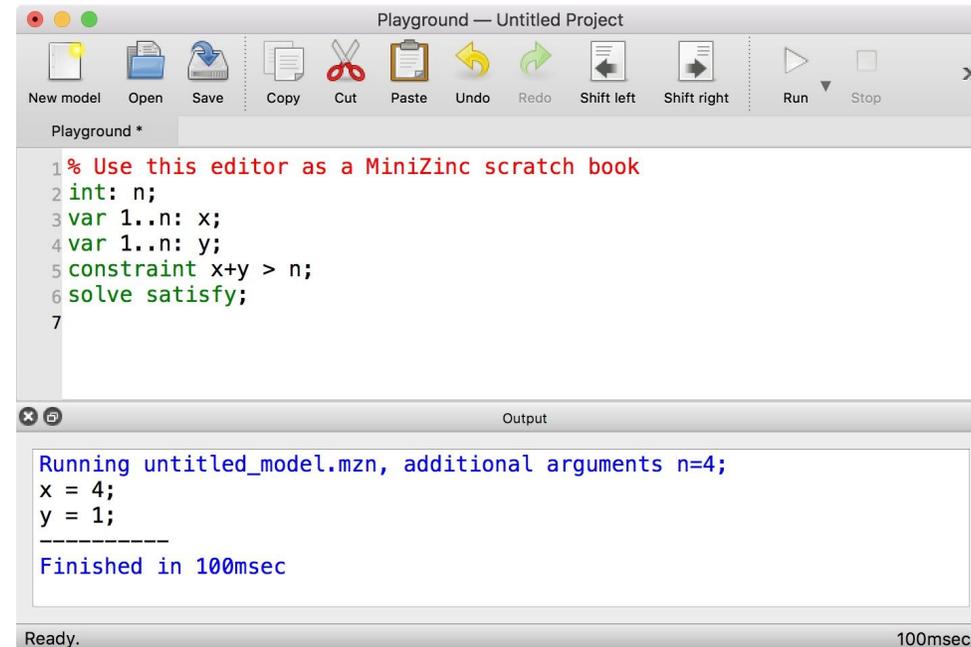
# Constraint Programming

**OR-Tools** is an open source software suite for optimization, for tackling problems in vehicle routing, flows, integer and linear programming, and constraint programming.

# Rule-based Programming

**Drools** is a powerful hybrid reasoning system. It allows you to define your business logic using business rules in various formats (for example using decision tables etc.).

# Logic Programming

**Prolog** is a logic programming language associated with artificial intelligence and computational linguistics

**SWI-Prolog** is a versatile implementation of the Prolog language.

# Lectures & Meetings

Teaching Hours:

- Wednesday 9am - 11am (Lab)
- Friday 9am - 11am (Lab)

Room: AB1

Students Meeting:

- After each lesson or,
- By requesting a meeting by sending an email to *lorenzo.rossi@unicam.it* or *fabrizio.fornari@unicam.it*
- Our office is in the main building of the Computer Science Department

**Note: only email coming from the @studenti.unicam.it domain will be processed.**

# Course Scheduling

1$^{st}$ part - *Prof. Rossi* https://unicam.webex.com/meet/lorenzo.rossi

- Constraint programming (Minizinc, …)
- Rule-based programming (Drools, …)

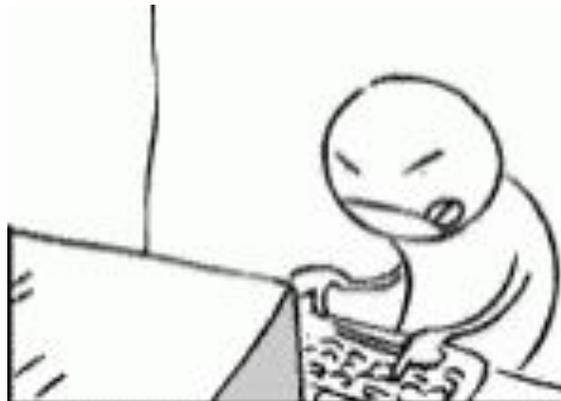2$^{nd}$ part - *Prof. Fornari* https://unicam.webex.com/meet/fabrizio.fornari

- Logic programming (Prolog,..)
- Rewriting Logic (Maude,..)

We will release the slides of the course within 2 days from the lesson

# Lectures

Course topics will be tackled with a practical approach!

**Learning by Doing!**

# Support Material

- Stuart J. Russell and Peter Norvig. *Artificial Intelligence A Modern Approach*. Third Edition. Pearson, 2016.

- Bratko, Ivan. *Prolog programming for artificial intelligence*. 4th edition Pearson education, 2011.

- Amador, Lucas. *Drools developer's cookbook*. Packt Publishing Ltd, 2012.

- The MiniZinc Handbook.

MiniZinc Handbook
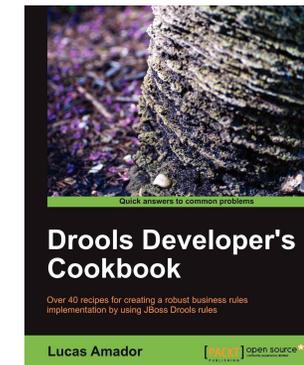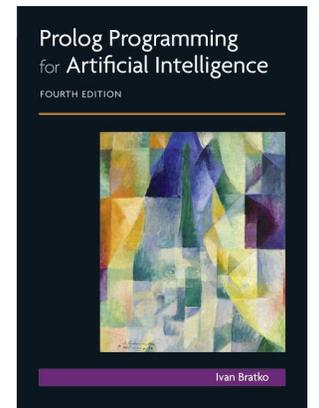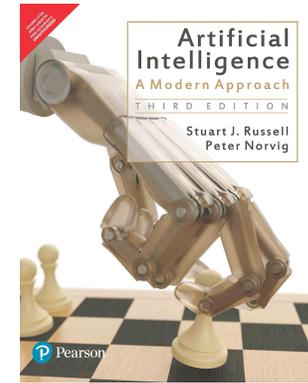
# Evaluation

During the course we assign **4 practical exercises** to solve outside course hours using the **tools** introduced during the course.

**Assignments** are **mandatory** for the final examination. They must be delivered **5 days before** the exam.

The **exam** consists of a **discussion** of the **assignments** and answers to **questions** on the topic treated during the course.

# Where to find course information?

- LCP Wiki Page

  http://didattica.cs.unicam.it/doku.php?id=didattica:ay2122:lcp:main

- App YoUnicam channel: #LCP

  https://www.unicam.it/studente/younicam-app

# Any Question?

What about you?

https://forms.gle/XCKrUZt9DYTF4zTU6