CAMUNDA CON LIVE

Controlling a Smart Factory with Processes in Camunda

Ronny Seiger, University of St. Gallen

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Controlling a Smart Factory with Processes in Camunda

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CamundaCon Live 2021
22 September 2021

"From insight to impact"

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Ronny Seiger

- Diploma (2011) & PhD (2018) in Computer Science at TU Dresden
- Post-Doc at University of St.Gallen since 2019
- Research
  - Cyber-physical Systems, Internet of Things
  - Software Engineering, Software Architecture
  - Business Process Management
- Teaching
  - BPM, Software Engineering

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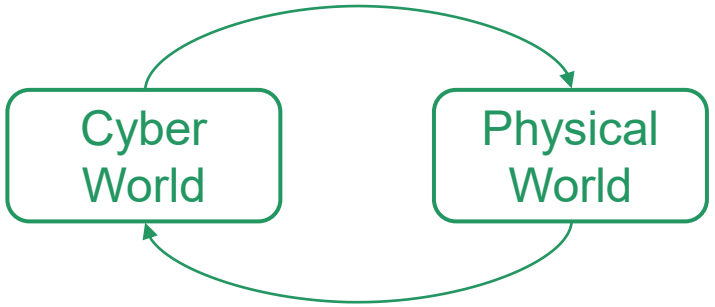
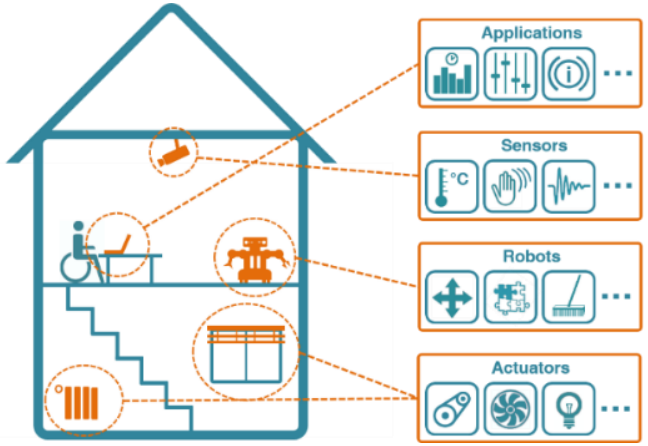
Emergence of Smart Spaces

Cyber-physical Convergence



Cyber-physical System



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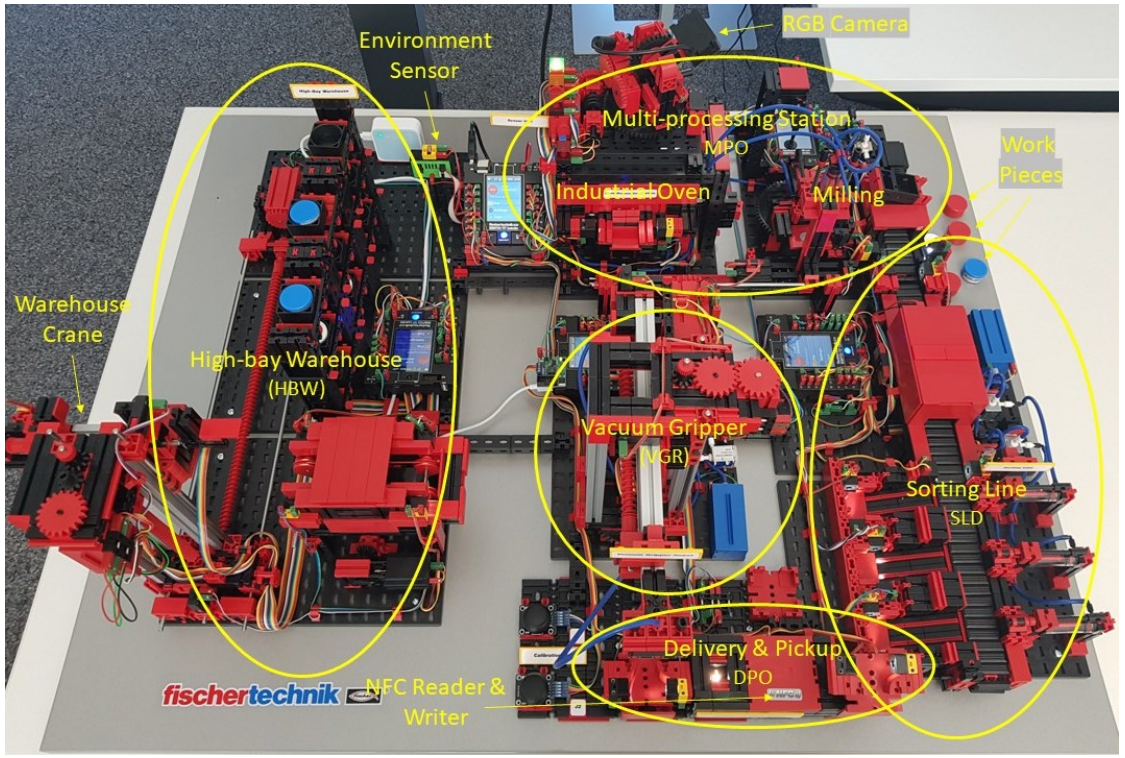
Smart Factory Simulation Models



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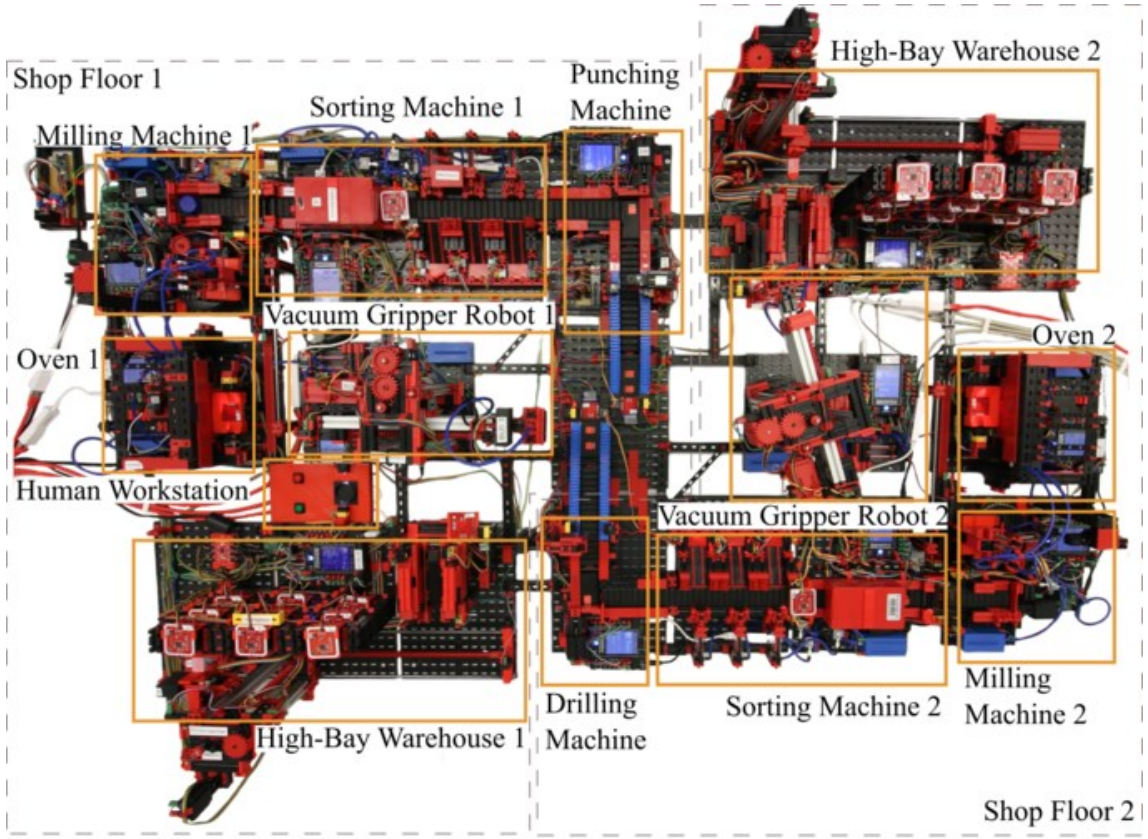

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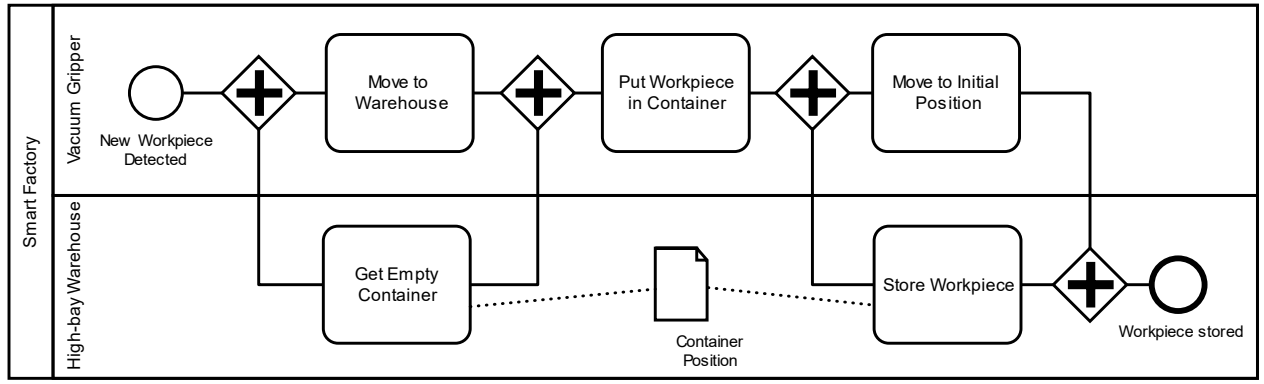
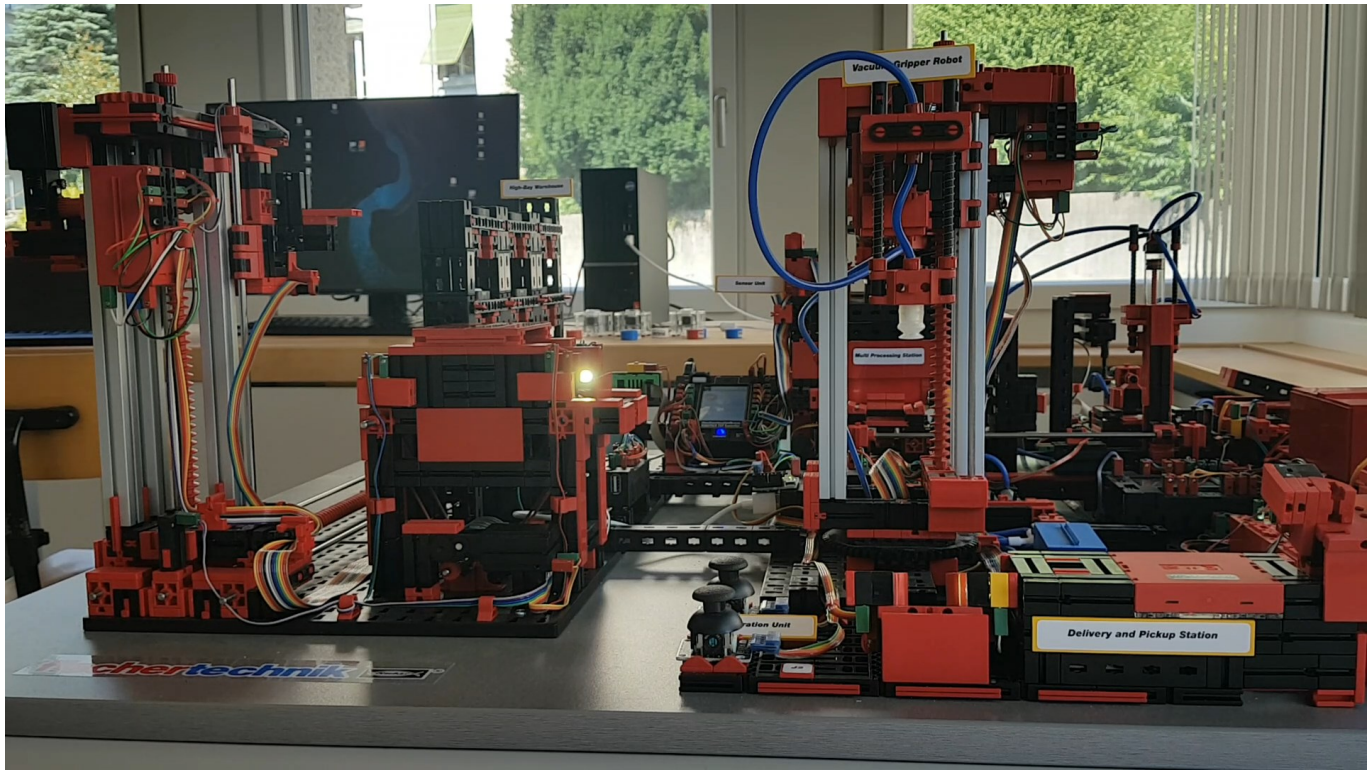
Smart Factory Process: Storage





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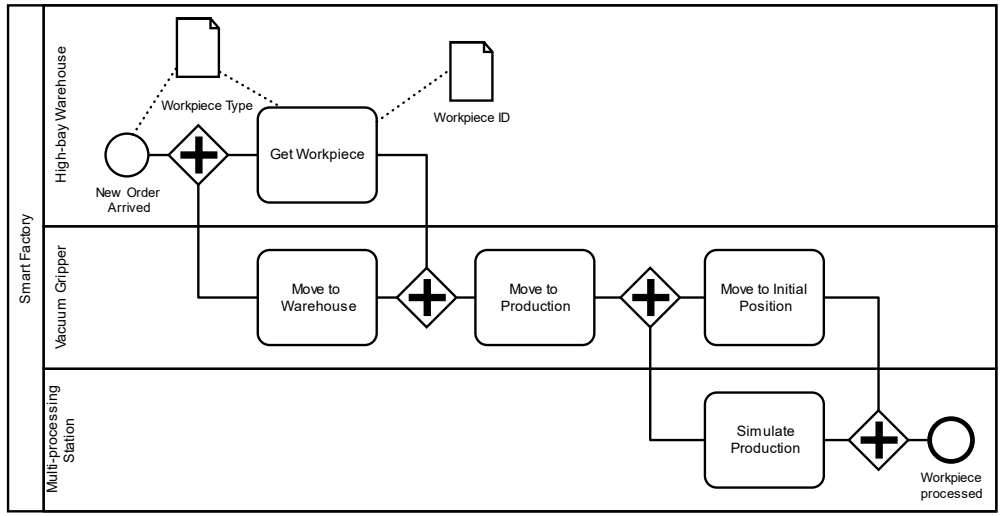
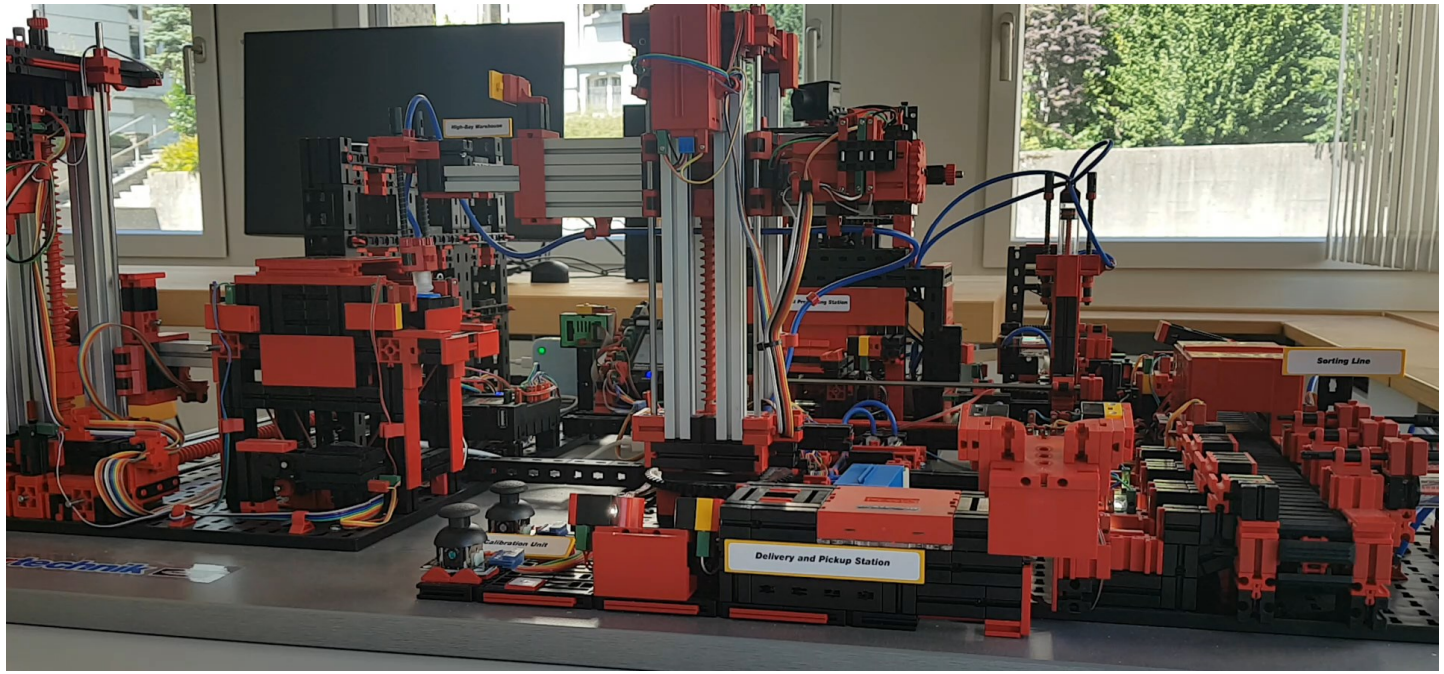
Smart Factory Process: Production





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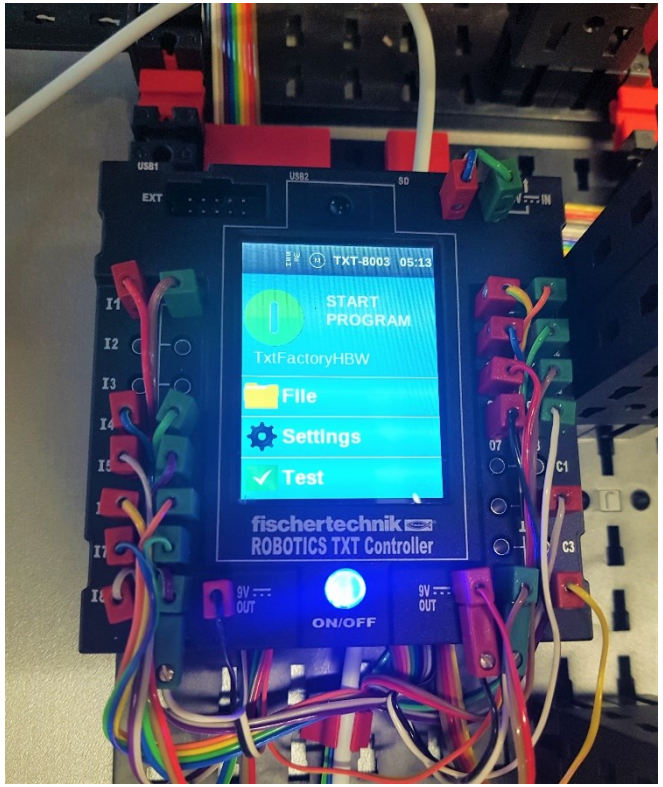
Programming the Factories: As-is State

```
#elif CLIENT_HBW
		if (msg->get_topic() == TOPIC_OUTPUT_STATE_ACK) {
			SPDLOG_LOGGER_DEBUG(spdlog::get("console"), "DETECTED state ack:{}", msg->get_topic());
			std::stringstream ssin(msg->to_string());
			Json::Value root;
			try {
				ssin >> root;
				std::string sts = root["ts"].asString();
				SPDLOG_LOGGER_DEBUG(spdlog::get("console"), "  ts:{}", sts);
				if (ft::trycheckTimestampTTL(sts))
				{
					hbw_.requestQuit();
				}
			} catch (const Json::RuntimeError& exc) {
				std::cout << "Error: " << exc.what() << std::endl;
			}
			SPDLOG_LOGGER_DEBUG(spdlog::get("console"), "OK.", 0);
		} else if (msg->get_topic() == TOPIC_LOCAL_SSC_JOY) {
			SPDLOG_LOGGER_DEBUG(spdlog::get("console"), "DETECTED joy:{}", msg->get_topic());
			std::stringstream ssin(msg->to_string());
			Json::Value root;
			try {
				ssin >> root;
				std::string sts = root["ts"].asString();
				SPDLOG_LOGGER_DEBUG(spdlog::get("console"), "  ts:{}", sts);
				if (ft::trycheckTimestampTTL(sts))
				{
					ft::TxtJoysticksData jd;
					jd.aX1 = root["aX1"].asInt();
					jd.aY1 = root["aY1"].asInt();
					jd.b1 = root["b1"].asBool();
					jd.aX2 = root["aX2"].asInt();
					jd.aY2 = root["aY2"].asInt();
					jd.b2 = root["b2"].asBool();
					hbw_.requestJoyBut(jd);
					SPDLOG_LOGGER_DEBUG(spdlog::get("console"), "  1:{} {} {} 2:{} {} {}", jd.aX1, jd.aY1, jd.b1, jd.aX2,
				}
			} catch (const Json::RuntimeError& exc) {
				std::cout << "Error: " << exc.what() << std::endl;
			}
			SPDLOG_LOGGER_DEBUG(spdlog::get("console"), "OK.", 0);
		} else if (msg->get_topic() == TOPIC_LOCAL_VGR_DO) {
			SPDLOG_LOGGER_DEBUG(spdlog::get("console"), "DETECTED vgr do:{}", msg->get_topic());
```



6–12 Embedded TXT Controllers

- 1 C++ application / controller
- 2 hard-wired processes

https://github.com/fischertechnik/txt_training_factory

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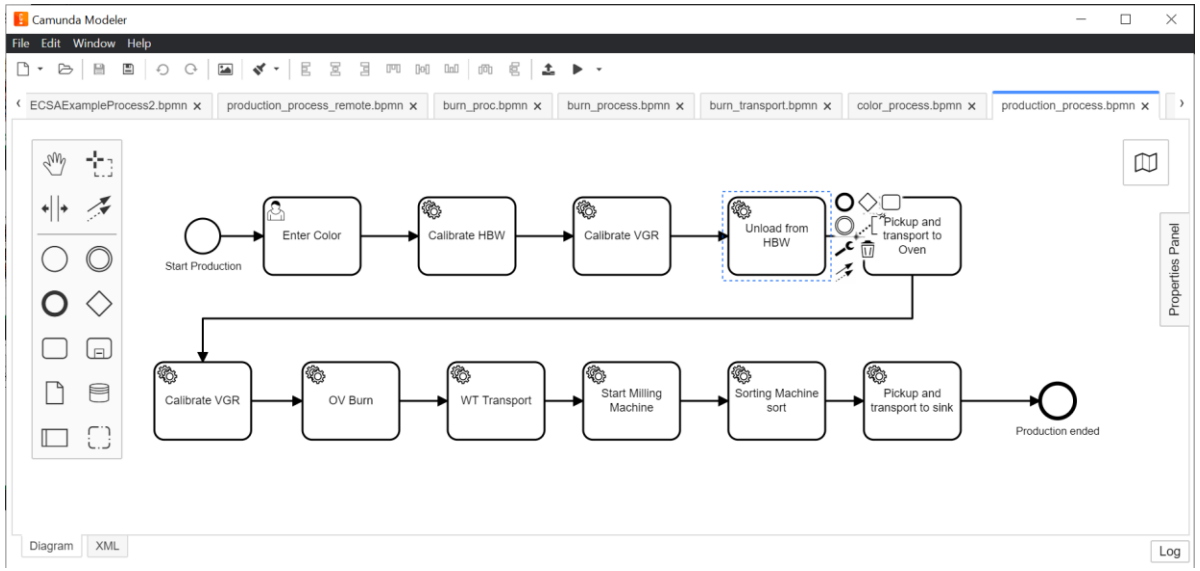
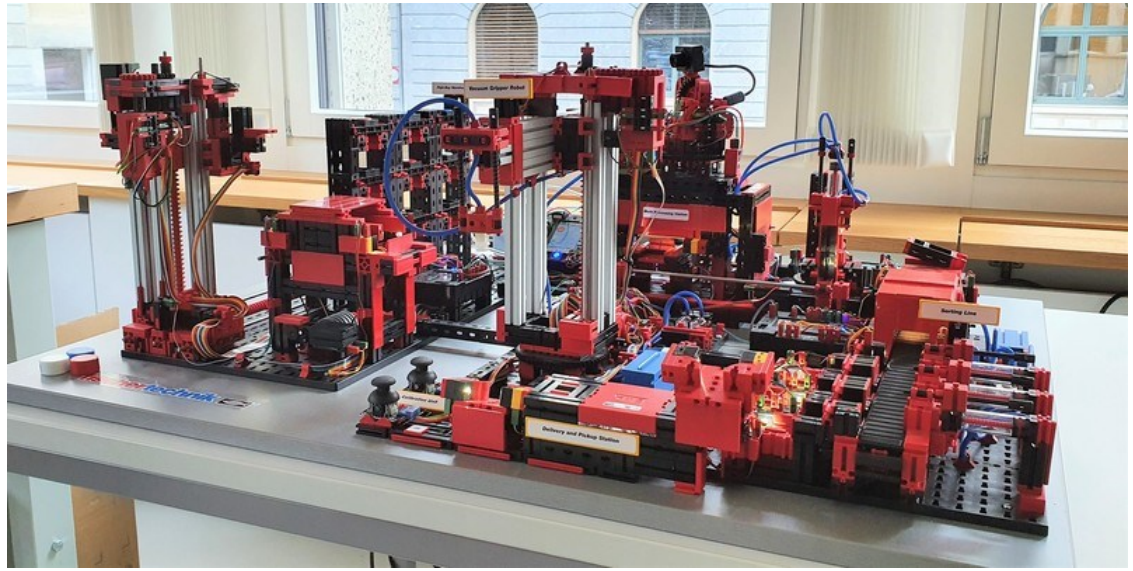
«Programming» the Factories: To-be State



Model Process in BPMN in Camunda Modeler (*low-code*)

Execute via Camunda Platform



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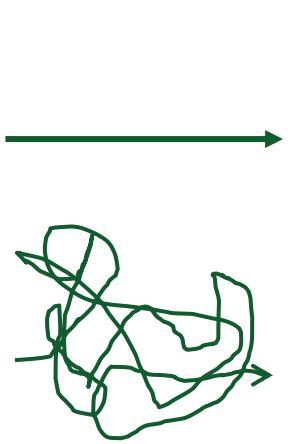
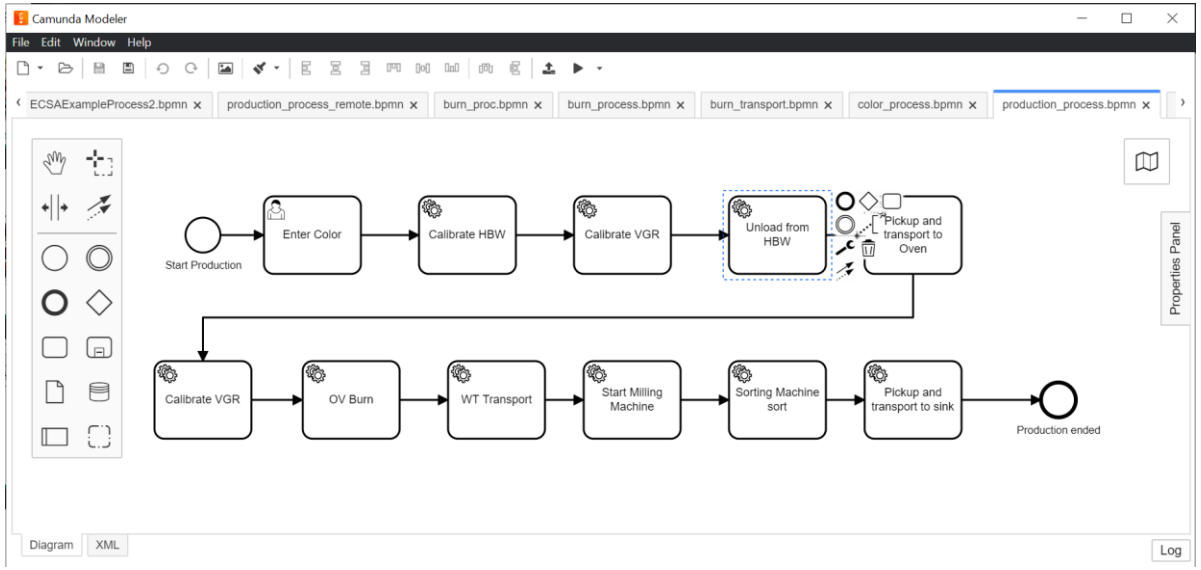
The Journey

```
elif CLIENT_HBW
        if (msg->get_topic() == TOPIC_OUTPUT_STATE_ACK) {
                SPDLOG_LOGGER_DEBUG(spdlog::get("console"), "DETECTED state ack:{}", msg->get_topic());
                std::stringstream ssin(msg->to_string());
                Json::Value root;
                try {
                        ssin >> root;
                        std::string sts = root["ts"].asString();
                        SPDLOG_LOGGER_DEBUG(spdlog::get("console"), "  ts:{}", sts);
                        if (ft::trycheckTimestampTTL(sts))
                        {
                                hbw_.requestQuit();
                        }
                } catch (const Json::RuntimeError& exc) {
                        std::cout << "Error: " << exc.what() << std::endl;
                }
                SPDLOG_LOGGER_DEBUG(spdlog::get("console"), "OK.", 0);
        } else if (msg->get_topic() == TOPIC_LOCAL_SSC_JOY) {
                SPDLOG_LOGGER_DEBUG(spdlog::get("console"), "DETECTED joy:{}", msg->get_topic());
                std::stringstream ssin(msg->to_string());
                Json::Value root;
                try {
                        ssin >> root;
                        std::string sts = root["ts"].asString();
                        SPDLOG_LOGGER_DEBUG(spdlog::get("console"), "  ts:{}", sts);
                        if (ft::trycheckTimestampTTL(sts))
                        {
                                ft::TxtJoysticksData jd;
                                jd.aX1 = root["aX1"].asInt();
                                jd.aY1 = root["aY1"].asInt();
                                jd.b1 = root["b1"].asBool();
                                jd.aX2 = root["aX2"].asInt();
                                jd.aY2 = root["aY2"].asInt();
                                jd.b2 = root["b2"].asBool();
                                hbw_.requestJoyBut(jd);
                                SPDLOG_LOGGER_DEBUG(spdlog::get("console"), "  1:{} {} {} 2:{} {} {}", jd.aX1, jd.aY1, jd.b1, jd.aX2
                        }
                } catch (const Json::RuntimeError& exc) {
                        std::cout << "Error: " << exc.what() << std::endl;
                }
                SPDLOG_LOGGER_DEBUG(spdlog::get("console"), "OK.", 0);
        } else if (msg->get_topic() == TOPIC_LOCAL_VGR_DO) {
```





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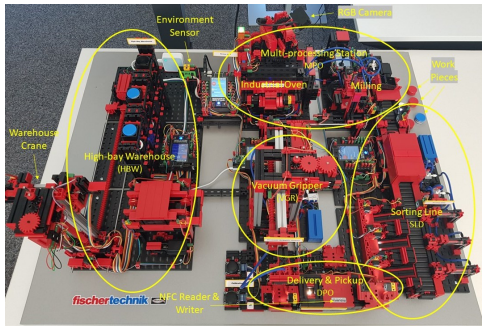
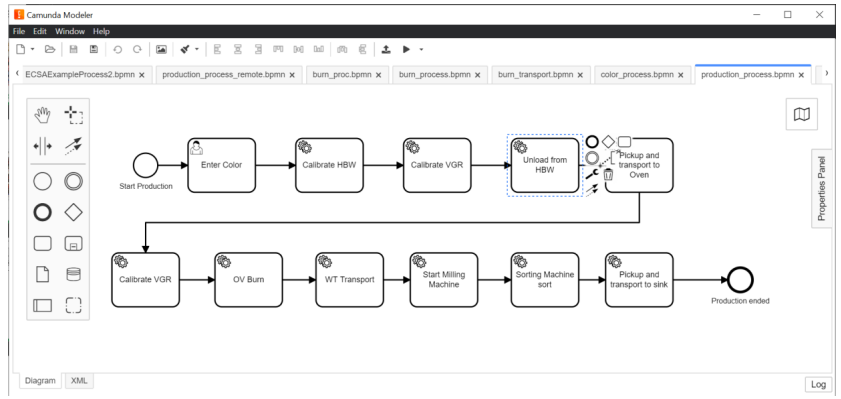
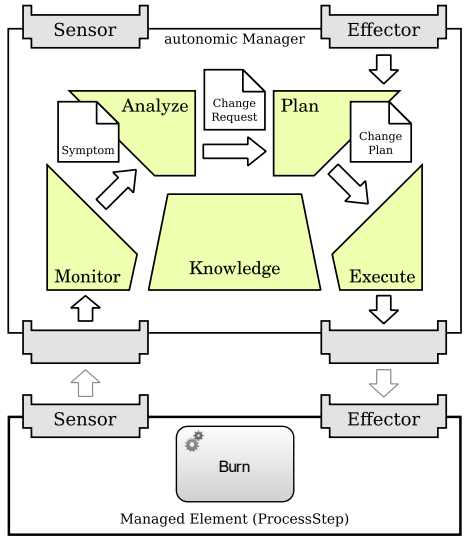
Agenda





- Hardware
- Programming
  - Low-level & High-level
- Web Services & Business Processes
- Sensors
  - Stream Processing & Machine Learning
- Research: Autonomous Processes



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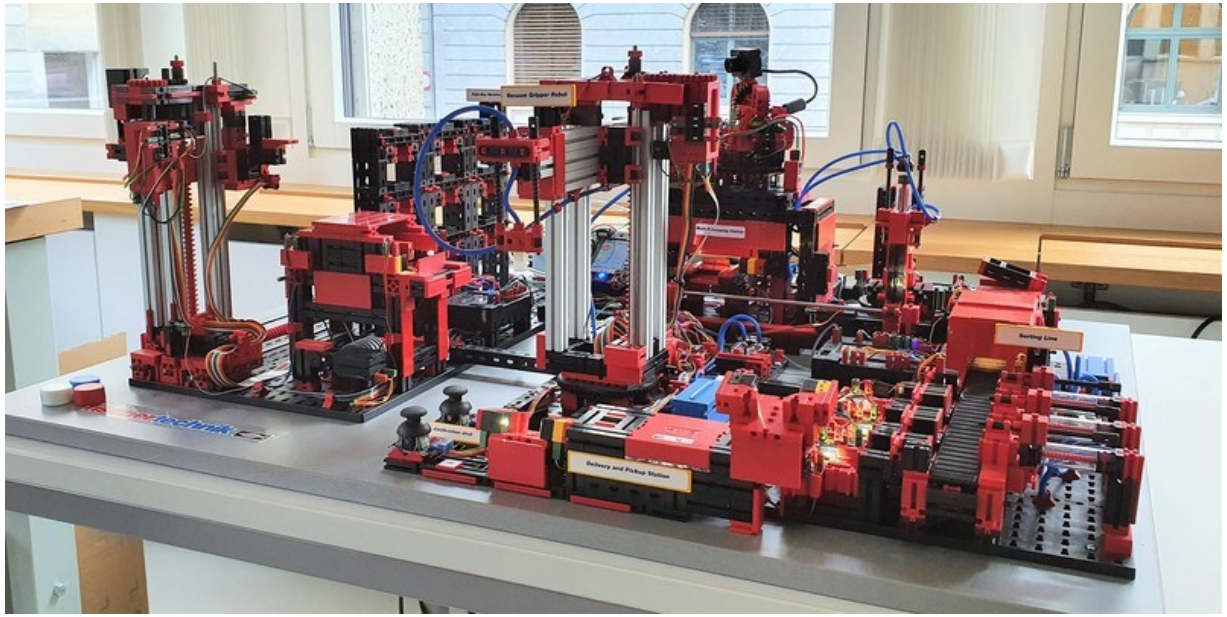
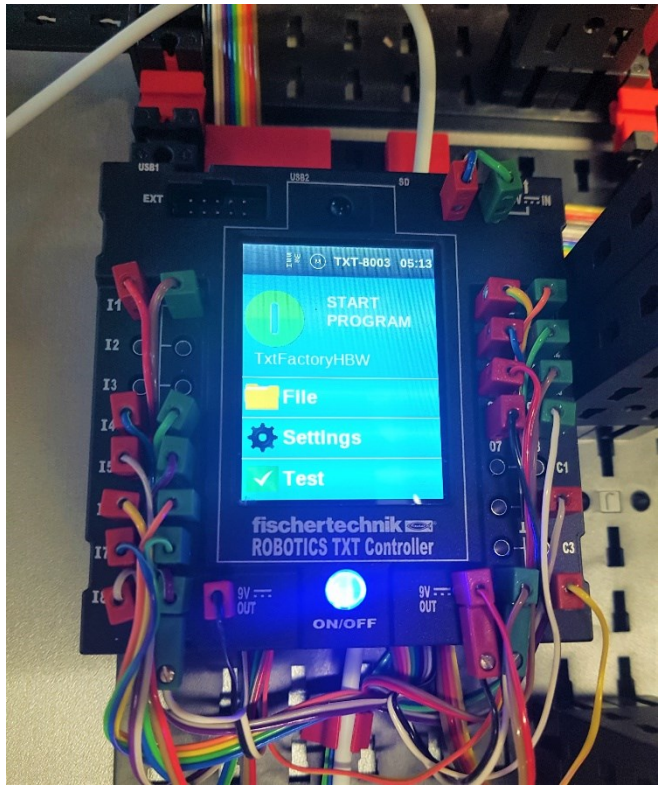
The Embedded TXT Controllers: Hardware





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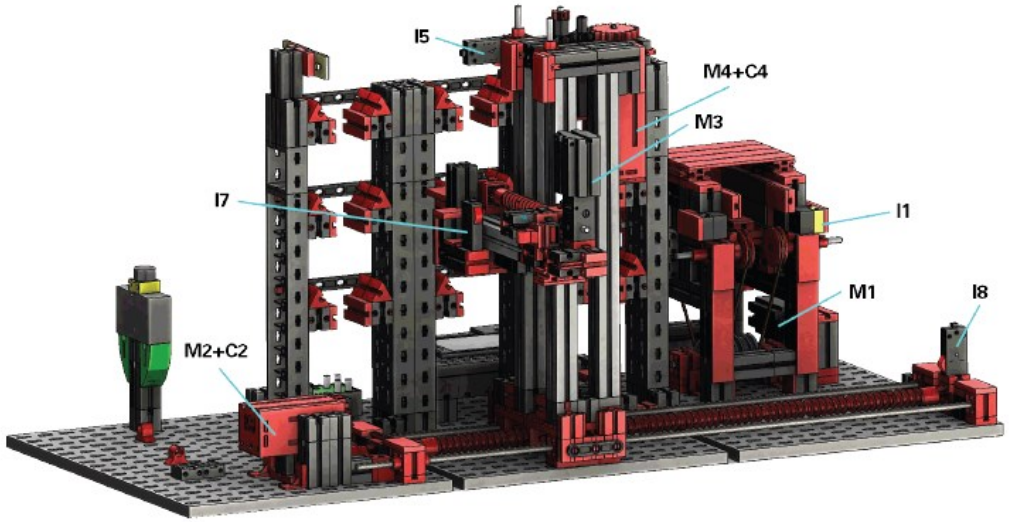
Know Your Wiring!

Number	Function	Input / output
1	Photo-transistor external	I1
2	Photo-transistor internal	I4
3	Reference pushbutton horizontal	I5
4	Reference pushbutton probe arm rear	I6
5	Reference pushbutton probe arm front	I7
6	Reference pushbutton vertical	I8
7	Encoder horizontal	C2
8	Encoder vertical	C4
9	Motor conveyor belt	M1
10	Horizontal motor	M2
11	Motor probe arm	M3
12	Vertical motor	M4



from https://www.fischertechnik.de/-/media/fischertechnik/fite/service/elearning/lehren/lernfabrik/fabrik_2019_englisch_neu.ashx

Hardware ✓

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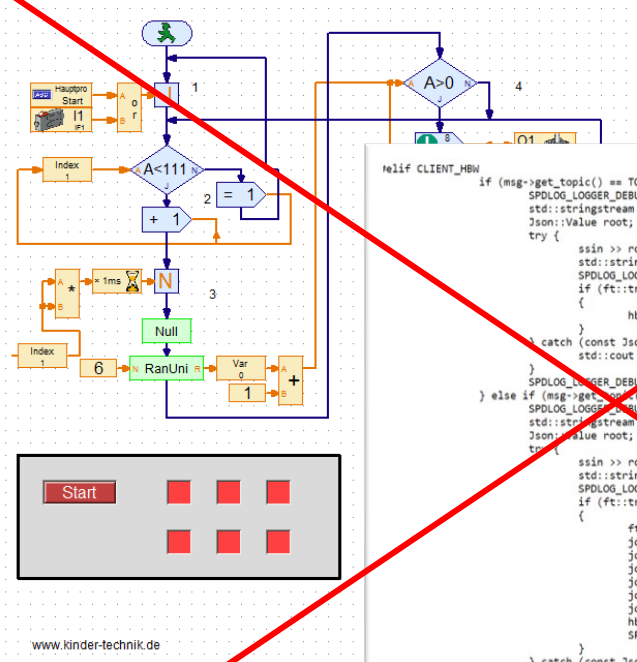
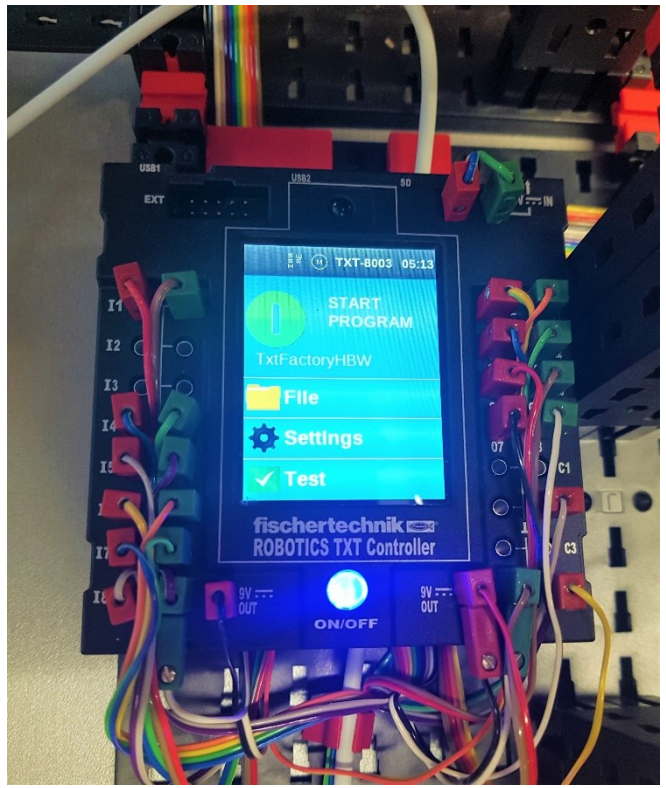
The Embedded TXT Controllers: Software



Fischertechnik RoboPro

```
#elif CLIENT_HBW
        if (msg->get_topic() == TOPIC_OUTPUT_STATE_ACK) {
                SPDLOG_LOGGER_DEBUG(spdlog::get("console"), "DETECTED state ack:{}", msg->get_topic());
                std::stringstream ssin(msg->to_string());
                Json::Value root;
                try {
                        ssin >> root;
                        std::string sts = root["ts"].asString();
                        SPDLOG_LOGGER_DEBUG(spdlog::get("console"), "  ts:{}", sts);
                        if (ft::trycheckTimestampTTL(sts))
                        {
                                hbw_.requestQuit();
                        }
                } catch (const Json::RuntimeError& exc) {
                        std::cout << "Error: " << exc.what() << std::endl;
                }
                SPDLOG_LOGGER_DEBUG(spdlog::get("console"), "OK.", 0);
        } else if (msg->get_topic() == TOPIC_LOCAL_SSC_JOY) {
                SPDLOG_LOGGER_DEBUG(spdlog::get("console"), "DETECTED joy:{}", msg->get_topic());
                std::stringstream ssin(msg->to_string());
                Json::Value root;
                try {
                        ssin >> root;
                        std::string sts = root["ts"].asString();
                        SPDLOG_LOGGER_DEBUG(spdlog::get("console"), "  ts:{}", sts);
                        if (ft::trycheckTimestampTTL(sts))
                        {
                                ft::TxtJoysticksData jd;
                                jd.aX1 = root["aX1"].asInt();
                                jd.aY1 = root["aY1"].asInt();
                                jd.b1 = root["b1"].asBool();
                                jd.aX2 = root["aX2"].asInt();
                                jd.aY2 = root["aY2"].asInt();
                                jd.b2 = root["b2"].asBool();
                                hbw_.requestJoyBut(jd);
                                SPDLOG_LOGGER_DEBUG(spdlog::get("console"), "  1:{} 2:{} {} {}", jd.aX1, jd.aY1, jd.b1, jd.aX2
                        }
                } catch (const Json::RuntimeError& exc) {
                        std::cout << "Error: " << exc.what() << std::endl;
                }
                SPDLOG_LOGGER_DEBUG(spdlog::get("console"), "OK.", 0);
        } else if (msg->get_topic() == TOPIC_LOCAL_VGR_DO) {
```

Fischertechnik C++ Project



fischertechnik TXT community firmware

ftrobopy

https://github.com/ftrobopy/ftrobopy

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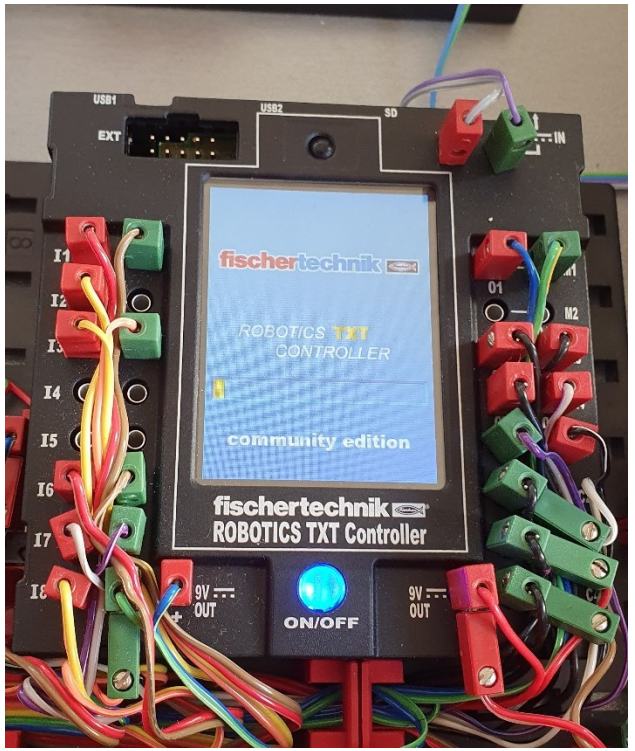
The Embedded TXT Controllers: Software

ftrobopy

- Unix Process on controller
  - Provides TCP Sockets
- Python library
  - Deploy locally or on remote computer




```
1  import ftrobopy
2
3  my_txt1 = ftrobopy.ftrobopy(host=f"192.168.0.12", port=65000, update_interval=0.01)
4
```

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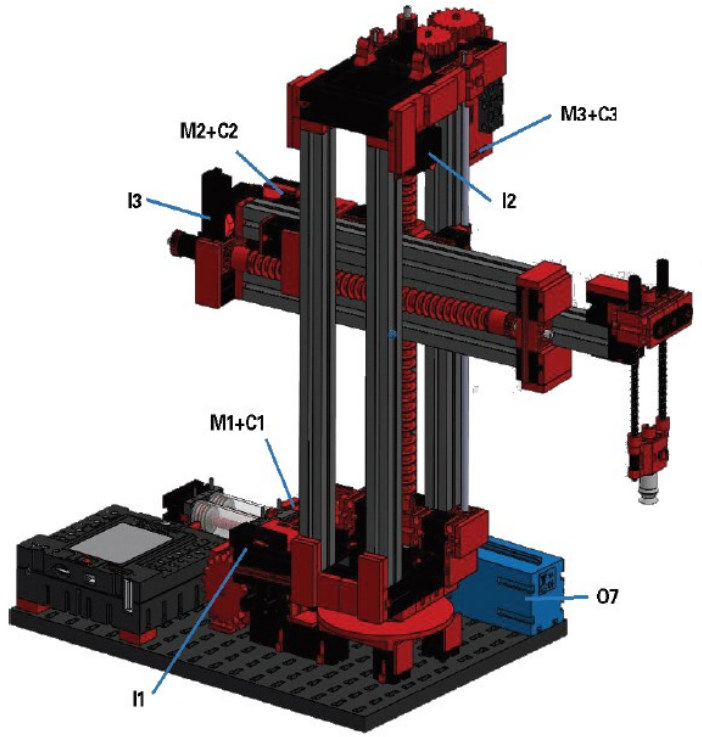
Bringing Hardware & Software Together

```
5   m1 = my_txt1.motor(1)
6   m1.setSpeed(512)
7
8   m2 = my_txt1.motor(2)
9   m2.setSpeed(-256)
10
11  o7 = my_txt1.output(7)
12  o7.setLevel(512)
13
14  i3 = my_txt1.input(3)
15  if i3.state() == 1:
16      print("Switch i3 pressed")
```



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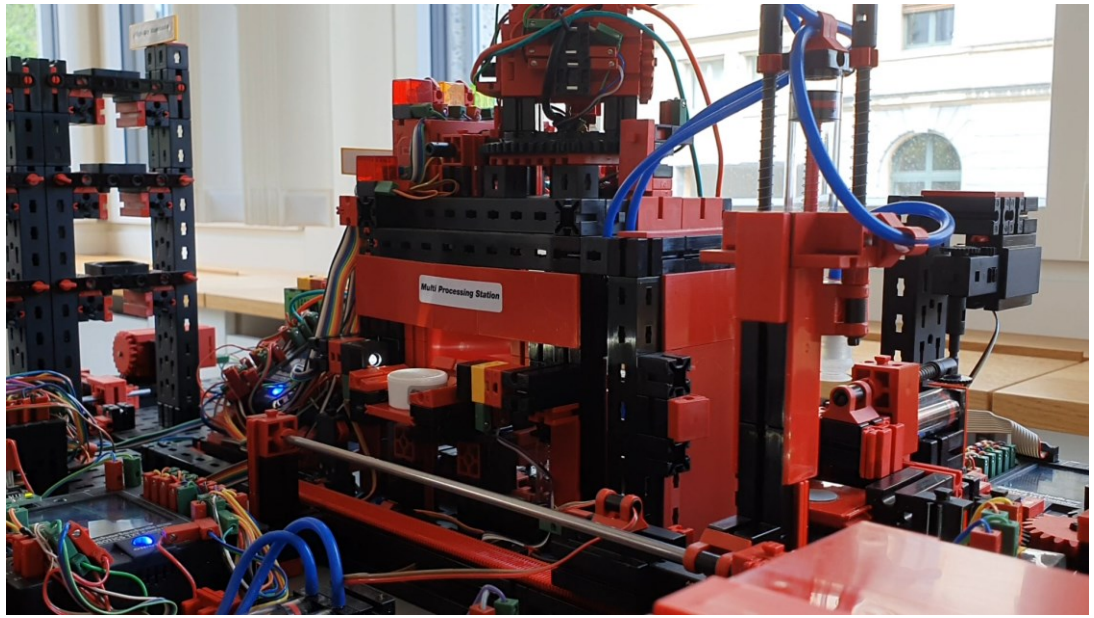
Small Example: Oven



```
import ftrobopy

oven_txt = ftrobopy.ftrobopy(host=f"192.168.0.14",
                             port=65000, update_interval=0.01)
o7 = oven_txt.output(7)
m1 = oven_txt.motor(1)
i1 = oven_txt.input(1)

# Open Oven door
o7.setLevel(512)

# Drive in slide
m1.setSpeed(-512)
while i1.state() == 0:
    pass
m1.stop()

# Close Oven door
o7.setLevel(0)
```

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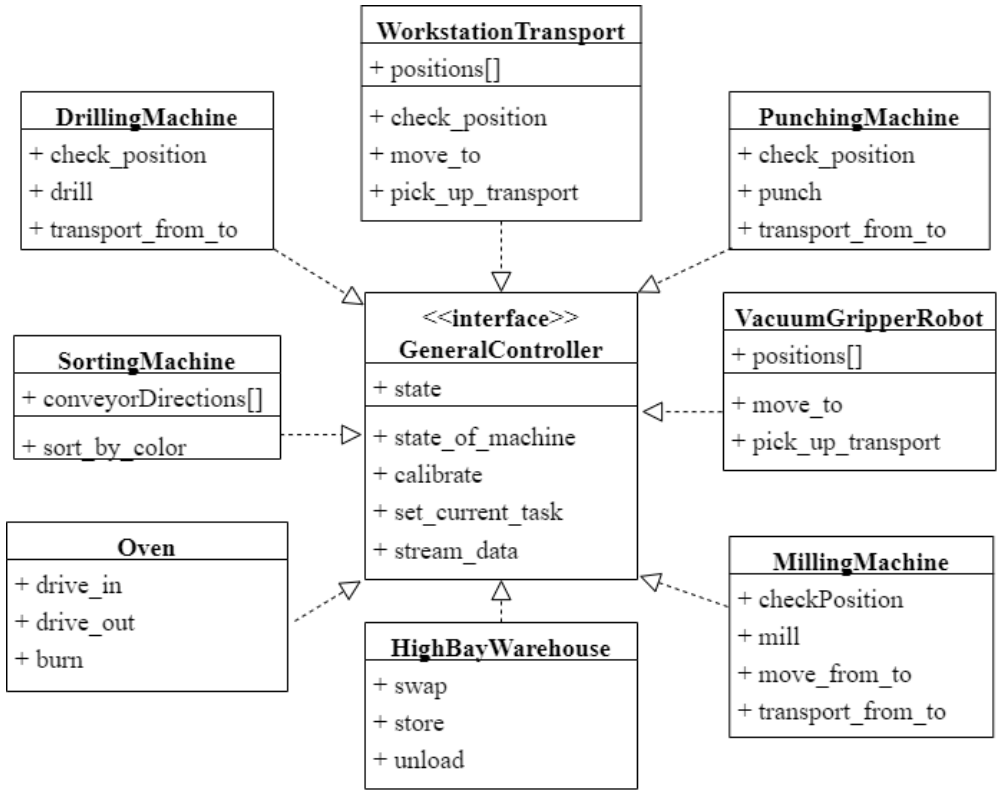
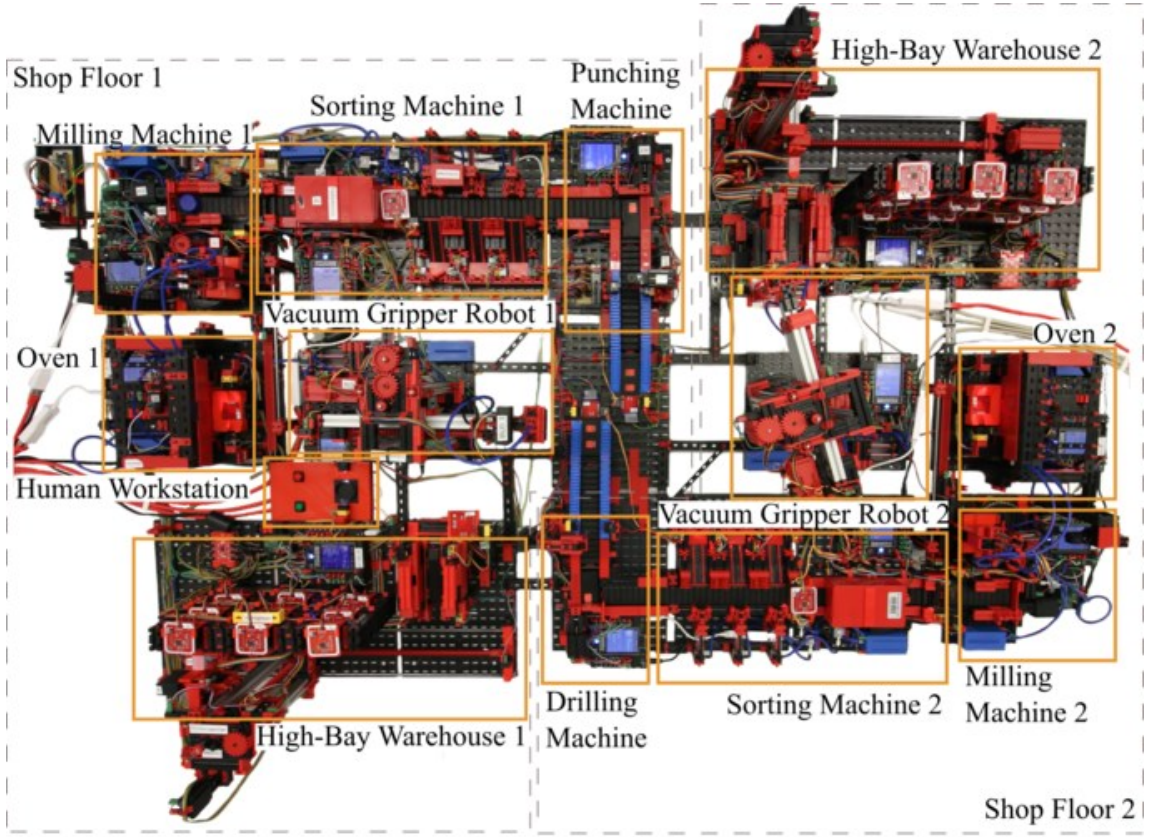
Going Object-oriented





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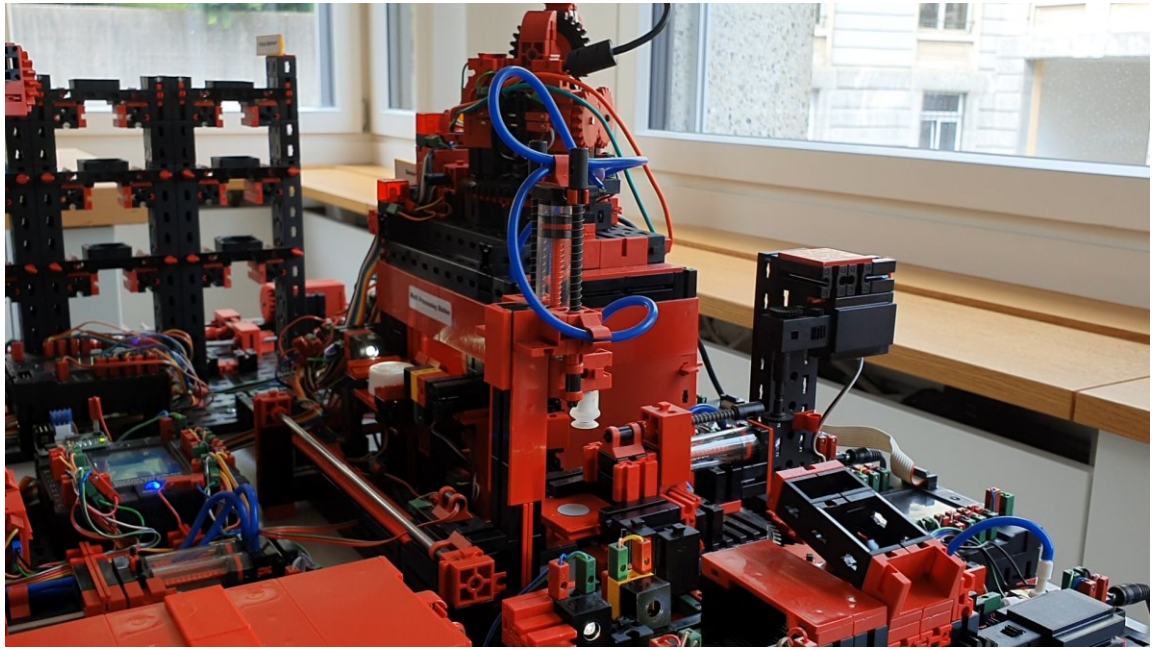
Going Object-oriented: Example



```
oven1 = Oven(12)
oven1.burn(5)

class Oven:
    def __init__(self, txt_number):
    ...

    def burn(self, time_in_seconds: int = 2) -> None:
        self._drive_into_oven()
        self.txt.play_sound(15)
        for i in range(time_in_seconds*8):
            if i%2==0:
                self.o8.setLevel(512)
            else: self.o8.setLevel(0)
            time.sleep(0.3)
        self.o8.setLevel(0)
        self._drive_out_of_oven()
        self._adjust_platform_for_workstation_transport()
        return
    ...

    def _adjust_platform_for_workstation_transport(self) -> None:
        self.m1.setDistance(100)
        self.m1.setSpeed(-1 * self.m1_speed)
        time.sleep(0.3)
        self.m1.stop()
        return
```

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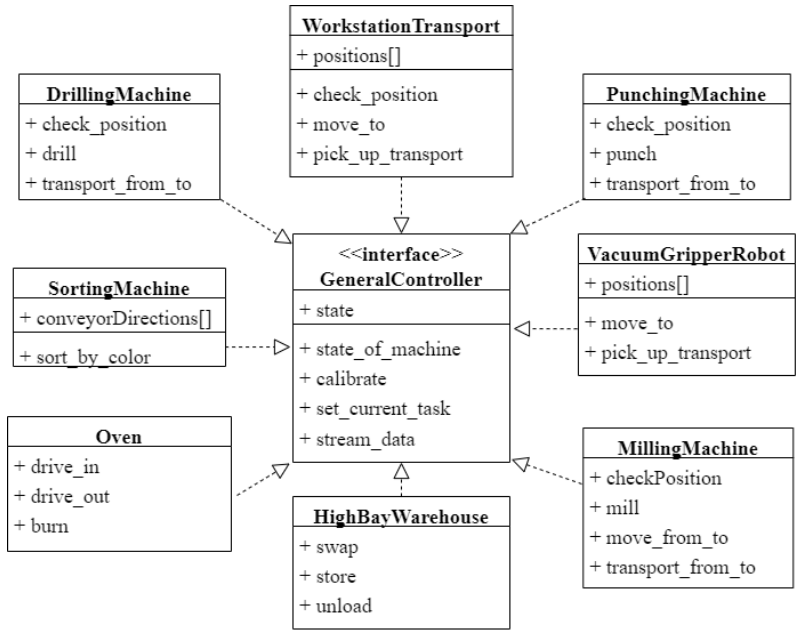
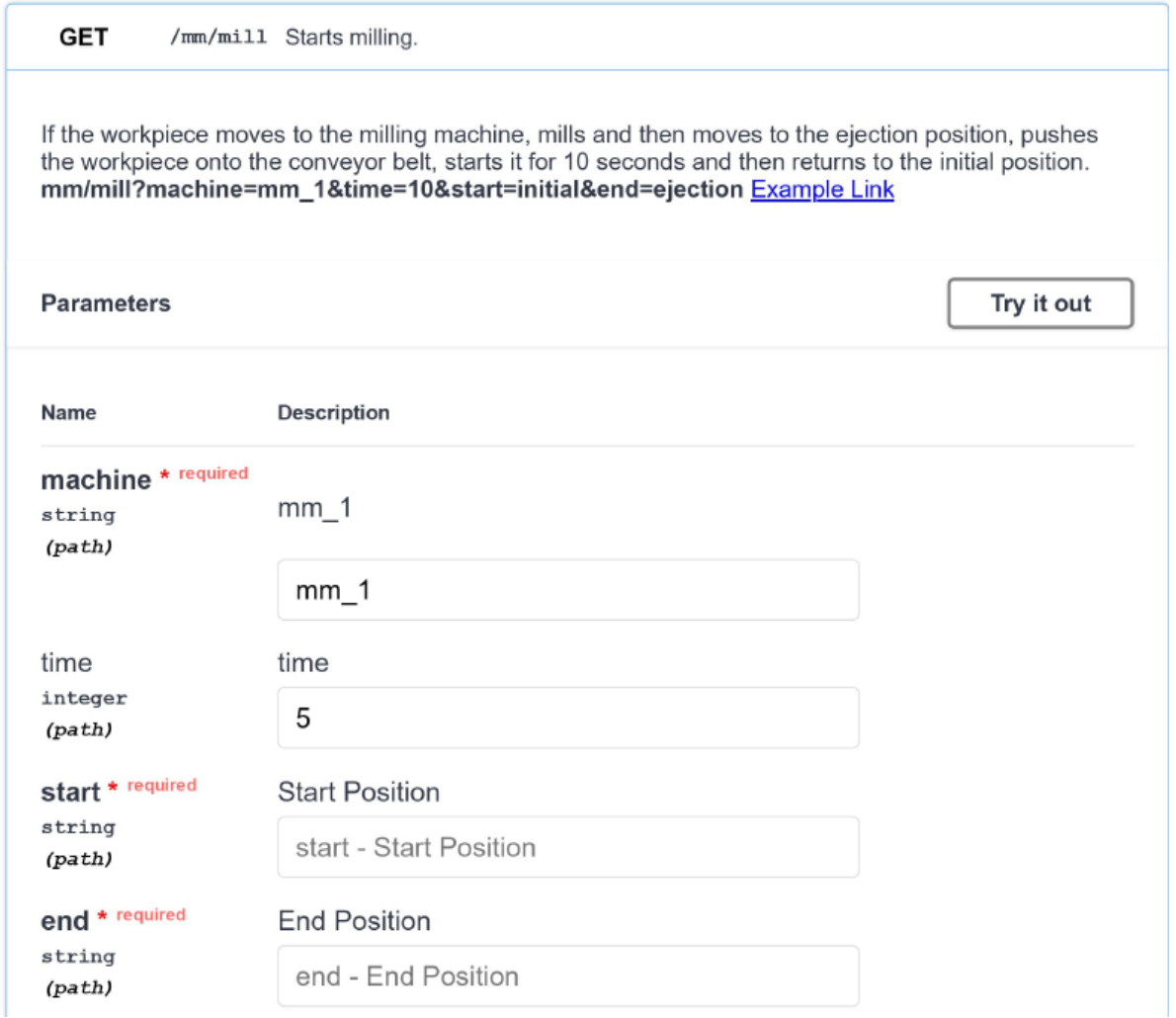
Going Service-based

- Expose high-level methods of OOP model 1:1 via RESTful web service
- HTTP GET with parameters
- Python Flask





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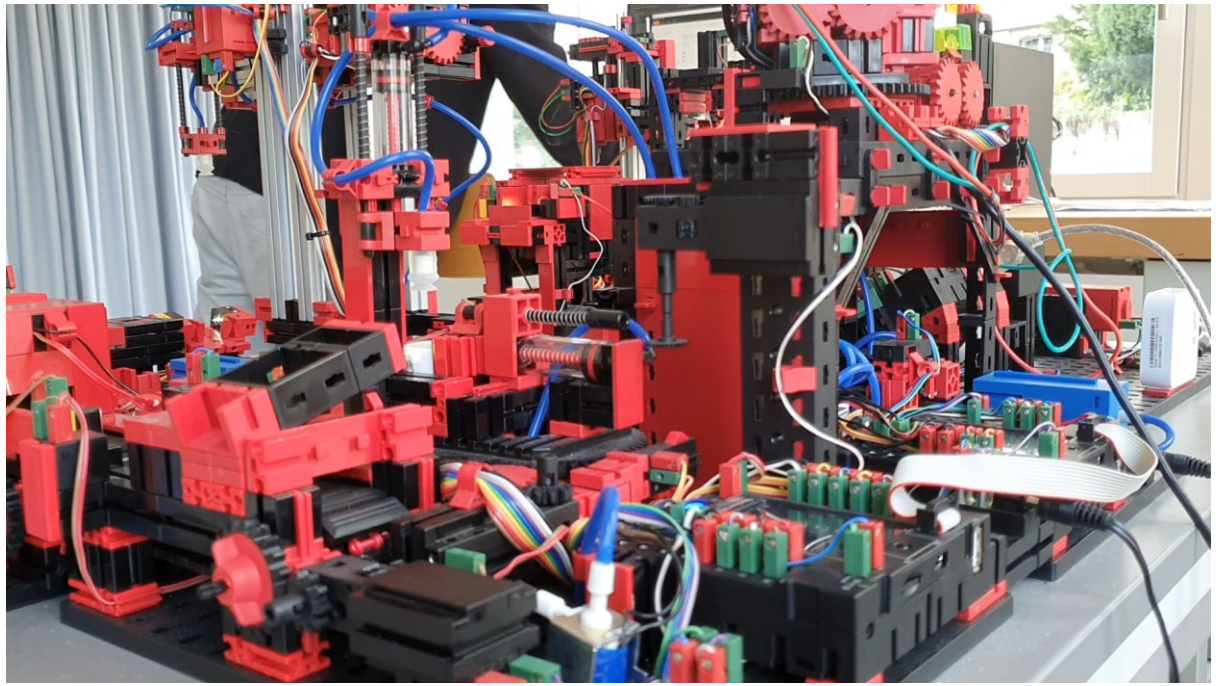
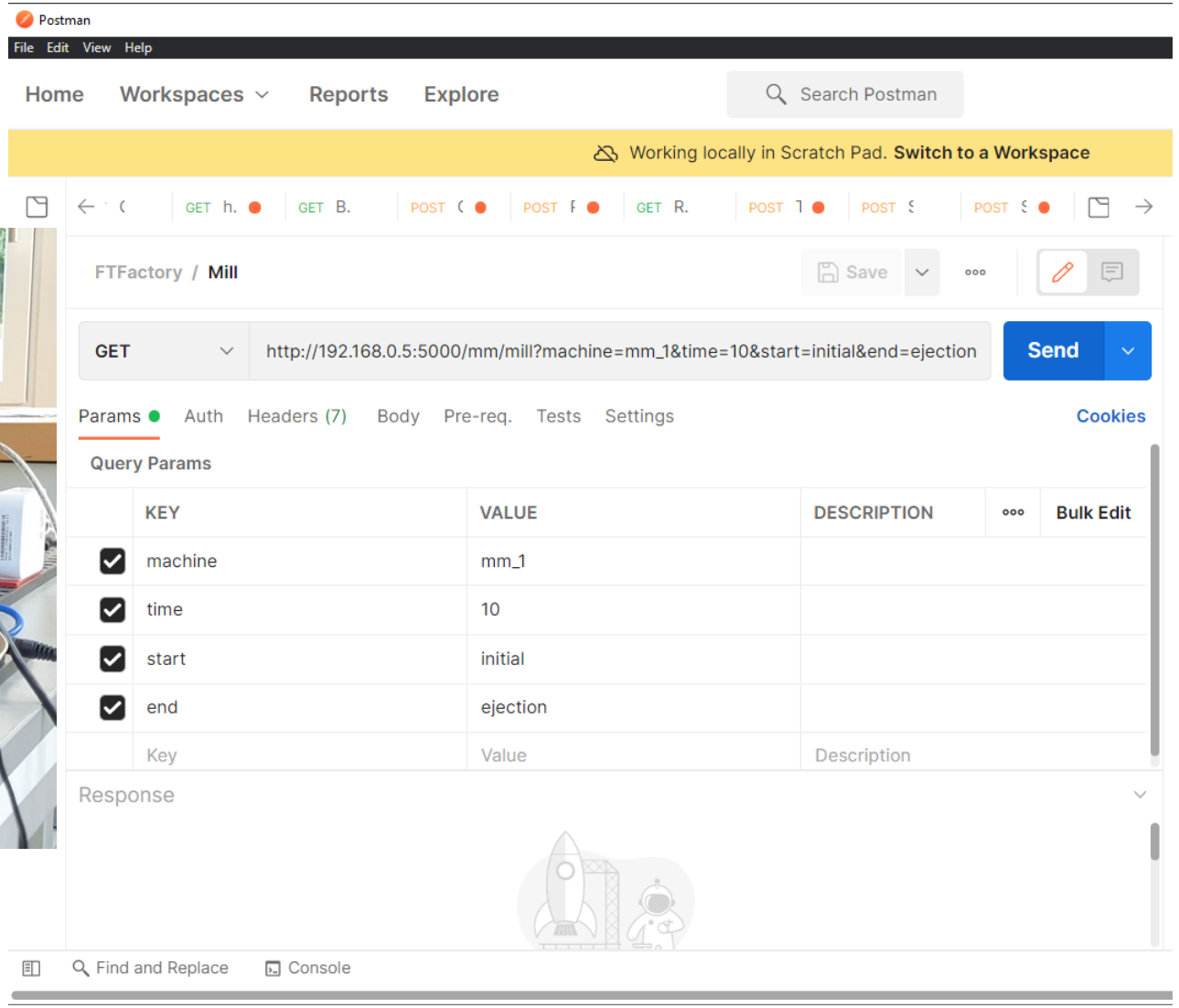
Going Service-based: Example





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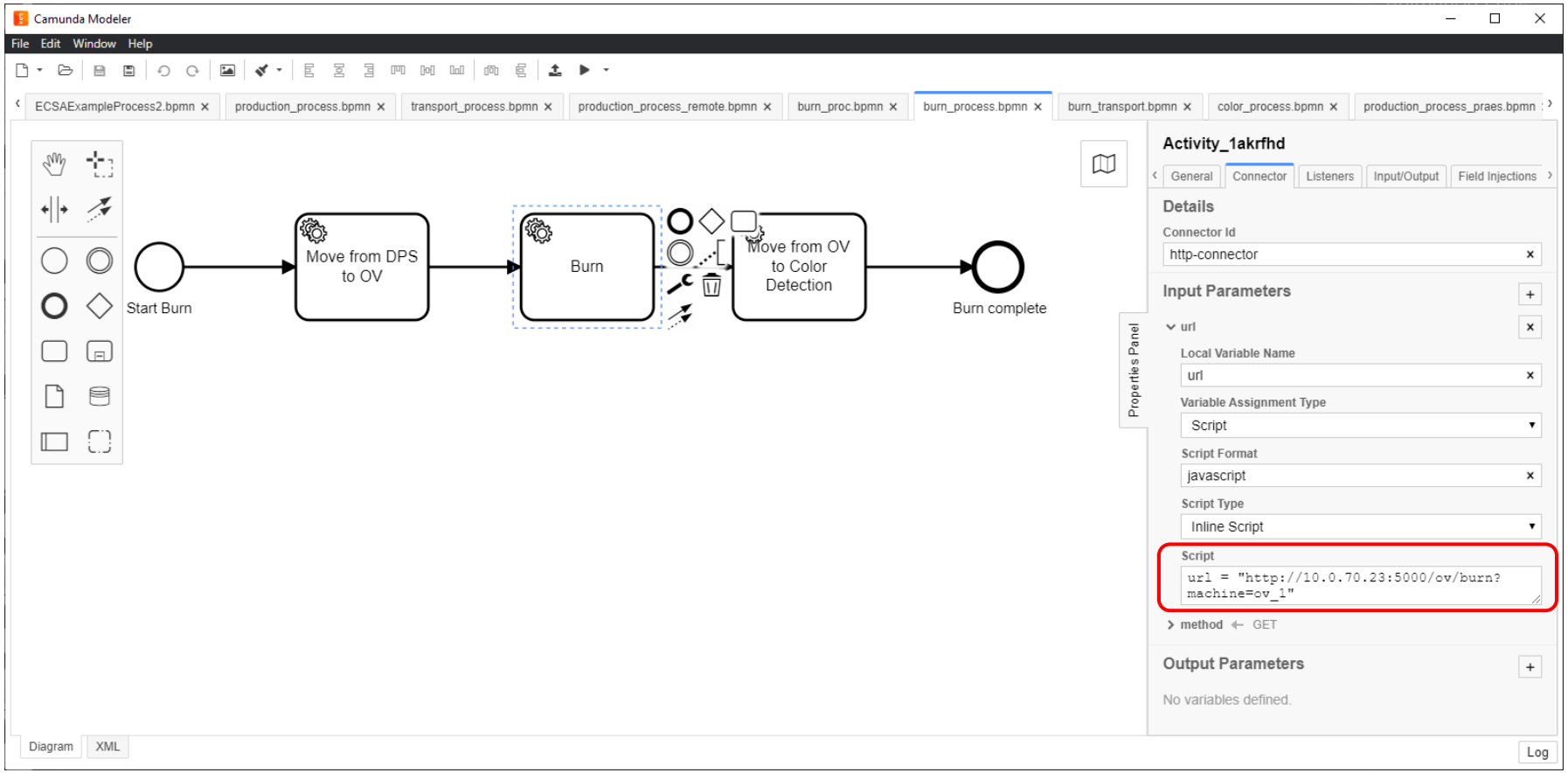
Going Business Processes

- Call web service via BPMN Service Tasks using http-connector



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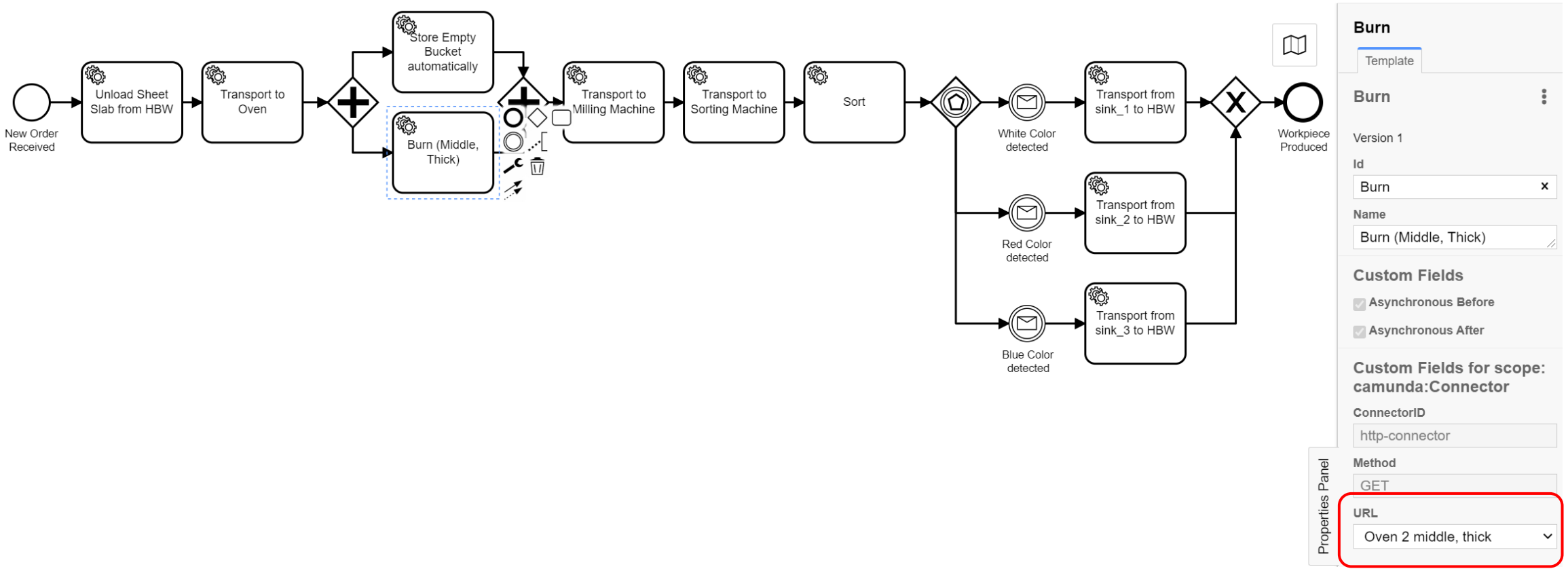
Going Business Processes

- Model processes with element templates



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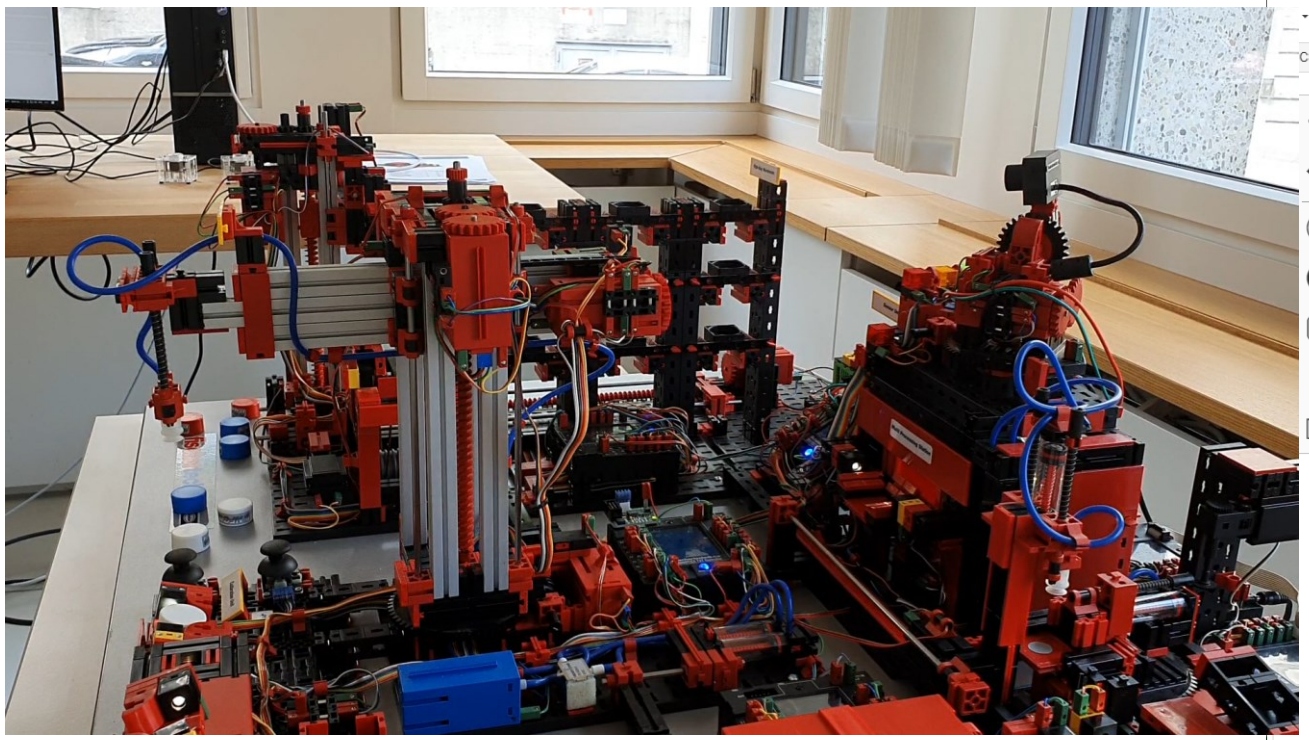
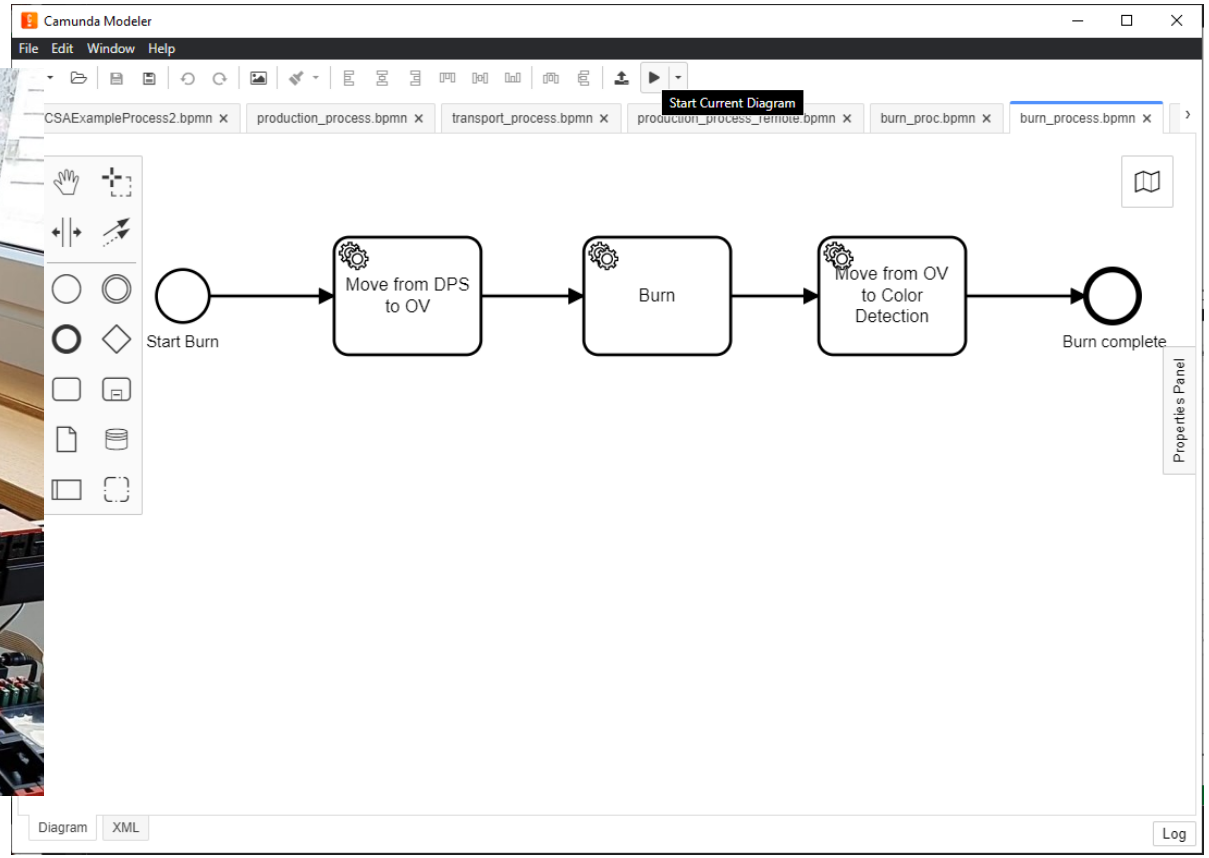
Going Business Processes: Example





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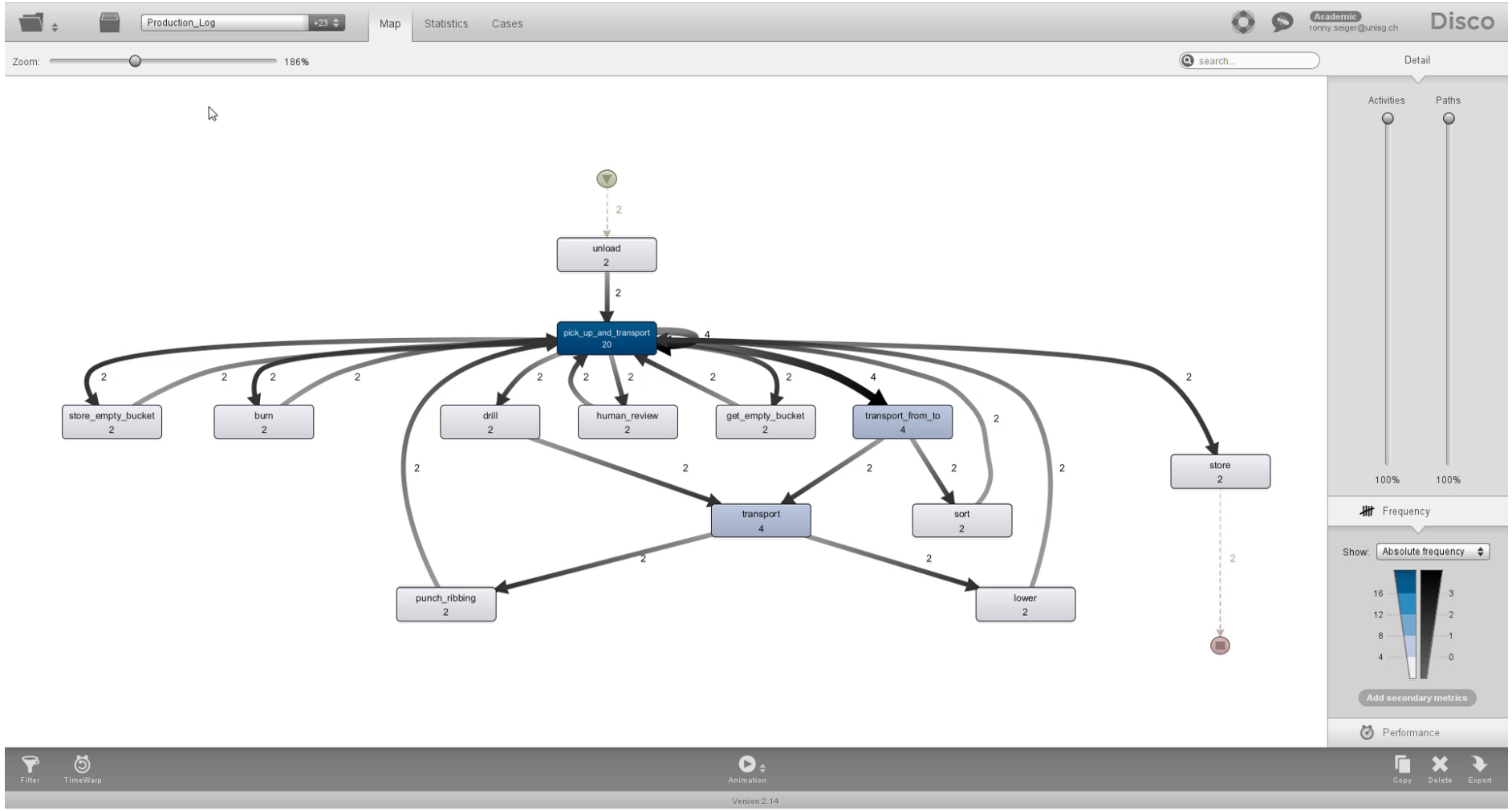
Process Mining almost for Free



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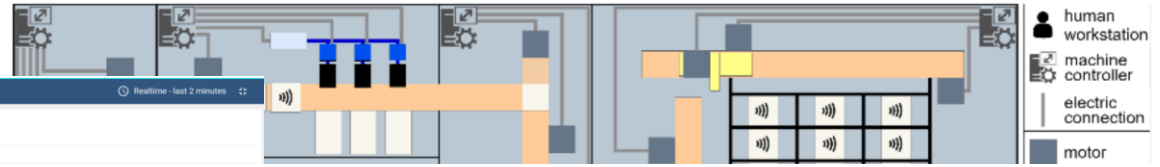
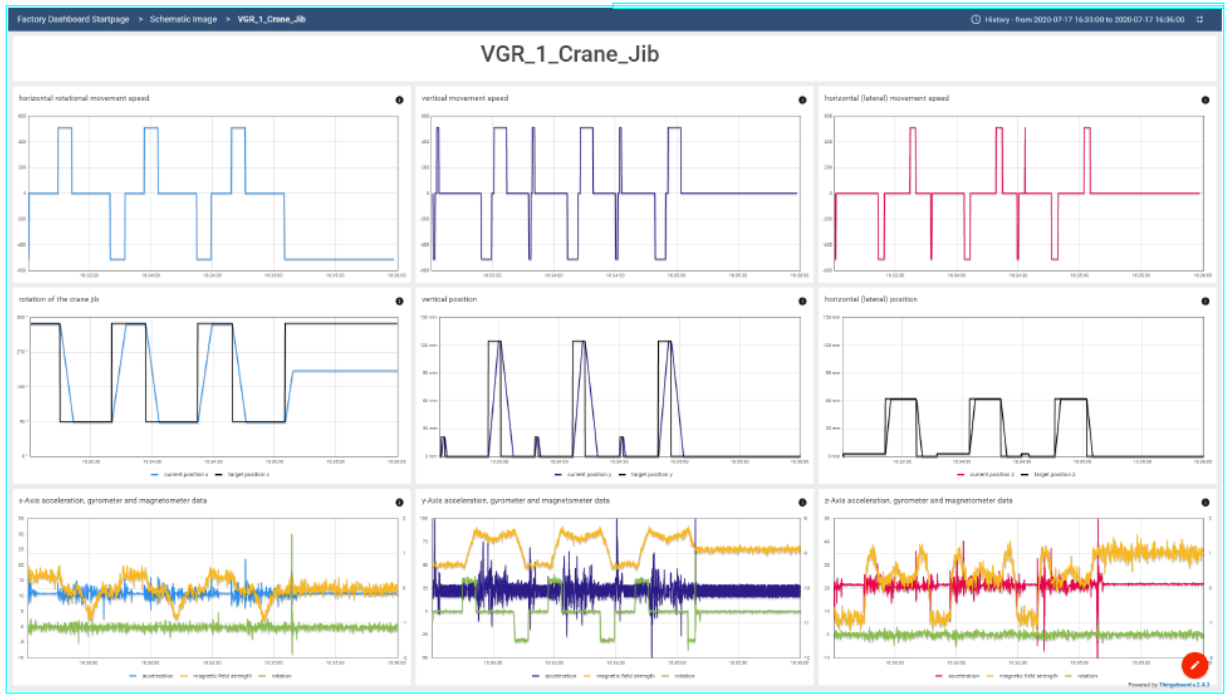
What about Sensors?





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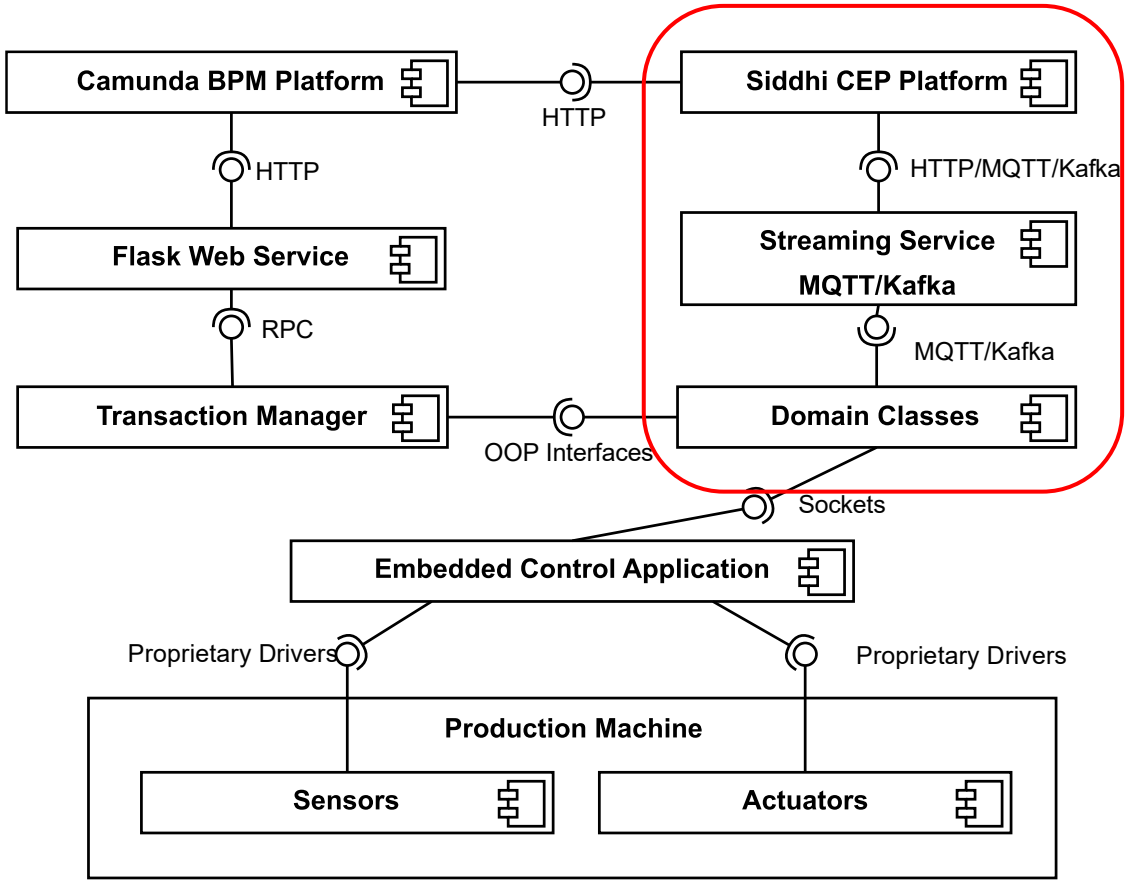
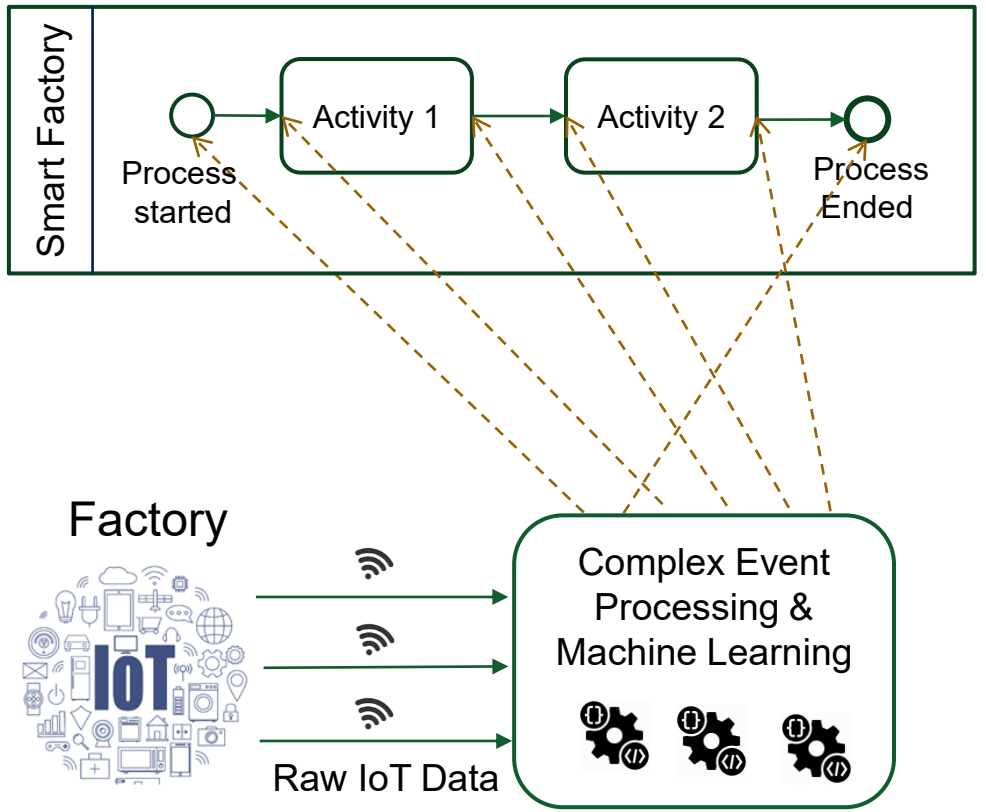
Going Event-driven





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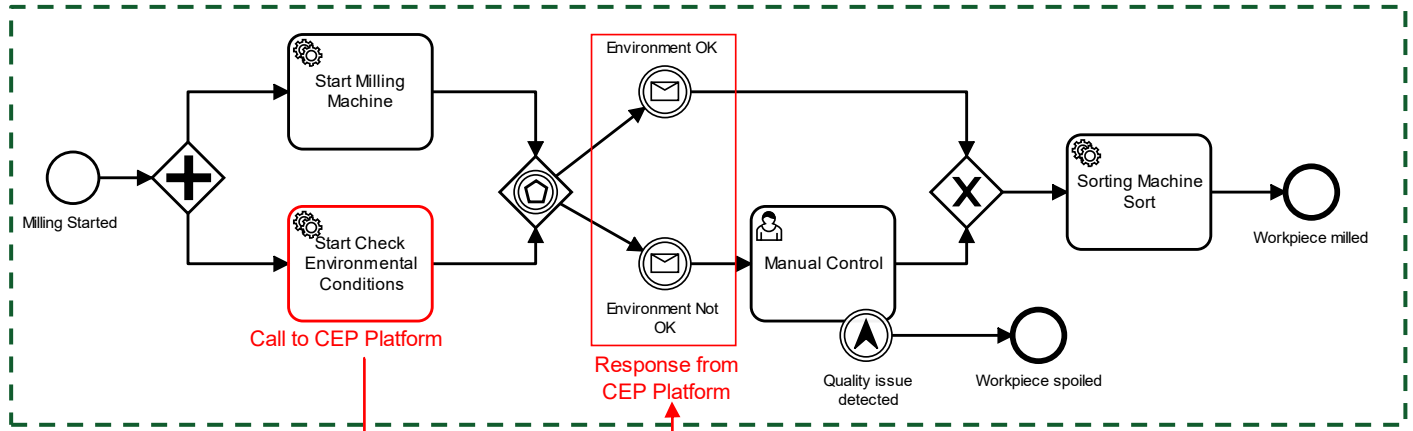
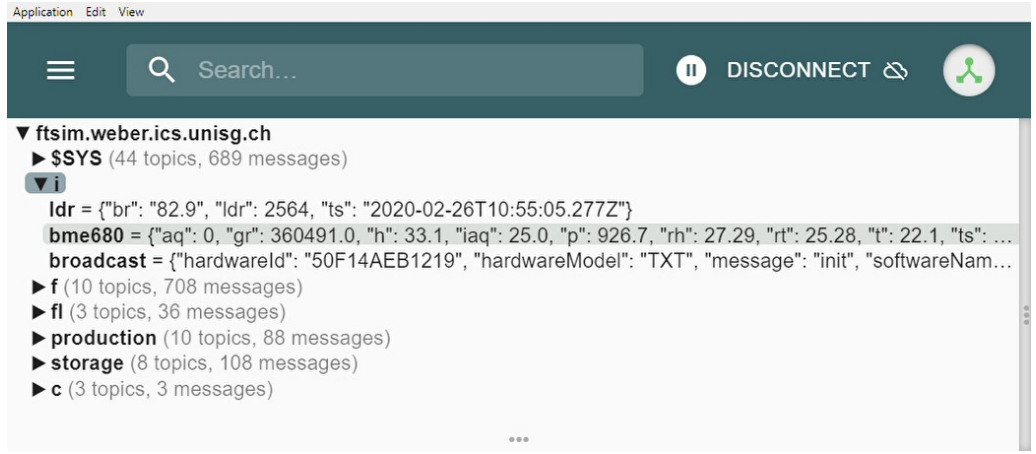
Going Event-driven: Quality Check Example



Camunda BPMS

MQTT Streaming



HTTP POST

HTTP POST

```
@info(name='EnvCheckOk')
from EnvAnalysisStream#window.timeBatch(10sec)
select "env_ok" as msgname,  avg(t) as avgtemp,
  avg(br) as avglight
having (avgtemp >= 22 and avgtemp<=25) and
  (avglight >= 80 and avglight <=85)
insert into EnvCheckStream;
```

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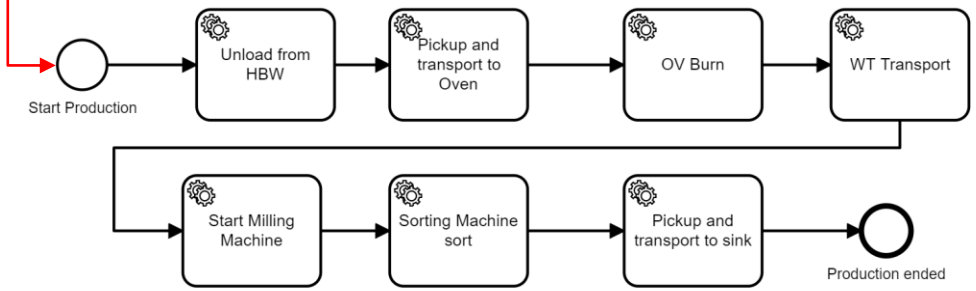
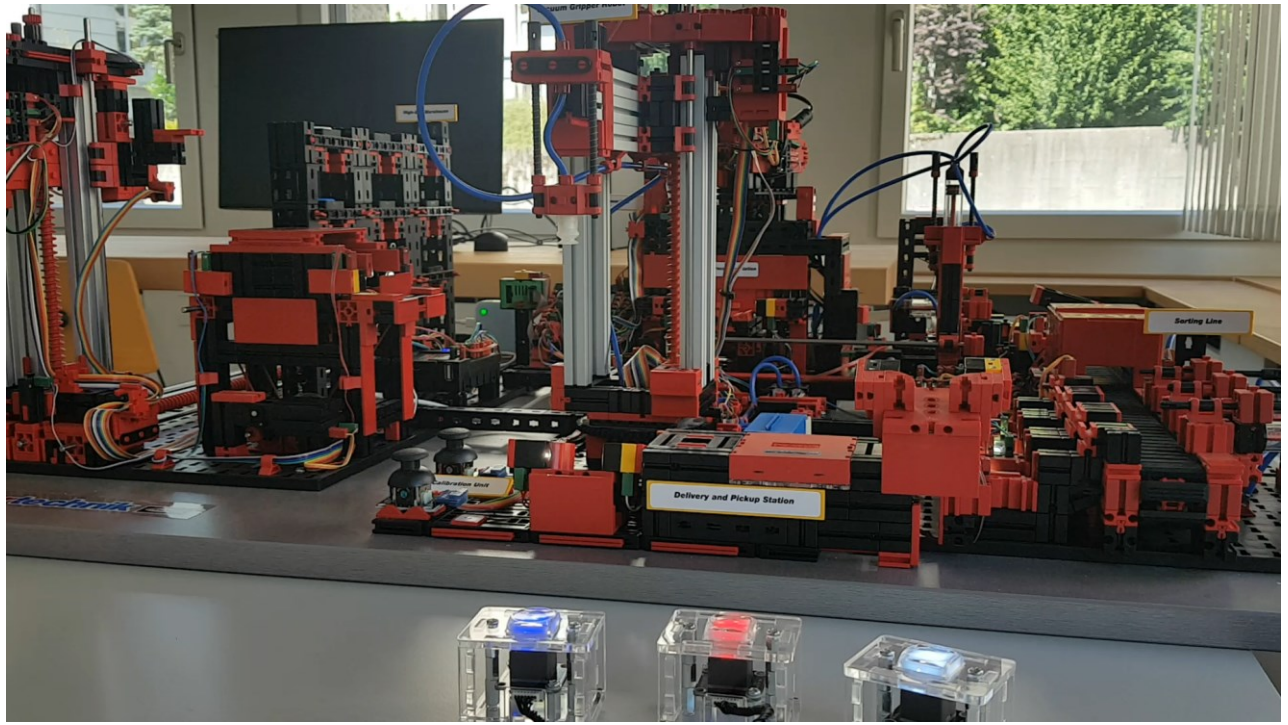
Going Event-driven: Starting a Process

```
@source(type = 'mqtt', url =
"tcp://broker.hivemq.com", client.id = “unisg", topic =
"TF_Buttons/M3X", @map(type = 'json’))
define stream BlueButtonStream (type string, state
string, ts string);

@info(name=‘bluebutton’)
from BlueButtonStream[state == 'pressed’]
select str:lower(type) as color
insert into ProcessStartStream;
```

HTTP POST





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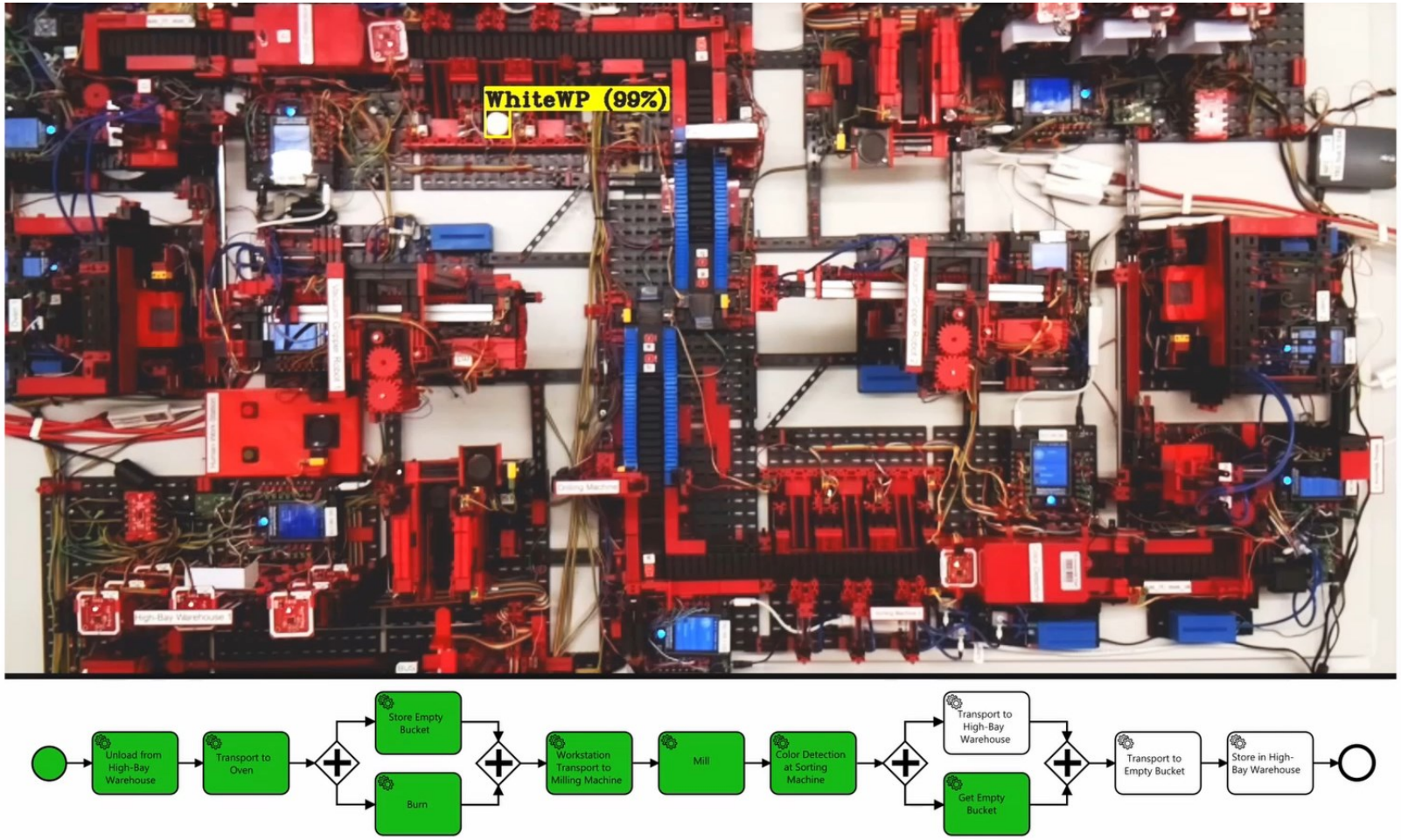
AI is Everywhere!



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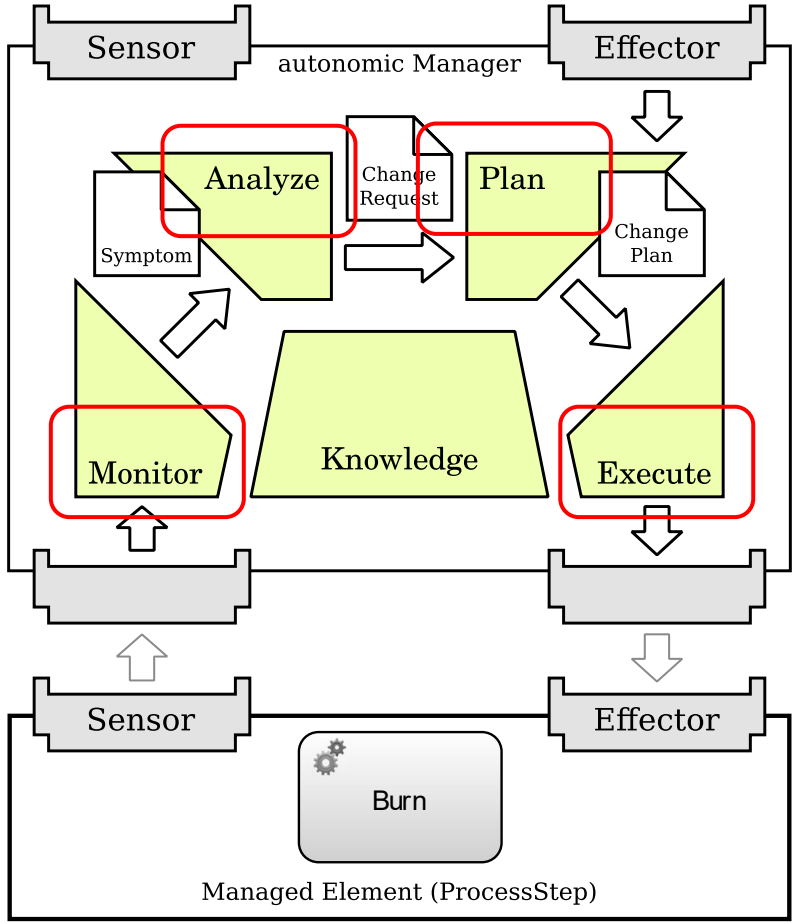
Now the Research

- **Error Handling & Autonomous Behavior**
- Monitor: Sensor Streaming
- Analyse: Complex Event Processing & Machine Learning
- Plan: Case-based Reasoning (Learn from the Past) & Automated (AI) Planning
- Execute: Adapt the Process
- Repeat



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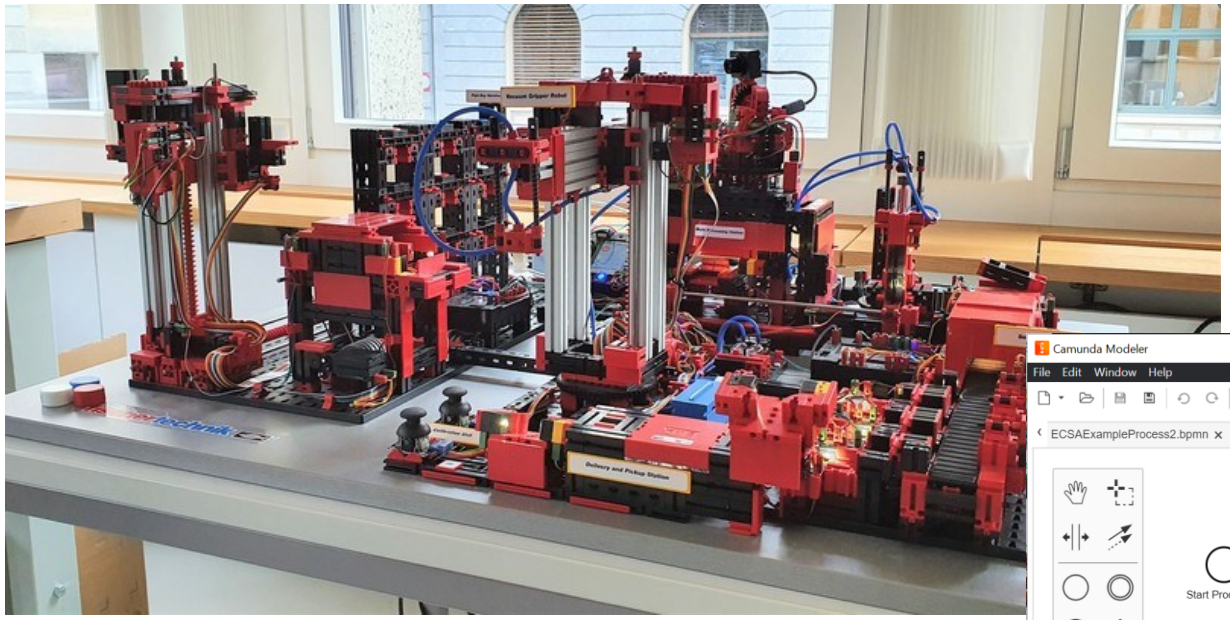
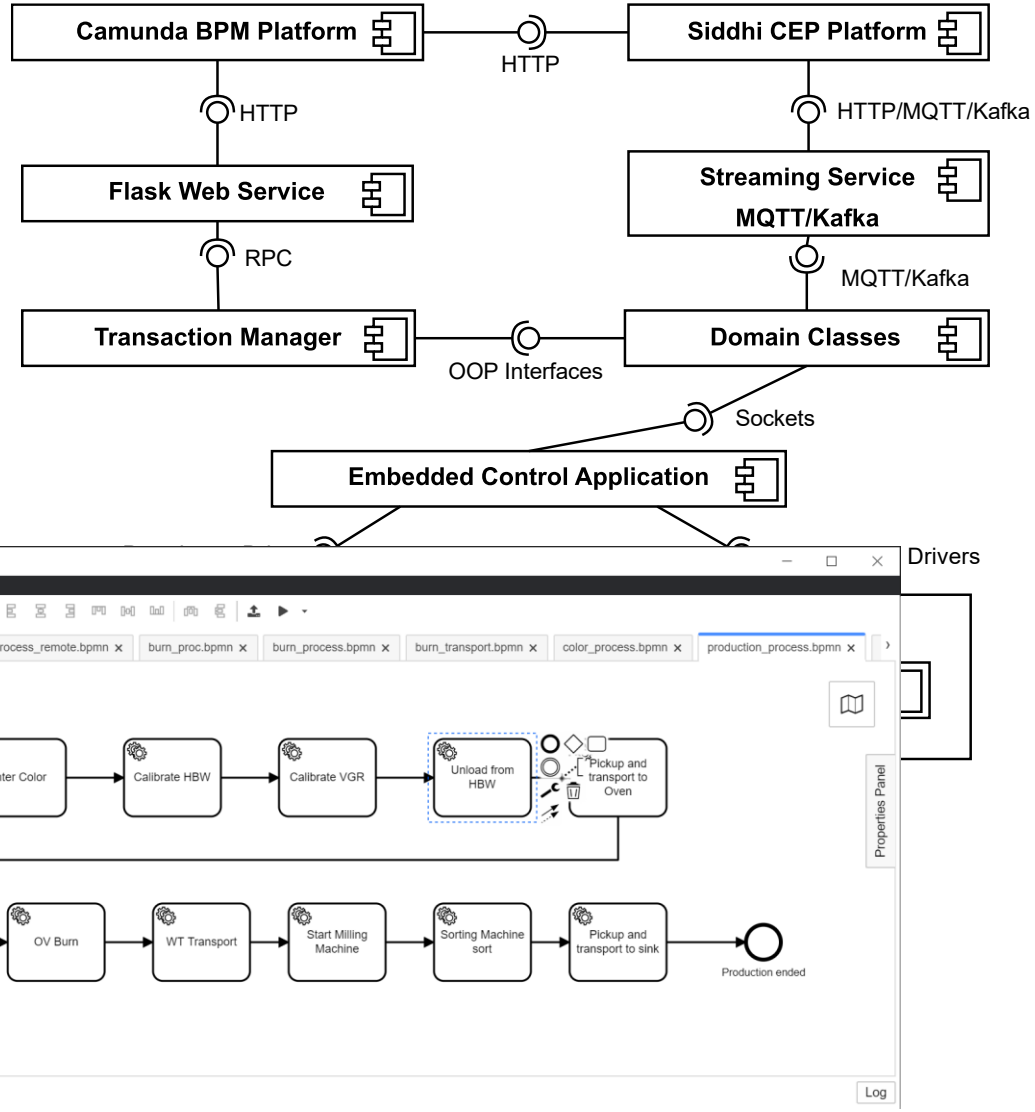
The Whole Picture





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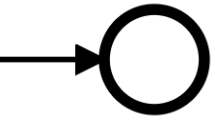

Presentation finished

Controlling a Smart Factory with Processes in Camunda

Get in Touch

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Questions?