Robot engineering with modular simulation

Autonomous robots, TME290

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Applied artificial intelligence
Vehicle engineering and autonomous systems
Mechanics and maritime sciences
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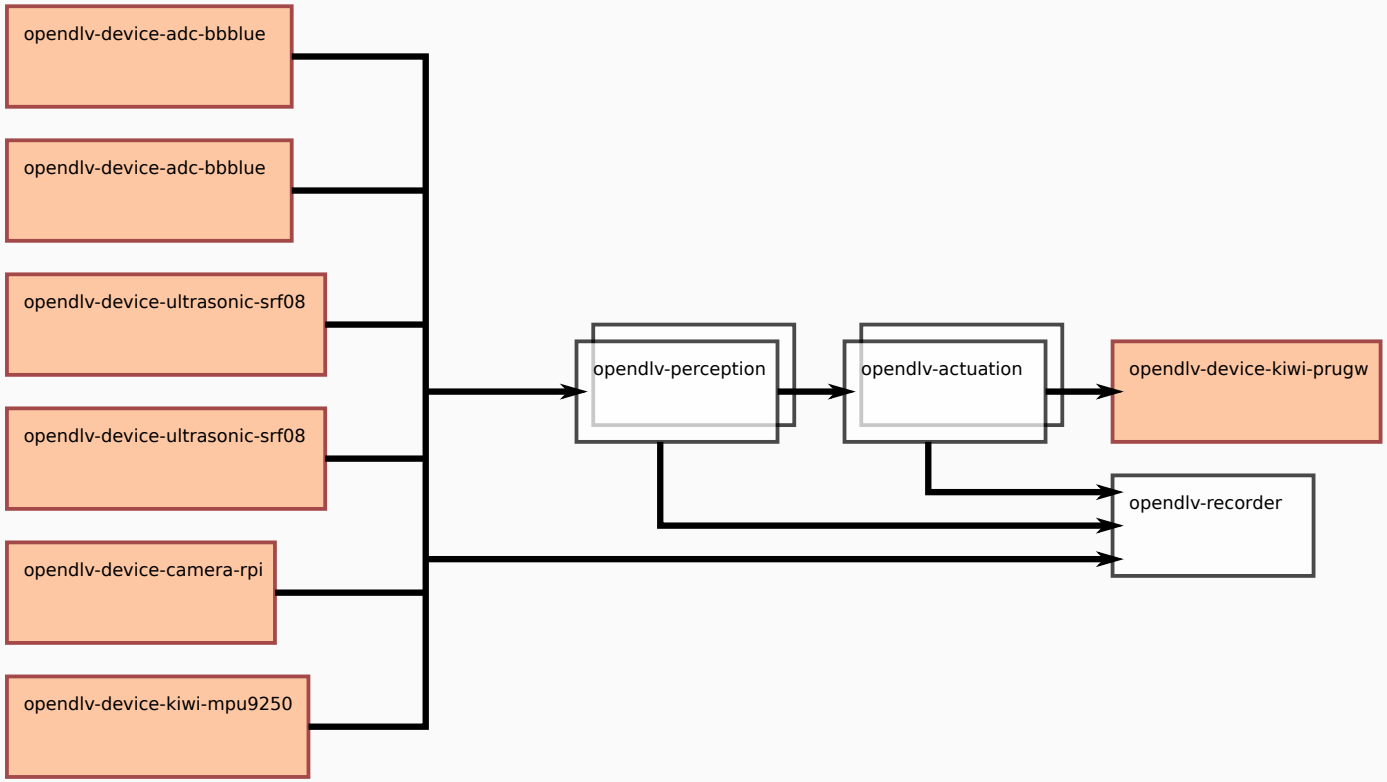
Course orientation

Learning outcomes, mapping of this lecture

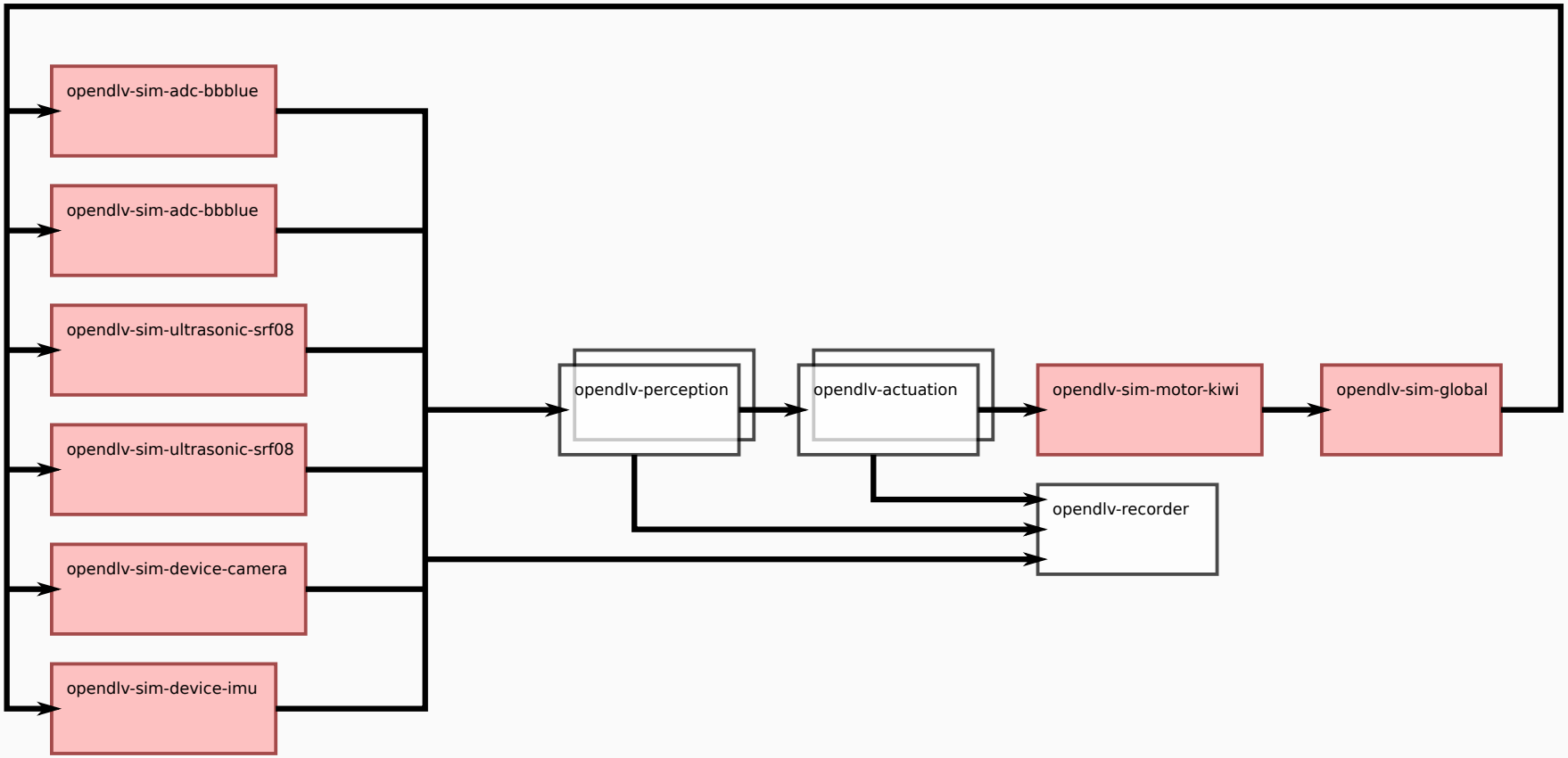
- Describe properties of common types of robotic hardware, including sensors, actuators, and computational nodes
- Apply modern software development and deployment strategies connected with autonomous robots
- Set up and use equations of motion of wheeled autonomous robots
- Apply basic sensor fusion
- **Set up and use computer simulations of autonomous robots**
- Apply global and local navigation of autonomous robots
- Apply the basics of behaviour-based robotics and evolutionary robotics
- Apply methods for decision making in autonomous robots
- Discuss the potential role of autonomous robots in society, including social, ethical, and legal aspects
- Discuss technical challenges with autonomous robots in society

Kiwi simulation

The Kiwi microservices



The Kiwi microservices, for simulation

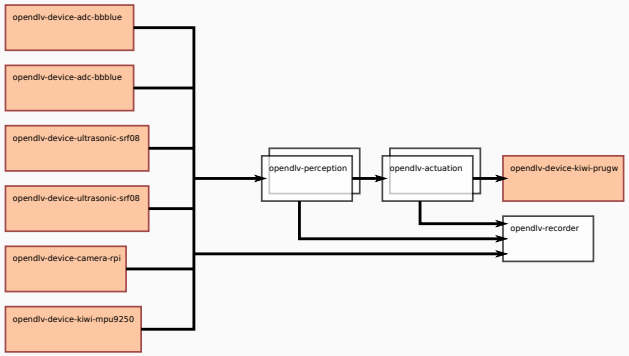


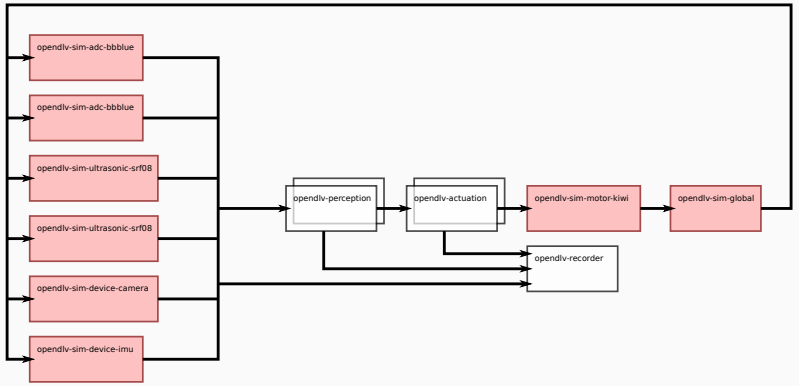
Simulation principle

Since a microservice does not know where the data comes from, it only care about type and content, then we can easily change microservices into simulated components (same principle as for replay).

- Even parts of the system can be simulated, alongside with physical parts

Messages, IR sensor (left and right)





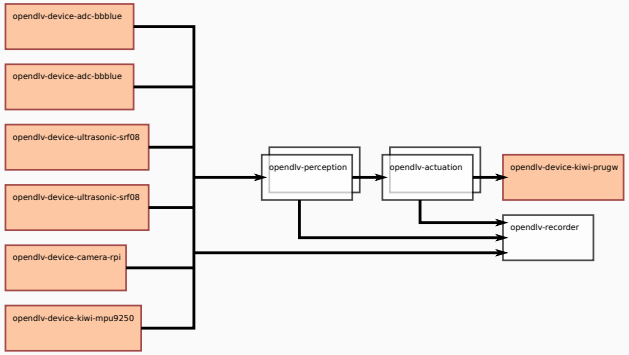
`opendlv-device-adc-bbblue`

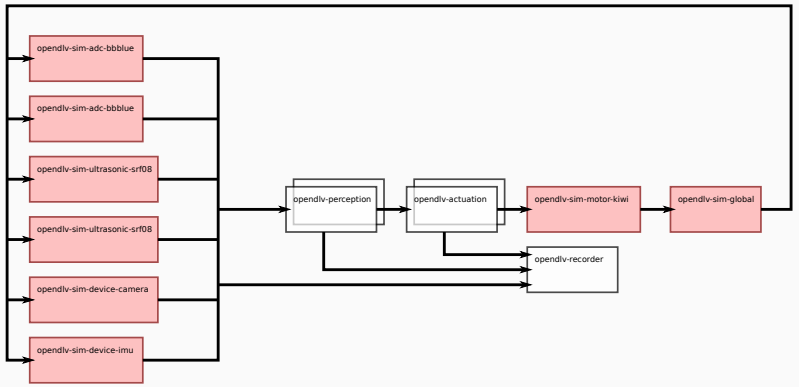
- Output: VoltageReading, DistanceReading
  (the message namespaces are omitted for readability)

`opendlv-sim-adc-bbblue`

- Input: Frame
- Output: VoltageReading, DistanceReading

Messages, ultransonic sensor (front and rear)





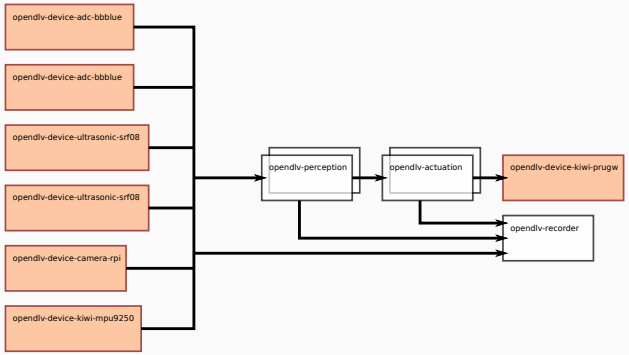
`opendlv-device-ultrasonic-srf08`

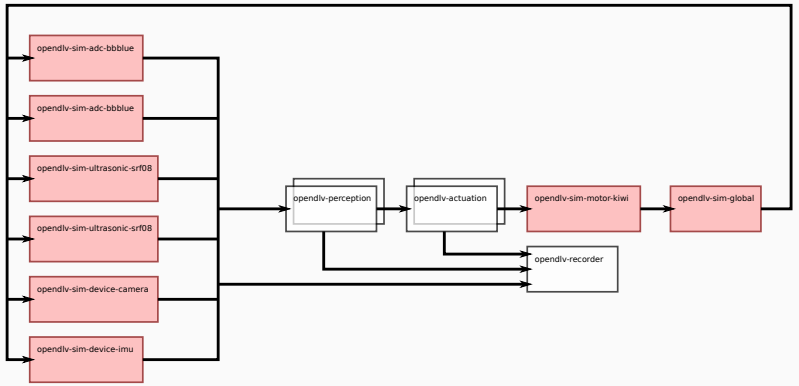
- Output: DistanceReading

`opendlv-sim-ultrasonic-srf08`

- Input: Frame
- Output: DistanceReading

Messages, camera





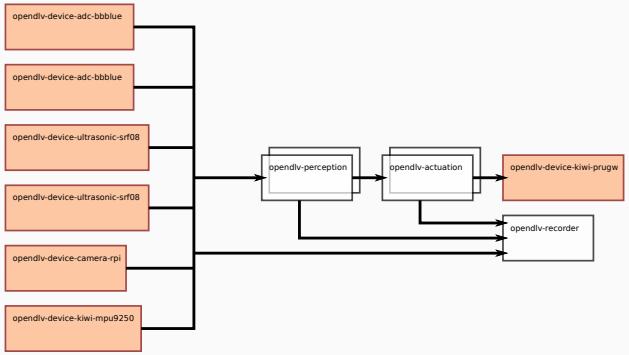
`opendlv-device-camera-rpi`

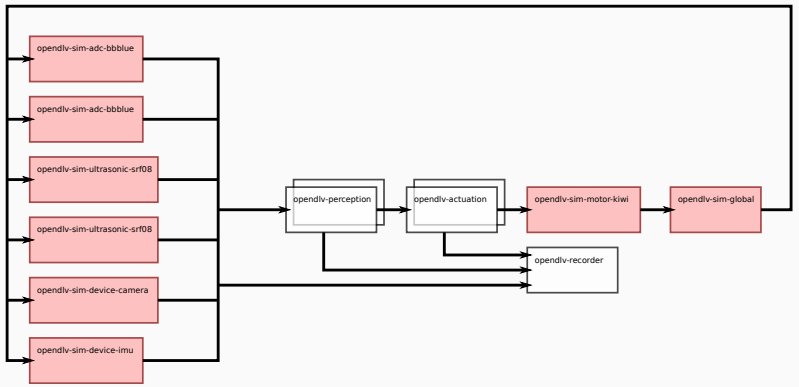
- Output (shared memory): ARGB and i420 image data

`opendlv-sim-device-camera`

- Input: Frame
- Output (shared memory): ARGB and i420 image data

Messages, IMU





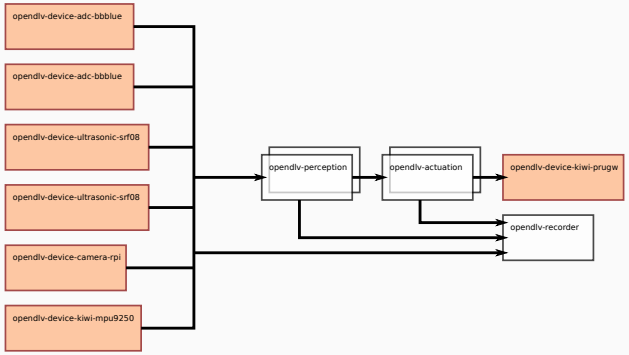
`opendlv-device-kiwi-mpu9250`

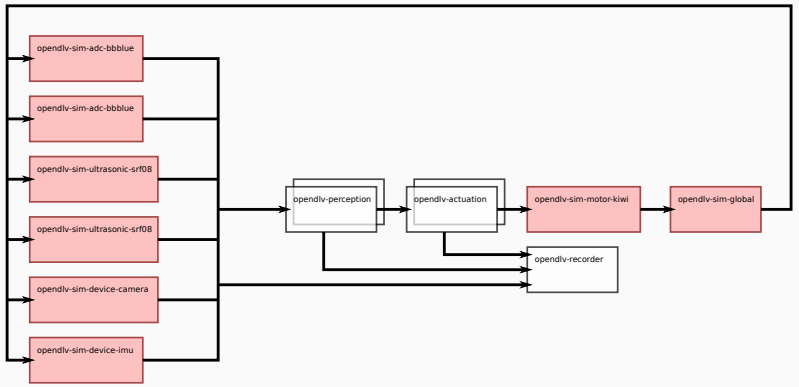
- Output: AccelerationReading, AngularVelocityReading, MagneticFieldReading, Orientation, GeodeticHeadingReading

`opendlv-sim-device-imu`

- Input: Frame, KinematicState
- Output: AccelerationReading, AngularVelocityReading, MagneticFieldReading, Orientation, GeodeticHeadingReading

Messages, motor controller





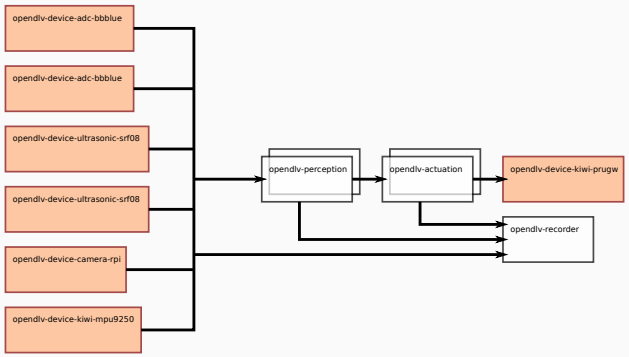
`opendlv-device-kiwi-prugw`

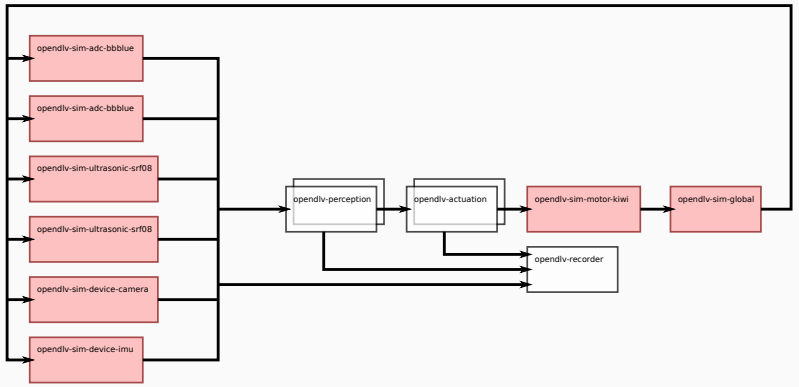
- Input: GroundSteeringRequest, PedalPositionRequest

`opendlv-sim-motor-kiwi`

- Input: GroundSteeringRequest, PedalPositionRequest
- Output: KinematicState

Messages, integrator (global coordinates)





`opendlv-sim-global`

- Input: KinematicState
- Output: Frame

How to use the simulation

On the Canvas page, we have uploaded the `simulate-kiwi.yml` and the `simulation-map.txt` files.

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An example without camera

This is simulation without the camera. This is relevant for the home assignments. For the project we would like to add camera, and that will be covered in the end of the lecture.

The `simulation-map.txt` is used for sensor simulation.

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Let's have a look inside:

```
-2.0,-2.0,-2.0,2.0;
-2.0,2.0,2.0,2.0;
2.0,2.0,2.0,-2.0;
2.0,-2.0,-2.0,-2.0;
```

Let's go through the `simulate-kiwi.yml` file (for docker-compose), part by part.

```
    sim-global:
        image: chalmersrevere/opendlv-sim-global-amd64:v0.0.5
        network_mode: "host"
        command: "/usr/bin/opendlv-sim-global␣--cid=111␣--freq=20␣--frame-id=0␣\
␣␣␣␣␣␣␣␣␣␣␣␣--x=0.0␣--y=0.0␣--yaw=0.2"
```

```
    sim-motor-kiwi:
        image: chalmersrevere/opendlv-sim-motor-kiwi-amd64:v0.0.6
        network_mode: "host"
        command: "/usr/bin/opendlv-sim-motor-kiwi␣--cid=111␣--freq=50␣--frame-id=0"
```

```
    sim-ultrasonic-srf08-front:
        image: chalmersrevere/opendlv-sim-ultrasonic-srf08-amd64:v0.0.4
        network_mode: "host"
        volumes:
          - ./simulation-map.txt:/opt/simulation-map.txt
        command: "/usr/bin/opendlv-sim-ultrasonic-srf08 \
␣␣␣␣␣␣␣␣␣␣␣␣␣--map-file=/opt/simulation-map.txt --x=0.2 --y=0.0 --yaw=0.0 \
␣␣␣␣␣␣␣␣␣␣␣␣␣--cid=111 --freq=10 --frame-id=0 --id=0"

    sim-ultrasonic-srf08-rear:
        image: chalmersrevere/opendlv-sim-ultrasonic-srf08-amd64:v0.0.4
        network_mode: "host"
        volumes:
          - ./simulation-map.txt:/opt/simulation-map.txt
        command: "/usr/bin/opendlv-sim-ultrasonic-srf08 \
␣␣␣␣␣␣␣␣␣␣␣␣␣--map-file=/opt/simulation-map.txt --x=0.2 --y=0.0 --yaw=3.14 \
␣␣␣␣␣␣␣␣␣␣␣␣␣--cid=111 --freq=10 --frame-id=0 --id=1"
```

```
    sim-adc-bbblue-left:
        image: chalmersrevere/opendlv-sim-adc-bbblue-amd64:v0.0.5
        network_mode: "host"
        volumes:
          - ./simulation-map.txt:/opt/simulation-map.txt
        command: "/usr/bin/opendlv-sim-adc-bbblue␣--map-file=/opt/simulation-map.txt␣\
␣␣␣␣␣␣␣␣␣␣␣␣--x=0.0␣--y=0.1␣--yaw=1.57␣--cid=111␣--freq=10␣--frame-id=0␣--id=2"

    sim-adc-bbblue-right:
        image: chalmersrevere/opendlv-sim-adc-bbblue-amd64:v0.0.5
        network_mode: "host"
        volumes:
          - ./simulation-map.txt:/opt/simulation-map.txt
        command: "/usr/bin/opendlv-sim-adc-bbblue␣--map-file=/opt/simulation-map.txt␣\
␣␣␣␣␣␣␣␣␣␣␣␣--x=0.0␣--y=-0.1␣--yaw=-1.57␣--cid=111␣--freq=10␣--frame-id=0␣--id=3"
```

```
    logic-test-kiwi:
        image: chalmersrevere/opendlv-logic-test-kiwi-amd64:v0.0.6
        network_mode: "host"
        command: "/usr/bin/opendlv-logic-test-kiwi␣--cid=111␣--freq=10"
```

In the second home assignment you should use two of these microservices as a starting point.

- opendlv-logic-test-kiwi (LINK)
- opendlv-sim-motor-kiwi (LINK)

Let's take a look at the logic (LINK)

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- Study this on your own later, it is expected that you understand most parts of the code.

Now it's time to test the simulation.

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- Simply start the use case with '`docker-compose -f simulate-kiwi.yml up`'
- Make sure that the `simulation-map.txt` is in the same folder

Recording the results

Most often it is desired to record the results of the simulation. We have therefore prepared a second docker-compose file named `interface-kiwi.yml` with a user interface.

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- Simply start the use case with '`docker-compose -f interface-kiwi.yml up`'
- To access the interface, point your browser to http://localhost:8081
- To record: Start the interface, start recording, in a second terminal start the simulation
- To analyse the data: Export as CSV (for example the opendlv::sim::Frame for position)

To modify a microservice, do the following:

- Download the source code, for example from HERE
- Make changes
- Recompile with, for example:
  `docker build -f Dockerfile.amd64 -t chalmersrevere/opendlv-logic-test-kiwi-amd64:v0.0.6 .`
- Restart the docker-compose. Your local version will replace the online one.

How about camera simulation?

We can easily add camera simulation as well, as there is a similar microservice for a simulated camera. For this part we can follow the same tutorial as in the last lecture.

- `https://github.com/chalmers-revere/opendlv-tutorial-kiwi`
- This lecture targets parts 3.1 and 3.2

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Note

Camera simulation uses 3D rendering to create the camera images. Preferably a GPU should be used to speed up this process, but VirtualBox does sadly only allow us to use rendering on a CPU (software rendering). It will be rather slow in VirtualBox!