TECHNISCHE UNIVERSITÄT DRESDEN

Endowed Chair of Construction Machines

OpenModelica Workshop 2018

Application of OpenModelica 1.12.0 for the Simulation of Mobile Machinery

Volker Waurich

Linköping, 05/02/2018

Outline

1. automation of a wheel loader
2. pile model
3. virtual sensors
4. operator control
5. wrap-up

AUTOMATION OF A WHEEL LOADER

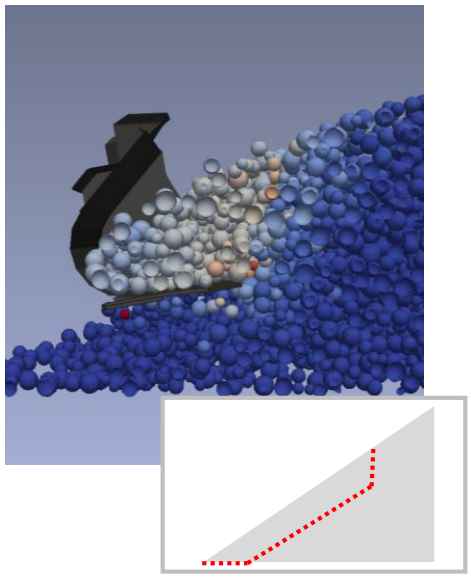
wheel loader operation

- effective earth-moving depends strongly on operator skill level
- potencial for energy saving, increase in productivity, cost reduction
- cutting and filling the bucket is crucial

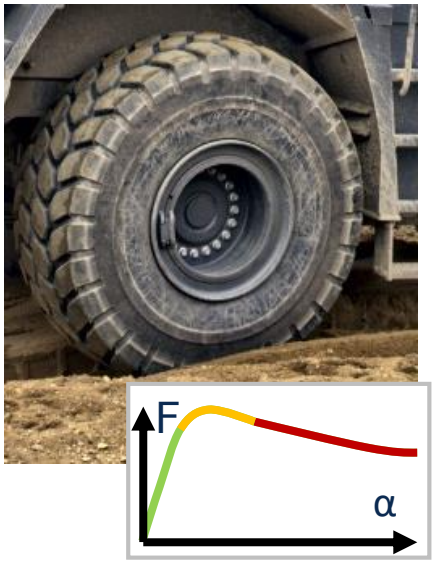
→ automation of a bucket filling process

considerations

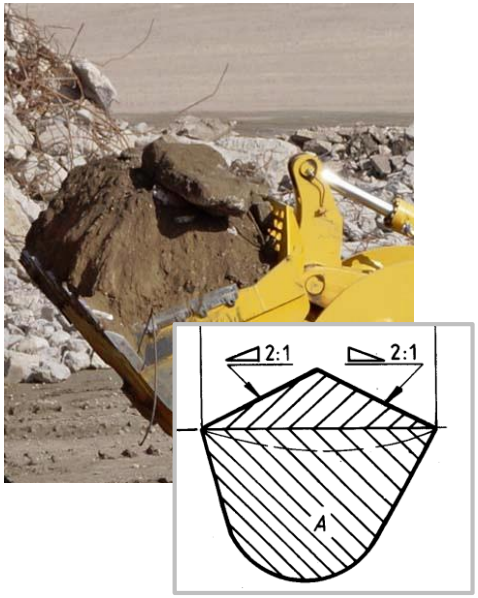
bucket trajectory



tire slip and wear

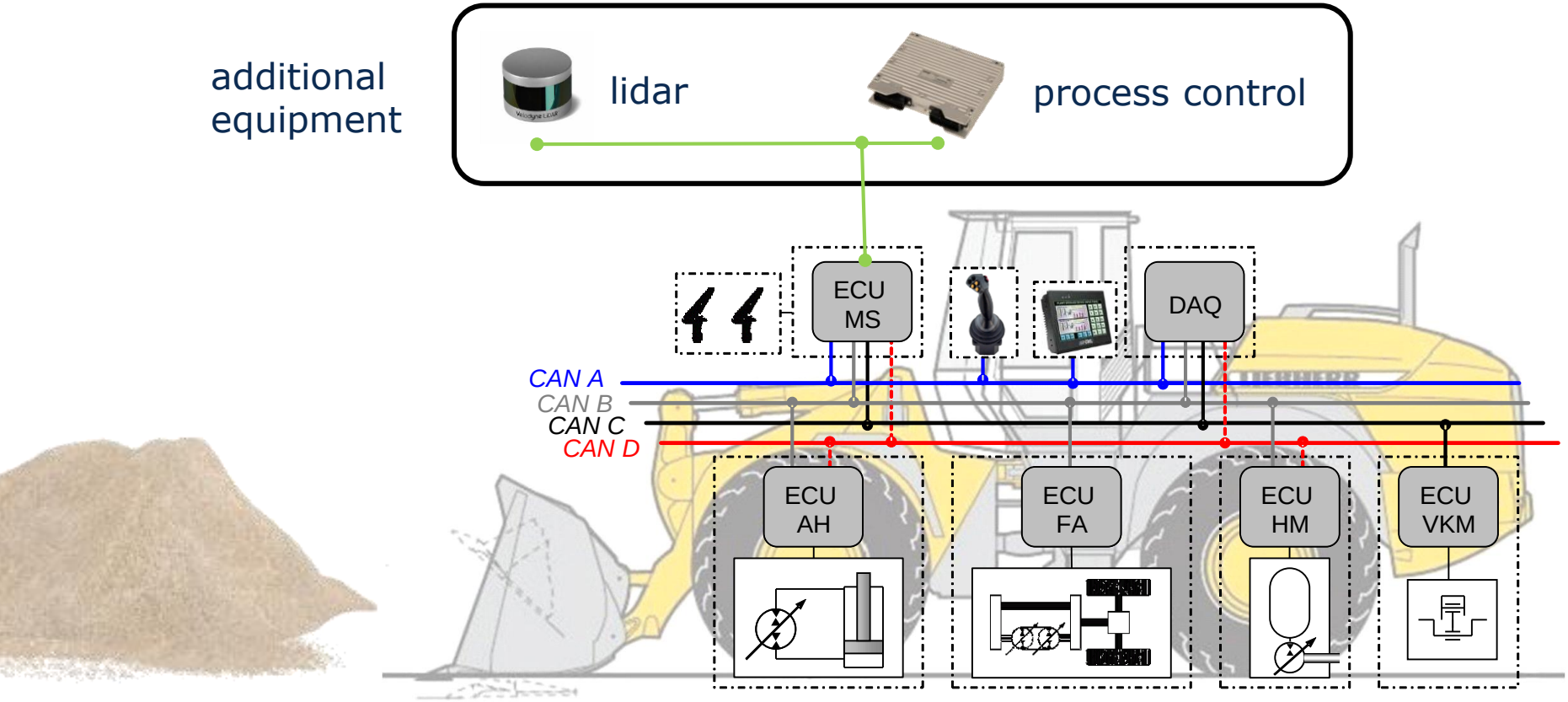


performance

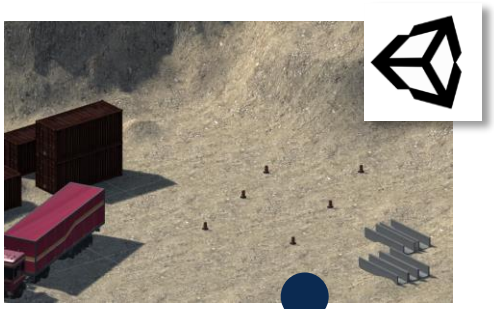


hardware setup

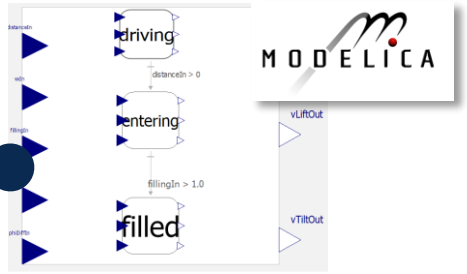
additional equipment



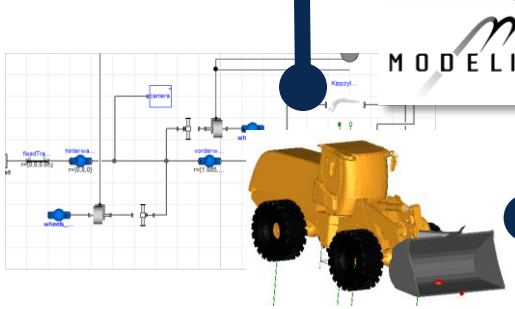
simulation setup



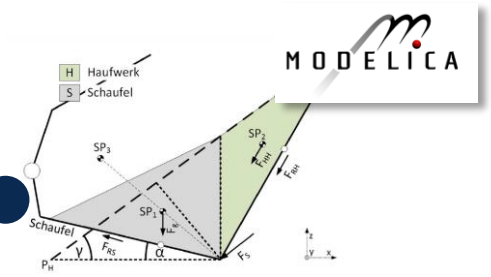
virtual 3D environment



process control



wheel loader mechanics and hydraulics

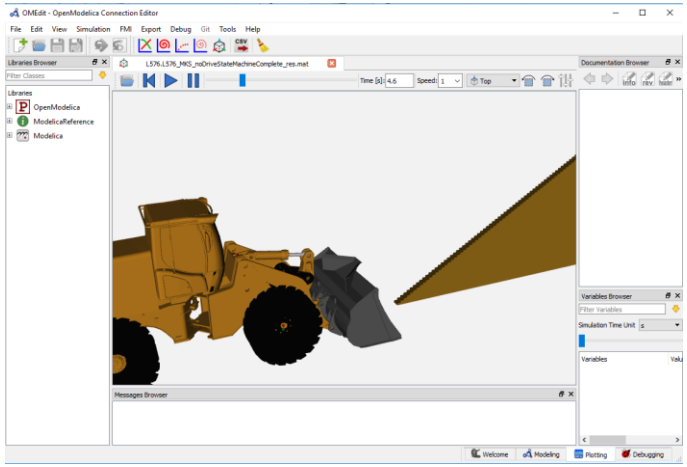


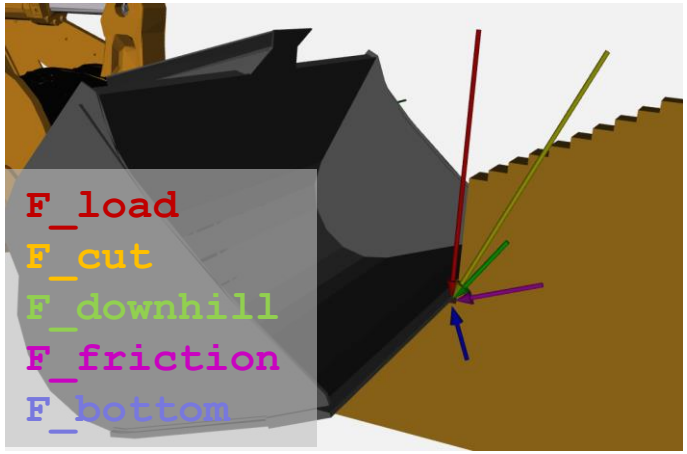
analytical pile model

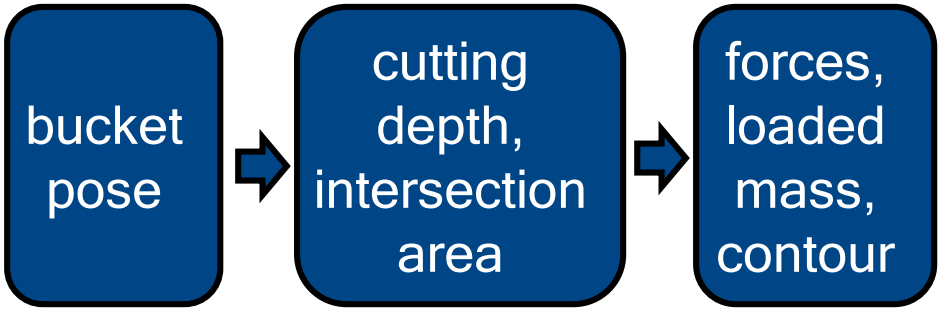
PILE MODEL

analytical pile model

- 2D-model in the centre plane of bucket
- analytical computation of component forces
- F_cut = f(cutting depth);

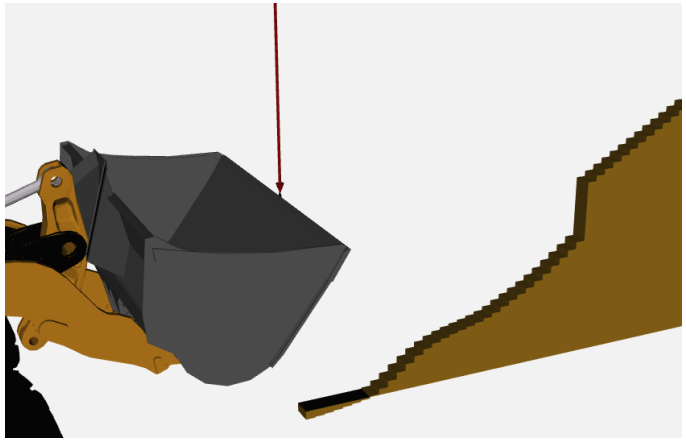






persistent contour

- pile surface must be persistent between loading cycles
- segmentation of surface
- enter segment: compute cutting depth
- leave segment: move contour, add load



```
pileHeight[i] := min(pileHeight[i],bucket.z);
```

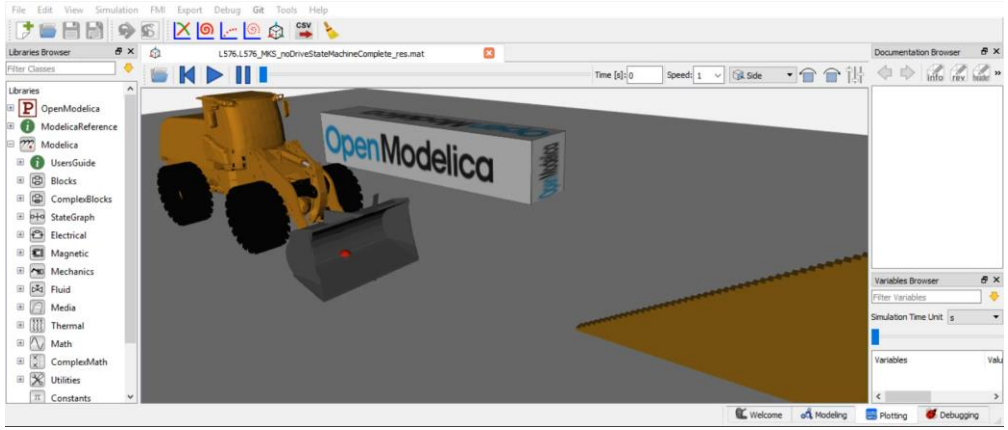
➡ not in continuous models (online minimum problem)

persistent contour

- discrete behaviour with sampled time or state events is not efficient
- realtime criteria

→ external C-model

```
intersec = getExtIntersection(pile, bucket.x, bucket.z, time);
```

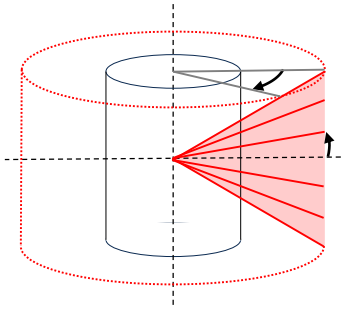


VIRTUAL SENSORS

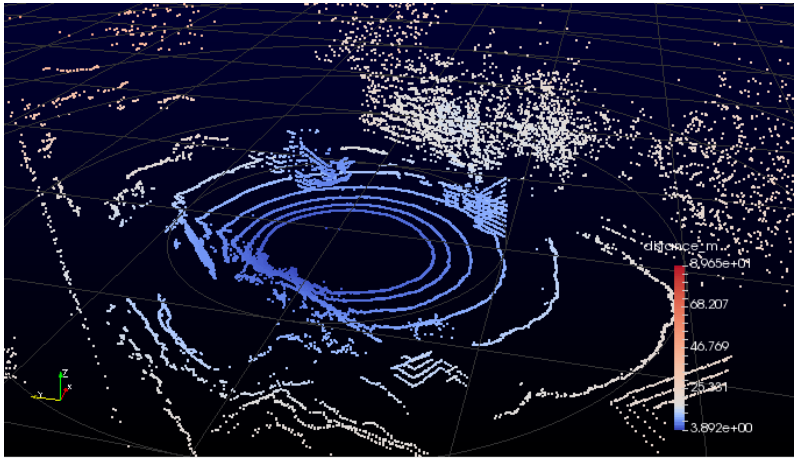
3D-perception by distance measurement

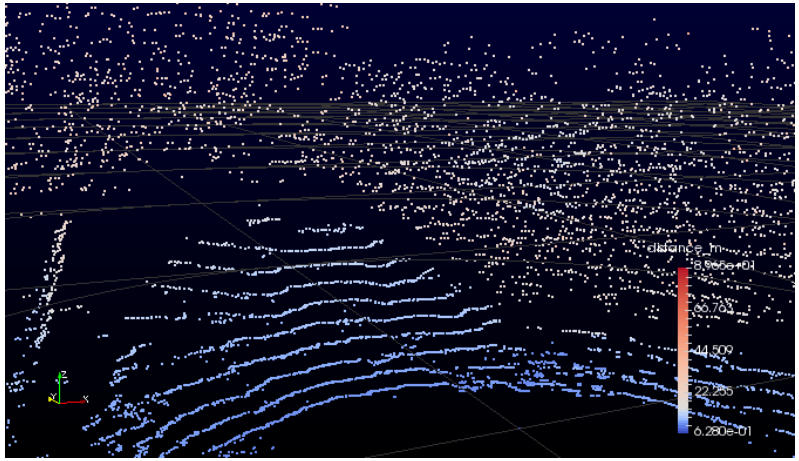
Lidar: TOF-measurements of laser beam

→ detection of angle of repose and distance to pile



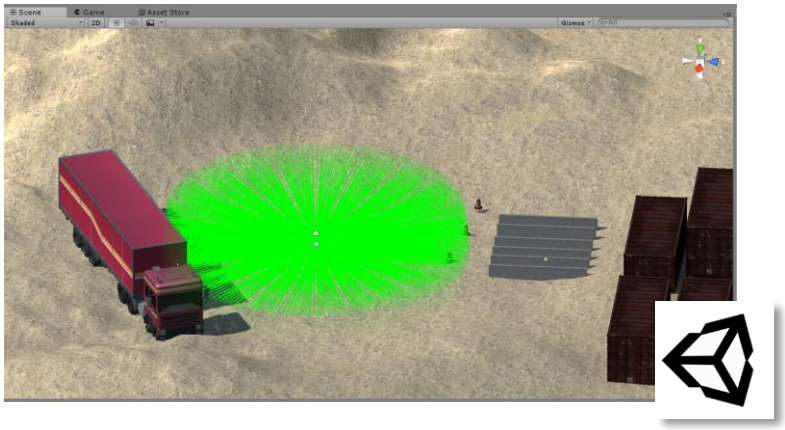
Velodyne VLP-16

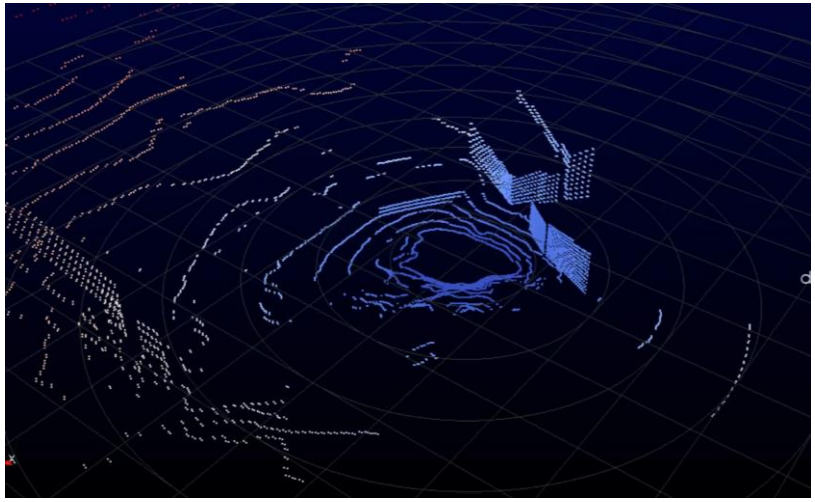




3D-lidar in unity

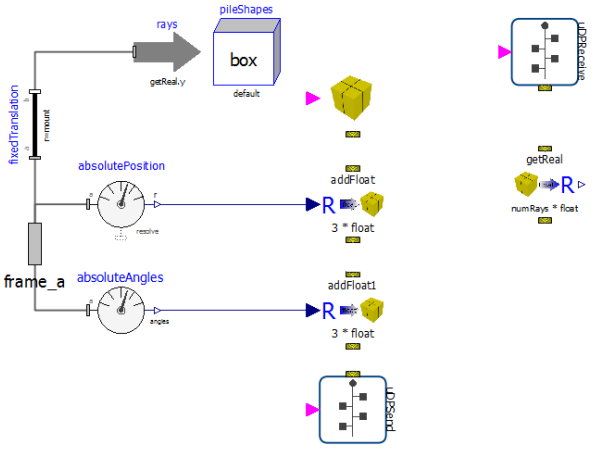
- comprehensive 3D world in *unity*
- virtual lidar using `raycast()` - bunch
- Velodyne VLP16 style UDP package

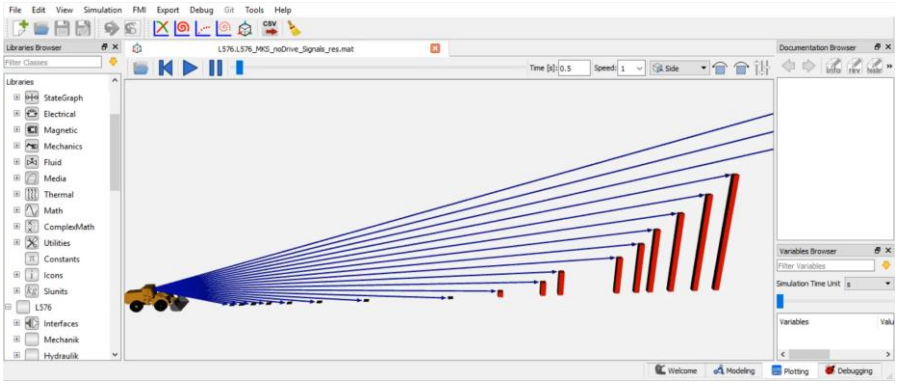




3D-environments in Modelica?

- coupling of *unity* with Modelica model
- model sends pose of sensor mounting
- sensor pose moves lidar gameObject
- lidar gameObject sends distance data

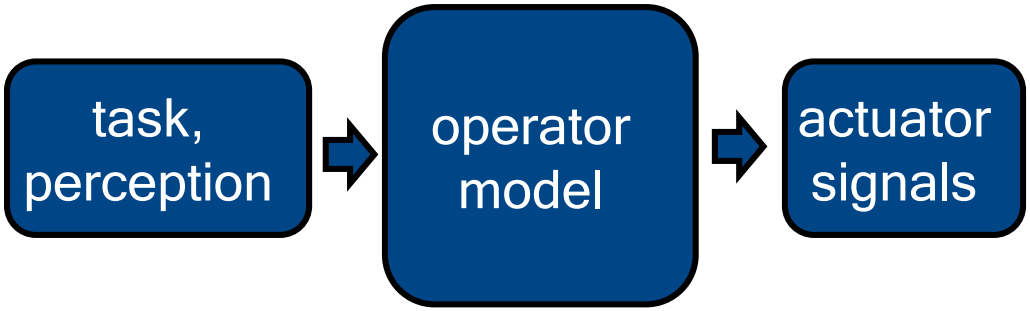




OPERATOR CONTROL

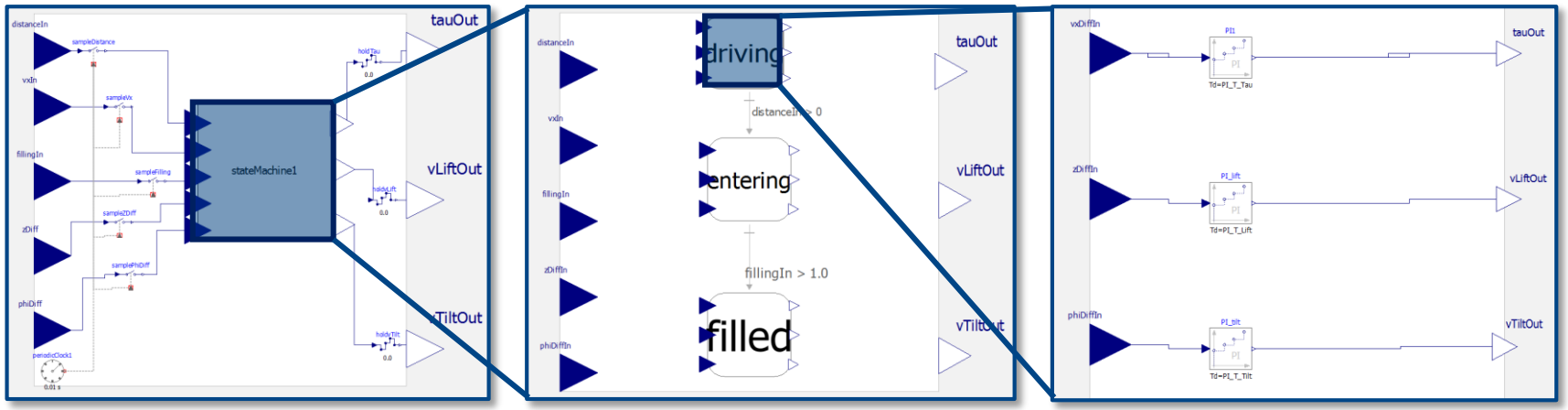
operator model

- to accomplish driving tasks, working cycles
- emulate real operator
- algorithm for automated functions



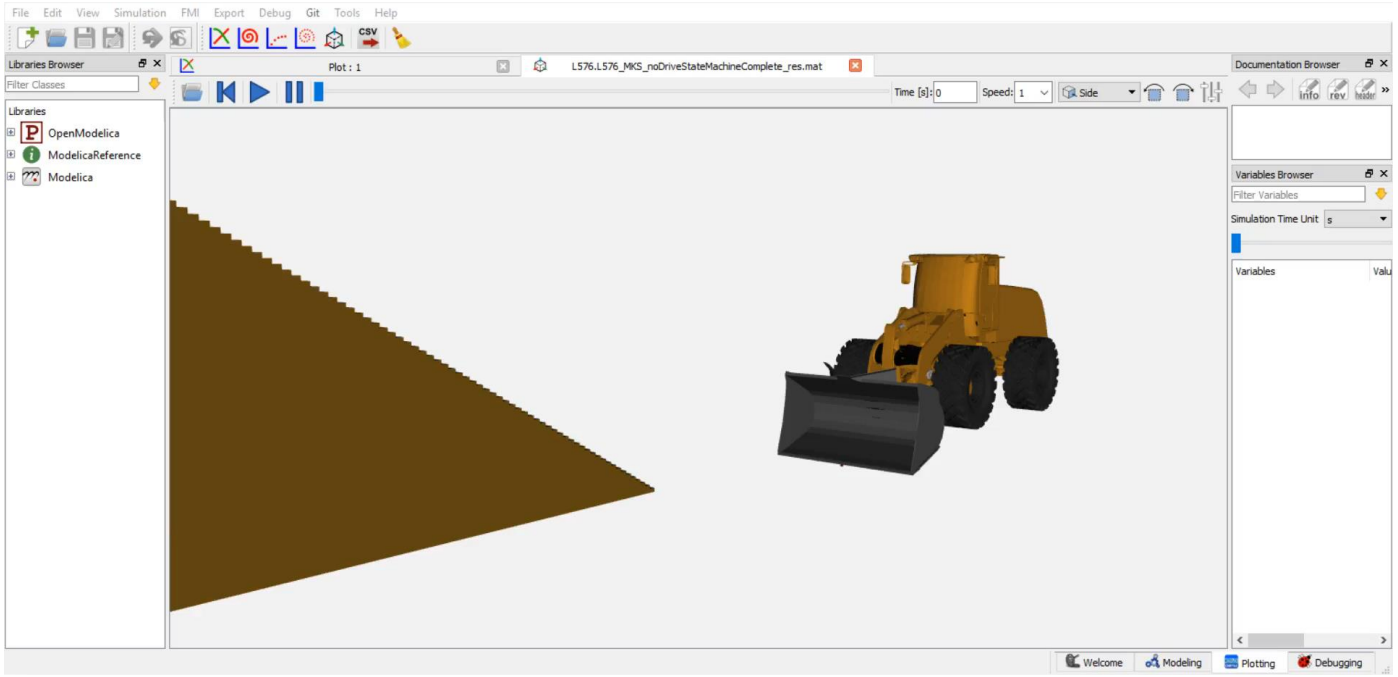
operator model

- modelling approach: discrete state machine



operator control

- target speed of cylinders , target wheel drive



WRAP-UP

summary

- OpenModelica is feasible to model mobile machinery (i.e. 3D mechanics, hydraulics, control)
- Modelica lacks comprehensive 3D-modelling and interaction
- tool-coupling to 3D-simulation software is a straightforward possibility to interact with 3D-worlds

OpenModelica achievements

- improvements with external C (Windows)

→ enhance system simulations with hardware, networks and virtual sensors

- important library improvements with OM 1.12.: OpenHydraulics and M_DD

→ hydraulic drive simulation and external tool coupling

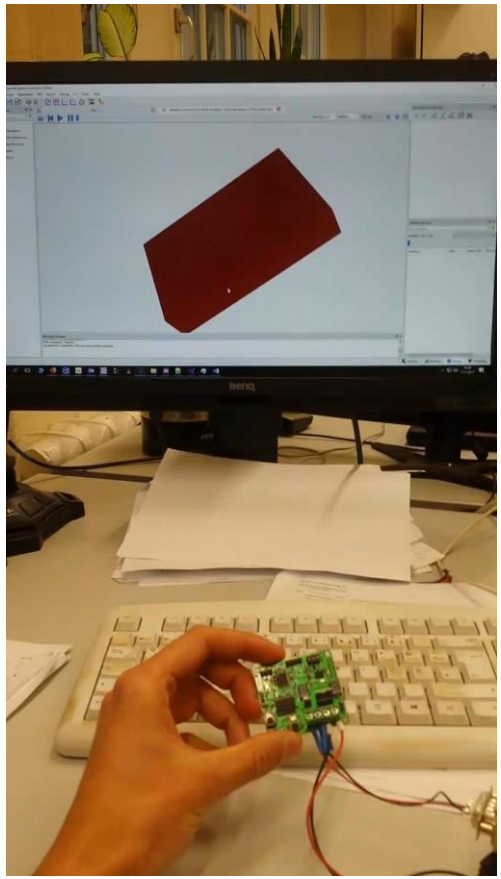
- synchronous and state-machines

→ operator control and process logic modelling

- 3D visualization

outlook

- better 3D modelling in OM (live 3D models?)
- closer interaction with 3D-tools
  - wheel-ground models
  - multiple, persistent soil interaction
  - collision detection
- hardware-in-the-loop (realtime!)
  - ECU-coupling
  - HMI-App design
  - IoT interfaces (MQTT)



IMU via CAN in OMEdit

Thank you for your attention.

Thank you OM-developers for your support.

Volker Waurich
volker.waurich@tu-dresden.de