Application of OpenModelica 1.12.0 for the Simulation of Mobile Machinery

Volker Waurich

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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
- potential 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
automation of a wheel loader

hardware setup

additional equipment

lidar

process control
simulation setup

virtual 3D environment

wheel loader mechanics and hydraulics

process control

analytical pile model
PILE MODEL
analytical pile model

- 2D-model in the centre plane of bucket
- analytical computation of component forces
- $F_{\text{cut}} = f(\text{cutting depth})$;
persistent contour

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

\[
pileHeight[i] := \min(pileHeight[i], \text{bucket.z});
\]

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

```c
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
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 control

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