The Future Worksite Demonstrator: a hardware infrastructure for testing automated earthmoving for planetary applications

Eric Halbach, Tomi Ylikorpi, Jussi Suomela, Jari Saarinen and Aarne Halme

Aalto University
School of Electrical Engineering

June 22, 2011

eric.halbach@aalto.fi

Authors

Eric Halbach

Tomi Ylikorpi

Jussi Suomela

Jari Saarinen

Aarne Halme

Earthmoving for Planetary Applications

- clearing / bulldozing / grading:
  - landing pads, roads, surface modules/infrastructure
- excavation / loading:
  - habitat foundations, obtaining regolith for ISRU
- filling / earthworks:
  - blast berms, burying structures for shielding

>> *Safety of human operators increased by using robotic machinery*

Control of Robotic Earthmoving Machines

- Direct Teleoperation
  - possible if humans located close enough
  - high workload
- Proximal Control
  - humans and machines working together on site
  - humans interact with/give directions to machines
- Supervisory Control
  - high-level plans specified by human
  - humans monitor work, no direct teleoperation
  - high degree of autonomy required

Future Worksite Concept

- Distributed multi-entity system for construction
  - humans and field robots working together
  - various control methods used together seamlessly
  - one operator typically controlling several machines
  - extend industrial state-of-the-art
    - limit/avoid direct teleoperation
    - supervisory control
    - working in unstructured environments

GIM Research Group

Generic Intelligent Machines (GIM) Research

- Tampere University of Technology, Department of Intelligent Hydraulics and Automation, Finland

- Aalto University, Department of Automation and Systems Technology, Espoo, Finland

Future Worksite Demonstrator

- Machines
- Test Facilities
- Simulators
- Software Infrastructure
- Perception
- Control Techniques

Machines

- Avant Tecno compact hydraulic loaders (http://www.avanttecno.com)

300 series – skid-steered

600 series – articulated steering

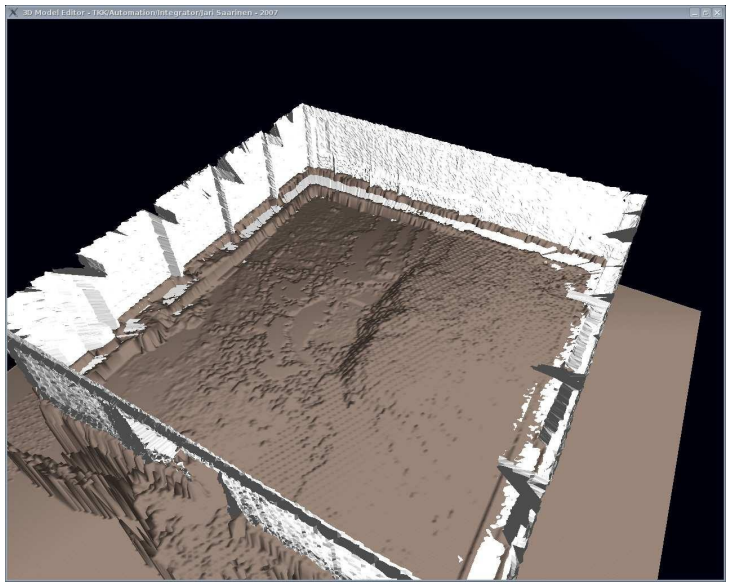
Machines

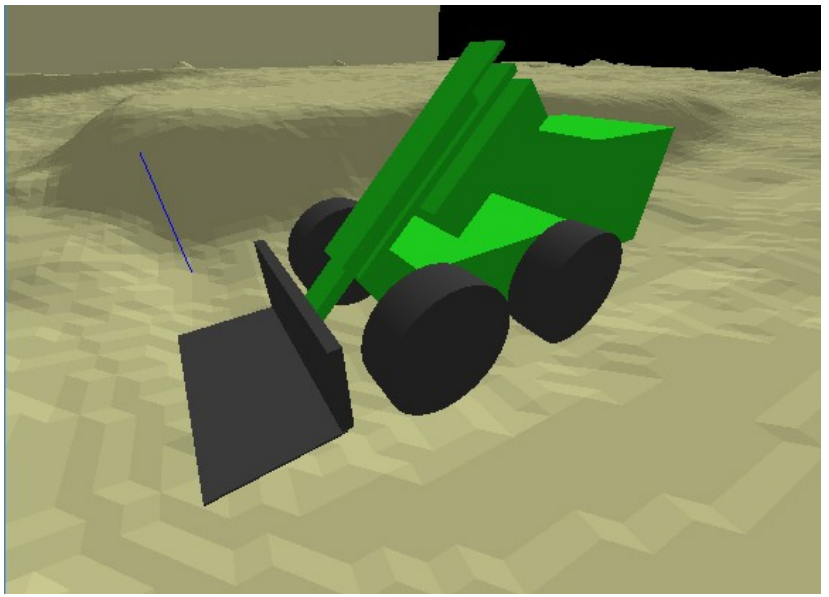
- Attachments
  - front scoop
  - excavator arm
- Computer-controlled

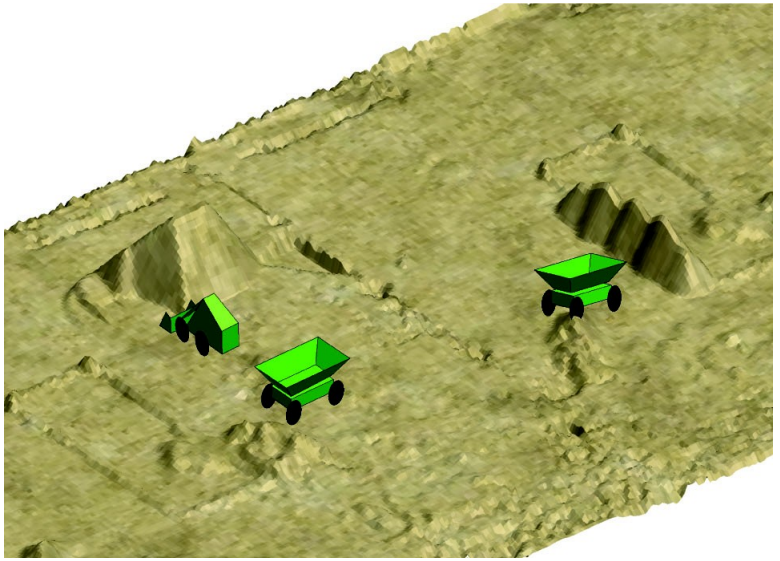
Tampere Test Hall

- covered outdoor hall
- 20m x 20m area
- gravel/sand ground
- WiFi, overhead video cameras

Simulators

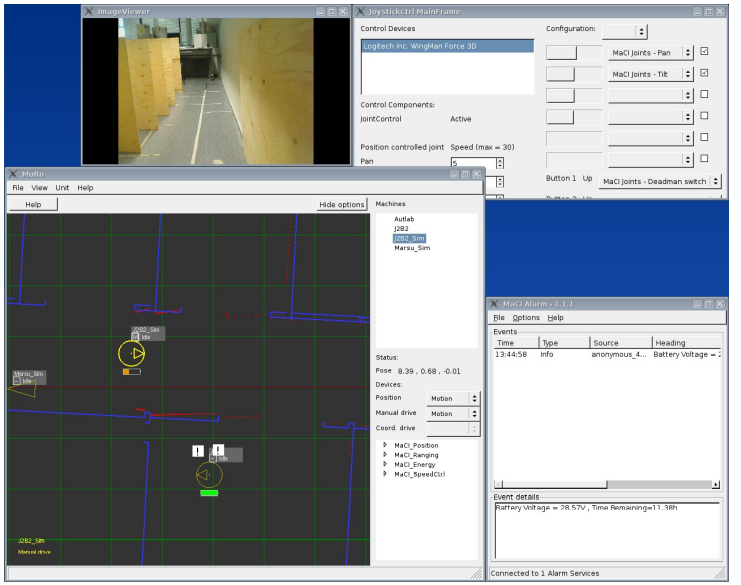






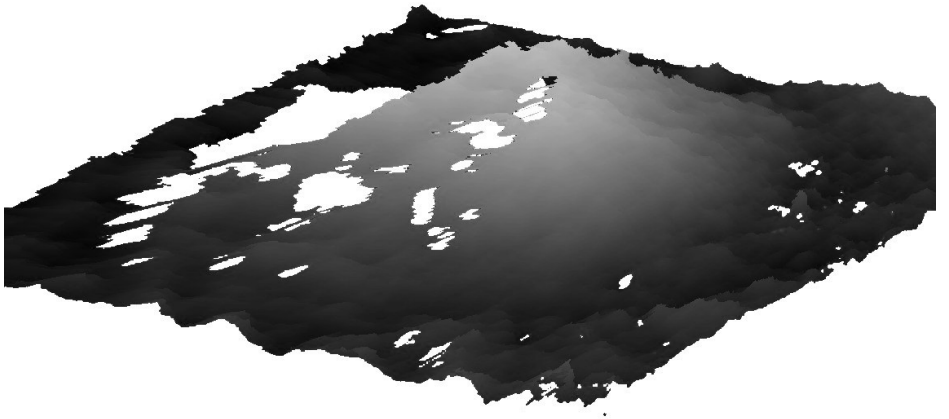
Software Infrastructure

- GIMnet (http://gim.tkk.fi/GIMnet)
  - enables Internet communication between entities regardless of network configurations (e.g. firewalls)
- Machine Control Interface (MaCI) (http://gim.tkk.fi/MaCI)
  - same interface for different types of machines (both simulated and real)



Perception

- stereo cameras
- 2D laser scanners
- 3D laser scanners



Teleoperation

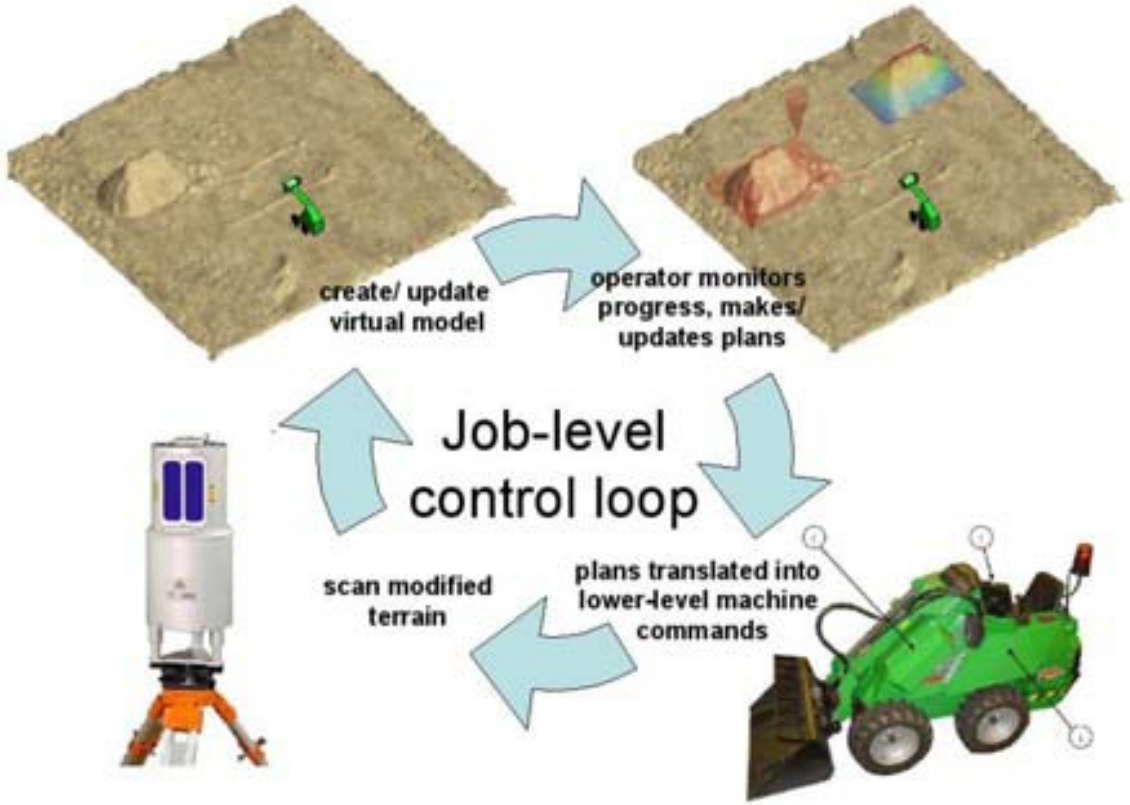
- Loaders controlled with camera feedback
- Control through the Internet from any PC running GIM software
- Driving and actuation control options:
  - keyboard, gaming steering wheel and pedals, joystick, gaming controller

Proximal Interaction

- Human located on site with machines
- Human gives instructions to machines
- Communication methods: gesture, voice, placing markers, portable computer

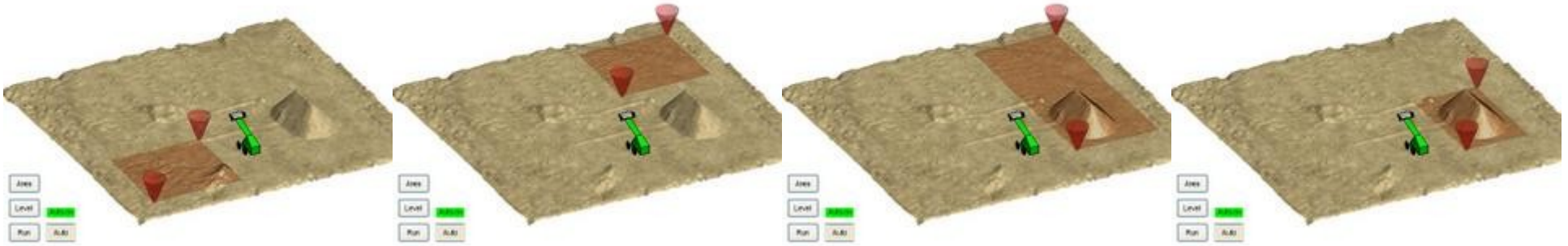
Supervisory Control

- based on “common model” of worksite
- high-level plans specified on model, current state is updated, plans changed if necessary

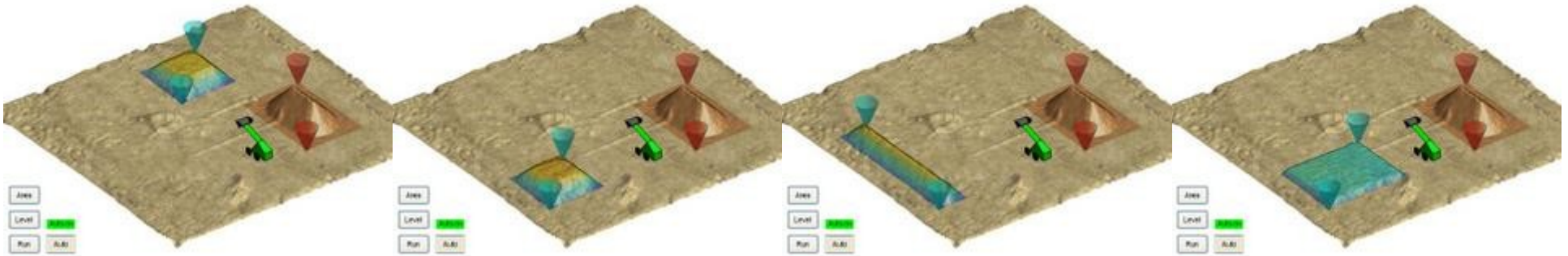


3D Graphical Job Planning

- Application: “Pile-transfer task”
  - Click and drag surface to specify source pile

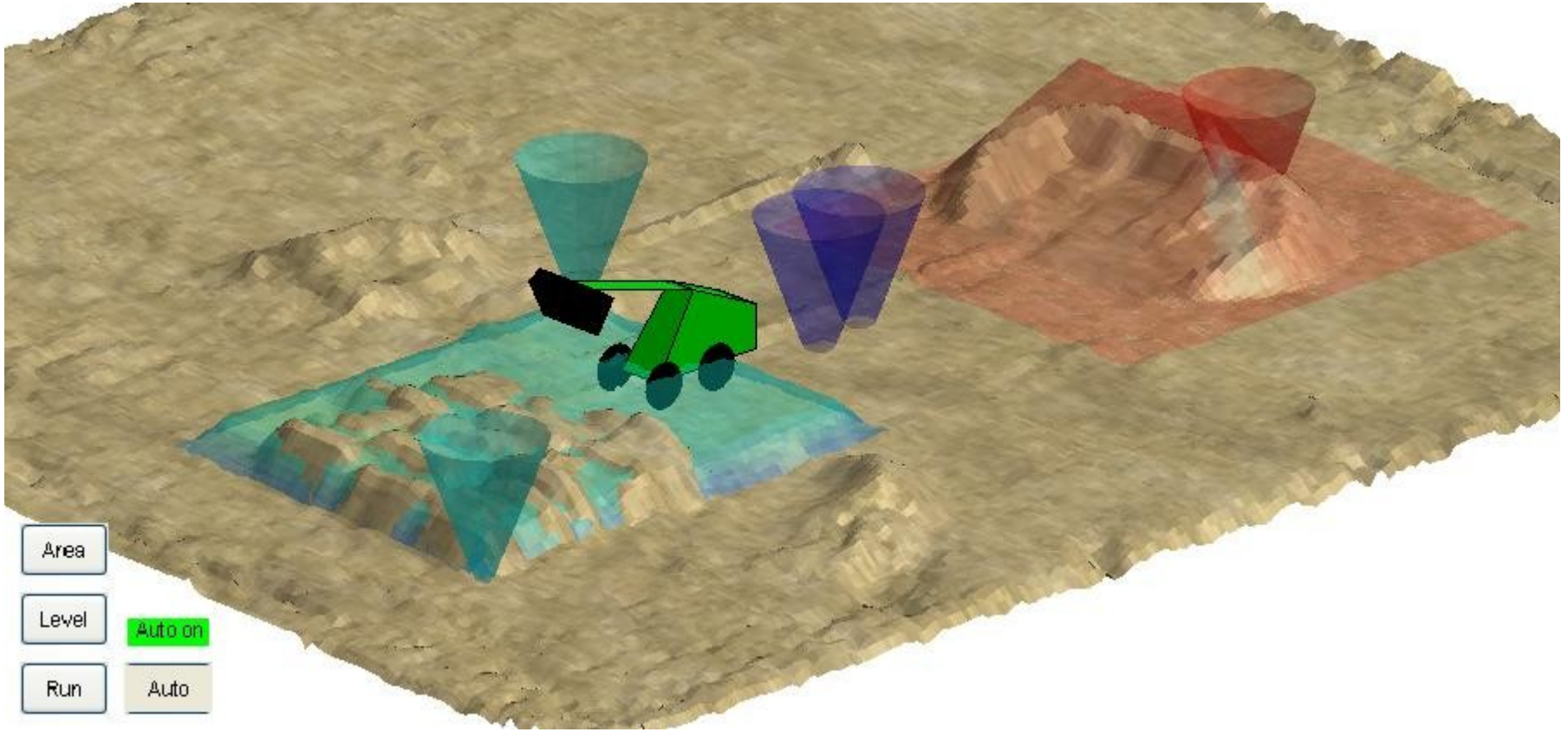


  - Click and drag virtual pile to specify dump pile

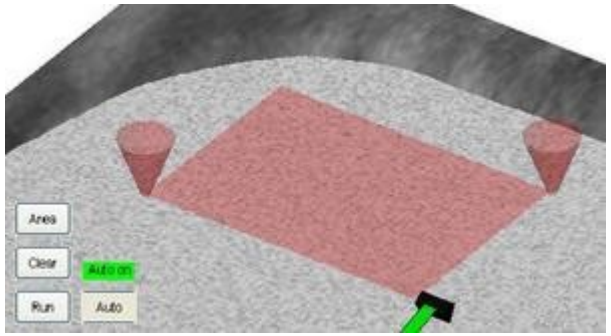


Pile-Transfer Simulation

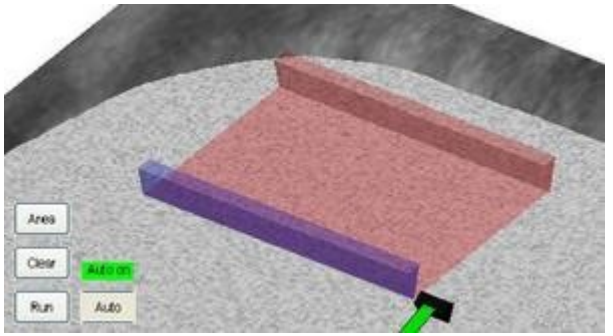
- Automated lower-level planning



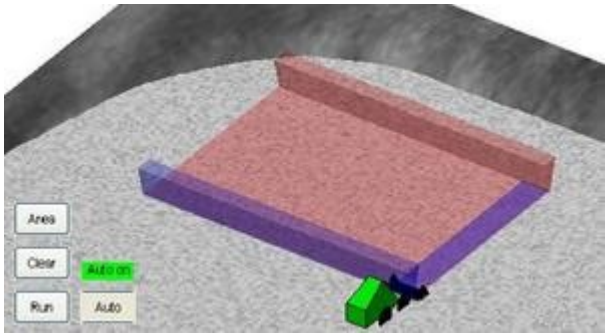
Bulldozing Simulation



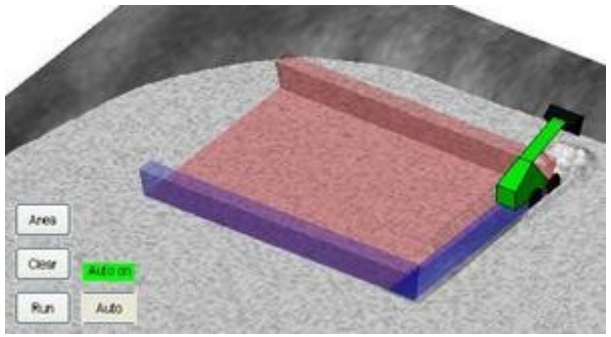
a) specify area

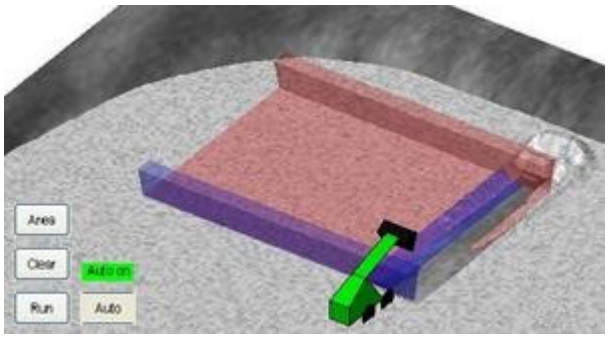


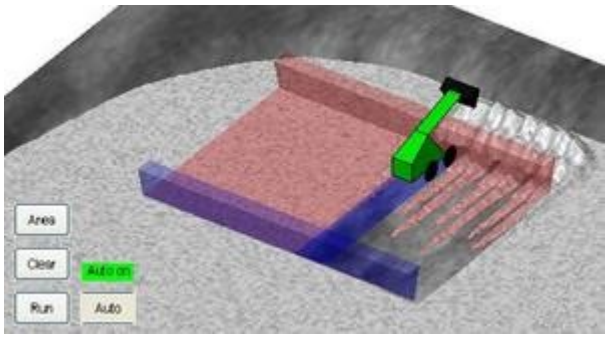
b) specify direction



c) find first path







d) clear from right to left...

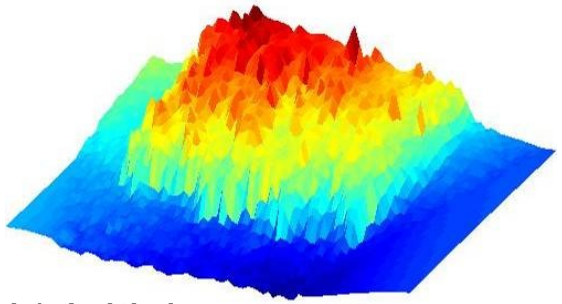
Outdoor Test

- Purpose: obtain real surface scan data from a bulldozing job to test graphical job control functions
- Hardware: Avant 320 compact wheel loader and Riegl 3D laser rangefinder

Outdoor Test

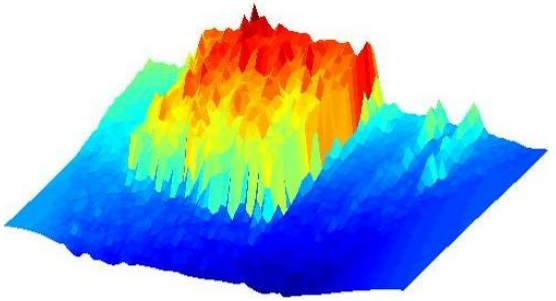
- Clear area from right to left, as in simulation
- Take new scan after each drive

a) Initial state



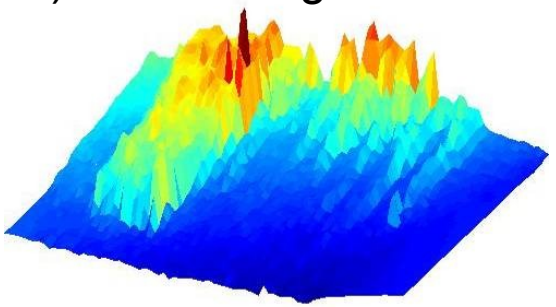
b) Initial scan

c) 2nd clearing drive



d) Scan after 2nd drive

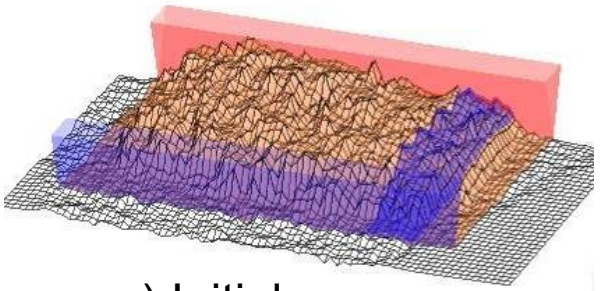
e) 5th clearing drive



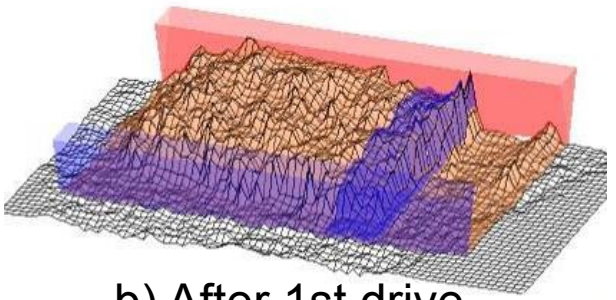
f) Scan after 5th drive

Outdoor Test

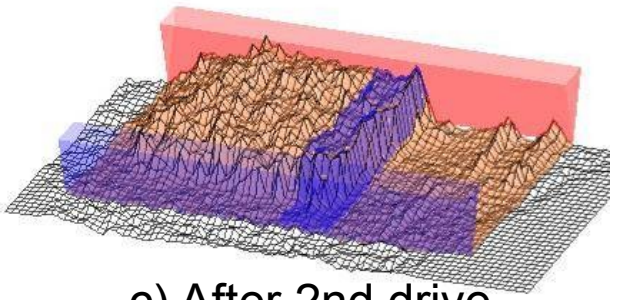
- Graphical tools with real scan data
- Automatically finds next path to clear



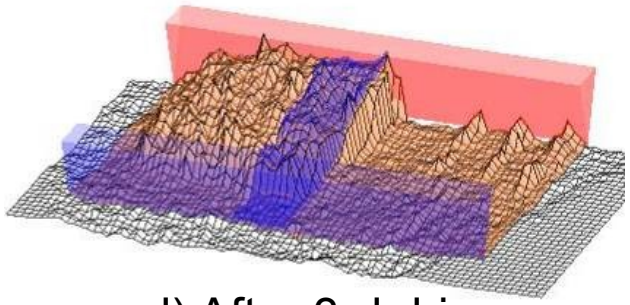
a) Initial scan



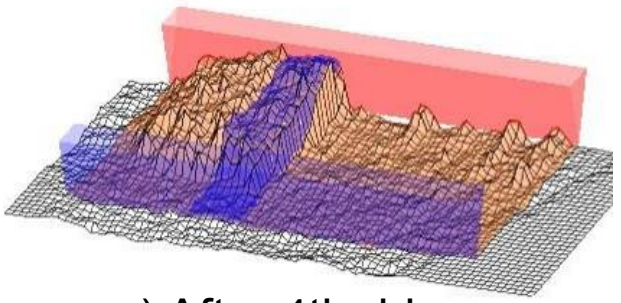
b) After 1st drive



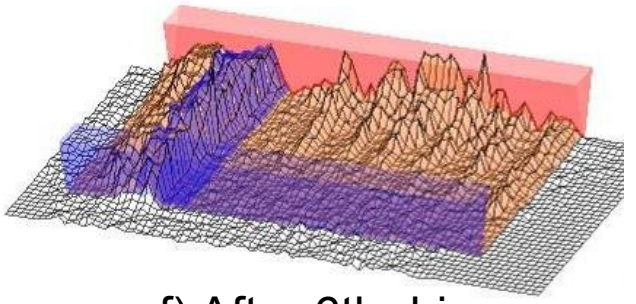
c) After 2nd drive



d) After 3rd drive



e) After 4th drive



f) After 6th drive

Conclusion

- Future Worksite Demonstrator offers platform for testing teleoperated and semi-autonomous earthmoving jobs
- Level of autonomy increasing
- Goal is high-level supervisory control with no direct teleoperation