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Teleoperated Hybrid Locomotion in Uneven Terrain

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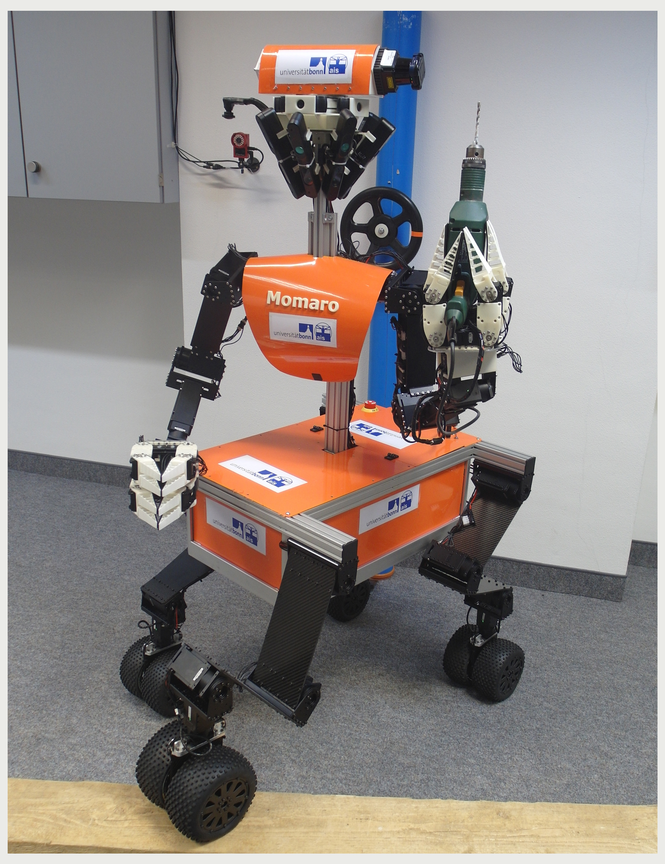
1. Mobile Manipulation Robot Momaro

- Developed for participation in the DARPA Robotics Challenge [1]
- Four legs ending in pairs of steerable wheels ⇒ capable of omnidirectional driving, adjustment to terrain and stepping
  - Three pitch joints in hip, knee and ankle
  - Yaw joint in the ankle
  - Robotis Dynamixel Pro actuators
  - Leg segments are carbon fiber springs



References

[1] K. Iagnemma and J. Overholt, eds. *Journal of Field Robotics* 32.2 (May 2015): *Special Issue: DARPA Robotics Challenge (DRC)*.

[2] D. Droeschel, J. Stückler, and S. Behnke. "Local multi-resolution representation for 6D motion estimation and mapping with a continuously rotating 3D laser scanner". In: *Robotics and Automation (ICRA), 2014 IEEE Int. Conf.* IEEE. 2014, pp. 5221–5226.

2. Perception

Aggregation of 3D laser scanner measurements into 2D heightmap via an egocentric multiresolutional surfel map [2].

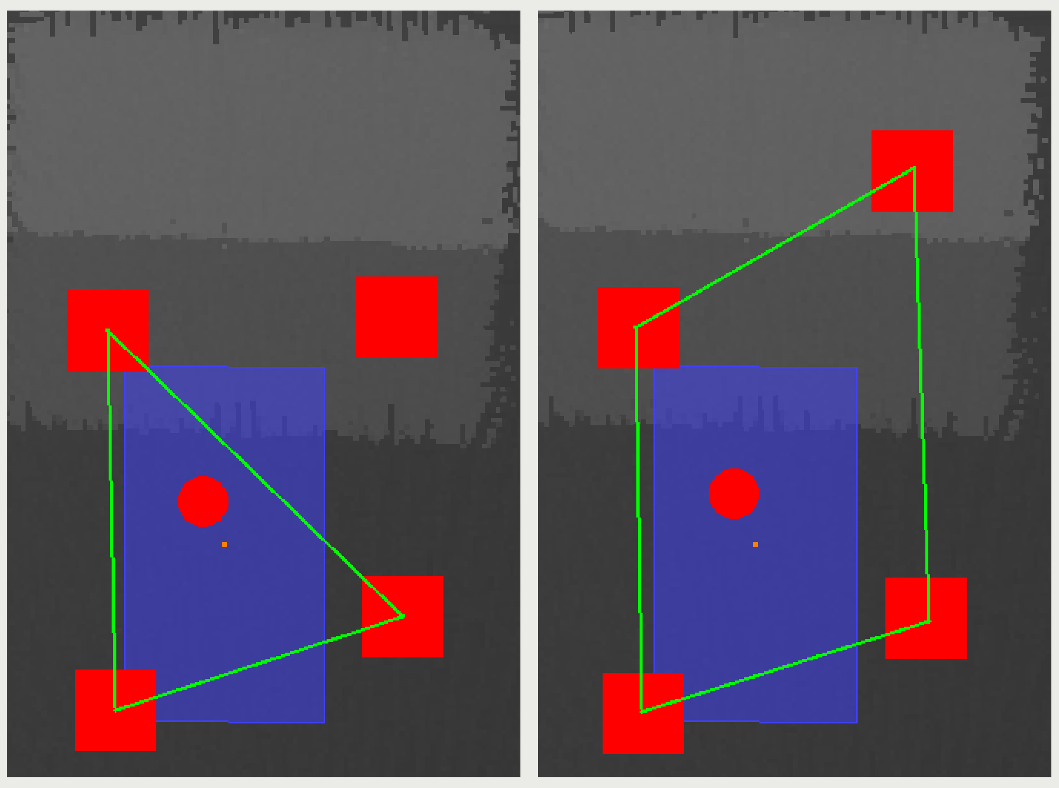


Figure 1: 2D height maps

3. Balance Control

Weight shifting to three legs is needed to ensure static balance during stepping. The system has three means to shift weight:

1. Moving the base relative to the wheels in sagittal direction,
2. Driving the wheels on the ground relative to the base (constrained by detected obstacles), and
3. Modifying the leg lengths (and thus the base orientation).

The autonomous balance control behavior uses options 2 and 3. If they do not suffice, the system waits for the operator to adjust the base position.

4. Teleoperation & Autonomy

- Base velocity is always controlled by the operator using a joystick.
- Weight shifting and step execution is performed autonomously, matching the commanded base velocity.
- Steps can be triggered manually or automatically. In automatic mode, the system determines the leg which needs stepping most urgently.
- Step motions are parametrized motion primitives in Cartesian space.
- As soon as the step is finished, the weight is shifted back.

5. Simulation Results

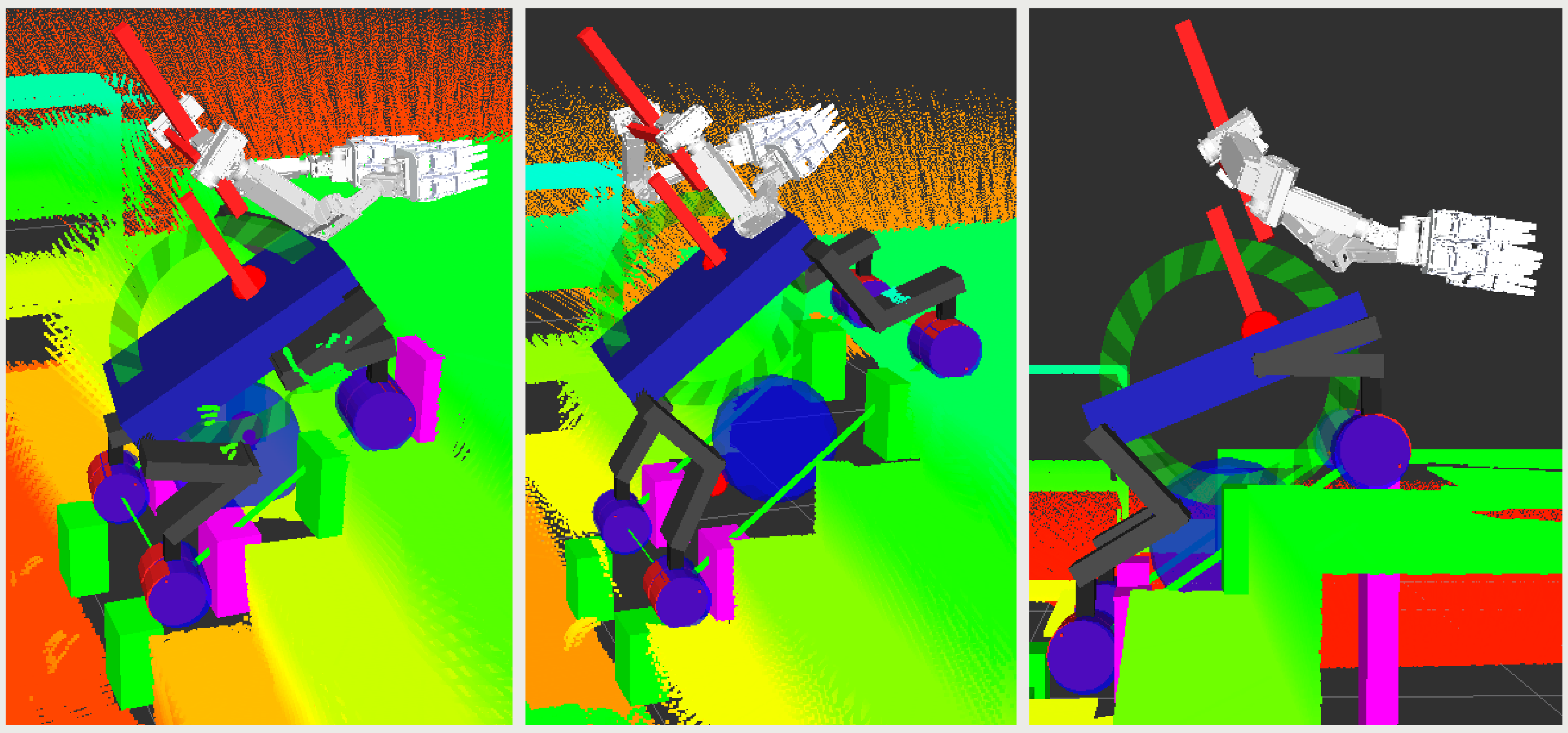


Figure 2: Stair climbing experiment in simulation. Detected steps constraining the leg motions are depicted as green and pink boxes.

- Initial development of step primitives and balance controller in the physics-based Gazebo simulation
- Successful and reliable handling of various obstacles (e.g. stairs of up to 40° incline)

6. Robot Experiments

Figure 3: Stepping experiments with the Momaro robot

Robotic experiments are ongoing and indicate that the system performs comparably to simulation results. Our team NimbRo Rescue will participate in the DARPA Robotics Challenge, June 5-6 2015.