TECHNISCHE UNIVERSITÄT DARMSTADT

Simulation, Systems Optimization and Robotics

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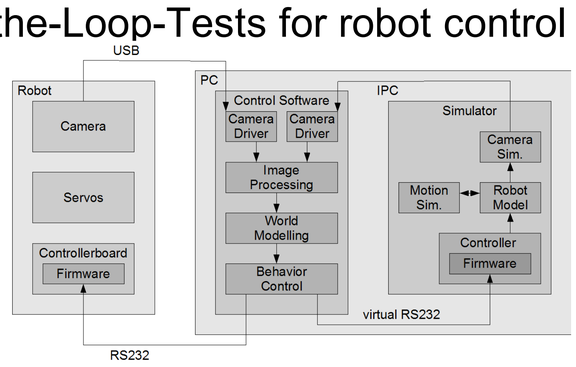
Tailored Real-Time Simulation for Teams of Humanoid Robots

Main Concepts

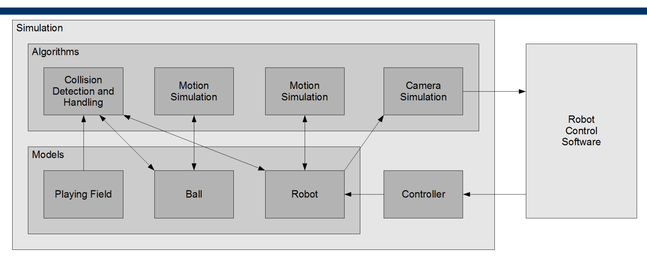
- Transparent Software-In- the-Loop-Tests for robot control software
- Real-Time Simulation of:
  - -Motion
  - -Cameras
  - -Collision



- Heterogeneous teams of robots may be simulated.
- Easy integration with `RoboFrame`
- Based on `MuRoSimF` (Multi-Robot-Simulation-Framework)
- Applications:
  - -Tests of behavior control and vision under optimal conditions.
  - -Tests of team cooperation
  - -Reduced strain on Hardware

Integration of Simulation

- Simulation consist of
  - -Model data of simulated scene
  - -Algorithm modules



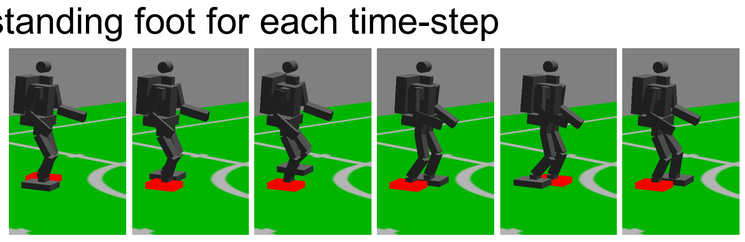
- Flexible exchange of simulation algorithms:
  - -Algorithms may be chosen and combined for each simulated robot individually.
  - ➢Simulation can be tailored to individual requirements.
  - ➢Simulation is scalable in complexity and accuracy.

Efficient Motion Simulation

- Two O(n) algorithms are provided

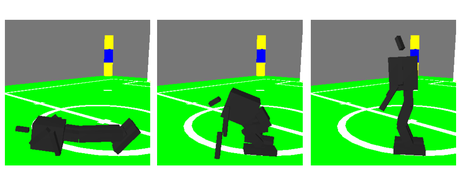
Kinematic Walking Simulation

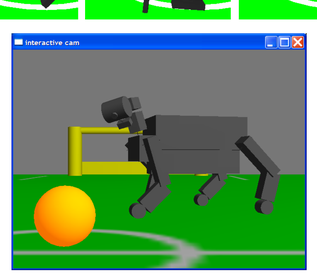
- Simulation method:
  - -Based on direct kinematics
  - -Assuption: standing foot is fixed (no sliding of falling)
  - -Recalculation of standing foot for each time-step
- Limitations:
  - -Biped robots
  - -Walking motions



Simplified Dynamics Simulation

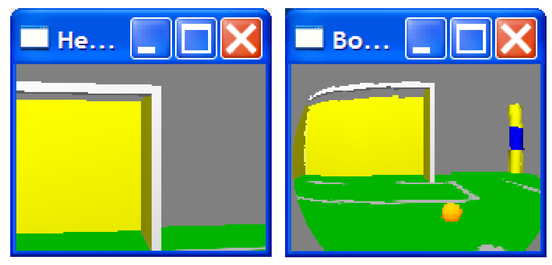
- Simulation method:
  - -Calculate relative motion of robot's limbs by direct kinematics
  - -Sum up all external forces at CoM
  - -Calculate dynamic motion for CoM
- Allows motion beyond walking
- Not limited to biped robots





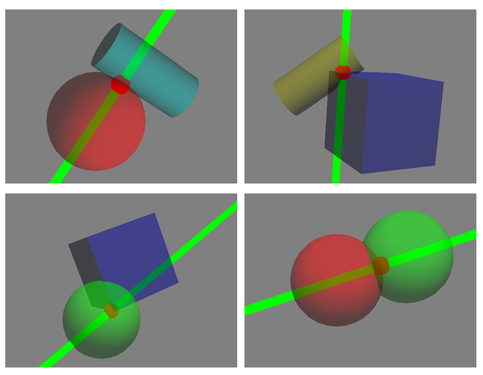
Camera Simulation

- Real-Time rendering based on OpenGL
- Optional simulation of distortion caused by lens



Collision Detection and Handling

- Detection and Handling of Collision are independent modules of the simulation



Collision Detection

- Calculates position, depth and normal direction of collision
- Primitive shapes: sphere, box, cylinder and plane
- Scalable: may be activated for each pair of bodies individually.

Collision Handling

- Calculation of forces and resulting torques
- Rebound based on spring-modell depending on depth d of collicion $F_{rebound} = c_1 \cdot d$
- Friction based on a viscous friction model depending on relative velocity v_{rel} of bodies $F_{friction} = c_3 \cdot v_{rel}$
- Surface parameters c_1 and c_2 are adjustable for each pair of surface-types.
- Each body has an associated surface type.

Results

- Simulation for several scenarios from RoboCup Humanoid League.
- Efficient Simulation for teams of 21 DOF robots on standard computer (Intel Centrino Duo (1.66GHz), 1GB RAM, Intel 945GM chipset):
  - -Robot motion only:
    - 10 robots using kinematic simulation
    - 8 robots using dynamic simulation
  - -Motion and one 20 fps camera per robot:
    - 6 robots using kinematic simulation
    - 5 robots using simplified dynamic simulation