## 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
  - Assumption: 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
  
  \[ F_{\text{rebound}} = c_1 \cdot d \]
  
  \[ F_{\text{friction}} = c_2 \cdot V_{\text{rel}} \]

- Rebound based on spring-model depending on depth \(d\) of collision
- Friction based on a viscous friction model depending on relative velocity \(v_{\text{rel}}\) of bodies
- 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