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Benchmarking in Humanoid Motion Planning

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Benchmark in motion planning

- Gait Planning
 - Online planning
- Whole body motion planning
 - Natural Looking
 - Manipulation tasks
 - Locomotion in complicated environment

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Online gait planning

Can the robot change the foot place?

1. How quickly ?
2. How largely ?
3. When?

How long does it take to calculate the gait?

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Overview of Online Gait Planning

ZMP trajectory

Horizontal CoG trajectory

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On line gait planning (Harada et al. 2004)

Change the walking direction to the left

Connection of trajectories

ZMP

CoG

Analytical solution based method (fast)

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On line gait planning (Harada et al. 2004)

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Connection of trajectories


ZMP

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Analytical solution based method (fast)

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Example 1

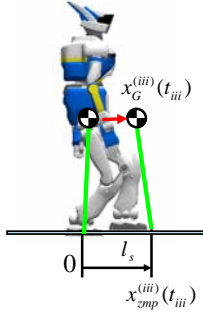


- Using wrist force sensor
- Change the foot placement of two steps later
- Deviation of ZMP trajectory
- 2[ms] to calculate 3 steps (Very fast using the analytical solution).
- Connection when the DS phase begins (Easy method)

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Emergency stop

[Morisawa et al. 05]



Cost function:

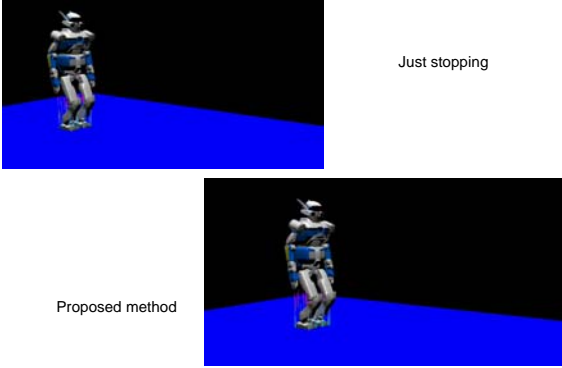
$$J(t_{iii}) = a_{ds} \left(x_{zmp}^{(iii)}(t_{iii}) \right)^2 + b_{ds} \left(x_G^{(iii)}(t_{iii}) \right)^2$$

Get t_{iii} such that:

$$\min_{t_{iii}} J_{ds}(t_{iii})$$

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Simulation




Just stopping

Proposed method

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Experiment

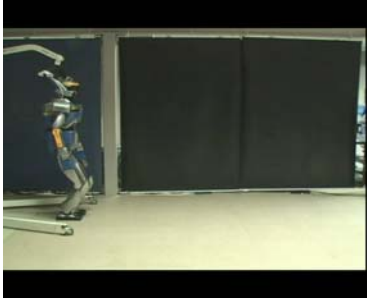


Emergency stop

$V=1.35[\text{km/h}]$ (Step length 0.3[m], Step cycle 0.8[s])

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Further Real-time approach [Morisawa et al. 06]



- Change of Foot place anytime
- Trajectory Connection before SS phase (Difficult)

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Whole body motion planning

1. Natural Looking?
2. Manipulation Task
3. Difficult Environment

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PRM Planner

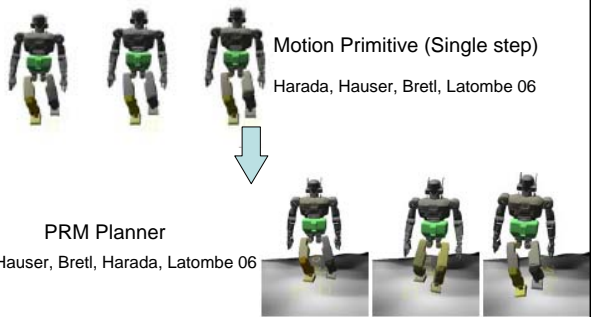


Hauser Brett and Latombe (2005)

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PRM Planner(2/5)~Primitive based motion planner



Motion Primitive (Single step)
Harada, Hauser, Bretl, Latombe 06


PRM Planner
Hauser, Brett, Harada, Latombe 06

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PRM Planner (3/5)~ Posture Optimization

(Harada, Hauser, Bretl and Latombe 06)



- Optimization in operational space
- Principal analysis
- Posture optimization
- Trajectory optimization

$$J = \tau(t)^T \tau(t) \quad \text{Height of CoG} \\ t = t_0 \dots t_m$$

$$J = \mathcal{L}(t)^T \mathcal{L}(t) \quad \text{Inclination of waist} \\ t = t_0 \dots t_m$$

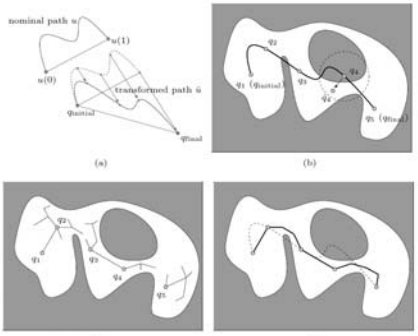
Upright posture
Swing body and arms

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PRM Planner(4/5)~Primitive based motion planner

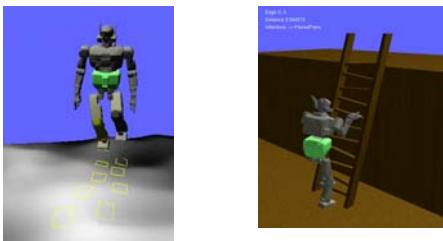
Hauser, Brett, Harada, Latombe ('06)



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PRM Planner (5/5) ~Simulation



Hauser, Brett, Harada and Latomnbe (2006)

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Optimization Approach (Escande, Khedder, Miossec 2006)



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Whole body motion planning

1. Natural Looking?
2. Manipulation Task
3. Gait in Complicated Environment

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Benchmark tasks: Level 1

- Locomotion on an uneven surface and/or in a complicated environment.
- Operation machines and equipments that we use now.

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Walk though the Gate (Harada et al. 2007)




PRM Planner

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Walk though the Gate (Harada et al. 2007)



Side obstacle Narrow space

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Passing Under Obstacles (Sanada et al. 2007)



Passing Under Obstacles with Humanoid Robots

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Locomotion in a complicated environment (Yoshida et al. 2006)





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Pivoting Manipulation (Yoshida et al. 05, 07)

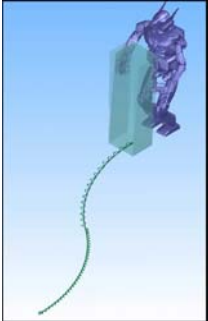

- Pivoting manipulation [Aiyama 93, *IROS*] [Yoshida et al. 06, *J. Applied Bionics and Biomechanics*]
 - Precision
 - Dexterity
 - Security
- Motion planning for humanoid manipulation
 - Collision-free manipulation planning
 - + Whole-body motion

Start Goal

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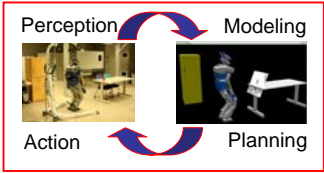
Benchmark tasks: Level 2

- Locomotion on an uneven surface and/or in a complicated environment,
- Operation machines and equipments that we use now,
- **With perception.**
 - Simultaneous Modeling and Planning (**SMAP**)

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Simultaneous Modeling and Planning (**SMAP**)

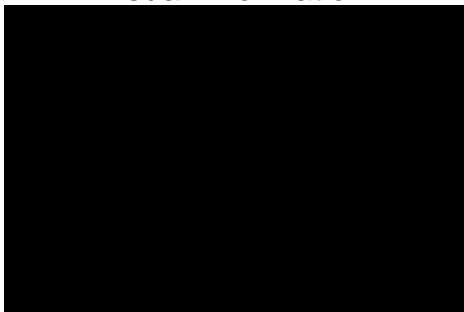


Make a real-time loop between a real and model world

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Locomotion planning with 3D Visual Information



[Stasse et al. ICRA2007 Finalist of Best Video]

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Visually-Guided Grasping while Walking

Visually-Guided Grasping while Walking

N. Mansard O. Stasse

[Stasse et al. ICRA2007 Finalist of Best Video]

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Take a Soda Can out form the Fridge



http://www.aist.go.jp/aist_e/latest_research/2006/20060213_2/20060213_2.html

Summary

- Gait Planning
Online planning
- Whole body motion planning
Natural Looking
Manipulation tasks
Locomotion in complicated environment