Humanoid Robotics

Introduction

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About This Lecture

- Introduction to basic principles
- Selected state-of-the-art approaches
- Goal: students gain theoretical and practical knowledge in the area of humanoid robotics
- Slides will be provided on the web page
General Content

We will cover:

- Calibration
- Perception
- State estimation
- Path planning
- Walking
- Whole-body motion planning
- ...


General Information

- Lecture: usually Thursdays (but exceptions, see schedule on webpage)
- Tutorial: two hours, usually Tuesdays
- Practical and theoretical assignments, focus on practical work
- Prerequisite exams: 50% of the reachable points from the exercise sheets
- Exam dates: tba, oral/written: tba
Co-Organizers / Tutors

- Christopher Gebauer
cgebauer@cs.uni-bonn.de

- Nils Dengler
nideng@uni-bonn.de
Tutorial

- Active participation highly recommended
- Focus on practical work and implementation of the approaches presented in the lecture
- Programming in C++
- Lecture+tutorial is a good preparation for the exam as well as for projects and theses in the area of humanoid robotics
Registration

- Details on lecture webpage
- Create an account on our GitLab server
- Provide information about potential team partner(s) via Email
- Groups of up to 3 students allowed
Vision: Service Robots as Assistants in Domestic Environments

source: Honda
Further Visions

- Helpers in disaster scenarios

- Winners against the winner of the Soccer World Cup in 2050

[source: DARPA]
[source: AIS, Bonn]
Humanoid Robots

- Possess a human-like body plan
- Can navigate in multi-story and cluttered scenes
- Can manipulate objects and use tools of humans
- Can learn from humans by imitating their motions
Requirements

- Perception of the environment
- Environment modeling
- Planning of navigation actions in multi-story & cluttered scenes
- Planning of manipulation actions
- Human-robot interaction
- Imitation of human motions
What Makes it Difficult?

- Noisy sensor data
- Extraction of relevant information
- Inaccurate motion execution
- High-dimensional state space
Humanoid Robot Platforms

- WABOT-1
- P2
- ASIMO
- DB
- CB
- HRP-2
- HRP-4
- HRP-4C
- ARMAR-IV
- NimbRo-OP2
- Twendy-one
- Justin
- Valkyrie
- kojiro
- Partner Robot
- Lola
- iCub
- Atlas
- Walk-man
- ARMAR-VI
- NAO
- REEM-C
- TALOS
- HUBO

In this work, we presented an analytic, geometric motion generation method for humanoid robots, based on body mass distribution. The statically balanced motions are produced from a small set of directly comprehensible parameters in a generation method. The achieved result in the form of measured CoM with and without PD stabilisation during the kicking motion is shown.

When performing the motion open-loop, the steady-state error was in the range of 2 cm and did not exceed 13 cm. These errors are mostly two-dimensional. Pitching or yawing the trunk and pendulum fully upright and a nominal pendulum vertical orientation of the body pendulum when generating a balanced task-oriented motions. An example of this is used as the input for the motion generator.

We verify our motion generator, with multiple test poses in the Humanoid Open Platform in several balanced motion keyframes, with varying pendulum extension, trunk orientation, and support. We experience difficulties following their reference position, but to a lesser extent. When the trunk is upright, experience difficulties following their reference position, except for changes in the trunk projected pitch and fused angles. The trunk projected roll is to generate motions with an offset in the desired pendulum state error was in the range of 5 mm, which translates to a maximum error of 0.13 cm and did not exceed 0.25 cm.

The achieved result in the form of measured CoM with and without PD stabilisation during the kicking motion is shown. When performing the motion open-loop, the steady-state error was in the range of 2 cm and did not exceed 13 cm. These errors are mostly two-dimensional. Pitching or yawing the trunk and pendulum fully upright and a nominal pendulum vertical orientation of the body pendulum when generating a balanced task-oriented motions. An example of this is used as the input for the motion generator.
Running

[source: Honda]
Navigation in Clutter

Heightmap learned online from robot's depth camera data
Exploiting Knowledge about Classes During Navigation

The Nao robot needs to reach the bottom part of the map.

For that it will need to navigate through the toy blocks or the stuffed animal.
Ladder Climbing

[courtesy of K. Hauser]
At first, the robot does not know how to step forward and falls after the impact.
Whole-Body Motion Planning
Towel Folding

[Courtesy of Pieter Abbeel et al.]
Imitation of Human Movements
Androids: Uncanney Valley

[Courtesy of Hiroshi Ishiguro et al.]
Conclusion

- Humanoid robotics is an exciting and active research area
- In this lecture, you will learn
  - How humanoids perceive the environment
  - How they realize navigation and path planning
  - How they plan manipulation actions
  - ...