Universität Hamburg
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MIN Faculty
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Introduction to Robotics

Summary

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Technical Aspects of Multimodal Systems

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Outline

Outline (cont.)

Overall Summary

Introduction

– Definition;
+ Basic components;
+ DOF;
– Classification of Robots

Spatial Description and Transformations

+ Specification of position and orientation;
+ Rotation matrices, their inverse and their operations;
+ Homogeneous transformations;
+ Transformation equations [5, 39, 6, 4];
+ More on presentation of orientation

Forward Kinematics and Robot Description

+ DH-conventions and their applications (classic or modified);
+ Universal Robot Description Format (URDF)

Overall Summary (cont.)

Inverse Kinematics

+ Workspace;
+ Difference and problems of forward and inverse kinematics;
– Algebraic and geometric solution of inverse kinematics;

Jacobian

– Differential motion and velocity;
– velocity propagation;
+ Jacobian-matrices;
+ Singularities [5, 39, 6, 4]

Trajectory Generation

– Tasks and constraints;
+ Trajectories in Cartesian space and joint space;
+ Trajectory generation methods;
– Polynomial solutions between two and four points;
– Factors of an optimal motion;
+ Concepts and properties of B-Spline interpolation;

Overall Summary (cont.)

– B-Spline basis functions [39, 6, 4, B-Spline Literature]

Path planning

+ Configuration space;
– Object representation;
+ Discretized Space Planning;
+ Potential field method;
+ Probabilistic approaches;
+ Rapidly-exploring Random Trees;
– Task and Manipulation Planning

Dynamics

+ Problems;
+ Newton-Euler equations and Lagrangian Equations;
– Solution for arms with 1 or 2 joints;
+ General dynamic equations of a manipulator [39, 6, 4]

Overall Summary (cont.)

Control

- – Control systems of a PUMA robot;
- – Linear and model-based control;
- + PID controller;
- + Control concepts in Cartesian space [39, 6, 4]

Sensors

- ○ Classification;
- + Intrinsic sensors, principle and application in control;
- – extrinsic sensors [39, 6, 4]

Robotic applications

- – Walking robot;
- – Grasping;
- – Telerobotics

Overall Summary (cont.)

Control architectures

- Subsumption;
- CMAC;
- Hierarchical

Additional references: [40, 41, 42, 43]

Summary – Control

- Industrial Robots:
  - position control with PID controllers
  - featuring gravity compensation
- Research:
  - model-based control
  - hybrid force-position control
  - `under-actuated control`
  - `backwards controllable` (`direct drive`, `artificial muscle`) structure
  - external-sensor based control
    $\rightarrow$ Intelligent Robots/Applied Sensor Technology

Summary – Mechanical Structures of Robots

Things we talked about

- Open chain of rotational joints
- Hybrid joints for rotational and translational motion (SCARA)
- Mobile robots, running machines

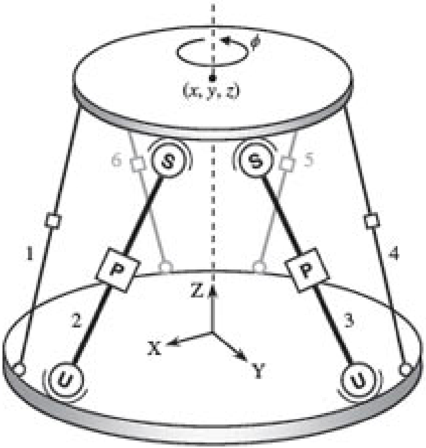
Things we did not talk about

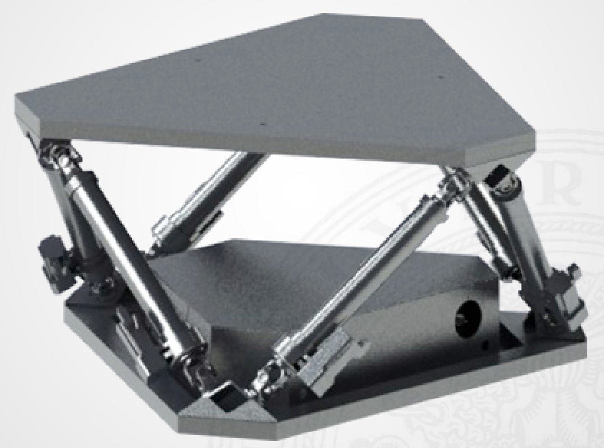
- Closed chain, including Steward Mechanism [39, p. 279]
- Drive without motors (micro- and biomimetic-robots)

The Stewart-Platform

- Tool plate mounted to base plate with six translational joints (usually hydraulic) called `leg`
- `Legs` are connected to the plates with universal joints
- Mathematically 6-DOF configuration space without singularities
- Parallel mechanism provides high payload
  - Sequential manipulator applies forces and torques unequally

The Stewart-Platform (cont.)





Summary – Algorithms

- Transformations
- Forward and inverse kinematics
- Trajectory generation (e.g. linear Cartesian trajectory)
- Approximated representation of robot joints and objects
- Search algorithms
- Further path planning algorithms
- Sensor fusion
- Vision
  - detection (static, dynamic)
  - reconstruction of position and orientation
- Action planning
- Sensor guided motion

Outline

Outline (cont.)

Intelligent Robots

Underlying robot-technique as described, additionally:

External Recognition

- Reliable measurements of the environment;
- Scene interpretation

Knowledge base

- About environment;
- Its own state;
- Everyday knowledge comparable to a human

Autonomous planning

- Action;
- Coarse motion;
- Grasping;
- Sensor data acquisition

Intelligent Robots (cont.)

Human friendly interface

- Understanding of naturally spoken commands;
- Generation of robot actions;
- Solving of disambiguity in context-aware situations

Adaptive Control

- Evolution instead of programming;
- Ability to learn

Autonomous Planning Systems

Action Planning

- Task-Specification;
- State representation;
- Task-decomposition;
- Action-sequence generation

Motion Planning

- Representation of the robot and the environment;
- Calculation and representation of configuration space;
- Search algorithms

Planning of Sensing

- Which sensors;
- Which time intervals;
- Where to measure;
- Internal and external parameters of the sensor

Sensor driven motion

Goal

Intelligent Control including the ability to adapt to different situations and to react to uncertainties

Control Architecture

Integration of perception, planning and actions

Tasks of sensor data processing

Position detection;
Proximity detection;
Slip detection;
Success confirmation;
Error detection;
Inspection

Sensor driven motion (cont.)

Applied sensors

- Tactile sensors;
- Vision systems;
- Force-torque measurement systems;
- Distance sensors

Strategies

- `calibrated` based on absolute reference values;
- `uncalibrated` based on relative information

Types of perception

- `passive` based on a certain sensor-actor configuration;
- `active` depending on the plan for sensing

Future Commercial Robots

will be:

- dexterous
- smaller
- faster
- lightweight
- powerful
- intelligent
- easier to operate
- cheaper

Challenges in the Field of Robotics

Methods

- Symbolical understanding of the environment;
- Integrated sensor-motor-coupling;
- Self-learning

Systems

- Synergetic multi-sensor;
- Agile mobility;
- Dexterous manipulation capabilities

Technical

- Sensor complexity similar to a human;
- New drive types;
- Nano-robots;
- Multifinger hand;
- Anthropomorphic robots;
- Flying robots

Continuing Education at University of Hamburg

Intelligent Robots Project
: Build a complex robotic system from the available hardware at TAMS. Current Hardware includes PR2, TASER, 2 KUKA lightweight arms, 2 Mitsubishi PA10-6C, UR5 Arm, 4 Turtlebots, Shadow Hand C6, Shadow Hand C5, Robotiq adaptive gripper, SCHUNK gripper, 2 Barret Hands...

Intelligent Robots/Applied Sensor Technology Lecture
: Intrinsic and Extrinsic sensor technology and their application for intelligent robotic systems.

Machine Learning Lecture
: Machine learning techniques allow robots to learn from observation and experience

Neural Networks Lecture
: Neural Networks allow robots to learn and offer new approaches to planning and control

Image Processing I&II Lecture
: Image processing is required for robots to observe the environment and recognize/classify/detect objects and humans

Continuing Education at University of Hamburg (cont.)

Knowledge Processing Lecture
: The gained knowledge from observance and sensing has to be processed efficiently

Language Processing Lecture
: How to extract knowledge and information from human speech

Real-Time Systems Lecture at TUHH
: Robots have to process information and act in Real-Time environments

Fundamentals of Control Technology Lecture at TUHH
: Control Technology is required for the technical control of robotic systems.
Advanced Lecture with large prerequisites.

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