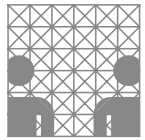

Master's Thesis: Real-Time Object Shape Perception via Force/Torque Sensor

Current Status

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Fachbereich Informatik

Technische Aspekte Multimodaler Systeme

31.01.2017

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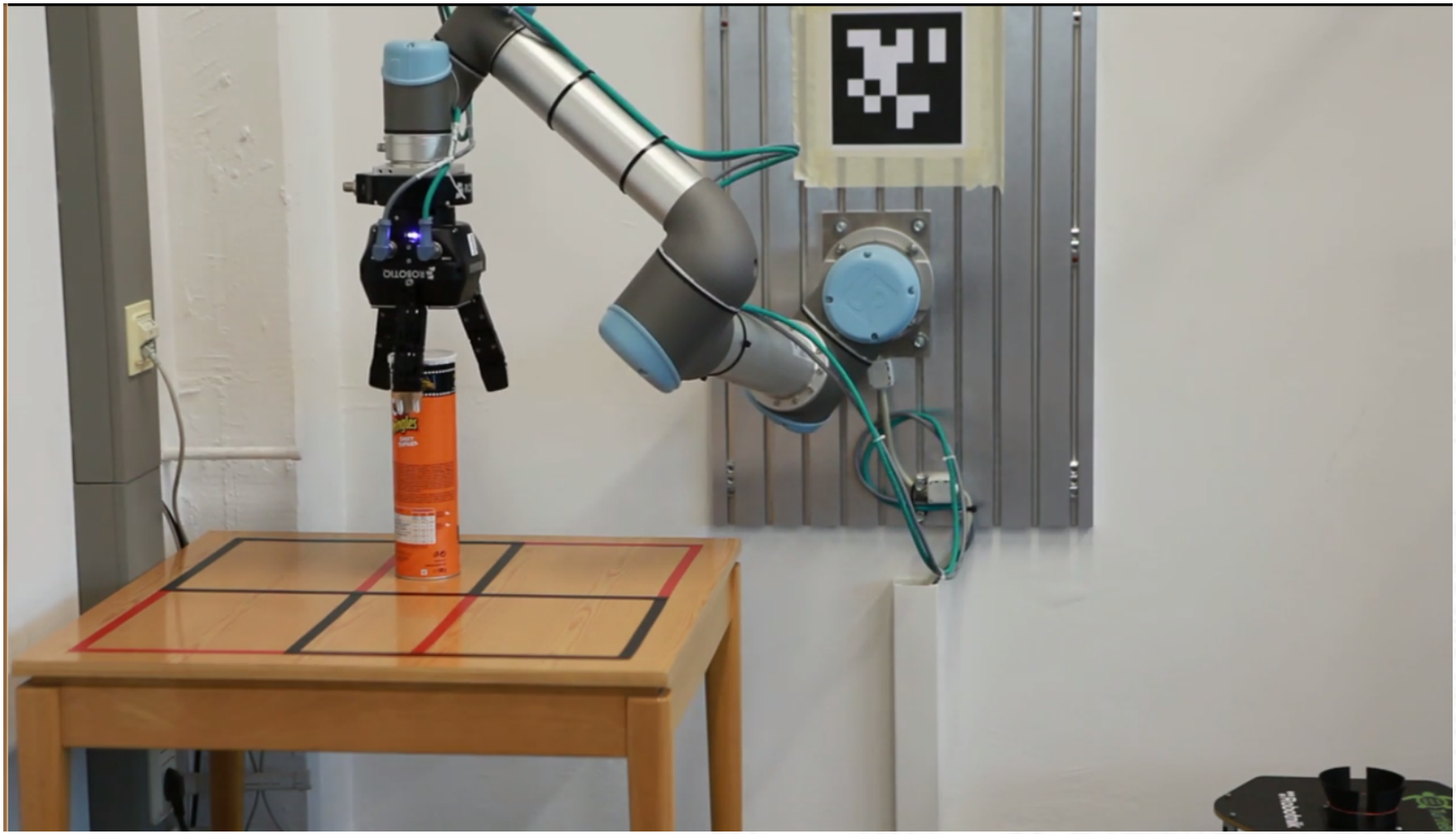
Personal Interest...

...raised by the TAMS Masterproject Intelligent Robotics



... and IROS 2015.

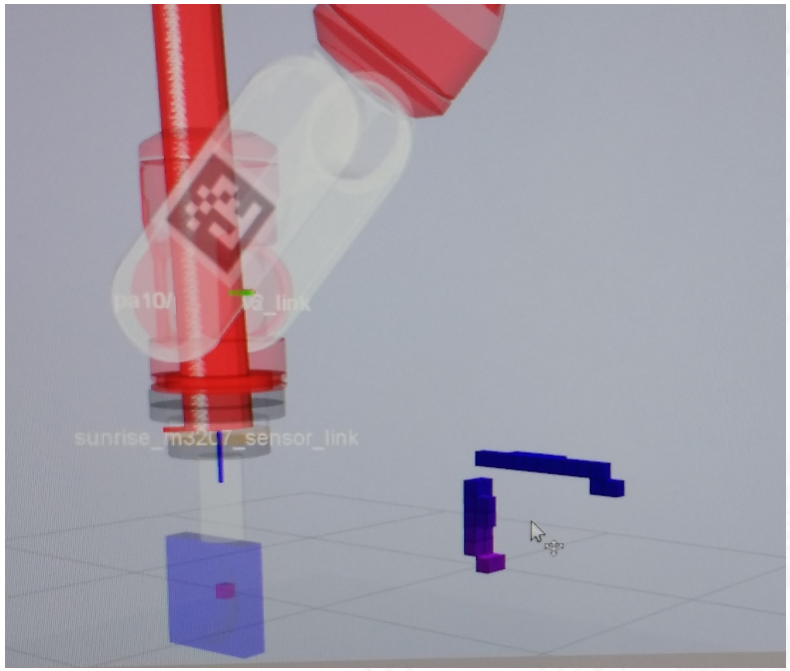
Explore Environment

- Importance of grasping objects
- Identifying object before grasping
- Good exploration yields good manipulation
- Methods: Vision, ..., **haptic exploration**

Haptic exploration is suitable in exploration scenarios with low visibility conditions as underwater, in foggy environments, with bad lighting conditions.

Goal

- Model the shape of objects with force and torque sensor data
  - Generate 3D model
    - later used for: collision planning, grasping/manipulation, deburring...



Hardware Setup

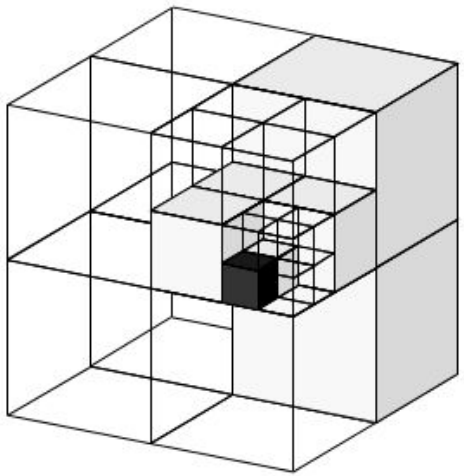
- Mitsubishi PA-10 6-DOF
- Sunrise M3207 F/T-Sensor
- Drill chuck
- Sphere fixed at/as the tip

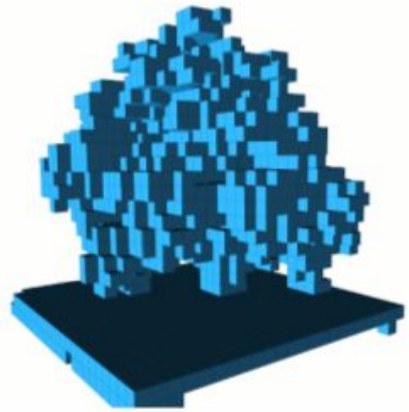
Tools

- ROS
  - Simplifications for programming with robots
  - Extensive use of tf package
- Reflexxes Motion Libraries
- Force and torque sensor readings
- OctoMap

- FK/IK solver for the PA10 provided by Norman Hendrich
- PA10_reflexxes ROS package provided by Norman Hendrich

- 3D mapping framework based on octrees
- OctoMap library implements 3D occupancy grid mapping approach
- RViz display plugins
- `octomap.github.io`

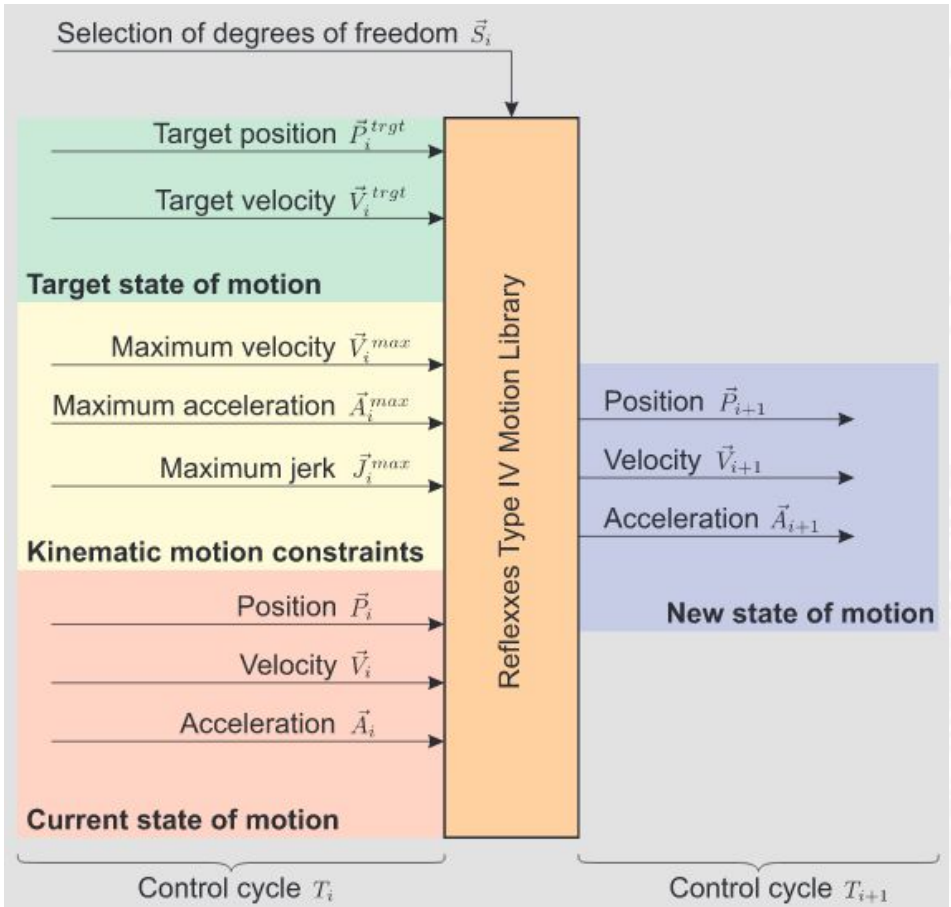




[HWB+13]

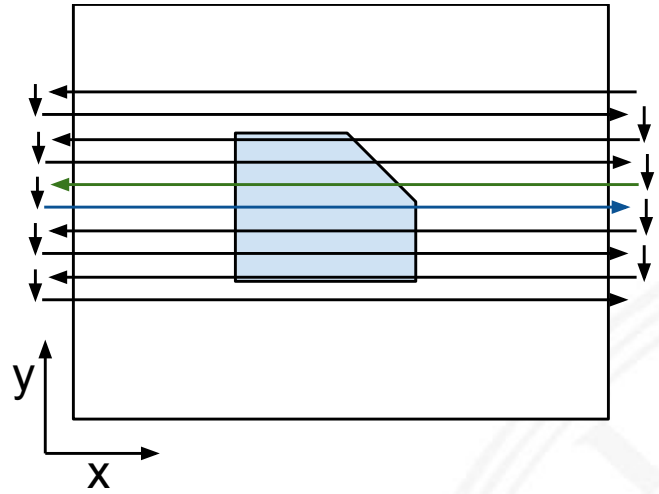
Setup
Reflexxes Motion Libraries

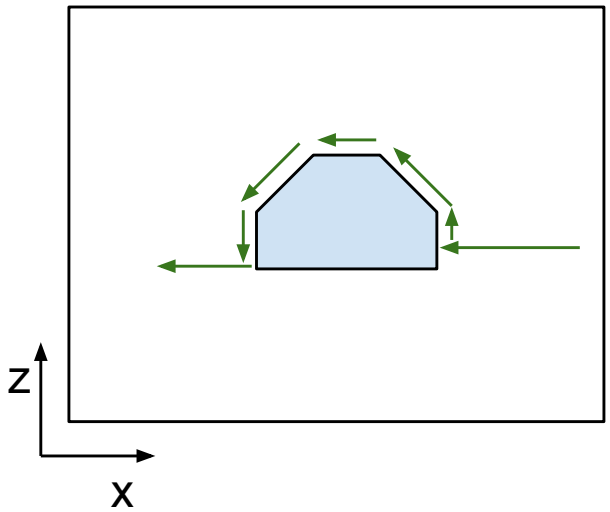
- Real time (online) motion control
- "New motions are calculated within one low-level control cycle (typically within one millisecond or less)." [Krö11]

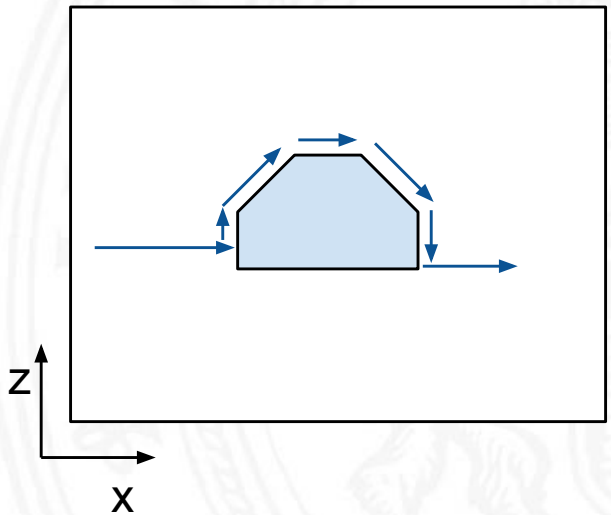


General Heuristic

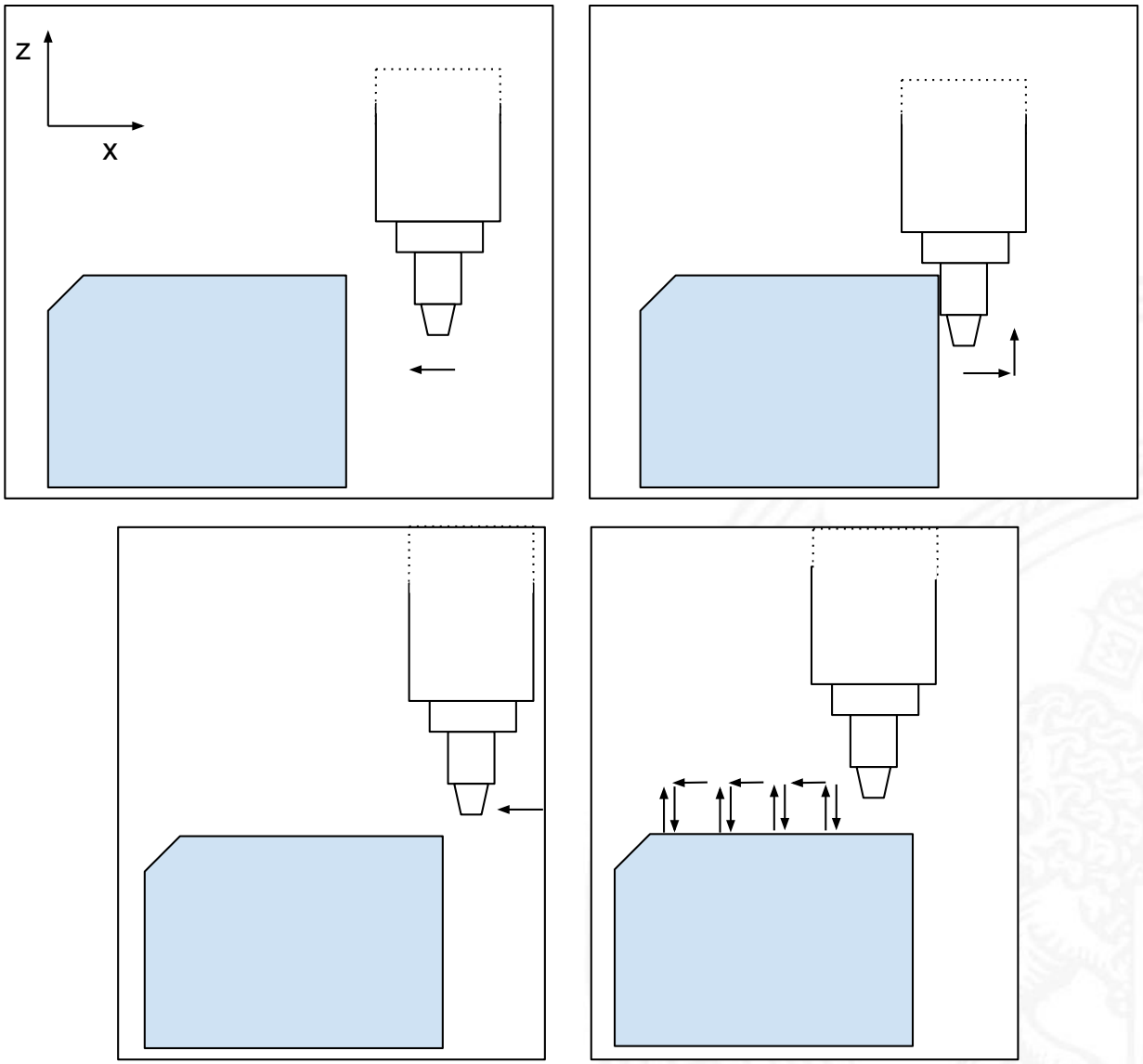
The end effector moves along x-axis and reacts in z-axis direction when force is encountered.



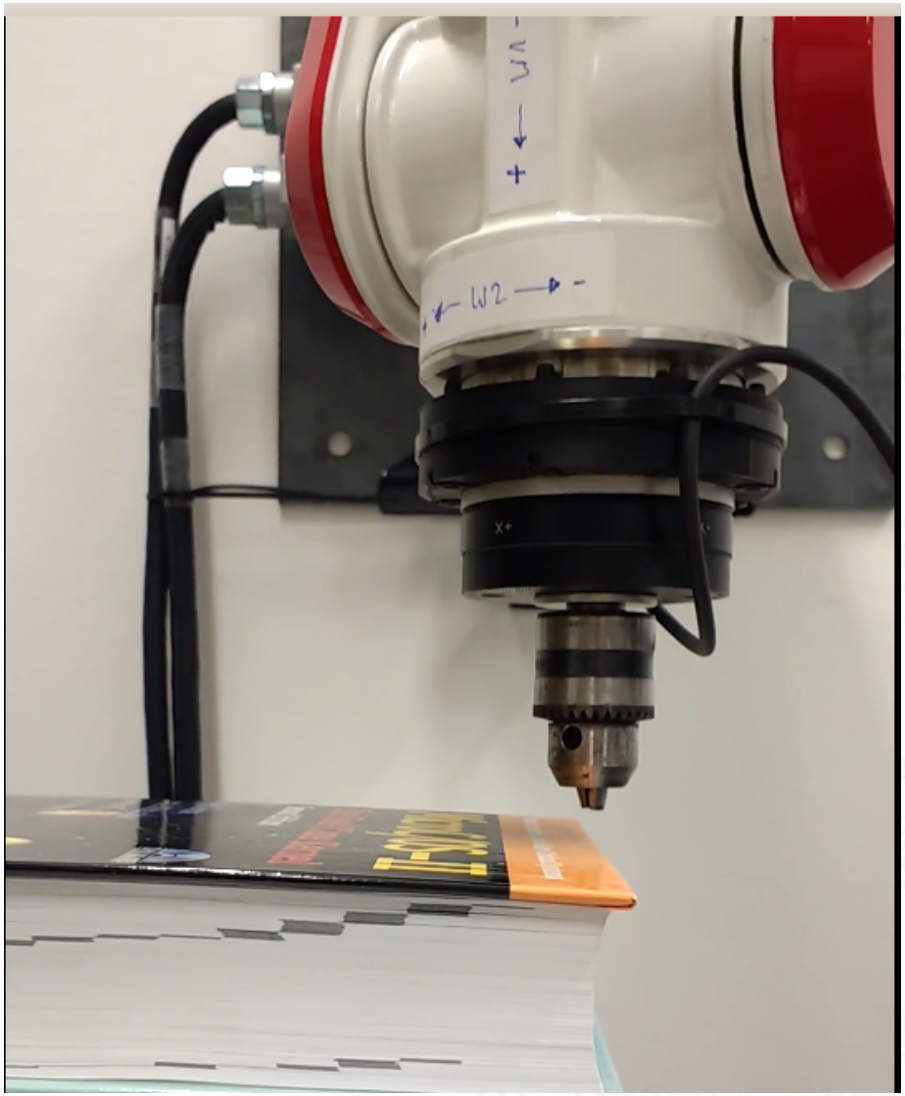




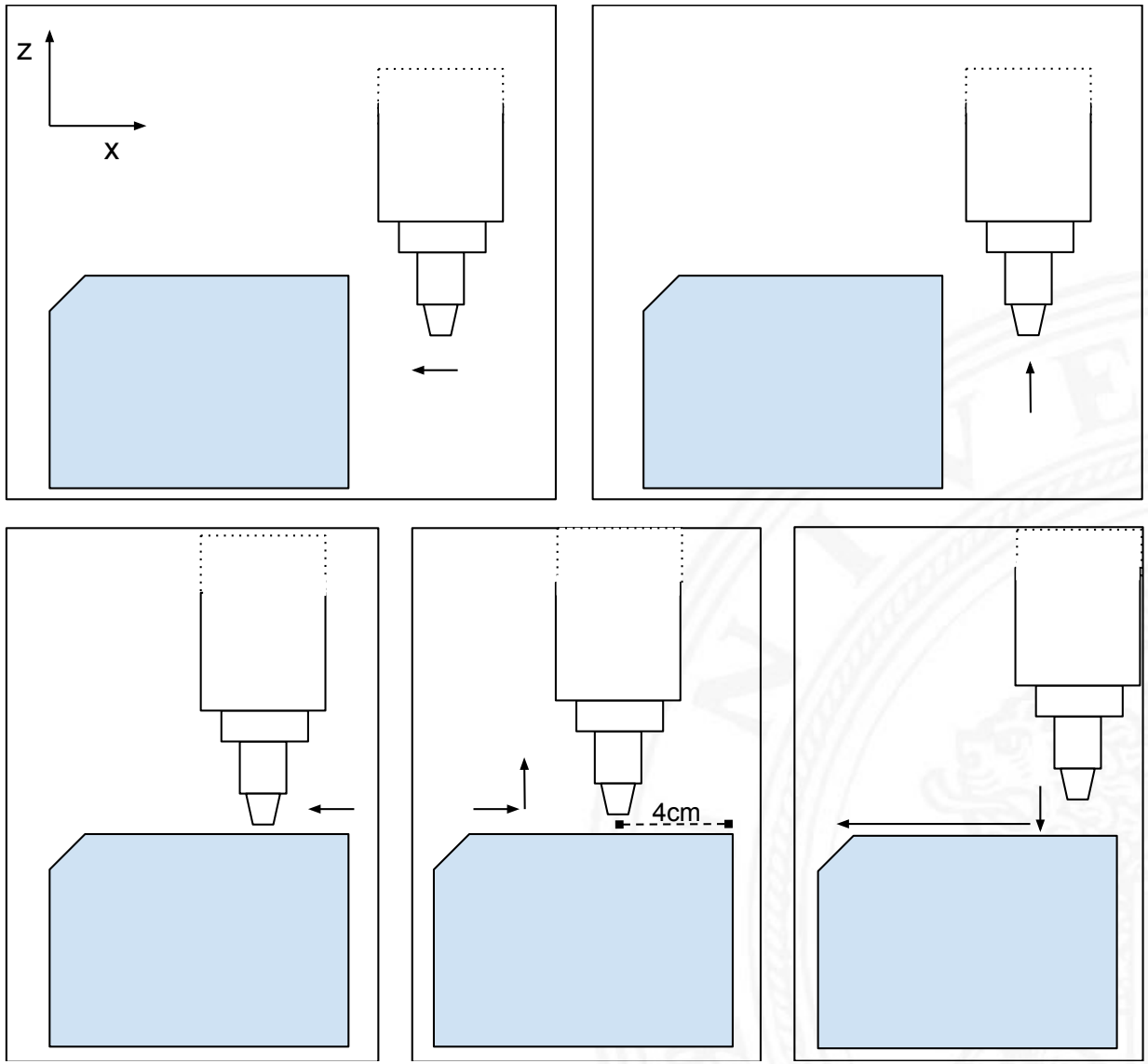
Approach 1



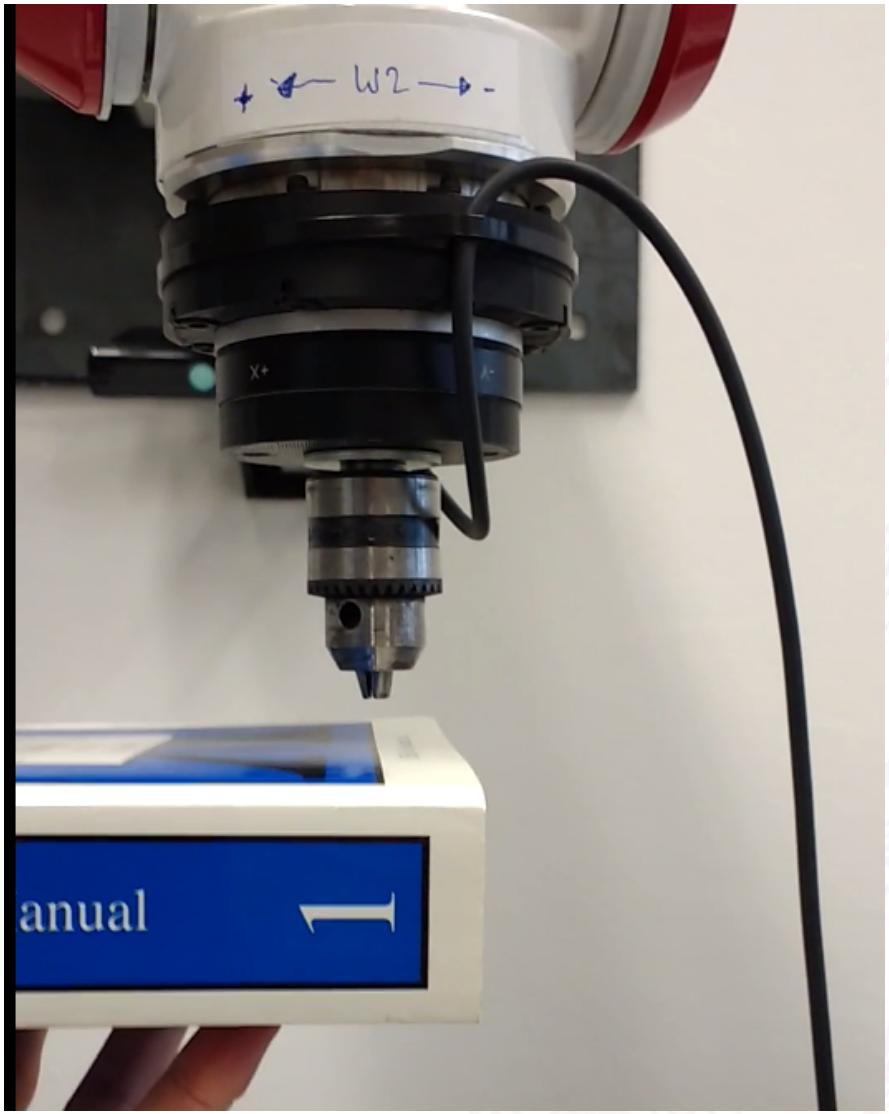
Approach 1



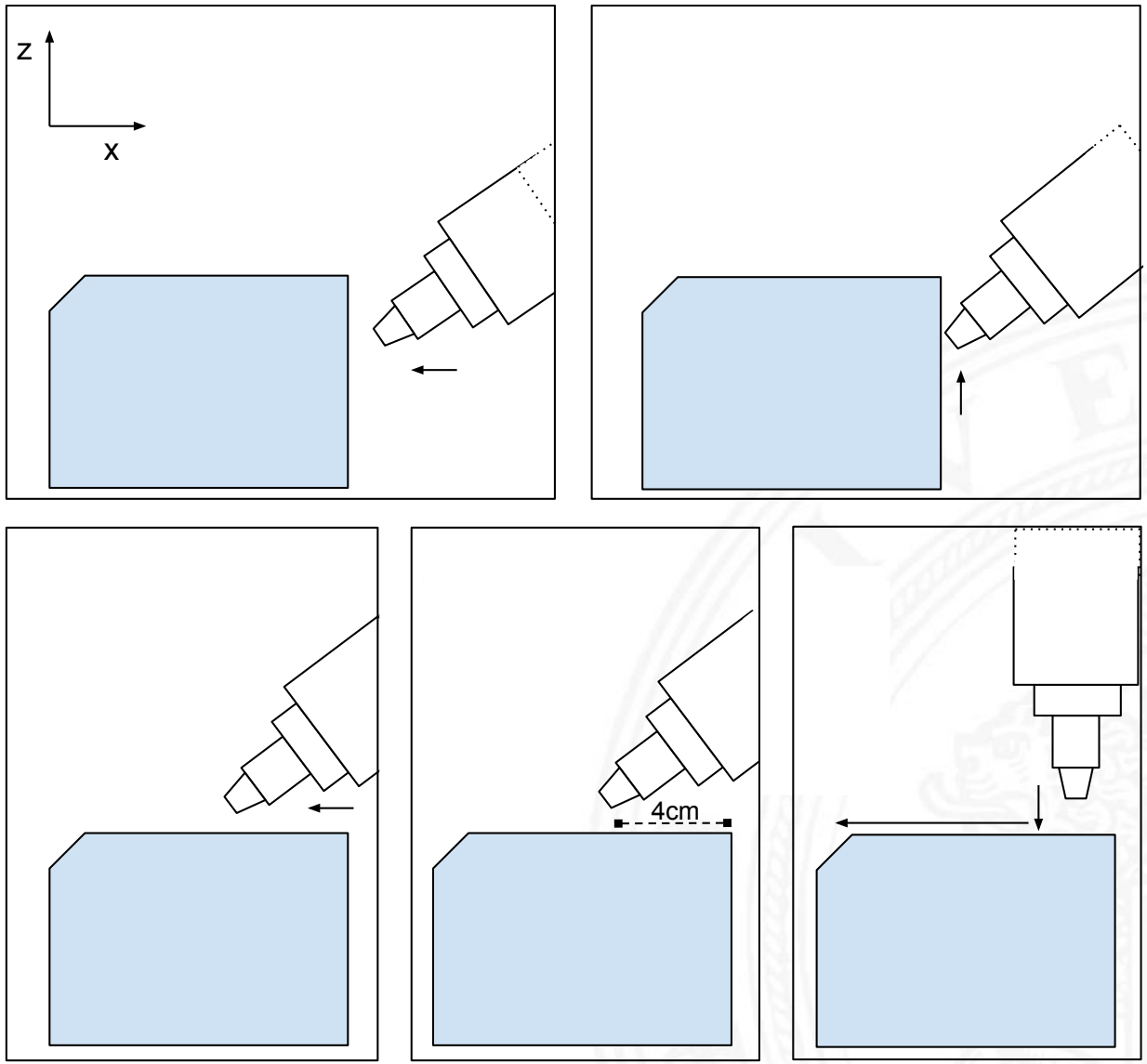
Approach 2



Approach 2



Approach 3



Approach 3

Problems with Approaches 1-3

- Risk of unwanted collision between object and PA10
- Static ">4cm" parameter
- Slow execution of change in orientation

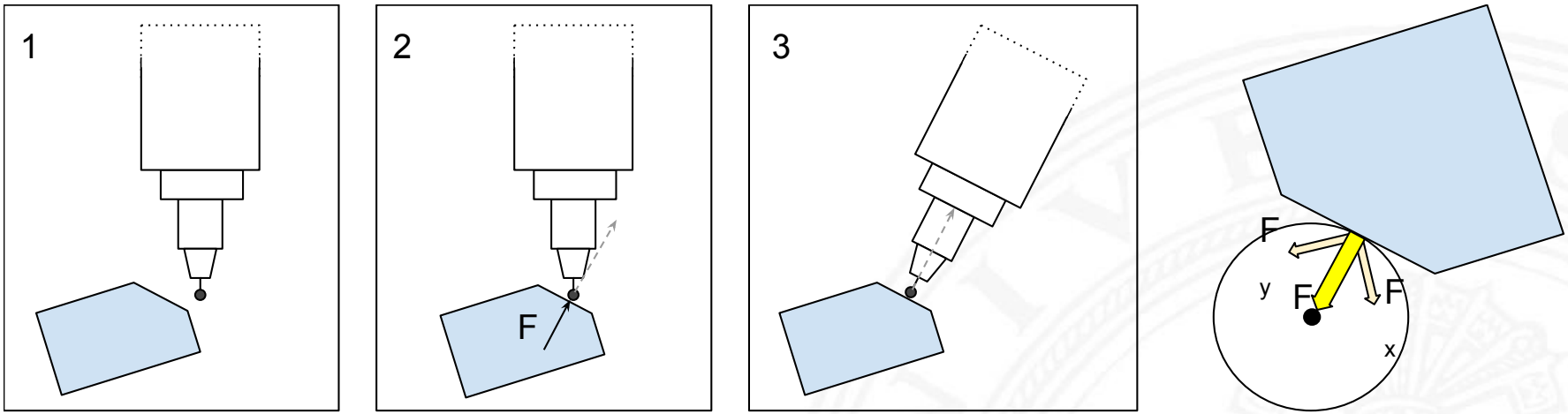
The risk of collision between object and a link of a robotic arm without force sensitivity hardly preventable.

New approach:

- Make ">4cm" vanish
- Aim for smooth movement execution along object

Approach 4

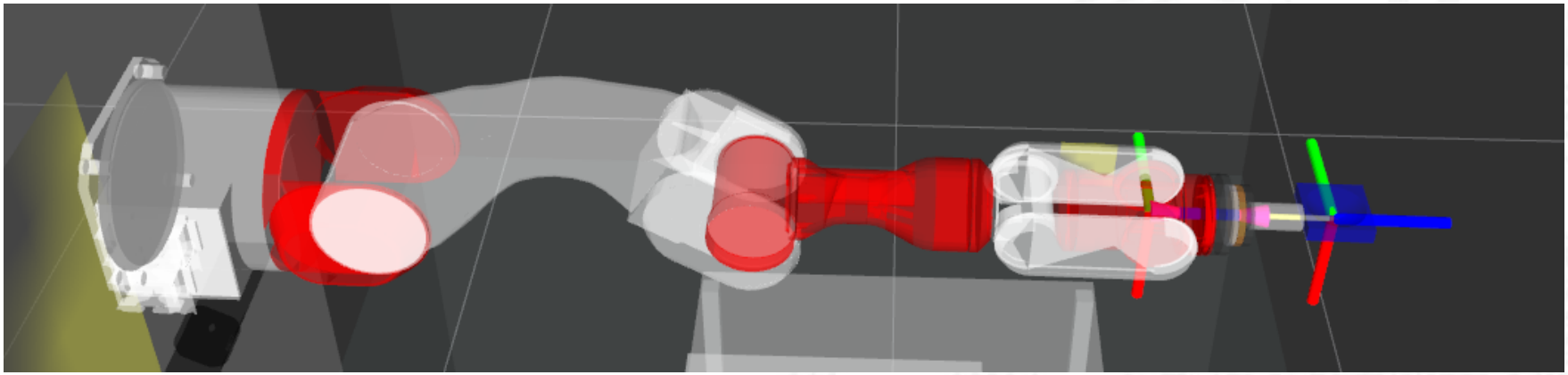
- End effector link orientation is -F
- Tip of robotic arm remains at contact location



The rotation of the appropriate joint needs to be calculated.

Approach 4

- Put sphere as new tip
- Set frame in center of sphere
  - Same orientation as last joint frame
    -> Z-axis points in same direction



Approach 4

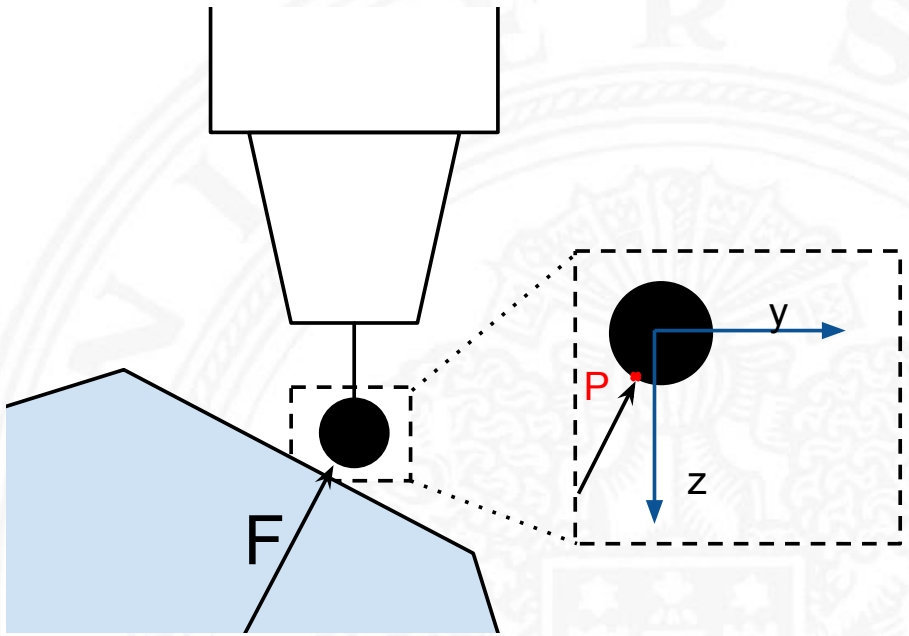
Procedure to calculate the rotation to make Z-axis point in -F direction:

1. Find acting point on sphere
2. Find rotation quaternion for appropriate joint

1.)

$$P = \begin{bmatrix} x \\ y \\ z \end{bmatrix} = r * \begin{bmatrix} Fx/norm(F) \\ Fy/norm(F) \\ Fz/norm(F) \end{bmatrix}$$

r = Radius of sphere
F = Force vector acting on sphere

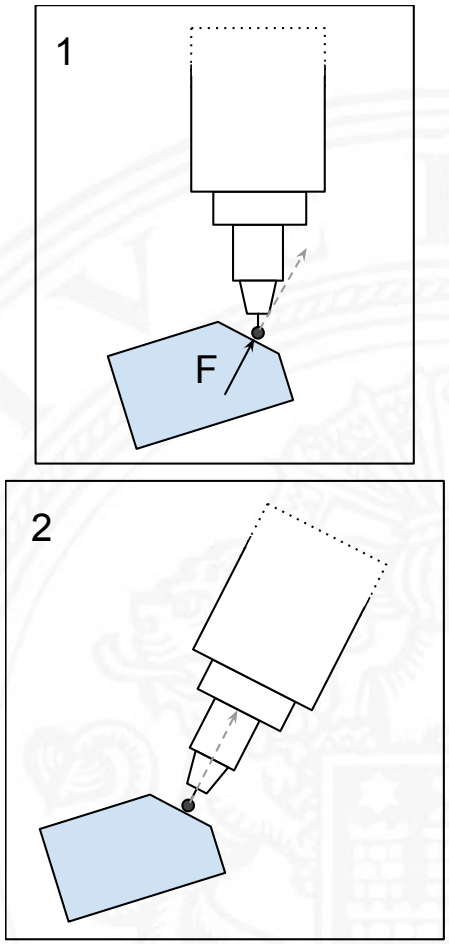


Approach 4

2.) Find rotation quaternion for appropriate joint:

1. Rotation axis $v = a \times b$
2. Rotation angle $\theta = acos(norm(a) \cdot norm(b))$
3. Rotation matrix: Rodriguez rotation formula
   $R = I + (\sin\theta)K + (1 - \cos\theta)K^2$
4. Extract quaternion from R

$a = (0, 0, 1)$
$b =$ acting point on sphere
$K =$ cross-product-matrix of v
$I =$ 3x3 identity matrix

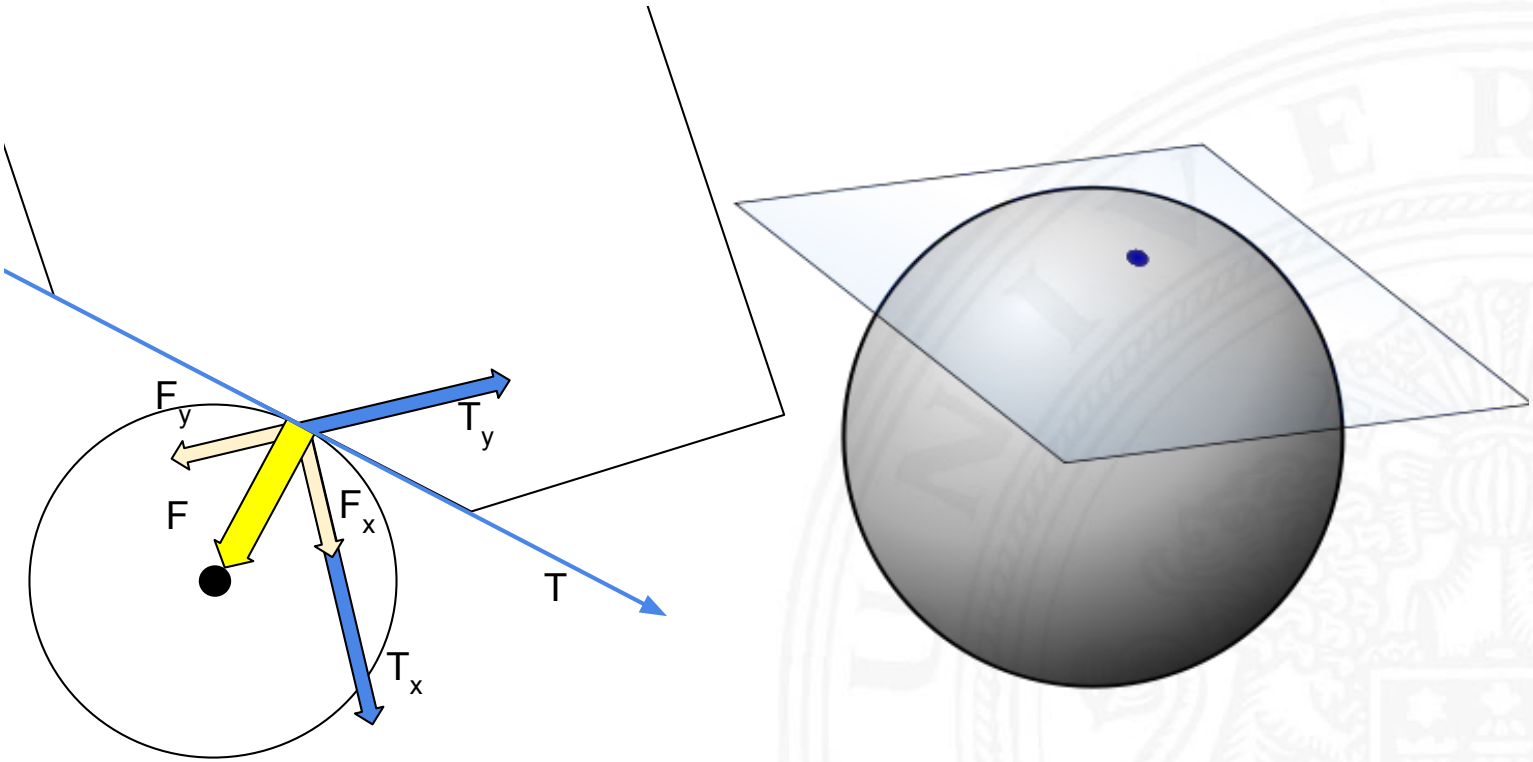


Approach 4

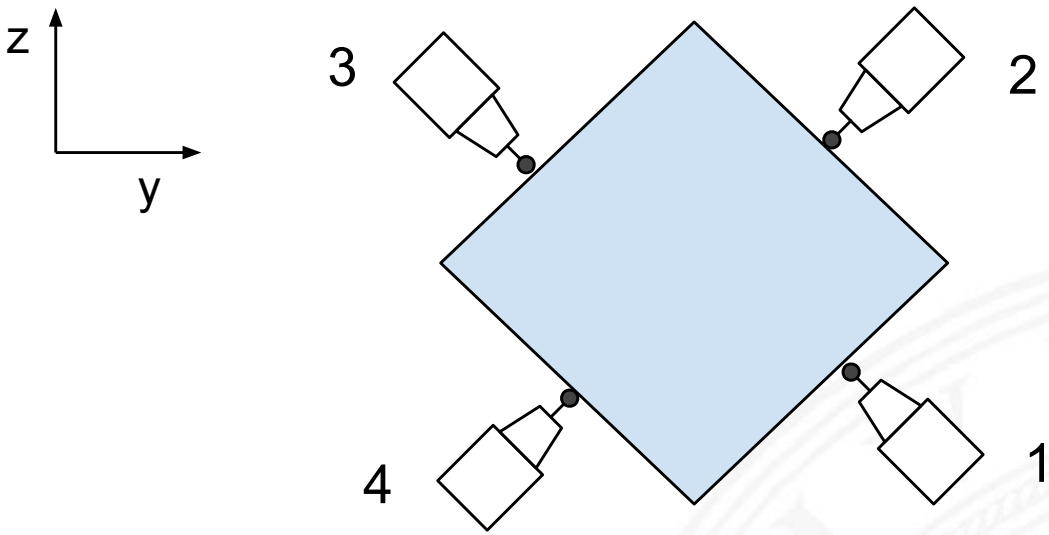
Approach 4

Heuristic to move along Object on y-axis:

- Force normal to tangent
- Use tangent in desired direction



Approach 4



in -y direction: 1. ↘ : ↗ 2. ↗ : ↖ 3. ↖ : ↙ 4. ↙ : ↘

in y direction: 4. ↙ : ↖ 3. ↘ : ↗ 2. ↗ : ↘ 1. ↘ : ↙

References

[HWB+13] Armin Hornung, Kai M. Wurm, Maren Bennewitz, Cyrill Stachniss, and Wolfram Burgard.
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Autonomous Robots, 2013.
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