Robot Locomotion

Integrated Seminar Intelligent Robotics

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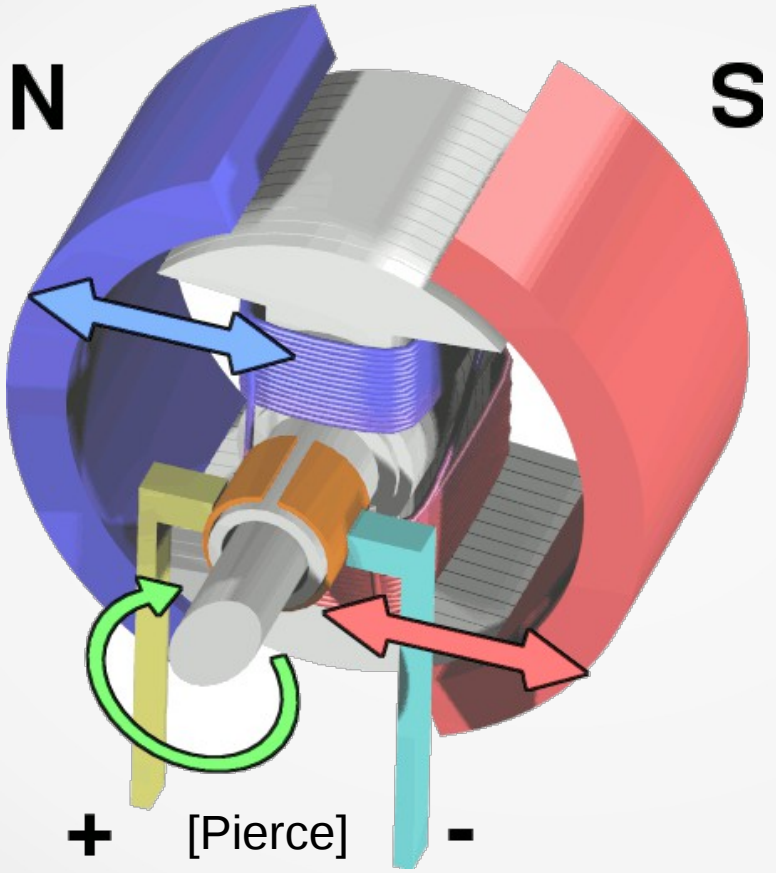
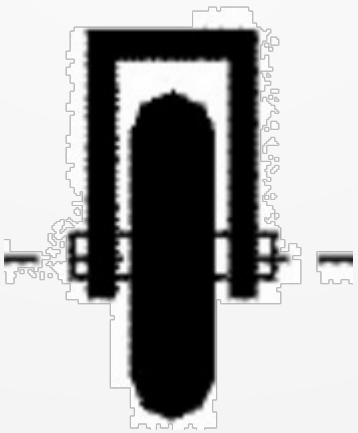
What is robot locomotion

- Methods for robots to move unbounded throughout their environment [Siegwart]
- Related Topics are:
  - Pathplaning
  - Kinematics and Inverse Kinematics

Motors



Wheeled locomotion

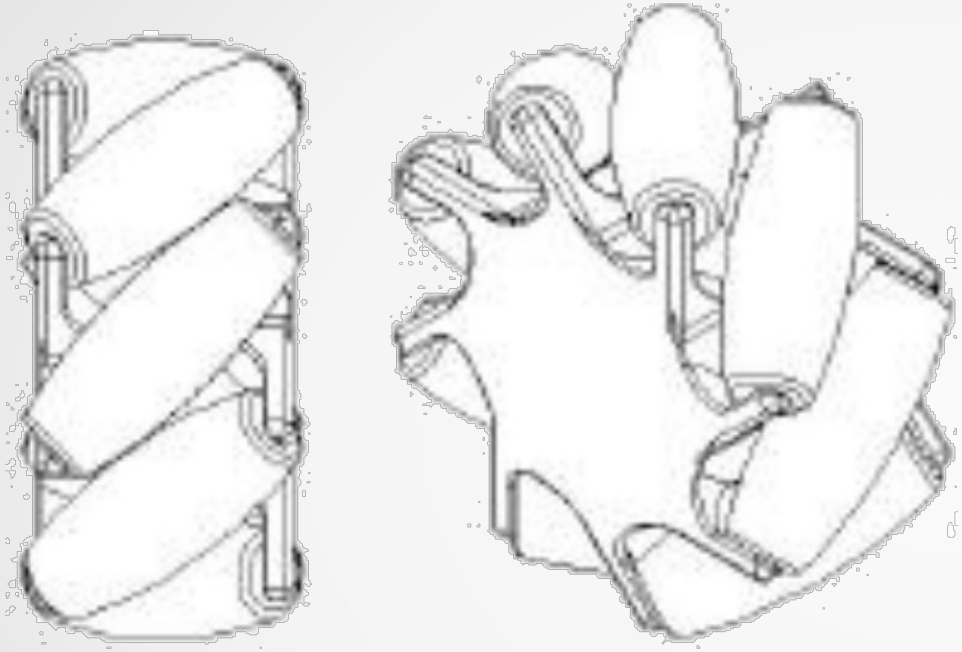


[Siegwart]

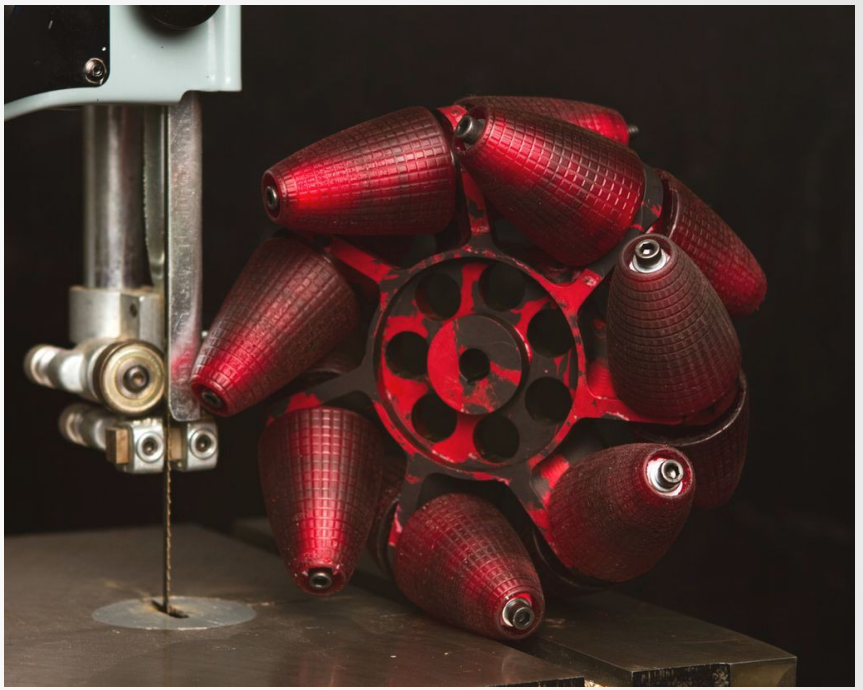
Wheeled locomotion

- Locomotion with normal wheels is easy
- Normal wheels are not very maneuverable
- Normal wheels are energy efficient on a planar surface

Mecanum wheel

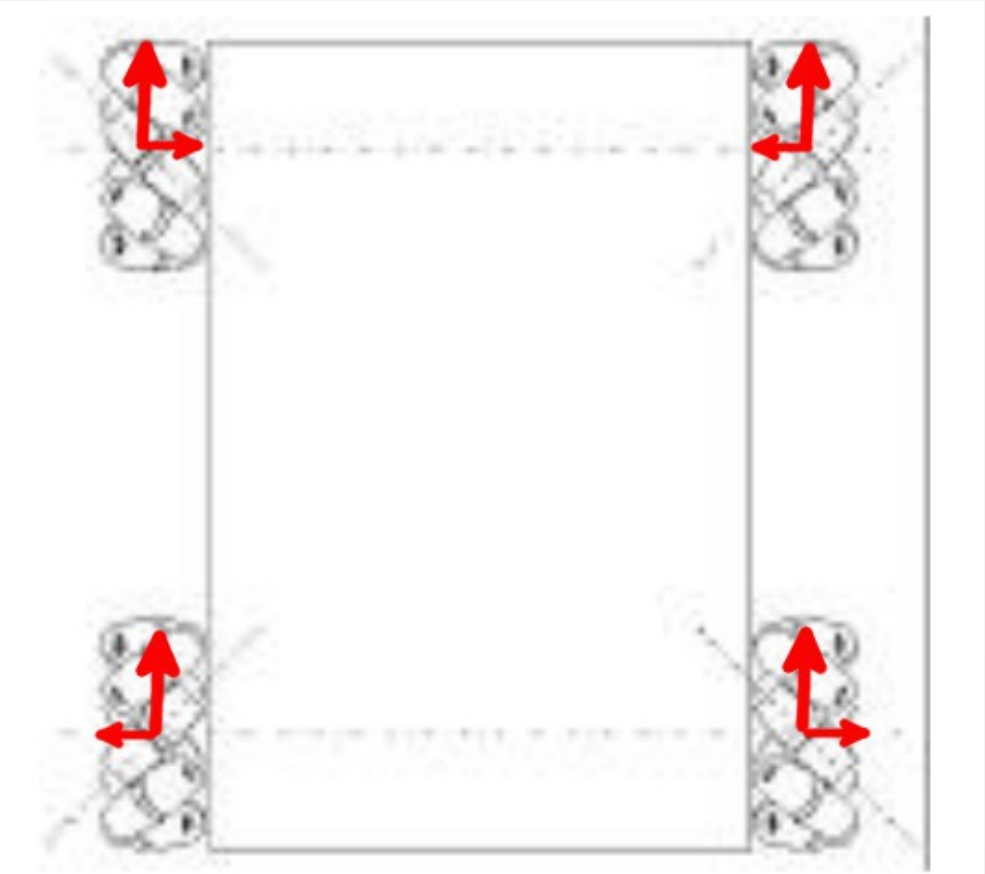


[Siegwart]



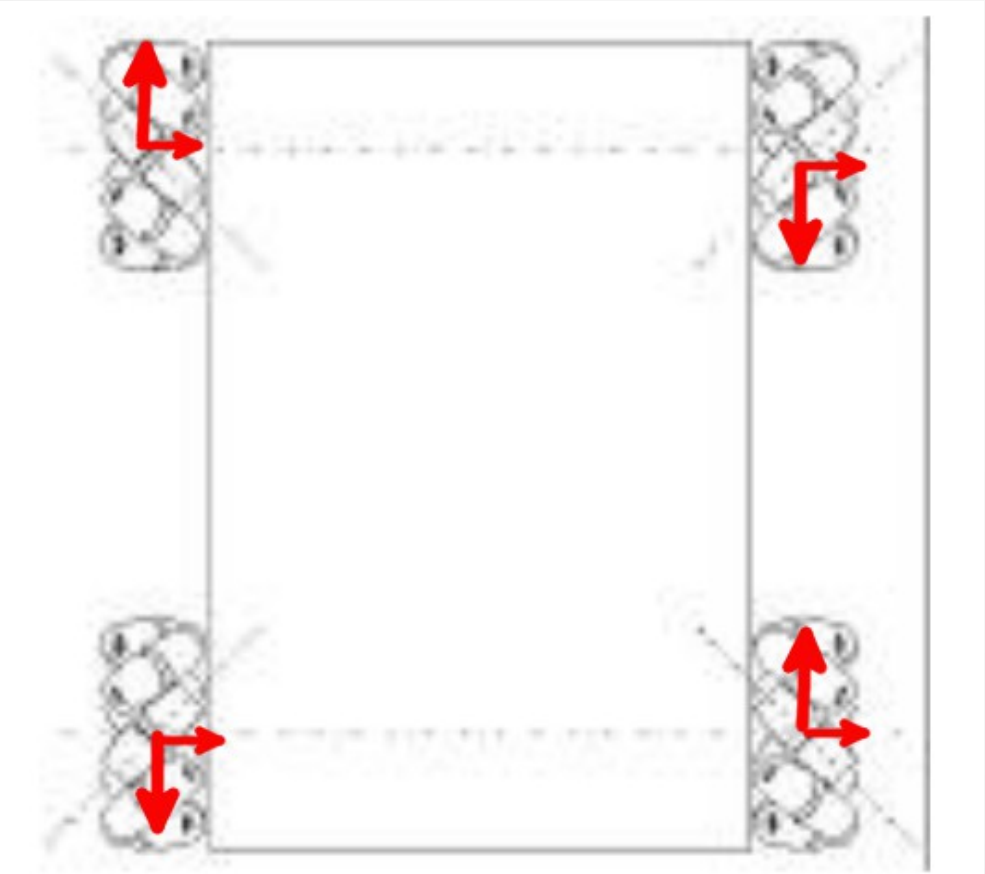
[Leitholt]

Mecanum wheel



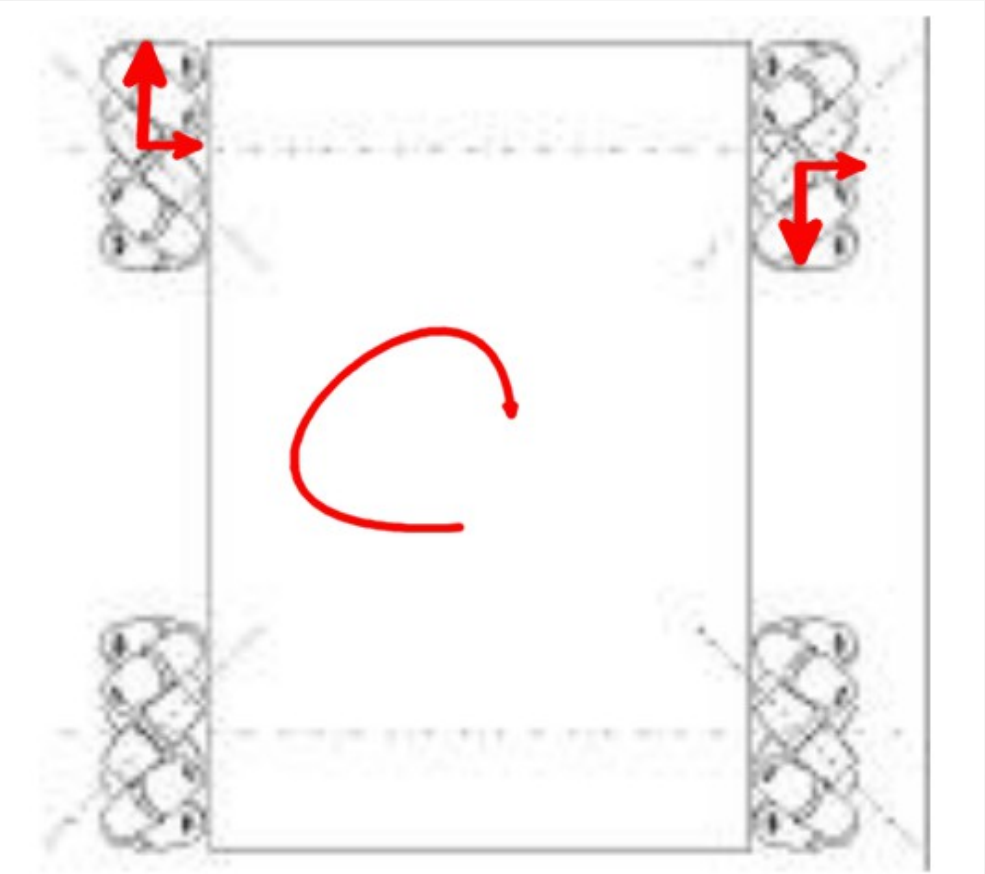
Pencil drawing: [Siegwart]

Mecanum wheel



Pencil drawing: [Siegwart]

Mecanum wheel



Pencil drawing: [Siegwart]

Mecanum wheel

Mecanum wheel

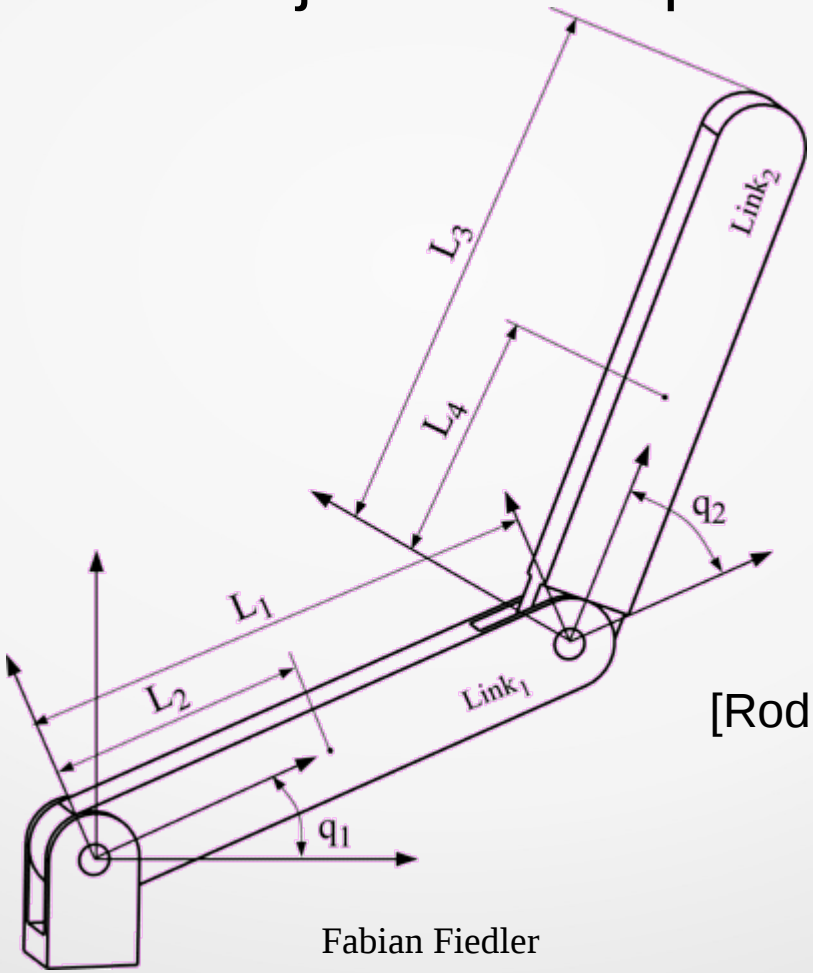
- A mecanum wheel needs a hard surface to drive on
- Uneven surface, stairs?

Legs

- Nature inspired design
- More flexible than wheels

Degrees of Freedom (DOF)

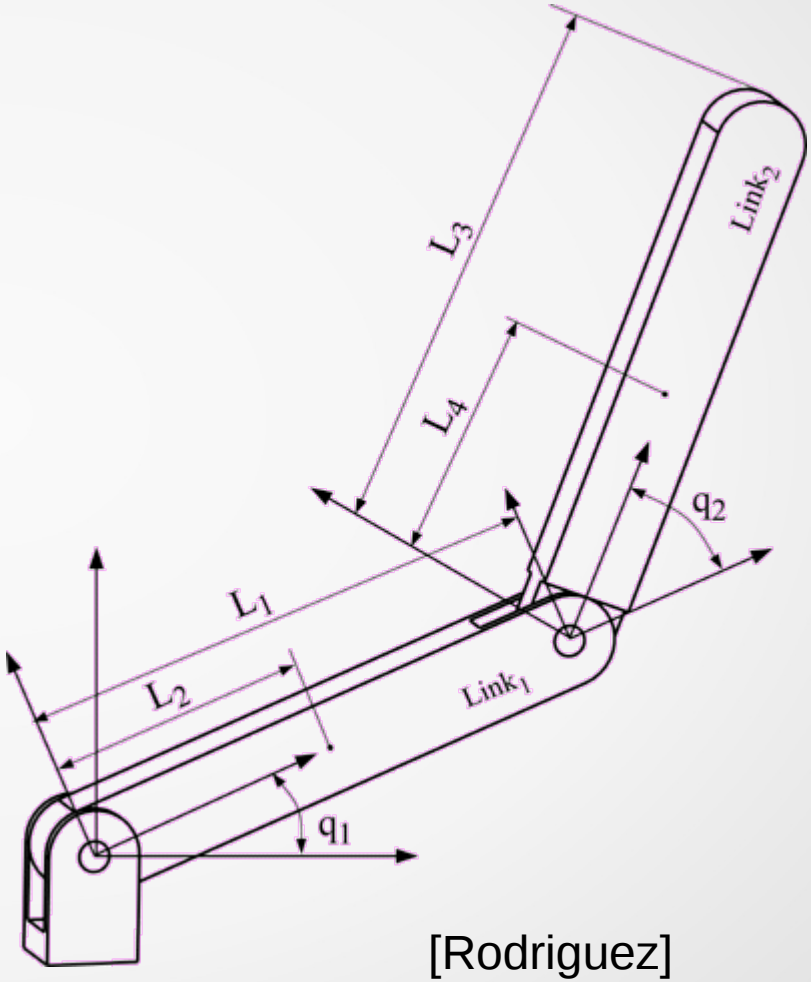
- The number of independent coordinate planes or orientations on which a joint or end-point of a robot can move.[Zhang]



[Rodriguez]

Kinematics

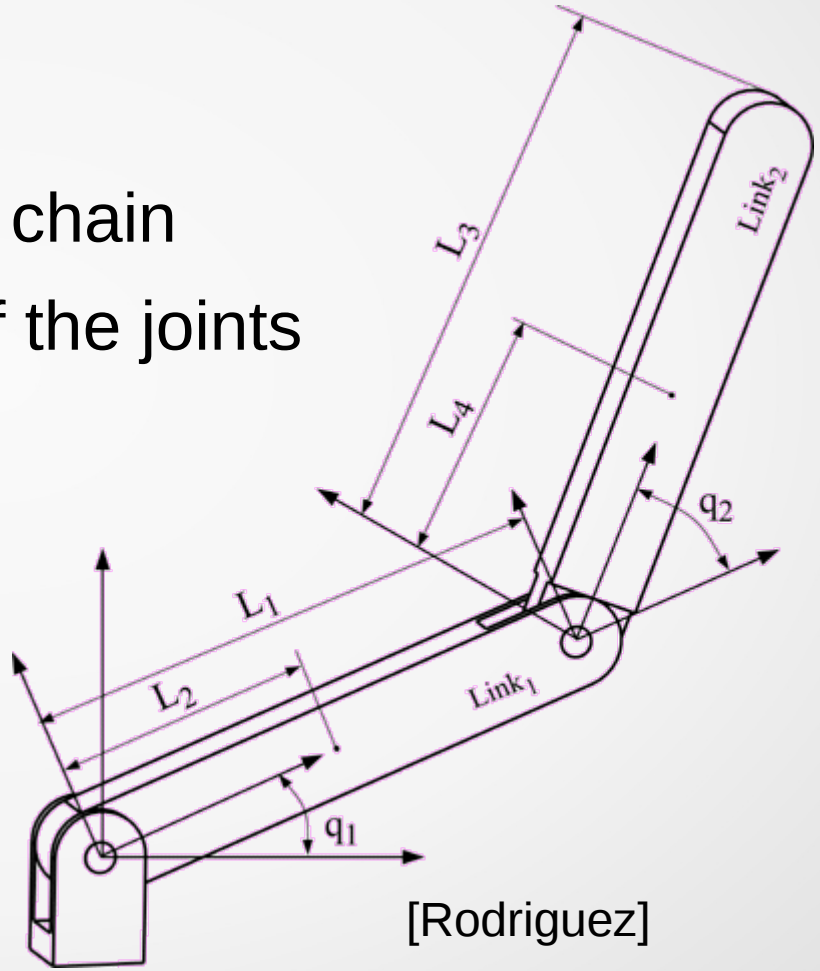
- Known information:
  - Angle of the joints
  - Distance between joints
- Where is the endpoint of the kinematic chain



[Rodriguez]

Inverse kinematics

- Known information:
  - Distance between joints
  - Endpoint of the kinematic chain
- Determine the parameters of the joints
- Calculation is expensive

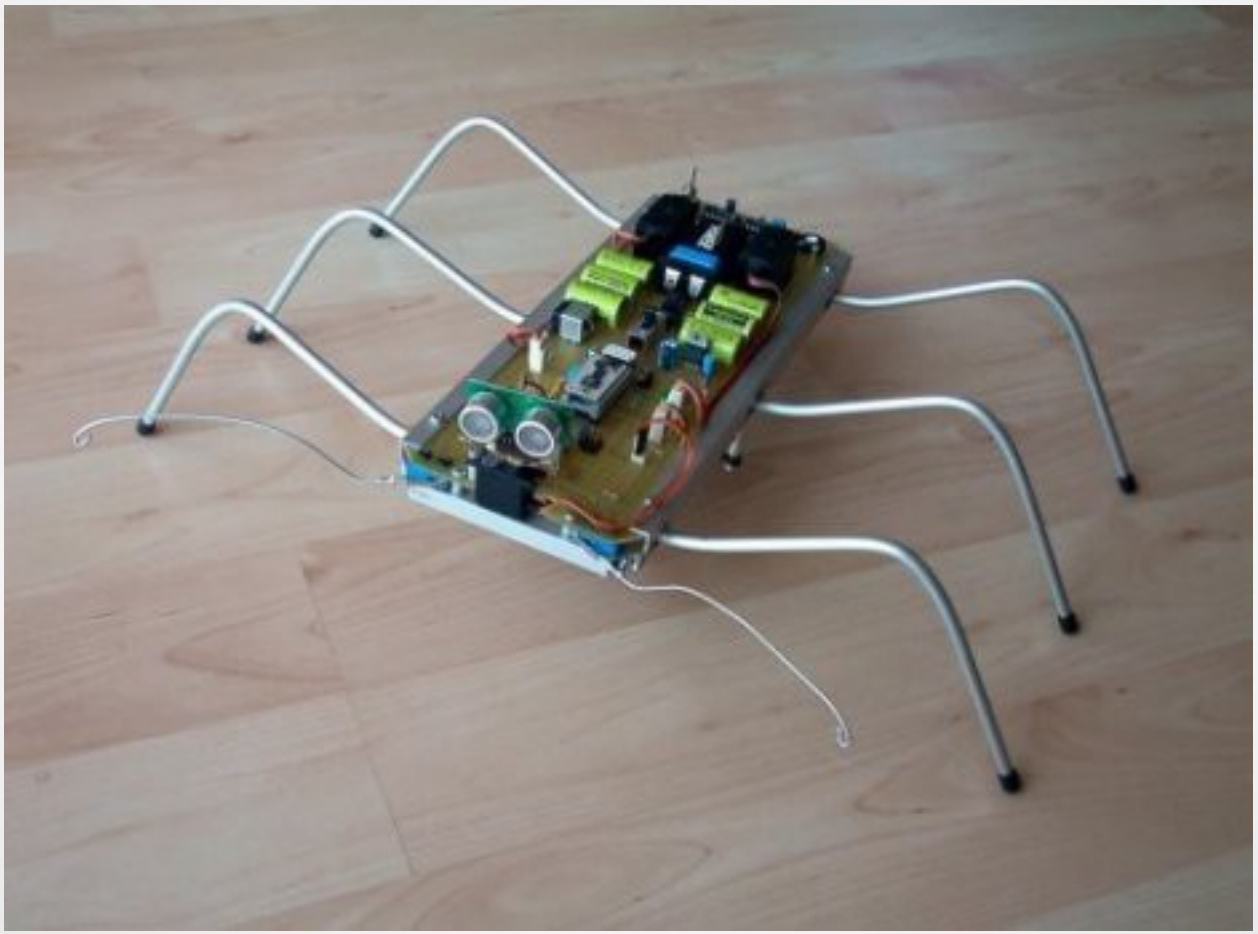


[Rodriguez]

Legged Walking

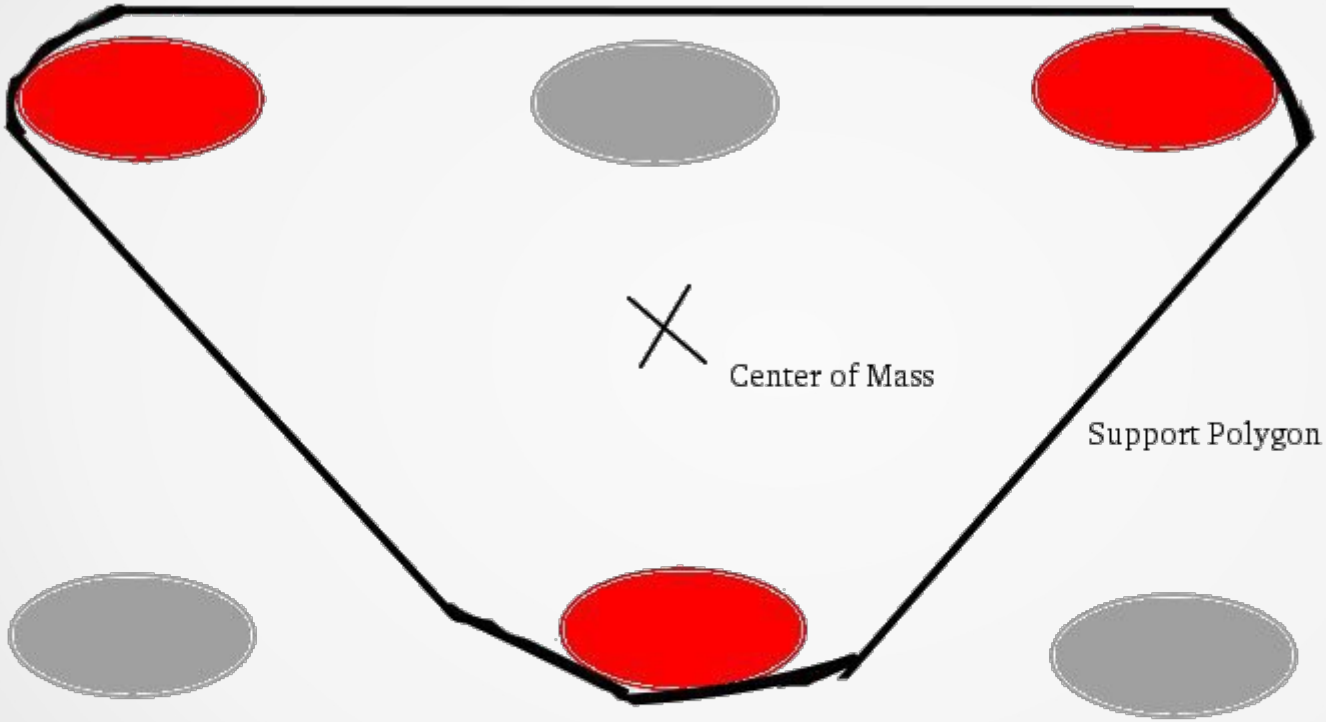
- Static stability
- Dynamic stability with the Zero-Moment-Point

6-Legged Robots



[ubergizmo]

Static Stability



Static Stability

- Very stable walking
- Static stable walking is slow
- Fast movements of the Robot leads to strong forces
  - Center of Mass is then no longer the most relevant stability reason
- Inverse Kinematics for 6-Legged-Robots is very expensive

Zero-Moment-Point

- The main idea of the ZMP-Walking during a step is:
  - The body and therefore the Center of Mass of the robot moves
  - The sole of the foot does not move or turn
- Position of the Zero-Moment-Point is an indicator how well the robot stands
  - The center of the feet is the optimal point

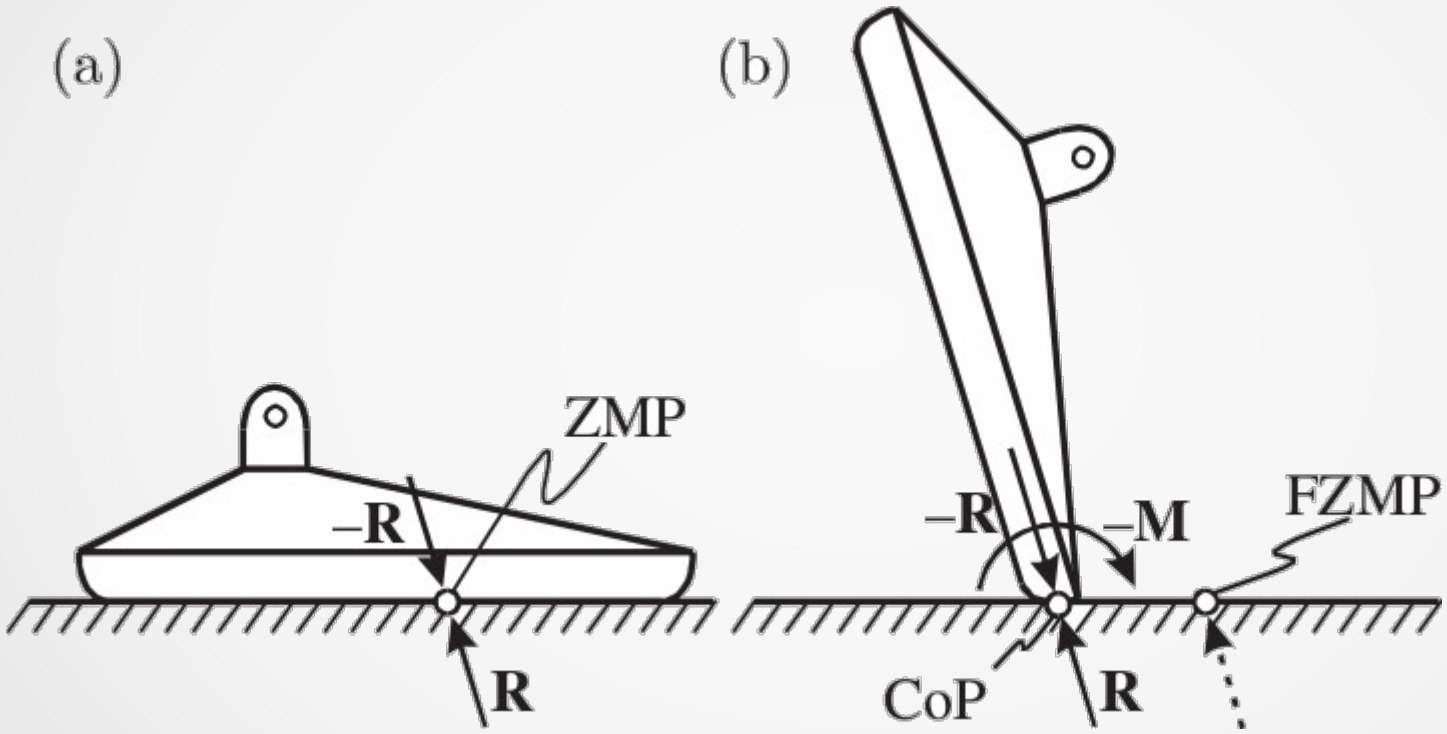
Zero-Moment-Point

- The Zero-Moment-Point (ZMP) „is defined as that point on the ground at which the net moment of the inertial forces and the gravity forces has no component along the horizontal axes“ [Dasgupta]
- The Robot moves itself via steps
  - The sole has no moment along the horizontal axes
- If the ZMP is in the Support Polygon, the robot is stable
- Otherwise the ZMP is not defined, the robot is falling in the direction of the calculated (F)ZMP

Center of Pressure

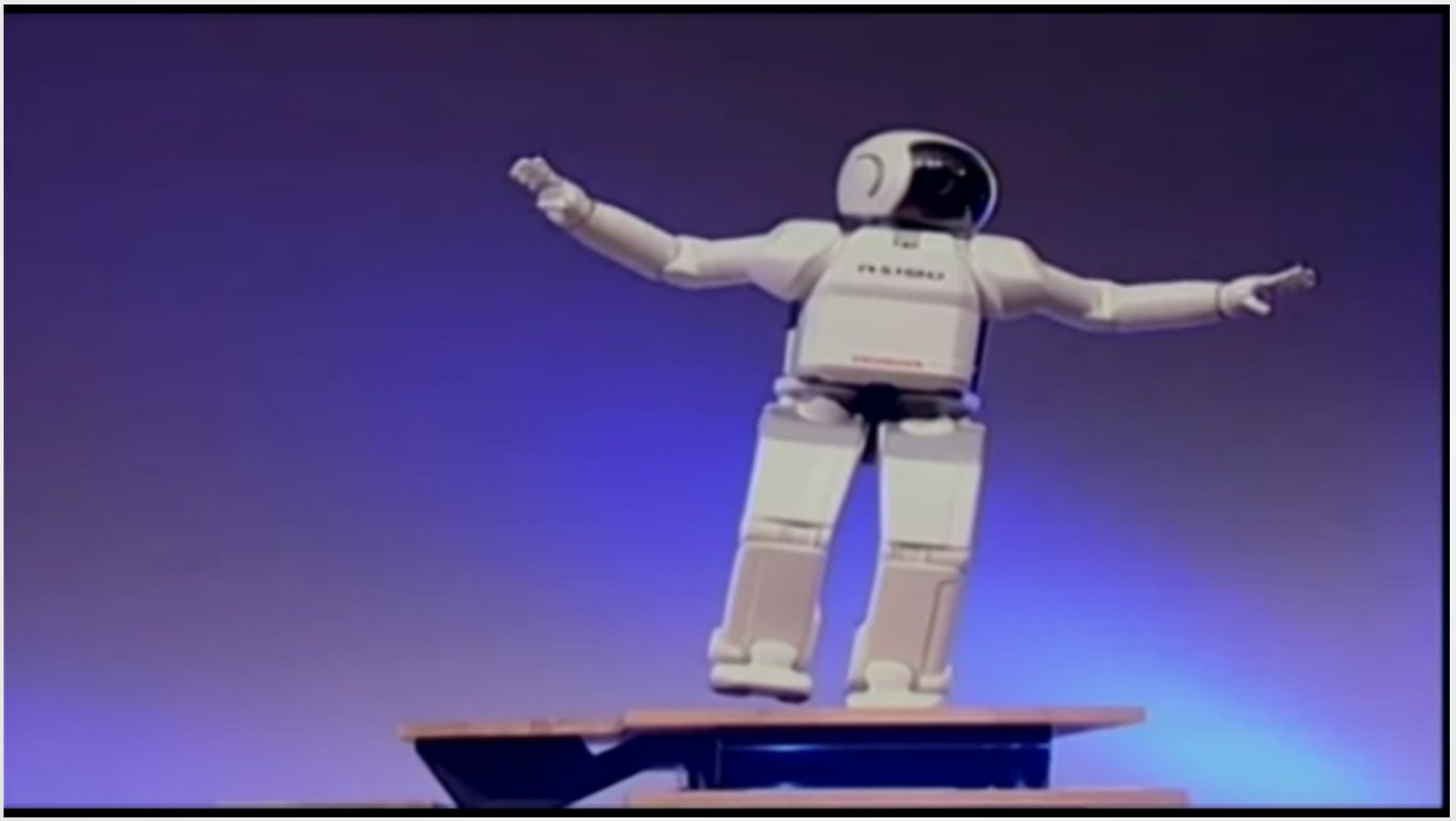
- The pressure between the foot and the ground can be replaced by a force acting at the center of pressure. [Vukobratovic]
- If there exists a ZMP it coincides with the Center of Pressure

ZMP



[Vukobratovic]

ASIMO



[Honda]

Zero-Moment-Point

- Moment about a point Q is (as in [Sardain]):

$$\boldsymbol{M}_Q^{gi} = \boldsymbol{QG} \times m\boldsymbol{g} - \boldsymbol{QG} \times m\boldsymbol{a}_G - \dot{\boldsymbol{H}}_G$$

- If the Moment is orthogonal to the z axis, Q is the Zero-Moment-Point
  - i.e. $\boldsymbol{M}_Q^{gi} \times \boldsymbol{z} = \boldsymbol{0}.$
- The moment of gravitation and translation of the robot is:

$$\boldsymbol{R}^{gi} = m\boldsymbol{g} - m\boldsymbol{a}_G$$

Zero-Moment-Point

- With Euler's Extension of Newton's Laws of motion one can see, that the robot is stable if a point Q exists, which is in the support polygon and fulfills the following equations

$$\boldsymbol{R}^c + \boldsymbol{R}^{gi} = \mathbf{0} \qquad \boldsymbol{M}_Q^c + \boldsymbol{M}_Q^{gi} = \mathbf{0}.$$

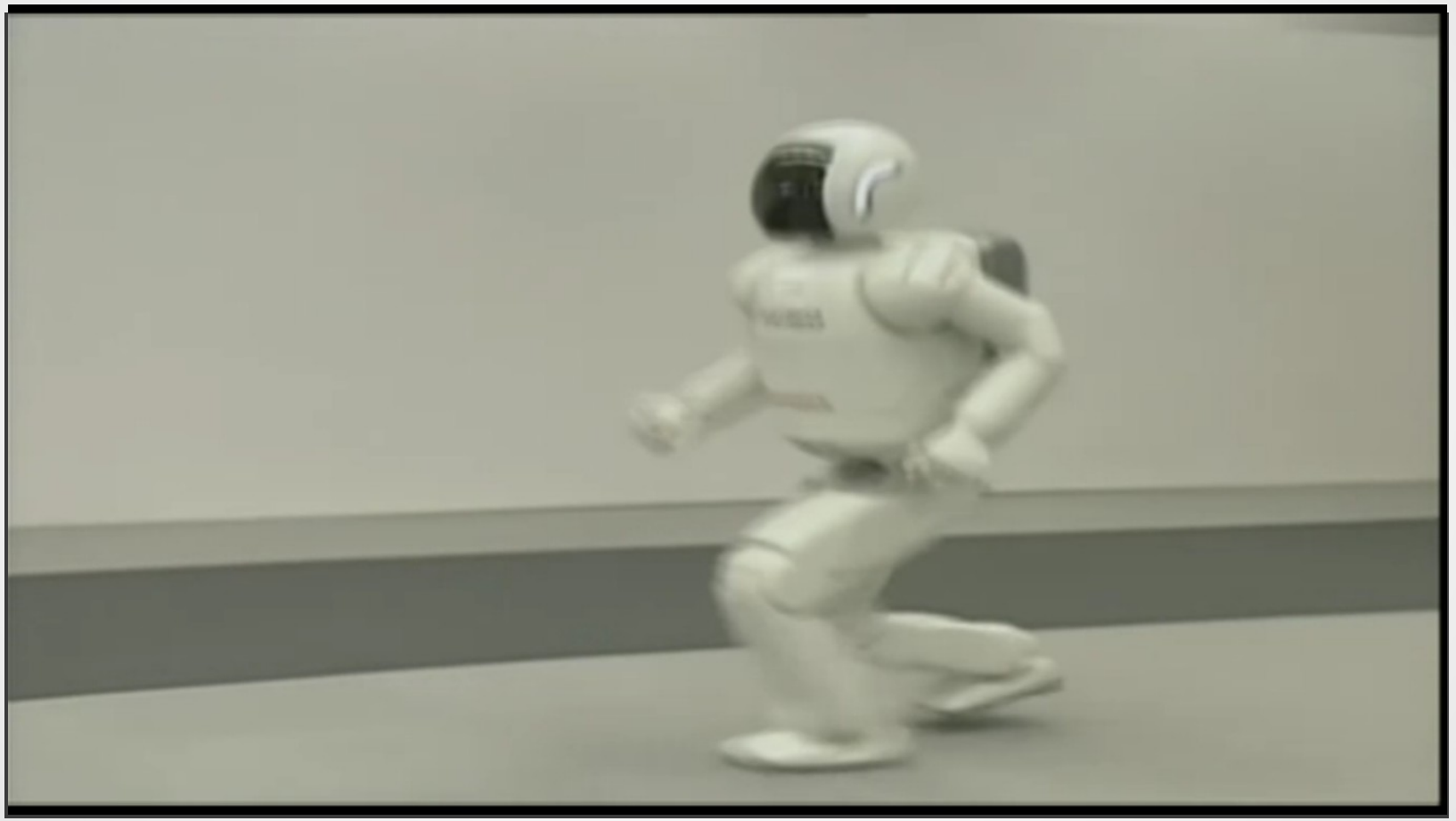
- The friction of the robot with the floor must be high enough.
- There is only one point on the z axis which fulfill the second equation

Zero Moment Point

- To solve the second equation one can use this formula:

$$\boldsymbol{OD} = \frac{mg\boldsymbol{z} \times \boldsymbol{OG} \times \boldsymbol{z} + \boldsymbol{z} \times \dot{\boldsymbol{H}}_O}{mg + m\boldsymbol{a}_G \cdot \boldsymbol{z}}$$

Asimo



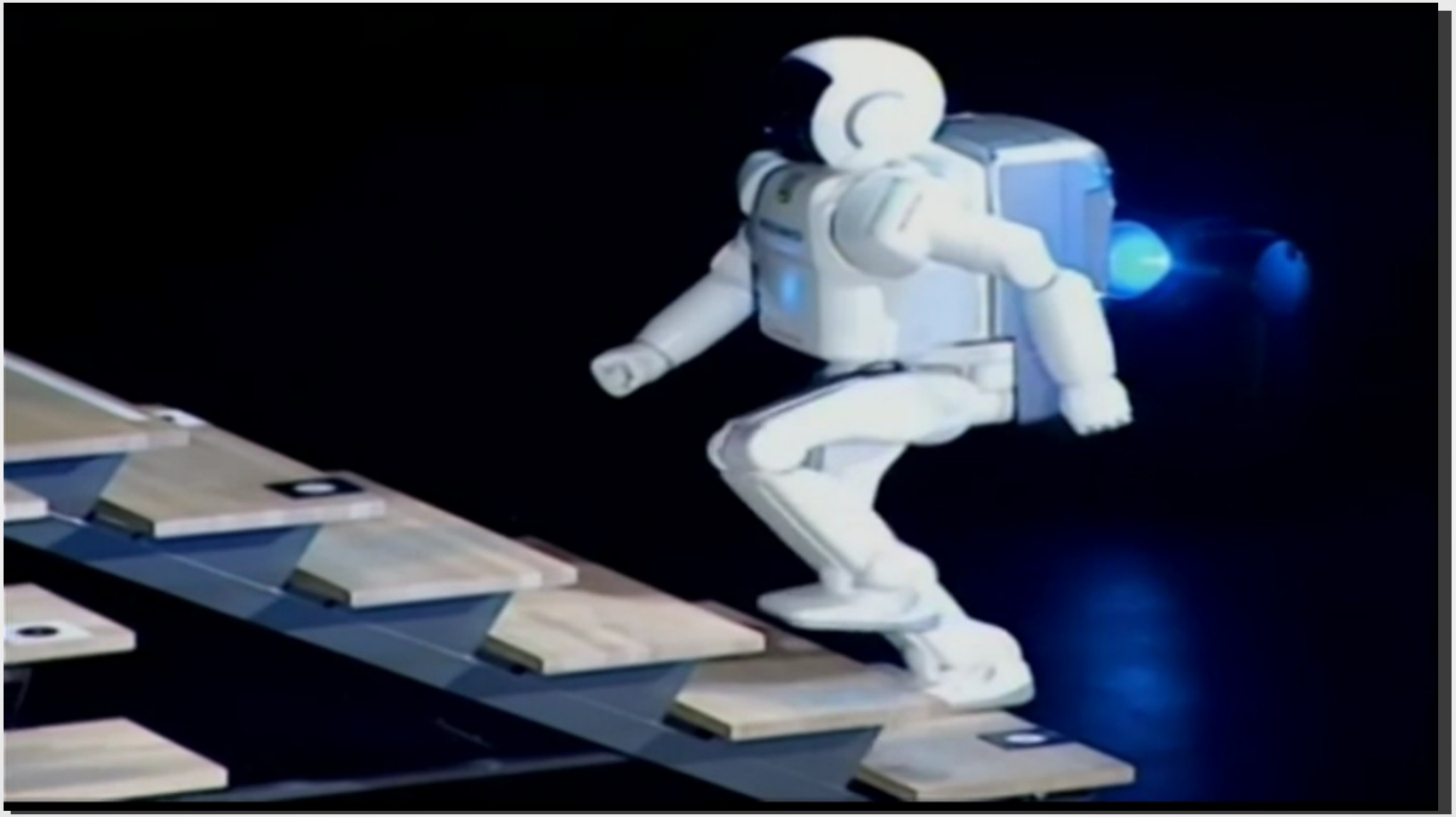
[Honda]

ZMP and Stairs

- The Definition of the ZMP assumes the support polygon is in one height
- during the double support phase if you go up- or downstairs the Support Polygon is in two heights
- Pseudo ZMP: $\alpha_1 \boldsymbol{CC}_1 + \alpha_2 \boldsymbol{CC}_2 = \mathbf{0}$

$$\alpha_1 = \frac{R_1^p}{(R_1^p + R_2^p)} \qquad \alpha_2 = \frac{R_2^p}{(R_1^p + R_2^p)}$$

Asimo



[Honda]

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