Autonomous and Mobile Robotics

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Real-time Evasive Motions for Humanoid Robots

(slides prepared by Daniele De Simone)

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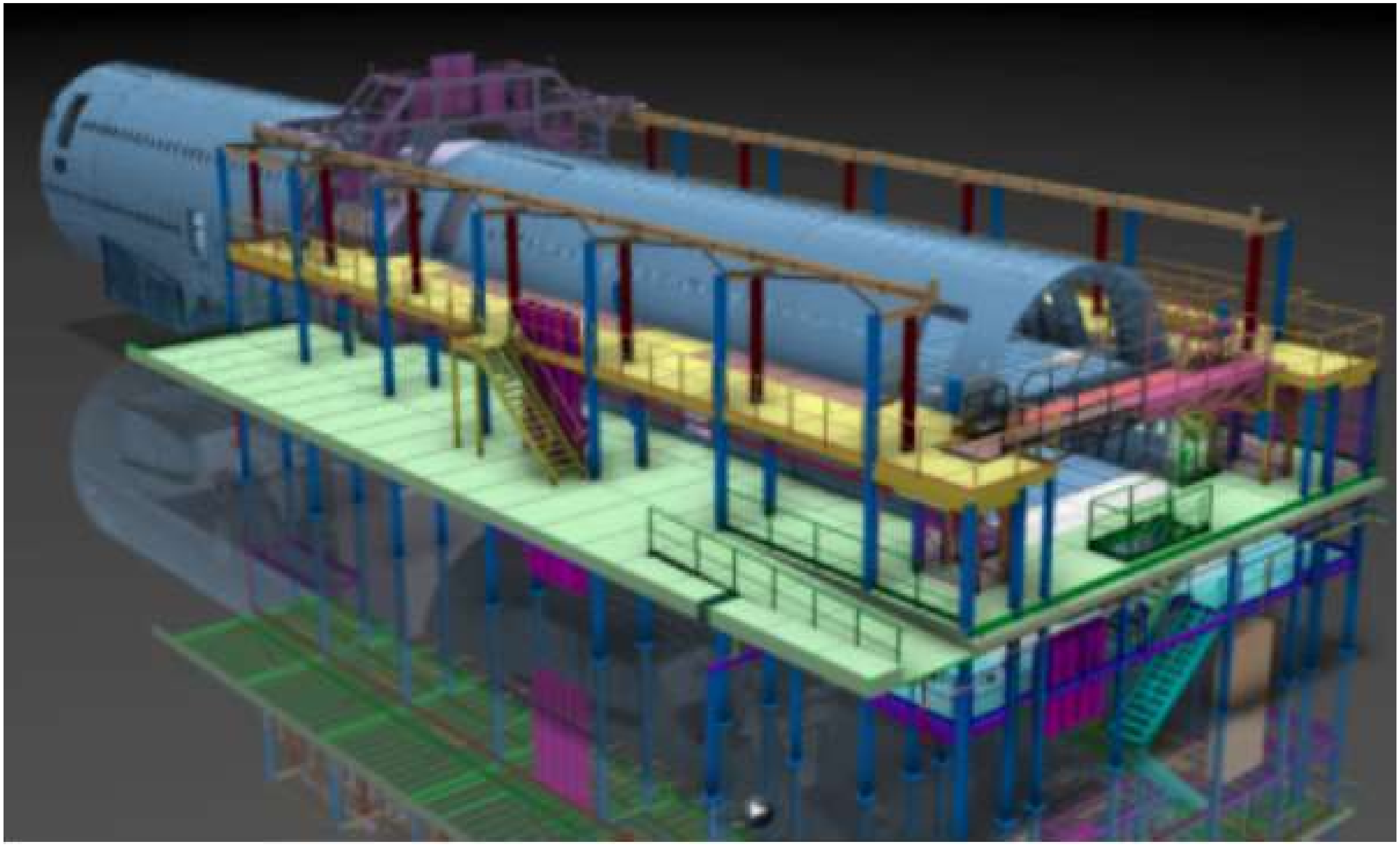
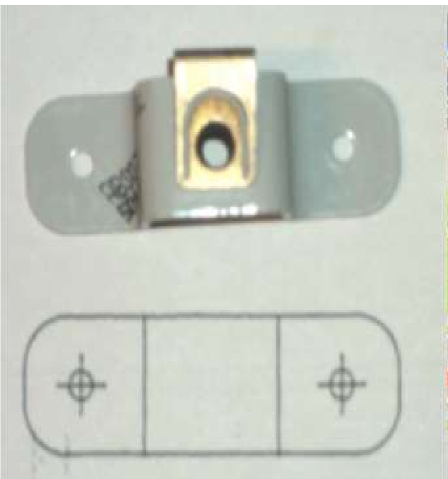
Introduction

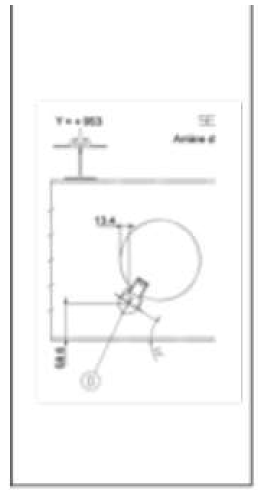
- COMANOID: Multi-contact Collaborative Humanoids in Aircraft Manufacturing started on January 1, 2015



Introduction

- Automate the process of printing brackets for wires in the aircraft





Introduction

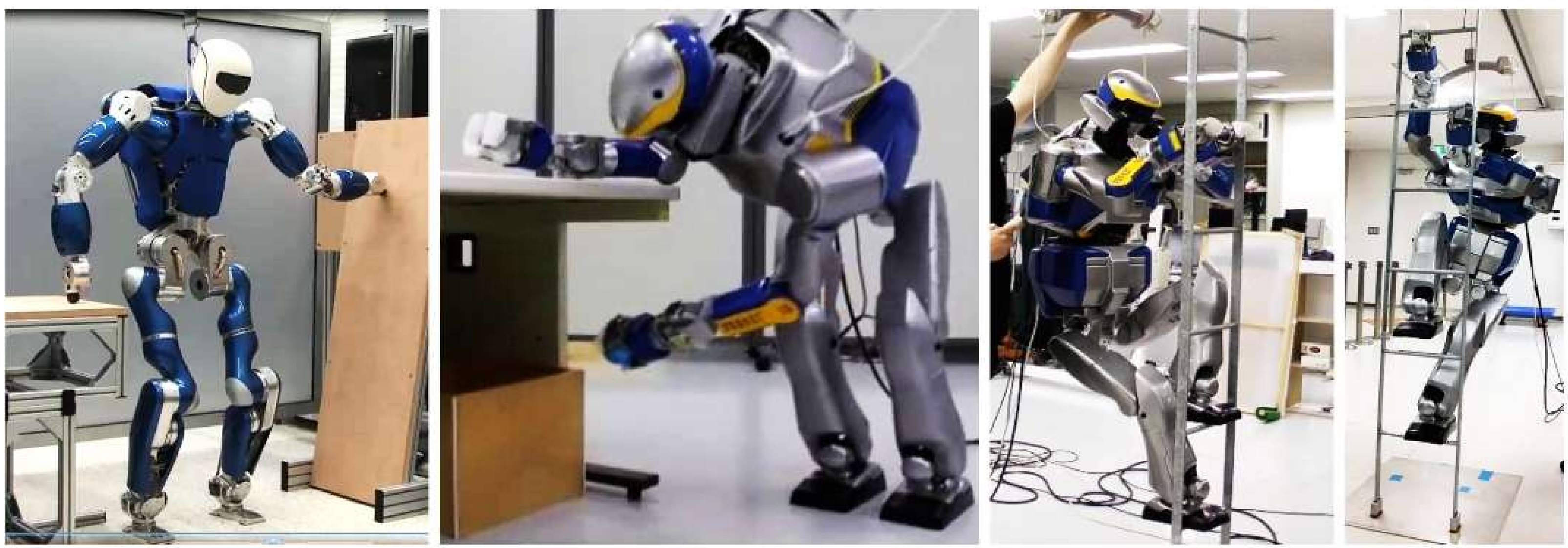
- Airbus Group ready to deploy COBOT in production
- COBOT can work only in the 60% of the environment

Introduction

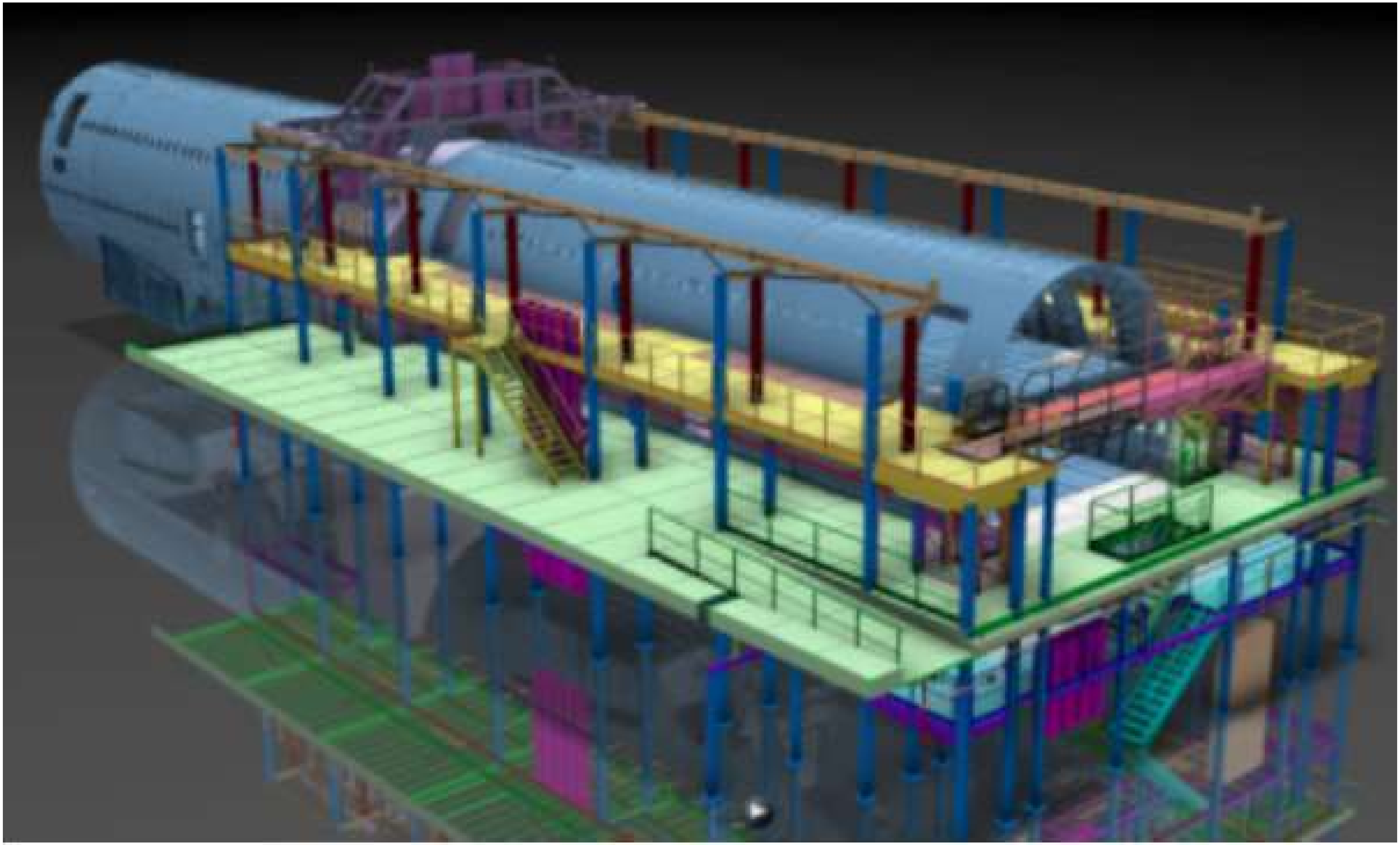
- Environment too complex for a wheeled robot

Introduction

- Tasks are achieved in constrained or hard postures
- Multi-contact situations

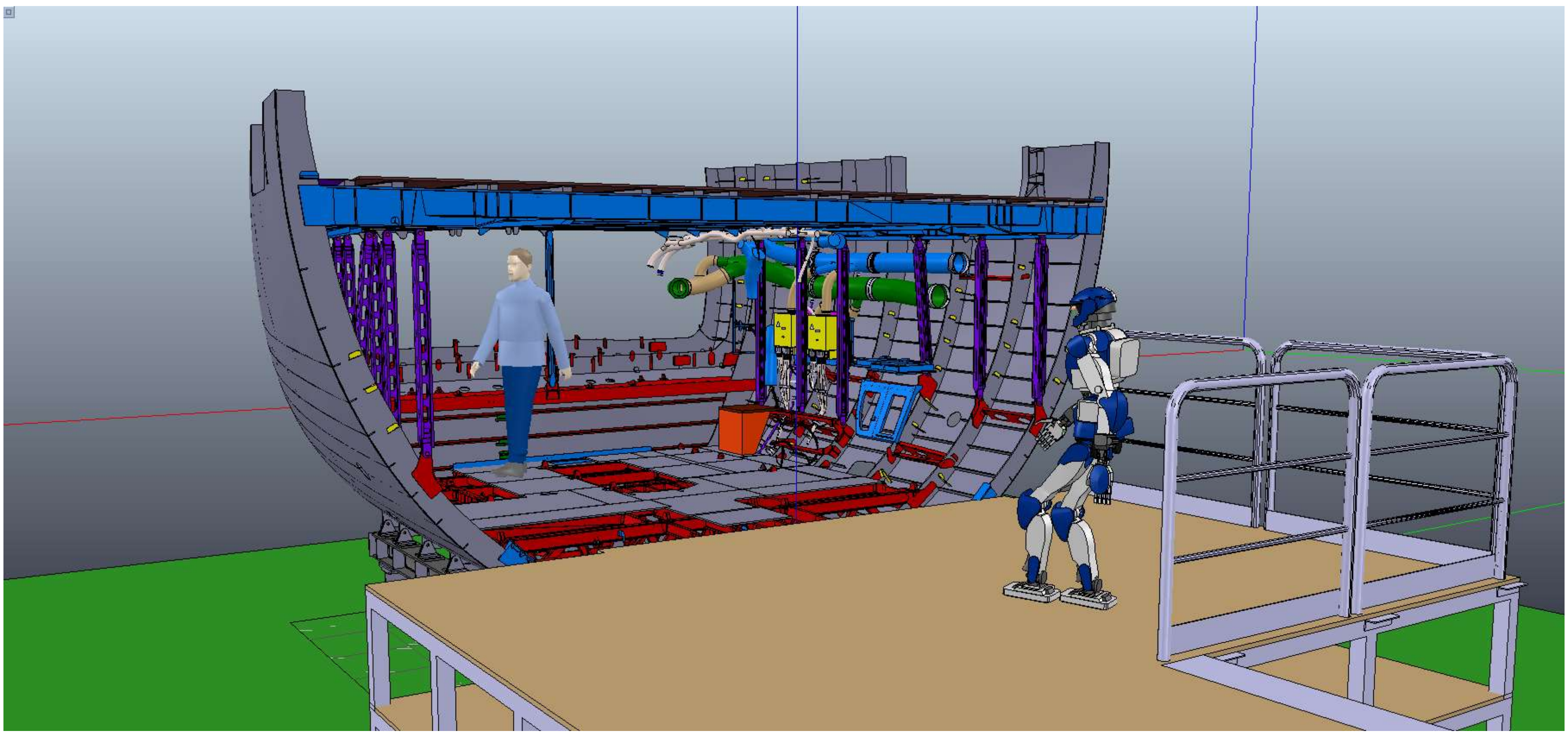


Introduction



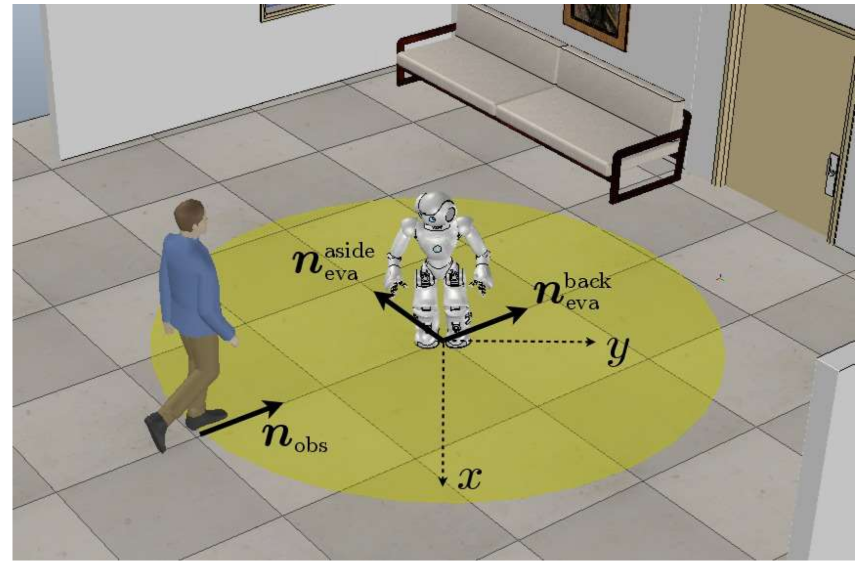
Motivations

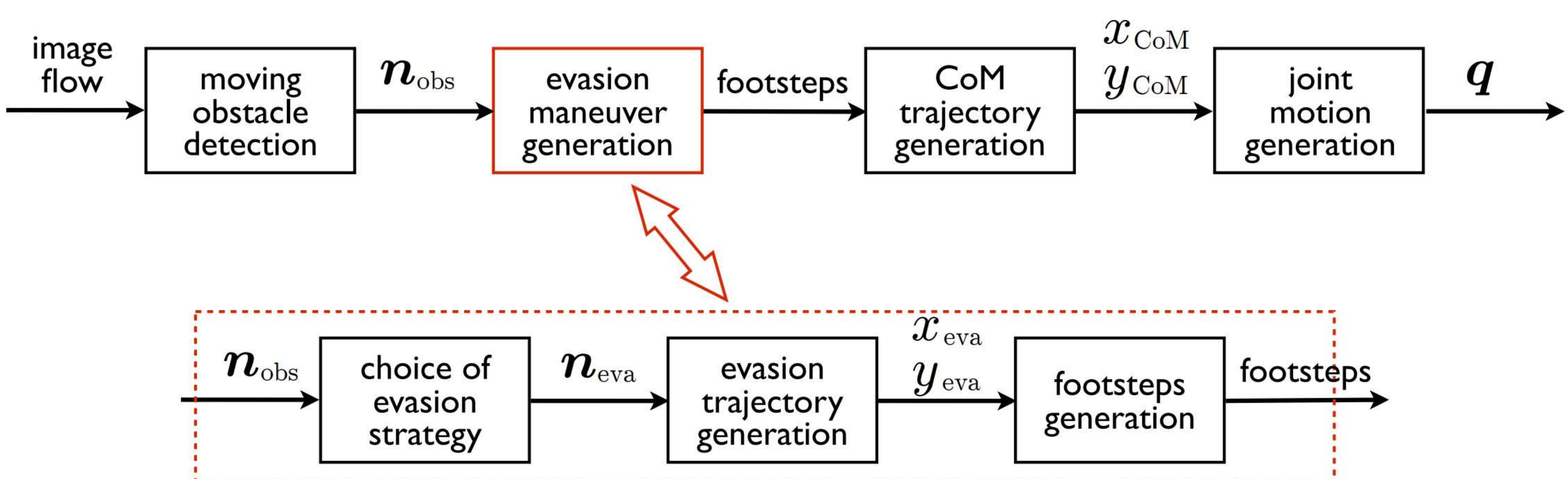
- Human-robot coexistence
- Robots and human workers share their workspace
- We need to guarantee **safety** for both humans and robots



Problem Formulation

- A humanoid robot is standing in its workspace when a moving obstacle enters its **safety area**
- An evasive motion must be generated to avoid the collision
- Commands should be made available to the robot controller in **real time**

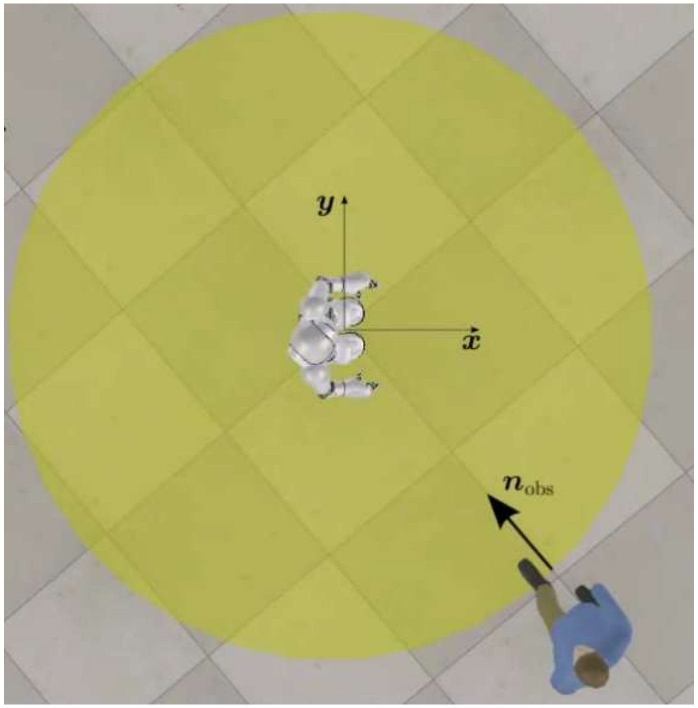




Moving Obstacle Detection

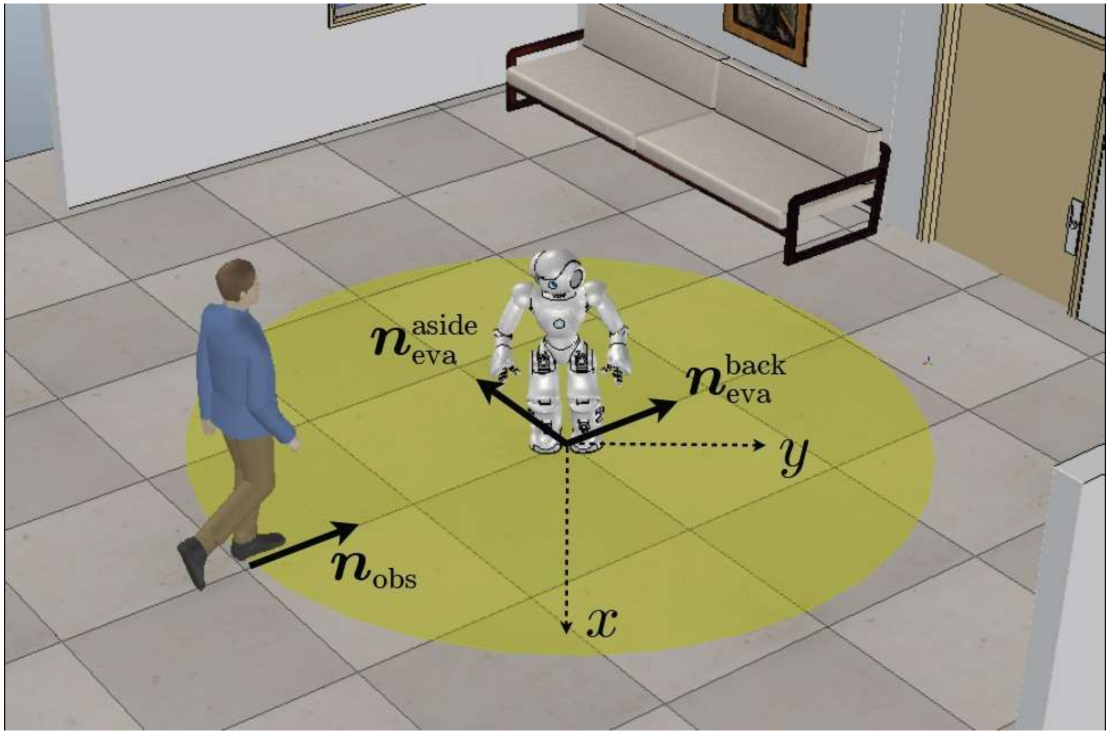
- Using a depth camera the obstacle is detected while entering the robot safety region

- Through the sensor, the approach direction of the obstacle relative to the humanoid is computed



Evasion Maneuver Generation

- Two possible evasion strategies:
  - **Move Back:** the humanoid aligns with the direction of the incoming obstacle and moves backwards
  - **Move Aside:** the humanoid aligns with the direction orthogonal to that of the moving obstacle and moves backwards

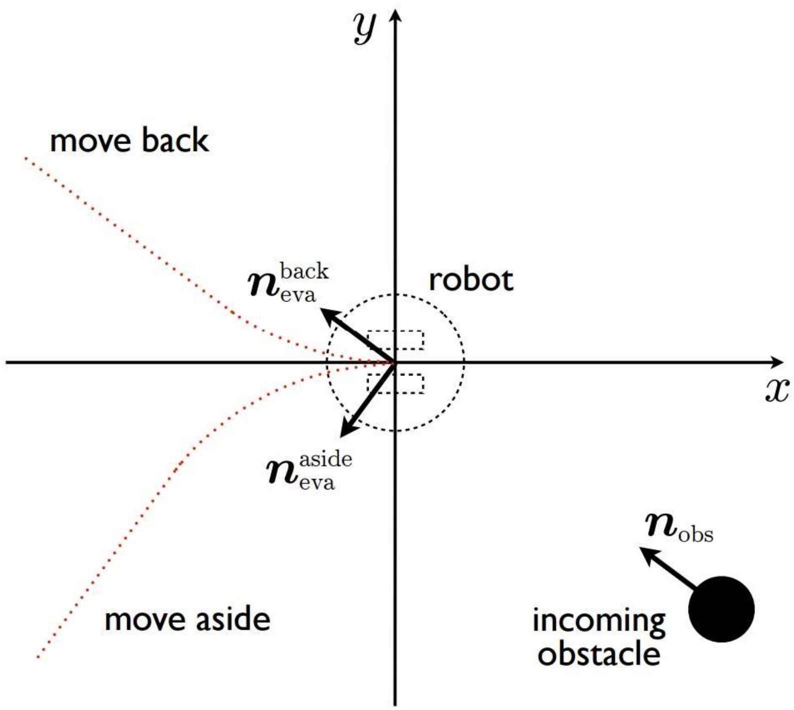


Evasion Maneuver Generation

- A controlled unicycle model is used to generate the evasion trajectory

$$\dot{x} = v \sin\theta$$
$$\dot{y} = v \cos\theta$$
$$\dot{\theta} = \omega$$

$$v = \bar{v}$$
$$\omega = k \, \text{sign}(\theta_{\text{eva}} - \theta)$$



Evasion Maneuver Generation

- Integration of model equation under the proposed control law provides a closed form for the evasion trajectory

$$
\begin{aligned}
x(t) &= \bar{v}\,\frac{\sin kt}{k} \\
y(t) &= \text{sign}(\theta_{\text{eva}})\,\bar{v}\,\frac{1-\cos kt}{k} \\
\theta(t) &= \text{sign}(\theta_{\text{eva}})\,kt
\end{aligned}
$$

for $t \leq t_s$ and

$$
\begin{aligned}
x(t) &= x(t_s) + \bar{v}(t - t_s)\cos\theta_{\text{eva}} \\
y(t) &= y(t_s) + \bar{v}(t - t_s)\sin\theta_{\text{eva}} \\
\theta(t) &= \theta_{\text{eva}}
\end{aligned}
$$

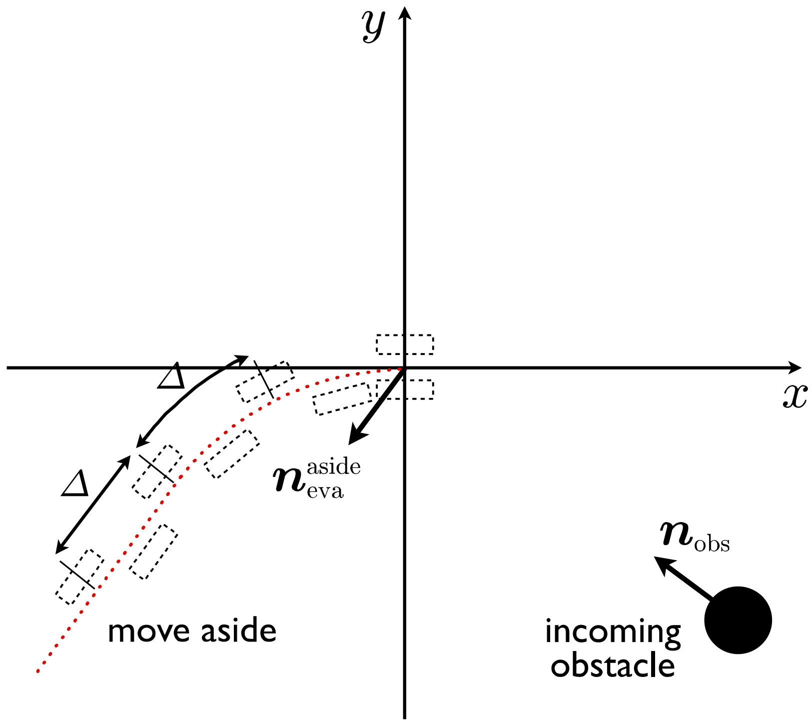
for $t > t_s$

Evasion Maneuver Generation

- Once the trajectory is computed, footsteps for the robot are planned to follow the trajectory
- The trajectory is sampled using a constant time interval and the coordinates of the footsteps are computed by displacing samples alternatively to the left and right of the trajectory

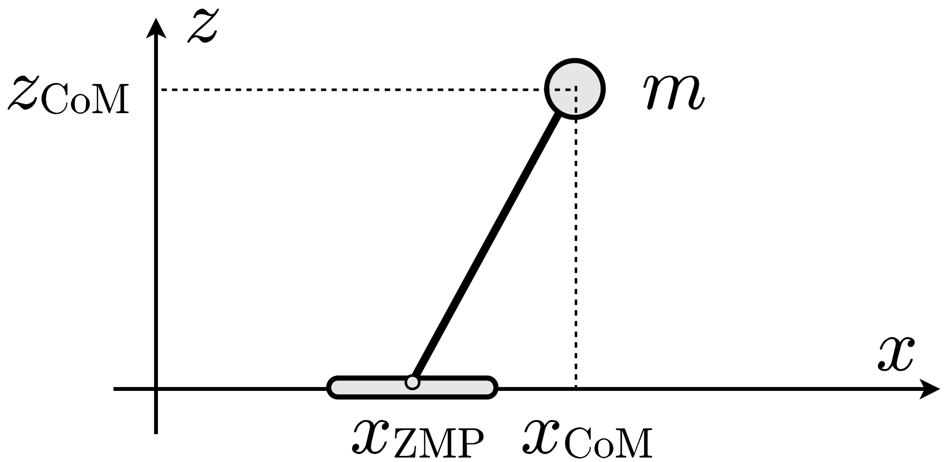
$$x_{r,k} = x_k + d\sin\theta_k$$

$$y_{r,k} = y_k - d\cos\theta_k$$



Center of Mass Trajectory Generation

- Zero Moment Point based locomotion for a humanoid
- Humanoid dynamics modeled as a Linear Inverted Pendulum

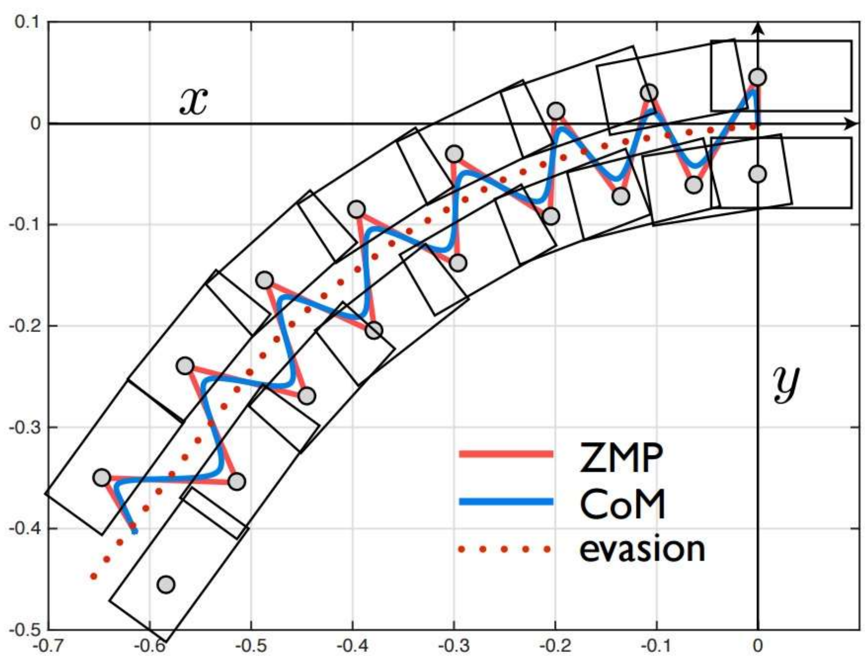


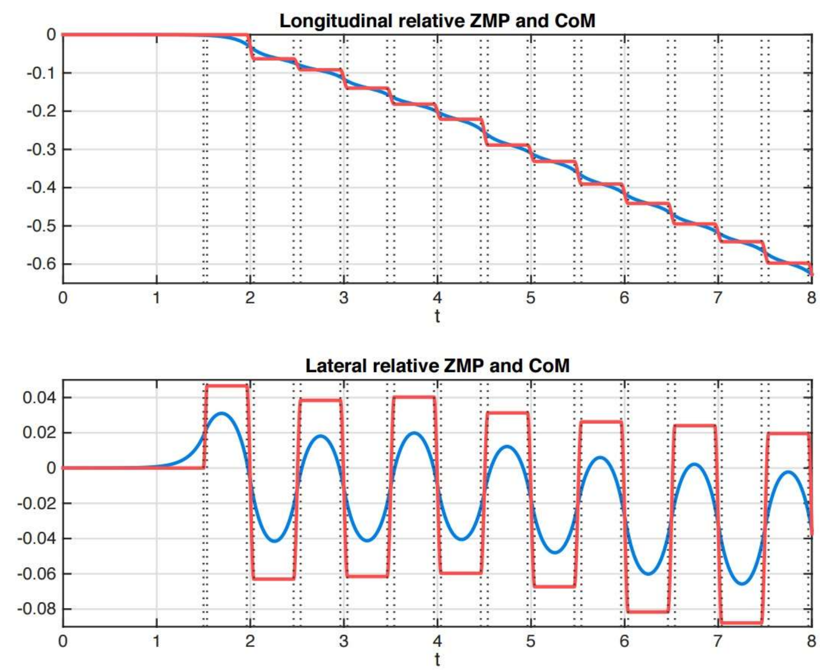
$$\ddot{x}_{\mathrm{CoM}}(t) - \eta^2 (x_{\mathrm{CoM}}(t) - x_{\mathrm{ZMP}}(t)) = 0$$

Center of Mass Trajectory Generation

- ZMP reference is generated starting from the footsteps
- The Center of Mass trajectory is computed with the ZMP as an input

$$x^*_{\mathrm{CoM}}(t) = e^{-\eta t} x_{\mathrm{CoM}}(0) + \frac{x_{\mathrm{s}}(t) - e^{-\eta t} x_{\mathrm{u}}(0) + x_{\mathrm{u}}(t)}{2}$$





Kinematic Controller

- To track the reference trajectory for the CoM a classic kinematic controller is used

$$\dot{q} = J^{\#}(q)\left(\dot{t}_d + K(t_d - t)\right) + \left(I - J^{\#}(q)J(q)\right)w$$

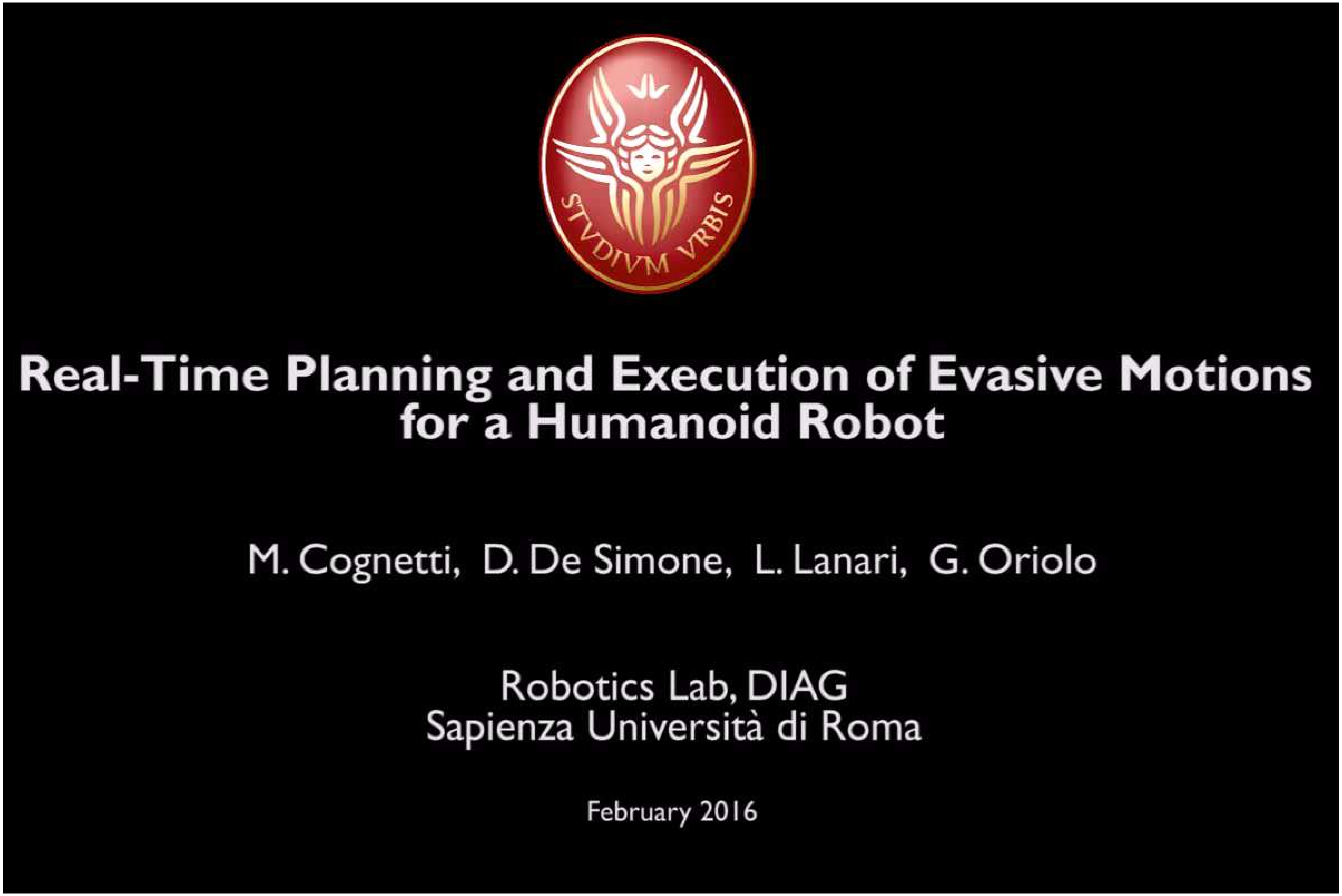
- Possible choice for the nullspace

$$w = \nabla_q H(q)$$

- Maximize distance from singular configurations

$$H(q) = \sqrt{\det J(q)J^T(q)}$$

Wrapping Up


STVDIVM VRBIS
Real-Time Planning and Execution of Evasive Motions for a Humanoid Robot
M. Cognetti, D. De Simone, L. Lanari, G. Oriolo
Robotics Lab, DIAG
Sapienza Università di Roma
February 2016

References

- *Real Time Planning and Execution of Evasive Motions for a Humanoid Robot* – M. Cognetti, D. De Simone, L. Lanari, G. Oriolo
- *Boundedness Issues in Planning of Locomotion Trajectories for Biped Robots* – L. Lanari, S. Hutchinson, L. Marchionni