

Les défis de l'interaction humain-robot

Bruno Watier



Introduction

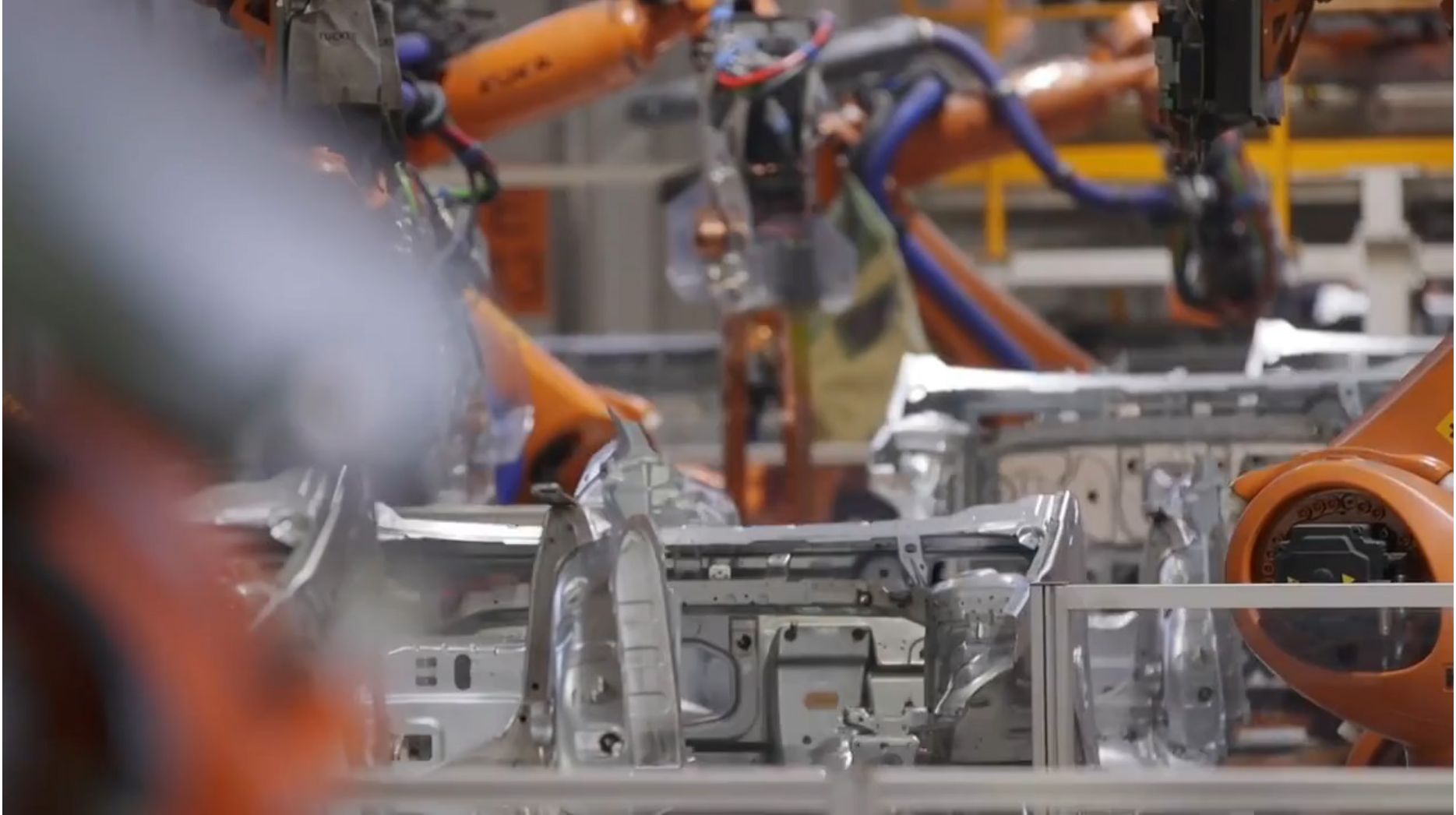
■ Les raisons de la collaboration

- 3,2% du cout du travail
- La réduction de la charge de travail est la principale source de réduction des pathologies
- Industrie 5.0

Common MSDs	General symptoms	General signs
Cubital tunnel syndrome	Painful joints	Decreased range of motion
Rotator cuff syndrome	Pain in wrists, shoulders, forearms, knees	Deformity
DeQuevain's disease	Pain, tingling or numbness in hands/ feet	Decreased grip strength
Trigger finger	Fingers or toes turning white	Loss of muscle function
Sciatica	Shooting or stabbing pains in arms/legs	Paresthesias
Epicondylitis	Back or neck pain	
Tendinitis	Swelling or inflammation	
Raynoud's Phenomenon	Stiffness	
Carpet layer's knee	Cramping	
Herniated spinal disc	Burning sensations	
Low back pain	Heaviness	
Hand-arm vibration syndrome	Inability to do everyday tasks	
	Weakness or clumsiness in hands, dropping things	

Introduction

- Usine Seat (robots KUKA)



Introduction



Crédit : LAAS-CNRS

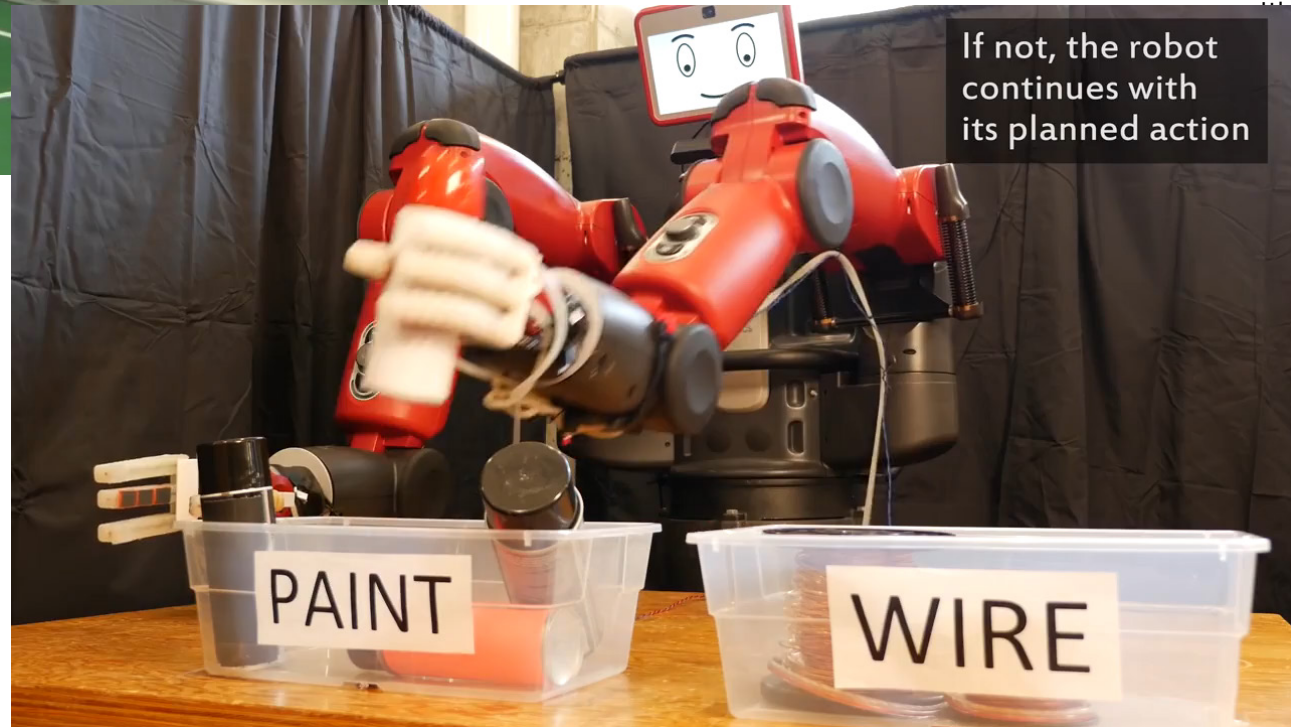
Introduction

Real-time... Without any interaction



- Boston university – MIT CSAIL

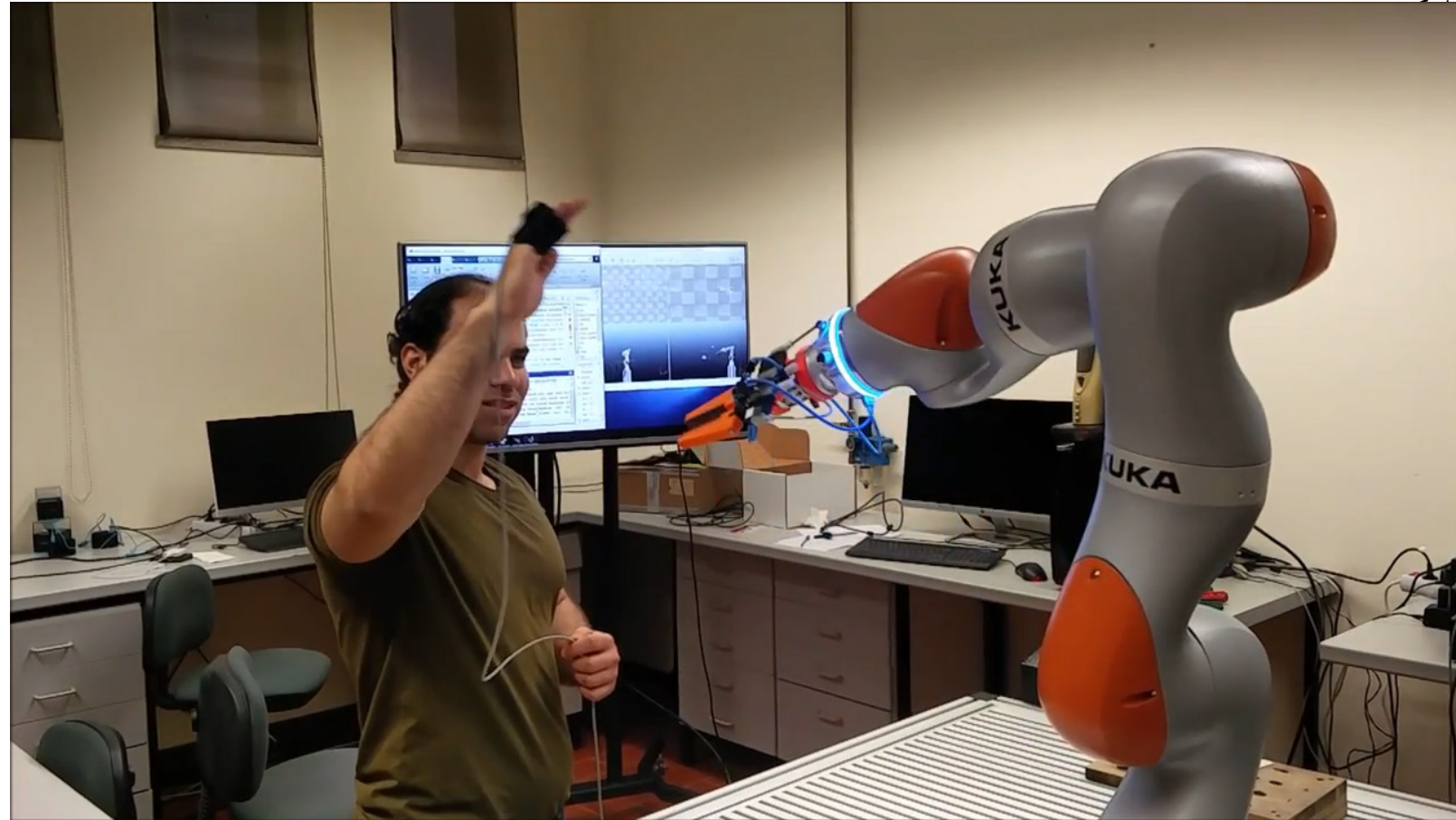
- University of western Sydney



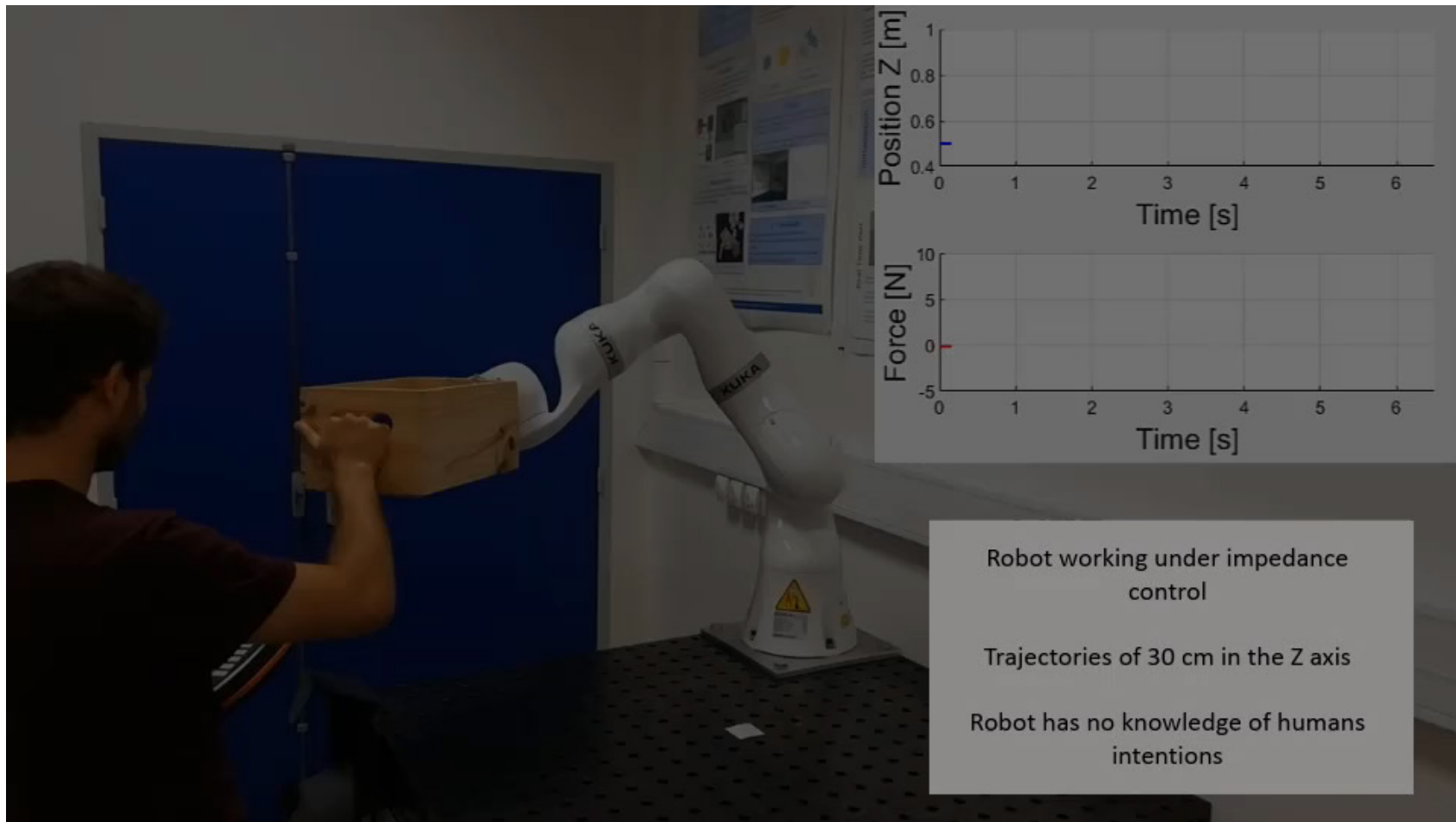
Introduction

Human-robot collision avoidance

Crédit : Université de Coimbra



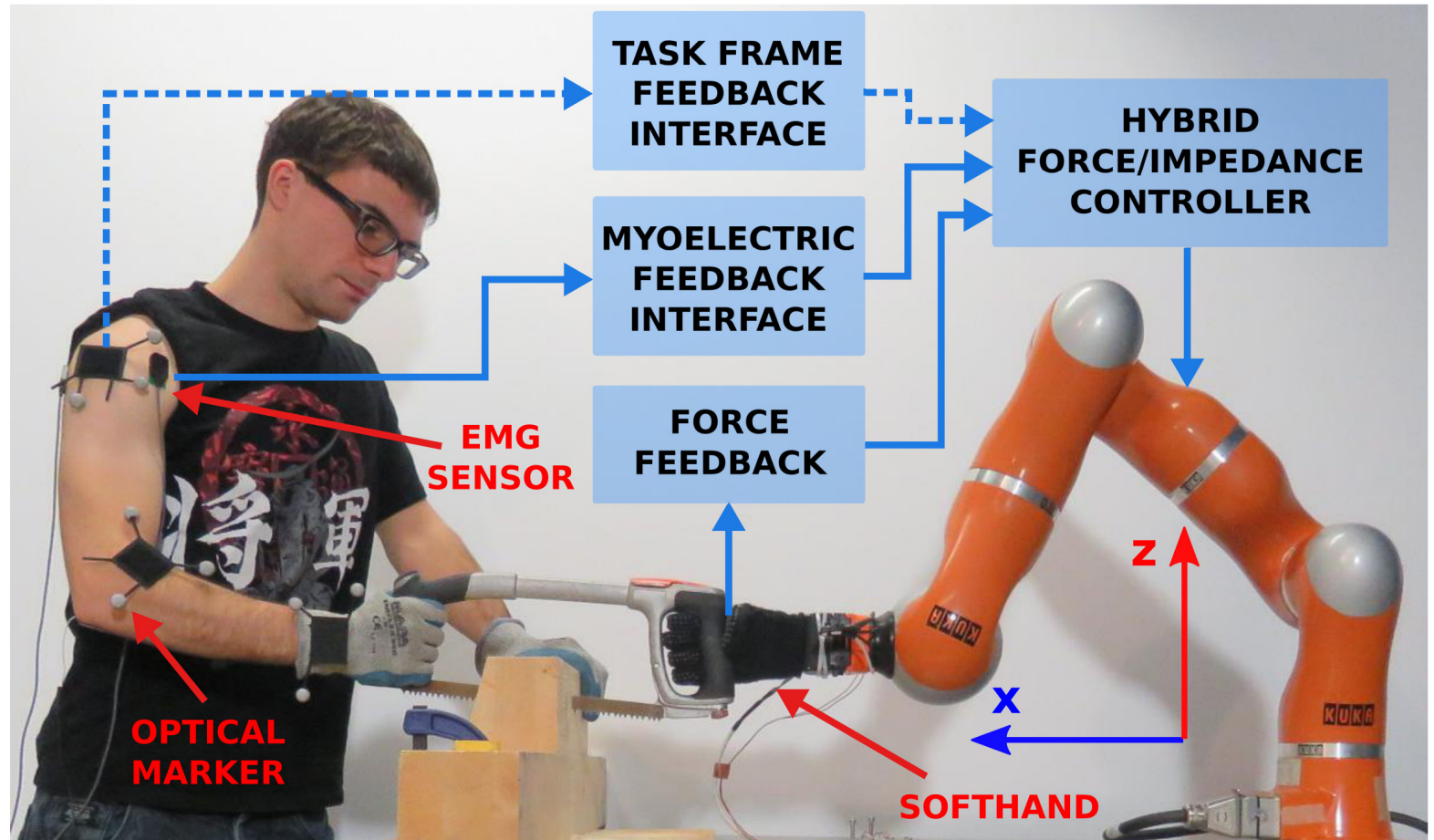
Introduction



- Iphrimob (projet LGP/LAAS-CNRS)

Introduction

L. Peternel, N. Tsagarakis, and A. Ajoudani, "Towards multi-modal intention interfaces for human-robot co-manipulation," in *2016 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 2016, pp. 2663–2669



Introduction



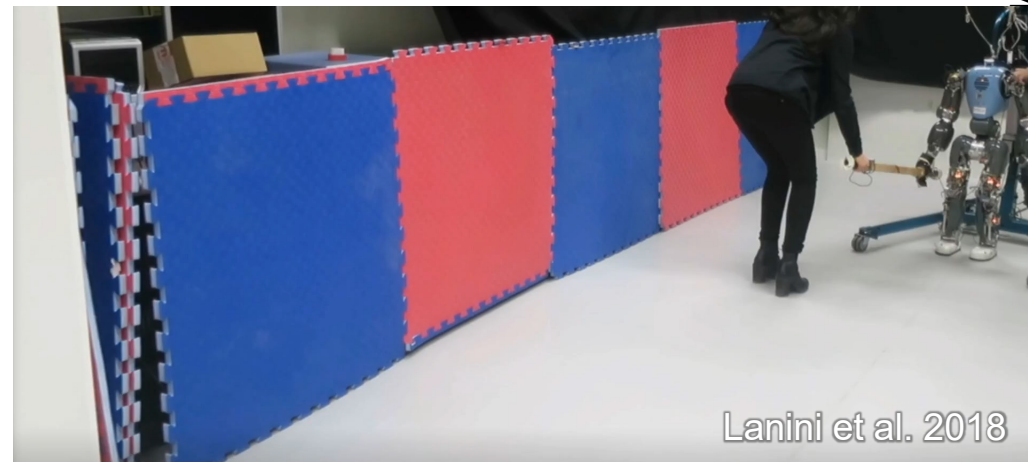
- Service départemental de secours des Pyrénées orientales



Introduction



Bussy et al. 2012



Lanini et al. 2018



Agravante et al. 2019

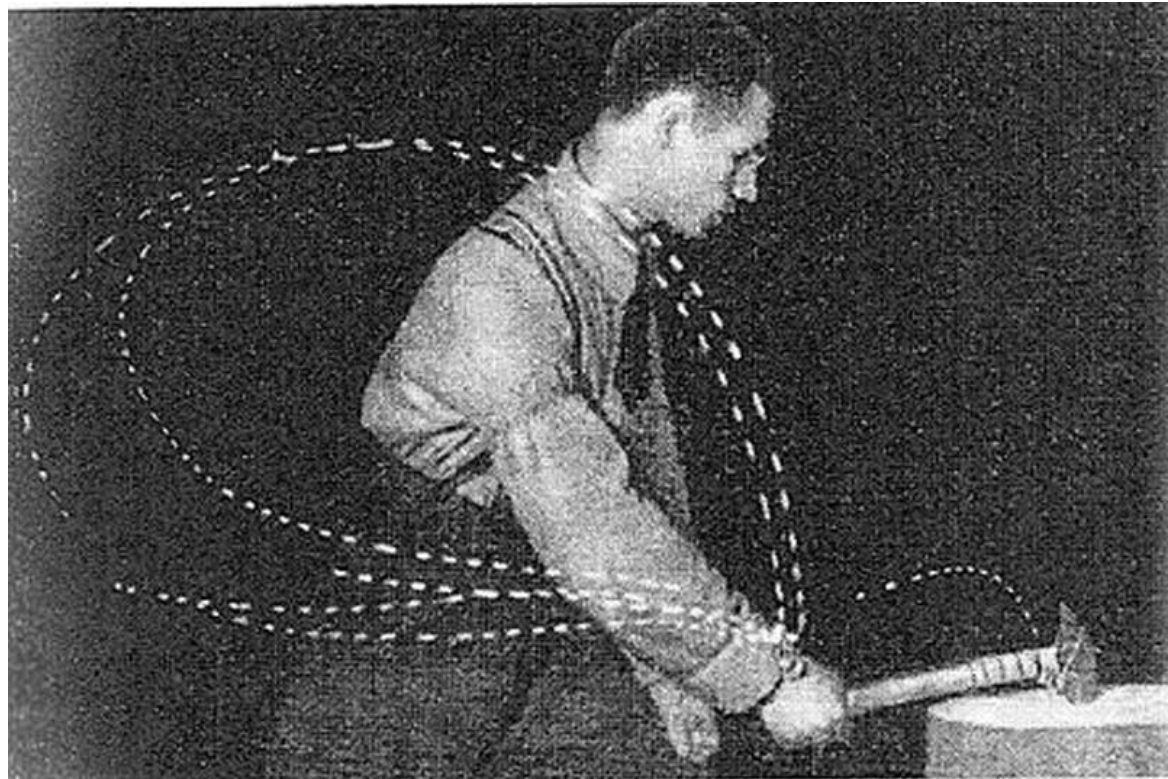


Agravante et al. 2019

Introduction

Le comportement humain est variable (inter et intra sujets)

Bernstein (1930)



Introduction

- Pour une meilleure collaboration:
 - Conception du robot
 - Puissance
 - Forces et couples articulaires adaptés
 - Modèle physique de l'humain
 - Préviation du comportement
 - Cinématique
 - Dynamique
 - Caractéristiques musculaires

Vers une collaboration efficace

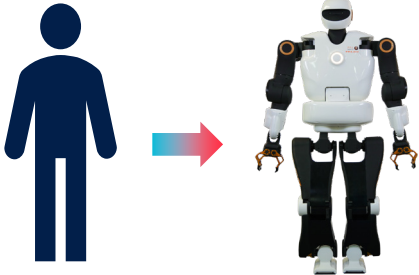


- Illustration à partir du projet CoBot

**Collaborer c'est
comprendre le
« sens du
mouvement »
humain
(Berthoz A., 1997)**

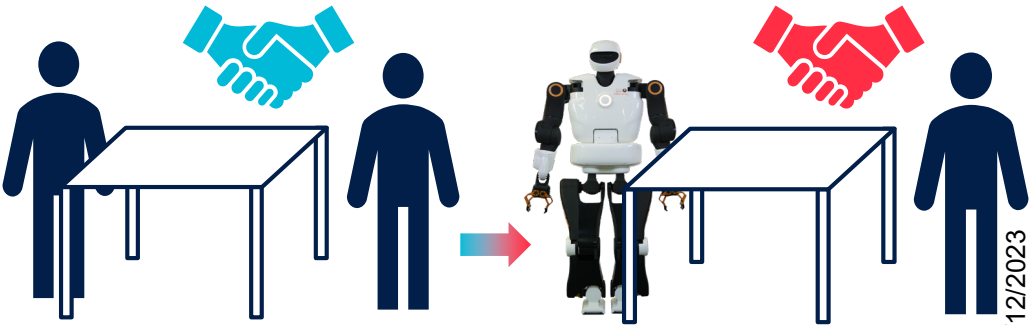
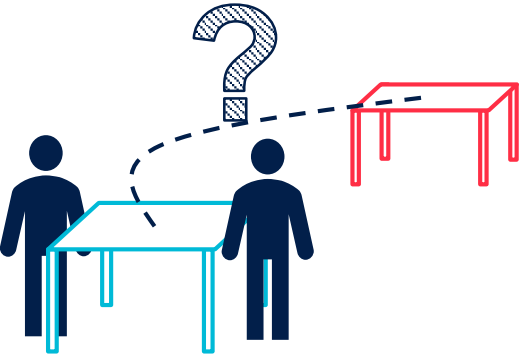
1

Reduced problem

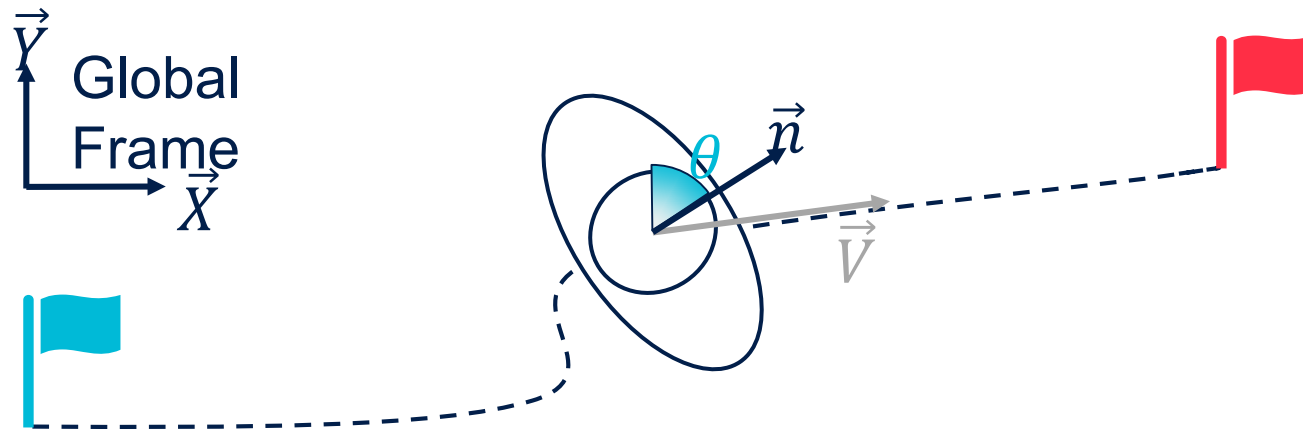
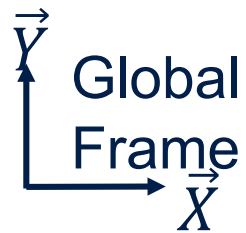
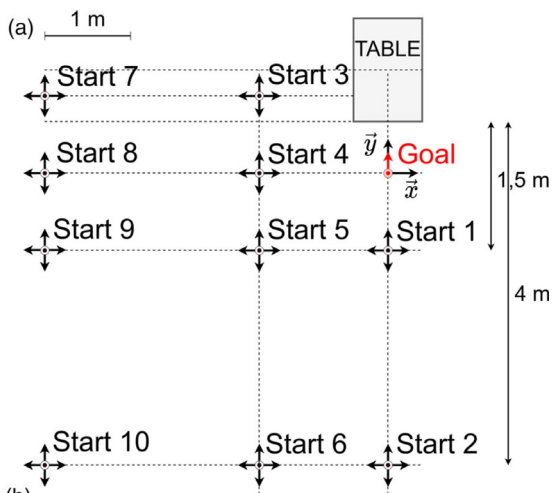


2

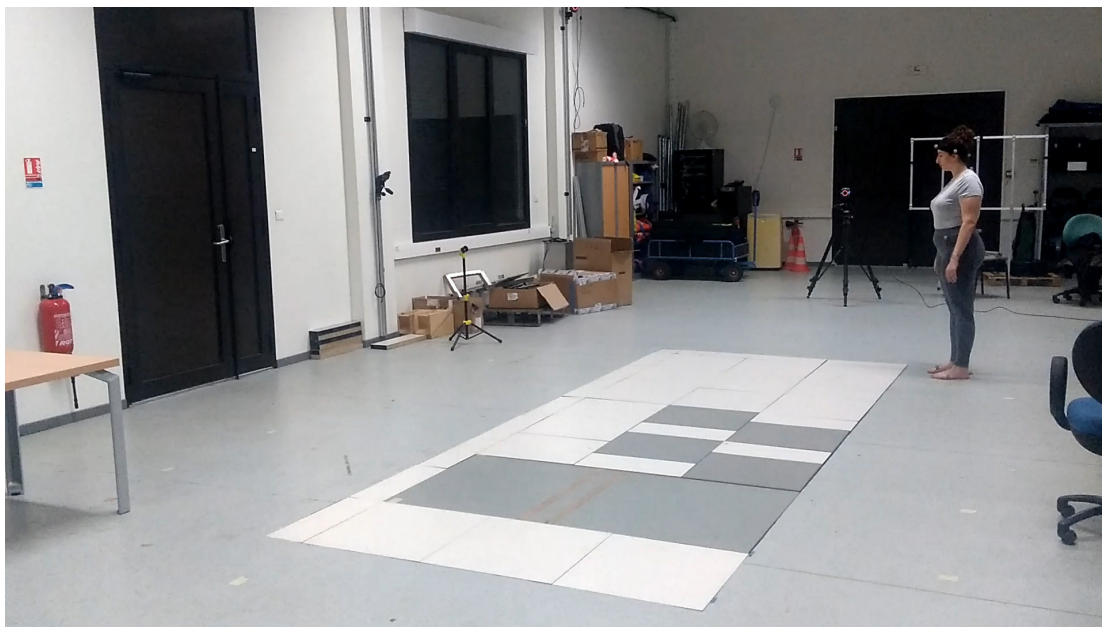
Final problem



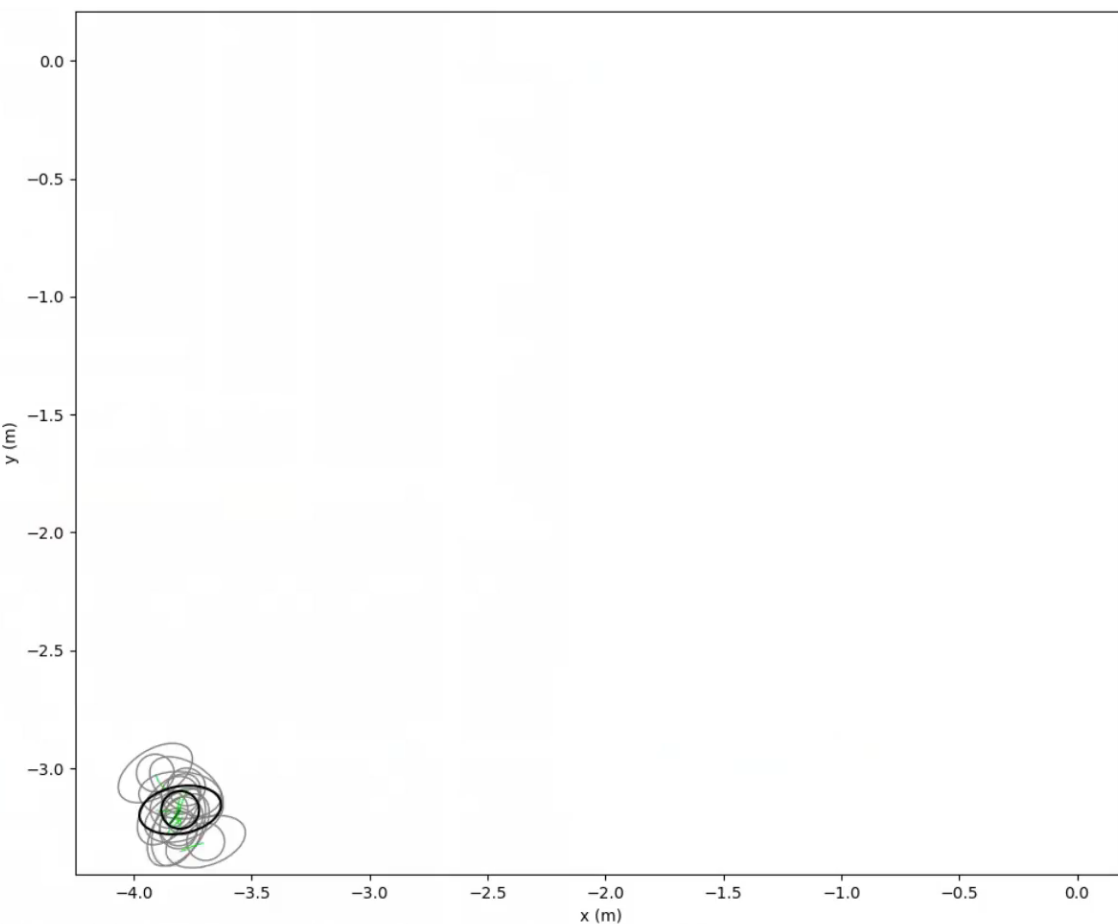
Reduced problem



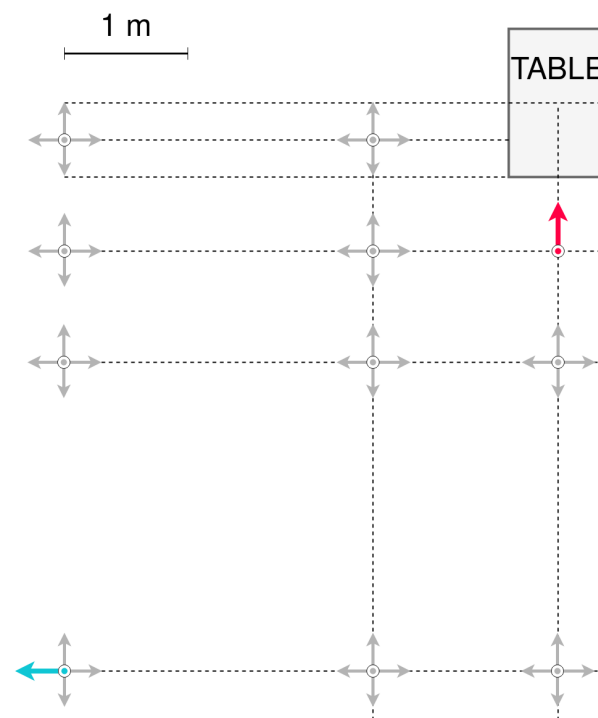
How can we generate human-like trajectories from a starting position to a goal position?



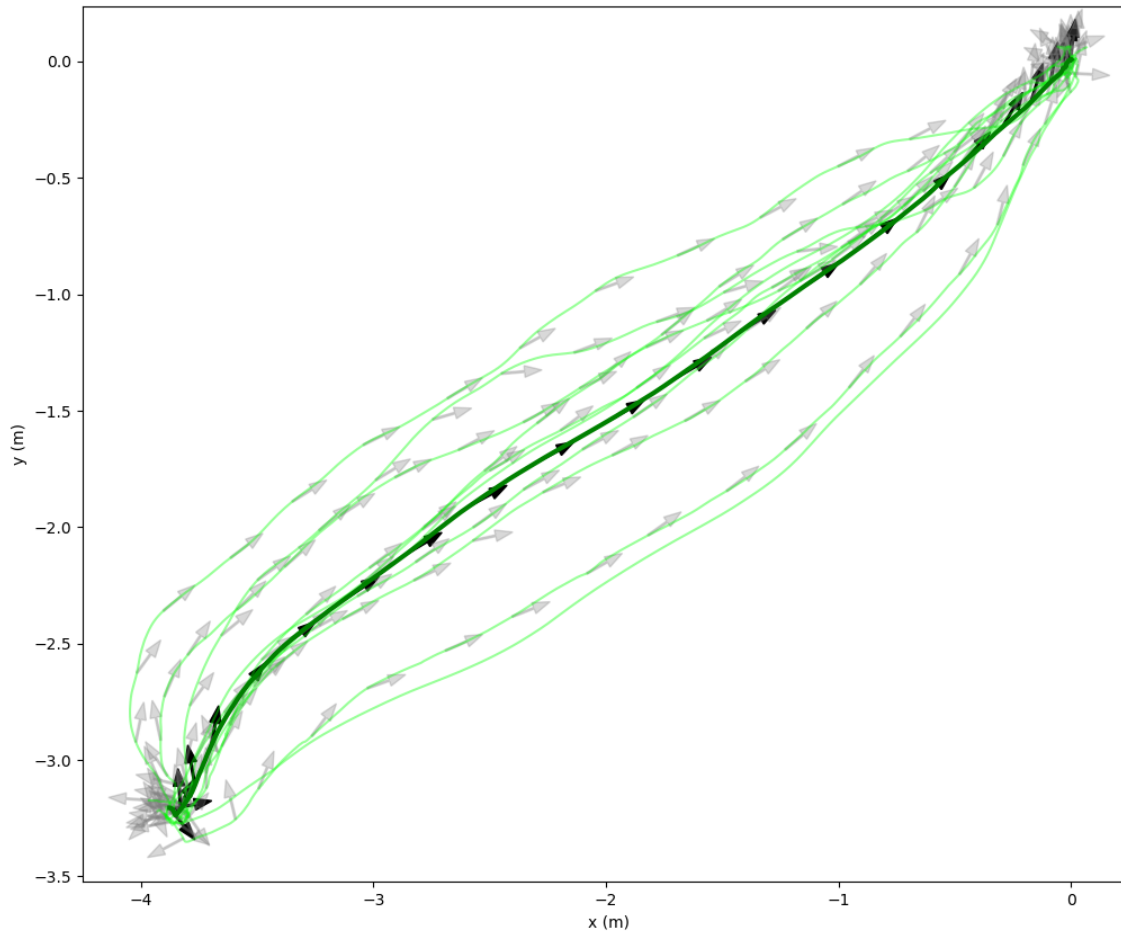
Reduced problem



Do all the subjects show a similar behaviour?



Reduced problem



Do all the subjects show a similar behaviour?



How can we quantify the differences?

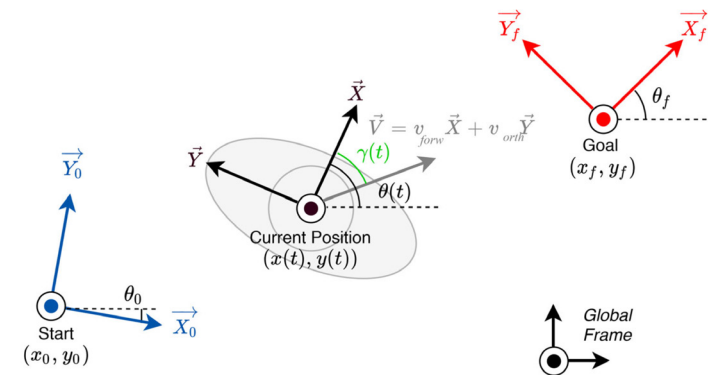
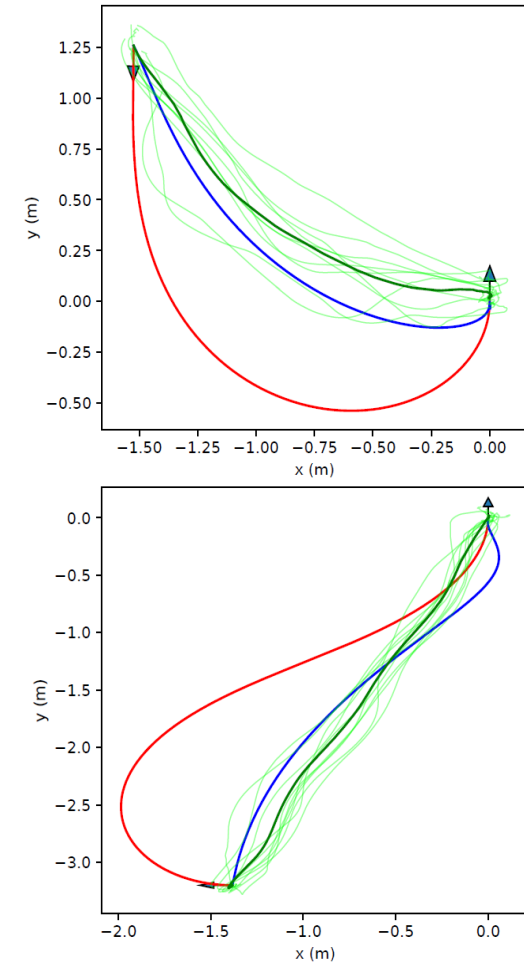
- > Linear distance d_{xy}
 ≈ 10 cm
- > Angular distance d_{θ}
 $\approx 27,5^{\circ}$

Reduced problem

- > Study of human-like trajectory models:
 - Implementation of 2 human-like trajectory models:
 - Clothoids curves¹
 - Optimal Control (OC) model²
 - Comparison with the measurements

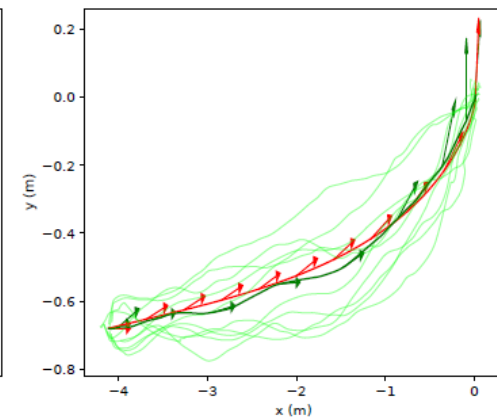
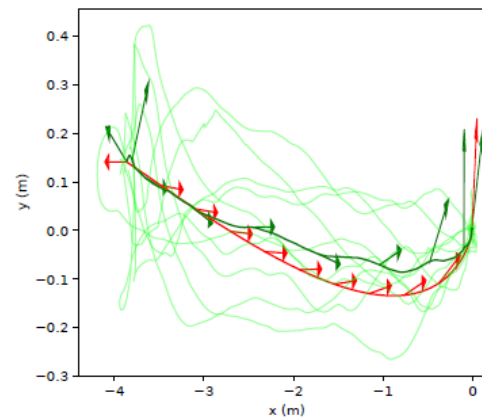
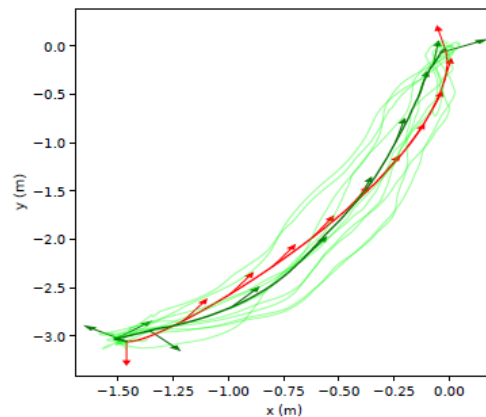
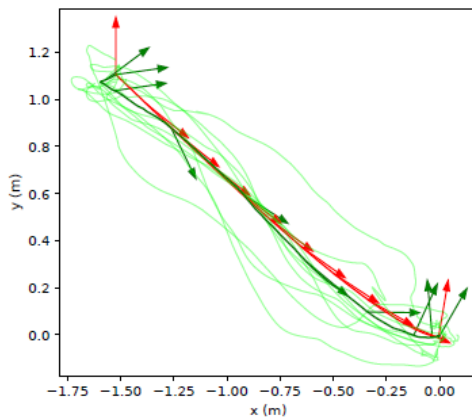
$$\min_{X(\cdot), U(\cdot), T} \int_0^T \phi_r(X(t), U(t)) dt + \phi_t(X(T))$$

$$\begin{cases} \phi_r(X(t), U(t)) = \alpha_0 + \alpha_1 u_1^2(t) + \alpha_2 u_2^2(t) + \alpha_3 u_3^2(t) \\ \quad + \alpha_4 \psi(X(t), X_f)^2 \\ \phi_t(X(T), U(T)) = \beta_0 ((x_f - x(T))^2 + (y_f - y(T))^2) \\ \quad + \beta_1 (\theta_f - \theta(T))^2 + \beta_2 (v_{forw}(T)^2 + v_{orth}(T)^2) + \beta_3 \omega(T)^2 \end{cases}$$



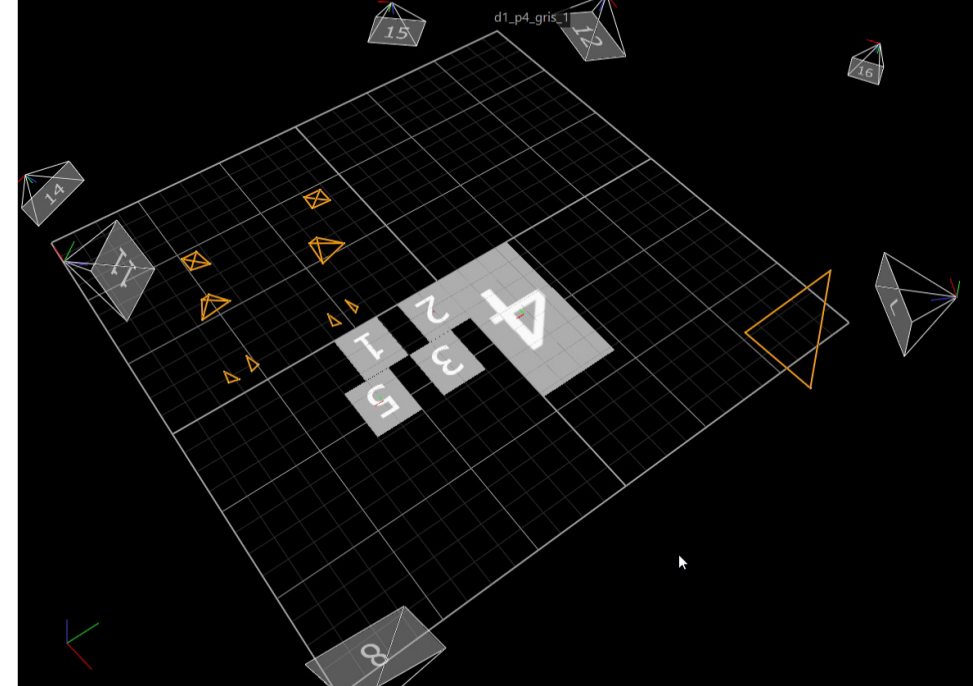
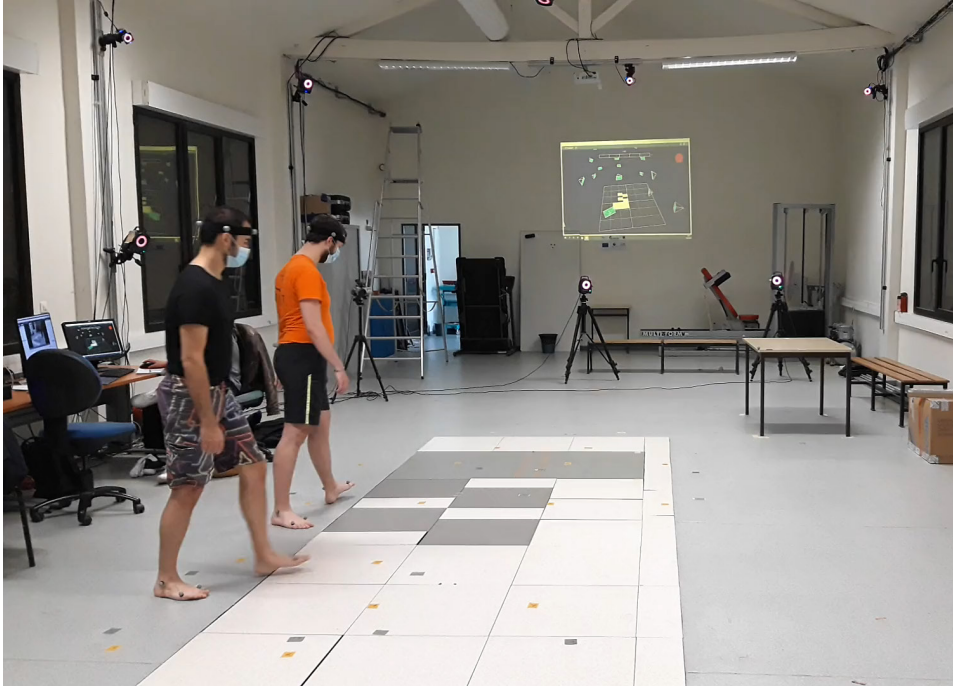
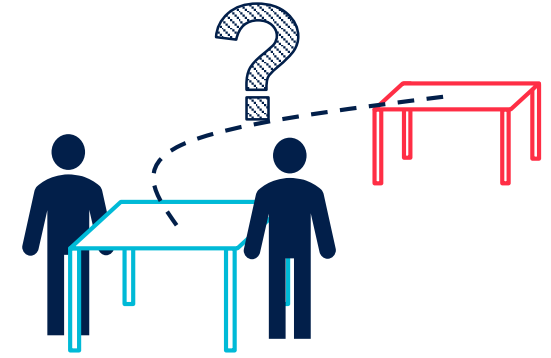
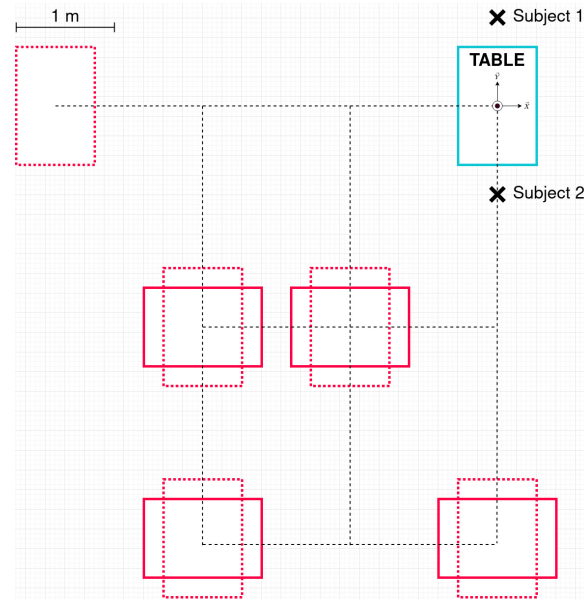
Reduced problem

- Results:
 - Linear distance $\approx 7,7$ cm
 - Angular distance $\approx 21,2^\circ$
 - **Homogeneous results** whatever the initial orientation or the initial distance to the goal are (*ANOVA test*)

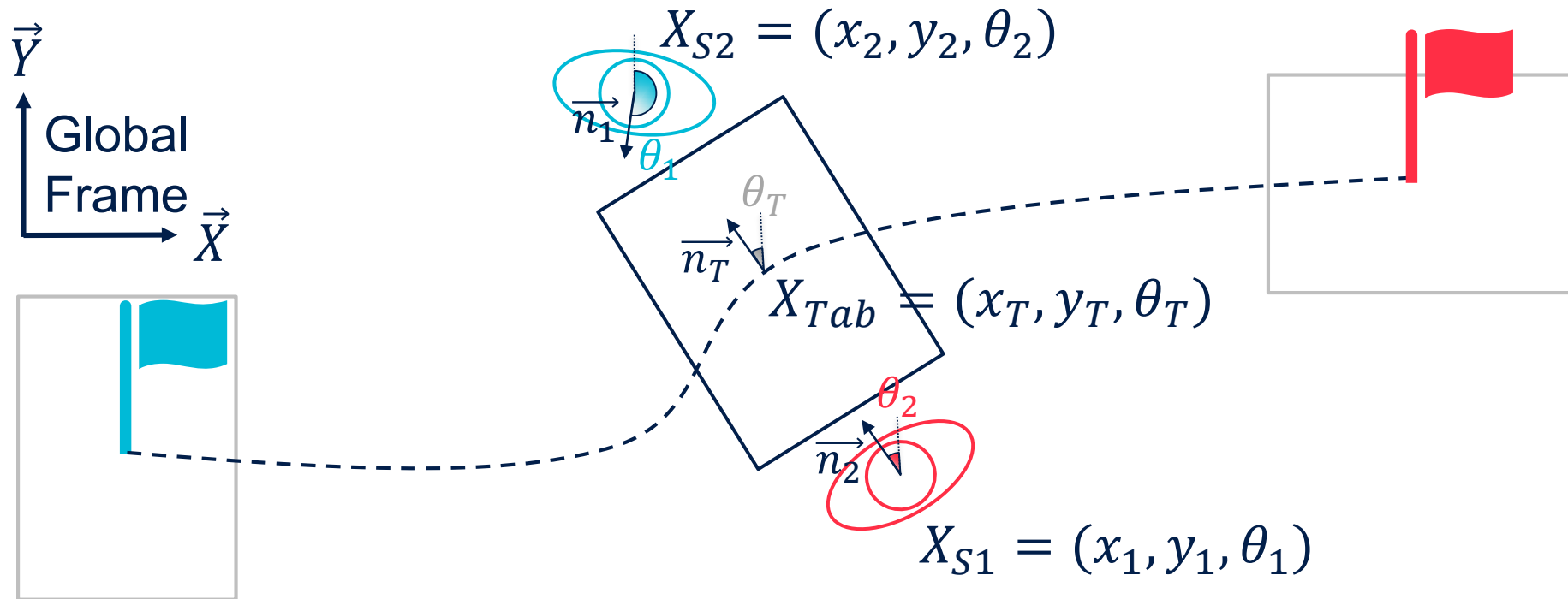


Final problem

- > Positions and orientations of the subjects' **Center of Mass** recorded using a *Motion Capture* system

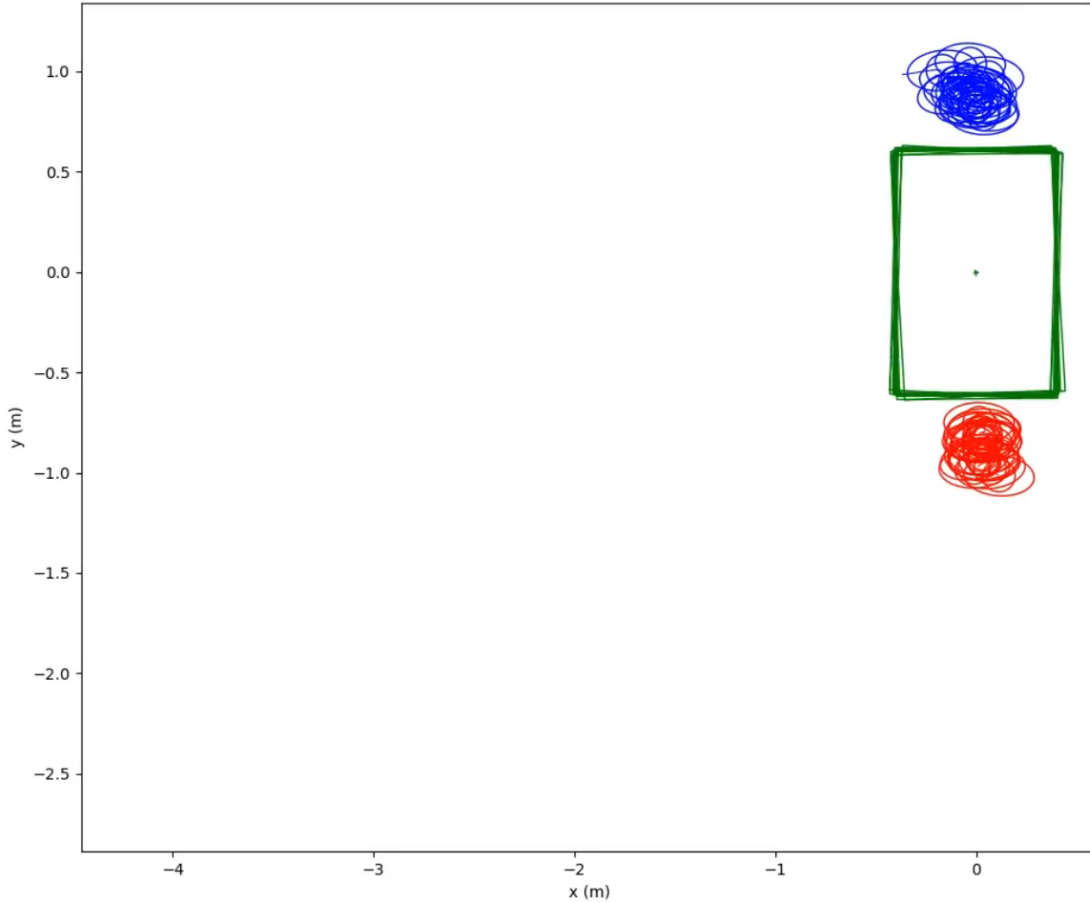


Final problem

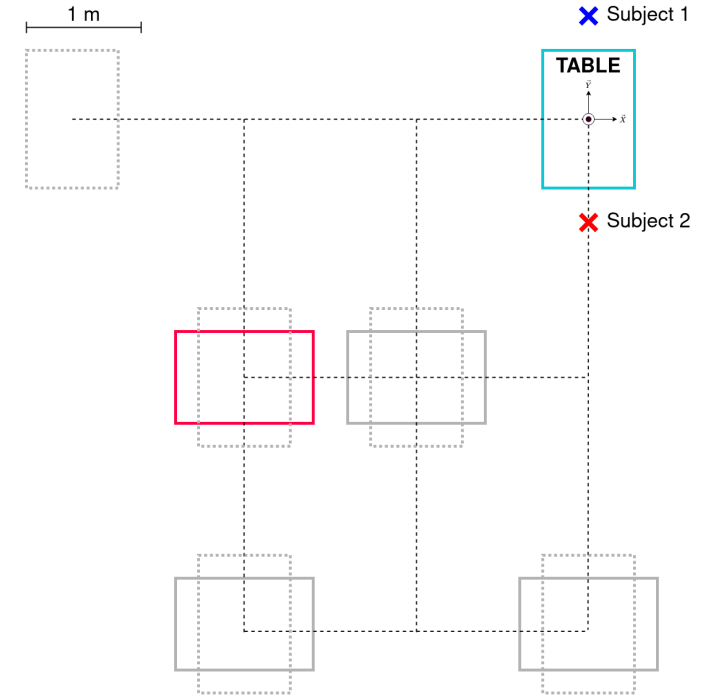


How can we generate the table trajectories from a starting position to a goal position?

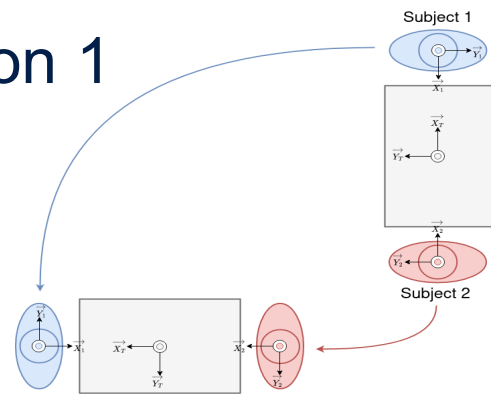
Final problem



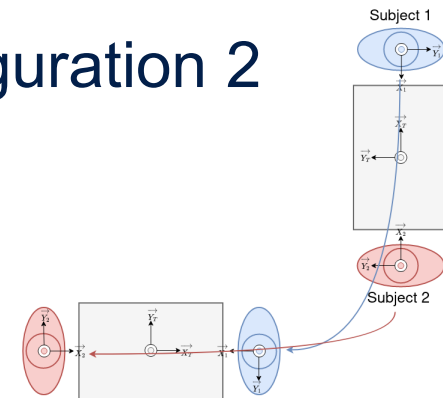
> Both subjects know the goal position



Configuration 1

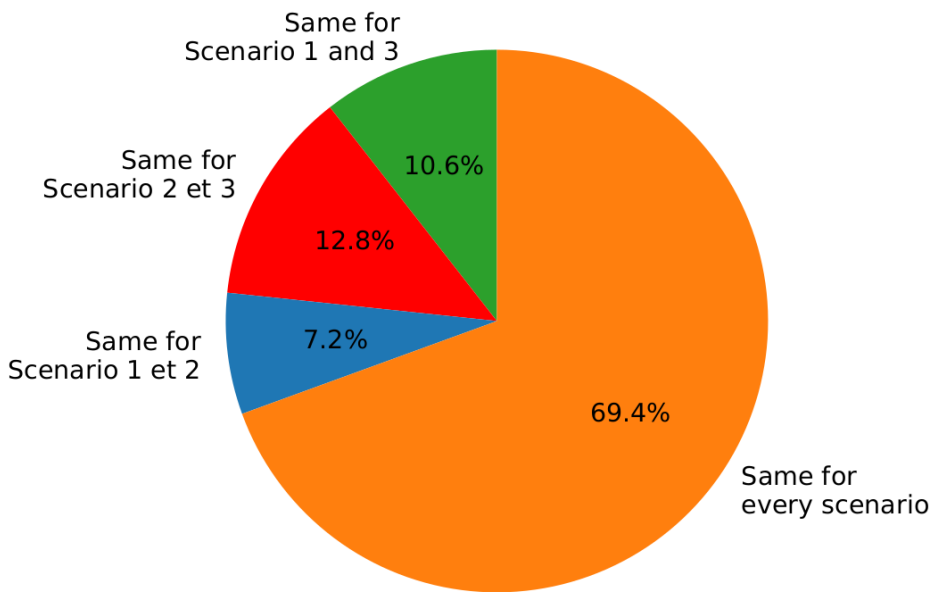


Configuration 2



Final problem

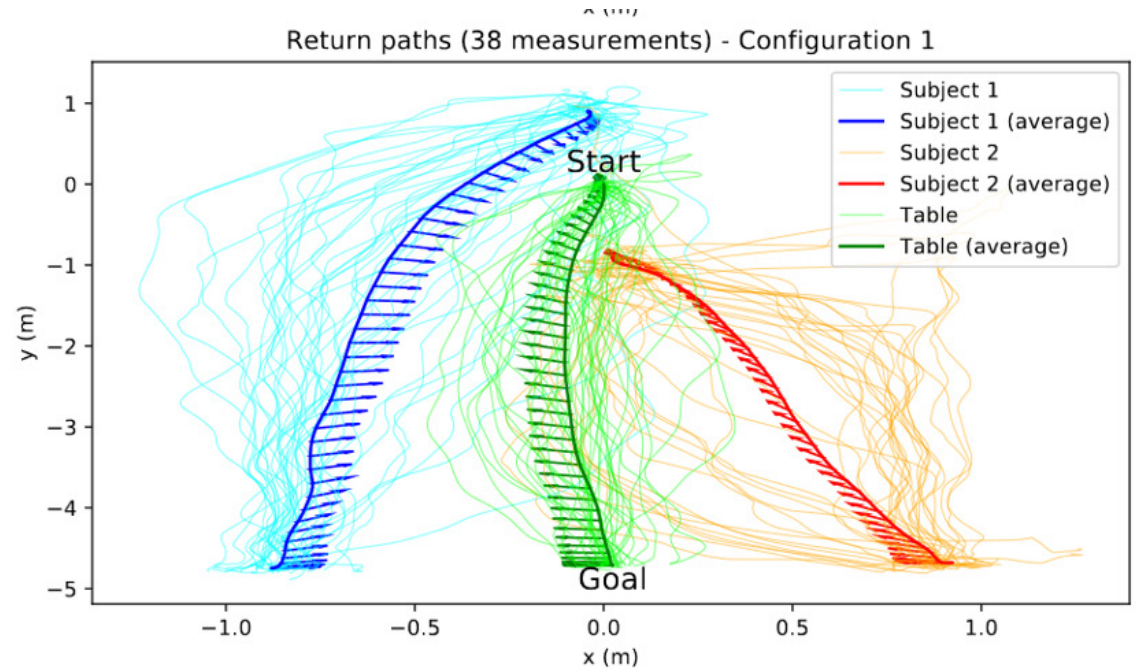
- > Great range of behaviour:
 - Different configurations



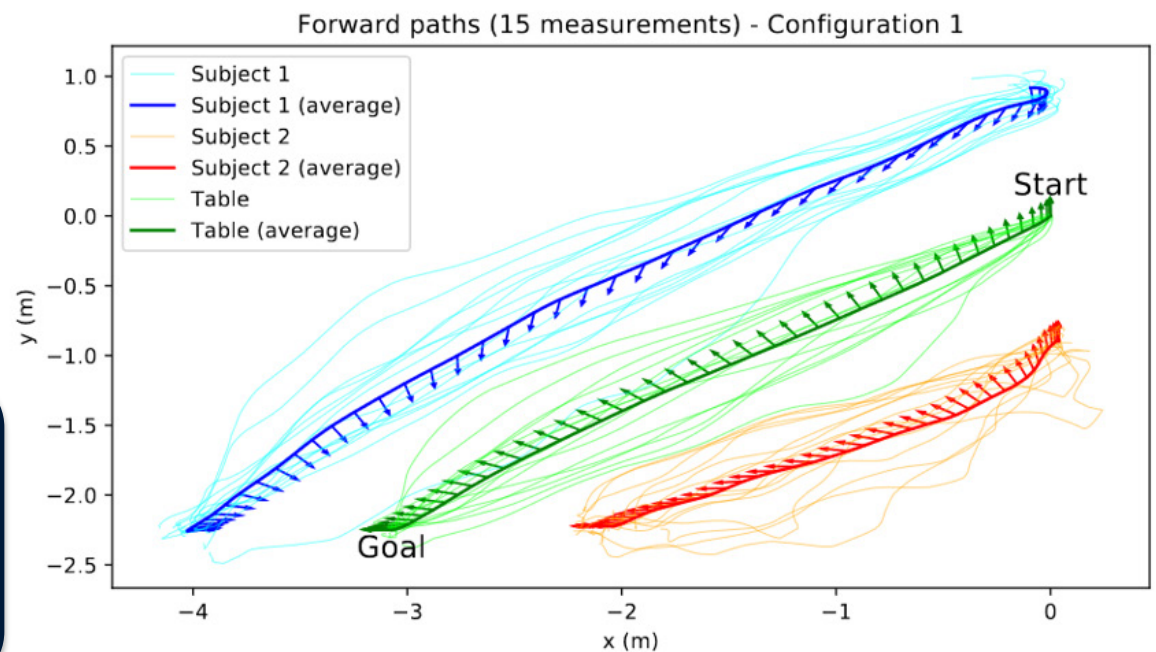
$$d_{xy} \approx 20 \pm 14 \text{ cm}$$

$$d_{\theta} \approx 11 \pm 8^{\circ}$$

$$\text{Max: } d_{xy} \approx 128 \text{ cm} \ \& \ d_{\theta} \approx 60^{\circ}$$



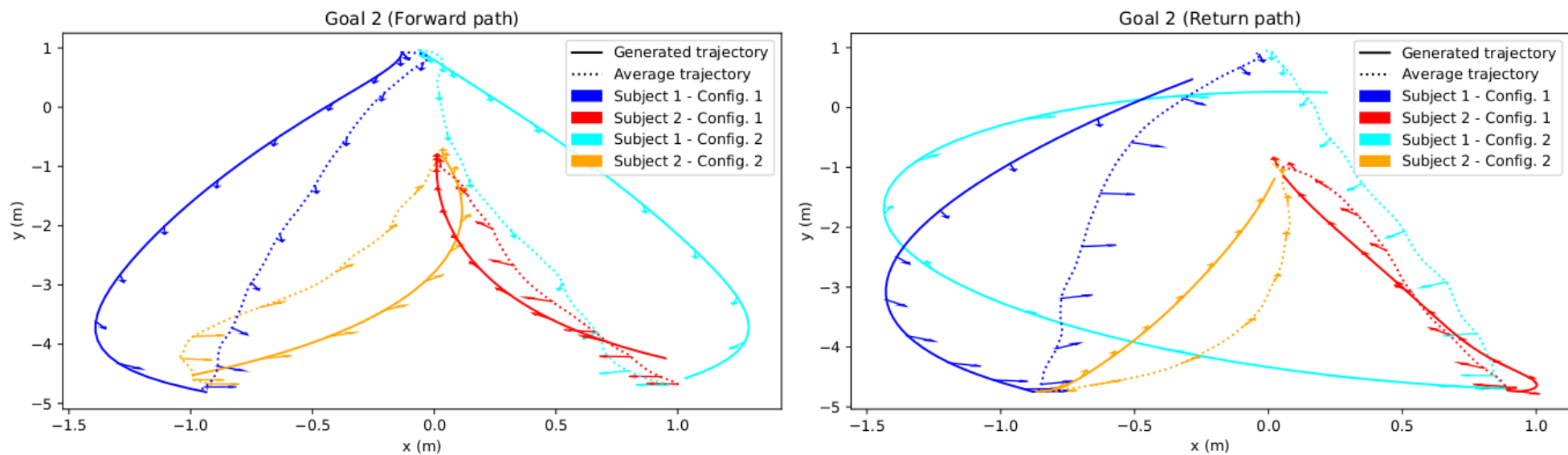
(a) Trajectori



Final problem

- > Same modeling strategy: OC model with IOC scheme

$$\min_{X_{S1}, X_{S2}, U_{S1}, U_{S2}, T} \int_0^T \phi_r(X_{S1}(t), X_{S2}(t), U_{S1}(t), U_{S2}(t)) dt + \phi_t(X_{S1}(T), X_{S2}(T))$$



FAIL!

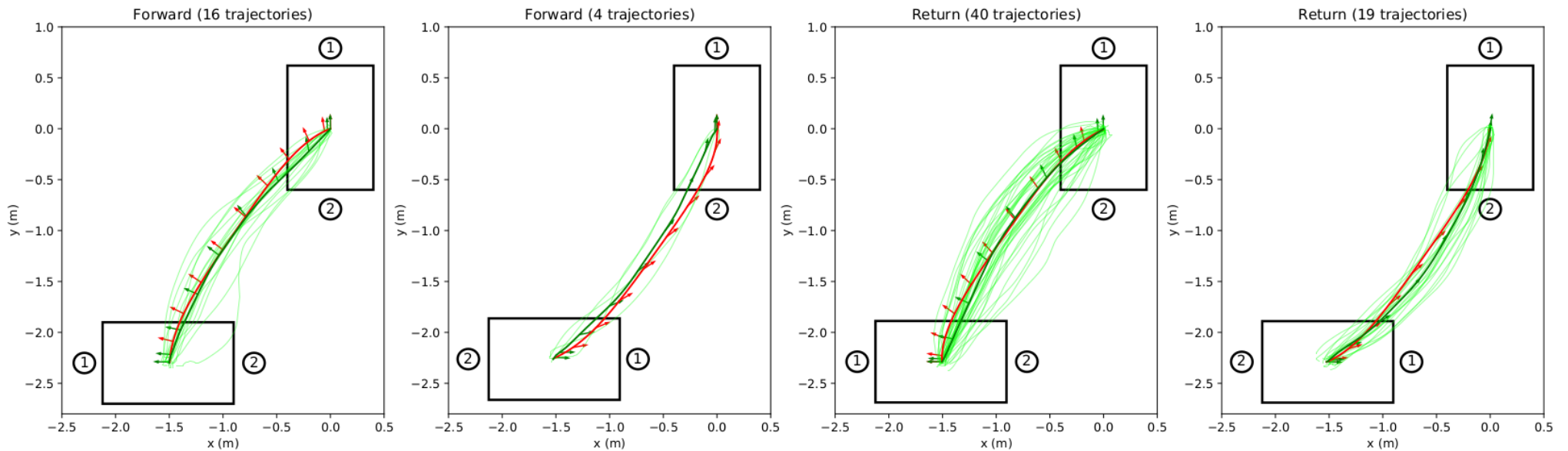
$$d_{xy} \approx 35 \text{ cm}$$

$$d_{\theta} \approx 40,6^{\circ}$$

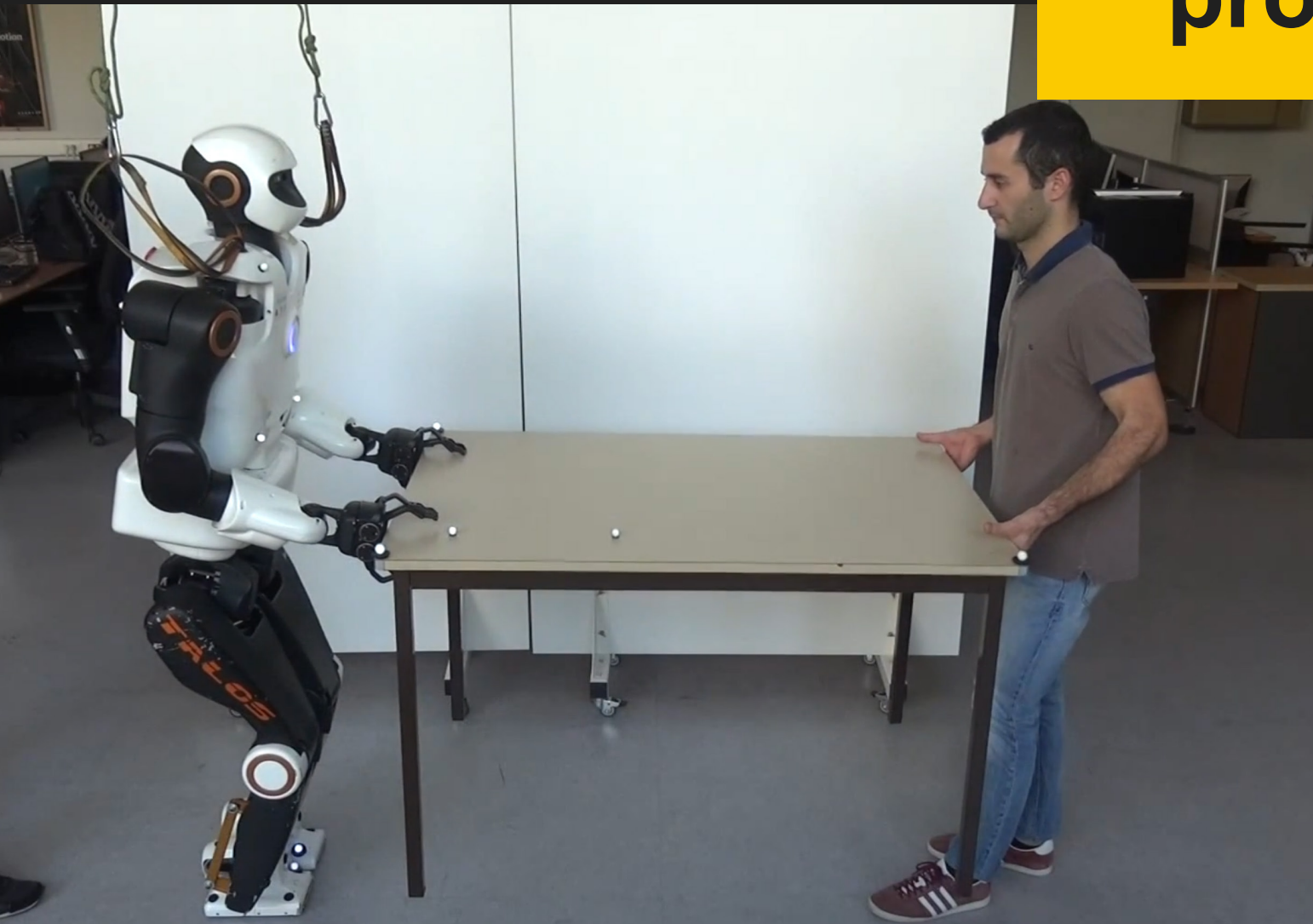
Final problem

- > Same modeling strategy: OC model with IOC scheme

$$\min_{X_{Tab}, U_{Tab}, T} \int_0^T \phi_r(X_{Tab}(t), U_{Tab}(t)) dt + \phi_t(X_{Tab}(T))$$



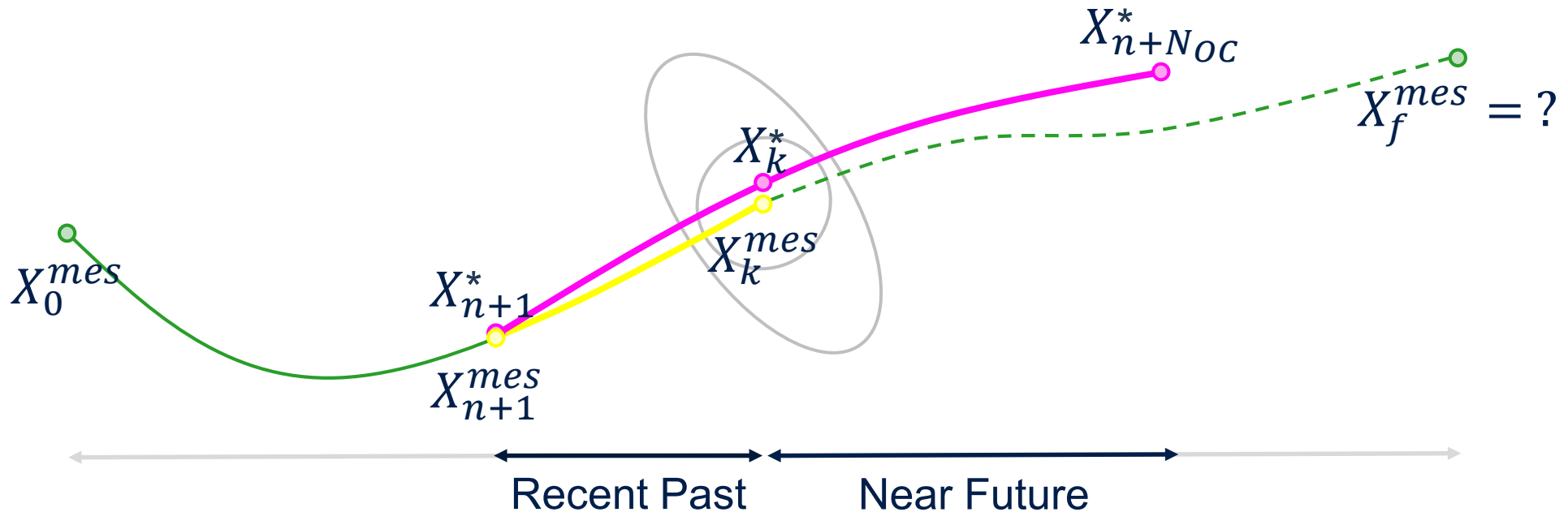
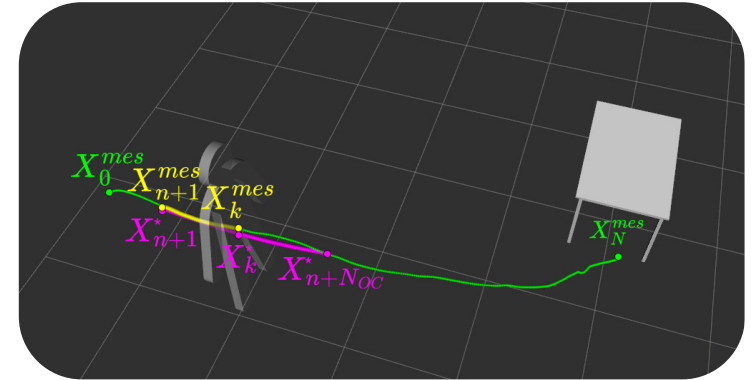
Prediction process



- We need a personalised pro-active behavior

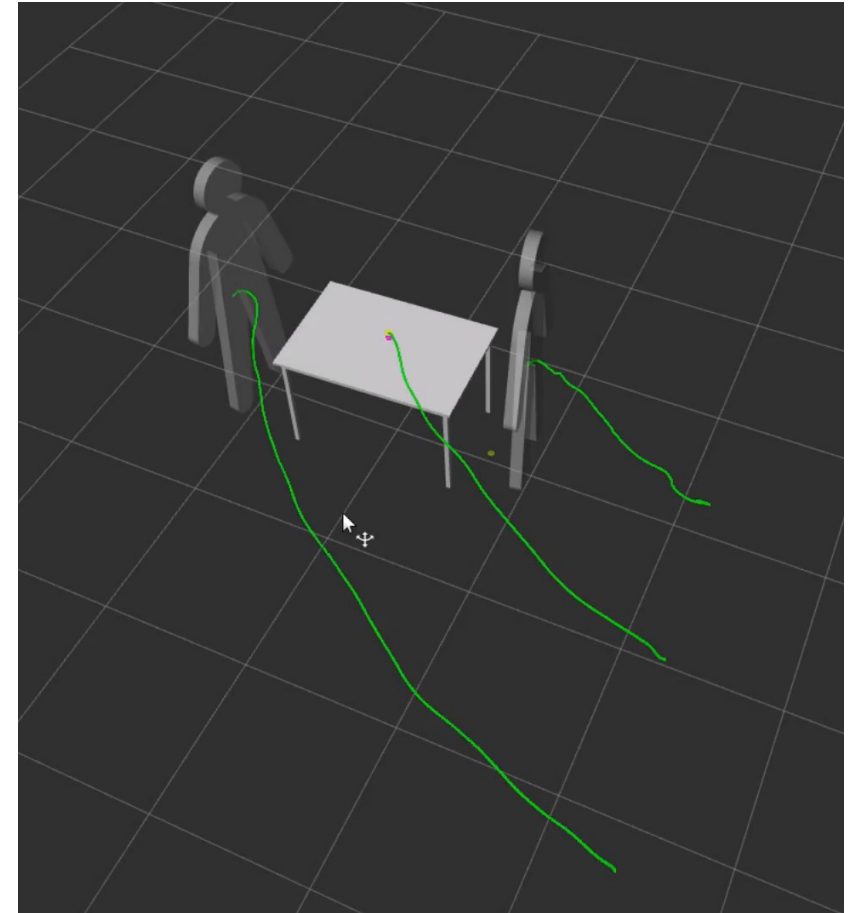
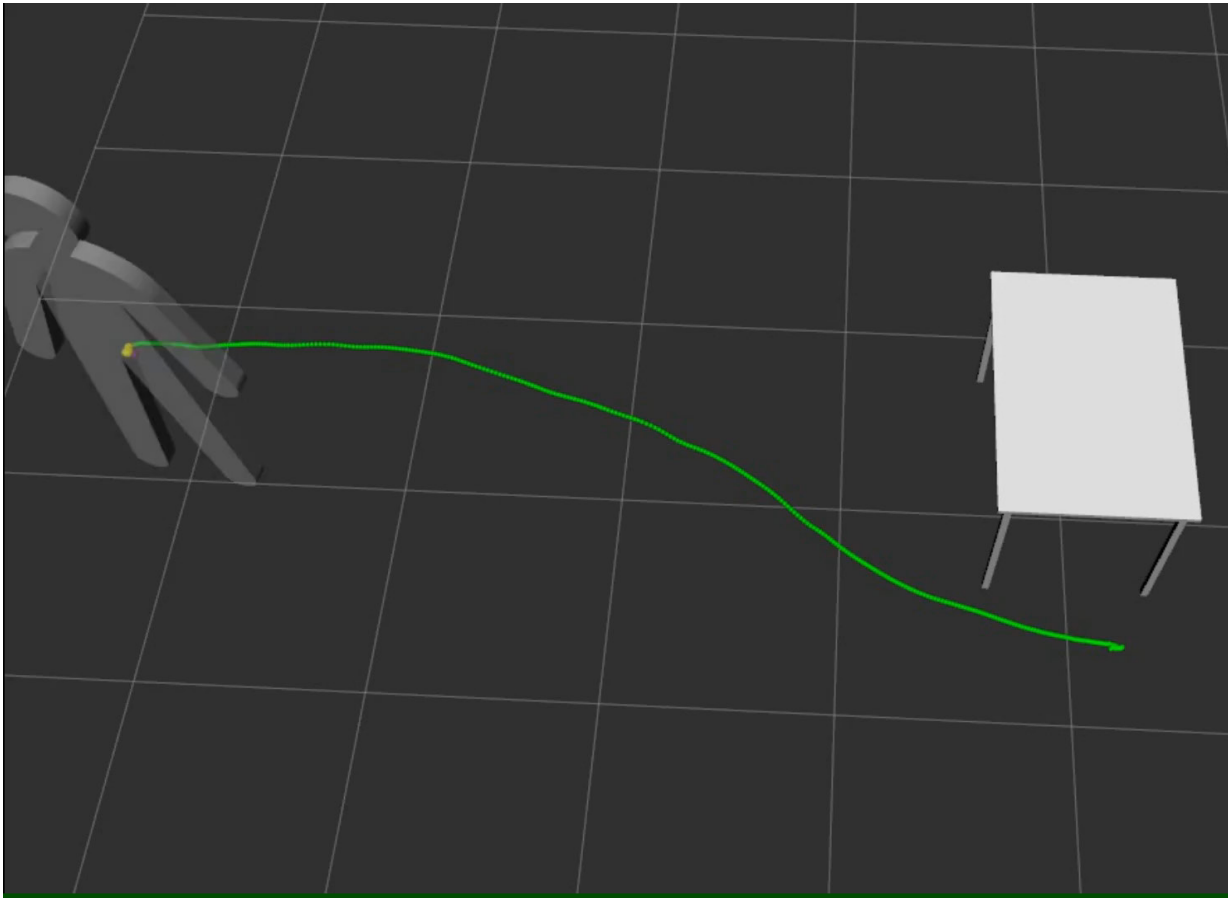
Prediction process

- The human trajectory is recorded in real time
- The prediction process:
 - Input: the last N_0 measurements
 - Output: trajectory of size $N_{OC} > N_0$
 - $n = k - N_0 - 1$

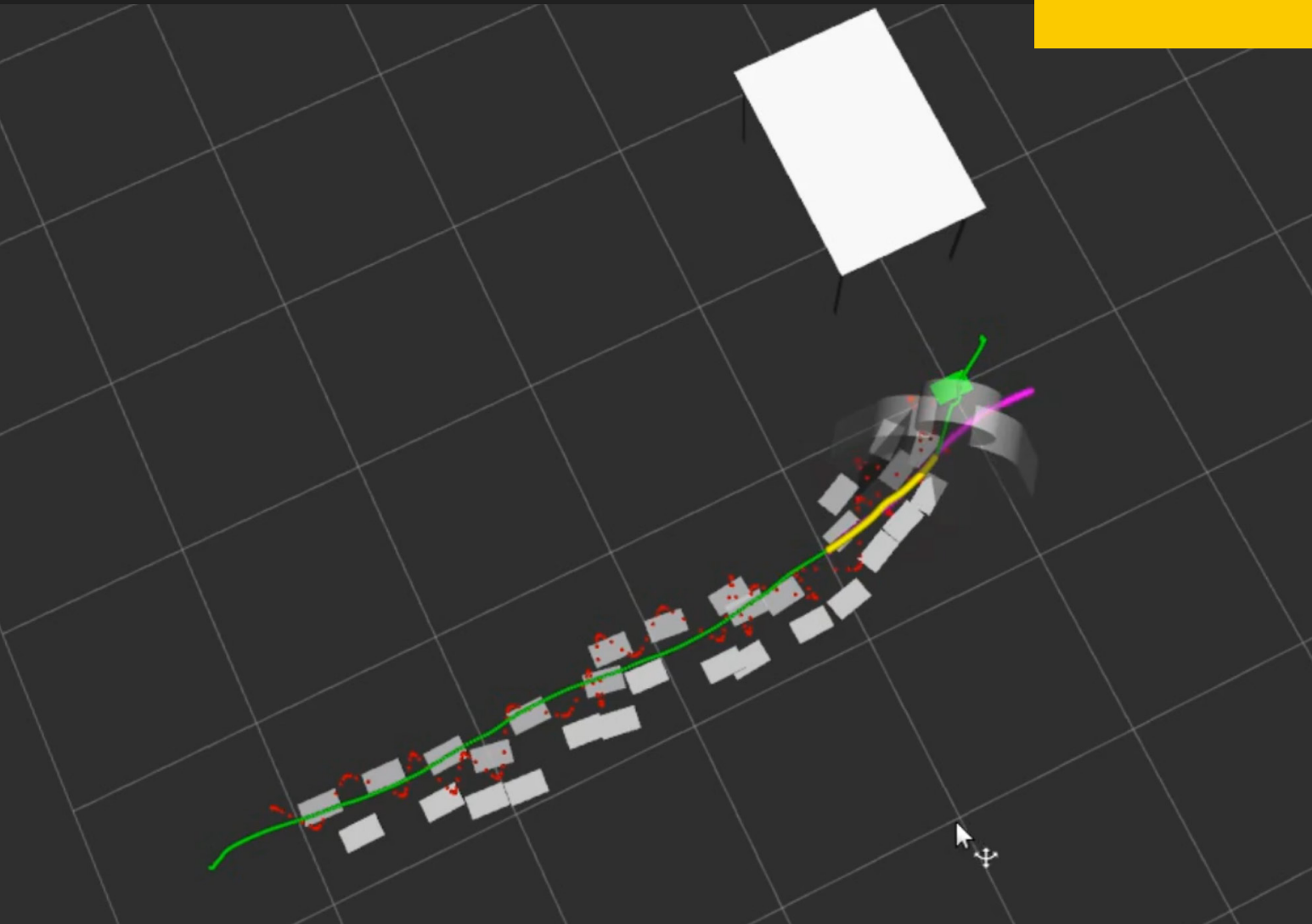


Prediction process

- Tested for all the measured trajectories with different parameters
- Computation of the **linear, angular and predicted distance**:
 - Better results for the prediction of the table's trajectories
 - Accuracy and predicted distance **depend on N_0 and N_{0c}**

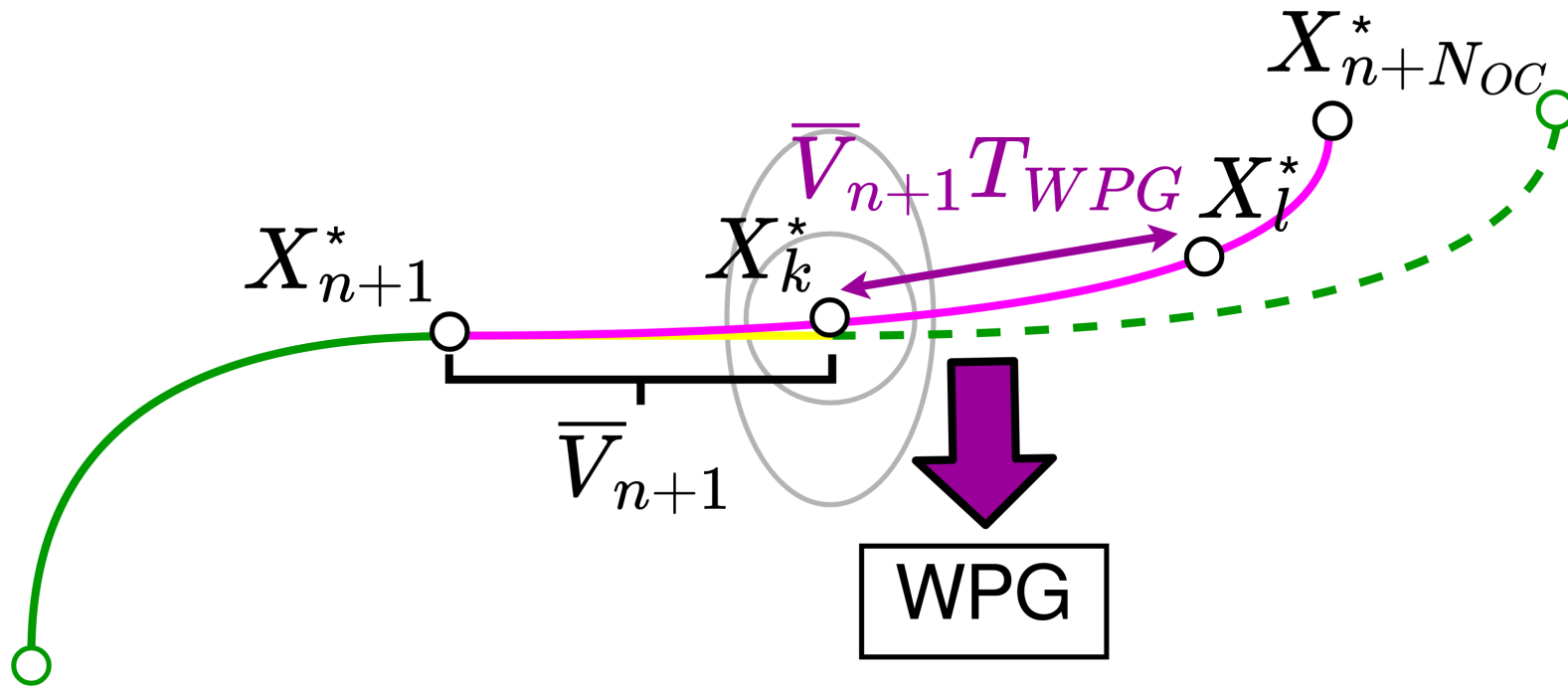


Gait generation

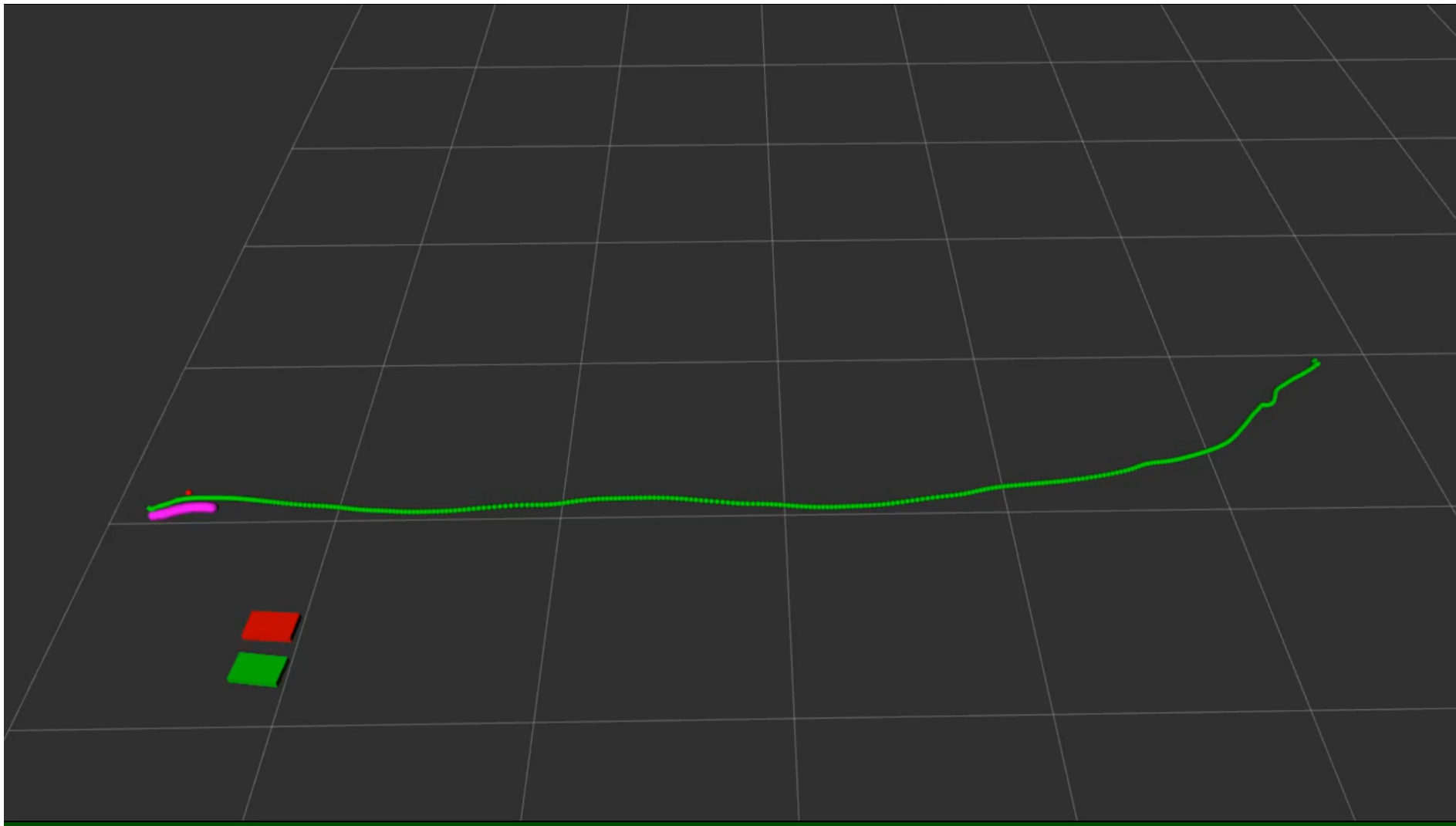


- We need a real-time gait generation

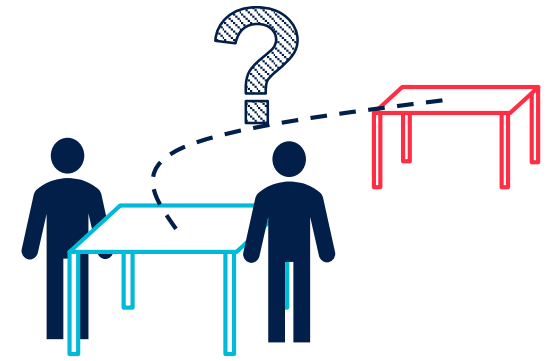
Walking pattern generator



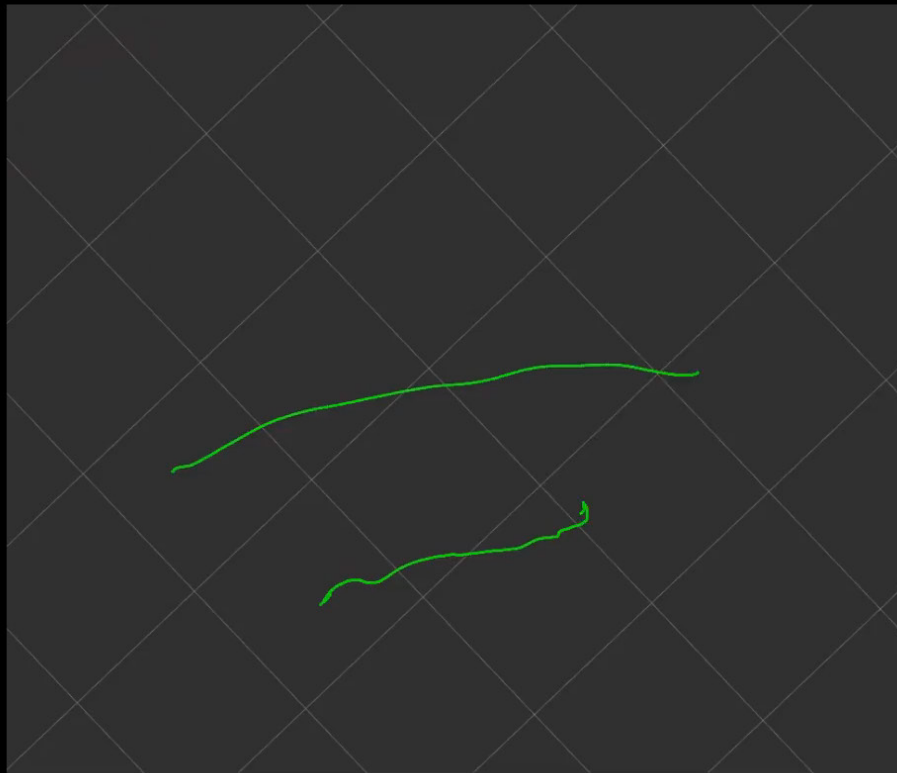
Walking pattern generator



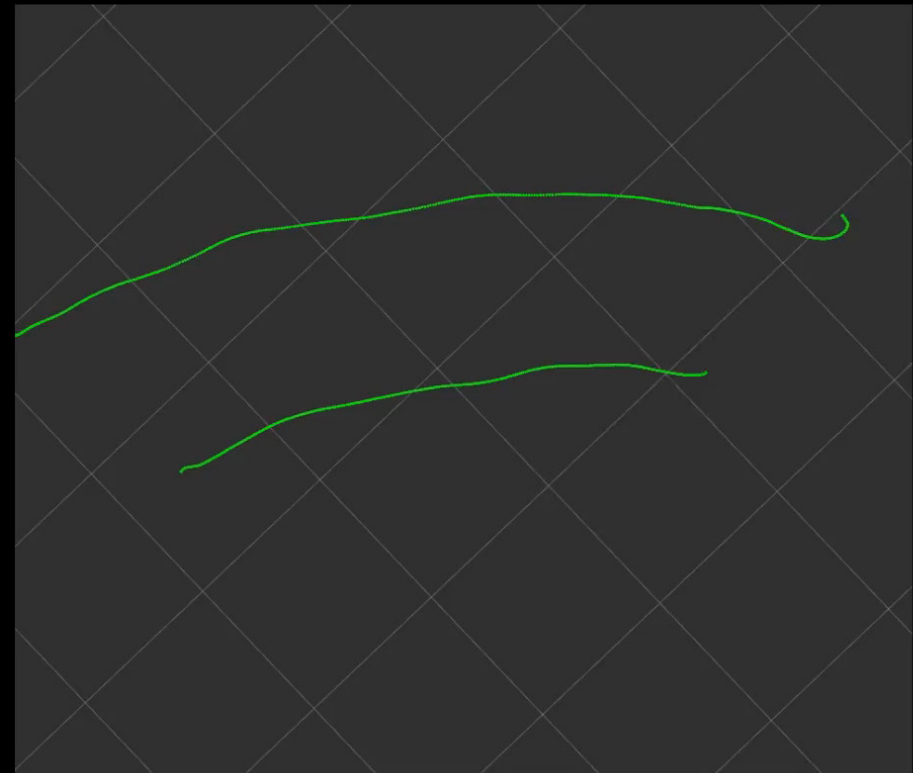
Walking pattern generator



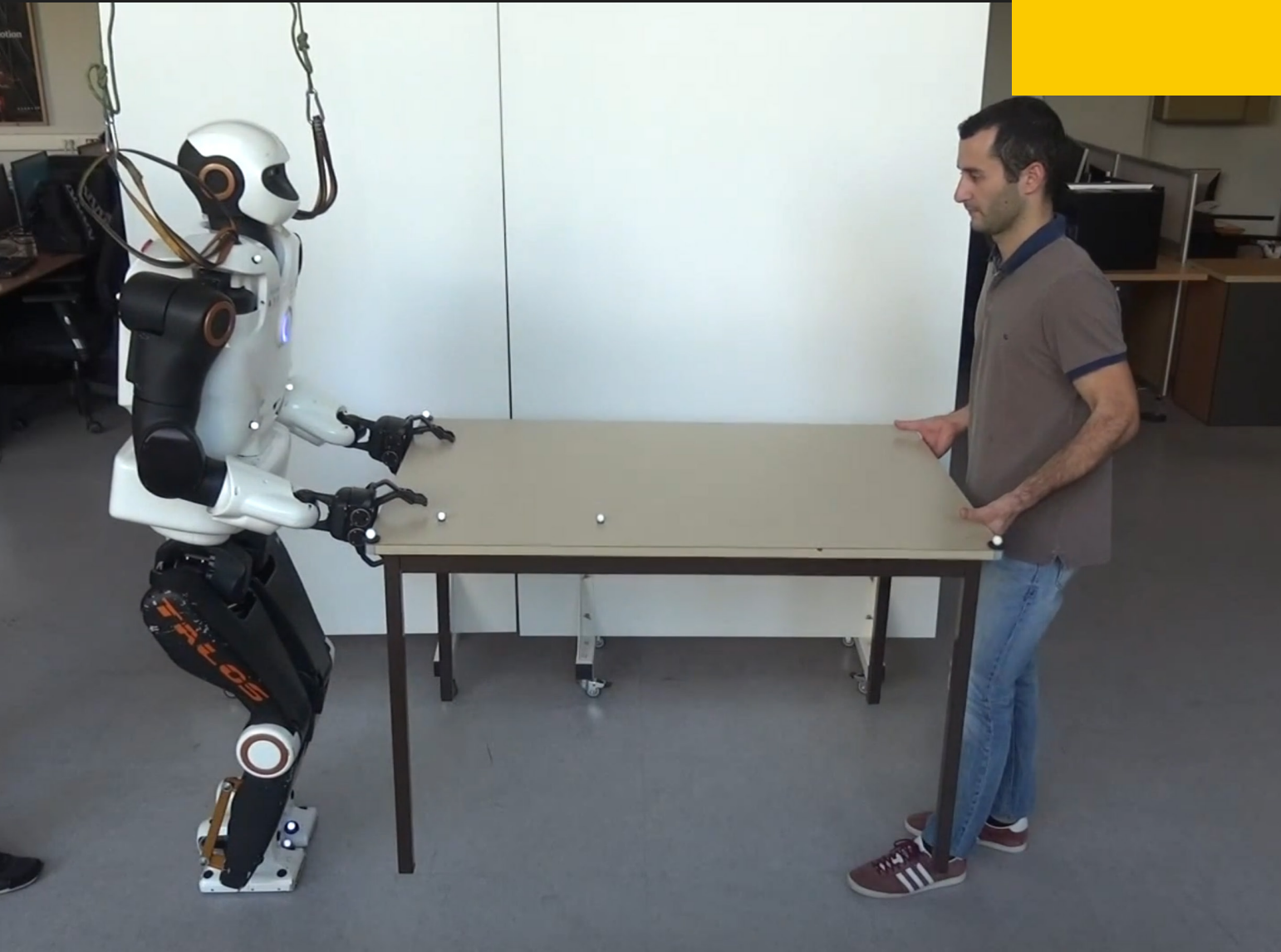
Subject 1 is replaced
by the robot



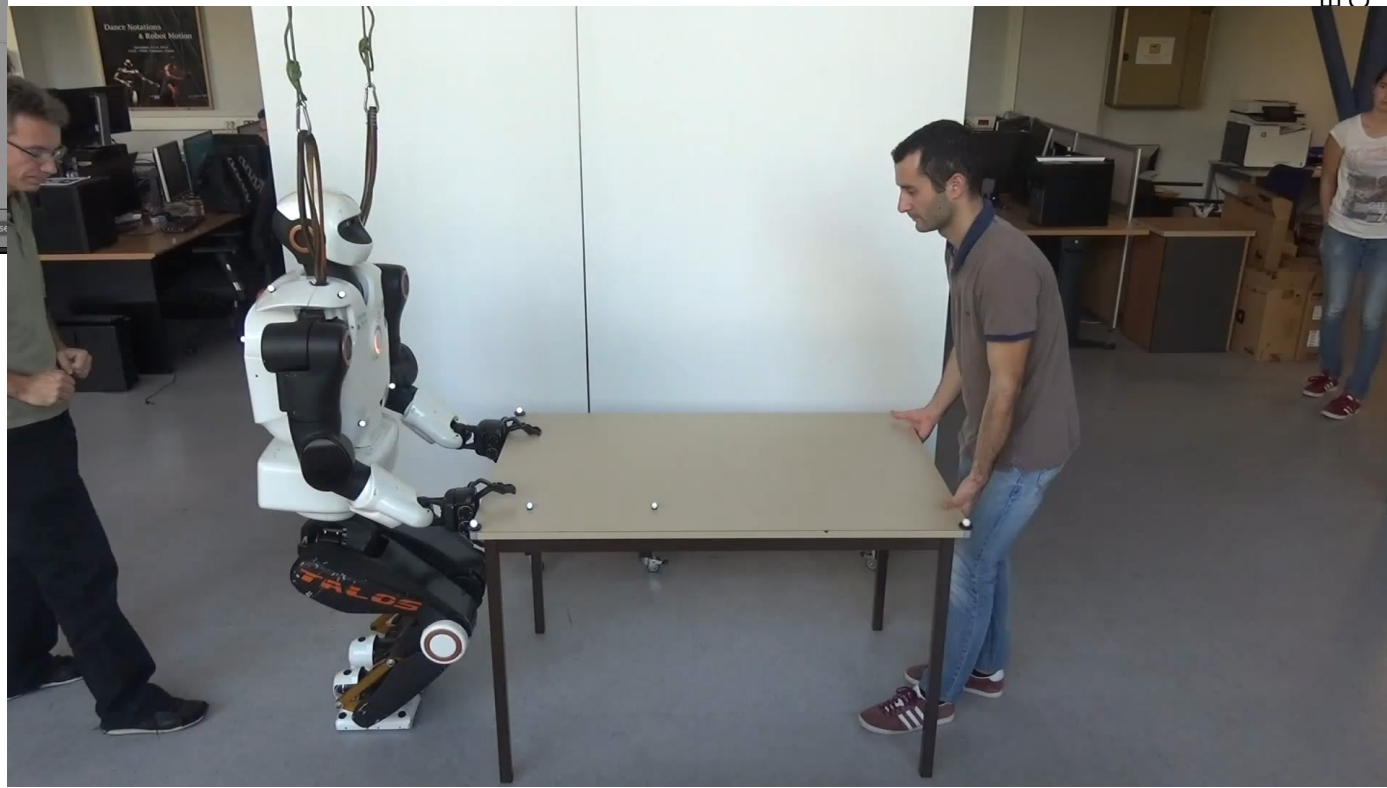
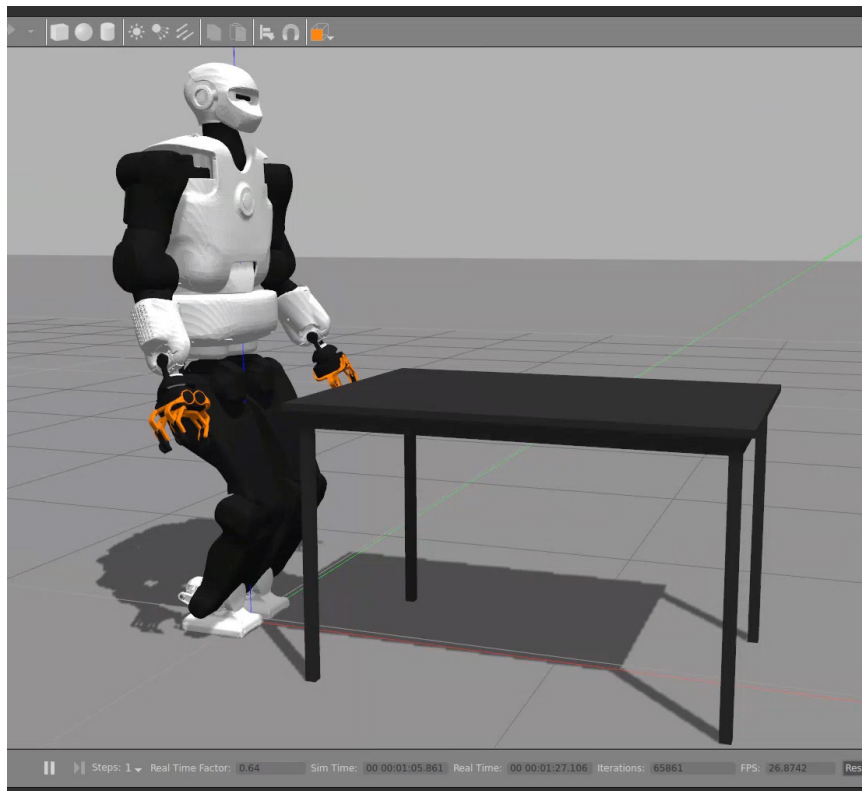
Subject 2 is replaced
by the robot



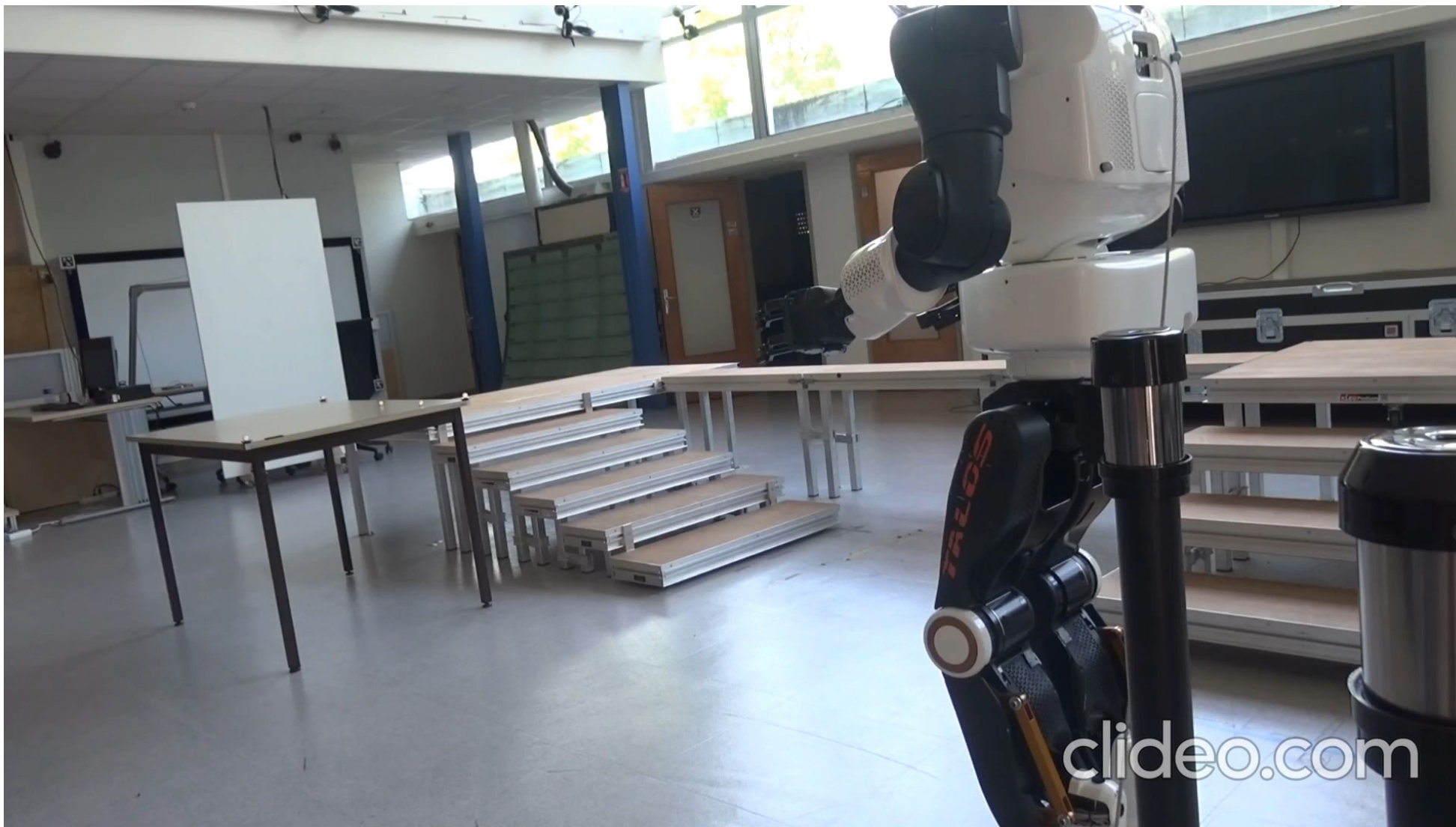
Implementation



Implementation



Implementation

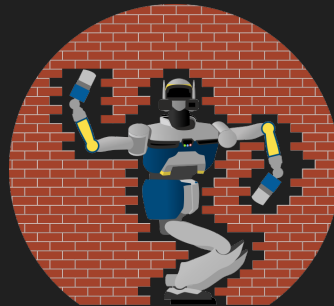
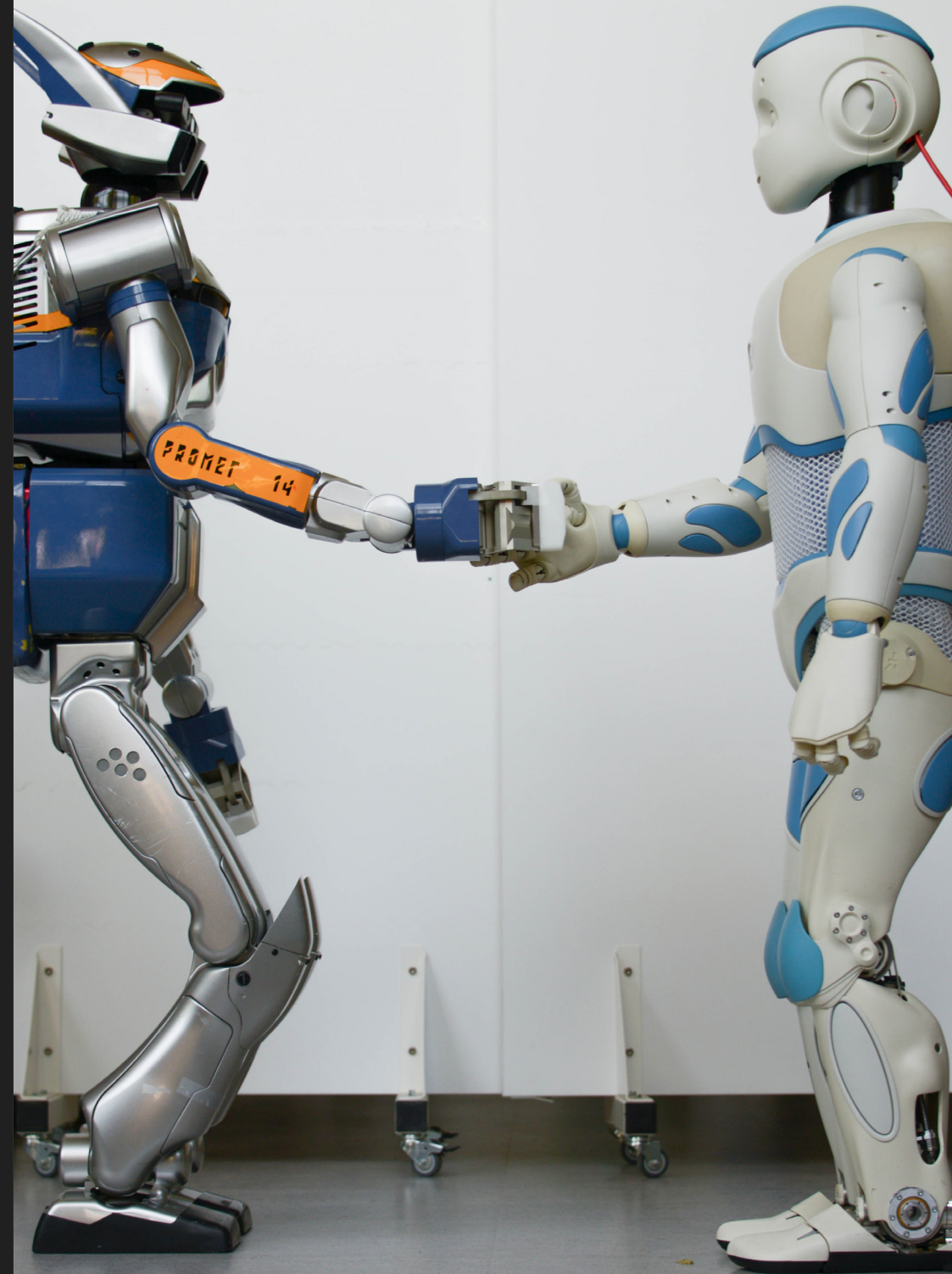


Dynamic simulation



“

Questions



Gepetto
LAAS-CNRS



Titre de la diapositive

Aenean at eros at nulla fermentum euismod vel sit amet urna. Cras non lorem vehicula, fringilla leo sit amet, semper orci. Mauris varius libero ac sapien tempor, non auctor nisi dapibus.