A predictive approach for maintenance and Safety of a wheeled humanoid robot

IEEE RTSI 2024
Research and technologies
for society and industry

Politecnico di Milano
Polo Territoriale di Lecco
September 18__20 2024

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Chairman & Founder Oversonic

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ROBOTICS FOR HUMANS

ROBEE

R19

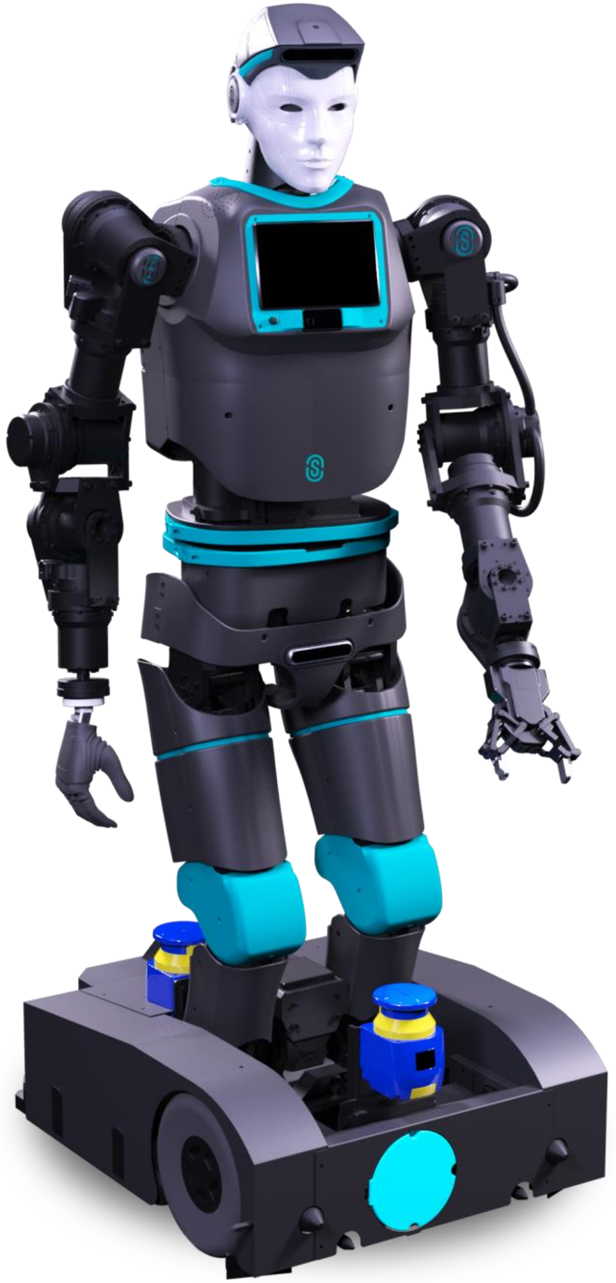
The first **Cognitive Humanoid Robot** designed by Oversonic to operate in industrial manufatcuring and logistics.

Weight
Up to 120 kg depending on the configuration

Height
135 – 200 cm

Total Degrees of Freedom
39

Footprint
65 cm in diameter



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ROBEE

M01

A **Social Cognitive Humanoid Robot**, capable of interacting directly with humans, able to activate and make effective empathic interaction with patients.

Weight
Up to 80 kg depending on the configuration

Height
175 cm

Total Degrees of Freedom
39

Footprint
55 * 42 cm

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Bimanual

Interaction and prediction

Safety

Bimanual

Interaction and prediction

Safety

Bimanual

Why bimanual planning is useful and what complexities it hides.

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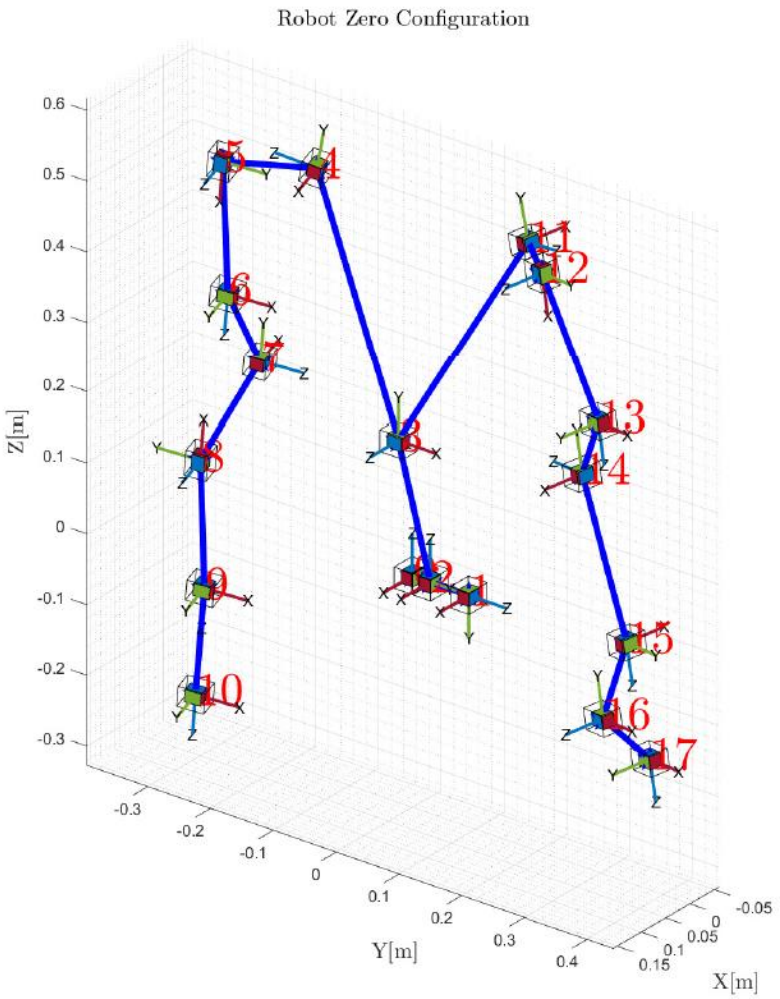
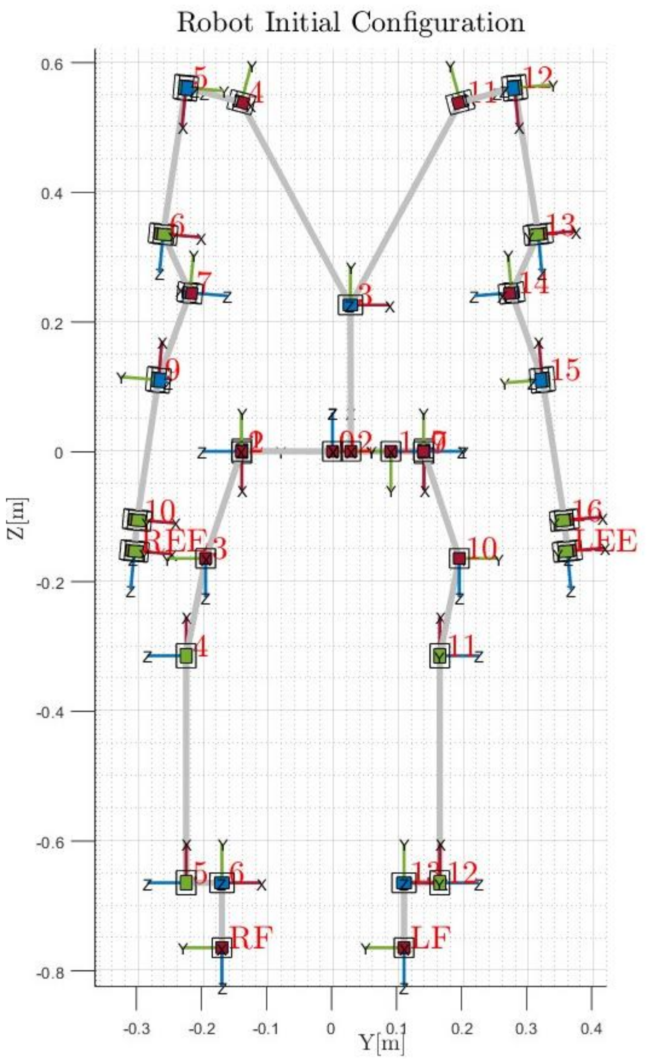
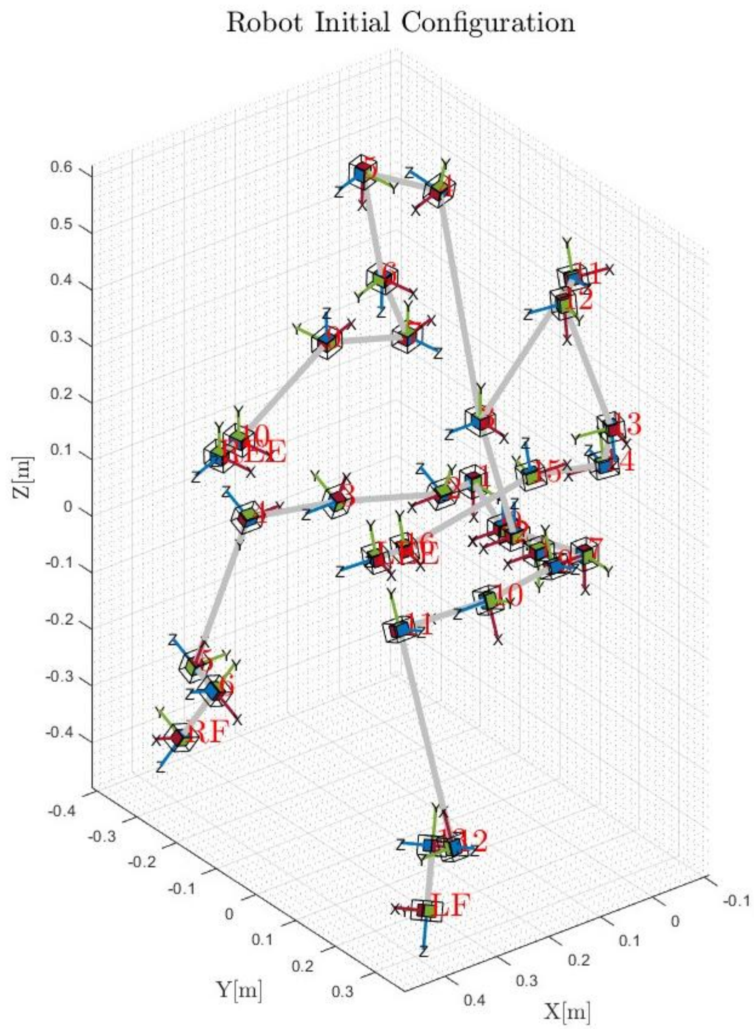
KINEMATIC ANALYSIS

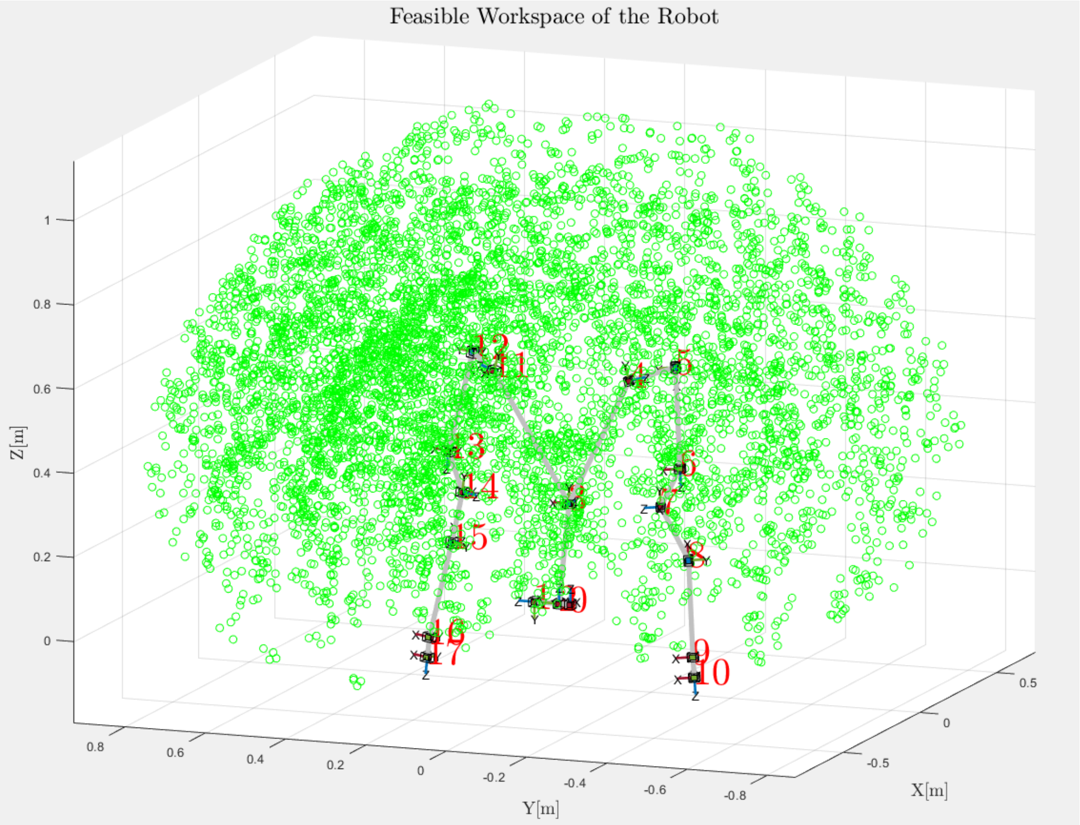




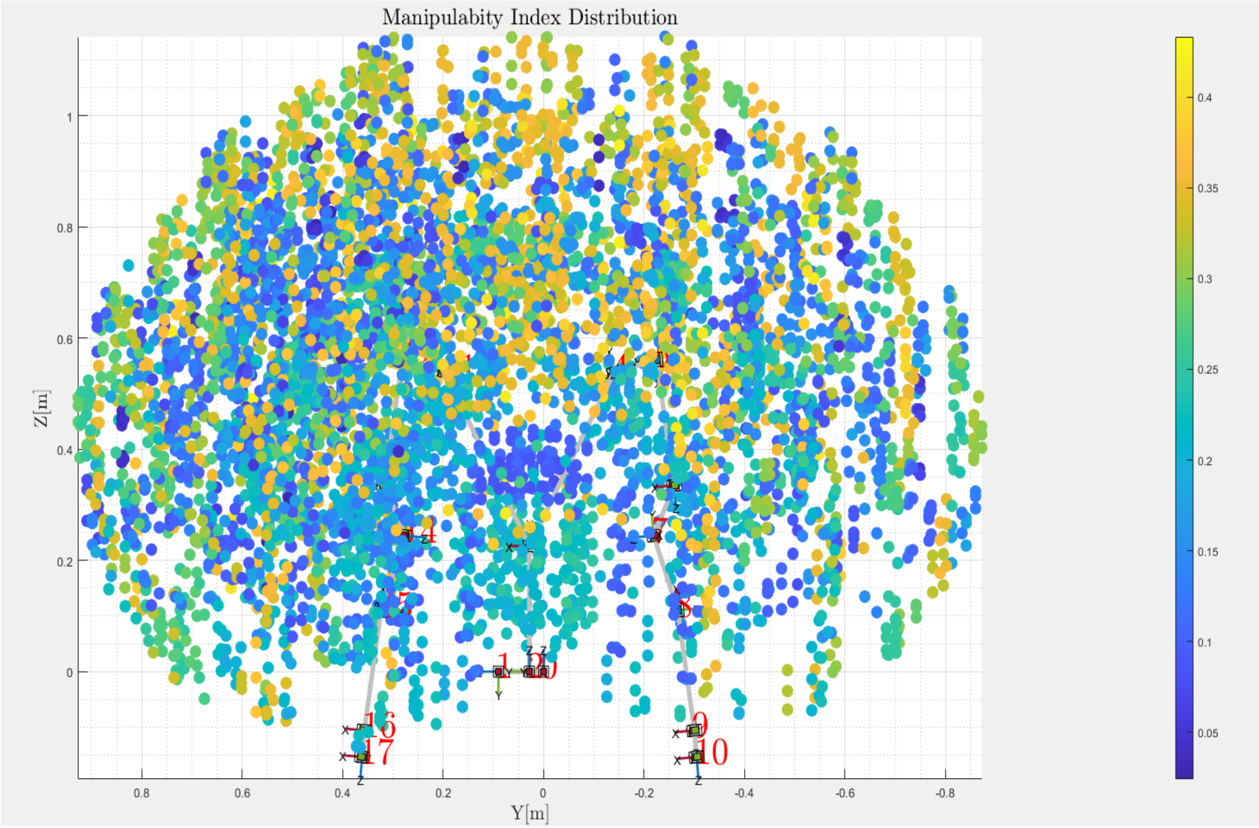


KINEMATIC ANALYSIS

WORKSPACE ANALYSIS



MANIPULABILITY ANALYSIS



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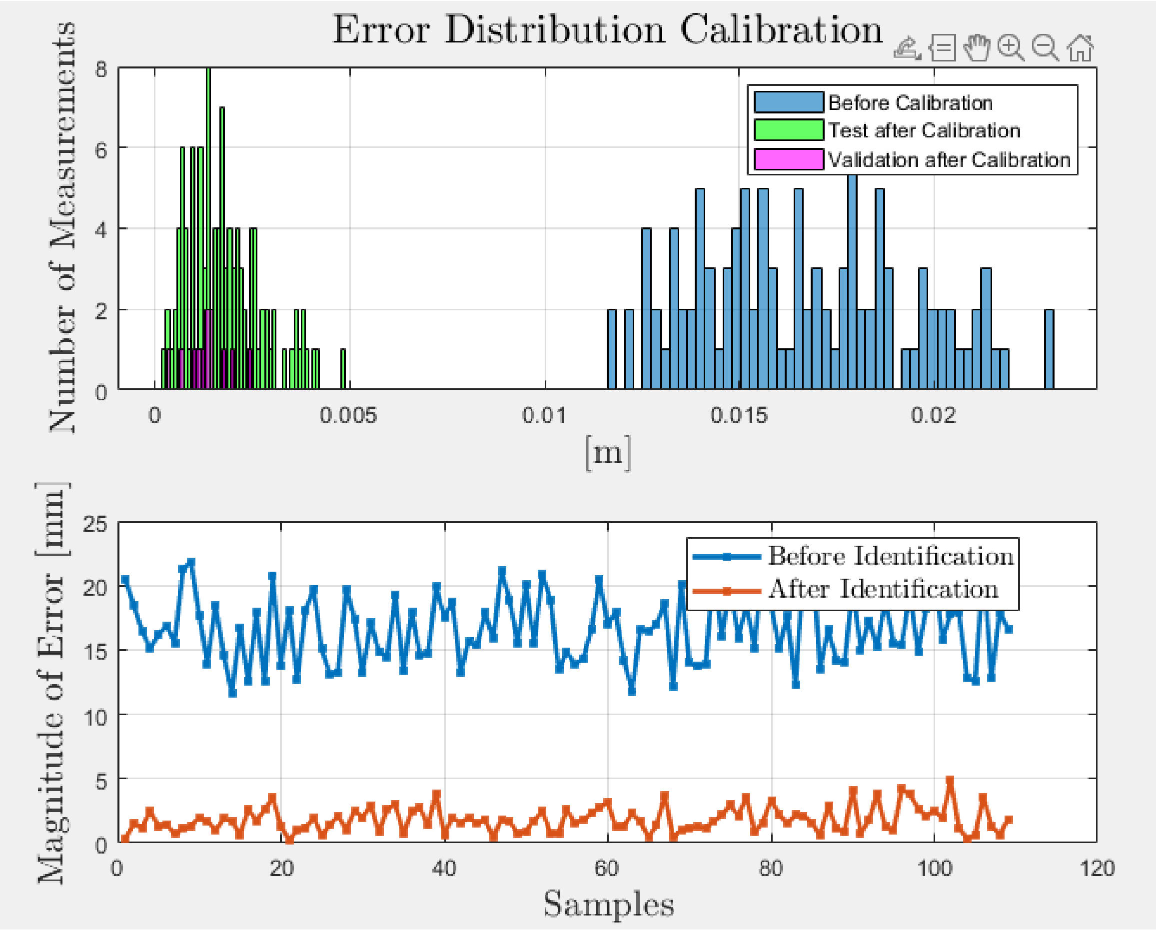
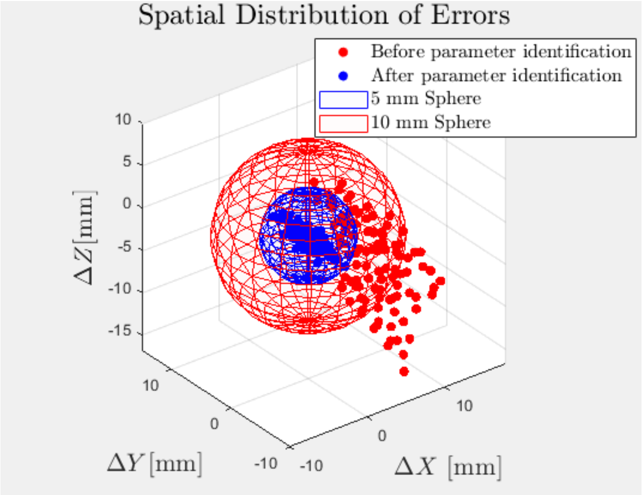
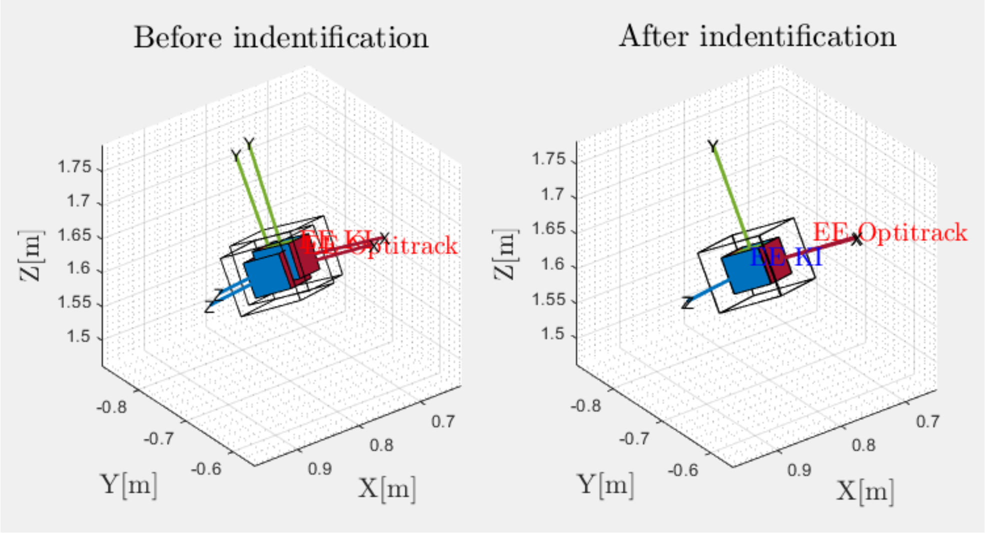
KINEMATIC ANALYSIS

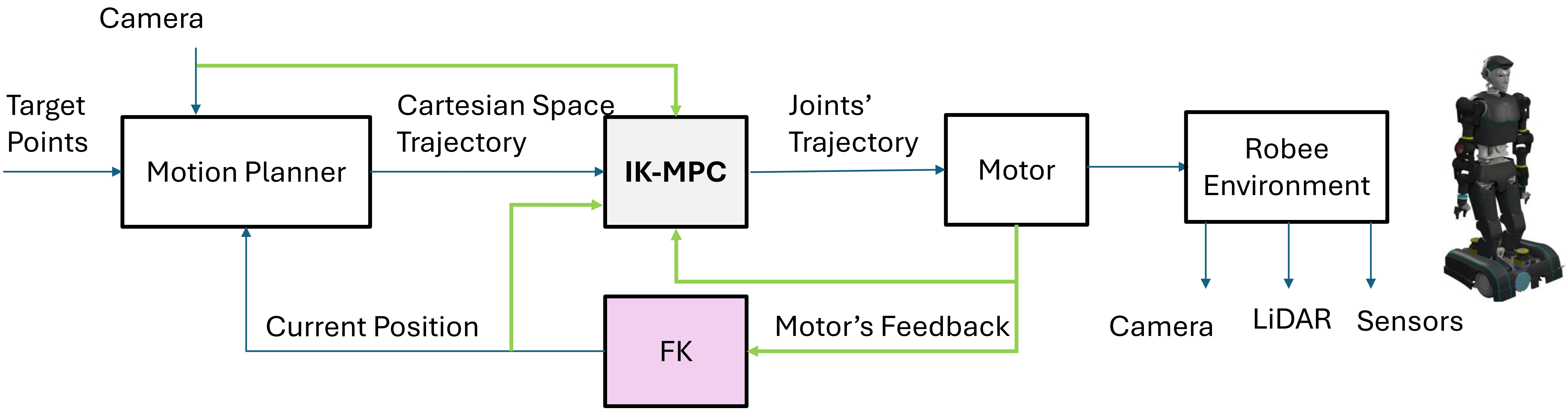
KINEMATIC CALIBRATION







METHOD



*Obstacle avoidance for a robotic manipulator with linear-quadratic Model Predictive Control
Gonzalo Meza*, Kristoffer Fink Løwenstein, and Lorenzo Fagiano. August, 2024

METHOD

Optimization Problem:

$$\min_{U_k} \mathcal{L}(U_k, \hat{Q}_k, \hat{\dot{Q}}_k, X_d, \dot{X}_d, k)$$

Subject to:

- LTI System
- Inequality Constraints
  - Kinematic Constraints
  - Obstacle Avoidance
  - Self-Collision Avoidance
  - Dynamic Model , ZMP
  - ...

Acceleration Level: $u(k) = \ddot{q}(k)$

$$U_k = [u(0|k)^T, u(1|k)^T, ..., u(M-1|k)^T]^T$$

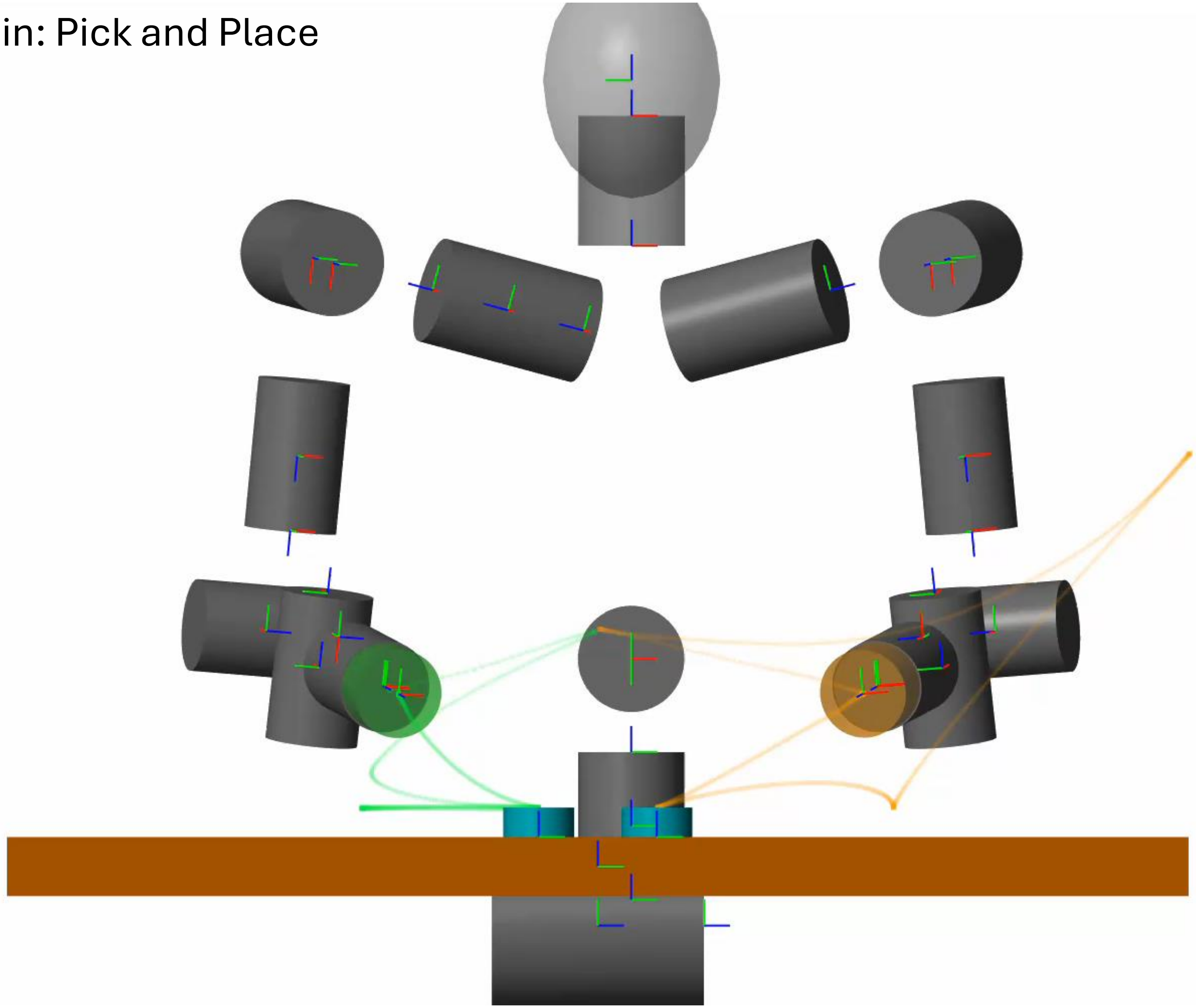
Cost Function:

FK — Jacobian

$$\mathcal{L} = a\sum(Error + Error\ Velocity) + b\sum Joints'\ Velocity + c\sum Joints'\ Acceleration + d\sum Joints'\ Jerk + f\sum l1(Joints)$$

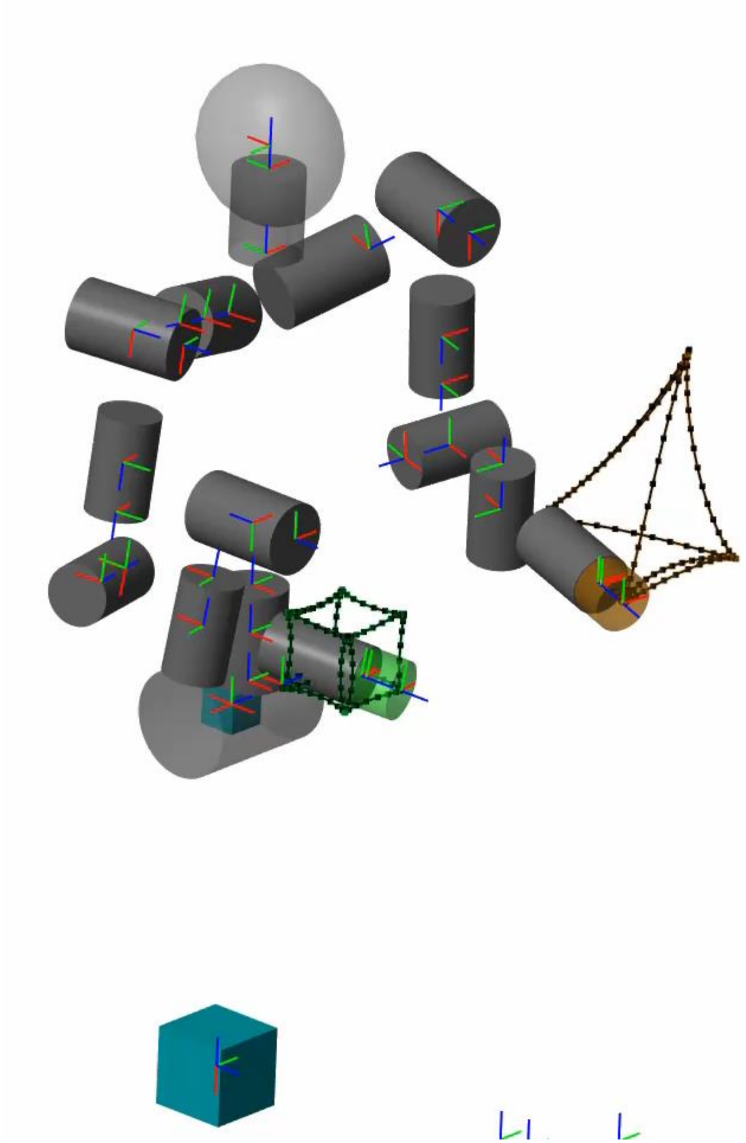
RESULTS

Whole Kinematic Chain: Pick and Place

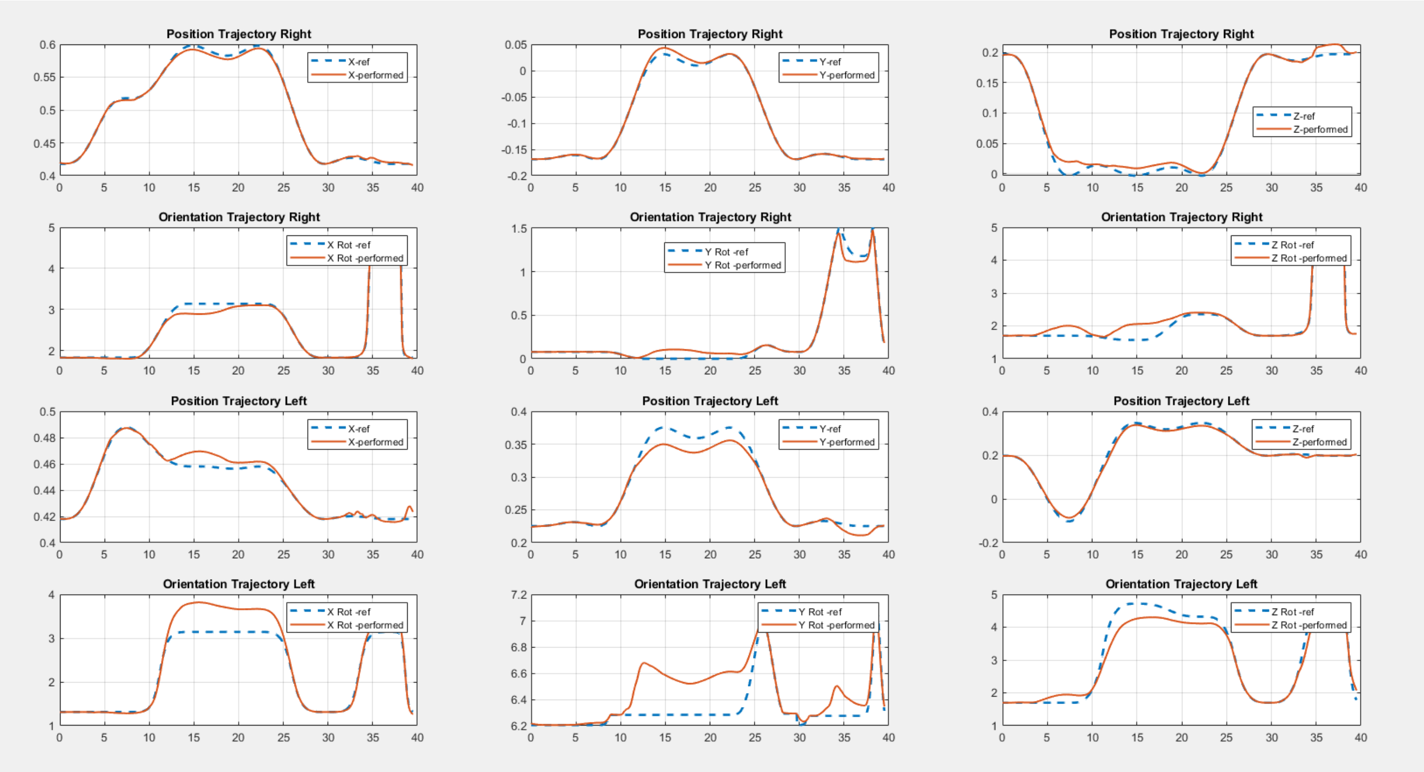


RESULTS

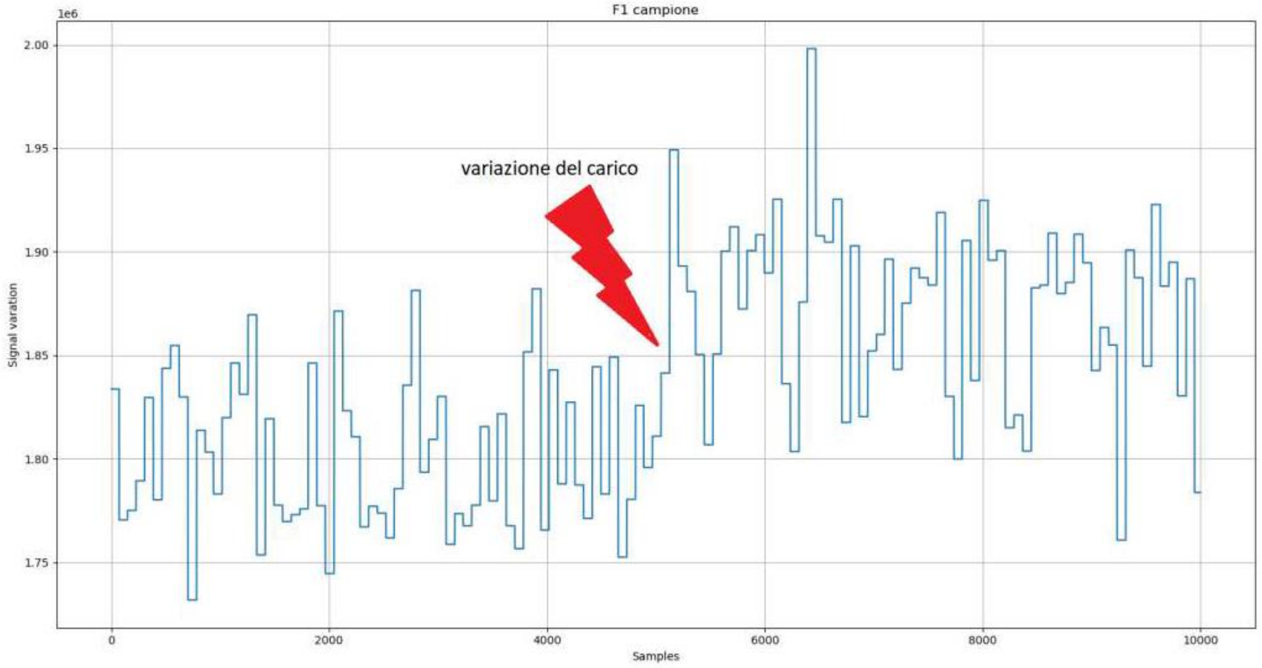
Whole Kinematic Chain: 3D Figures



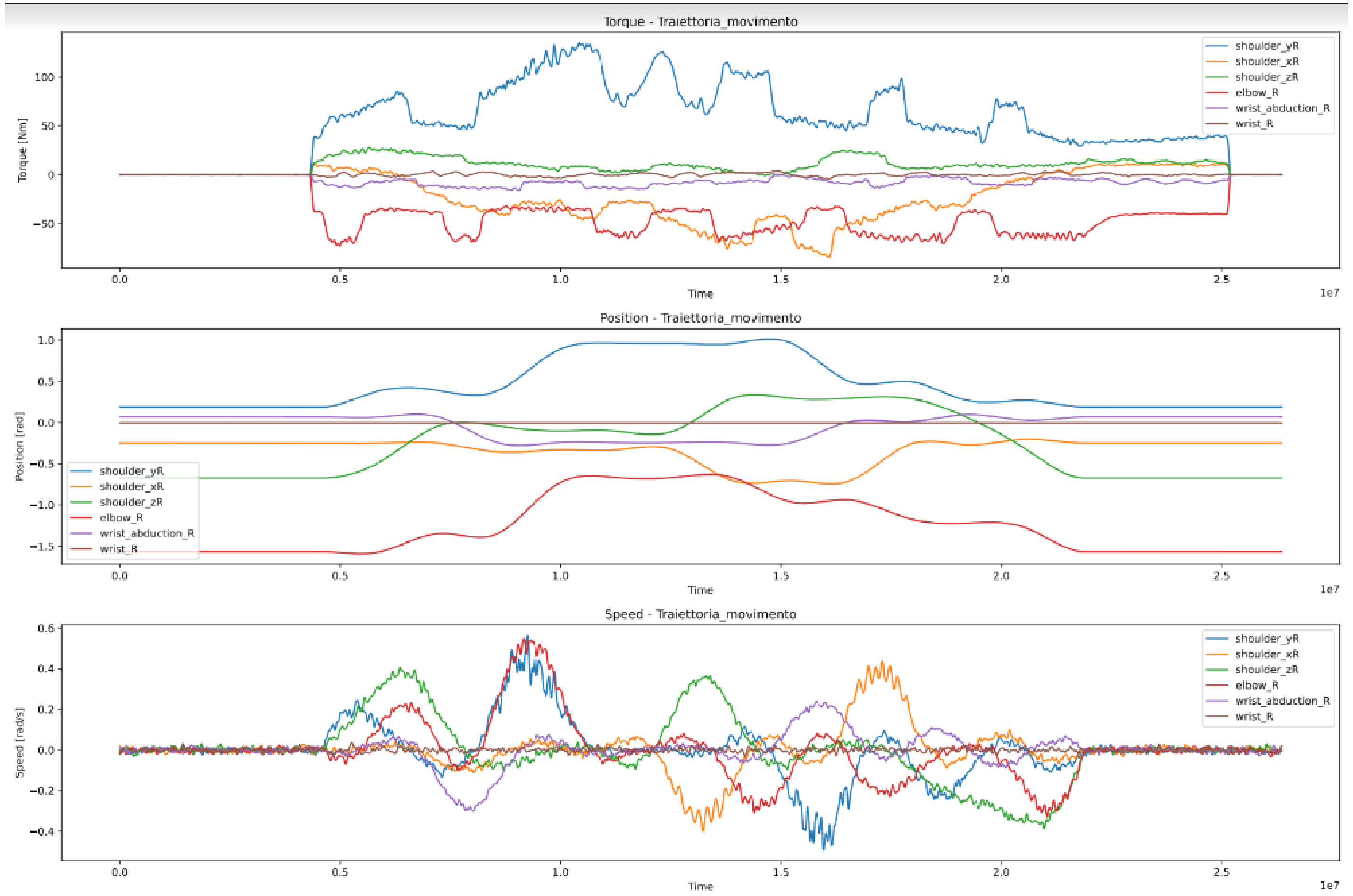
Position/Speed /Acceleration/Jerk



Position/Speed /Acceleration/Jerk



Sensors for reinforcement learning



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Interaction and prediction

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Interaction and prediction

How to adapt to dynamic contexts, prevent obstacles and deal with problems in complex environments.

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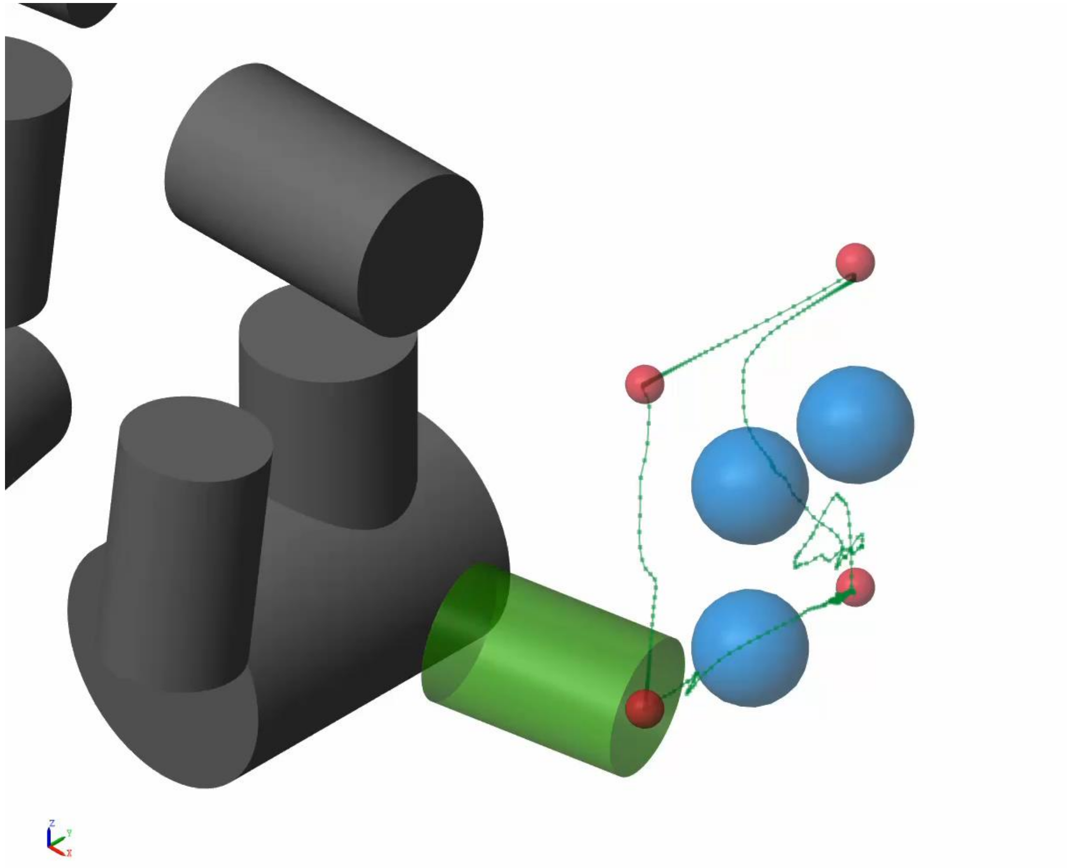
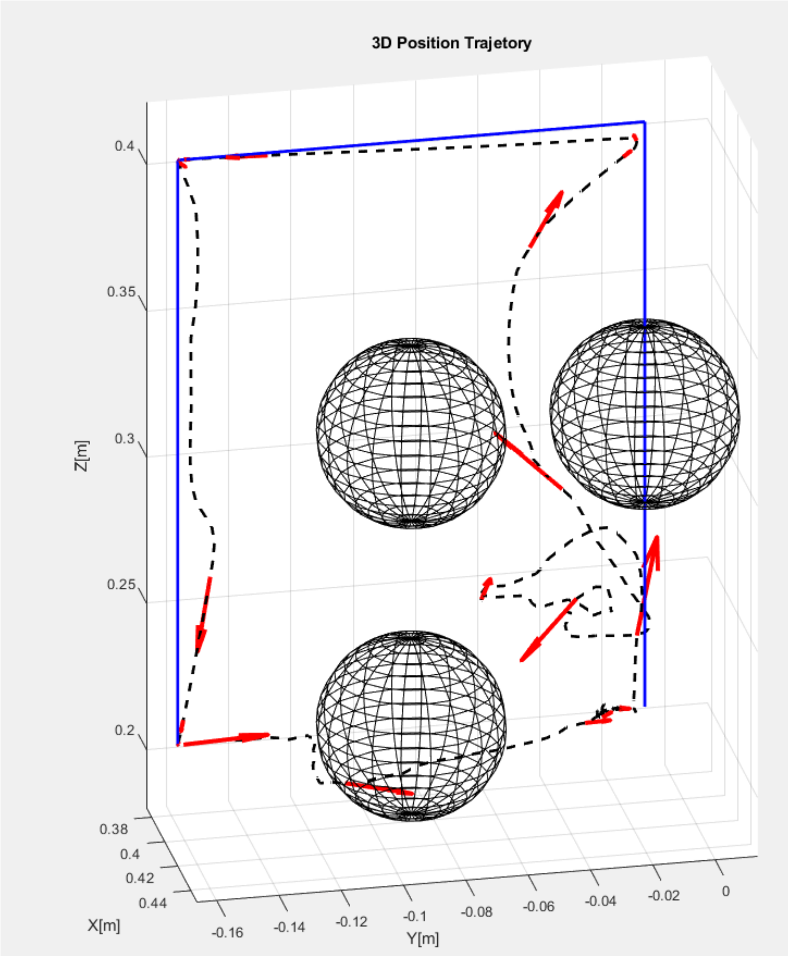
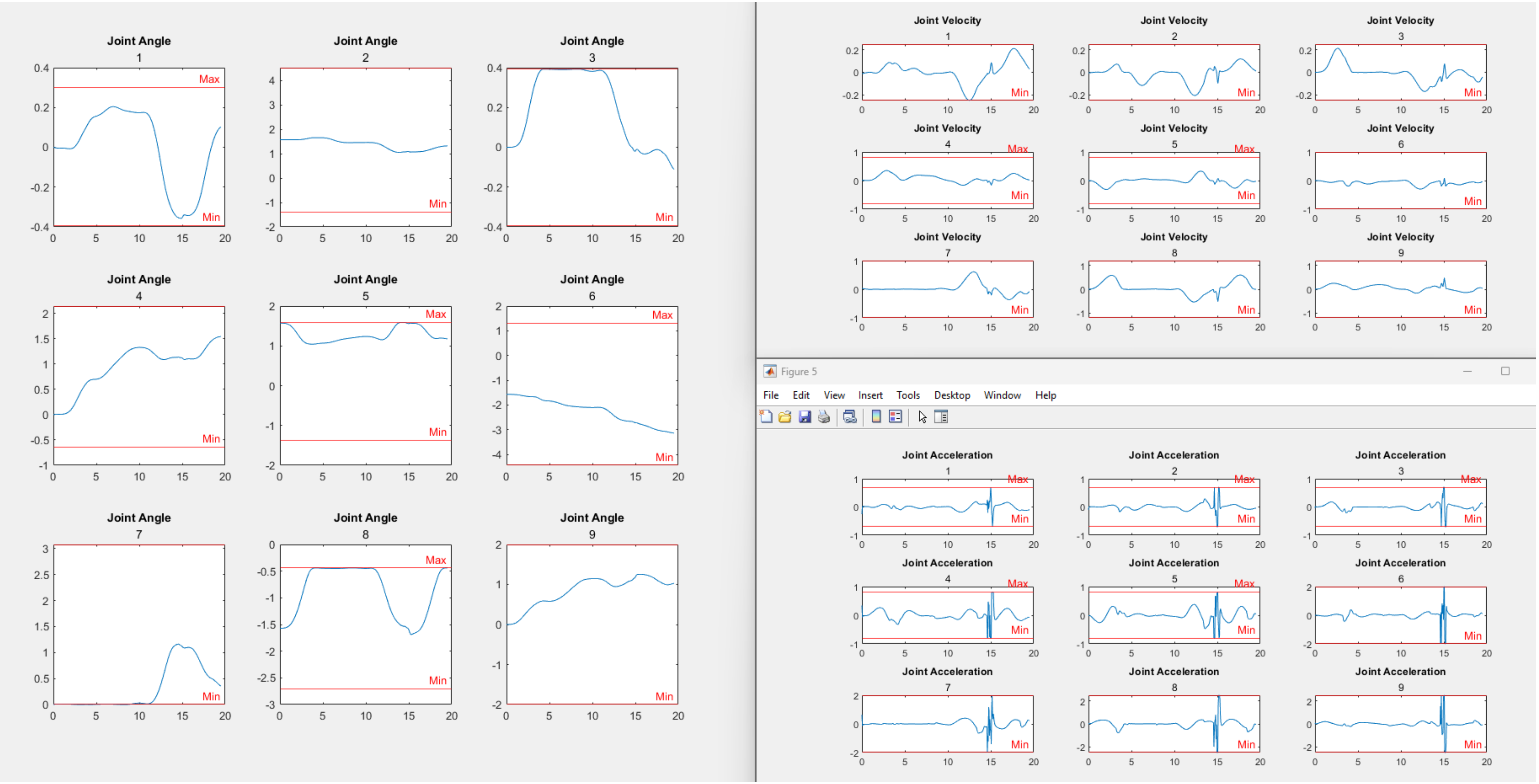
Right Arm Chain: Reference and Obstacle Avoidance





Results



Joint Angle 1
Joint Angle 2
Joint Angle 3
Joint Angle 4
Joint Angle 5
Joint Angle 6
Joint Angle 7
Joint Angle 8
Joint Angle 9
Max
Min
Joint Velocity 1
Joint Velocity 2
Joint Velocity 3
Joint Velocity 4
Joint Velocity 5
Joint Velocity 6
Joint Velocity 7
Joint Velocity 8
Joint Velocity 9
Figure 5
File
Edit
View
Insert
Tools
Desktop
Window
Help
Joint Acceleration 1
Joint Acceleration 2
Joint Acceleration 3
Joint Acceleration 4
Joint Acceleration 5
Joint Acceleration 6
Joint Acceleration 7
Joint Acceleration 8
Joint Acceleration 9

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Interaction and prediction

Safety

Safety

How can a humanoid robot work with more flexibility by operating within safety and regulatory parameters.

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ISO/TS 15066: Robots and robotic devices – Collaborative robots

A **collaborative robot** is a robot that capable of performing a collaborative operation

Collaborative operation
state in which a purposely designed robot system and an operator work within a collaborative workspace

[SOURCE: ISO 10218-1:2011, 3.4, modified]

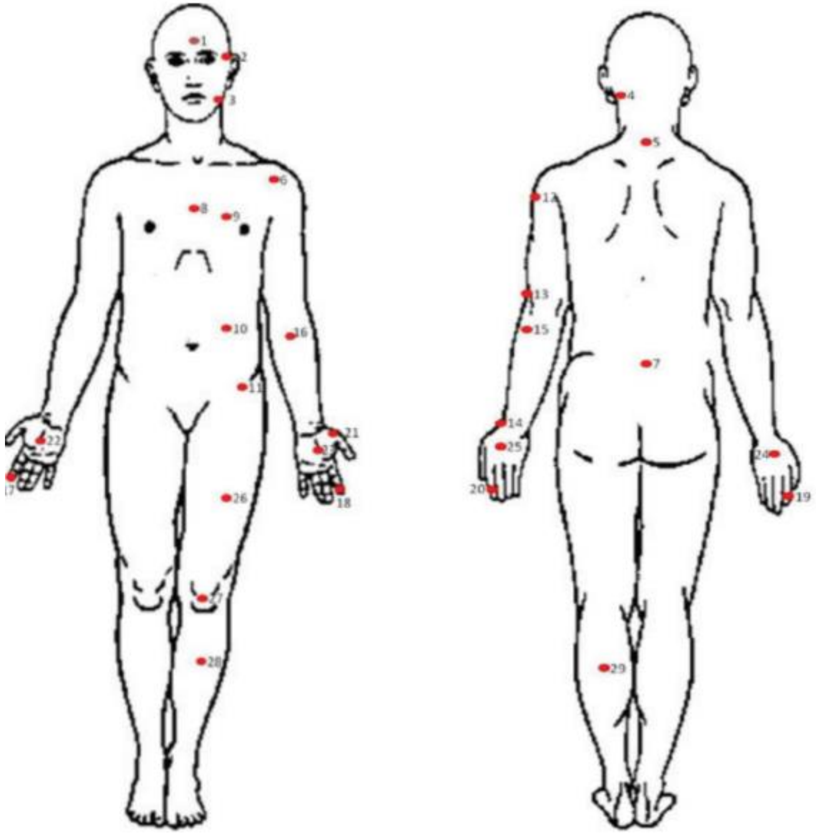
Collaborative workspace
space within the operating space where the robot system (including the workpiece) and a human can perform tasks concurrently during production operation

[SOURCE: ISO 10218-1:2011, 3.5, modified]

Robot motion or stop function		Operator's proximity to collaborative workspace	
		Outside	**Inside**
Robot's proximity to collaborative workspace	**Outside**	Continue	Continue
	Inside and moving	Continue	**Protective stop**
	Inside, at Safety - Rated Monitored Stop	Continue	Continue

SOURCE : ISO TS 15066:2016Figure 2 — Truth table for safety-rated monitored stop operations

Biomechanical limits - ISO/TS 15066:2016(E)



SOURCE : ISO/TS 15066:2016(E): Figure A.1 — Body model

Body region		Specific body area	Quasi-static contact: Maximum permissible pressure [a] p_s N/cm²	Quasi-static contact: Maximum permissible force [b] N	Transient contact: Maximum permissible pressure multiplier [c] P_T	Transient contact: Maximum permissible force multiplier [c] F_T
Skull and forehead [d]	1	*Middle of forehead*	*130*	*130*	*not applicable*	*not applicable*
	2	*Temple*	*110*		*not applicable*	
Face [d]	3	*Masticatory muscle*	*110*	*65*	*not applicable*	*not applicable*
Neck	4	Neck muscle	140	150	2	2
	5	Seventh neck muscle	210		2	
Back and shoulders	6	Shoulder joint	160	210	2	2
	7	Fifth lumbar vertebra	210		2	2
Chest	8	Sternum	120	140	2	2
	9	Pectoral muscle	170		2	
Abdomen	10	Abdominal muscle	140	110	2	2
Pelvis	11	Pelvic bone	210	180	2	2
Upper arms and elbow joints	12	Deltoid muscle	190	150	2	2
	13	Humerus	220		2	
Lower arms and wrist joints	14	Radial bone	190	160	2	2
	15	Forearm muscle	180		2	
	16	Arm nerve	180		2	
Hands and fingers	17	Forefinger pad D	300	140	2	2
	18	Forefinger pad ND	270		2	
	19	Forefinger end joint D	280		2	
	20	Forefinger end joint ND	220		2	
	21	Thenar eminence	200		2	
	22	Palm D	260		2	
	23	Palm ND	260		2	
	24	Back of the hand D	200		2	
	25	Back of the hand ND	190		2	
Thighs and knees	26	Thigh muscle	250	220	2	2
	27	Kneecap	220		2	
Lower legs	28	Middle of shin	220	130	2	2
	29	Calf muscle	210		2	

SOURCE : ISO/TS 15066:2016(E) : Table A.2 — Biomechanical limits

THANK YOU

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