Istituto di Tecnologie Industriali e Automazione
Consiglio Nazionale delle Ricerche

COMAU ROBOTICS

COMAU

from research …. to market

Machining Applications, from Die Casting to Shoes Manufacturing

***Nicola Pedrocchi**, Lorenzo Molinari Tosatti, CNR-ITIA*
Aldo Bottero, Fabio Abbà, Gian Paolo Gerio, COMAU Robotics

Workshop on Advances in robot machining,
ERF, Rovereto, Italy, March 12th, 2014,

ROBOFOOT

SEVENTH FRAMEWORK PROGRAMME

SEVENTH FRAMEWORK PROGRAMME

FLEXICAST

September, 2010-March, 2013

December 2012-December 2016

Roughing of the uppers and Grinding/Deburring

→ Many Differences (accuracy, dexterity, federate, stiffness, *etc)*

→ Many Similarities (control of forces stable and robust,

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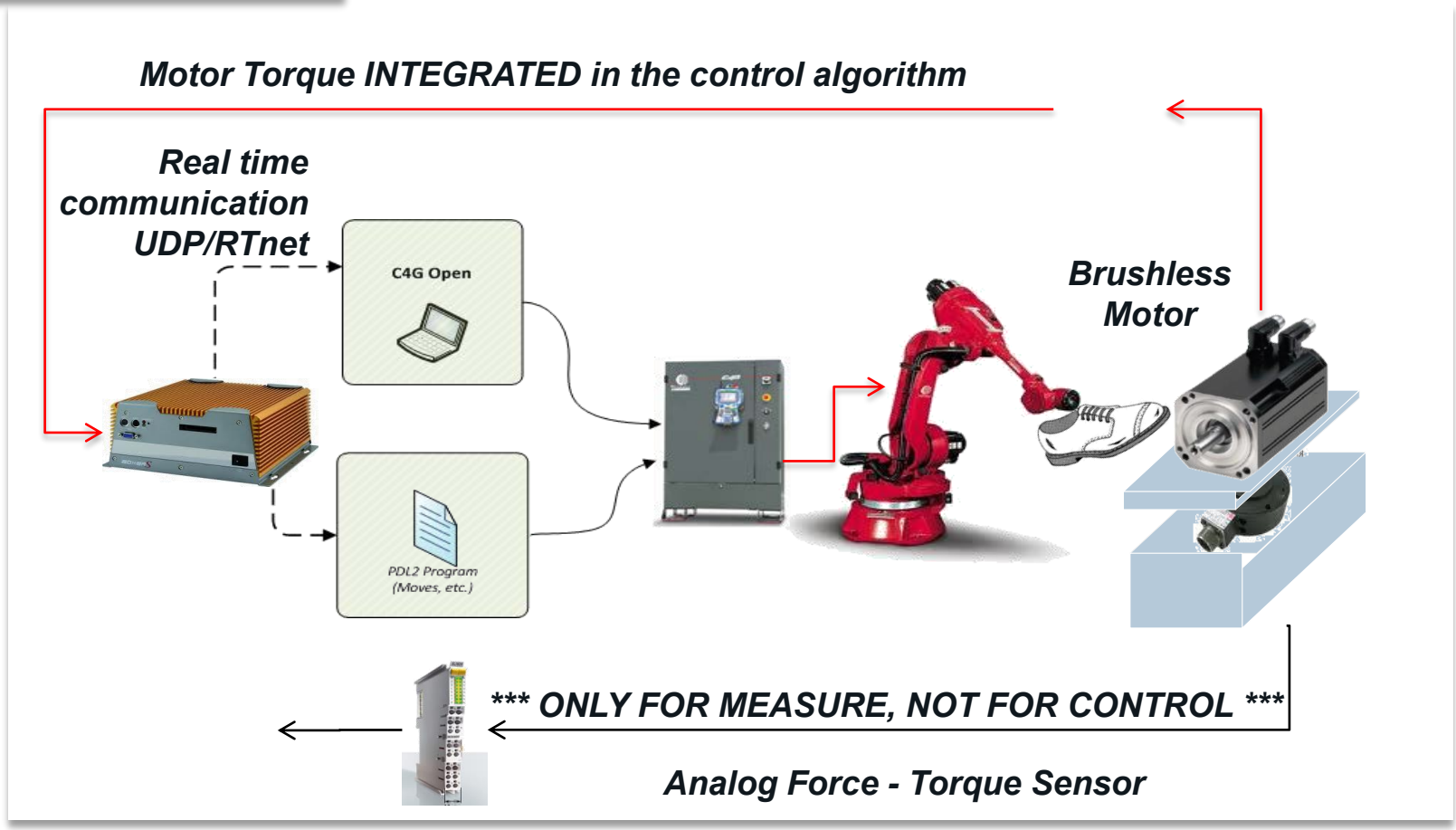

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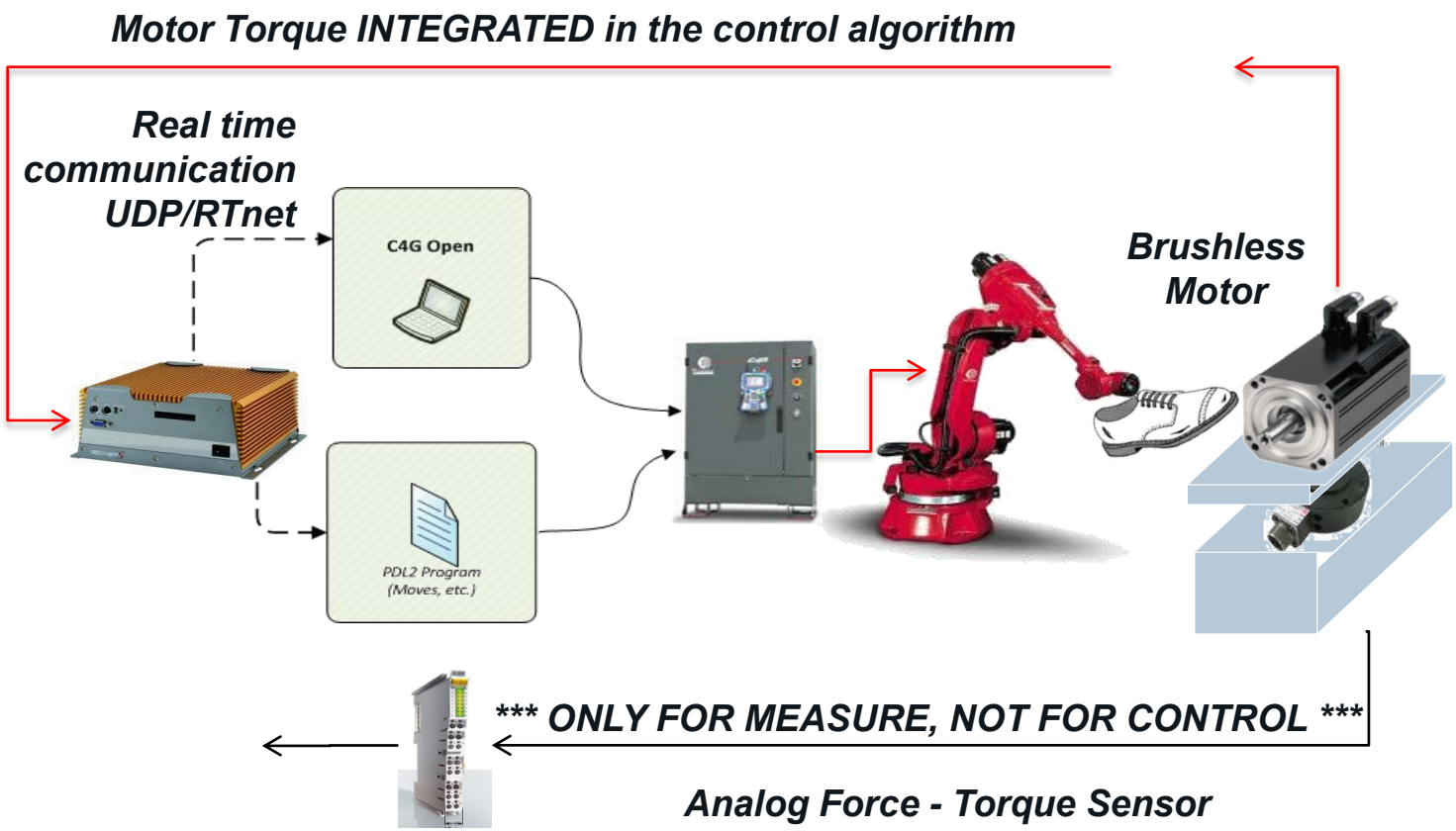

CNR/COMAU ASSUMPTION 1

IMPORTANCE OF THE INTEGRATION OF THE ROBOT DYNAMIC IN THE CONTROLLER

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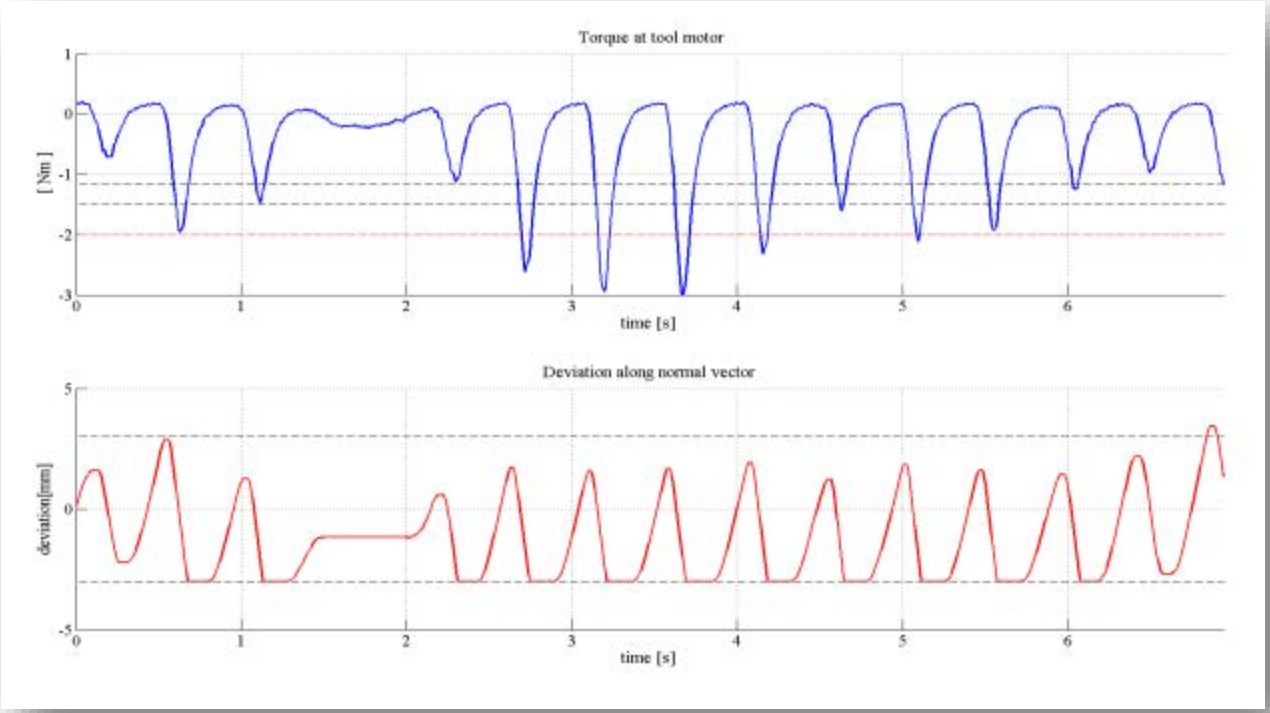
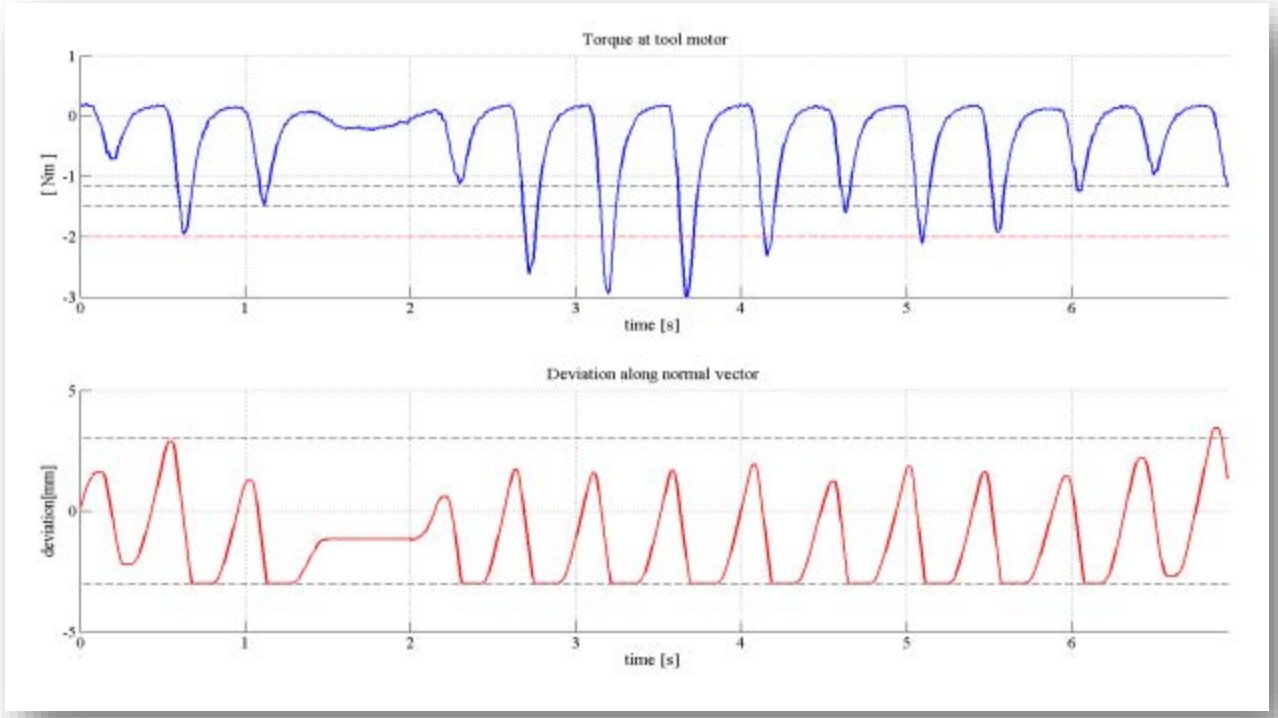


Simple PID regulator
No Dynamic Compensation
(torque feedforward)



Simple PID regulator
No Dynamic Compensation
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ISSUE

Standard Electric CAM modality does not provide dynamic compensation of the deviation imposed

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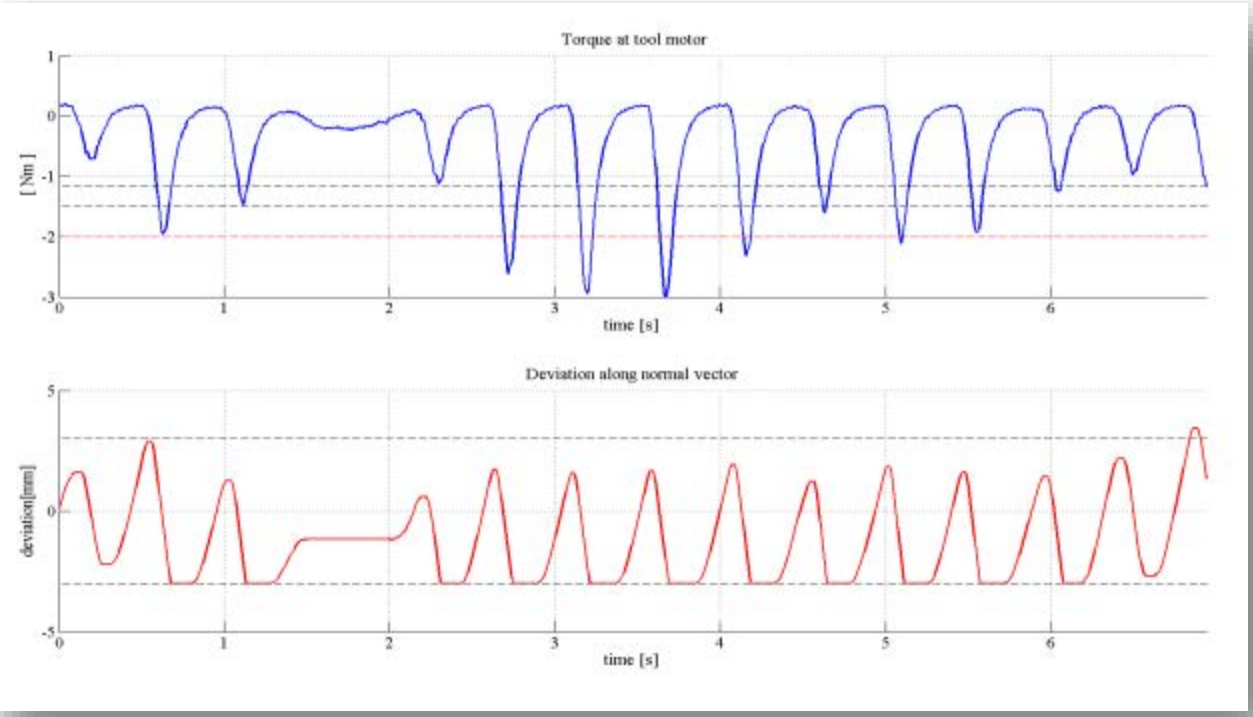

Simple PID regulator
No Dynamic Compensation
(torque feedforward)

ISSUE

Standard Electric CAM modality does not provide dynamic compensation of the deviation imposed

The reliability of standard control solutions is limited by the following issues:

- estimation of the stiffness of the environment;
- modelling arm flexibilities;
- estimating joint friction;
- compensating drive train backlash.

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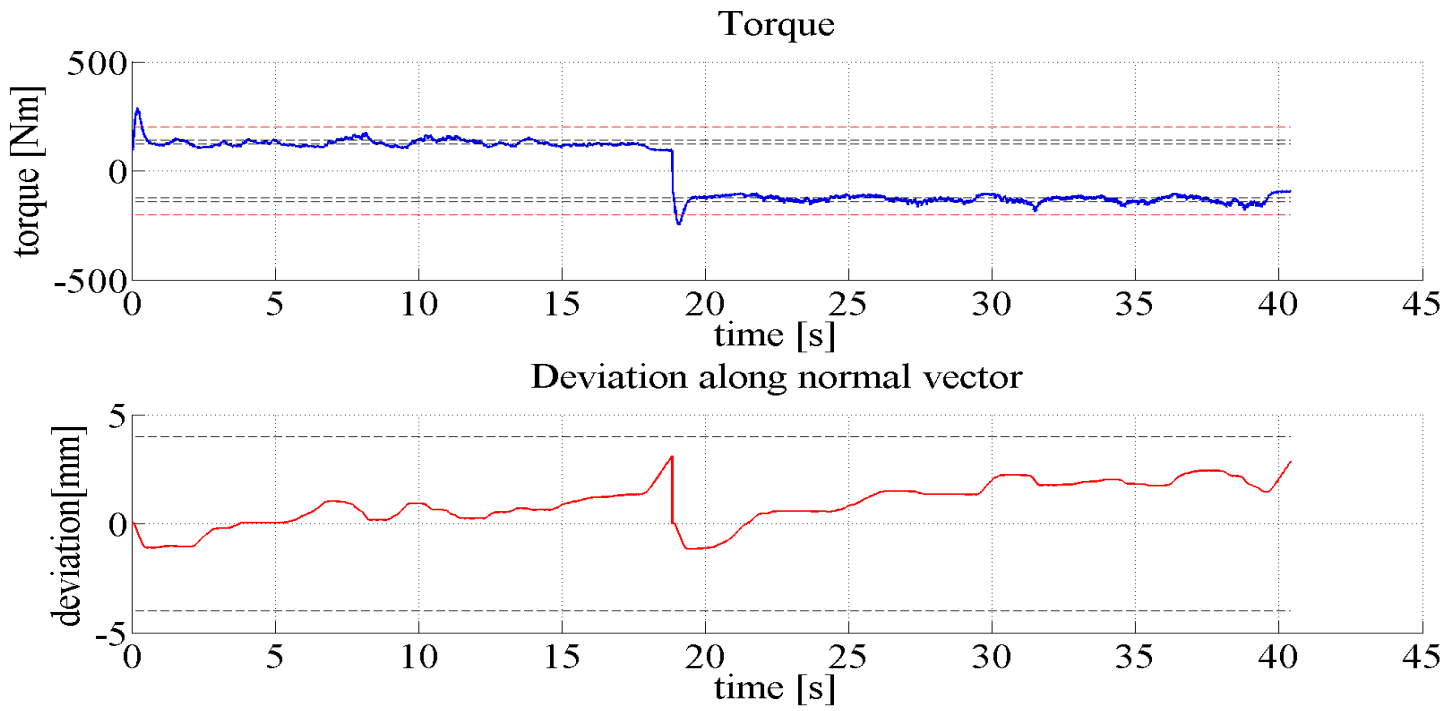
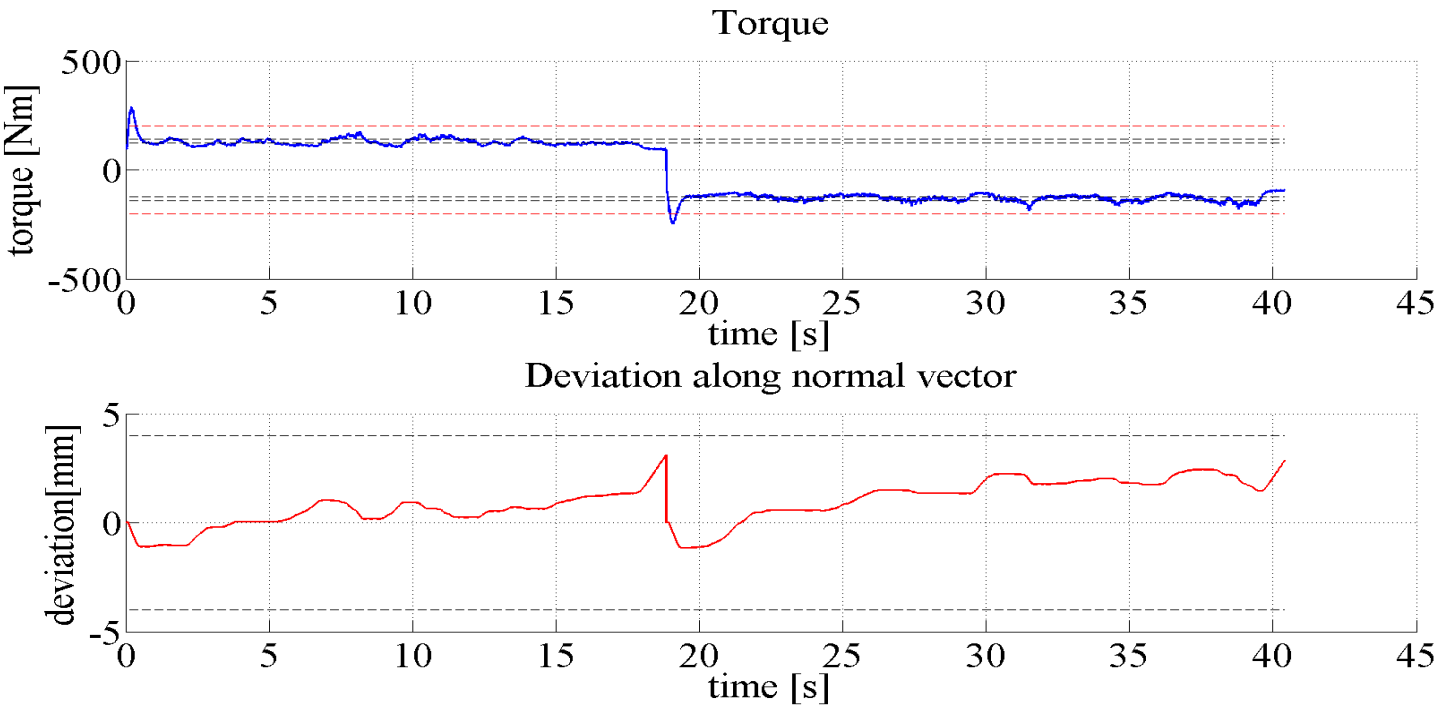
Dynamic Compensation



Solved by using COMAU - C4GOPEN



CNR/COMAU ASSUMPTION 2
QUALITY OF DYNAMIC MODEL

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many **good** papers from 1985 focused on methods for the identification of dynamic parameters of Industrial Robots

Mean Error in Prediction of Torque Estimation attained by state-of-the-art algorithms for **Industrial Robots** is around 5% of Nominal Axis Torque

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To improve the torque prediction accuracy, have we need of using more complex models?

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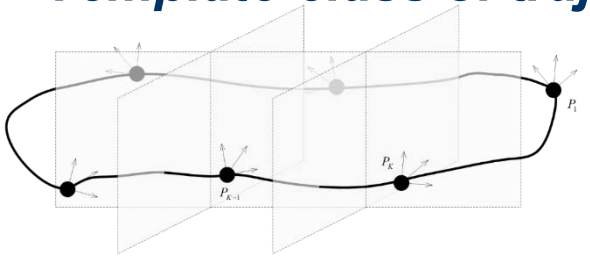
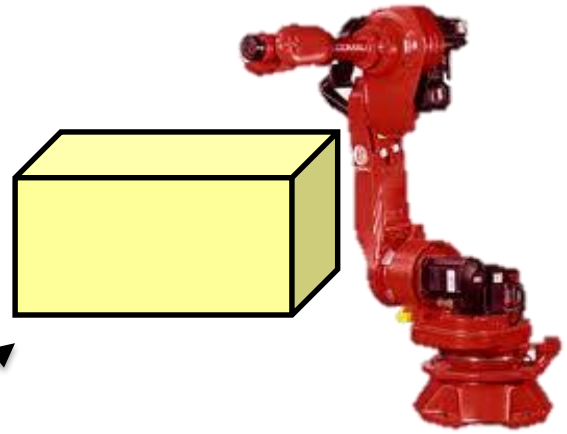
ROBOFOOT APPROACH

Machining tasks require high accuracy in (selectable) sub-region of the workspace.

Template-class of trajectories





Dynamic estimation optimization machining sub-region

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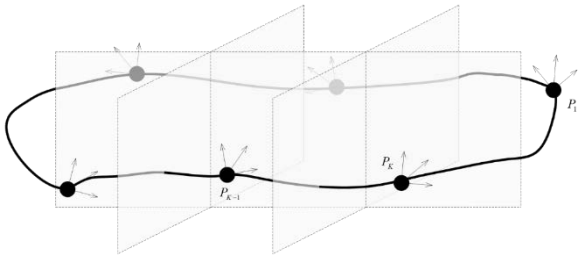

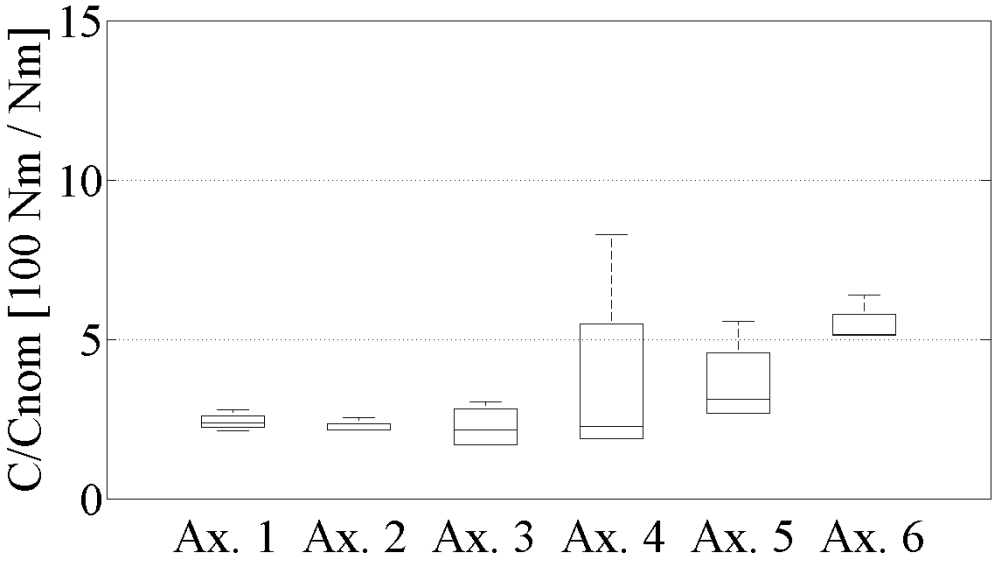

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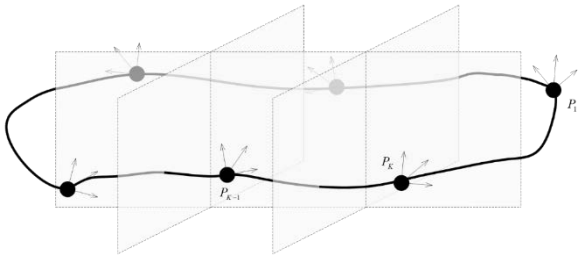

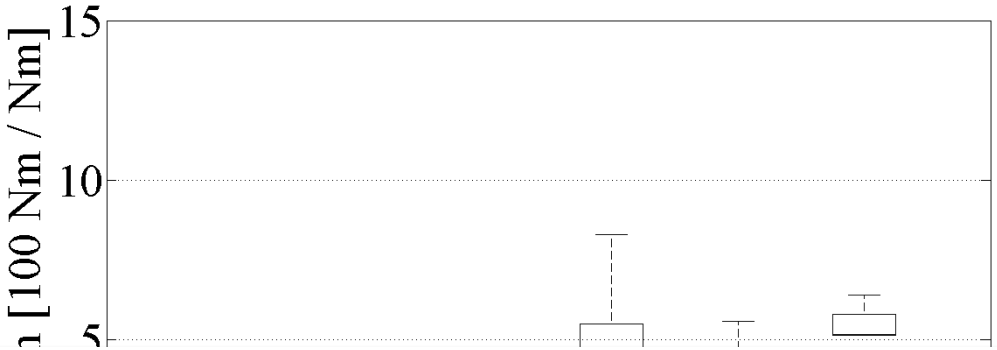

.[1] N. Pedrocchi, E. Villagrossi, F. Vicentini, and L. Molinari Tosatti, “Robot-Dynamic Calibration Improvement by Local Identification,” in Proceedings of 2014 IEEE International Conference on Robotics and Automation, 2014.
[2] N. Pedrocchi, E. Villagrossi, F. Vicentini, and L. Molinari Tosatti, “On robot dynamic model identification through sub-workspace evolved trajectories for optimal torque estimation,” in 2013 IEEE/RSJ International Conference on Intelligent Robots and Systems, 2013, pp. 2370–2376.
[3] E. Villagrossi, N. Pedrocchi, F. Vicentini, and L. Molinarii Tosatti, “Optimal robot dynamics local identification using genetic-based path planning in workspace subregions,” in 2013 IEEE/ASME International Conference on Advanced Intelligent Mechatronics, 2013, pp. 932–937.

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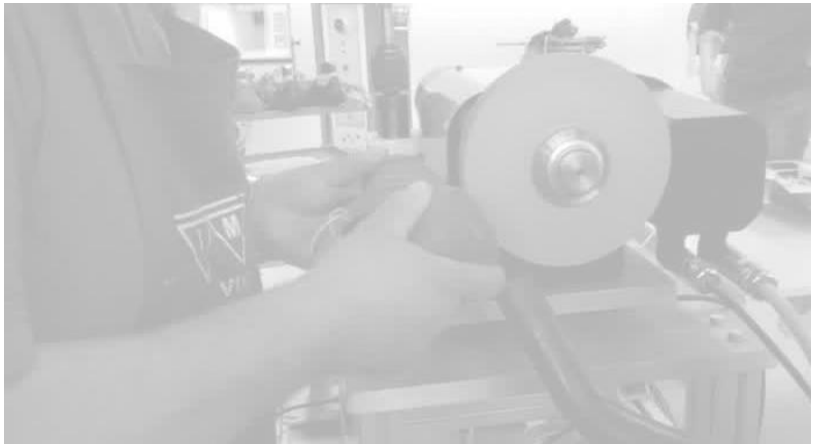
FLEXICAST



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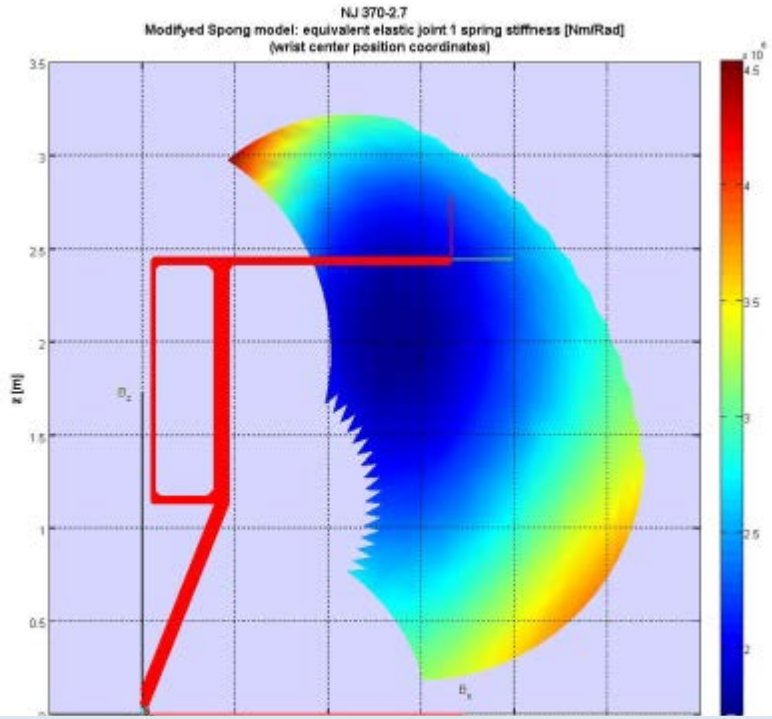
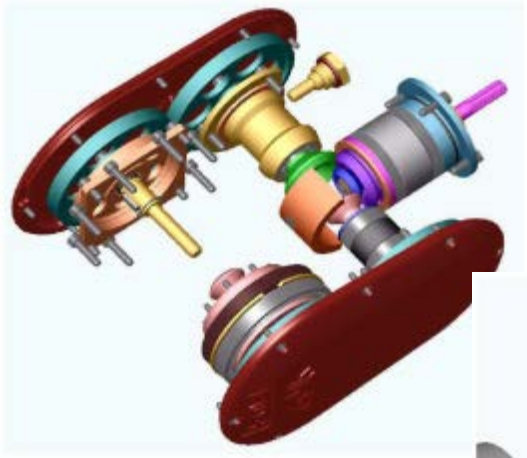
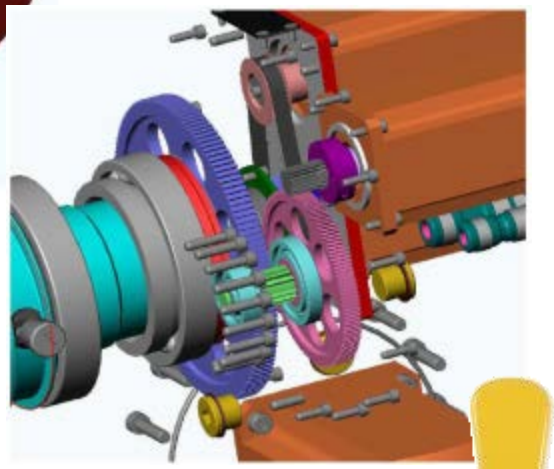
To improve the torque prediction accuracy, have we need of using more complex models?

- ***Integration of Robot Elastic Model in the Robot Control (COMAU and CNR-ITIA)***

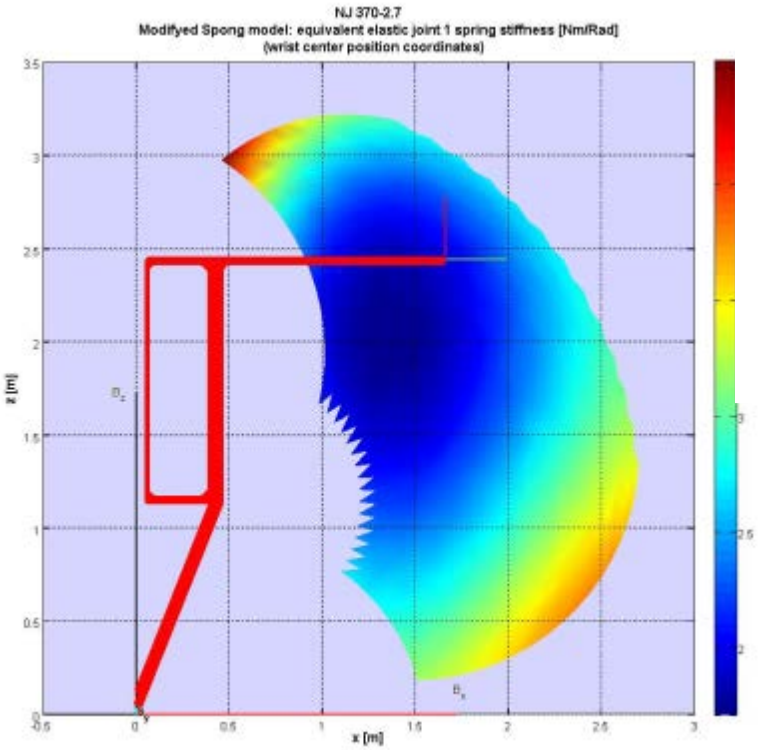


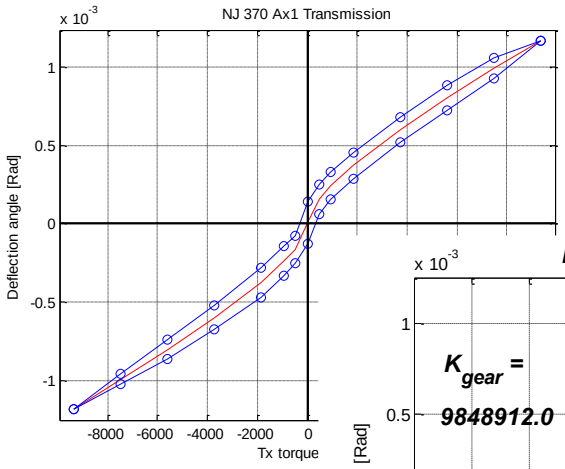


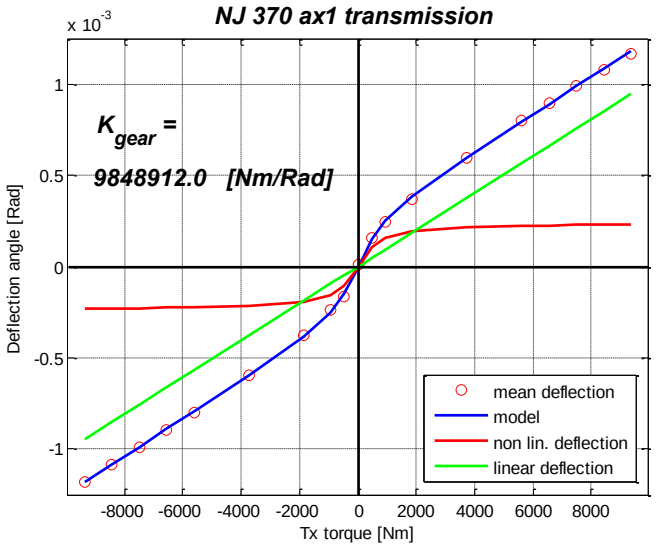


CNR/COMAU ASSUMPTION 3
IMPORTANCE OF REALISTIC ELASTO-DYNAMIC MODEL

- ***Integration of Robot Elastic Model in the Robot Control (COMAU and CNR-ITIA)***

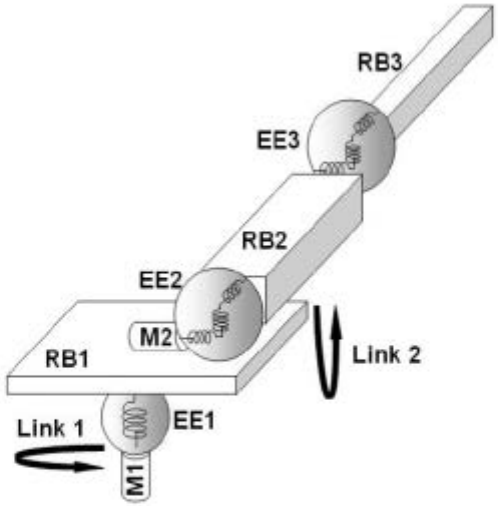






- ***Integration of Robot Elastic Model in the Robot Control (COMAU and CNR-ITIA)***

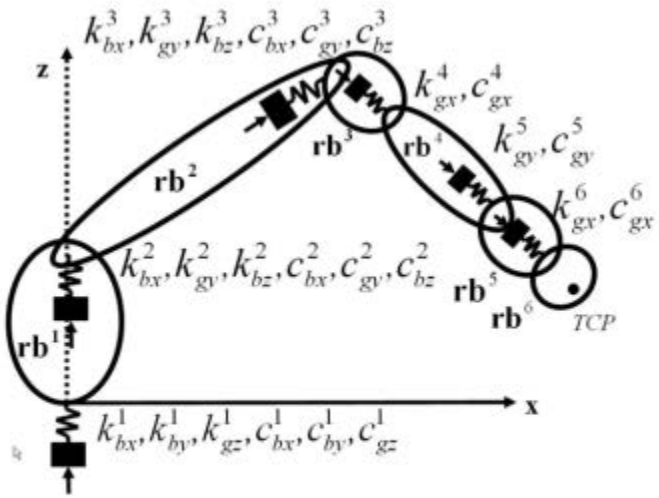
Spong's models

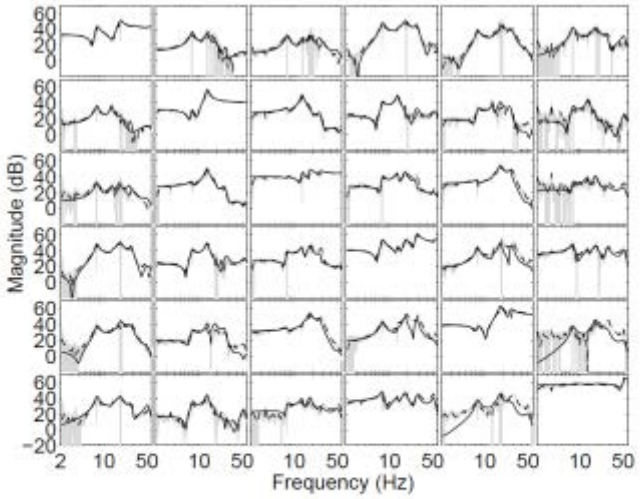


$$
\begin{aligned}
{}_a(q_b, q_a)\begin{pmatrix}\dot{v}_b\\ \dot{v}_a\end{pmatrix} &= c(q_b, q_a, v_b, v_a) + g(q_b, q_a) - \begin{pmatrix}\tau_b\\ \tau_g\end{pmatrix}\\
M_m\dot{v}_m &= \tau_g + u\\
\tau_g &= K_g(q_a - q_m) + C_g(v_a - v_m)\\
\tau_b &= K_b q_b + C_b v_b\\
v_a &= \dot{q}_a\\
v_m &= \dot{q}_m.
\end{aligned}
$$

- ***Integration of Robot Elastic Model in the Robot Control (COMAU and CNR-ITIA)***

Spong's models



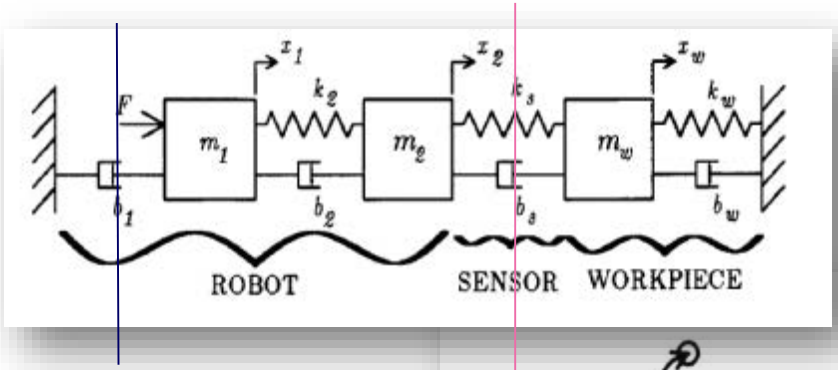


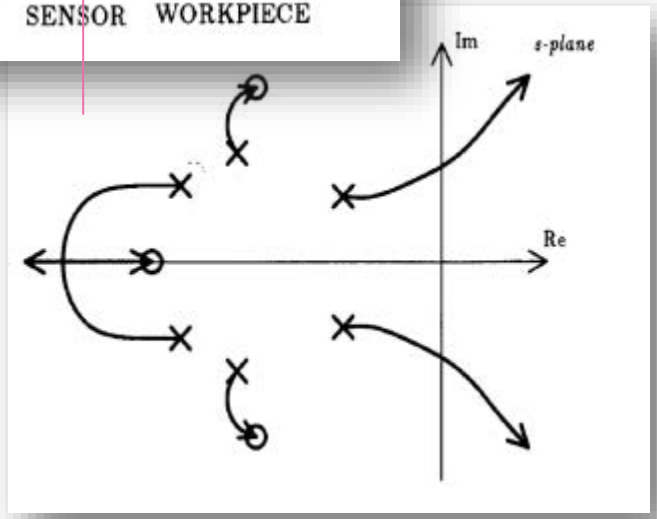
The model is actually used to predict the modal frequencies in the new motion planner (eMotion) with the goal to increase the dynamic performance

- ***Integration of Robot Elastic Model in the Robot Control (COMAU and CNR-ITIA)***

#1 Issue

- ***Sensing non collocation***





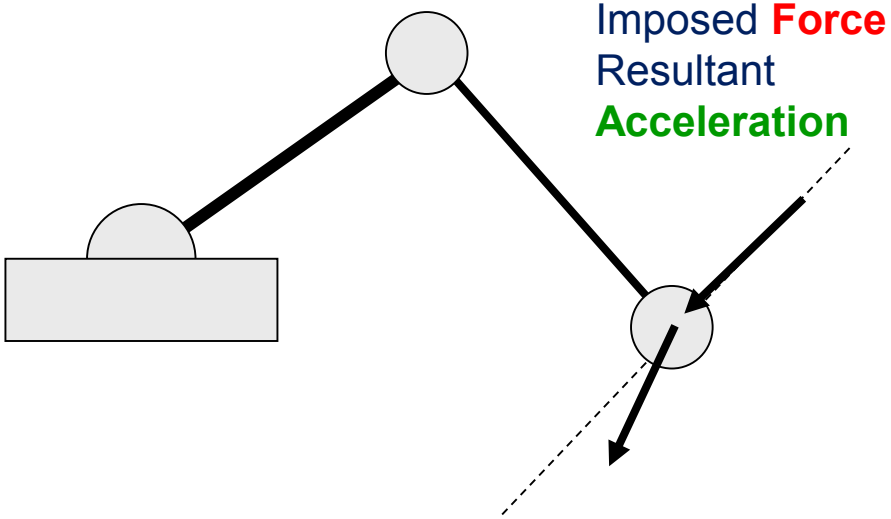
- ***Integration of Robot Elastic Model in the Robot Control (COMAU and CNR-ITIA)***

#1 Issue

- ***Sensing non collocation***

#2 Issue

- ***Coupled Elasto-Dynamics***



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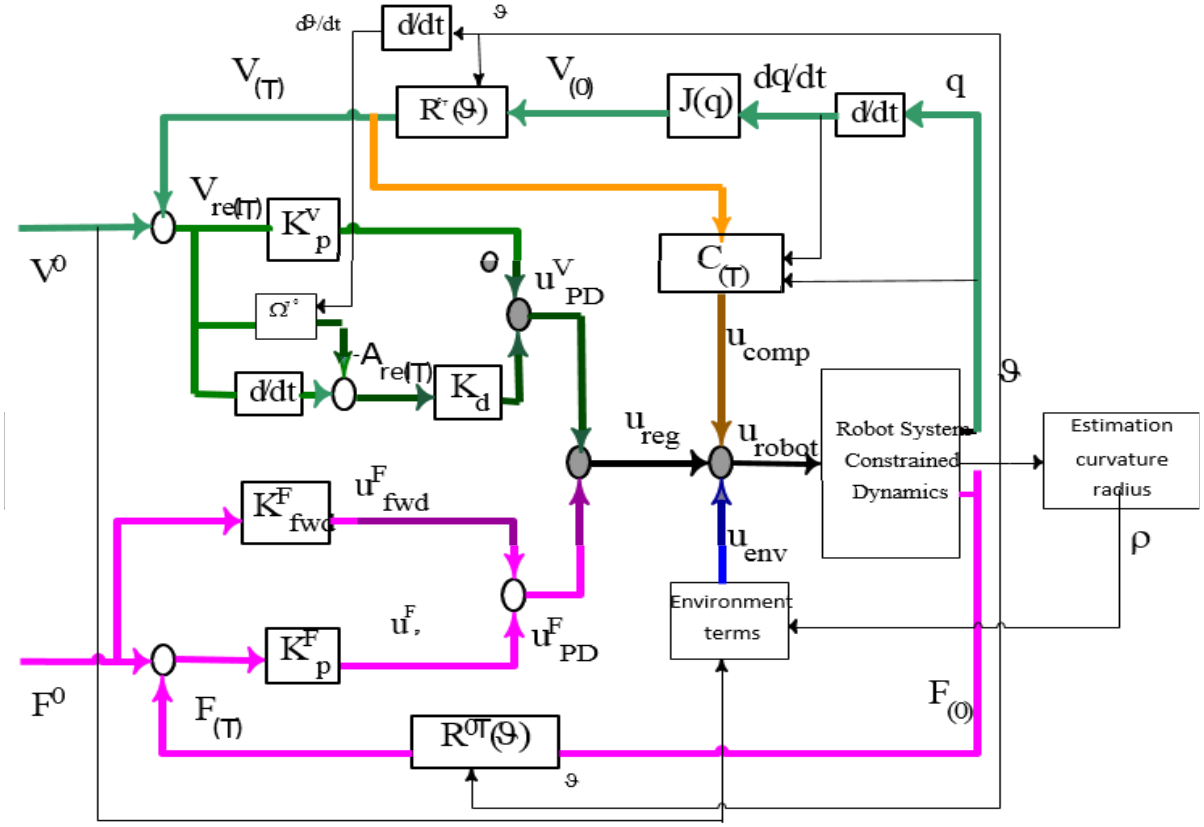

CNR/COMAU ASSUMPTION 4
IMPORTANCE OF Centralized MIMO schemes (c5gopen)

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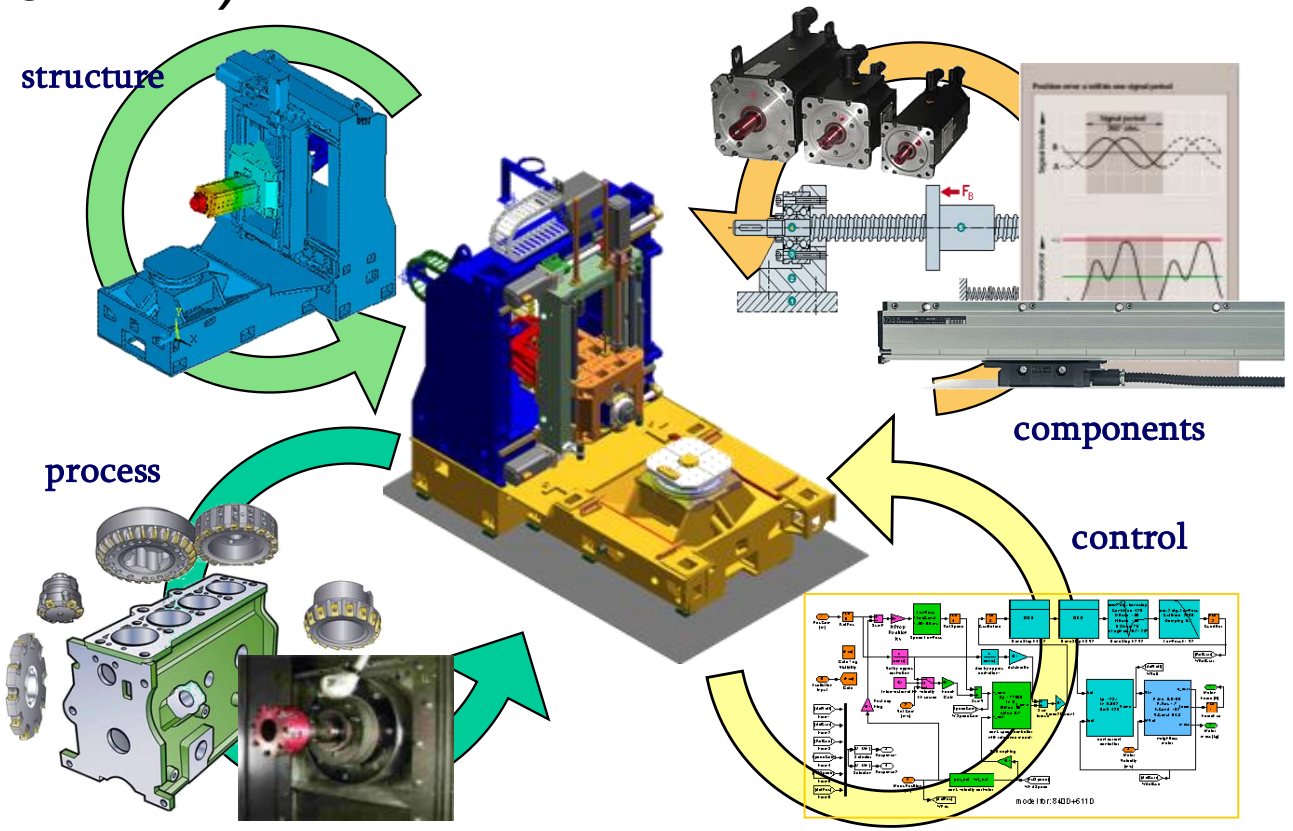

CNR/COMAU ASSUMPTION 5

Virtual prototyping necessary for the designer to investigate the machine behavior in operational conditions

COMAU & CNR-ITIA Action Plan :

1. **Sharing Personnel**
   → one CNR-ITIA researcher is already working one week per month in COMAU in order to integrate our expertize

2. **Improve Robot Dynamic models (both elastic and rigid models for the robot)**
   → The goal is increase dramatically the prediction power in torque estimation during free-movement

3. **Virtual Prototyping of the Grinding/Deburring**
   → The goal is to integrate the robot models in virtual environment integrating the process model in order to better understand the operating condition

4. **Develop MIMO Model Based Control Strategies for optimum grinding/deburring operation**
   → The goal is increase dramatically the performance of the COMAU control in the free-space movements

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Thanks for your kind attention

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