Politecnico di Torino
Dipartimento di Automatica e Informatica

PhD in Computer and Control Engineering
34th cycle

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Computational Intelligence (CI) techniques for applications in the context of industrial robotics

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1. Introduction / Context

Computational Intelligence (**CI**) is "a set of nature-inspired computational methodologies and approaches to address complex real-world problems to which mathematical or traditional modelling can be useless". Main CI techniques are: *Evolutionary Computing* (EC), *Fuzzy Logic* (FL), and *Artificial Neural Networks* (ANN),

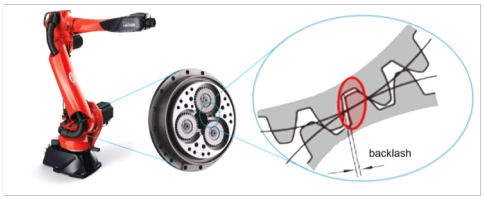
CI is the perfect tool when dealing with lots of data and continuously changing, complex, non-linear systems as **robotic manipulators**.

2. Objectives

Explore **new applications of CI in robotics** and investigate *performance*, *trade-offs*, and *feasibility* of their use in an **industrial context**.

The case study is to develop a **Condition Based Maintenance (CBM) tool** to detect problems of mechanical components aging (i.e., **gear backlash**) in a robotic joint.

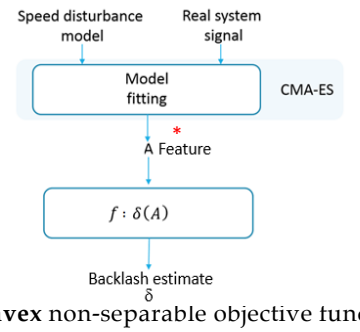
The strategy is based on measures gathered by a specifically developed **virtual sensor**.



3. Method

The problem of measuring backlash is managed as an **optimization problem** where data are fitted on a model. Then the parameters of the model are used as **features** representative for the backlash evolution over time.

Backlash estimate as a model fitting problem



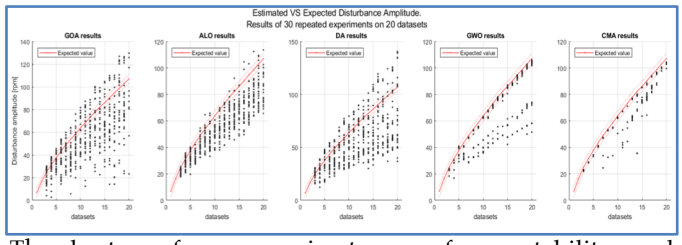
* **non-convex** non-separable objective function

Many **CI strategies** have been tested and compared to find the most suitable for the problem of interest:

- Covariance Matrix Adaptation-**Evolution Strategy** (CMA-ES),
- Dragonfly Algorithm (DA),
- Antlion Optimizer (ALO),
- Grasshopper Optimizer (GOA),
- Grey wolf Optimizer (GW).

} **Swarm Algorithms**

4. Results



The best performances in terms of repeatability and accuracy were from **CMA-ES**. This algorithm was the final chioce for the method implemetation. A fine tuning of the algorithm parameters was performed to further increase the results quality and meet problem requirements.

Final validation of the method on **real data** from robots currently operating in **industrial plants**.

5. Conclusions

CMA-ES has been succesfully applied to detect and estimate backlash in robotic joints.

The full procedure will be implemented as a CBM tool of the **Comau IoT platform** (**inGRID**).

Data acquisition is currently ongoing on robots on plants.

6. References

- ***Virtual Sensor for Backlash in Robotic Manipulators*** - *Giovannitti, Eliana; Squillero, Giovanni; Alberto, Tonda, Sayyidshahab Nabavi. --- journal publication*
- ***Exploiting Artificial Swarms for the Virtual Measurement of Backlash in Industrial Robots*** - *Giovannitti, Eliana; Squillero, Giovanni; Alberto, Tonda, Sayyidshahab Nabavi. - CEC2021*
- ***Virtual Measurement of the Backlash Gap in Industrial Manipulators*** -*Giovannitti, Eliana; Squillero, Giovanni; Alberto, Tonda. - SEMCCO & FANCCO 2019*
- ***Evolutionary Antivirus Signature Optimization*** - *Giovannitti, Eliana; Mannella, Luca; Marcelli, Andrea; Squillero, Giovanni – Congress Evolutionar Computation 2020*