REHAssist research group

From Interactive robotics to Cobotics
Basics, concepts of interaction and applications

EPFL REHAssist

Dr Mohamed Bouri
REHAssist, Group leader

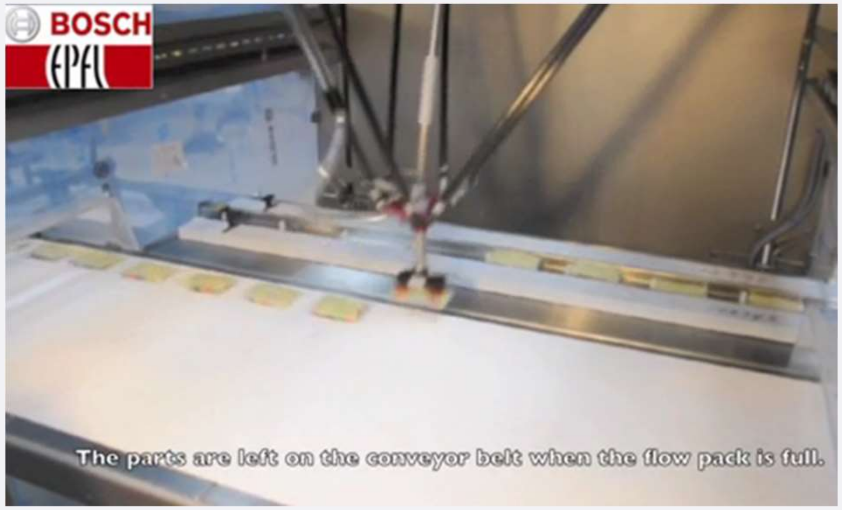
Part 1

Examples of implementations

From Motion to Interactions with Human

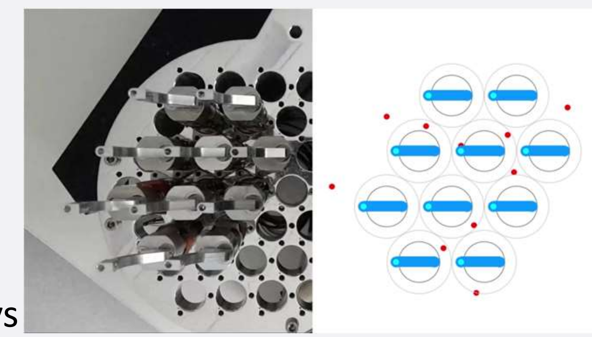
From Robotics to Collaborative robotics

Position control



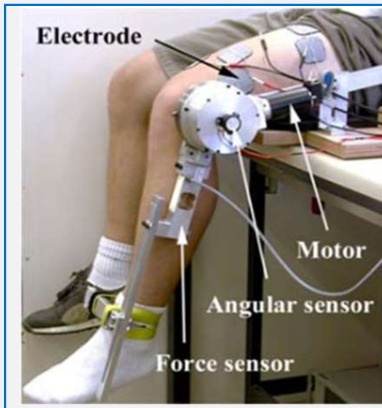
Direct Drive Actuated Delta realized for **BOSCH Packaging Technology**

[Patent 2015] Device For Moving And Positioning An Object In Space, Huser M., Tschudi M., …, Bouri M., Clavel R., Demaurex MO., Device For Moving And Positioning An Object In Space, reference WO2012152559

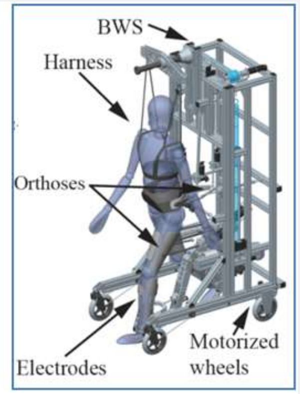


Astrobots
Robots for astrophysics surveys

Rehabilitation Robotics for lower limbs

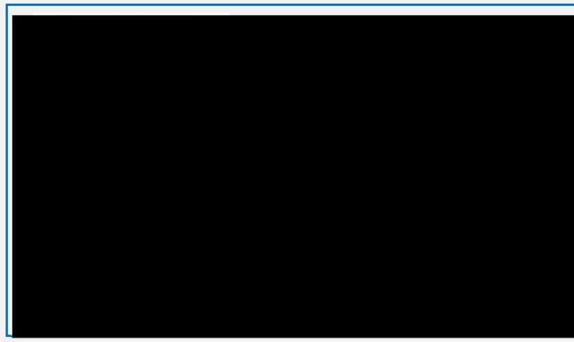


Feasibility – (2000)

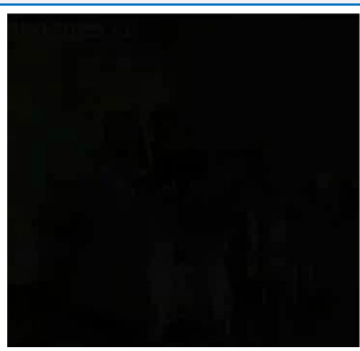


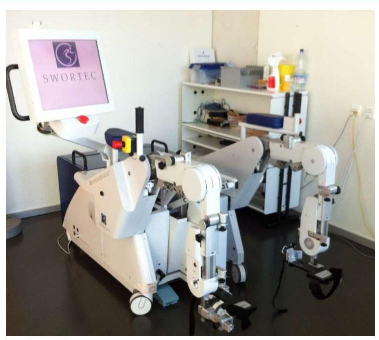
Concept – (2007)

Prototype-0
In clinical trial (2008-2009)

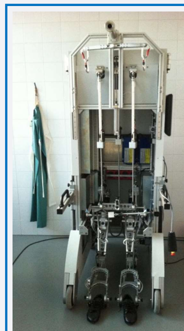


Prototype-0
In clinical trial (2003 – 2005)



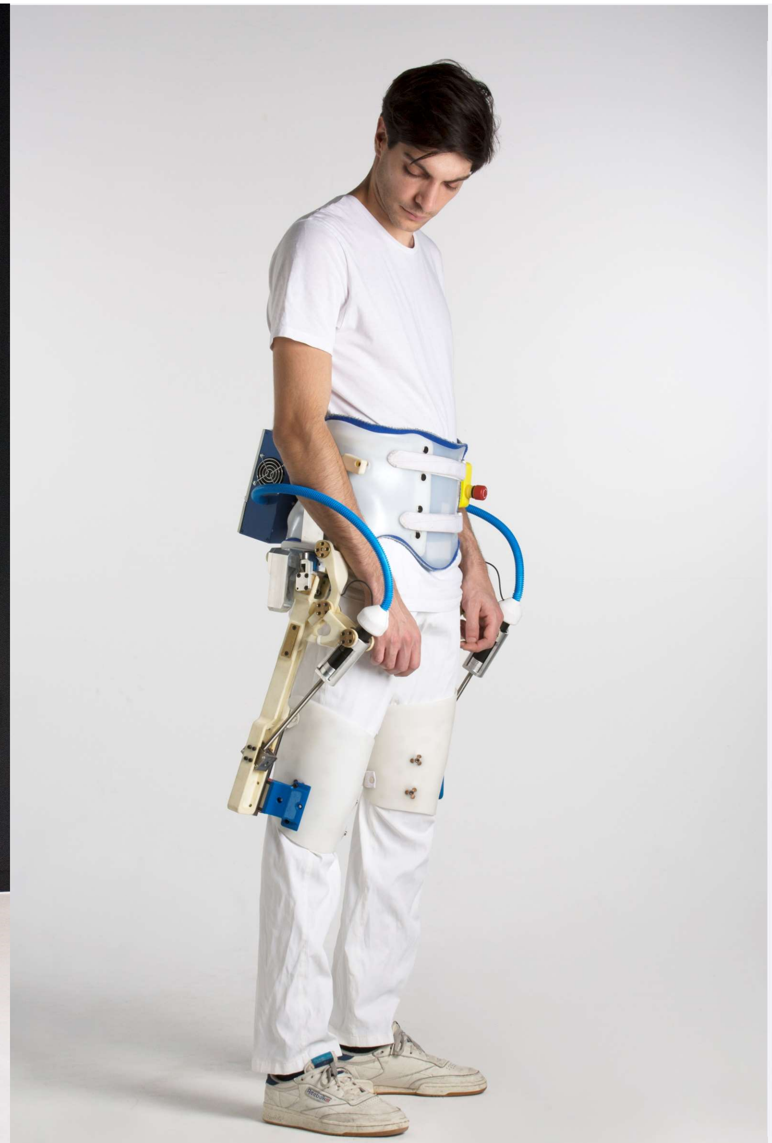


Product certified (2008)



Product certified (2013)

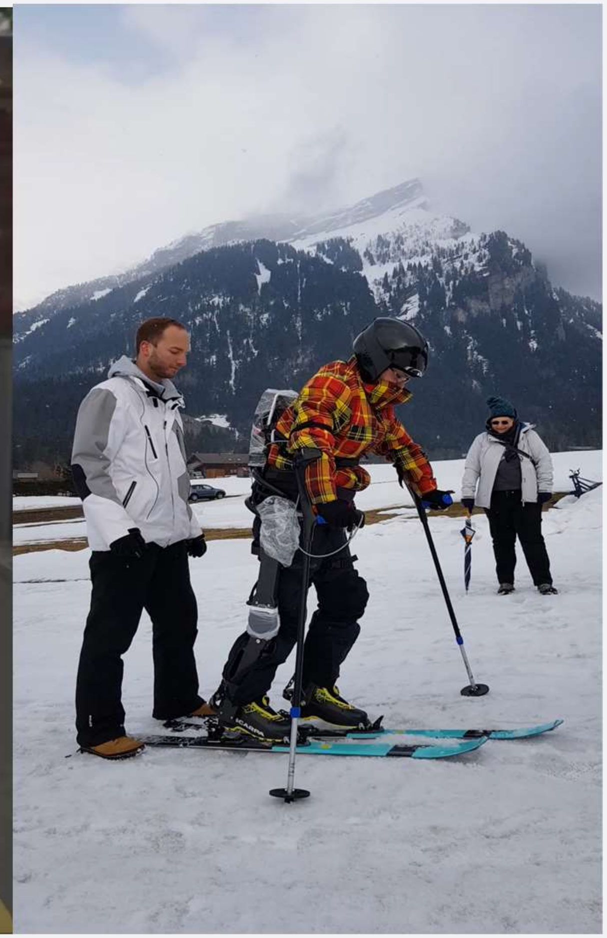
TWIICE, Vouga, ICORR 2017
Baud, ICORR 2019
Fasola, ICORR 2019



HiBSO, Olivier et al. Rob & Aut Sys, 2015

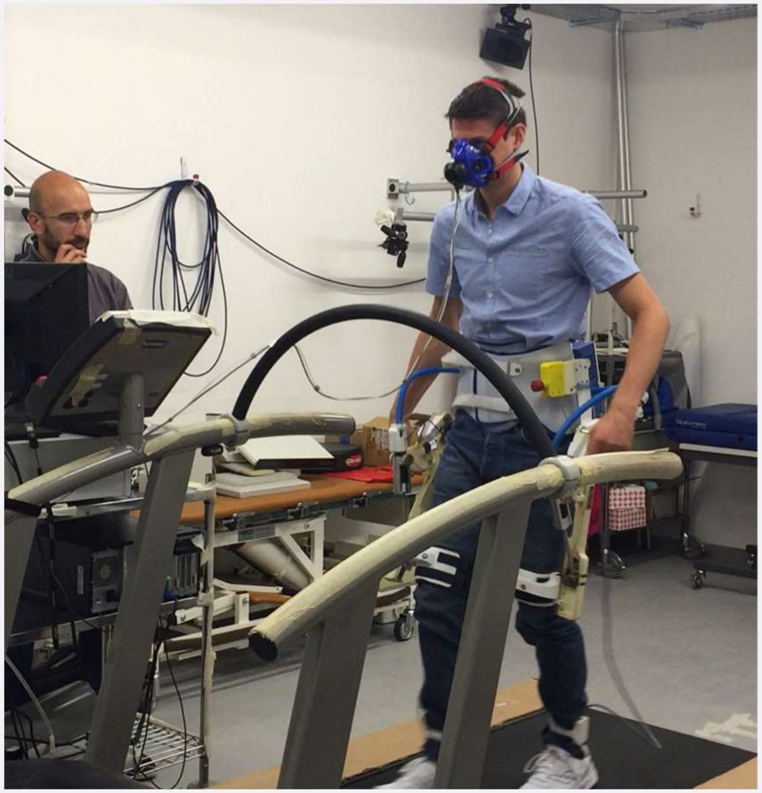
Autonomyo, Ortlieb et al, ICORR 2017

Daily living activities

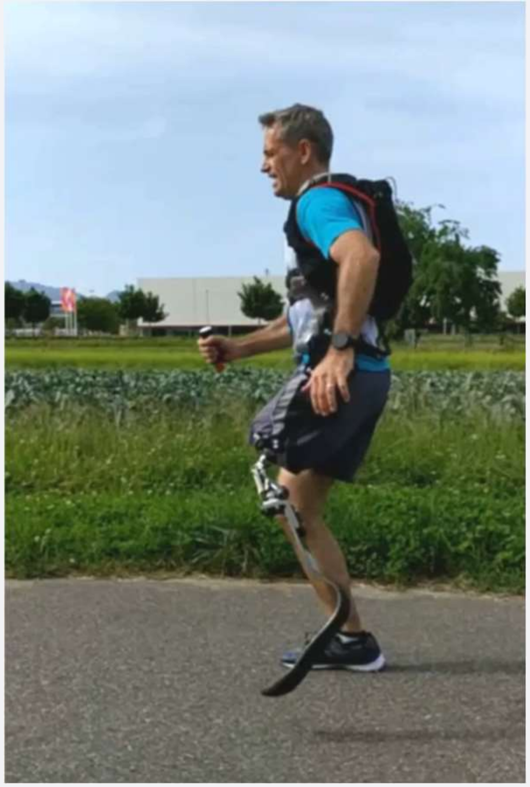


Partially assist to enable gait or make it more effective

Autonomyo: 3 DoF / leg



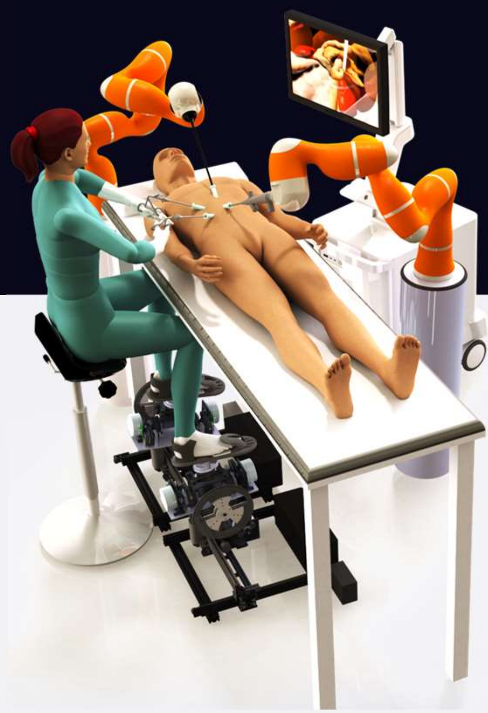
HiBSO: bi-lateral hip assist



Runner: unilateral hip assist

Human-inspired Balance control

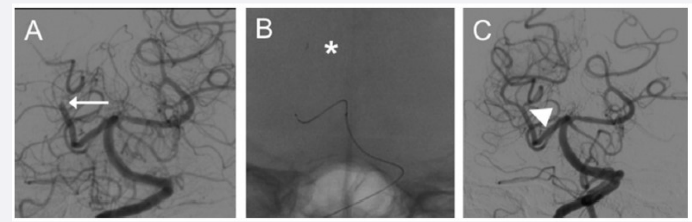
4 Handed manipulation to enhance robotic surgery [2017-2022]



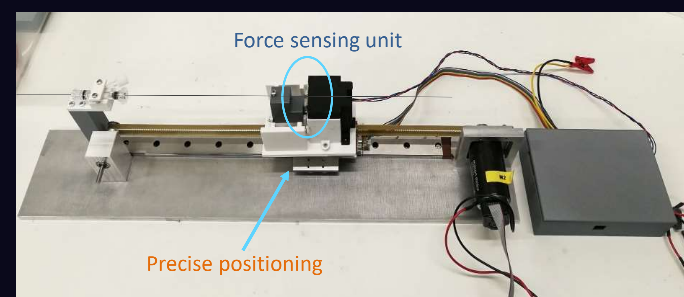
Haptic intervention for intelligent thrombectomy

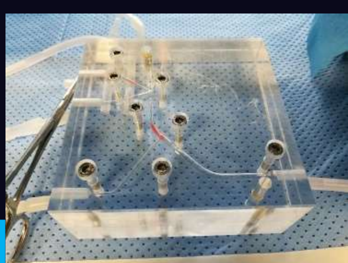
nio Machi

Hôpitaux Universitaires Genève

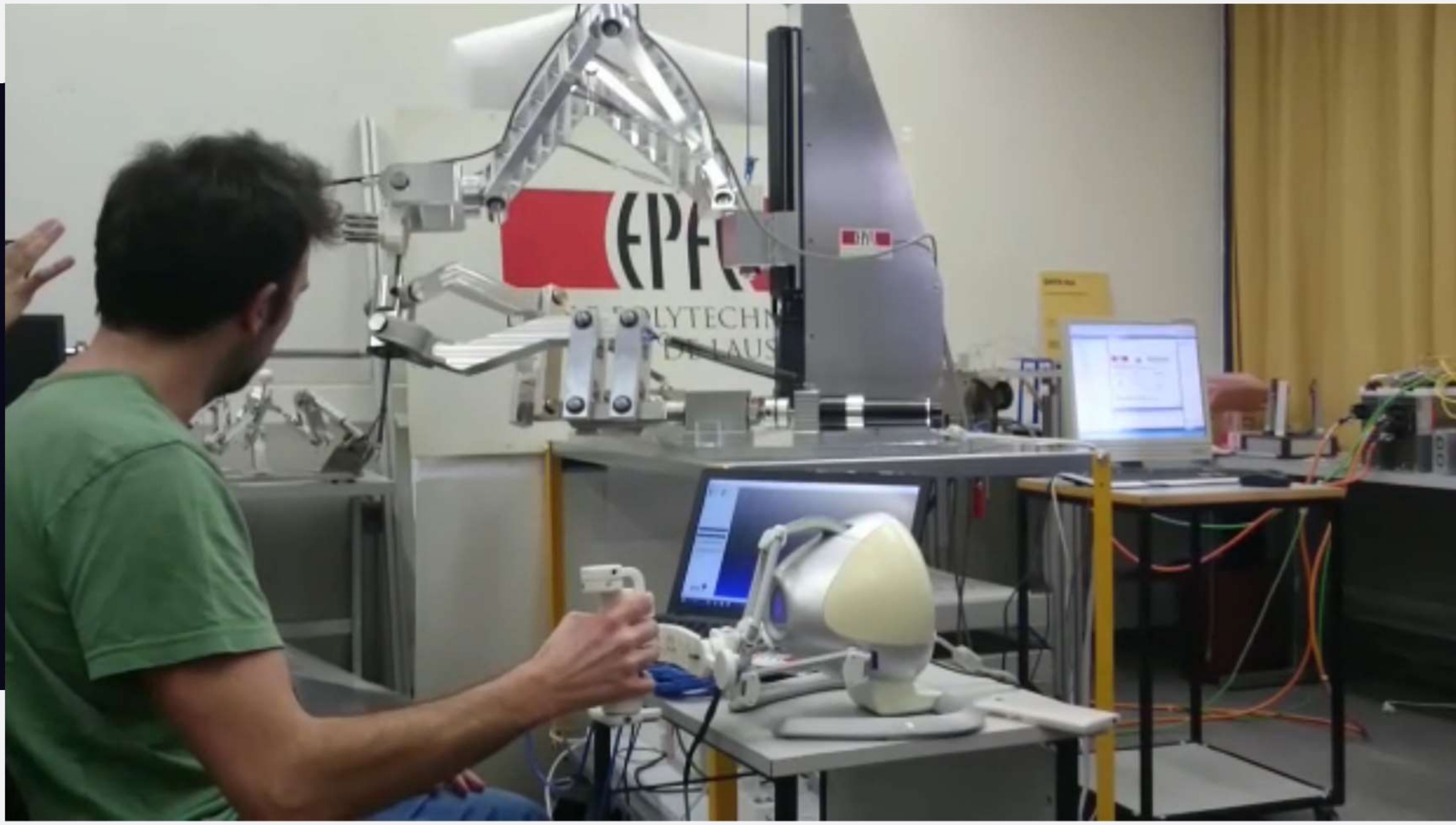


Hofmeister et al, 2017





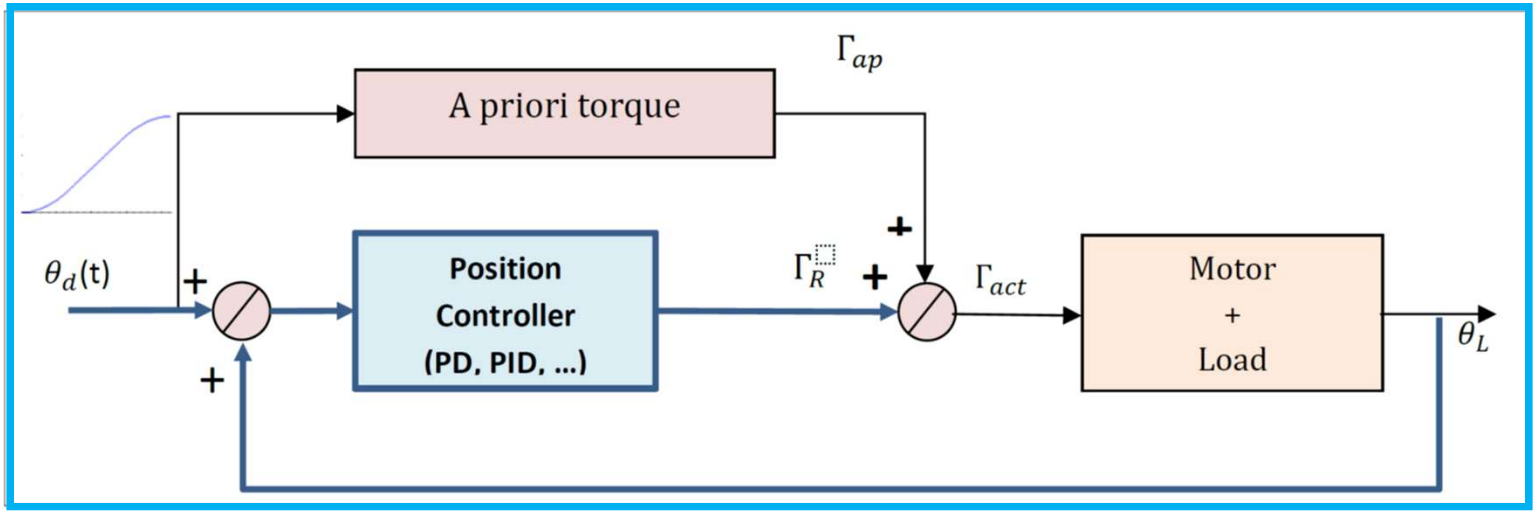
Laparoscopic Surgery
Requirements for force feedback [2016]



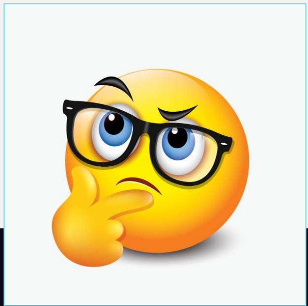
Part 2

Robot control strategies

$$\Gamma_{act} = \Gamma_{PID} + J_{RL}\ddot{\theta}_d + M_d g\, r_g \sin(\theta_d) + k_{vis}\,\dot{\theta}_d + \Gamma_{dry}$$



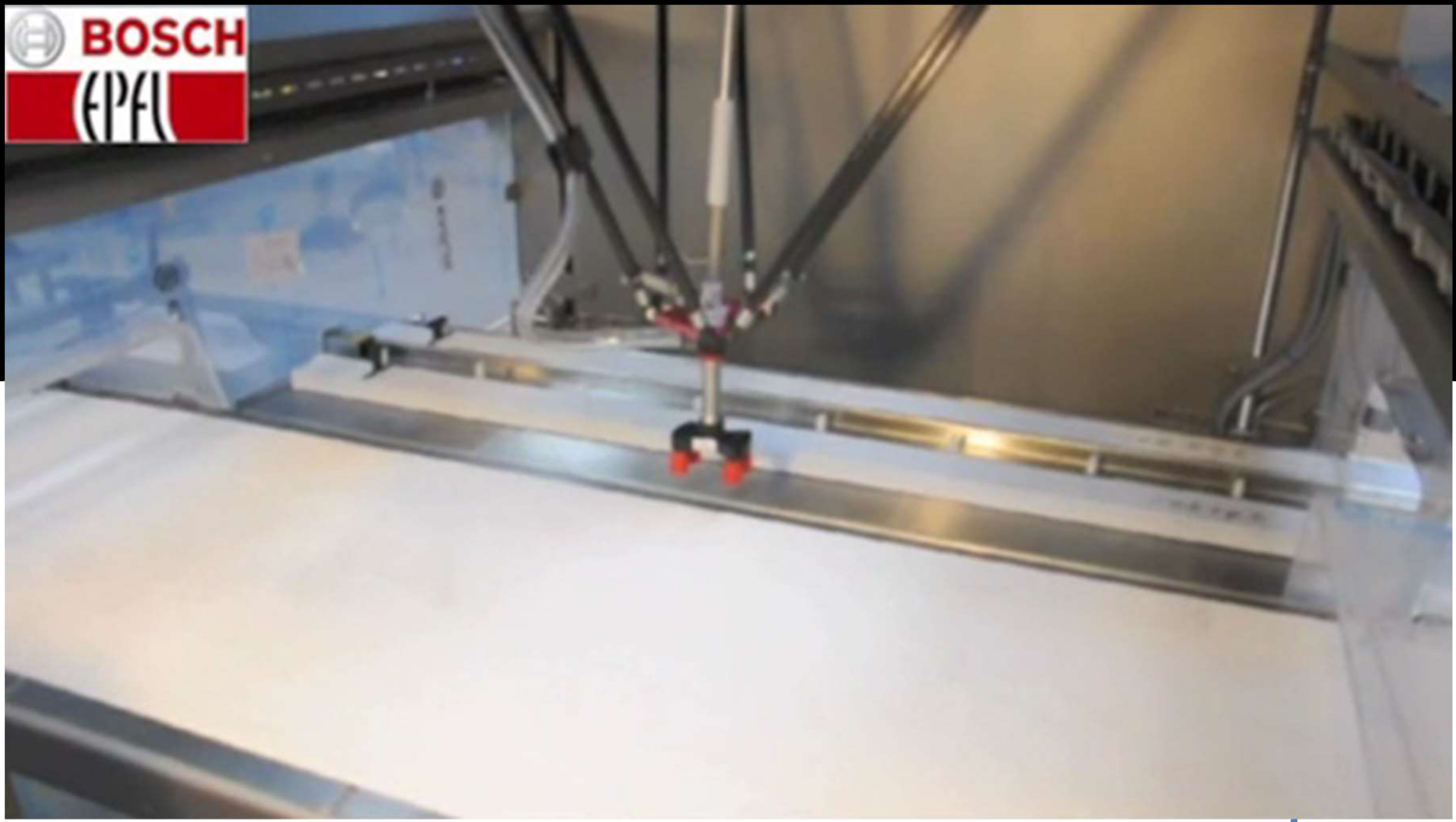
Feedforward compensation (a priori control) for position control



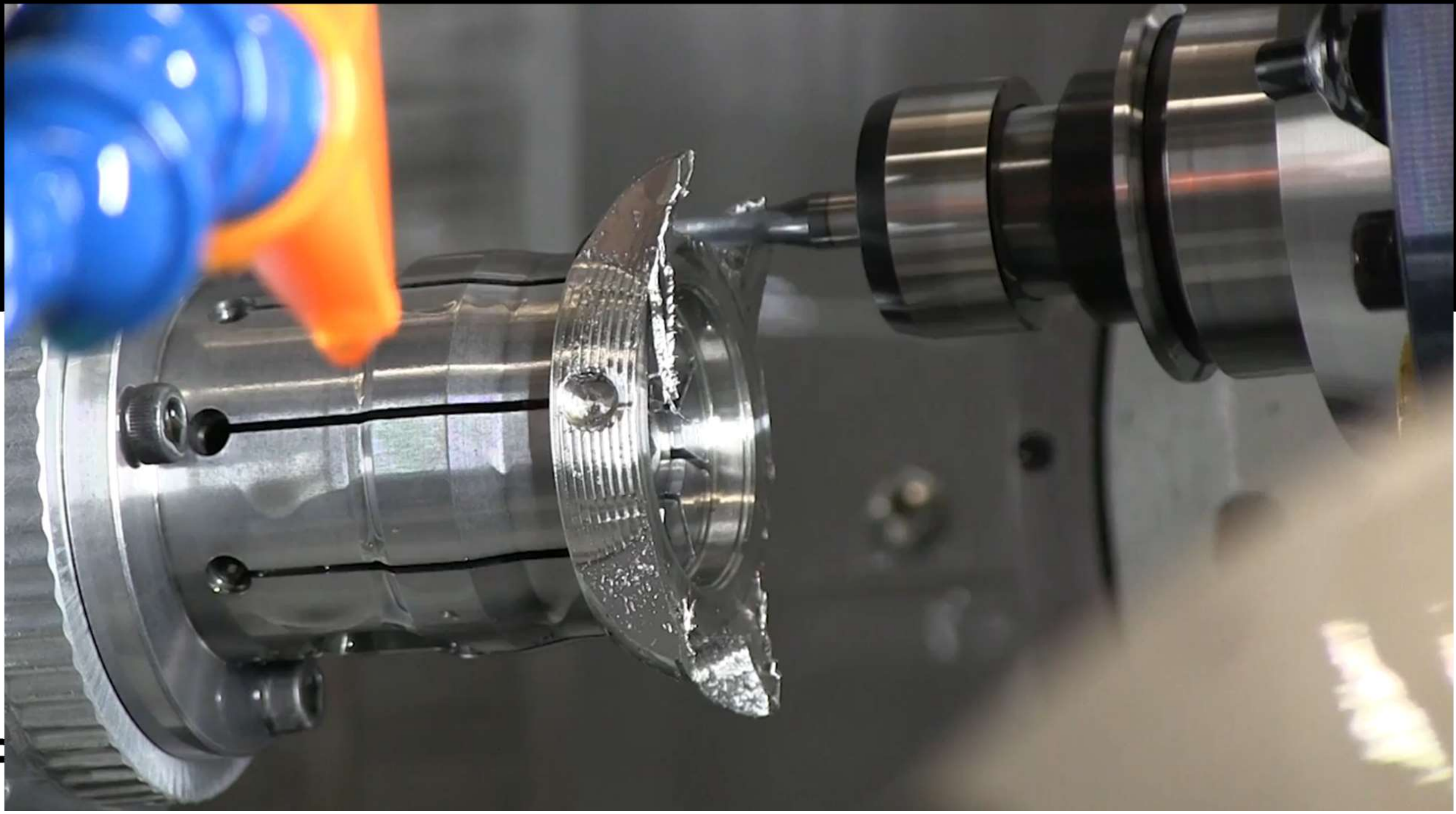
Discussion

Identify the mode of control ?

Delta Direct drive for fast pick and place



Machining

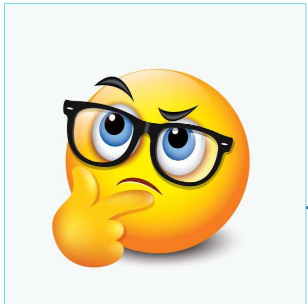


And what else?

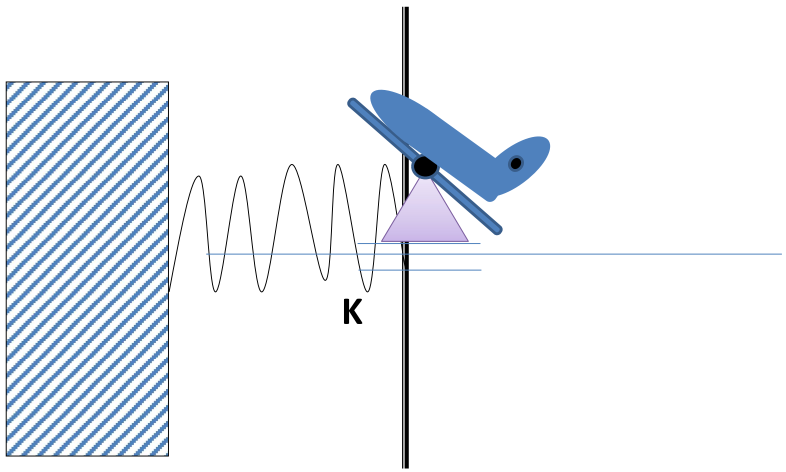
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Human Robot Interaction

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE



What is mechanical impedance ?



Mechanical impedance concerns **INTERACTION**.

The simplest way to feel/implement interaction is a **SPRING**.

is oscillatory

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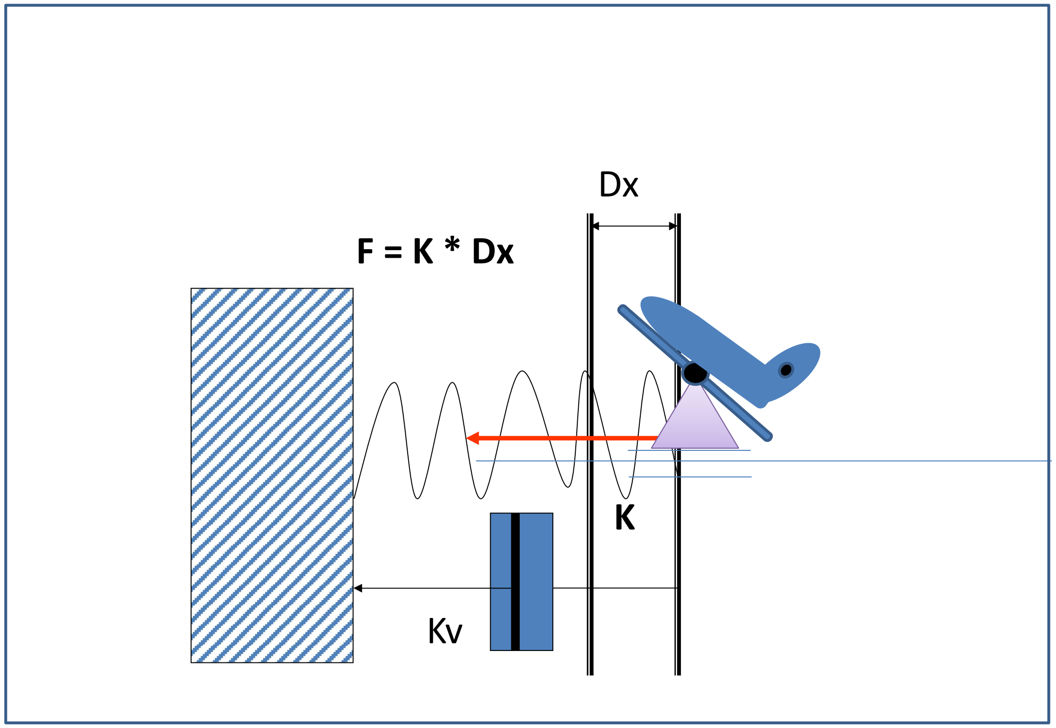
What is mechanical impedance ?



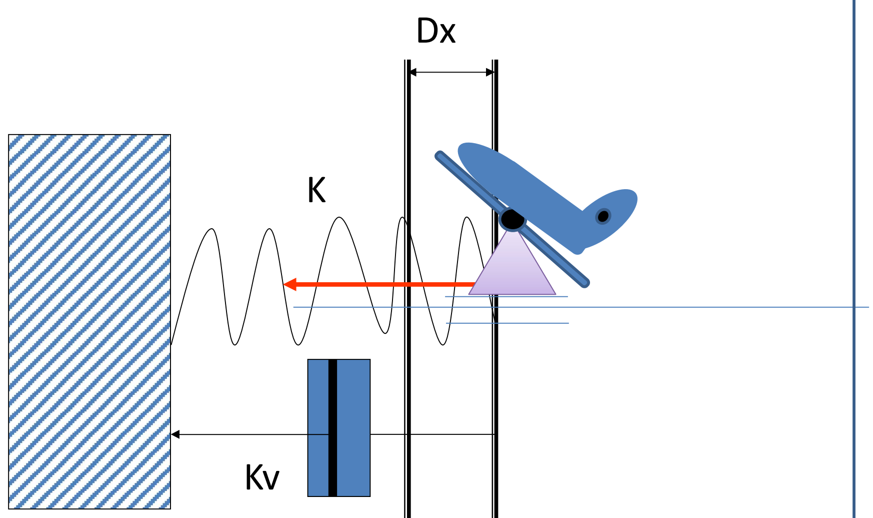
a **SPRING** ⊕ a **DAMPER**

Is stable

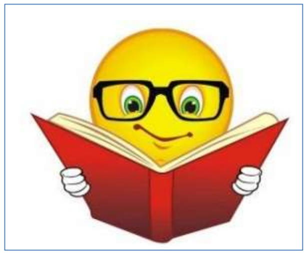
$$F = K * Dx + Kv * d(Dx)/dt$$

Simulated impedance using an electrical actuator

Fmot = Kp * Dx + Kd * d(Dx)/dt

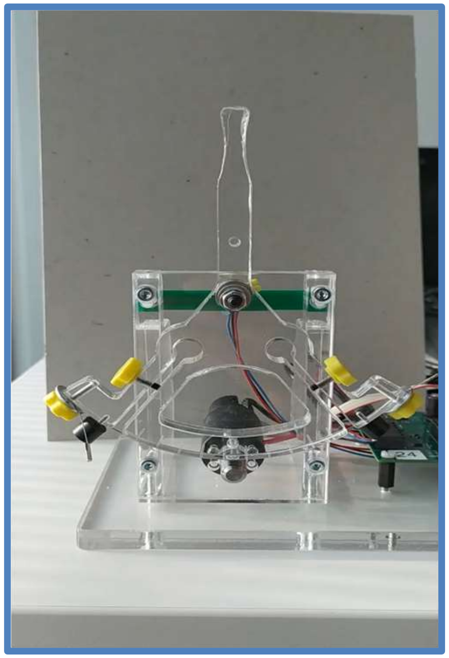


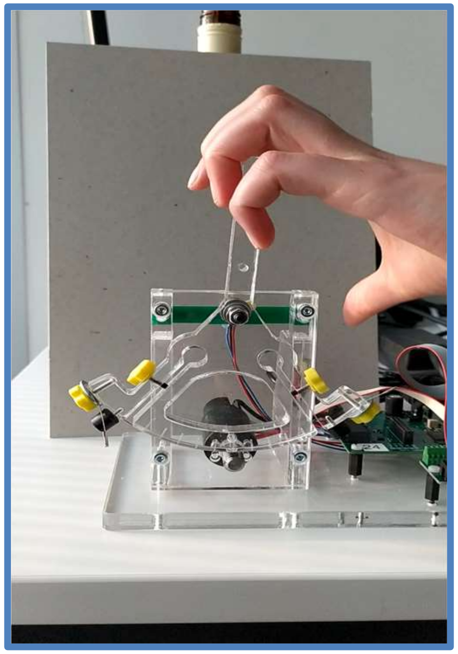
Mechanical Impedance denotes the quality of <u>compliance</u> : stiffness of the interaction (Kp, Kd)

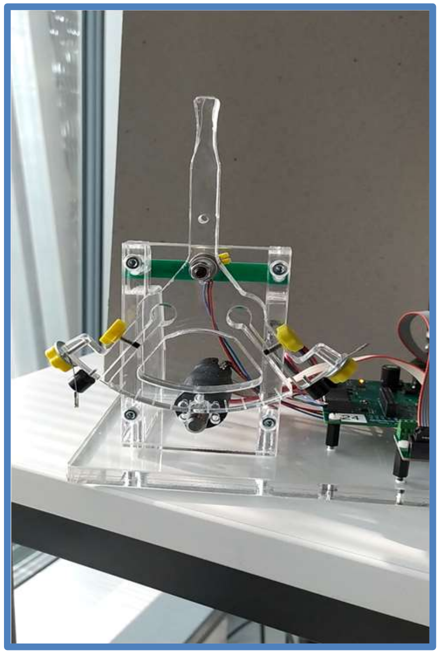


Simulated impedance using an electrical actuator

Examples of behaviors



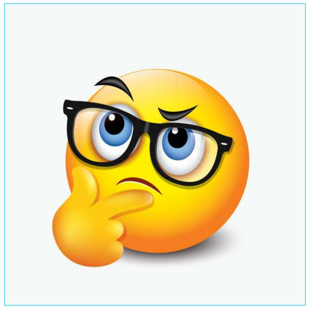




Stiff

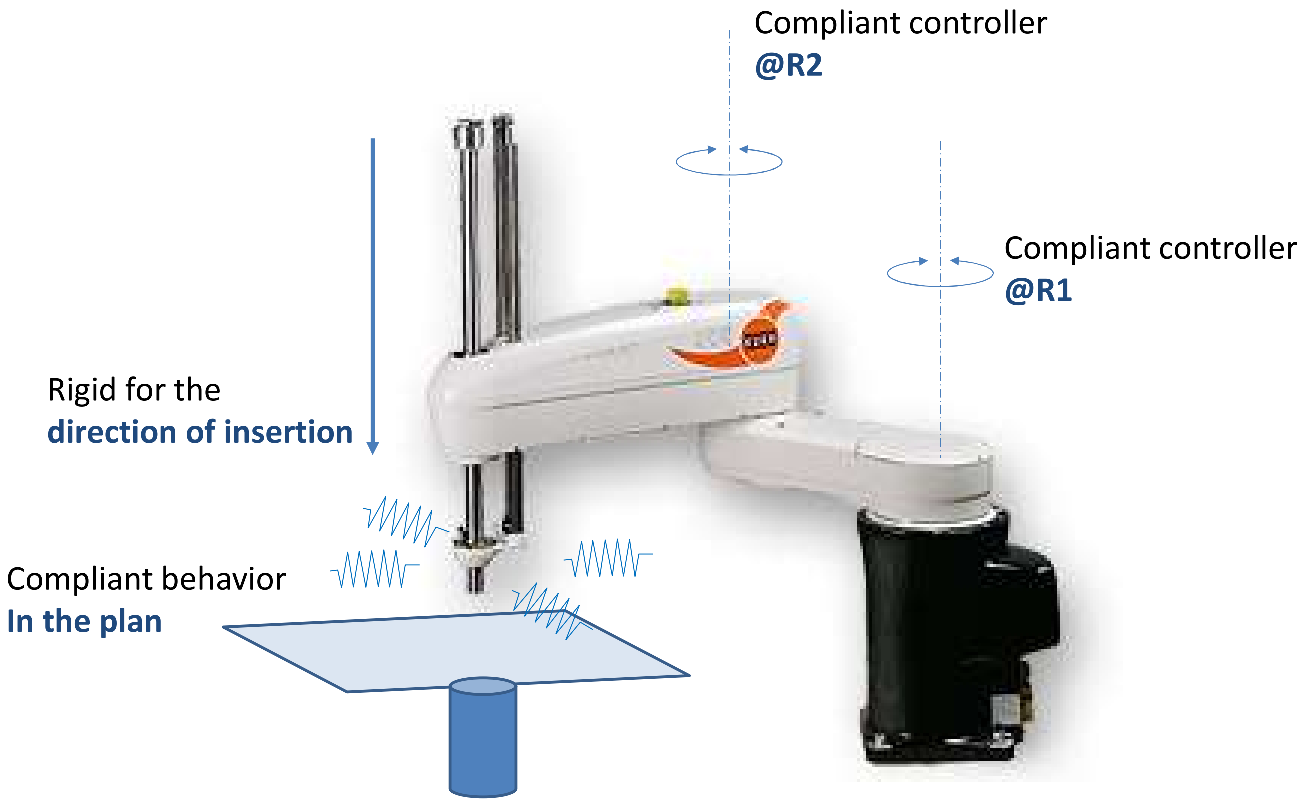
compliant

damped

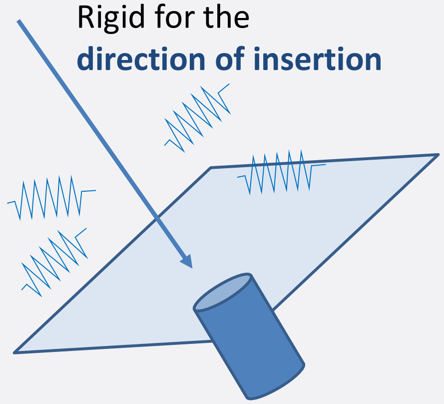


What is “Selective Compliance” ?

The SCARA, a mechanically **selective compliant** robot

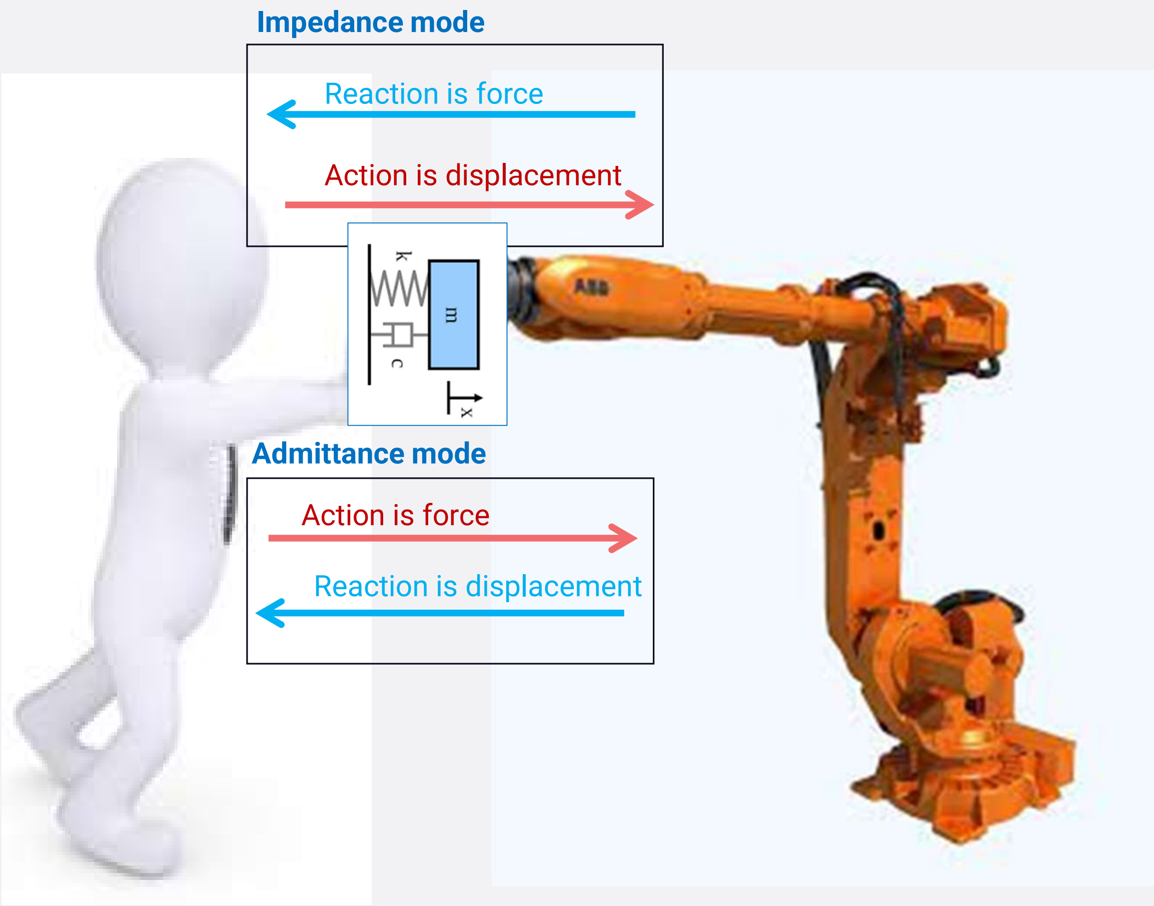


6 Dof selective compliance…



Control strategies may implement a selective compliance for any single or combined directions (dofs)

Did you say “Impedance” or “Admittance” ?



That is it, for this short tour on control concepts!

Part 3

Tell me about “Cobots”

La « **Cobotique** » concerne l’implémentation d’une solution robotique centrée autour **de la collaboration avec l’humain.**

La **Cobotique** est la science d’ingénieur qui traite de la «**Robotique Collaborative** : Collaborative Robotics ».

Il s’agit souvent
- d’une [**interaction robot-humain**] [**partageant une tâche donnée**],
- d’une **programmation du robot apprise de l’humain**.

Dans tous ces cas, **la proximité du robot avec l’humain est importante** et **la sécurité** de ce dernier l’est encore plus.

M. **Bouri, 2021**

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Colgate, J. Edward, et al. "Cobots: Robots for collaboration with human operators." (1996).

Part 3

Tell me about “Cobots”

“**Cobotics**" concerns the implementation of robotic solutions centered around **collaboration with humans**.

Cobotics is the engineering science that deals with "**Collaborative Robotics**".

It is often

- about a [**robot-human interaction**] [**sharing a given task**],
- a robot **programming learned from the human**.

In all these cases, **the proximity of the robot to the human is important** and the **safety of the human** is even more important. Translated with www.DeepL.com/Translator (free version)

M. **Bouri, 2021**

Colgate, J. Edward, et al. "Cobots: Robots for collaboration with human operators." (1996).

Cobots - examples
Universal robots

One of the most known “cobots”
Link to Universal robots

Full video link

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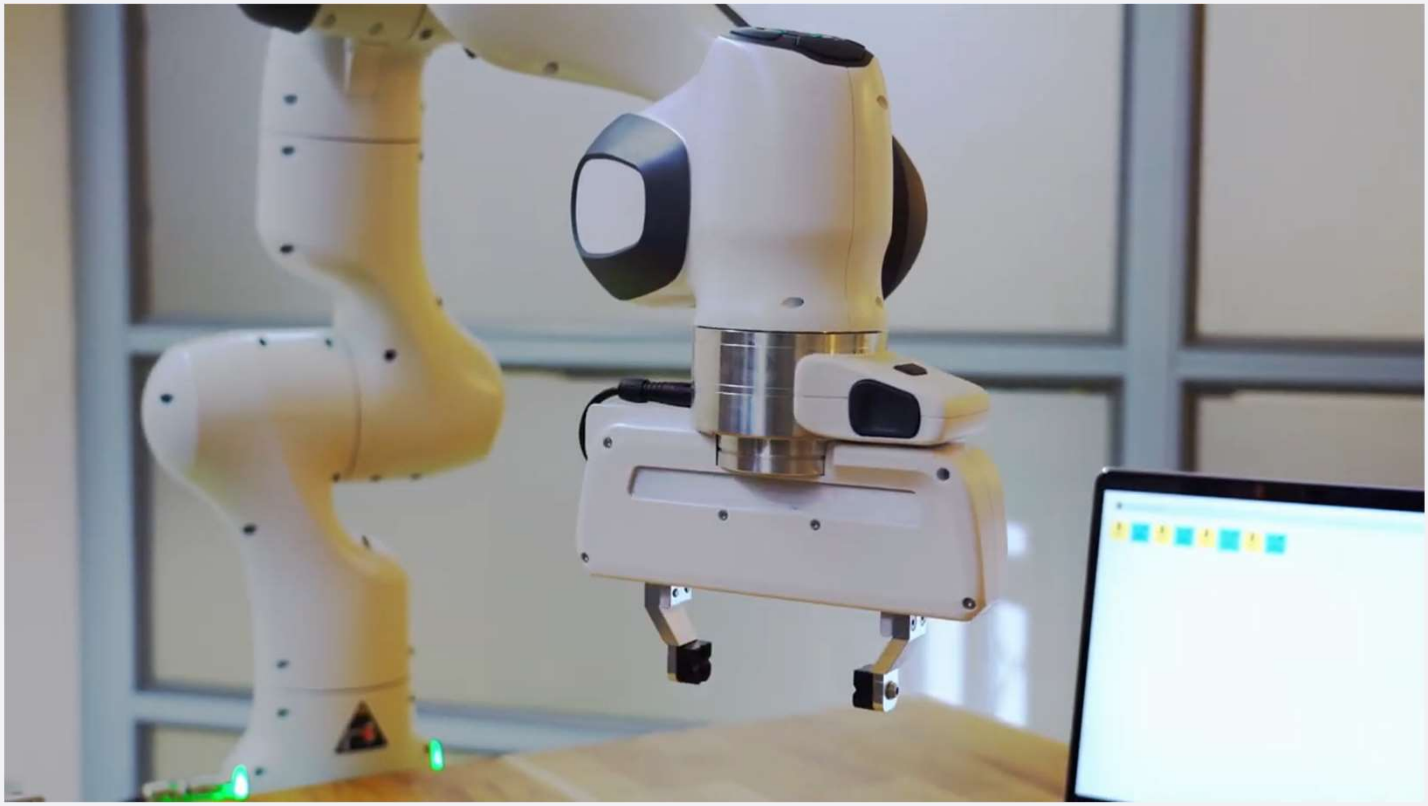
Cobots - examples
Franka emika

One of cheapest “cobots”

Link to Franka



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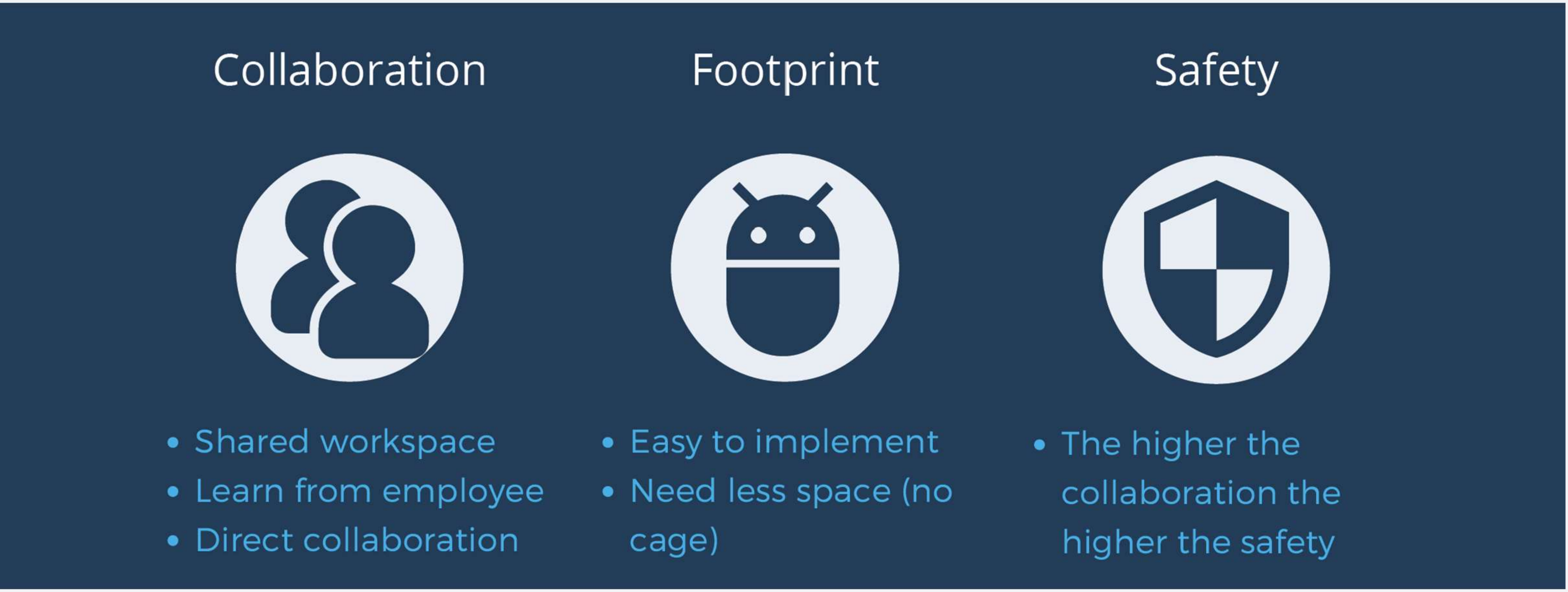
Cobots
Part 4 – Values and applications



Cobots
Part 4 – Values and applications

Collaborative industrial robots are a class of robots that perform **tasks in collaboration with workers in industrial settings**.

The IFR defines two types of robots designed for collaborative use.
[1] One group that complies with the International Organization for Standards (ISO) norm 10218-1 which specifies requirements and guidelines for the inherent safe design, protective measures and information for use of industrial robots.

[2] The other group that does not satisfy the requirements of ISO 10218-1. This does not imply that these robots are unsafe. They follow different safety standards, for example national or in-house standards, other applications (for example healthcare, food preparation and in public spaces) are covered by separate ISO norms and will **therefore not be included in the IFR statistics** on collaborative industrial robots.

[Ref. Ifr.org]

Cobots
[Value 3] Safety –in collision

not even afraid

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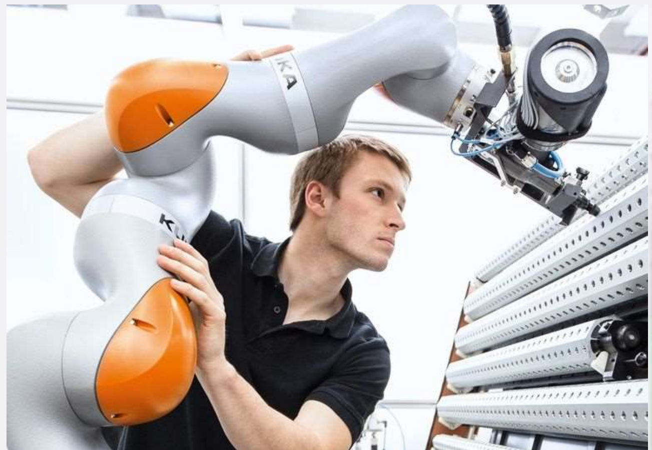
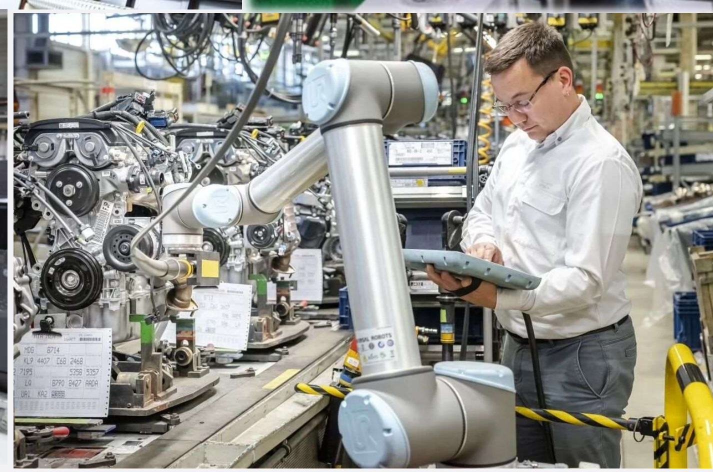
Cobots

[Value 1.1] Collaboration : Shared workspace



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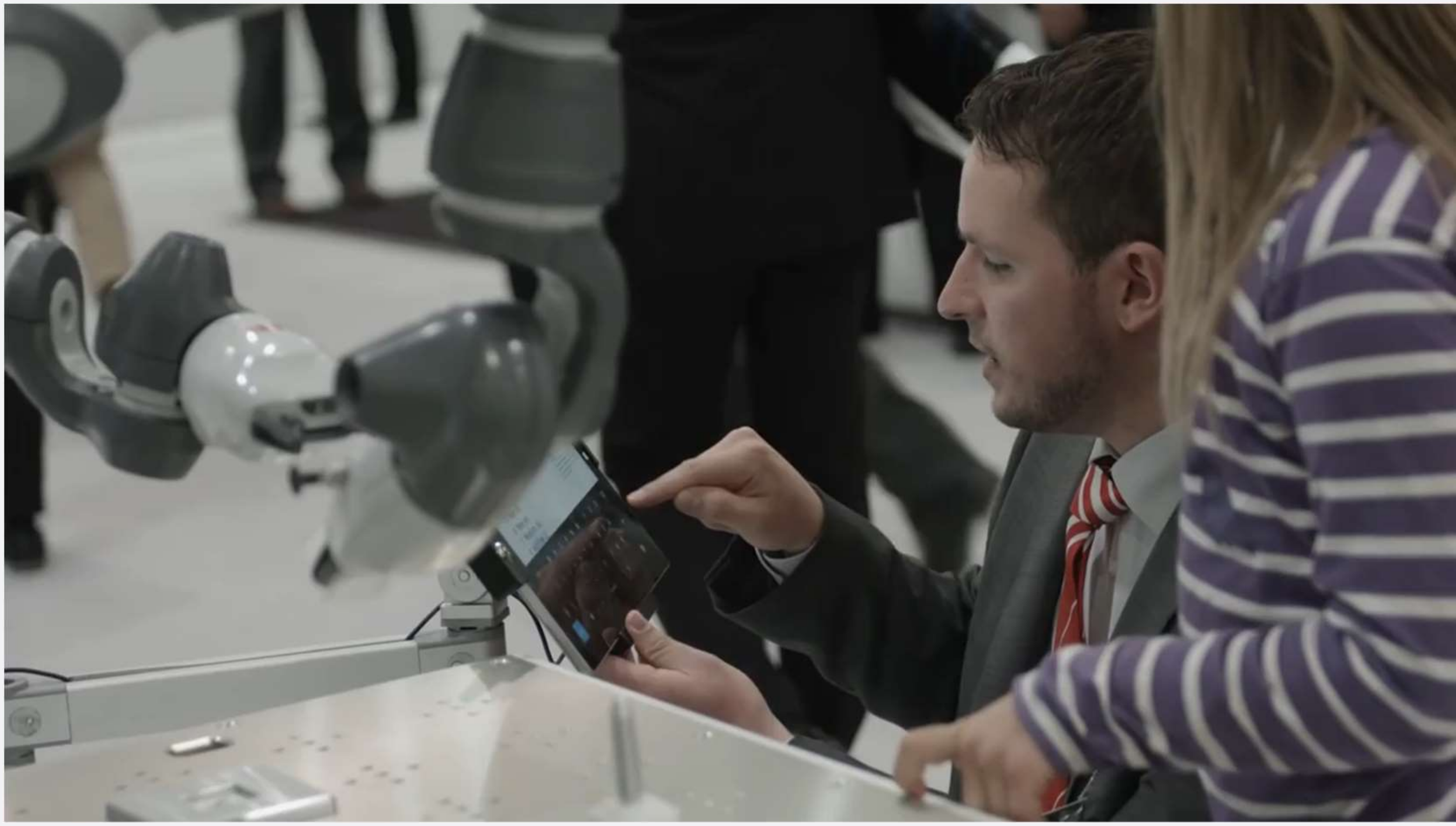
Cobots
[Value 1.2] Collaboration : Programming by learning / from operators



Cobots
[Value 1.3] Collaboration : co-working / co-manipulation

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Cobots
[Value 2] Footprints

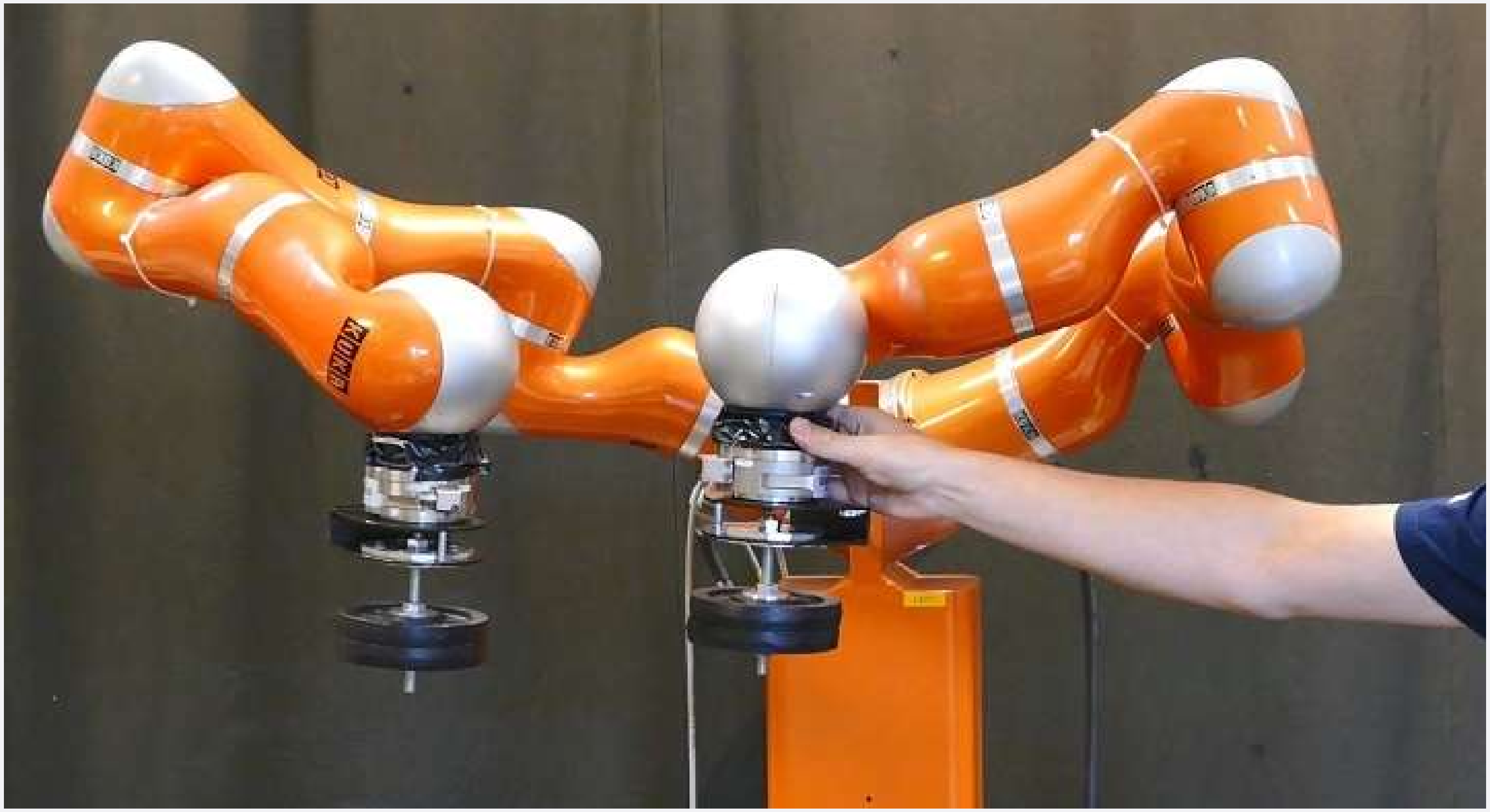
- More relevant for bi-manual cobots

Siasun DSCR3

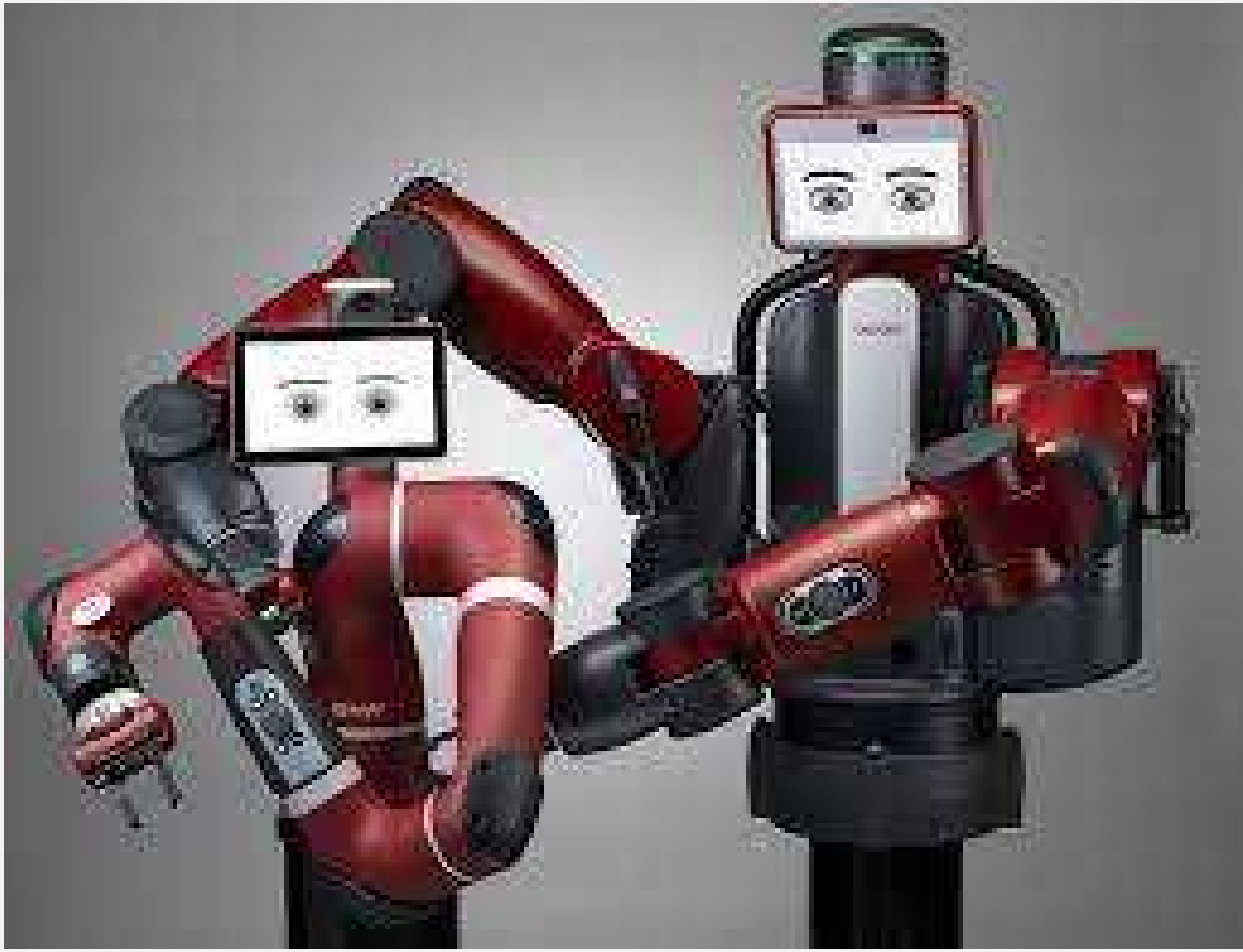
Kawasaki
duAro1 dual SCARA

ABB
Yumi

Dual or single arm?



Definitely YES or NO ?



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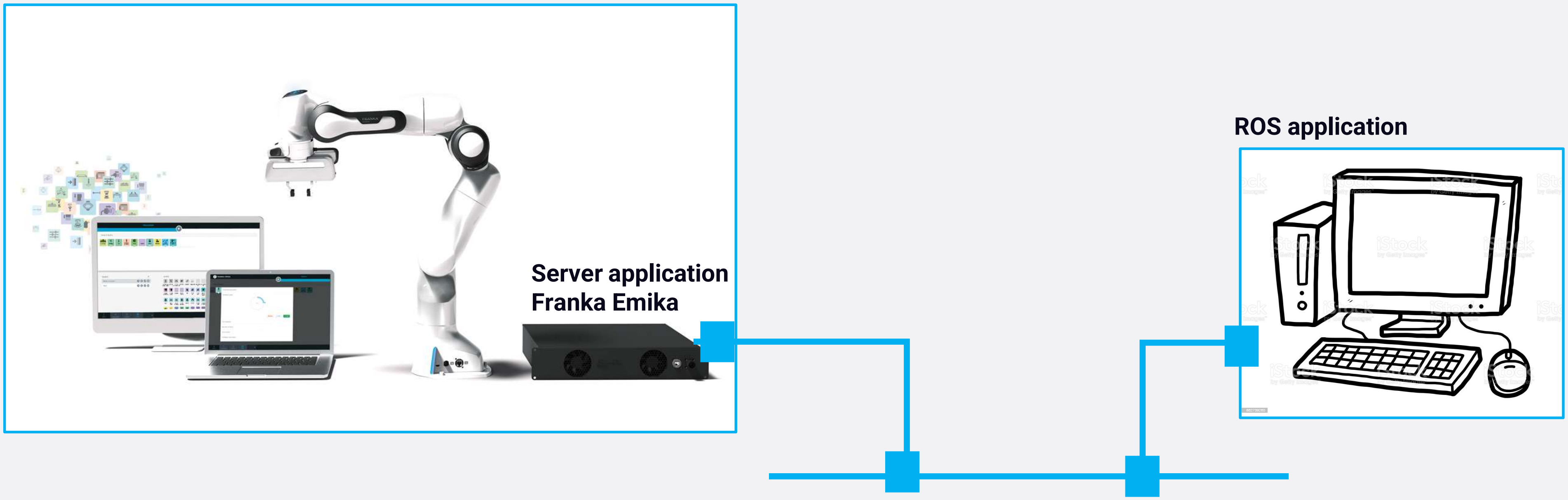
Cobots

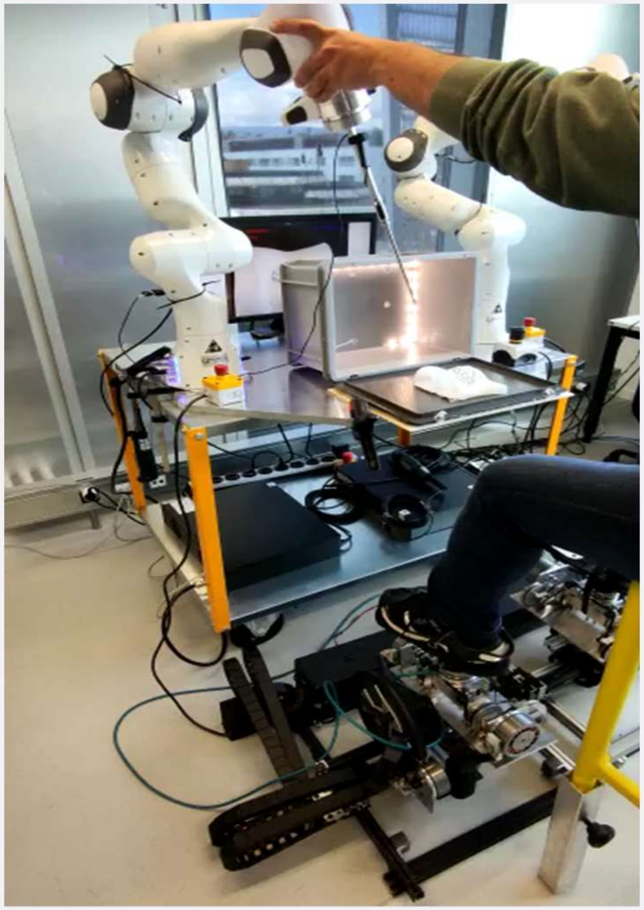
[Other values] Open to implement new control strategies / using ROS



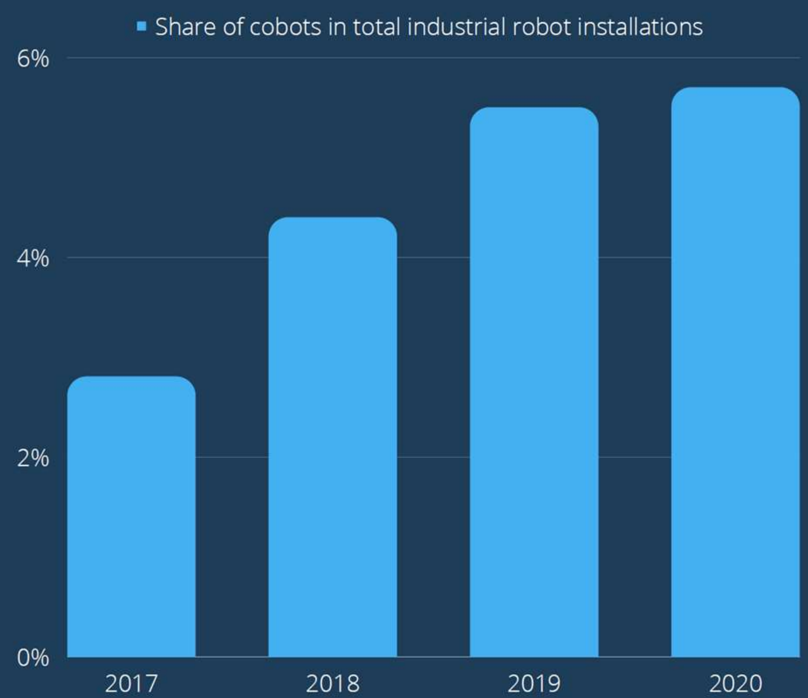
Cobots
Example of 2-scenarios

Scenario 1- Being more specific in defining workspace limits

Scenario 2- admittance control/ robot guidance



Numbers



Growth of the market

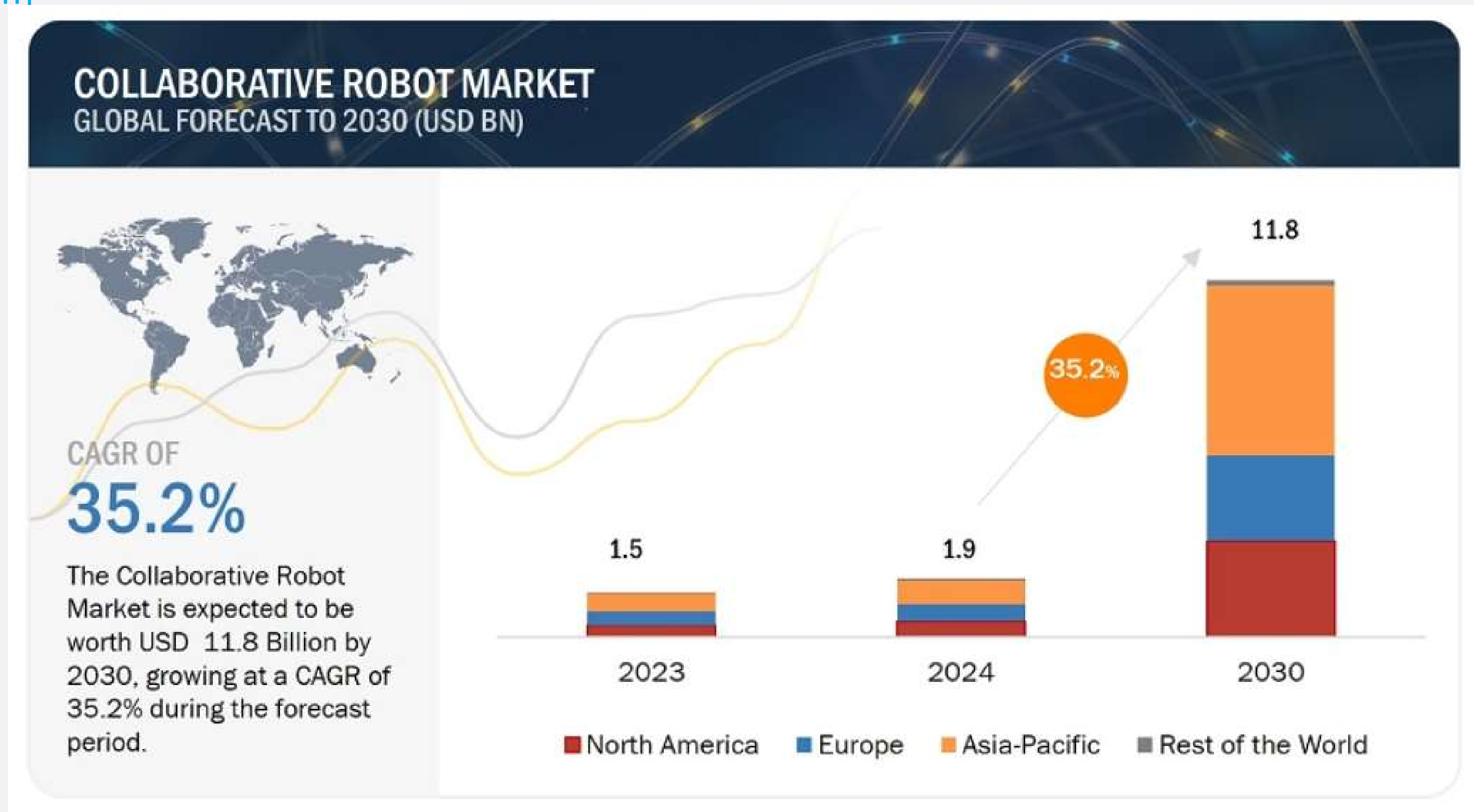
- 22'000 of newly depolyed cobots which is 6% growth from 2019-2020
- 5.7% share of the industrial robot intallations

Competitiveness and opportunities

- New suppliers have entered the market
- COVID-19 provided excellent conditions for growth

Numbers

[source marketsandmarkets.com]



Applications
Nonexhaustive [source IFR.org]

For tedious, repetitive and unergonomic tasks- [Co-manipulation]

To improve manufacturing productivity when used to automate tedious, repetitive tasks that do not need to be performed at very high speeds and that do not require human dexterity. These include fetching and carrying materials and parts, holding heavy parts in position for employees to work on them, feeding machines, conducting quality inspections and performing a variety of assembly tasks such as placing and screwing parts, applying adhesives and coating or polishing surfaces.

Applications
Non exhaustive [Source IFR.org]

For tedious, repetitive and unergonomic tasks- [Co-manipulation]

In production lines that include workers

Though the range of tasks a collaborative robot can perform is impressive, there are still many tasks that are easy for humans but hard to automate cost-effectively. These include dealing with unsorted parts and irregular or flexible shapes, or tasks that require continuous fine-tuning of pressure applied to surfaces in tasks such as polishing and grinding. The majority of production lines - particularly in assembly - are therefore most productive when they combine robots and workers, each doing the tasks they perform best. A key advantage of collaborative robots is that they can be easily incorporated into production lines working alongside humans.

Applications
Non exhaustive [Source IFR.org]

For tedious, repetitive and unergonomic tasks- [Co-manipulation]

In production lines that include workers

In short or variable production runs

Programming collaborative robots is fast for most applications and doesn’t require extensive training. This makes collaborative robots viable for manufacturers with short or variable production runs as the robot can be quickly re-tasked to the new run.

Comparative user guide…

[Link]

Collaborative Robots Comparison

COBOT	PAYLOAD (KG)	HORIZONTAL REACH (MM)	REPEATABILITY (MM)	DOF
ABB Dual-Arm YUMI	0.5	559	0.02	14
ABB Single-Arm YUMI	0.5	559	0.02	7
AUBO i3	3	625	0.03	6
AUBO i5	5	924	0.05	6
AUBO i7	7	1150	0.03	6
AUBO i10	10	1350	0.05	6
Automata Eva	1.25	600	0.5	6
Bosch APAS	5.5	911	0.03	6
Comau e.DO	1	478	1	6
Denso Cobotta	0.5	342.5	0.05	6
Dobot CR6-5	5	902	0.03	6
Dobot Magician	0.5	320	0.2	4
Dobot Magician Lite	0.25	250	0.2	4
Doosan Robotics M0609	6	900	0.1	6
Doosan Robotics M1509	15	900	0.1	6
Doosan Robotics M1013	10	1300	0.1	6
Doosan Robotics M0617	6	1700	0.1	6

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Open discussion

Do you believe in “Cobotics” ?

Do you find it particular ?


thank you
danke
謝謝
ngiyabonga
teşekkür ederim
gracias
спасибо
dank je
mochchakkeram
go raibh maith agat
dziękuję
bedankt
obrigado
sukriya
kop khun krap
terima kasih
ありがとう
감사합니다
grazie
arigatō
takk
dakujem
merci
мерси
ευχαριστώ
hvala
mauruuru
sagolun
tapadh leat
Баярлалаа
рахмат
хвала
faafetai lava
blagodaram
chnorakalutioun
tanemirt
rahmet
dhanyavadagalu
shukriya
najis tuke
kam sah hamnida
eskerrik asko
paldies
grazzi
dhanyavaad