Ergonomie et les robots collaboratifs (COBOTS)
Ergonomie en collaborative robots (COBOTS)

INTRODUCTION

Que ce soit dans l'industrie ou, entre autres, en milieu hospitalier, l'optimisation des postes de travail pour améliorer la sécurité, la santé et la performance des opérateurs est un enjeu déterminant.

Néologisme issu des mots « coopération » et « robotique », la cobotique constitue une nouvelle piste de solution dans les systèmes de suppléance mécanique.

Sortis de leurs « cages », ces nouveaux types de robots sont développés pour travailler plus étroitement avec l'opérateur. Du point de vue ergonomique, ces systèmes l'accompagnent et interagissent avec lui dans des situations particulières en termes de cadence de travail, d'effort à fournir, de postures statiques, de vibrations ou encore de protection face à des environnements dangereux (pyrotechnique, radioactif, risque de chute/collision, etc.) ou à des facteurs d'ambiance physique (température, humidité, poussière, etc.).

La cobotique actuelle se caractérise par l'interaction réelle, directe ou téléopérée, entre un opérateur humain et un système robotique asservi ou pseudo-autonome. Il est donc indispensable de penser dès la phase de conception à l'ergonomie de l'interaction entre le robot et son utilisateur.

Les « exosquelettes », sortes de prolongements du corps humain, constituent quant à eux une classe de cobots singuliers, différenciés presqu'uniquement par le fait que l'utilisateur est inclus dans le dispositif, alors que l'usager est habituellement hors du cobot. Au-delà des amplifications motrices et des performances dans les déplacements et les forces motrices dans les domaines militaires, agricoles et industriels, les exosquelettes ont pénétré le milieu de la santé et celui du handicap.

Cette journée d'étude nationale vise à donner un éclairage sur cette nouvelle technologie ses normes, ses applications, ses avantages et ses limites.

Aux travers de cas pratiques d'utilisation de cobots et de démonstrations en salle, nous allons également discuter de la manière dont des entreprises réfléchissent à l'intégration de ces cobots et nous pourrons avoir un premier contact concret avec ces évolutions technologiques.

INLEIDING

De optimalisatie van werkposten om de veiligheid, gezondheid en prestaties van operatoren te verbeteren is van cruciaal belang, onafhankelijk van het feit of het over onder andere ziekenhuizen of industrie gaat.

Cobotica, een neologisme uit de woorden coöperatie en robotica, stelt een nieuwe oplossingspiste voor wat betreft mechanische vervangingssystemen.

Deze nieuwe types van robots ontwikkeld om nauwer samen te werken met de operator. Vanuit een ergonomisch oogpunt begeleiden en werken deze systemen in specifieke situaties met hem samen in termen van werksnelheid, vereiste inspanning, statische houdingen, trillingen of zelfs bescherming tegen gevaarlijke omgevingen (pyrotechniek, radioactief, risico op vallen/botsing, enz.) of fysieke omgevingsfactoren (temperatuur, vochtigheid, stof, enz.).

De huidige cobotica worden gekenmerkt door de echte interactie, direct of via bediening op afstand, tussen een menselijke operator en een ondergeschikt of pseudo-autonooom robotsysteem. Het is daarom van essentieel belang om vanaf de ontwerpfase te denken aan de ergonomie van de interactie tussen de robot en zijn gebruiker.

De « exoskeletten », een soort verlengstuk van het menselijk lichaam, vormen op hun beurt een klasse van enkelvoudige cobots, bijna uitsluitend gedifferentieerd door het feit dat de gebruiker is opgenomen in het apparaat, terwijl de gebruiker meestal buiten de cobot is. Naast de motorische versterkingen en prestaties in verplaatsingen en de drijvende krachten in de militaire, agrarische en industriële domeinen, drongen de exoskeletten door in de omgeving van de gezondheid en die van de handicap.

Deze nationale studiedag wil een licht werpen op deze nieuwe technologie, de normen, de toepassingen, de voordelen en de limieten ervan.
Aan de hand van praktische gevallen bij het gebruik van cobots en demonstraties in de zaal zullen we ook bespreken hoe bedrijven denken over de integratie van deze cobots en kunnen we een eerste concreet contact hebben met deze technologische ontwikkelingen.De ergonomie komt natuurlijk op de eerste plaats. De deelnemers krijgen de gelegenheid om hun ervaringen te delen met collega – ergonomen en andere belanghebbenden (bijvoorbeeld door ondersteunende structuren voor de ontwikkeling van technologische innovaties).

Cette journée est également ouverte aux personnes non membres de la BES.
Deze studiedag is ook toegankelijk voor niet leden van BES.

Une traduction simultanée en français et en néerlandais sera assurée.
Er is een simultaanvertaling in het Frans en Nederlands.

Pour les gens qui ont suivi la formation **disability management à l'INAMI** : cette journée d'étude est reconnue dans le cadre de la recertification disability management
Voor de personen die de opleiding **disability management** gevolgd hebben bij het **RIZIV**: deze studiedag is erkend in het kader van de recertificatie disability management.

PROGRAMM(E)(A)

08.30 Accueil / Onthaal
09.00 **Bienvenue / Welkom**
Véronique Crutzen, DG Humanisation du travail
SPF Emploi, Travail et Concertation sociale

09.15 **Introduction de la journée / Inleiding van de dag**
Dirk Delaruelle, European Ergonomist, nationaal voorzitter BES

09.30 **Is your next colleague a cobot ?**
Filiep Vincent, Engineer Smart Production & Factory of the Future, SIRRIS
10.00 **The path towards the safe Human / Robot Collaboration application**
Timen FLORÉ , PILZ

10.30 **Pause/Pauze**

11.00 **Conception de systèmes cobotiques industriels – Application chez Ariane Group**
David Bitonneau, Responsable d'Études Procédés – Cobotique, ARIANE group
Théo Moulières-Seban, Autorité Industrielle – Cobotique, ARIANE group
11.30 **BruBotics - The Brussels Human Centered Robotic research center**
Prof dr ir Bram Vanderborght, VUB
12.00 **Lunch**

13.30 **Presentation & demonstration of exoskeletons**
Boudewijn Wisse, LAEVO

14.00 **Exemples d'études sur cobots et exosquelettes**
Nicolas PERSON, TEA – Tech Ergo Appliquées, Nancy

14.30 **Demo cobots en exosquelettes/exoskeletten**
15.40 **Clôture de la journée d'étude / Einde studiedag**
16.00 **Assemblée générale / Algemene Ledenvergadering**

Federale Overheidsdienst Werkgelegenheid, Arbeid en Sociaal Overleg
Service public fédéral Emploi, Travail et Concertation sociale

FEES federation of european ergonomics societies

BES BELGIAN ERGONOMICS SOCIETY

INSCRIPTION uniquement en ligne: cliquer ici (date limite 15/03/2018)
Merci de préciser vos nom, prénom, organisation, email, votre choix parmi les possibilités suivantes et de verser le montant correspondant sur le compte BE 16 7755 9267 5374 BIC: GKCCBEBB en précisant «Journée nationale et votre nom» sur le versement. Si vous souhaitez une facture, merci d'également communiquer les données relatives à la facture et le n° de TVA.

INSCHRIJVEN kan enkel via internet: hier klikken (ten laatste op 15/03/2018)
Gelieve uw naam, voornaam, organisatie, e-mail, de keuze van de hierna volgende mogelijkheden te bezorgen. Het overeenstemmende bedrag kan je overschrijven op rekening BE 16 7755 9267 5374 BIC: GKCCBEBB met vermelding van «Nationale studiedag en je naam». Wie een factuur wenst, gelieve ook de factuurgegevens en BTW-nummer te bezorgen.

- ❑ Membres / Leden BES: avec/met lunch 110€, sans/zonder lunch: 80€
- ❑ Non-membres / Niet leden BES: avec/met lunch 160€; sans/zonder lunch: 130€ (incl. lidgeld 2018 - inclus cotisation 2018)
- ❑ Etudiants / Studenten: avec/met lunch: 60€; sans/zonder lunch: 30€
- ❑ Etudiants (inscription groupée minimum 10) / Studenten (groepinschrijving minimaal 10): 15**€ zonder lunch

Date / Datum 22/03/2018

Lieu / Plaats
FOD Werkgelegenheid, Arbeid en Sociaal Overleg
SPF Emploi, Travail et Concertation sociale
Auditorium Storck - rue Ernest Blerotstraat 1 - 1070 Bruxelles - Brussel

Situation: le SPF Emploi se situe à 30 mètres de la gare SNCB Bruxelles-midi, en face de la sortie "Place Horta". Parking payant sous le bâtiment.

Ligging: De FOD Werkgelegenheid bevindt zich op 30 meter van het NMBS-station Brussel-Zuid recht tegenover de uitgang Hortaplein. Onder het gebouwencomplex is een betaalparking.

Renseignements - Inlichtingen president@besweb.be or secretary@besweb.be

BELGIAN ERGONOMICS SOCIETY

Is your next colleague a cobot?

Belgian Ergonomics Society

22 March 2018

sirris
driving industry by technology

Agenda

- Sirris?
- Main features
- Cobots vs industrial robots
- Add-ons
- Trends
- Case assessment
- Feasibility tests examples

Collective center of the Belgian technology industry

.AGORIA → sirris

driving industry by technology

Transport systems & solutions – Contracting – Production technology & mechatronics – Subcontracting – Building technology – Energy systems & solutions – Aeronautics, space, security defence technology – Materials technology – Environment systems & solutions – Information & communication technologies

Driving industry by technology

"We help large and small companies in the Belgian **technology industry** to **make the right technological choices** and **realize innovation**, in order to achieve **sustainable economic growth.**"

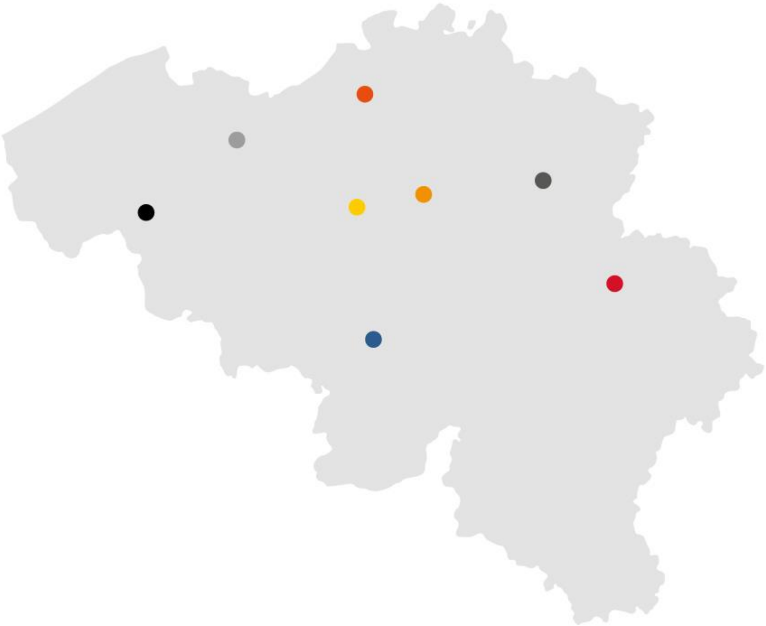
Technological innovation is our job!

CUSTOMISED TECHNOLOGICAL SUPPORT

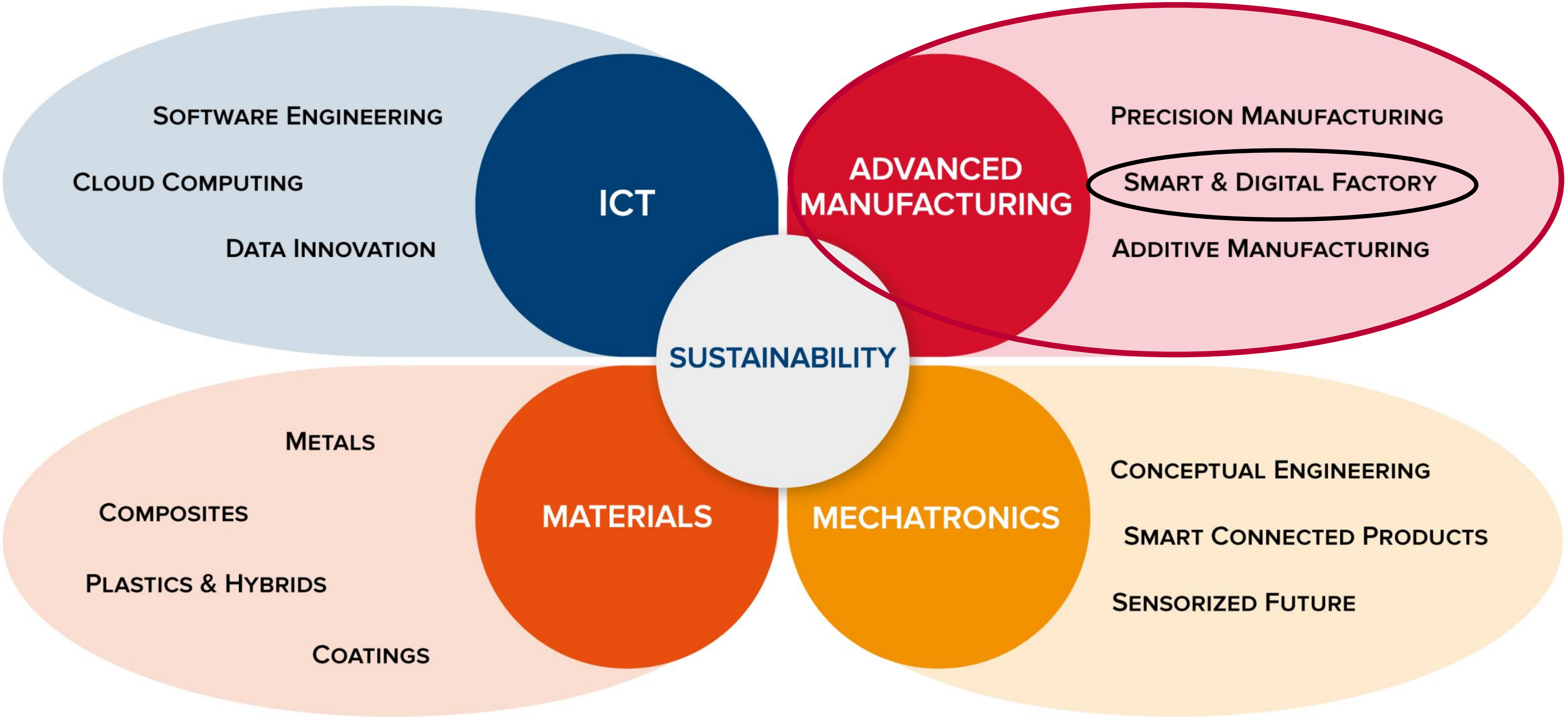
HIGH-TECH INFRASTRUCTURE & NETWORK OF PARTNERS

INSPIRATION FOR INNOVATION & TECHNOLOGY

High-tech infrastructure & Application Labs
close to the companies



140 experts covering 5 technology domains

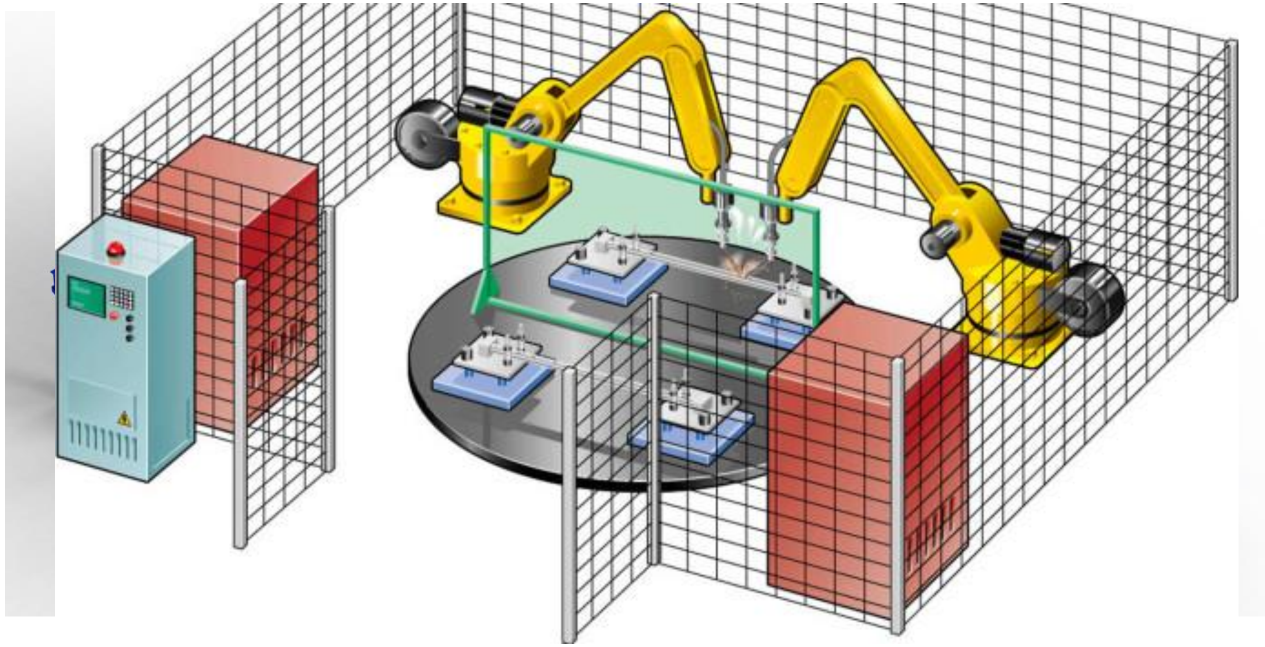


Smart & Digital Factory

- Infrastructure in
  - Diepenbeek, Leuven, Kortrijk
- 12 experts
- Themes:
  - Flexible automation for small series
  - Human-Robot Collaboration
  - Quick Response Manufacturing
  - Process organization
  - Digitizing manufacturing

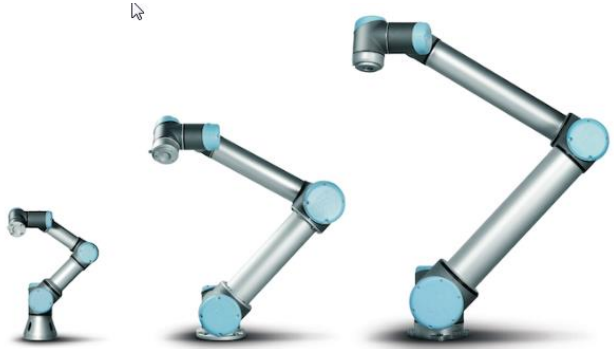
What’s in a name?

"*Collaborative robots are complex machines which work hand in hand with human beings. In a shared work process, they support and relieve the human operator.*" (*source: IFA*)



What's available on the (EU) market?

UR3-UR5-UR10



iiwa7/14

Yumi

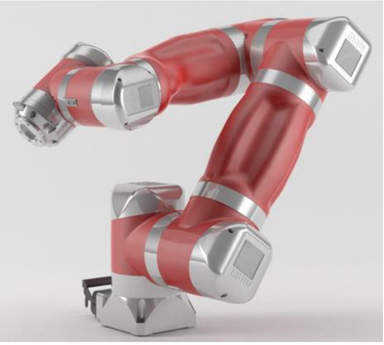
TM5

OB7

Sawyer

CR-35iA/7iA/4iA

Speedy 6-12



Franka Emika

HC-10

Aubo-i5

Aura

P-Rob 2

Cobot overviews

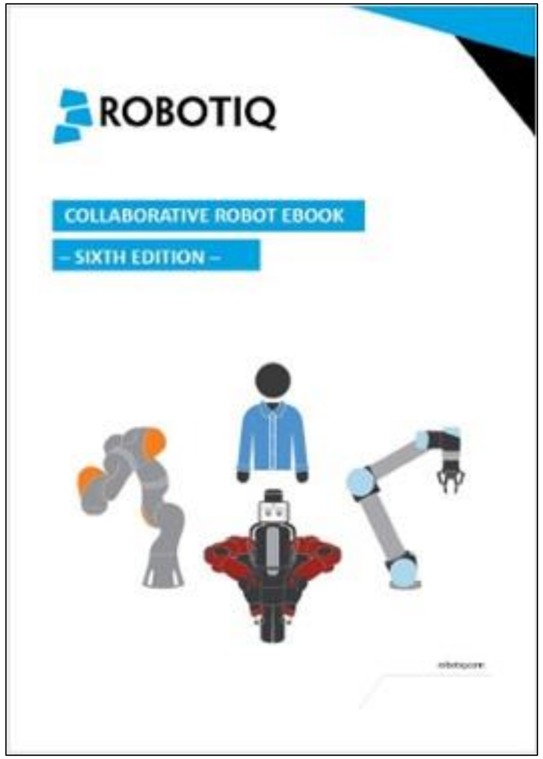


TABLE OF CONTENTS

[Website](#)

Cobotsguide

Cobot Comparison Chart

SORTED BY PAYLOAD	PAYLOAD	REACH	DOF (# OF AXIS)	WEIGHT	REPEATABILITY	PRICE RANGE
DENSO: COBOTTA	500 g	310 mm	6 axis	3.8 kg	n/a	n/a
ABB: YUMI	500 g	500 mm	7 axis	38 kg	0.02 mm	$$$
AUTOMATA: EVA	750 g	n/a	6 axis	2.3 kg	n/a	$
KAWADA: NEXTAGE	1.5 kg (each arm)	n/a	6-axis (+2 for neck, +1 for waist)	29 kg	+/- 0.5 mm	$$$$
KINOVA: MICO2	2.1 kg	700 mm	6 axis	4.6 kg	n/a	$$
RETHINK: BAXTER	2.2 kg	1210 mm	7 axis	75 kg	n/a	$$
KINOVA: JACO2	2.6 kg	900 mm	6 axis	4.4 kg	n/a	$$
UNIVERSAL ROBOTS: UR3	3 kg	500 mm	6 axis	11 kg / 24.3 lbs	0.1 mm to 0.0039	$$

[Website](#)

Typical applications

- Simple (boring) repetitive tasks (DDD)
- Pick&place application
  - From conveyor/pallet to box/package (and vice versa)
  - Machine tending
  - Test and sort (QC)
  - …
- As ‘process tool’
  - Third hand for operator
  - Light assembly (Connect 2 pieces)
  - Position object or tool (Glueing, polishing, cutting,…)
  - Open/close door, push button,…
  - …

Programming

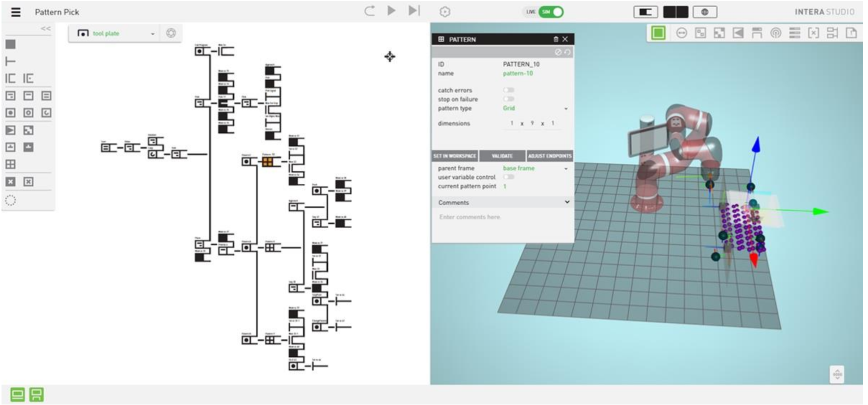
- Offline
  - Simulation purpose ➔ generate robot code
  - Production downtime = minimal
  - Branch specific program or…

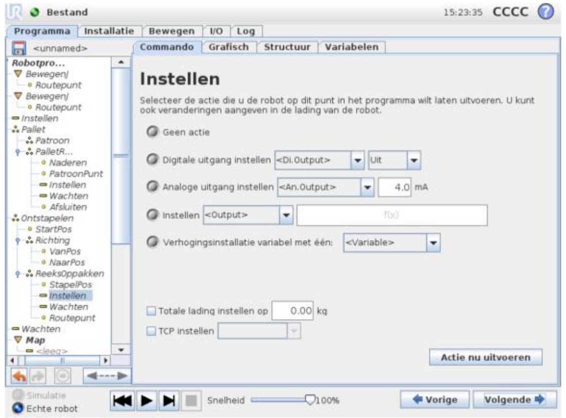
ARTIMINDS ROBOTICS

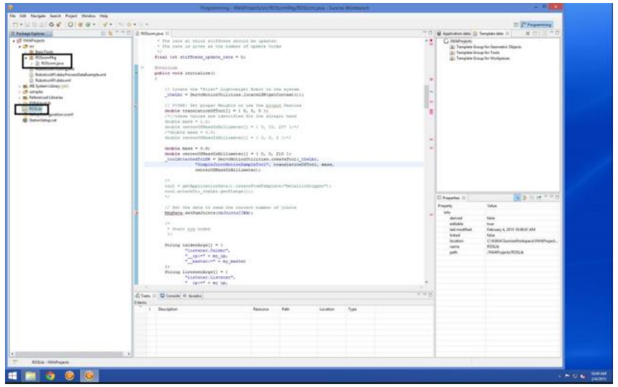
RoboDK ROBOT DEVELOPMENT KIT

- Online
  - Teach-in with teach pendant
  - Teach-by-demonstration


Online programming







Programming Complexity

Industrial vs collaborative robots

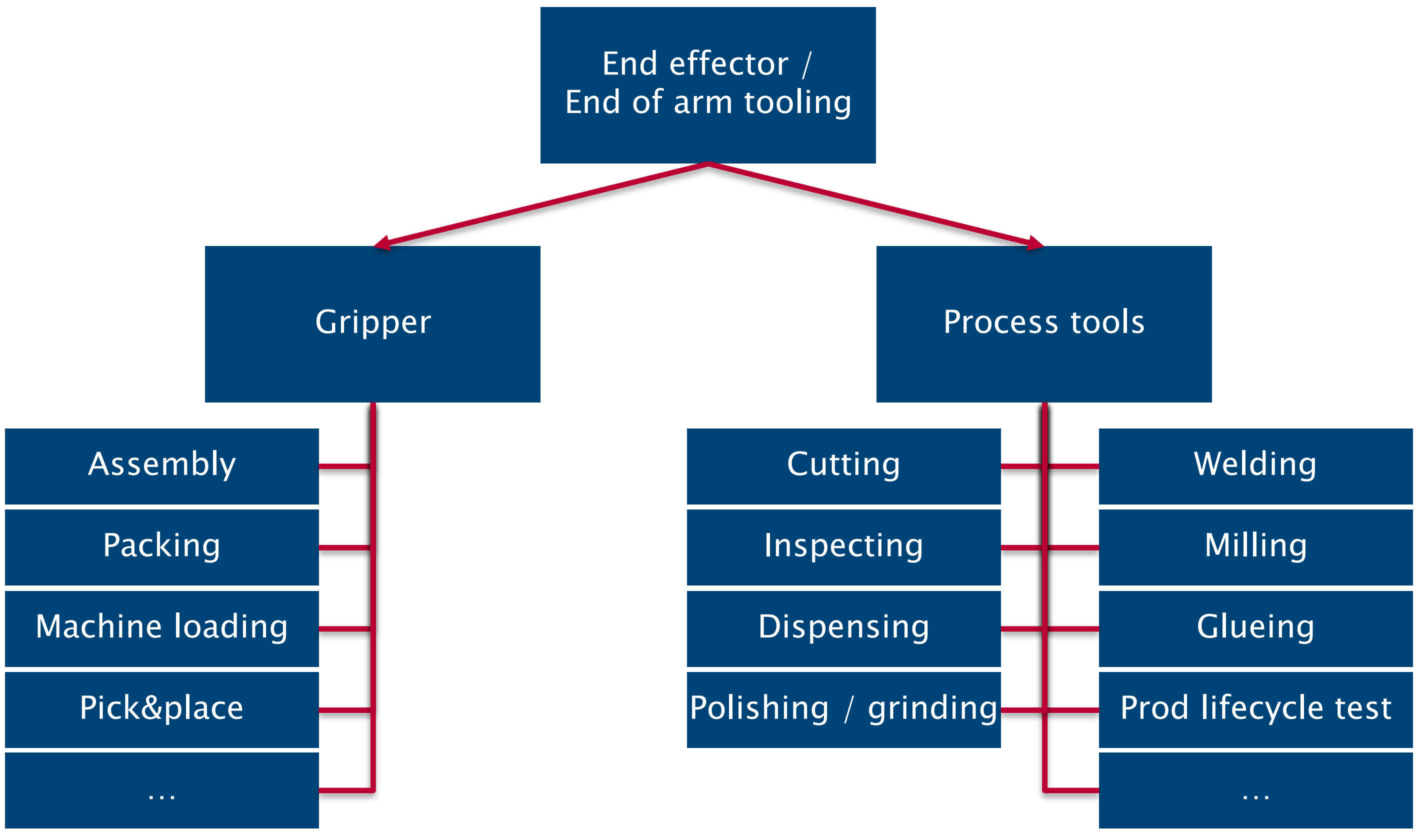
	Robot	Cobot
Payload	+++	+
Reach	+++	+
Position Accuracy	+++	++
Speed	+++	+
Human-robot interaction (safety)	+	+++
Simplicity of programming	++	+++
'Plug & produce' in production	+	+++
Task Variation (flexibility)	++	+++
Availability	+++	++

+: limited ++: good +++: very good

Cobot add-ons

- End-effector
- Eyes
- Sensitivity

Gripper terminology

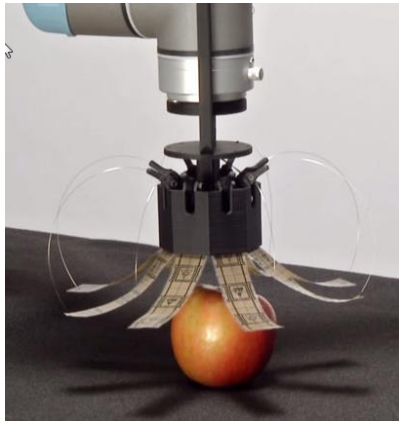


Grippers

- Fingers (2-5)
- Suction cups
- Magnetic
- Electrostatic
- Custom



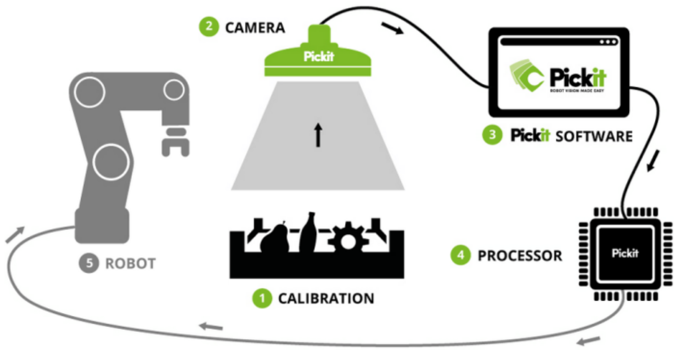




➔!All depending on Case and Product!

Eyes of your robot

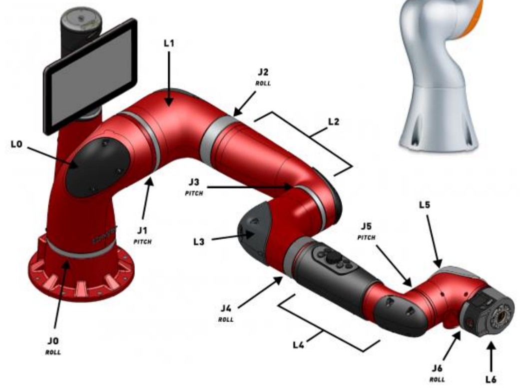
- Uncertain positions, flexibility ↑
- 2D Vision
  - XY-plane
  - Picking from conveyor, product sorting,…
- 3D Vision
  - XYZ-space
  - Bin picking
- Complexity ↑



Sensitivity of your robot

- Force torque sensors

- Internal
  - Eg. Kuka LBR iiwa, Sawyer
  - Force torque sensors in each joint
  - Mostly well kept secret…



- External
  - Eg. Robotiq sensor (FT150/300)
    Optoforce

Safety

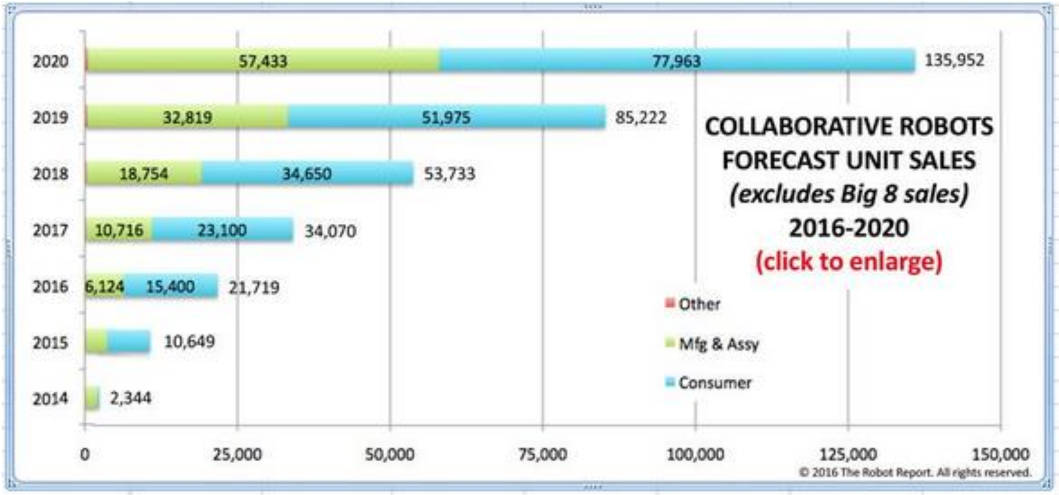
- ISO 10218 (Type C of safety standard)
  - ISO 10218-1: Industrial robots
  - ISO 10218-2: Industrial robot systems and integration
  - 4 collaborative modes are defined
- Strong reliance on *risk assessment* for defining thresholds (incl: robot, process, peripherals)
- ISO TS 15066
  - Since 15 Feb 2016
  - Offers guideline for the risk assessment for HRC

Some trends

- Technological
  - Integration of vision and sensitivity capacities
  - Gripper technology (dexterity ↑)
  - User friendliness ↑
  - Collaboration human-robot ↑ => Safety definition
  - Static => mobile robot
  - Robot => CoBot => learning robot

Trends – 2

- In general
  - Broad recognition for collaborative robotics (take-over, e.g. UR by Teradyne): investments → mainly driven by “service robotics”
  - Also China (56.000 from 225.000 in 2014; > 500 component manufacturers)
  - From 95mio$ (2014)
    To >1mia$ (2020)



Source: The Robo Report

sirris
driving industry by technology

Case assessment

- Product
  - Weight, size, shape, texture,…
  - Variance
  - Throughput
  - Presentation (for pick & place position)

- Process
  - External forces involved? (e.g. grinding, screwing,…)
  - Imagine doing the task without seeing or feeling and with 1 hand only
  - Many tasks are more complex than we think
    - Quality inspection, adjusting parameters, part or tool cleaning, registration,…

Case assessment – 2

- Environment
  - Safety and ergonomics
  - Dust, fluids, chemicals,…
  - Food approved, explosion proof,…
  - Interfacing
    - When start/stop?, communication with other systems
- Team
  - Get all stakeholders involved
  - Inform regarding the goal
  - Required skills
  - Team interest!

Case assessment

Technical and economical feasibility of light weight robot (LWR) for engraving and red-dot marking

FOMECO nv

Challenge

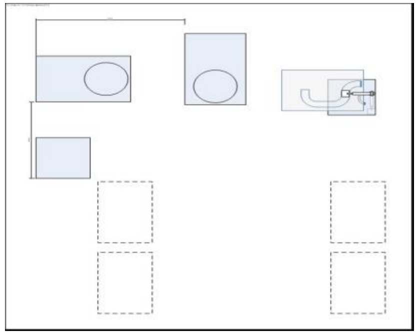
- In a cell with 5 processing stations, the cobot has to serve 1 station for a higher reliability and less time pressure for the operator
- The LWR has to operate in the same environment as the operator (but not simultaneously)
- Process to automate **“apply the marking and engravement on the tubes“**

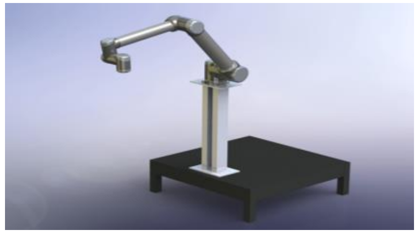
Contribution Sirris

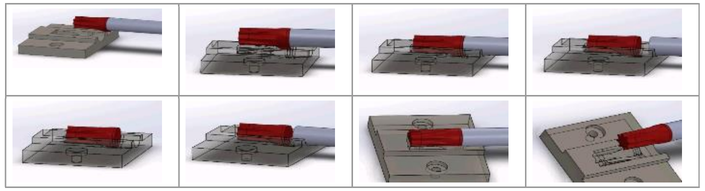
- Analysis of the current way of working
- Choice of the LWR robot
- Evaluation of the technical and economical feasibility.

Result

- Technical feasible
- Economical benefit only through lowering the cost of quality







sirris
driving industry by technology

Feasibility test

Case assessment

Technical and economical feasibility of light weight robot (LWR) for loading of IC-test machine

Melexis
Microelectronic Integrated Systems

Challenge

- Loading of testmachine via a cobot
- Current situation: one operator loads 5 machines

  => operator can't follow machine pace
- Cobot and operator in same working area

Approach

- Analysis of the current prodution situation
- Choice of LWR robot
- Evaluation of the technical en economical feasability of LWRs for loading of the IC-test machines

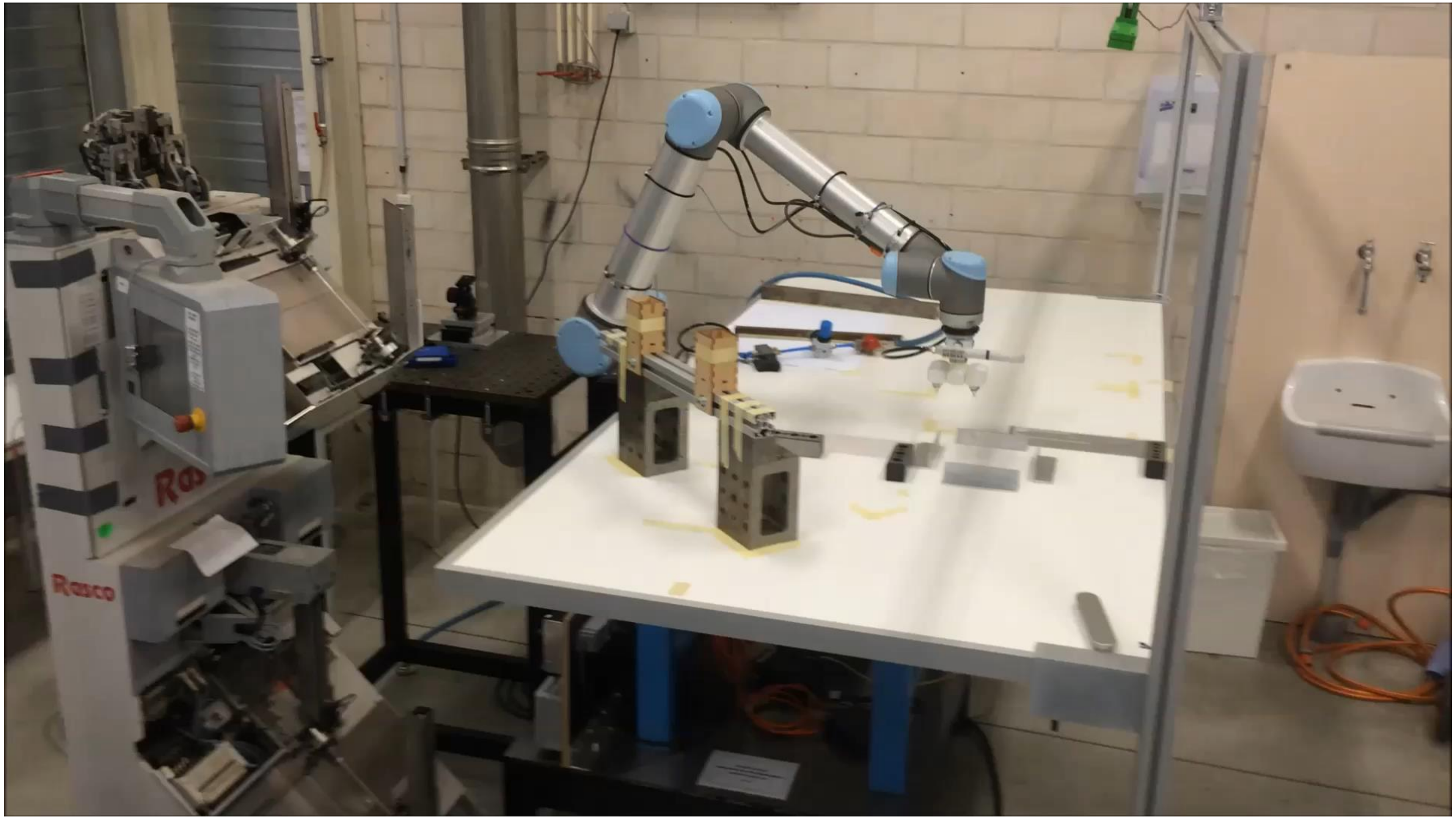
Result

- Technical en economical feasable → further detailing for implementation

Case assessment

Technical and economical feasibility of light weight robot (LWR) for loading of IC-test machine

Melexis
Microelectronic Integrated Systems



sirris
driving industry by technology

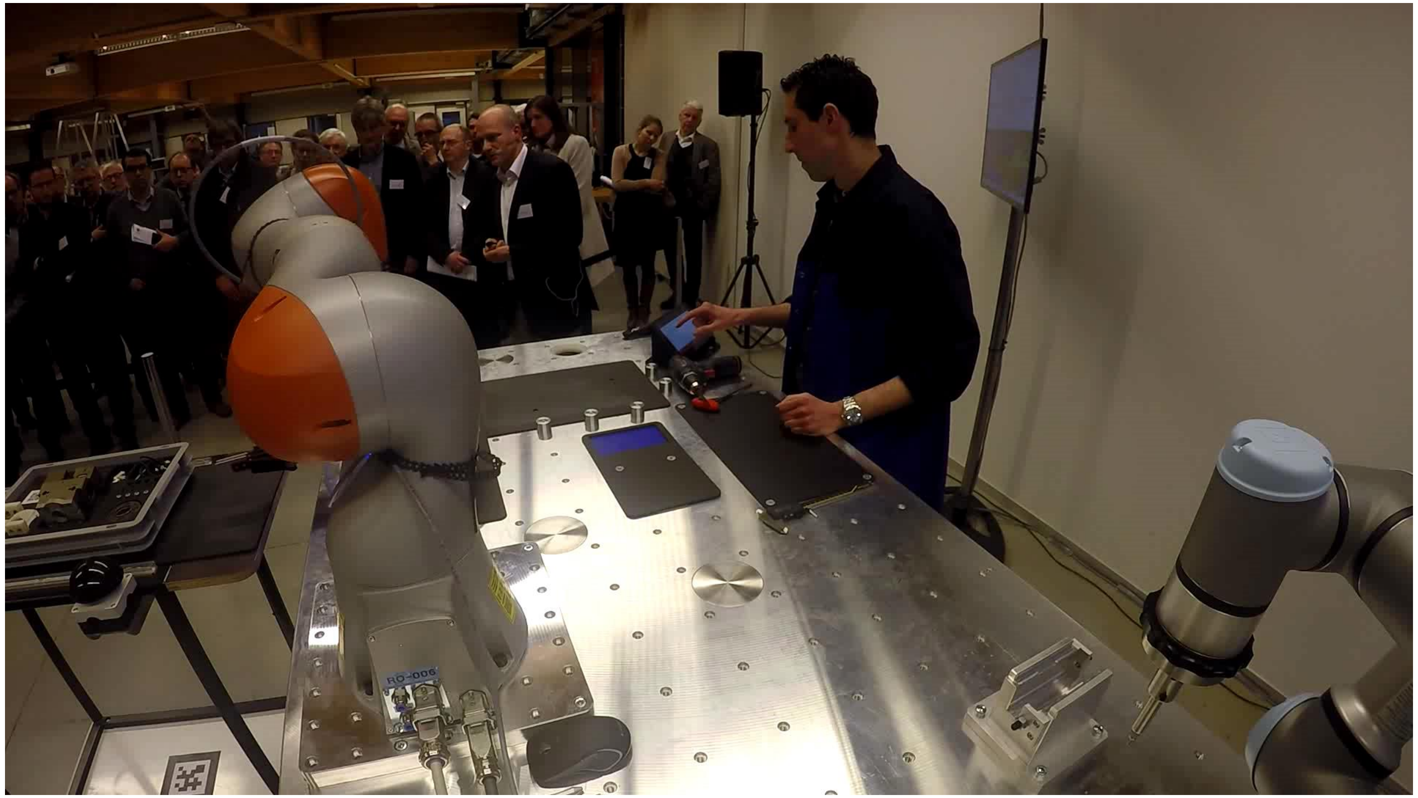
Case assessment

Technical and economical feasibility of light weight robot (LWR) for loading of IC-test machine

Melexis
Microelectronic Integrated Systems

sirris
driving industry by technology

Smart&Digital factory lab demo



- KUKA iiwa 14
  - 3rd hand
  - Pick&place
  - Senses object before grasping
- Universal Robots UR3
  - Screw application
  - Synchronized

Hands-on workshop “Meet the cobots”

- 31 May in Diepenbeek
  - Small groups
  - General introduction
  - Cobot programming
  - Gripper (electrical & pneumatic)
  - Camera (2D/3D) parameter setting

Youtube link

Thank you

for your attention!

Filiep Vincent

Filiep.vincent@sirris.be

+32 491 345 392

filiepvincent

www.linkedin.com/in/filiepvincent

www.sirris.be/cobots

sirris

driving industry by technology

sirris

driving industry by technology

http://www.sirris.be

http://techniline.sirris.be

#sirris

http://www.linkedin.com/company/sirris


WELCOME
PILZ
THE SPIRIT OF SAFETY

Human Collaborative Robots
HRC or cobots

BES nationale studiedag / journée nationale

Timen Floré
Sales manager Pilz Belgium

22 March 2018, Bruxelles

Agenda

Robots : introduction and standards

ISO/TS15066 - definitions

Steps to a safe collaborative robots system with ISO/TS 15066

Oxford English Dictionary

- "a machine capable of carrying out a complex series of actions automatically, especially one programmable by a computer"

ISO 10218

- "automatically controlled, reprogrammable multipurpose manipulator programmable in three or more axes which my be wither fixed in place or mobile for use in industrial automation applications"

PILZ
THE SPIRIT OF SAFETY

Robot kills worker at Volkswagen plant in Germany

Contractor was setting up the stationary robot when it grabbed and crushed him against a metal plate at the plant in Baunatal

An investigation is under way into whether human error was to blame for the death of a contractor at the hands of a robot at a Volkswagen production plant. Photograph: Joerg Sarbach/AP

A robot has killed a contractor at one of Volkswagen's production plants in Germany, the automaker has said.

The man died on Monday at the plant in Baunatal, about 100km (62 miles) north of Frankfurt, VW spokesman Heiko Hillwig said.

The 22-year-old was part of a team that was setting up the stationary robot when it grabbed and crushed him against a metal plate, Hillwig said.

He said initial conclusions indicate that human error was to blame, rather than a problem with the robot, which can be programmed to perform various tasks in the assembly process. He said it normally operates within a confined area at the plant, grabbing auto parts and manipulating them.

Another contractor was present when the incident occurred, but was not harmed, Hillwig said. He declined to give any more details about the case, citing an ongoing investigation.

German news agency DPA reported that prosecutors were considering whether to bring charges, and if so, against whom.

Legislation
Machinery Directive - 2006/42/EC

- There are 20+ product directives issued that require CE marking of products.
- One of the main applicable directives for robot application is the **Machinery Directive 2006/42/EC**
- The Directive aims to ensure identical Safety requirements for machinery in every state
- Defines a process and conformity procedures
- States essential health and safety requirements (EHSR)
- Defines the equipment it is applicable for, e.g.:
  - Machinery
  - Safety components
  - Partly completed machinery
  - Complex Assemblies

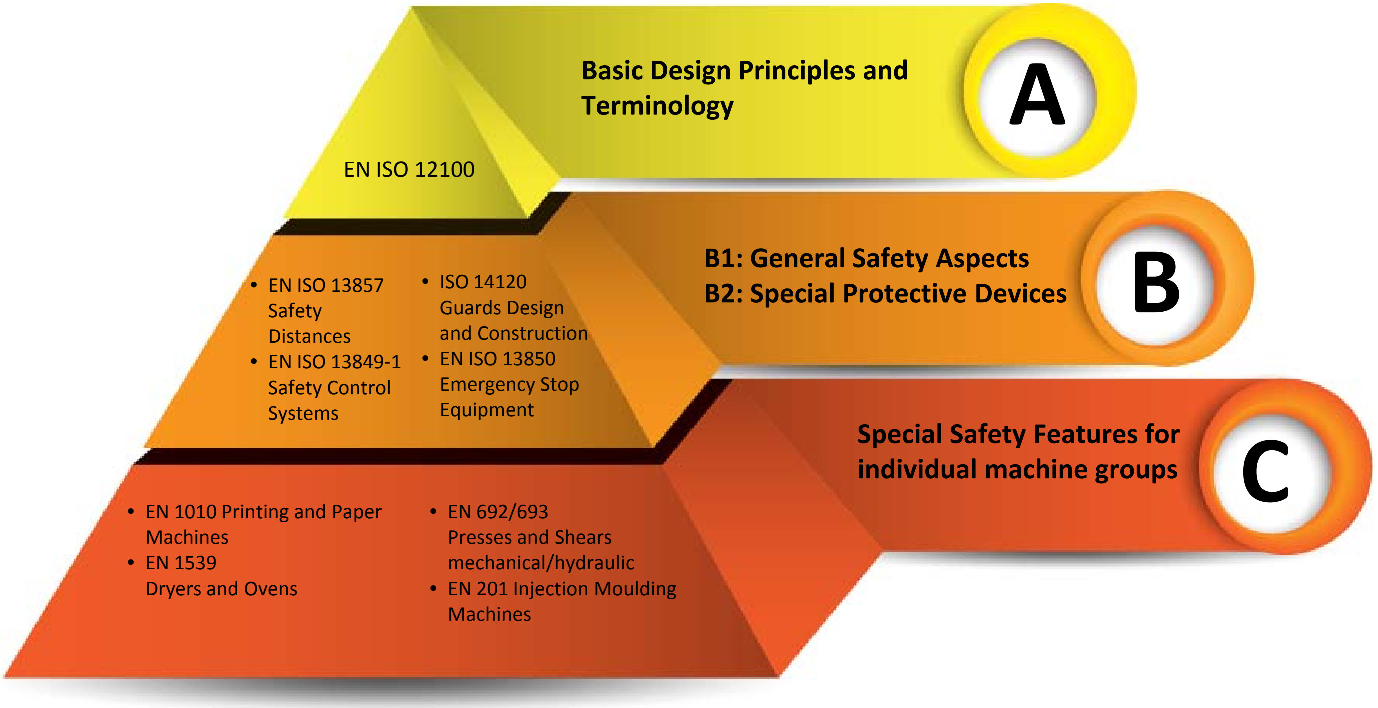
Standards
Subdivision of European Machinery Standards

A Standards
- Basic safety requirements

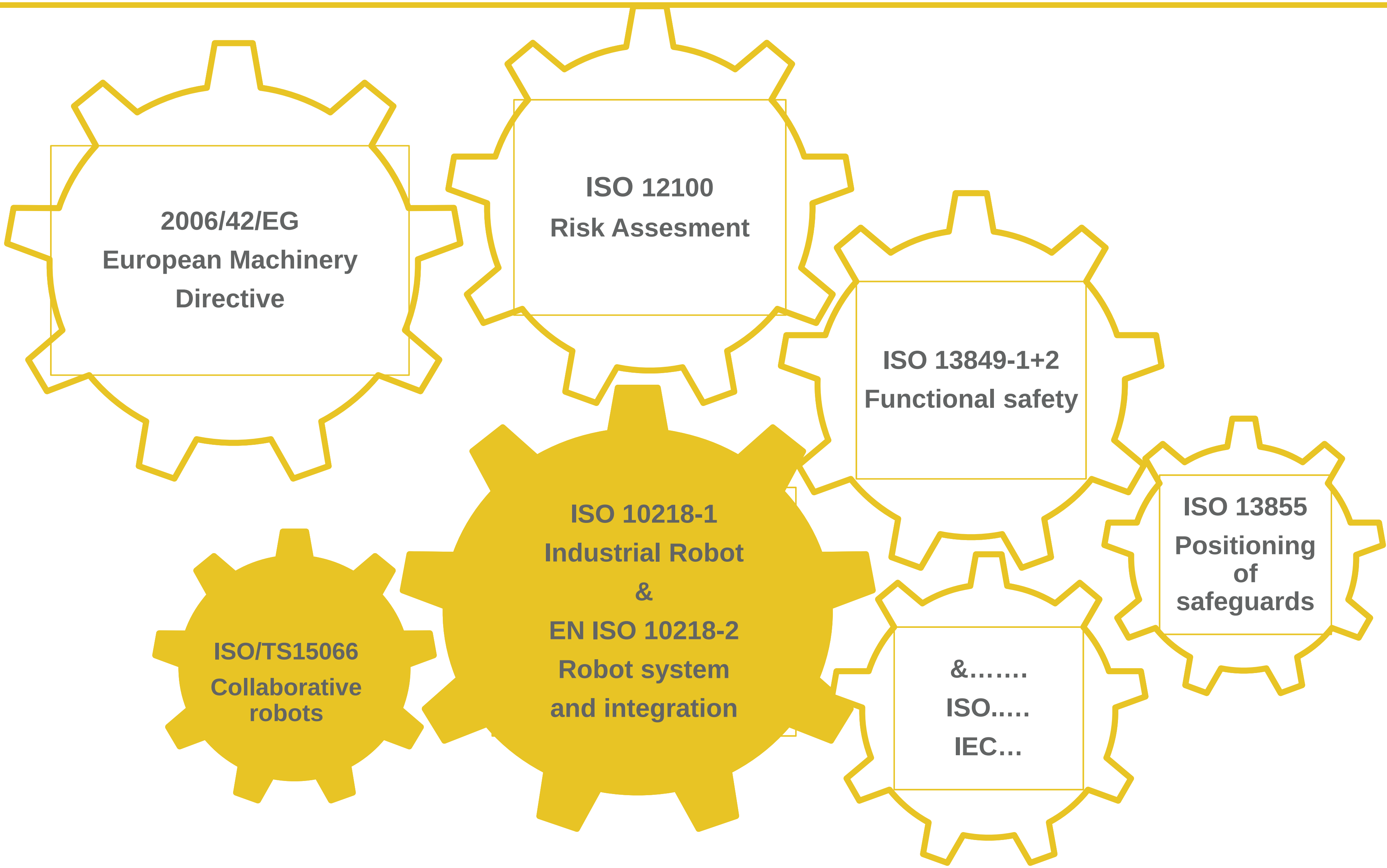
B1 Standards
- Safety aspects

B2 Standards
- Safety equipment

C Standards
- Specific machine
- Type or group



Directives and standards



The EN ISO 10218 is a C-Type standard in two parts:

- C-standards do describe technically complete the safety aspects of a type of machine.
- They have priority to A and B type standards

EN ISO 10218-1:

- Part 1 is meant for the robot manufacturer and describes the safety aspects for the construction of industrial robots. Aspects like inherent safe construction, protection measures, user information ,... are described
- Part 1 considers the robot as an incomplete machine – no CE mark

EN ISO 10218-2:

- Part 2 is meant for the robot integrator and describes the safety aspects for the delivery, integration and validation of industrial robot cells and applications.
- Part 2 considers the robot as a complete machine - CE marking is required

Robot manufacturer : EN ISO 10218-1

A robot is an incomplete machine:

- No intended use
- No purpose
- Not safe
- No CE under MD

It requires a:

- Declaration of incorporation
- Installation instructions
- Technical documentation cfr. Machinery directive, chapter VII b

Robot applications : EN ISO 10218-2

A robot cell or application is a complete machine :

- Intended use
- With a purpose
- Not safe
- CE under MD

It requires a :

- Responsible for safety
- Responsible for CE process
- CE mark on the application
- Operating instructions
- Declaration of conformity

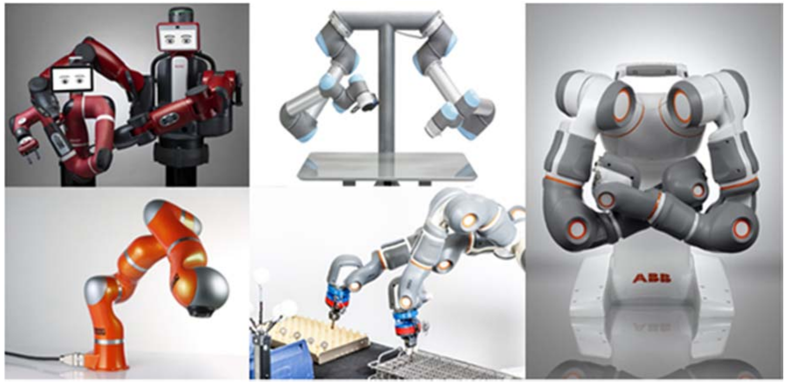
Agenda

Robots : introduction and standards

ISO/TS15066 - definitions

Steps to a safe collaborative robots system with ISO/TS 15066

What is a Cobot ?



ISO/TS15066 Collaborative robots

Why a TS ?

- HRC was dealt with only briefly in EN ISO 10218-2
- Urgent need for action : quicker to generate a TS than a new C standard

How does a TS fit in ?

- TS is a normative document of the ISO committee
- TS refers to harmonized C standard
- The presumption of conformity with MD is thus re-establised

What is a 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]

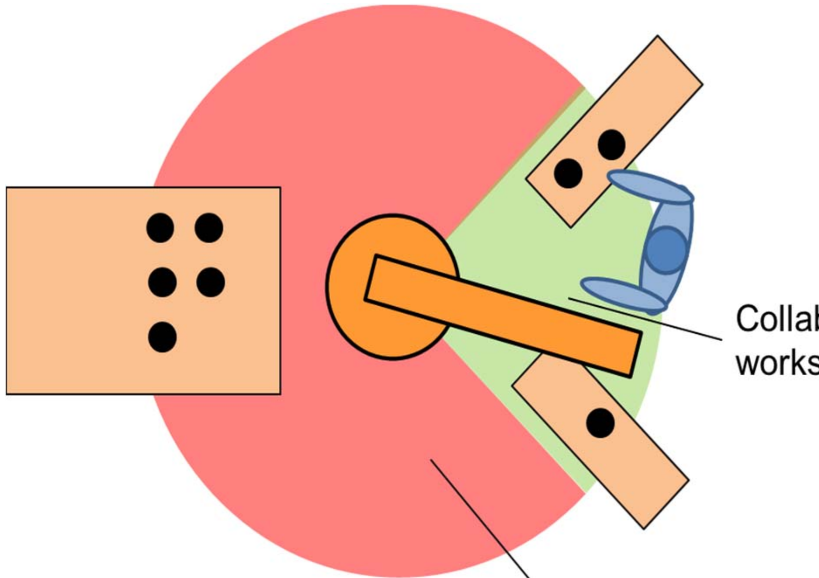


Figure 1 — Example of a collaboratve workspace

What is a Quasi-static contact?

Contact between an operator and part of a robot system where the operator body part can be clamped between a moving part of a robot system and another fixed or moving part of the robot cell

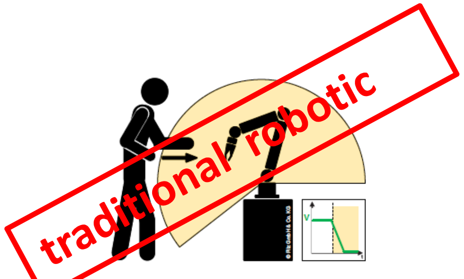
What is a Transient contact / Dynamic contact?

Contact between an operator and part of a robot system where the operator body part is not clamped and can recoil or retract from the moving part of the robot system

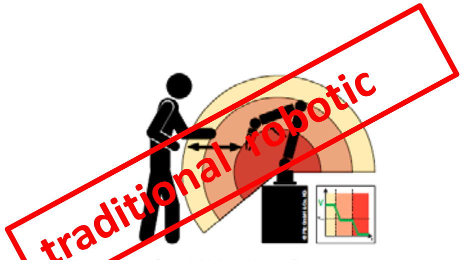
Methods in accordance with TS 15066

PILZ
THE SPIRIT OF SAFETY

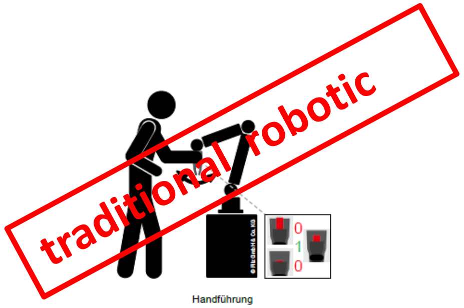
There are 4 methods of HRC



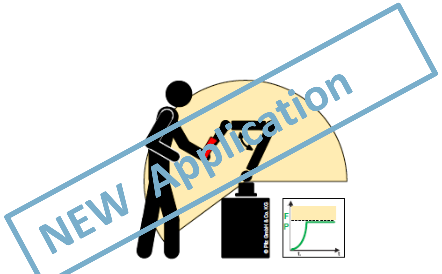
Sicherheitsgerichteter Stopp (STO)



Geschwindigkeits- und Abstandsüberwachung



Handführung



Leistungs- und Kraftbegrenzung

Methods in accordance with TS 15066
Method 4 – power and force limiting

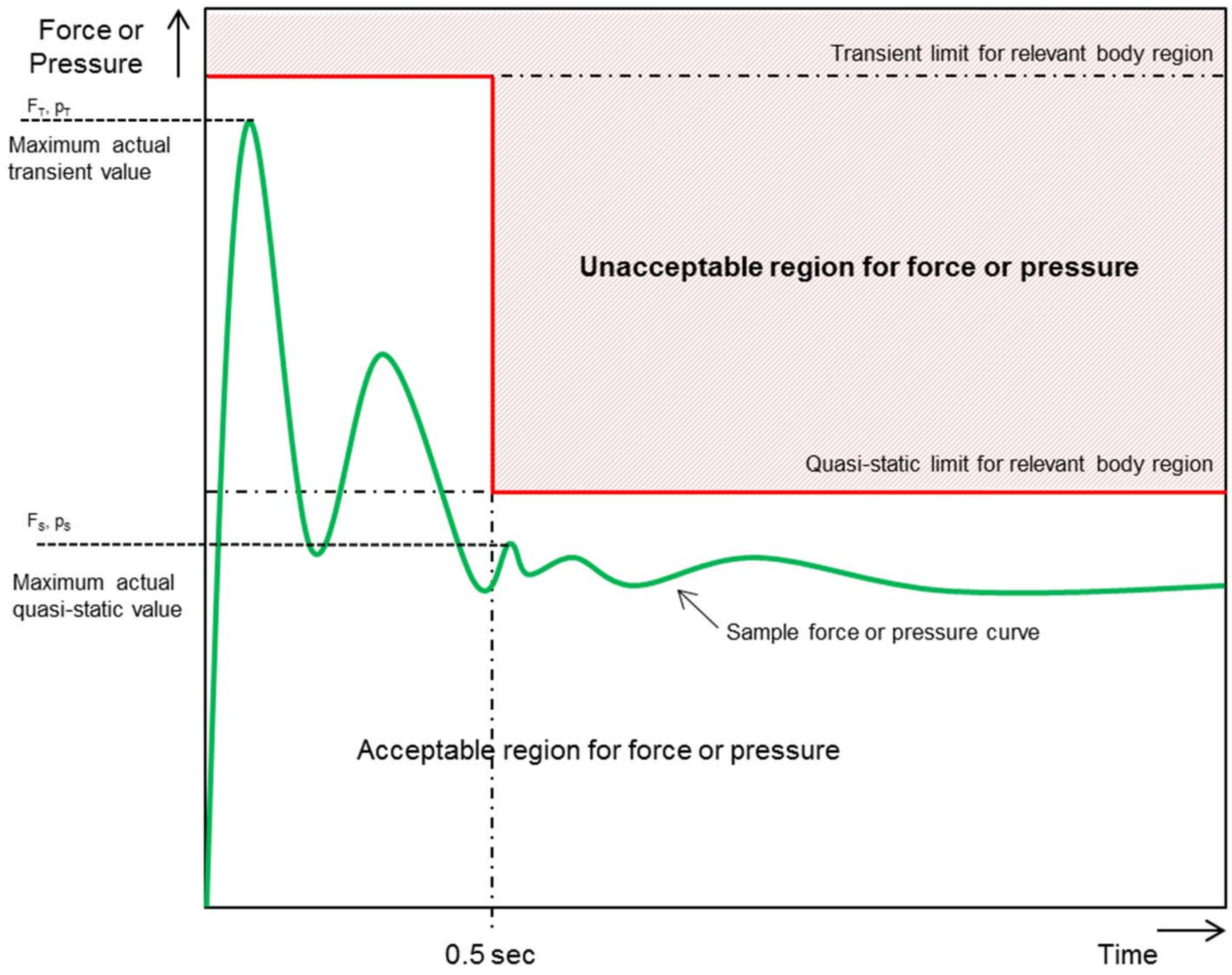


Figure 4 — Graphical representation of acceptable and unacceptable forces or pressures

Methods in accordance with TS 15066
Method 4 – power and force limiting

PILZ
THE SPIRIT OF SAFETY

ISO/TS 15066:2016(E)

Table A.2 — Biomechanical limits

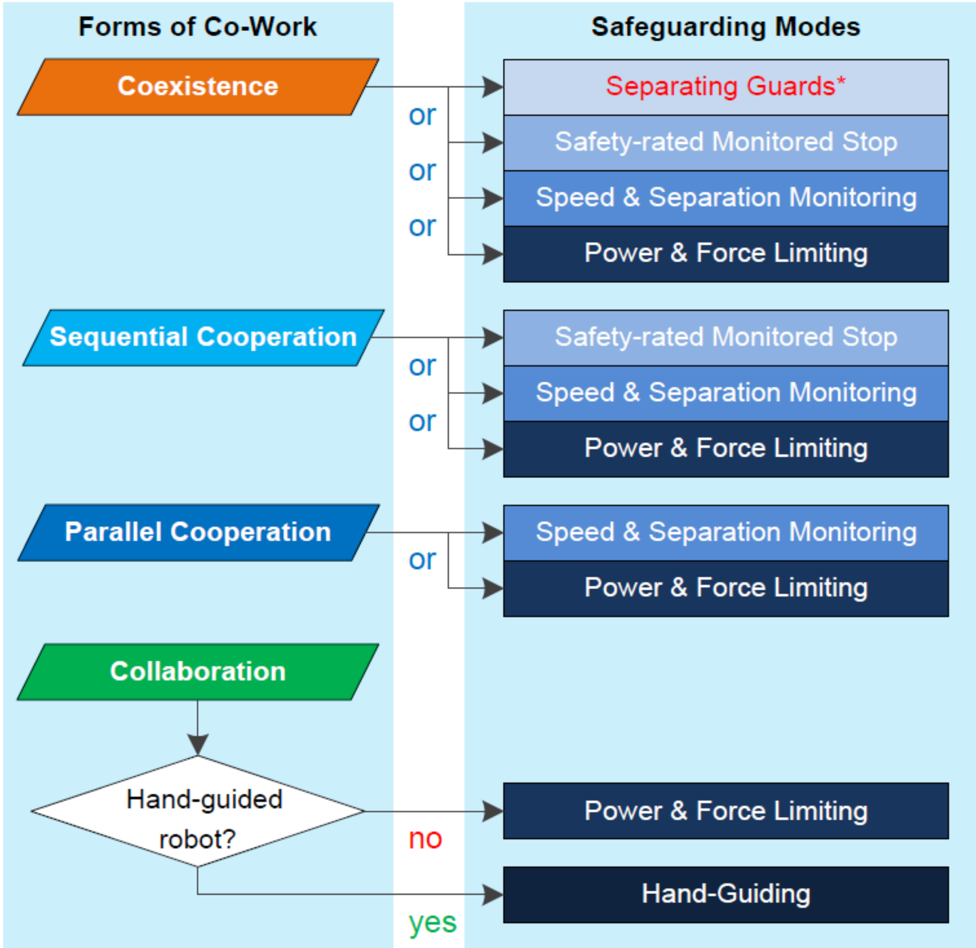
Body region		Specific body area	Quasi-static contact		Transient contact	
			Maximum permissible pressure [a] p_s N/cm²	Maximum permissible force [b] N	Maximum permissible pressure multiplier [c] P_T	Maximum permissible force multiplier [c] F_T
Skull and forehead [d]	*1*	*Middle of forehead*	*130*	*130*	*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

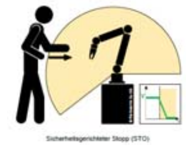
Types of interaction

- Coexistence
  - Human and robot have own independent workspaces
- Sequential cooperation
  - Human and robot work successively on the same workpiece
  - No simultaneous activiy inside collaboration space
- Parallel cooperation
  - Human and robot work simultaneously on the same workspiece
  - Simultaneous activity inside collaboration space
  - Collisions are not as intended
- Collaboration
  - Human and robot produce something together
  - Simultaneous activity inside collaboration space
  - Collisions are possible

Definition of HRC
Frauenhofer IFF Magedburg

Forms of HRC < -- > Methods





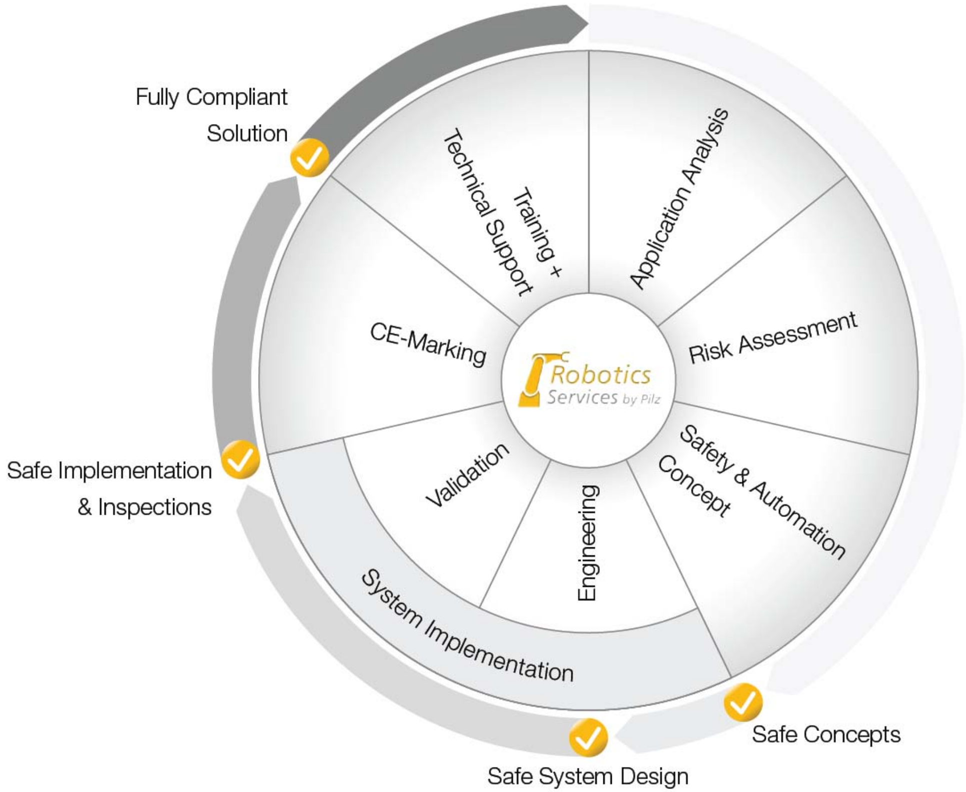
Agenda

Robots : introduction and standards

ISO/TS15066 - definitions

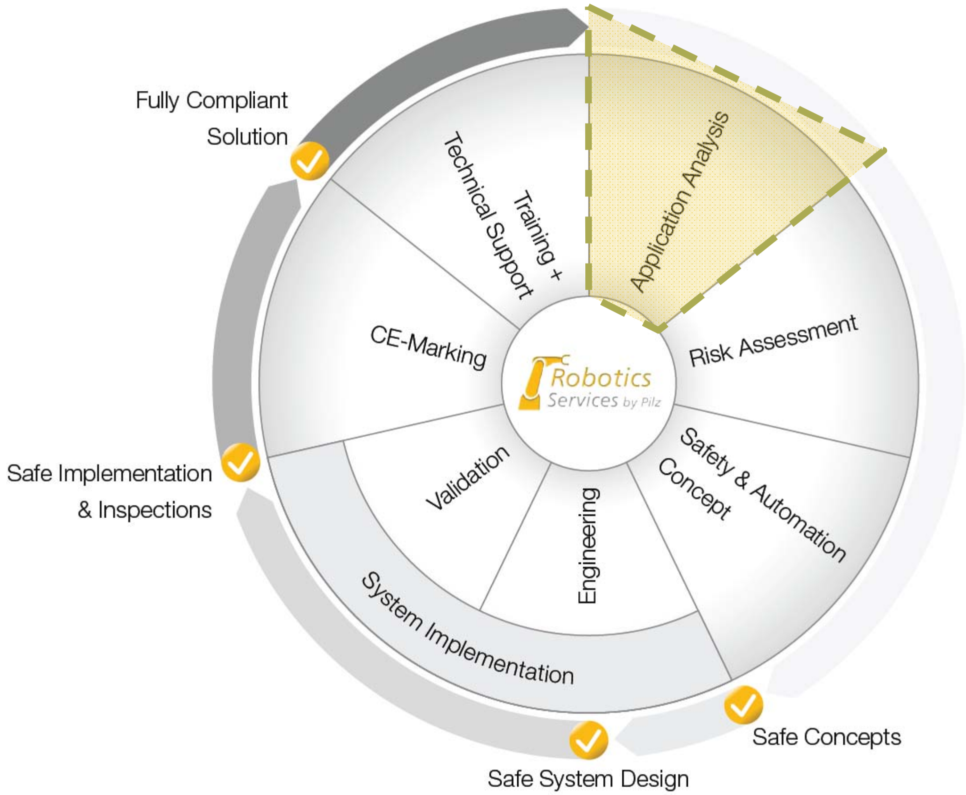
Steps to a safe collaborative robots system with ISO/TS 15066

Steps to a safe collaborative robots system with ISO/TS 15066



Steps to a safe collaborative robots system with ISO/TS 15066

PILZ
THE SPIRIT OF SAFETY

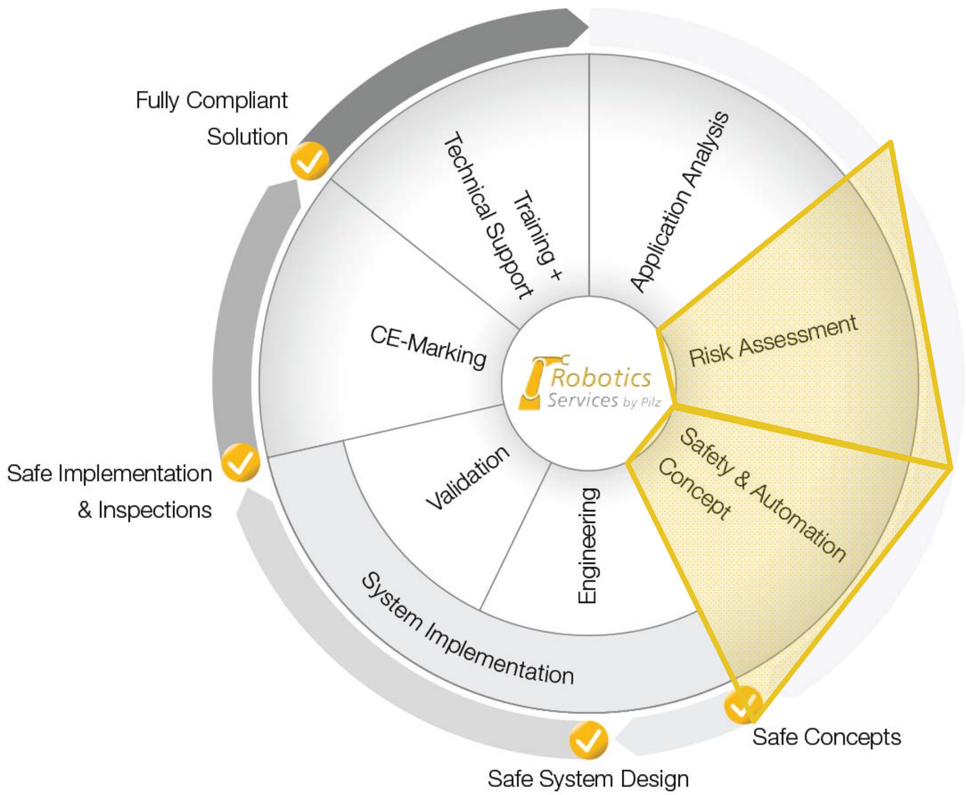


Application Analysis

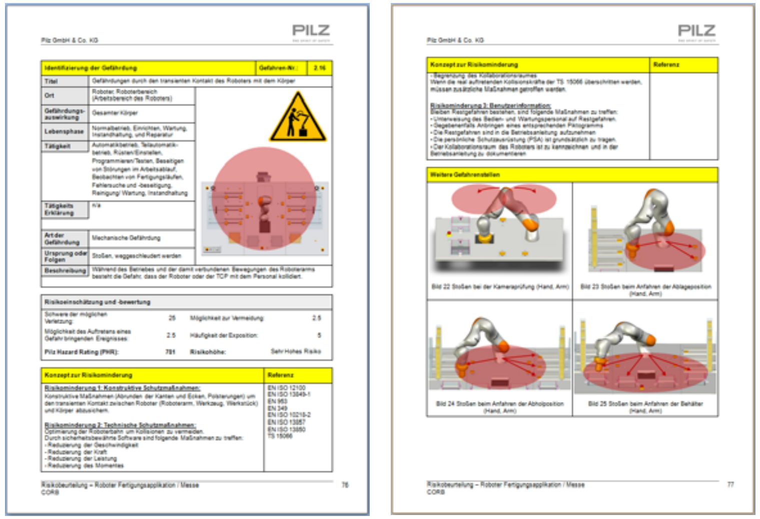
- Limits (three dimensional)
- Collaborative workspace : access and clearance, foreseeable contact, access routes,.......
- Ergonomics and human interface with equipment: possible stress, required training,....
- Cycle time : dynamics
- Design of tool and work piece
- Design of application
- Human tasks inside the application
- Human interaction with the Cobot

Robotics Services by Pilz

Steps to a safe collaborative robots system with ISO/TS 15066



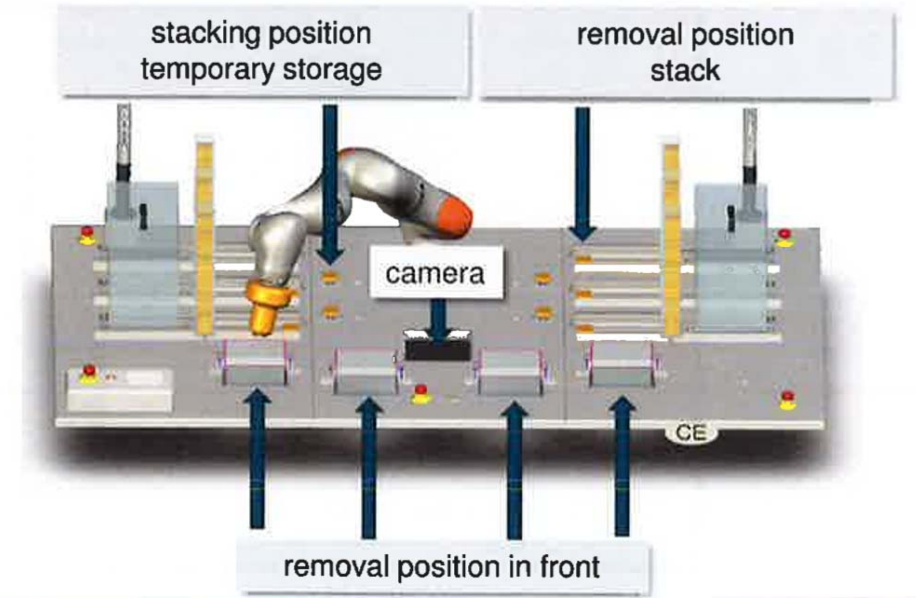
- Risk Assessment
- Safety Concept



Steps to a safe collaborative robots system with ISO/TS 15066 – risk assessment

PILZ
THE SPIRIT OF SAFETY

The risk assesment is the most important work for a a safe collaborative system



- Automatic mode
- Manual task – selection and output

Steps to a safe collaborative robots system with ISO/TS 15066 – risk assessment

Risk reduction by 3-step method:

1. Inherently safe design:
- Increase safety distances from hazard
- Modified design

2. Technical safeguards:
- EN ISO 13849 – Performance level
- Safe stop PL d, CAT3

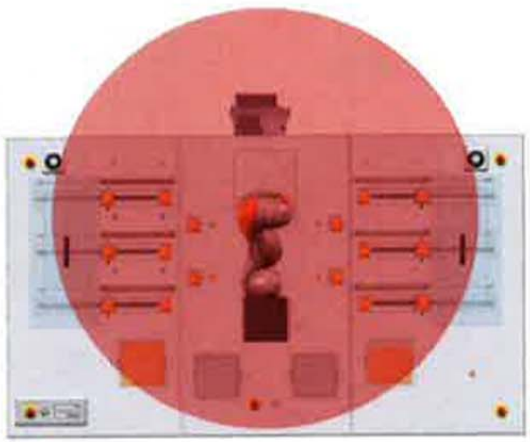
3. User Information:
- Operating instructions
- Personal protecion equipment, pictograms

Steps to a safe collaborative robots system with ISO/TS 15066 – risk assessment

PILZ
THE SPIRIT OF SAFETY

Hazard generated by transient contact

Where are the hazard locations?	Robot, robot area (working range of the robot)
What is affected?	Whole body
During which life cycle phases?	Normal operation, setup, maintenance, servicing and repair
What type of hazard?	Bumping, being dragged away



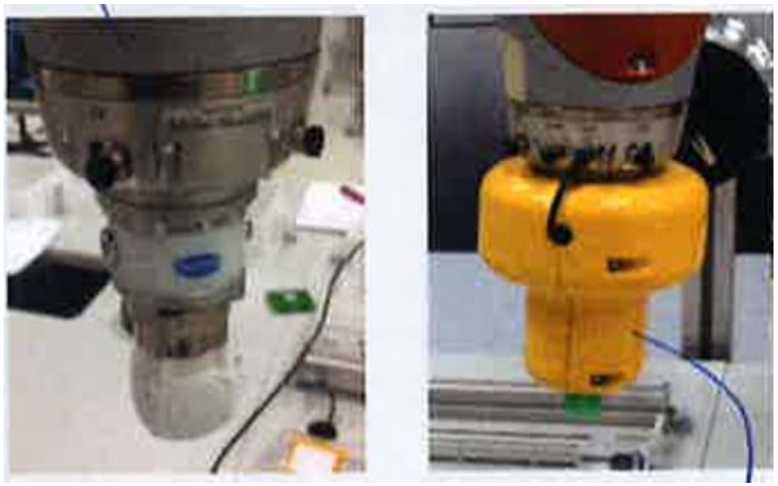
Steps to a safe collaborative robots system with ISO/TS 15066 – risk assessment

PILZ
THE SPIRIT OF SAFETY

Hazard generated by transient contact – risk reduction concept

1. Design safeguards

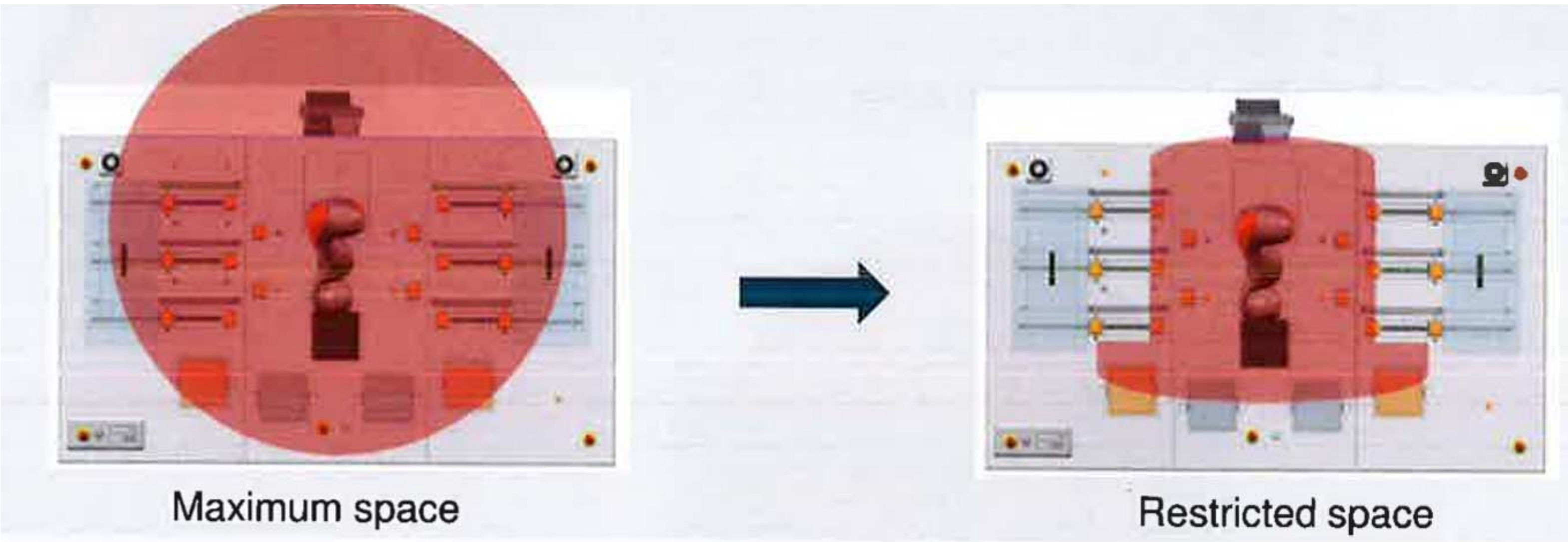
- Rounding edges and corners
- Padding
- Contact surfaces as large as possible to spread force over full surface
- Radii used no smaller than 5 mm



Hazard generated by transient contact – risk reduction concept

2. Technical safeguards

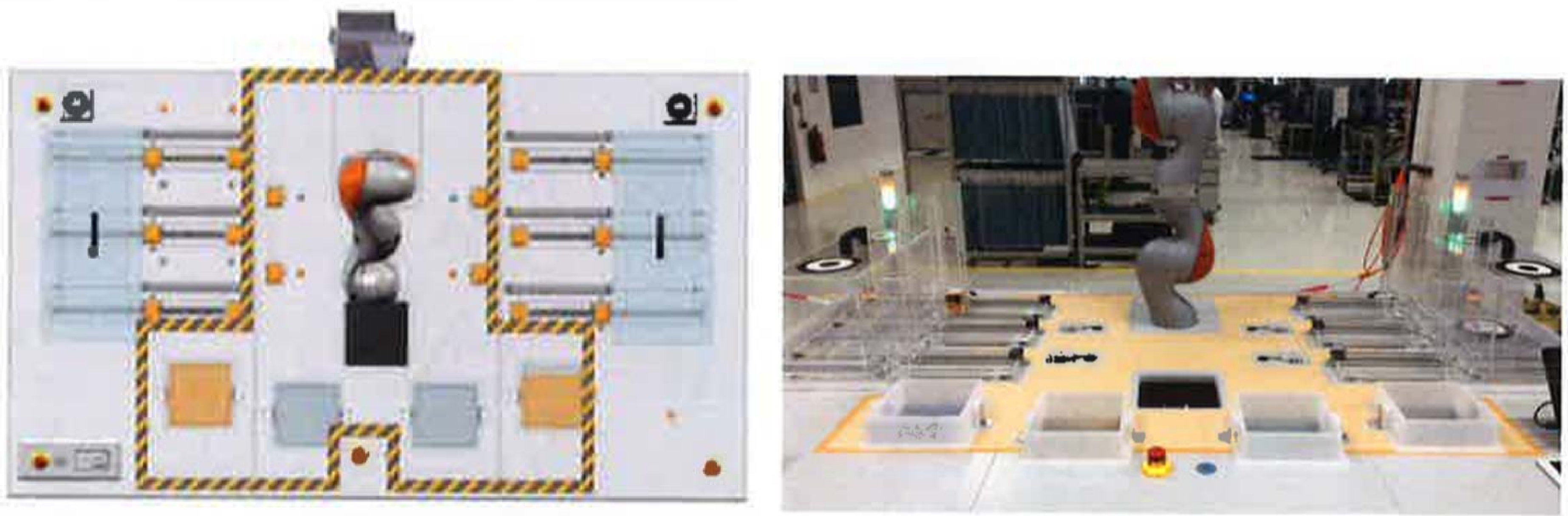
- Optimisation of the robot path (excl. body and head regions)
- Reduced dynamics (torque, force, speed, power)
- Restricted collaboration space



Hazard generated by transient contact – risk reduction concept

3. User information

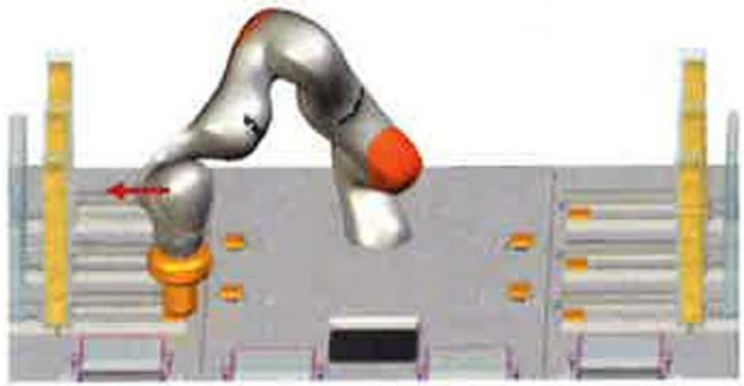
- Record limit values in the operating instructions
- Marking the collaboration space

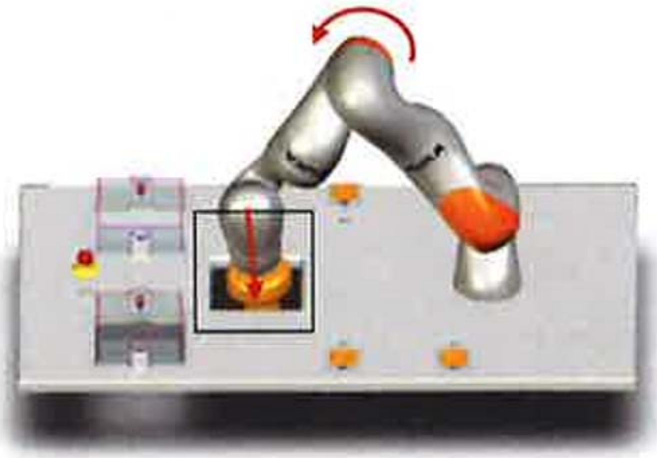


Steps to a safe collaborative robots system with ISO/TS 15066 – risk assessment

Hazard generated by quasi-static contact

Title	Hazard generated by quasi-static contact between robot and fixed structures
Where are the hazard locations?	Robot, robot area (working range of the robot)
What is affected?	Whole body
During which life cycle phases?	Normal operation, setup, maintenance, servicing and repair
What type of hazard?	Crushing, shearing



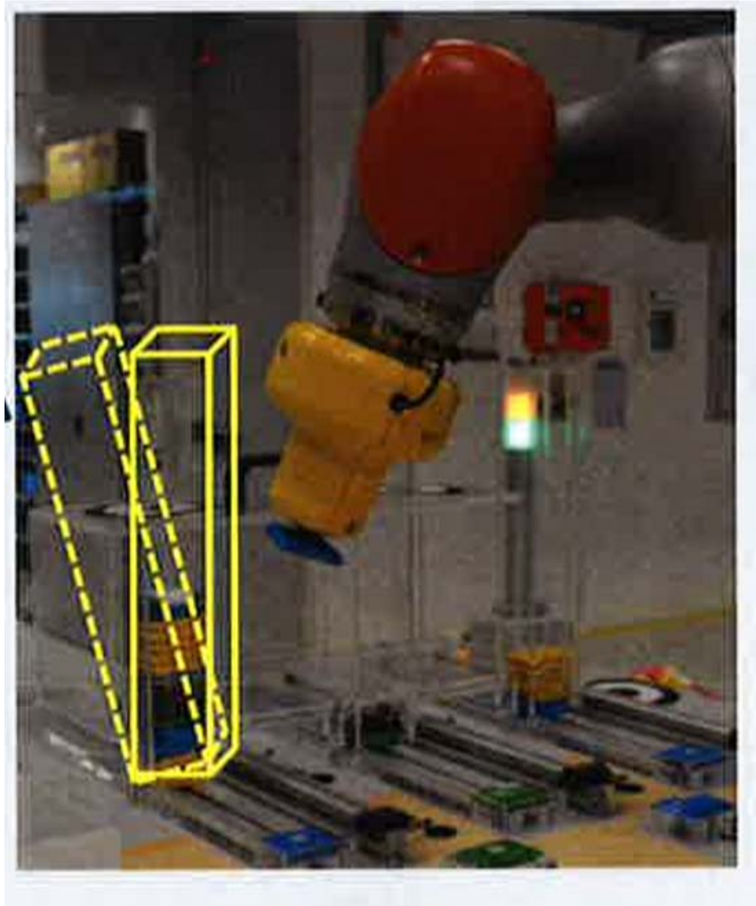


Steps to a safe collaborative robots system with ISO/TS 15066 – risk assessment

Hazard generated by quasi-static contact – risk reduction concept

1. Design safeguards

- Avoid crushing and shearing points
- Resilient design

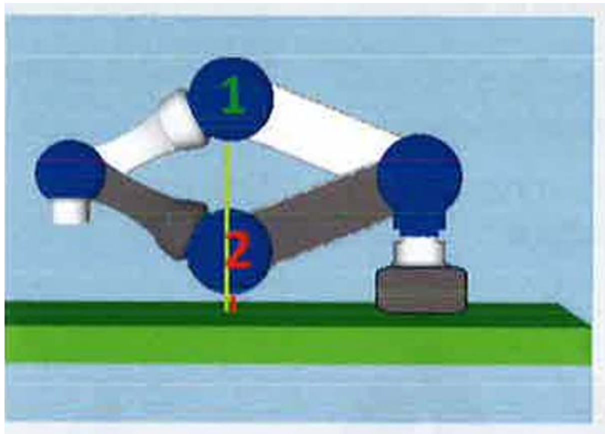


Steps to a safe collaborative robots system with ISO/TS 15066 – risk assessment

Hazard generated by quasi-static contact – risk reduction concept

2. Technical safeguards

- Optimisation of the robot path (excl. body and head regions)
- Reduced dynamics (torque, force, speed, power)
- Restricted collaboration space
- Inverse kinematics :
  - 1 bumping
  - 2 crushing



3. User information

- Record limit values in the operating instructions
- Marking the collaboration space

Steps to a safe collaborative robots system with ISO/TS 15066 – risk assessment

Hazard generated by quasi-static contact

Title	Hazard generated by quasi-static contact between robot axes
Where are the hazard locations?	Robot, robot area (working range of the robot)
What is affected?	Whole body
During which life cycle phases?	Normal operation, setup, maintenance, servicing and repair
What type of hazard?	Crushing, shearing

Steps to a safe collaborative robots system with ISO/TS 15066 – risk assessment

PILZ
THE SPIRIT OF SAFETY

Hazard generated by quasi-static contact – risk reduction concept

1. Design safeguards

- When selecting the robot, look for rounded edges and corners on the joints and superstructures

2. Technical safeguards

- Optimisation of the robot path (widest possible axis angles)
- Reduced dynamics (torque, force, speed, power)
- Limit the minimum possible axis angle

3. User information

- Record limit values in the operating instructions
- Marking the collaboration space

Steps to a safe collaborative robots system with ISO/TS 15066 – risk assessment

Hazard generated by falling into the robot

Title	Hazard generated by falling into the robot
Where are the hazard locations?	Robot, robot area (working range of the robot)
What is affected?	Whole body
During which life cycle phases?	Normal operation, setup, maintenance, servicing and repair
What type of hazard?	Slipping, tripping and falling

Hazard generated by falling into the robot – risk reduction concept

1. Design safeguards

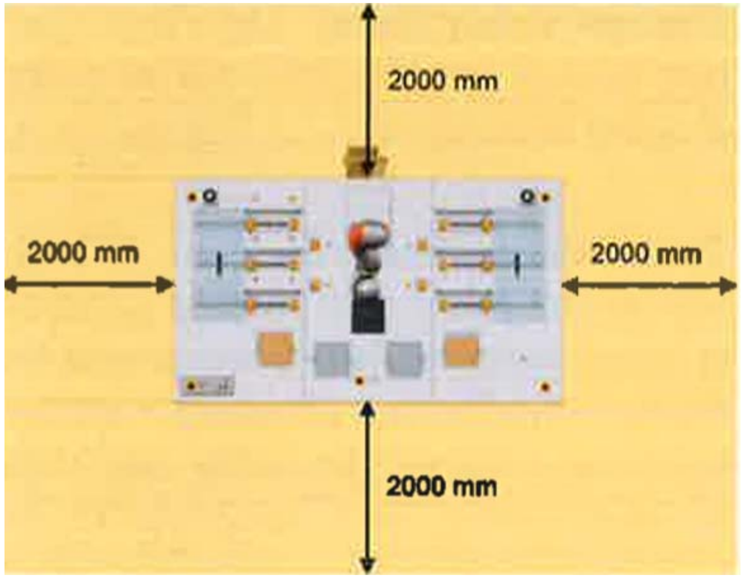
- No interfering edges from building structures, application, energy supply,...
- Minimum distance around the restricted space of 2m (if approach speed is considered 2000 mm/s, and the duration of the fall is 1s)

2. Technical safeguards

- Not required

3. User information

- Mark existing interfering contours



PILZ
THE SPIRIT OF SAFETY

Hazard generated by remote access to the robot control system

Title	Hazards generated by remote access to the robot control system
Where are the hazard locations?	Robot, robot area (working range of the robot)
What is affected?	Whole body
During which life cycle phases?	Normal operation, setup, maintenance, servicing and repair
What type of hazard?	Being dragged away, crushing, shearing, bumping

Steps to a safe collaborative robots system with ISO/TS 15066 – risk assessment

Hazard generated by remote access to the robot control system – risk reduction concept

1. Design safeguards

- Robot controls not connected to network if possible

2. Technical safeguards

- Prevent unauthorised remote access by means of
  - Protection software
  - Password protection
- Activation of remote control function only possible from local control unit
- Remote control in the operating mode „manual at high speed“ not permissible

3. User information

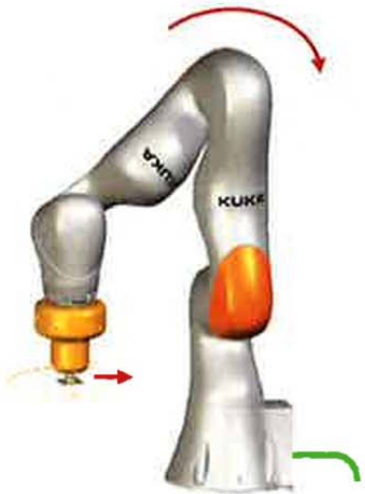
- Release for remote access only by authorised specialist personnel

Steps to a safe collaborative robots system with ISO/TS 15066 – risk assessment

PILZ
THE SPIRIT OF SAFETY

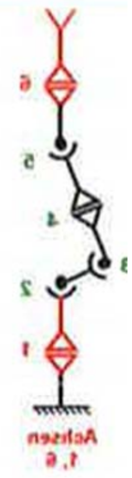
Hazard generated by singularities (not defined situation of the robot)

Title	Hazards generated by singularities
Where are the hazard locations?	Robot, robot area (working range of the robot)
What is affected?	Whole body
During which life cycle phases?	Normal operation, setup, maintenance, servicing and repair
What type of hazard?	Bumping, being dragged away



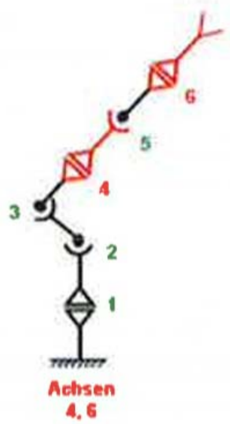
Steps to a safe collaborative robots system with ISO/TS 15066 – risk assessment

Hazard generated by singularities (not defined situation of the robot)



Singularity occurs when 2 robot axis are aligned to each other.
Robot axis 1 and 6 are on the same line to the tool
In case of rotation robot controller can use axis 1 or 6
(undefined situation)

Zero crossing of axis 5, which means that axis 4 and 6 are aligned.
The result is an infinite number of axis positions which can lead to an undefined situation.

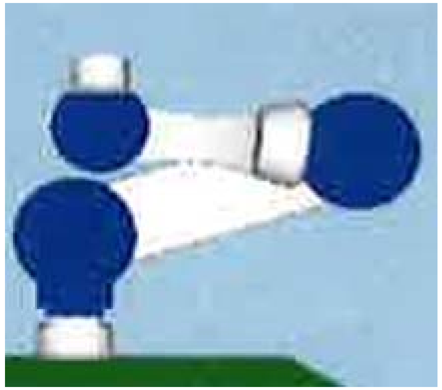


Avoidance by optimizing the robot path.
The robot must stop when singularity occurs.

Steps to a safe collaborative robots system with ISO/TS 15066 – risk assessment

PILZ
THE SPIRIT OF SAFETY

Hazard generated by singularities (not defined situation of the robot) – risk reduction concept



1. Design safeguards

- Optimise position of robot and tool

2. Technical safeguards

- Optimise robot path (avoid singularities)
- Reduction in TCP and axial speed (small movement in TCP can result in large movement of the robot)

3. User information

- Include hazards genrated by singularities in operating instructions

Other hazards

1. Hazards from the tool :

- Avoid pointed or sharp tools
- Caution with pressurised media

2. Hazards during commissioning

- Enclose machine sections with incomplete protective devices
- Emergency stop circuits must be activated and operational
- Move the robot only at reduced speed, otherwise location-dependent device

3. Hazard from loss of workpiece

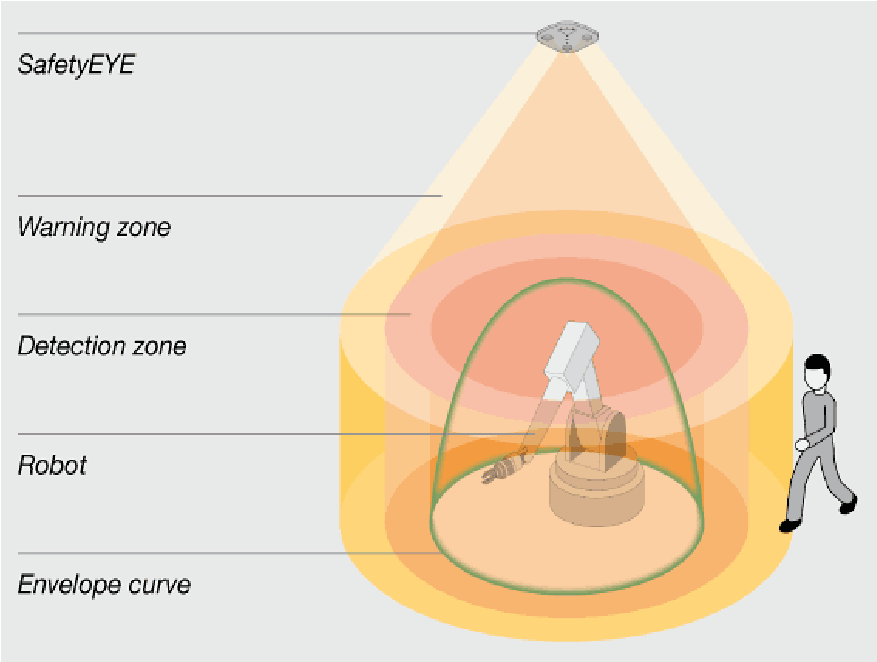
- Optimisation of robot path – prevent violent movements by programmig
- Traversing movements must be executed downwards where possible

Steps to a safe collaborative robots system with ISO/TS 15066 – risk assessment

PILZ
THE SPIRIT OF SAFETY

According to TS 15066 : transition from automatic to collaborative operation may not lead to any hazard

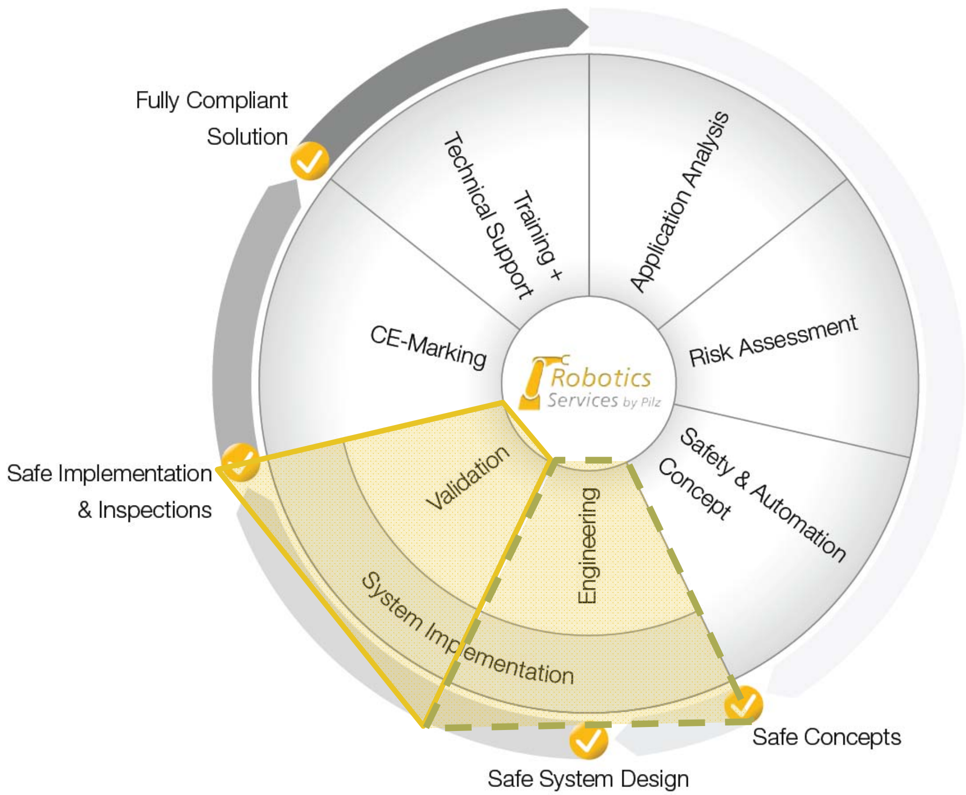
Use of safe sensors for switching collaborative into non collaborative operation -> reduced dynamics by violation of the safety zone



Other hazards – attention for HRC method 4 force/power reduction :

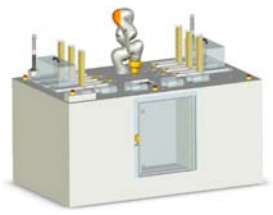
- Collisions are only considered safe if the limits of TS 15066 have been confirmed
- Until they have been confirmed temporary measures must be taken :
  - Trial operation
  - Additional temporary fences
  - Operation under supervision
  - Instructions for employees

Steps to a safe collaborative robots system with



- Engineering

KUKA IIWA - Application - HMI 2016



- Validation :
  - Evaluation of Application based on the Risk Assessment.
  - Calculation of the SRCF (PASCAL)
  - Evaluation EN ISO 10218-2 Annex G
  - HRC Force Measurement

Steps to a safe collaborative robots system with Safety validation

- Validation – check of the application on site
- The basis is the risk assessment with all relevant safety functions
- Validation contains:
  1. Verification of the required performance level PLr
  2. Safety check
     - Fault simulation (2 channel triggering, cross-fault,...)
     - Overrun traverse measuring for HRC method 3
     - Complete the checklist EN ISO 10218-2 appendix G
  3. New : collision measurement for HRC method 4

Steps to a safe collaborative robots system with Safety validation

Validation – Verification of the required performance level PLr

Example safe force limiting : exceeding the force limit promts immediate shutdown of the robot

This safety function is entirely robot-internal, safety characteristics supplied by the manufacturer :

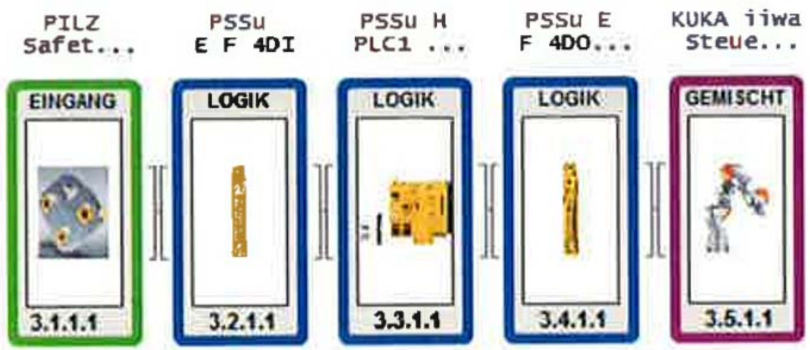
Steps to a safe collaborative robots system with Safety validation

Validation – Verification of the required performance level PLr

Example Safety Eye reduces the robot speed : entering the Safety Eye detection zone prompts activation of the robot-internal safe speed limiting function :

SENSOR	LOGIC external	LOGIC internal	ACTUATOR
Safety Eye	PSSuniversal	Robot controller	Robot arm
PILZ	PILZ	KUKA	KUKA

External sensor acts on robot :

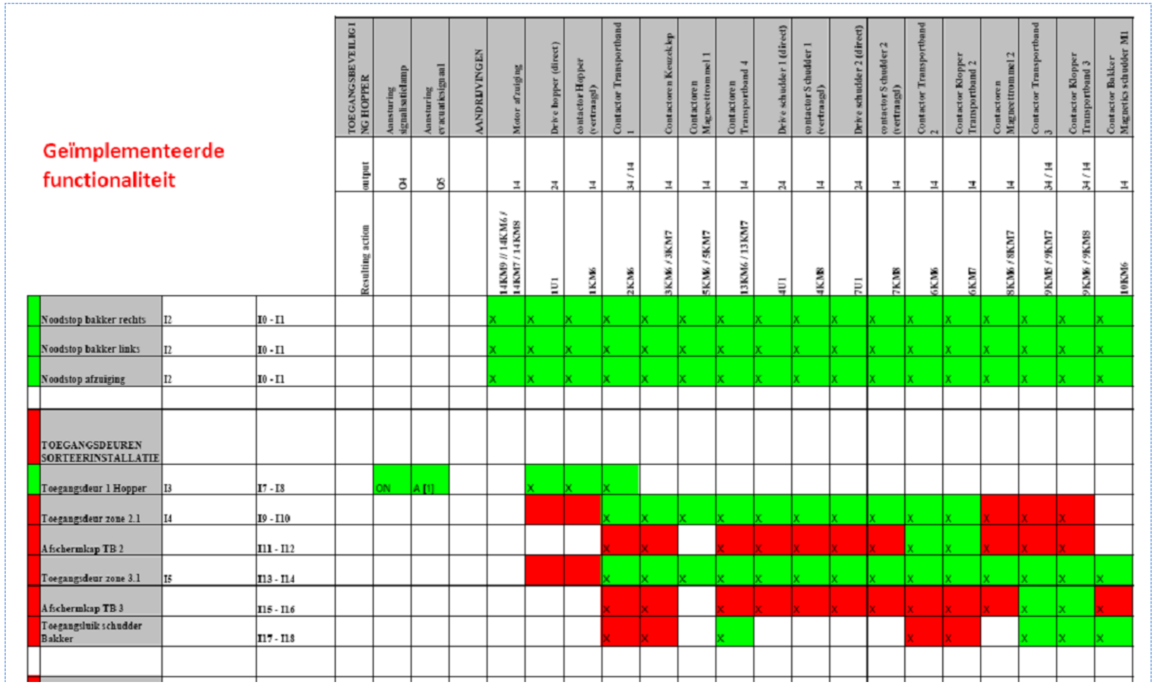


Steps to a safe collaborative robots system with Safety validation

PILZ
THE SPIRIT OF SAFETY

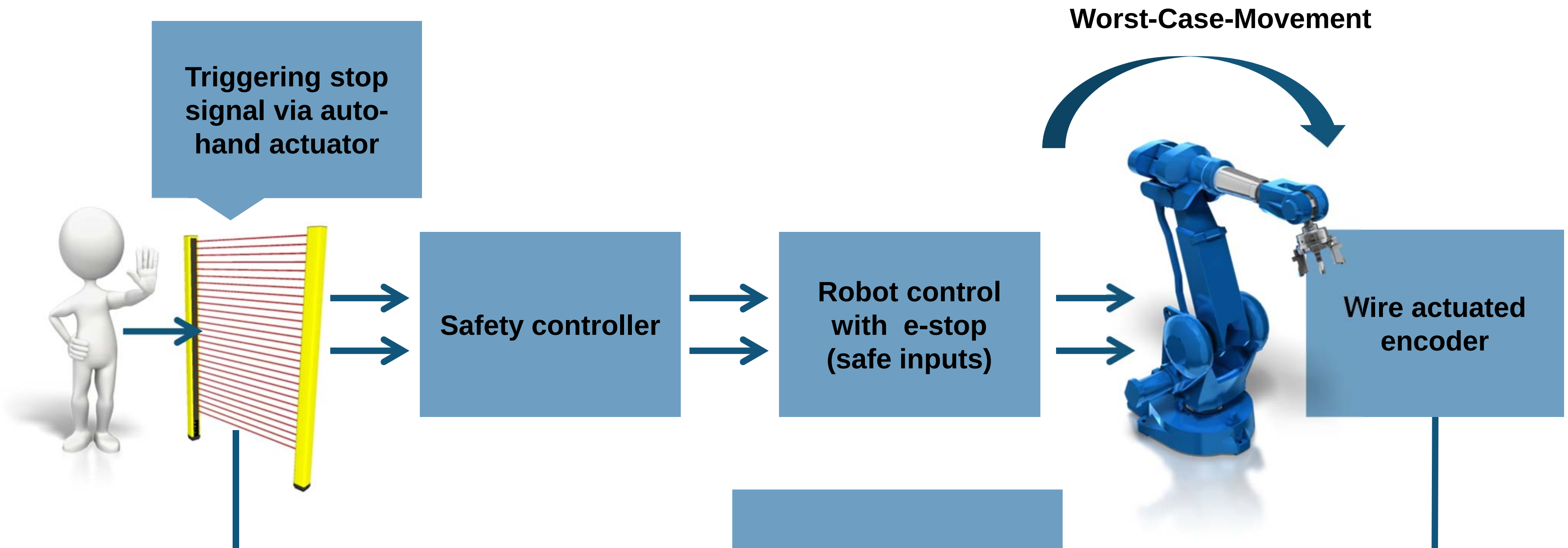
Validation – Fault simulation (2 channel triggering, cross-fault,...)

Component:	Noodstop Laagspanningskast				**Component aanwezig:**		
Component Type:	Noodstop				☒ Ja	☐ Nee	
Referentie Bestemming:	=AK1		+SEC		-2DK4.1		
Functie Groep:	Noodstoppen						
Physical Groep:	Laagspanningskast		**Physical Sub-Groep:**				
Input Address:	I0 - I1		**Input Terminal:**		X5		
Output Address:	/		**Output Terminal:**		/		
Reset:	☐ Automatic		☒ Manual		☐ Monitored		
Schakelvertraging:	☒ None						
Reset Ingang Adres:	I2		**Reset Ingang Terminal:**		X5		
Safety Architectuur	☐ 1	☐ 2	☐ 3	☒ 4	**JA**	**NEE**	**N.V.T.**
Visuele Inspectie							
1	Geen mechanische defecten aanwezig aan het apparaat.				☒	☐	☐
2	Correct aangesloten bedienelement en schakelelement.				☒	☐	☐
3	Juiste kleur codering - rode knop met gele achtergrond.				☒	☐	☐
4	Elektrische installatie correct				☒	☐	☐
5	Locatie goed bereikbaar en herkenbaar voor de operator.				☒	☐	☐
Activering							
6	Geactiveerde knop indicatie op control component. (optische indicatie).				☒	☐	☐
7	Knop blokkeert automatisch bij bediening.				☒	☐	☐
8	Knop wanneer bediend wordt altijd geactiveerd.				☒	☐	☐
9	Activering resulteert altijd in blokkering.				☒	☐	☐



Steps to a safe collaborative robots system with Safety validation

Validation – Overrun traverse measuring for HRC method 3



Overrun measurement

time & path difference from the trigger point determined by overrun gauge

Stopping distances and stopping times for STOP 0, axis 1 to axis 3

The table shows the stopping distances and stopping times after a STOP 0 (category 0 stop) is triggered. The values refer to the following configuration:

- Extension l = 100%
- Program override POV = 100%
- Mass m = maximum load (rated load + supplementary load on arm)

	Stopping distance (°)	Stopping time (s)
Axis 1	47.63	0.93
Axis 2	34.47	0.625
Axis 3	29.21	0.475

Steps to a safe collaborative robots system with Safety validation

PILZ
THE SPIRIT OF SAFETY

Validation – Complete the checklist EN ISO 10218-2 appendix G

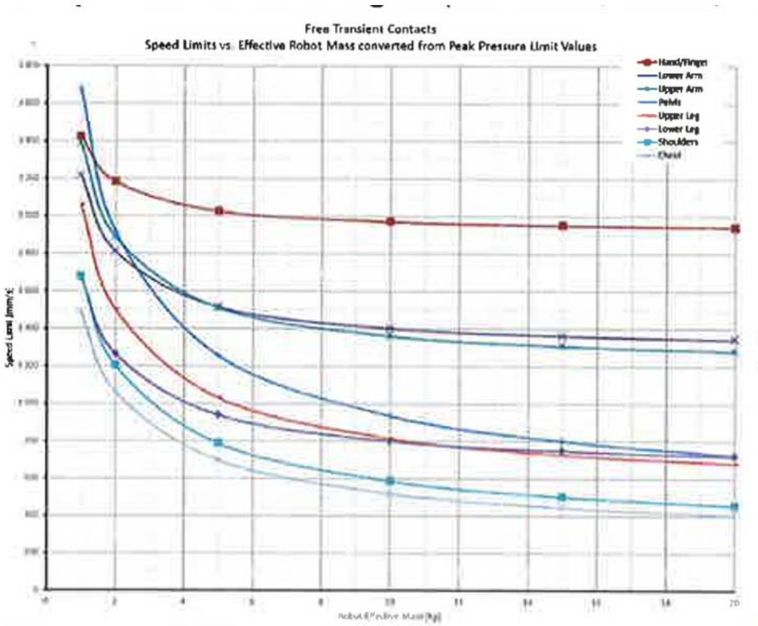
Table G.1 (*continued*)

Subclause	Safety requirements and/or measures	Verification and/or validation methods (see 6.2)								
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
5.6.2	Separate actuation required to initiate robot operation.	X	X		X	X	X			
5.6.2	Unambiguous indication of operating mode provided.	X	X		X					
5.6.2	Changing mode of operation does not create hazard.		X		X	X	X			
5.6.3.1	Entering safeguarded space while in automatic mode causes a protective stop.		X		X	X	X			X
5.6.3.2	Selection of automatic mode does not override protective stop or emergency stop condition.		X		X	X	X			
5.6.3.2	Selection of automatic mode is located outside safeguarded space.	X	X		X	X	X		X	X
5.6.3.2	Switching from automatic mode causes a stop.		X		X	X				
5.6.3.3	Automatic operation is initiated from outside the safeguarded space.		X		X	X	X		X	
5.6.3.3	Initiation of automatic mode only possible when all safeguards are active.		X		X	X	X		X	
5.6.3.4	Start and restart is a simple operation.	X	X		X					X
5.6.3.4	Protective measures are functional prior to start and restart.	X	X			X	X			X
5.6.3.4	Safety-related control function complies with 5.2.2.					X	X	X		X
5.6.3.4	Manually actuated interlocks for start and restart provided.		X			X	X			
5.6.3.4	Personnel are protected from start and restart while in the safeguarded space.	X	X		X	X	X		X	X
5.6.3.4	Manually actuated start and restart controls can not be activated from inside safeguarded space.	X	X		X	X			X	X
5.6.3.4	Functional safety and protective measures provided to ensure no one is in the safeguarded space prior to start and restart.		X		X	X	X			X

Steps to a safe collaborative robots system with Safety validation

Validation – collision measurement requirements
Two approaches of the TS 15066

1. Comply with treshold values for quasi static and transient contact : measurement
2. Mathematical approach : simplified -> total weight (axes,tools,...) and body region result in speed.



- Real measurement have proven this approach does not show the reality
- Robot system does not take account of dynamics

Steps to a safe collaborative robots system with Safety validation

Validation – collision measurement performing a measurement

1. Configure robot worse case

- Shut down grey technology
- Apply offset

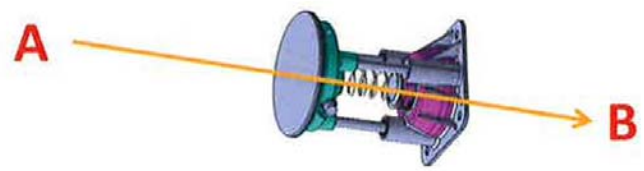
2. Configure measuring instrument

- Region of body
- TS 15066 limit values
- Use spring according to part of body

Body region	Effective spring constant K N/mm
Skull and forehead	150
Face	75
Neck	50
Back and shoulders	35
Chest	25
Abdomen	10
Pelvis	25
Upper arms and elbow joints	30
Lower arms and wrist joints	40
Hands and fingers	75
Thighs and knees	50
Lower legs	60

3. Install measuring instrument on application

- Position acc. to risk assessment
- Rigid
- As close as possible to the real measurement point



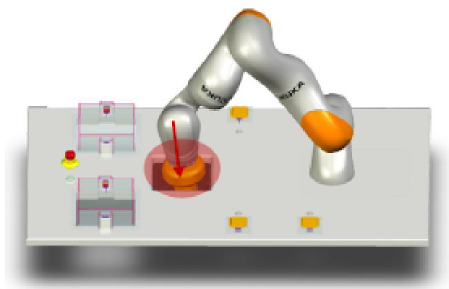
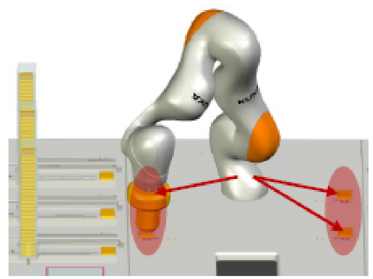
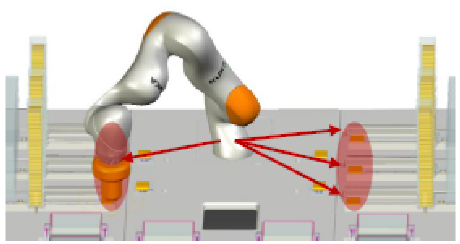
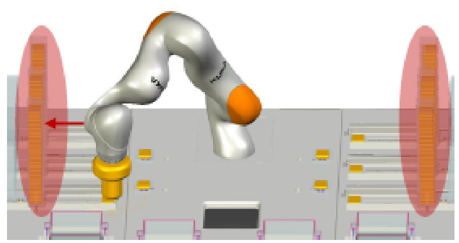
P_PROBmdf Product image & product description

- Recording of force and pressure
- Integral electronics
  - USB connection
- Convenient PC tool
  - Project data
  - Measuring point
  - Measurements
  - Automatic validation
  - Automatic protocol creation

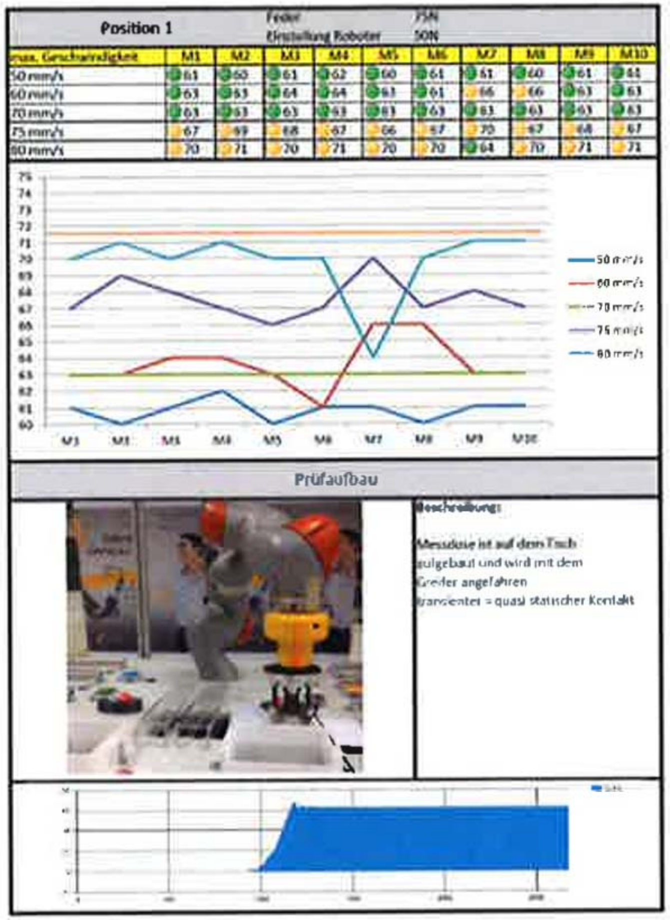
Steps to a safe collaborative robots system with Safety validation

Validation – collision measurement positions

Pilz GmbH & Co. KG

Definition der Messpunkte	
 Bild 38 Konzept 10 Messpunkt 5: Transienter und quasi statischer Kontakt bei der Kameraprüfung - Kollision Finger, Hand	 Bild 35 Konzept 10 Messpunkt 2: Transienter und quasi statischer Kontakt an den Zwischenablagen - Finger, Hand
 Bild 36 Konzept 10 Messpunkt 3: Transienter und quasi statischer Kontakt an den Abholpositionen - Kollision Finger, Hand	 Bild 39 Konzept 10 Messpunkt 6: Transienter und quasi statischer Kontakt beim Anfahren der Abholpositionen - Kollision Finger, Hand

Validation – result of the measurement



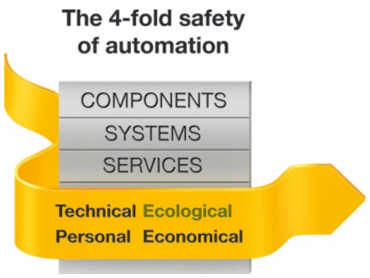
Position 1		Feder 75N Einstellung Roboter 50N								
max. Geschwindigkeit	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10
50 mm/s	61	60	61	62	60	61	61	60	61	61
60 mm/s	63	63	64	64	63	61	66	66	63	63
70 mm/s	63	63	63	63	63	63	63	63	63	63
75 mm/s	67	69	68	67	66	67	70	67	68	67
80 mm/s	70	71	70	71	70	70	64	70	71	71

- Green : under the limit value for quasi-static and transient contact = OK
- Yellow : 10% overstep = acceptable
- Red : more than 10%, not acceptable

Steps to a safe collaborative robots system
CE certifcation

Validation → OK

Customer:
Manufacturer - Integrator



Timen Floré

Pilz Belgium cvba
Bijenstraat 4
9051 Sint-Denijs-Westrem, Belgium
Tel.: +32 (0)9 321 75 70
Mail: timen.flore@pilz.be

Keep up-to-date on Pilz
www.pilz.be

arianeGroup

Conception de systèmes cobotiques industriels
Application chez ArianeGroup

Journée nationale de la BES 22 mars 2018 – Bruxelles

David Bitonneau

Théo Moulières-Seban

Introduction

Cobotique : collaboration homme-robot

Possibilité d'améliorer la performance **+** la santé

Déroulé de la présentation :

1. « Robotique » et « Cobotique »
2. Technologies pour la cobotique
3. Les systèmes cobotiques
4. Méthodologie de conception
5. Cas pratique : nettoyage des cuves

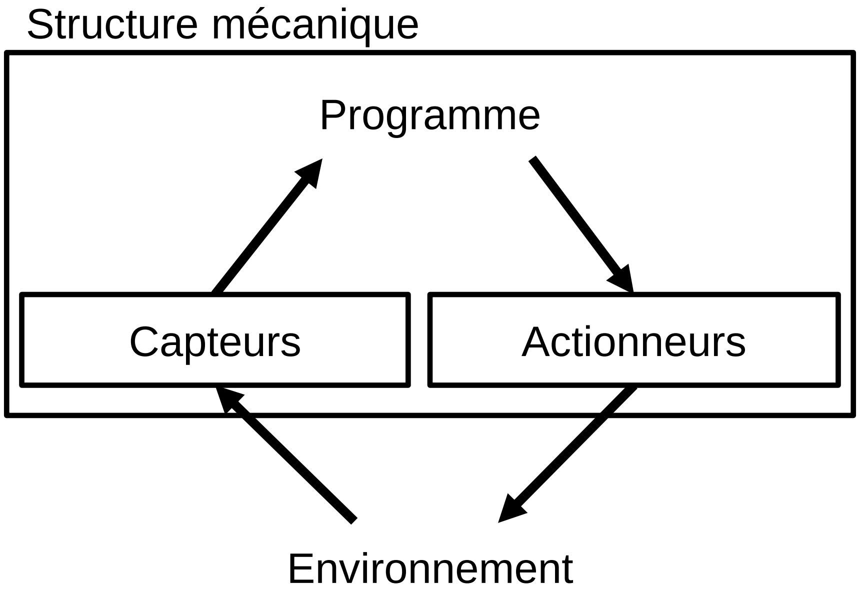
01

De la « robotique classique » à la « cobotique »

01 De la « robotique classique » à la « cobotique »

Robot et robotique industrielle

Robot



Définition de Chatila (2014)
Simplification du schéma de thèse de D. Bitonneau (à paraître, 2018)

01 De la « robotique classique » à la « cobotique »

Robot et robotique industrielle

Robot

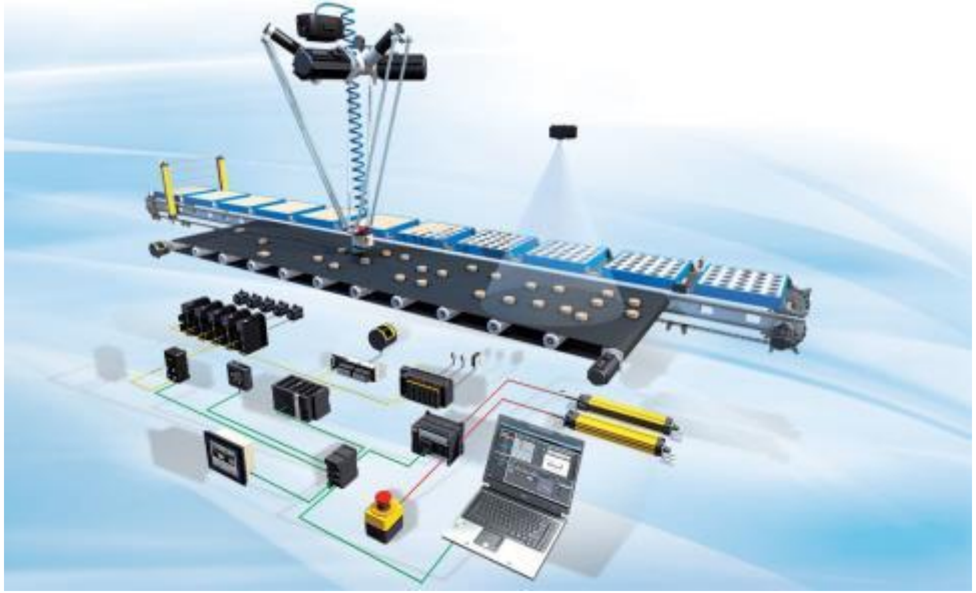
Robots industriels

(International Federation of Robotics, 2015)

01 De la « robotique classique » à la « cobotique »

Tâche et robotisation

Robotisation « classique » et tâches complexes



- ➔ Variabilités industrielles
- ➔ Complexité technologique
- ➔ Adaptation ?

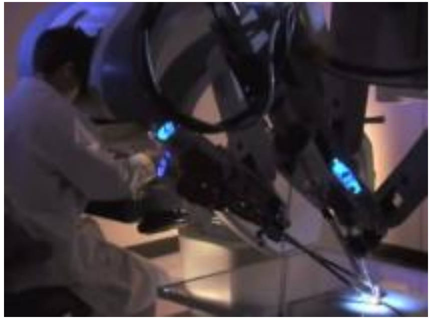
01 De la « robotique classique » à la « cobotique »

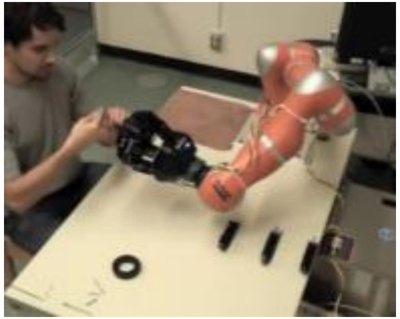
La cobotique industrielle

Cobotique : collaboration homme-robot

(Claverie et al., 2013)

Grâce à l'émergence de technologies





02
Technologies pour la cobotique

02 Technologies pour la cobotique

Du robot au manipulateur

Robots « classiques »

Robots collaboratifs pseudo-autonomes

02 Technologies pour la cobotique

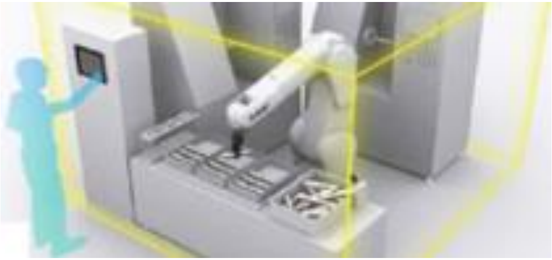
Du robot au manipulateur

Robots collaboratifs dépendants de l'action humaine

Manipulateurs (non-programmable)

02 Technologies pour la cobotique

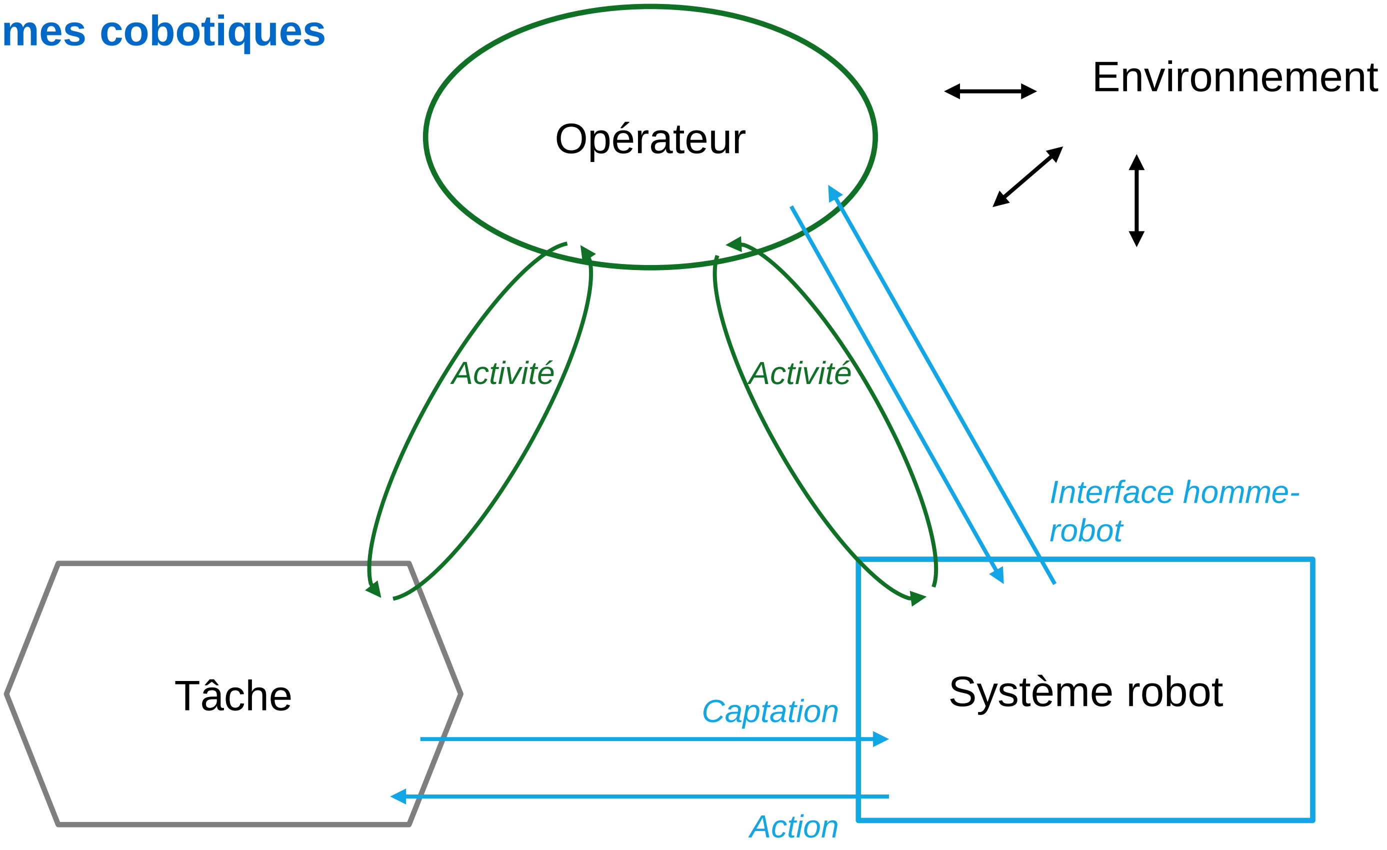
Les briques technologies additionnelles



03
Modélisation des systèmes cobotiques industriels

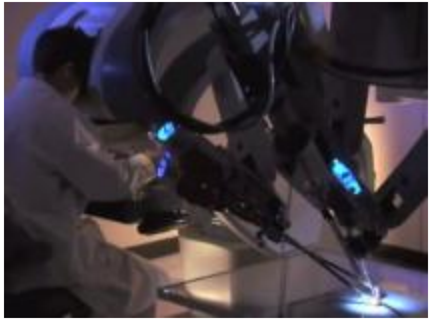
03 L’homme et le système cobotique industriel

Les systèmes cobotiques

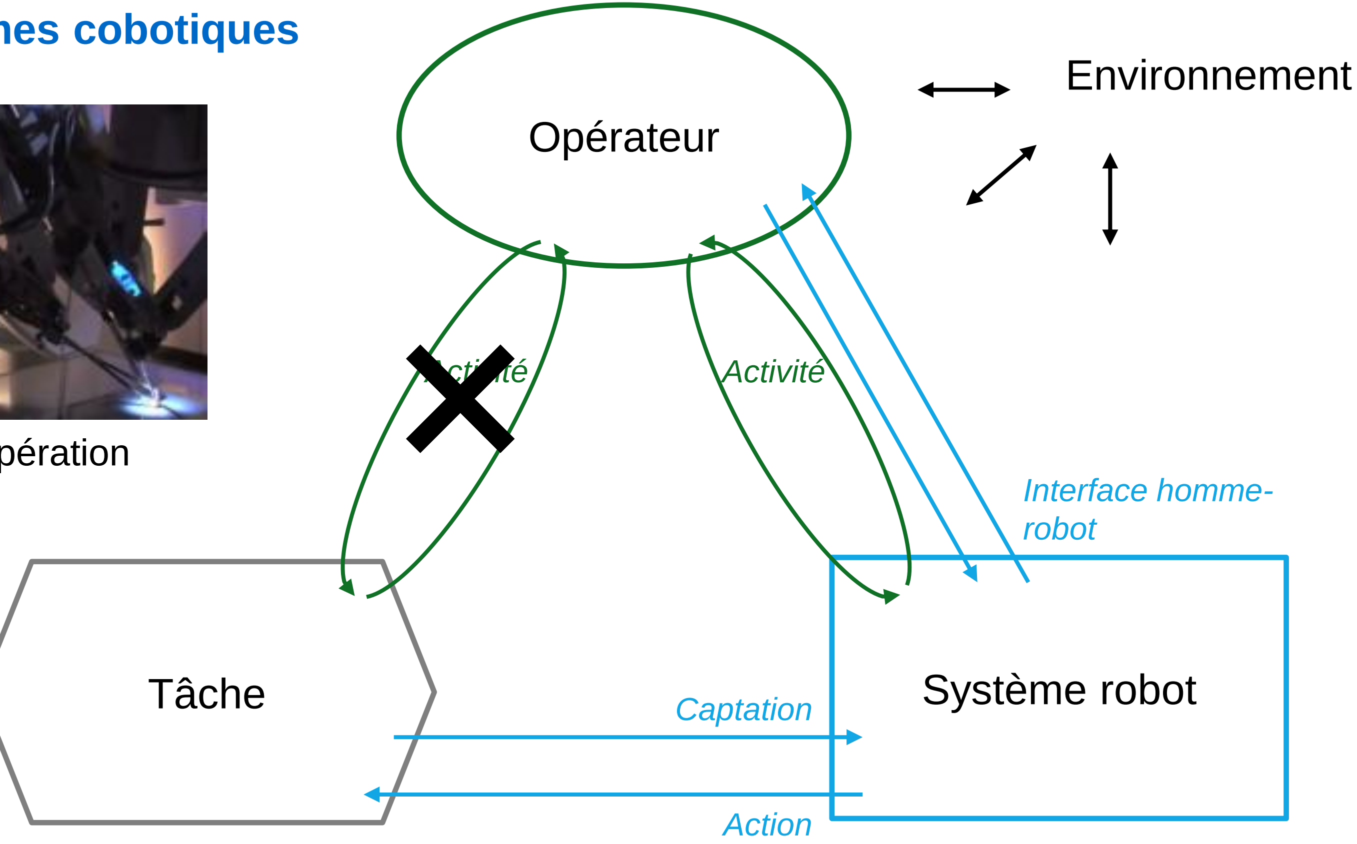


03 L'homme et le système cobotique industriel

Les systèmes cobotiques

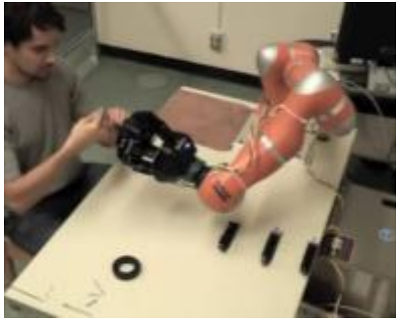


1. Téléopération

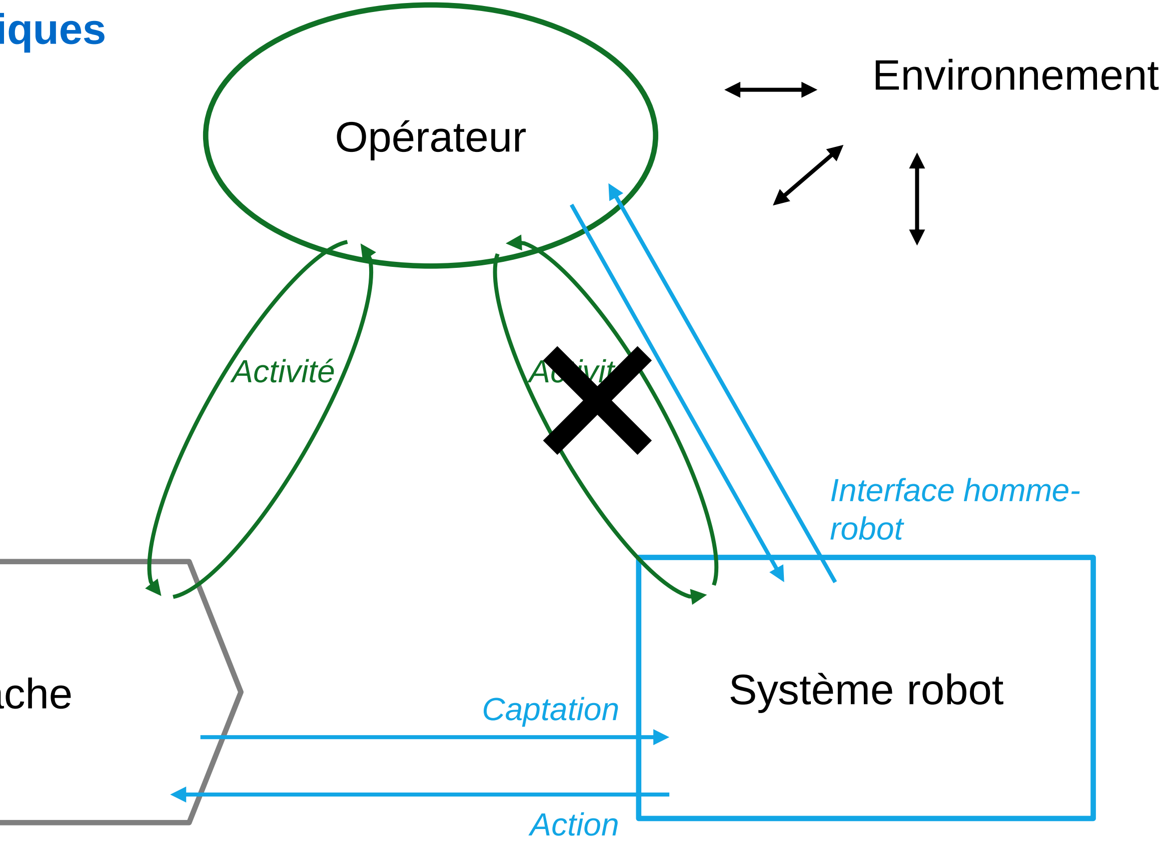


03 L’homme et le système cobotique industriel

Les systèmes cobotiques



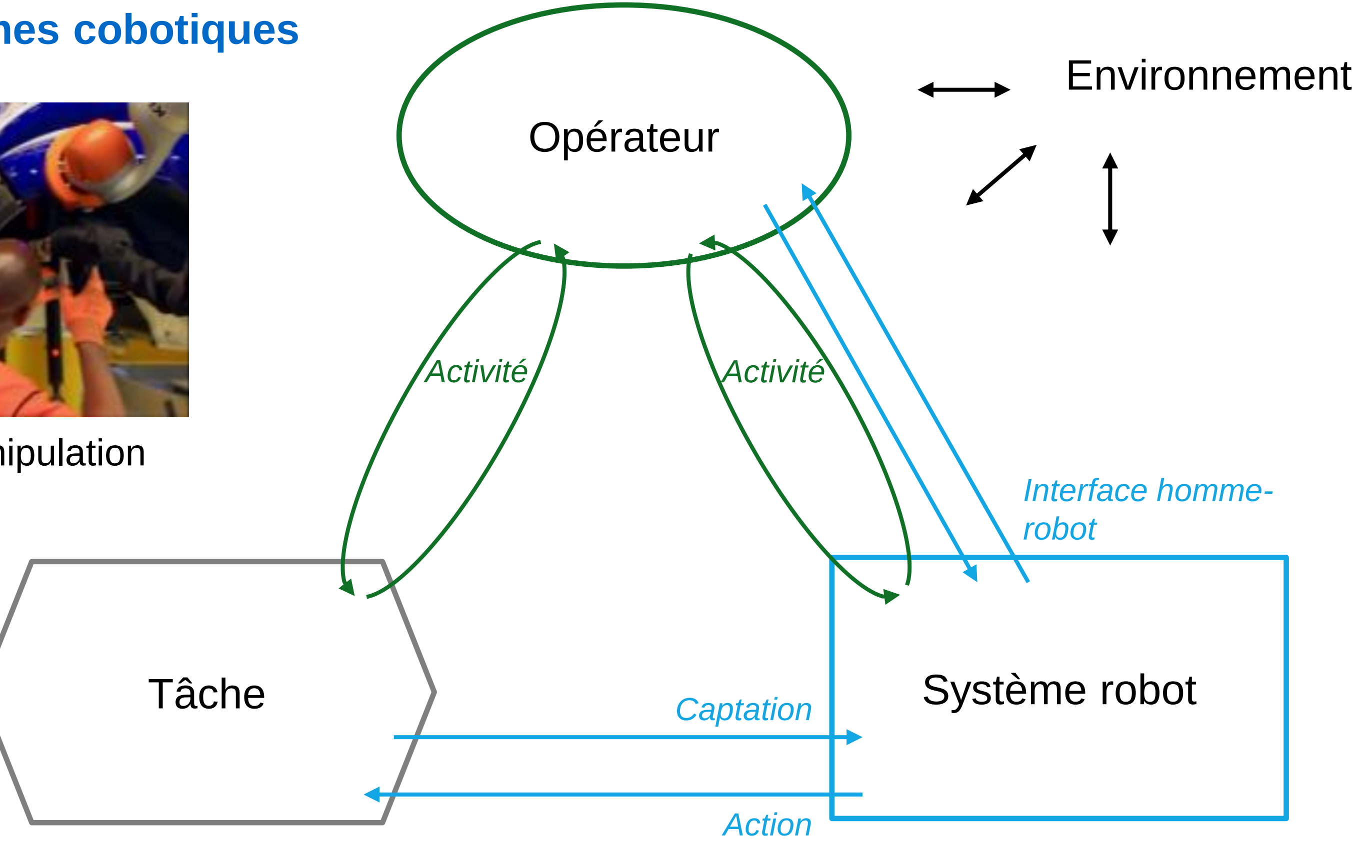
2. Colocalisation collaborative



03 L’homme et le système cobotique industriel

Les systèmes cobotiques

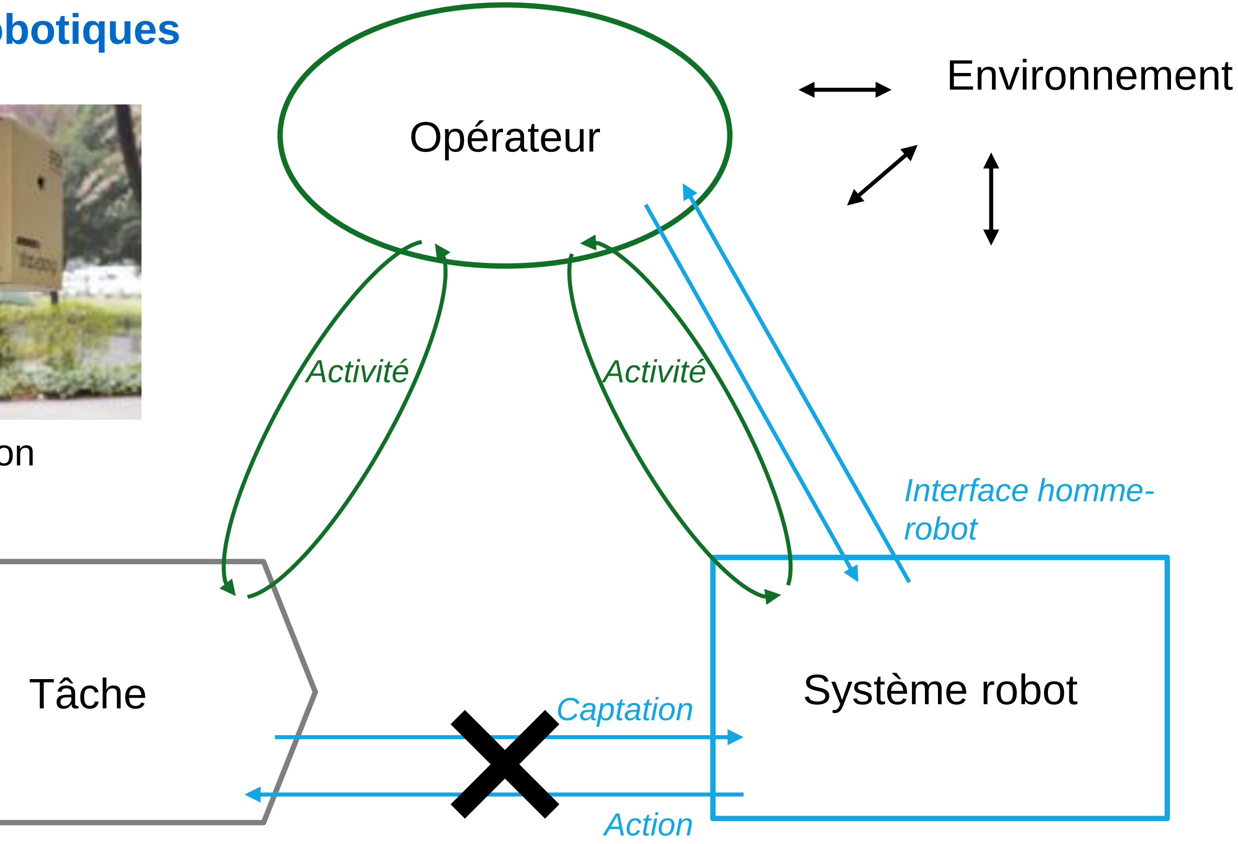
3. Comanipulation



03 L'homme et le système cobotique industriel

Les systèmes cobotiques

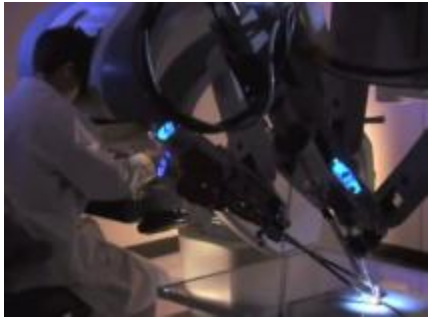
4. Exomanipulation



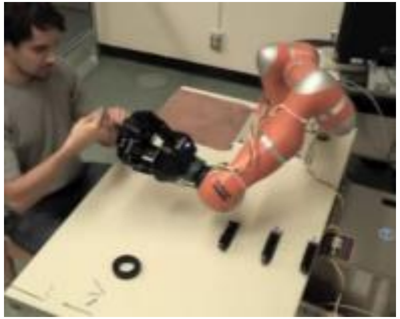
03 L'homme et le système cobotique industriel

Les systèmes cobotiques

Proximité homme-robot



1. Téléopération



2. Colocalisation collaborative

3. Comanipulation

4. Exomanipulation

Classification retenue

04

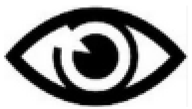
Méthodologie de conception d'un système cobotique

04 Méthodologie de conception d’un système cobotique

L’opérateur dans la conception

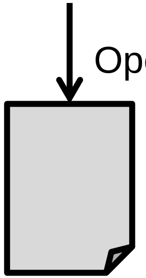
Analyse de l’activité

Entretiens



Observations

Débriefing



Opérations réelles

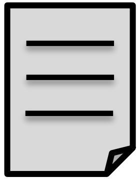
Formalisation

(Daniellou et Beguin, 2004)

04 Méthodologie de conception d’un système cobotique

L’opérateur dans la conception

Simulations



Scénarios d’activité future

- Basés sur les analyses préliminaires
- Proposition des rôles respectifs de l’homme et du robot

Support de simulation

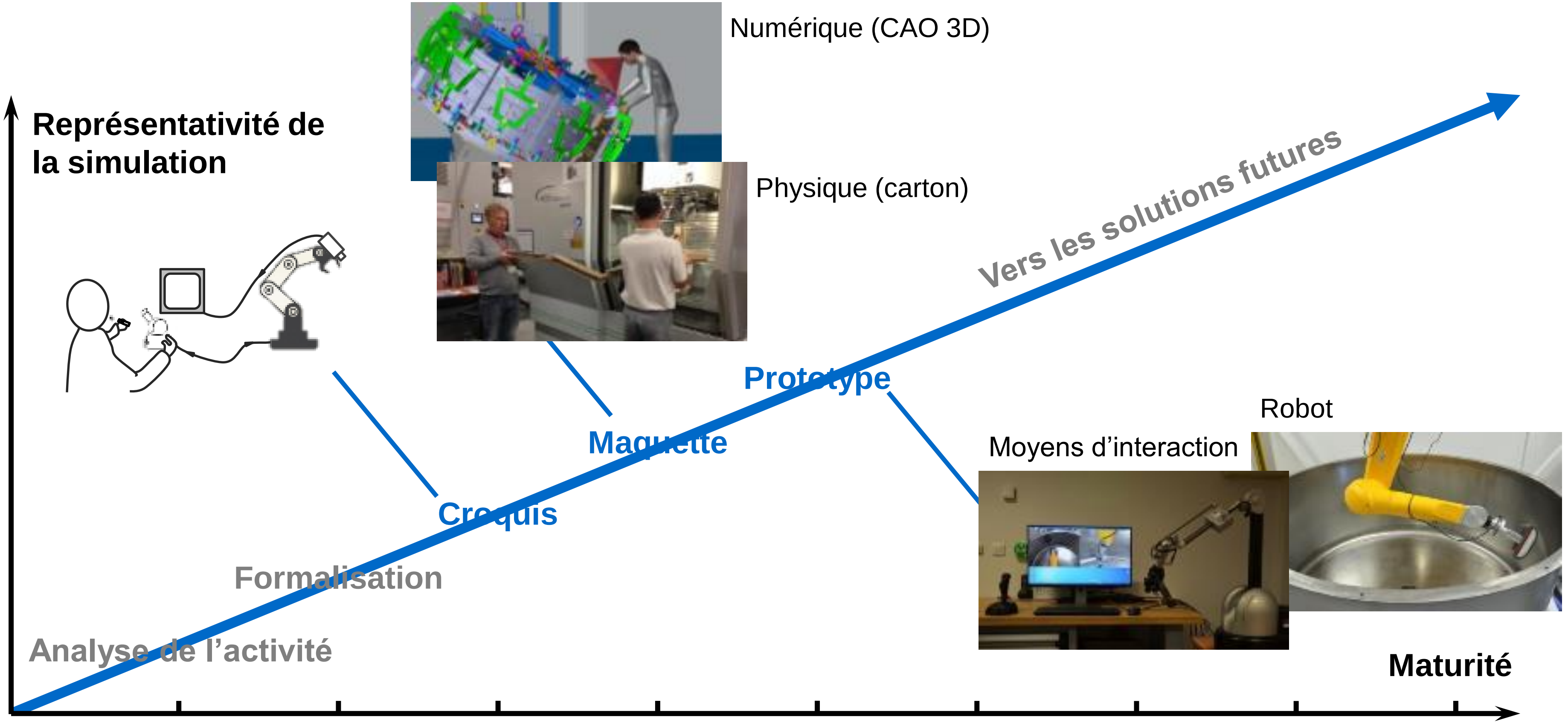
- Croquis
- Maquette
- Prototype

Evaluation des situations futures avec les utilisateurs

(Thibault, 1998)

04 Méthodologie de conception d’un système cobotique

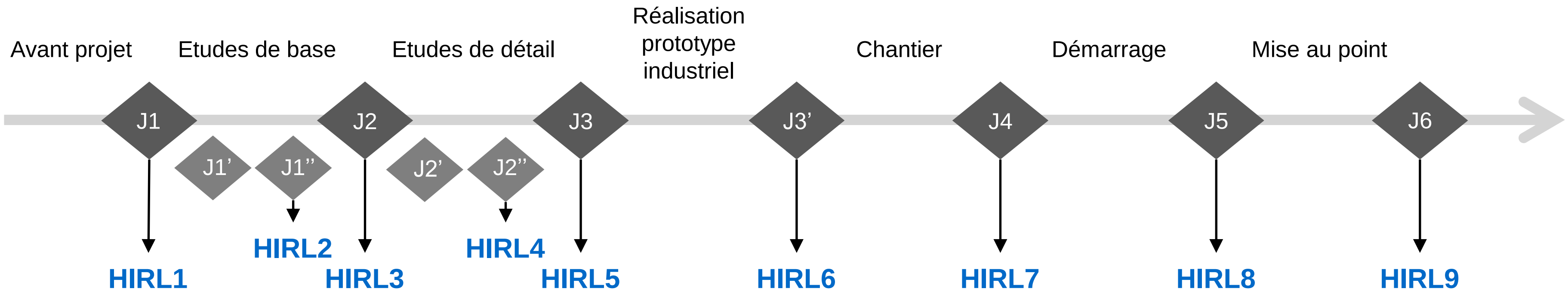
L’opérateur dans la conception



04 Méthodologie de conception d'un système cobotique

Ingénierie des Systèmes Cobotiques (ISC)

Conduite de projet SAFRAN



HIRL = Human Integration Readiness Level

05

Cas d’étude : le nettoyage des cuves

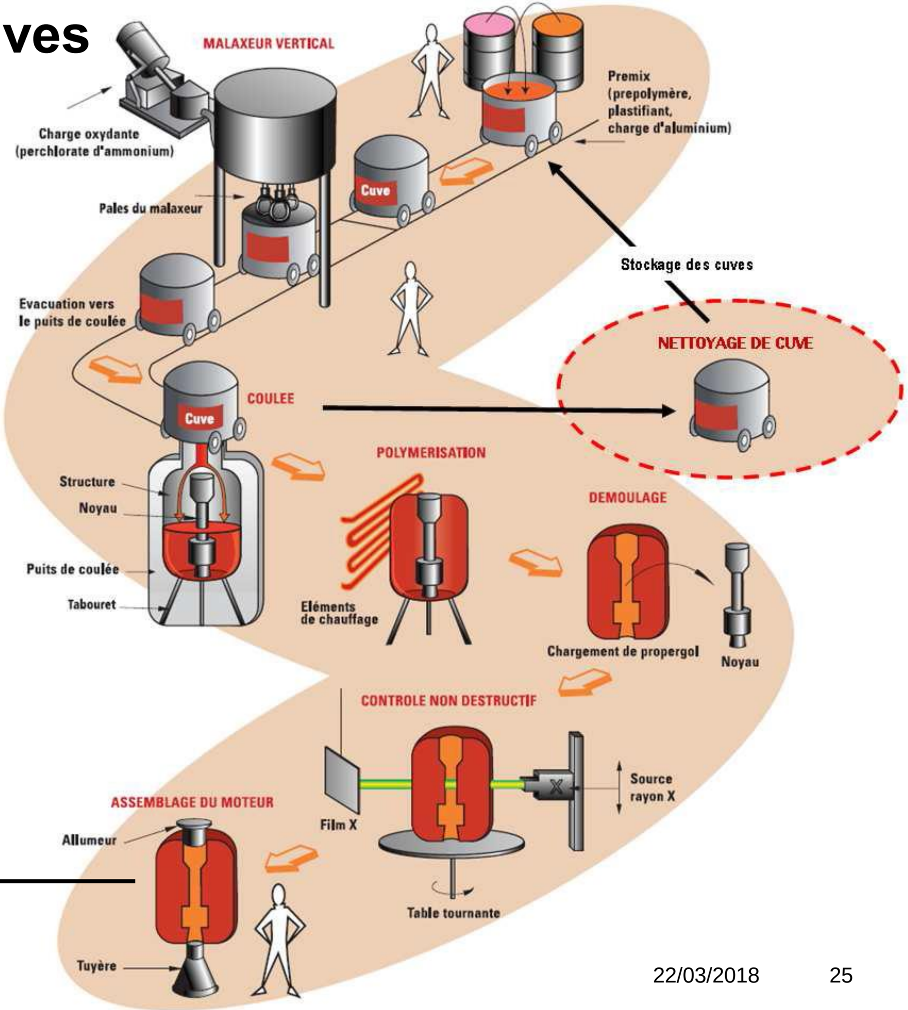
Centre Spatial Guyanais

05 Cas d’étude : le nettoyage des cuves

Fabrication d’un booster

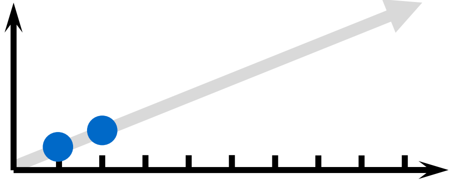
Fabrication d’un matériau pyrotechnique

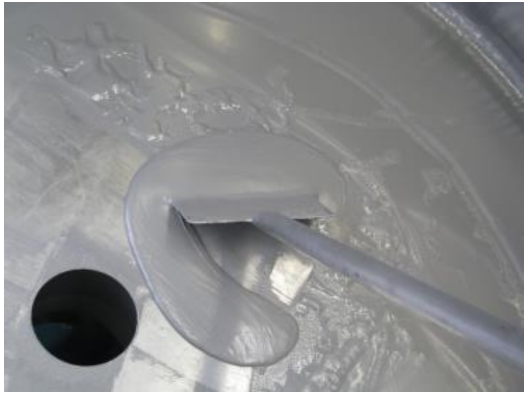
Booster

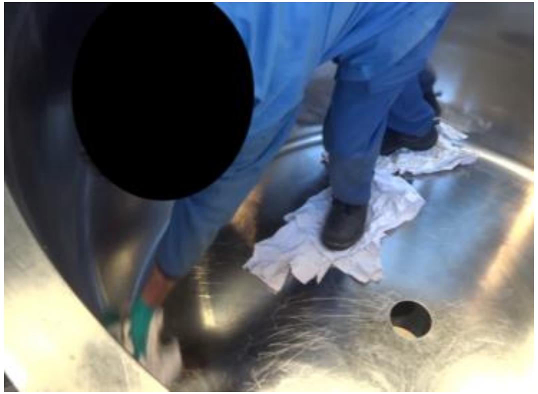


05 Cas d’étude : le nettoyage des cuves

Analyses et formalisation du besoin → HIRL1 et HIRL2

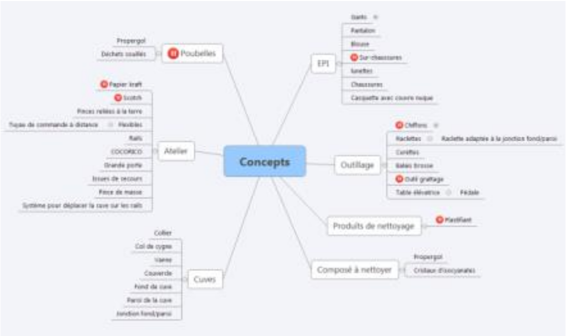


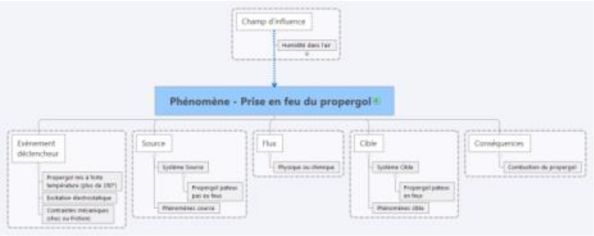




Diagrammes MASK

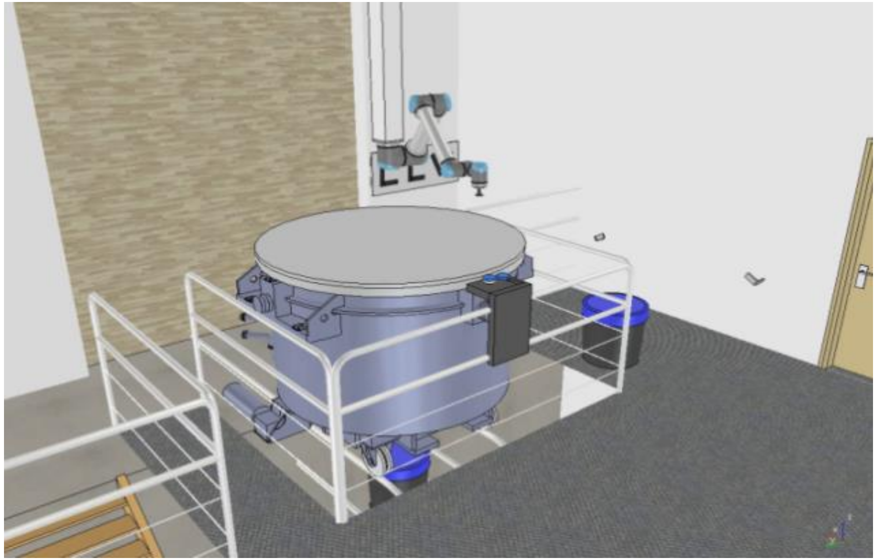
(Ermine et al., 1996)

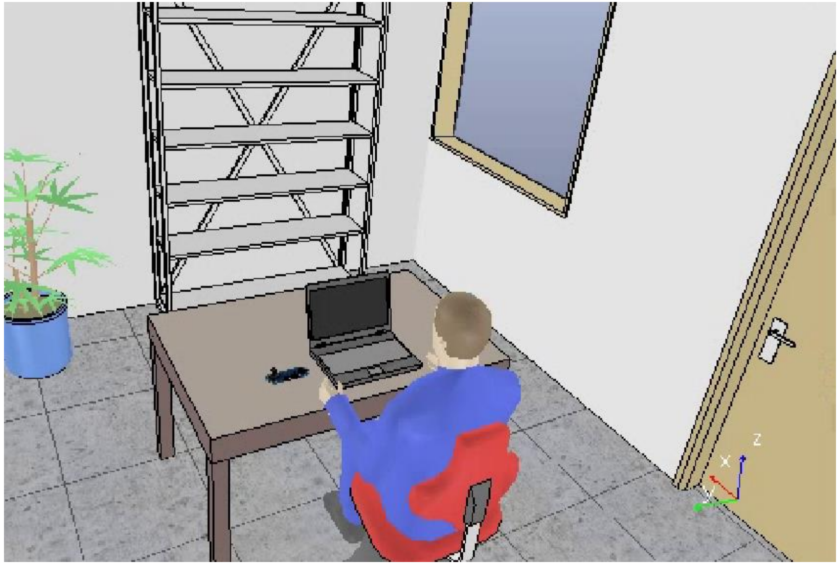




05 Cas d’étude : le nettoyage des cuves

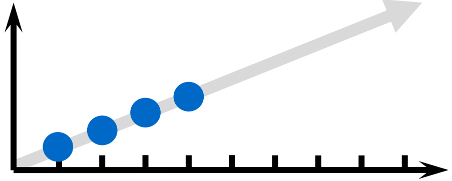
Principe de solution → HIRL3

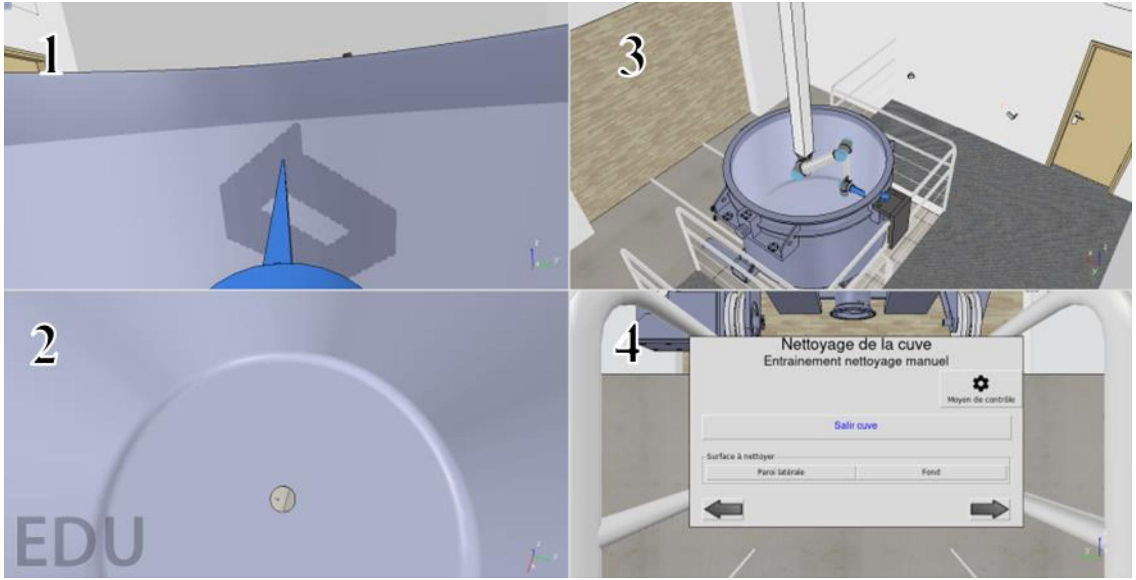




05 Cas d'étude : le nettoyage des cuves

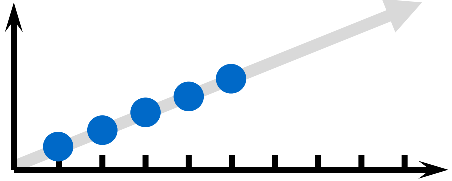
Etude de base et maquette interactive → HIRL4

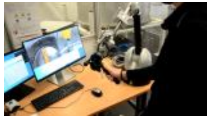




05 Cas d'étude : le nettoyage des cuves

Etude de détail et prototype → HIRL5





05 Cas d’étude : le nettoyage des cuves

Préparation de l’industrialisation

Simulation de l’implantation du système cobotique dans l’atelier numérique à l’échelle 1 en salle de réalité virtuelle

06

Conclusion

06 Conclusion

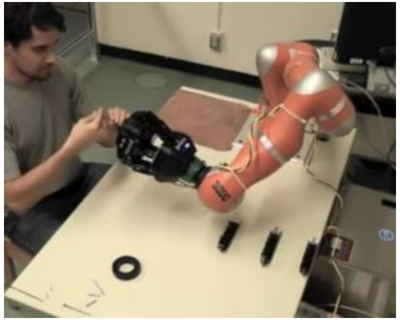
Déploiement de la méthode

La cobotique : axe de développement

Equipe dédiée Cobotique
ArianeGroup en lien
avec le groupe Safran

Projet Ambition Factory 4.0
7 sujets en cours d'étude

Projet Usine du Futur
Plus de 100 systèmes
cobotiques en perspective



06 Conclusion

L'usine cobotique du futur

➔ Transformation du travail :

Performance + Santé

➔ Perspectives pour la propulsion solide et Ariane 6

➔ L'industrie du futur

Combining strengths of humans and robots for better and healthier jobs

Prof dr ir Bram Vanderborght

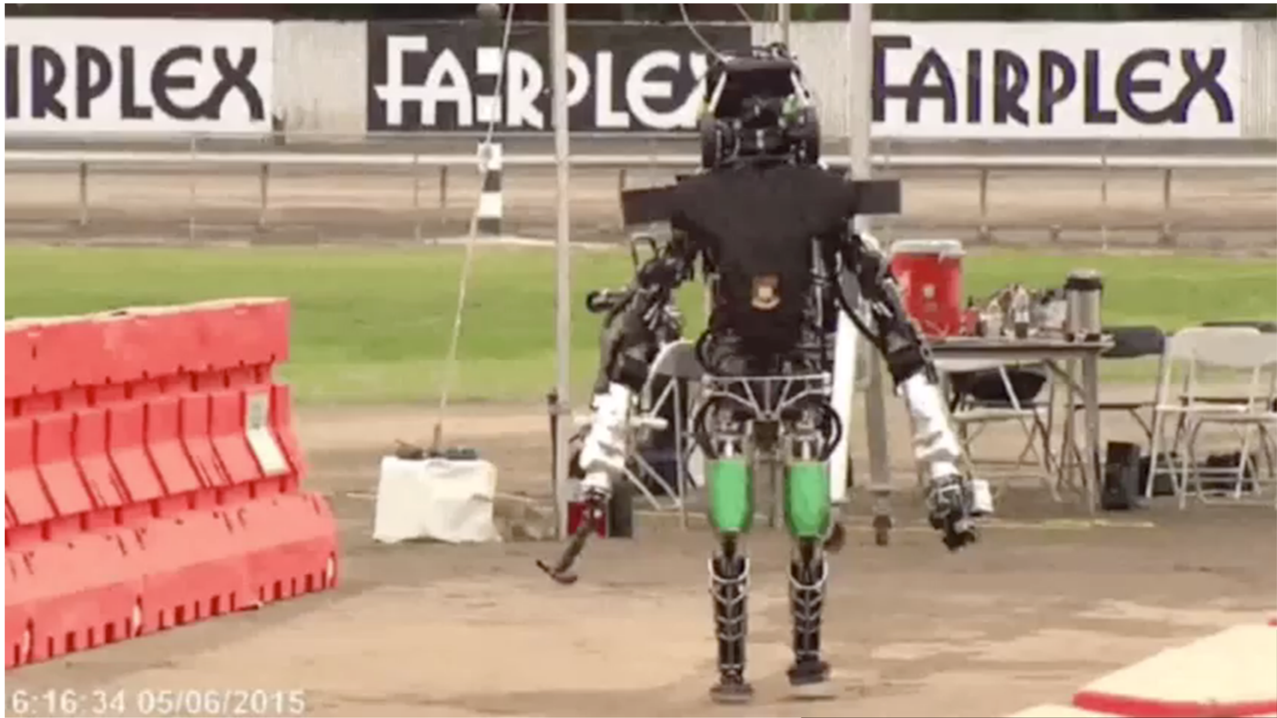
VRIJE UNIVERSITEIT BRUSSEL

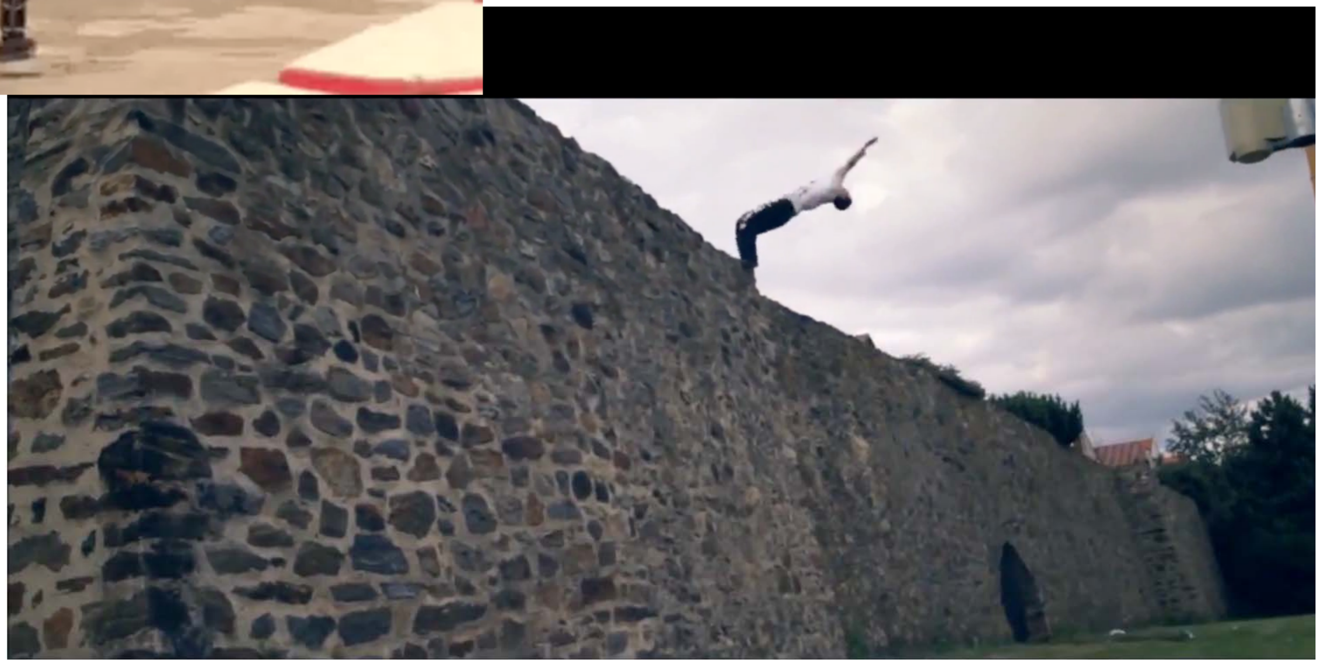
brubotics® Brussels Human Robotic Research Center

FLANDERS MAKE MANUFACTURING INNOVATION NETWORK

BramVDBorght

Robots vs Humans

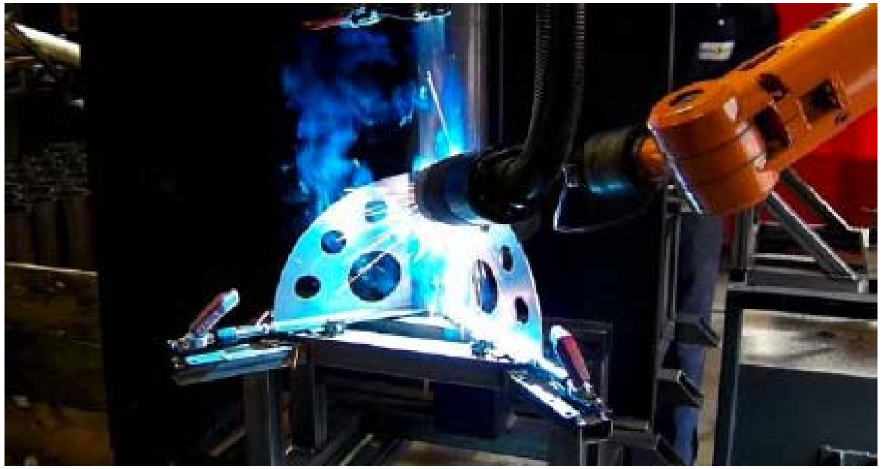




Societal challenges: Ageing population

3D story —> 4D story

Dirty



Dangerous

Difficult/Dull

Demographics

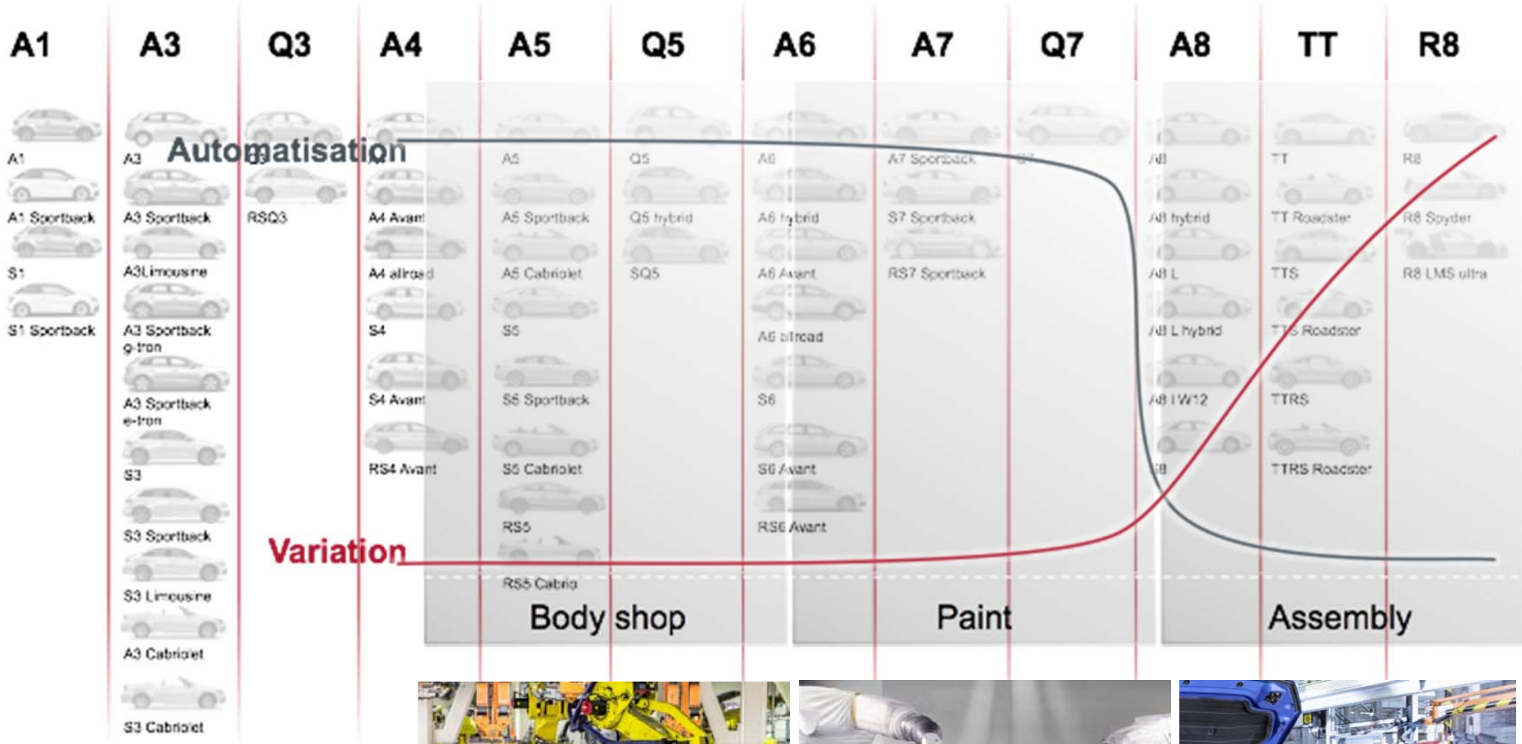
slide Audi Brussels

Control product variation: case Audi Brussels

Control complexity

Extensive range of variants due to individual requirements of customers

59 model versions in 12 different model series (2016)



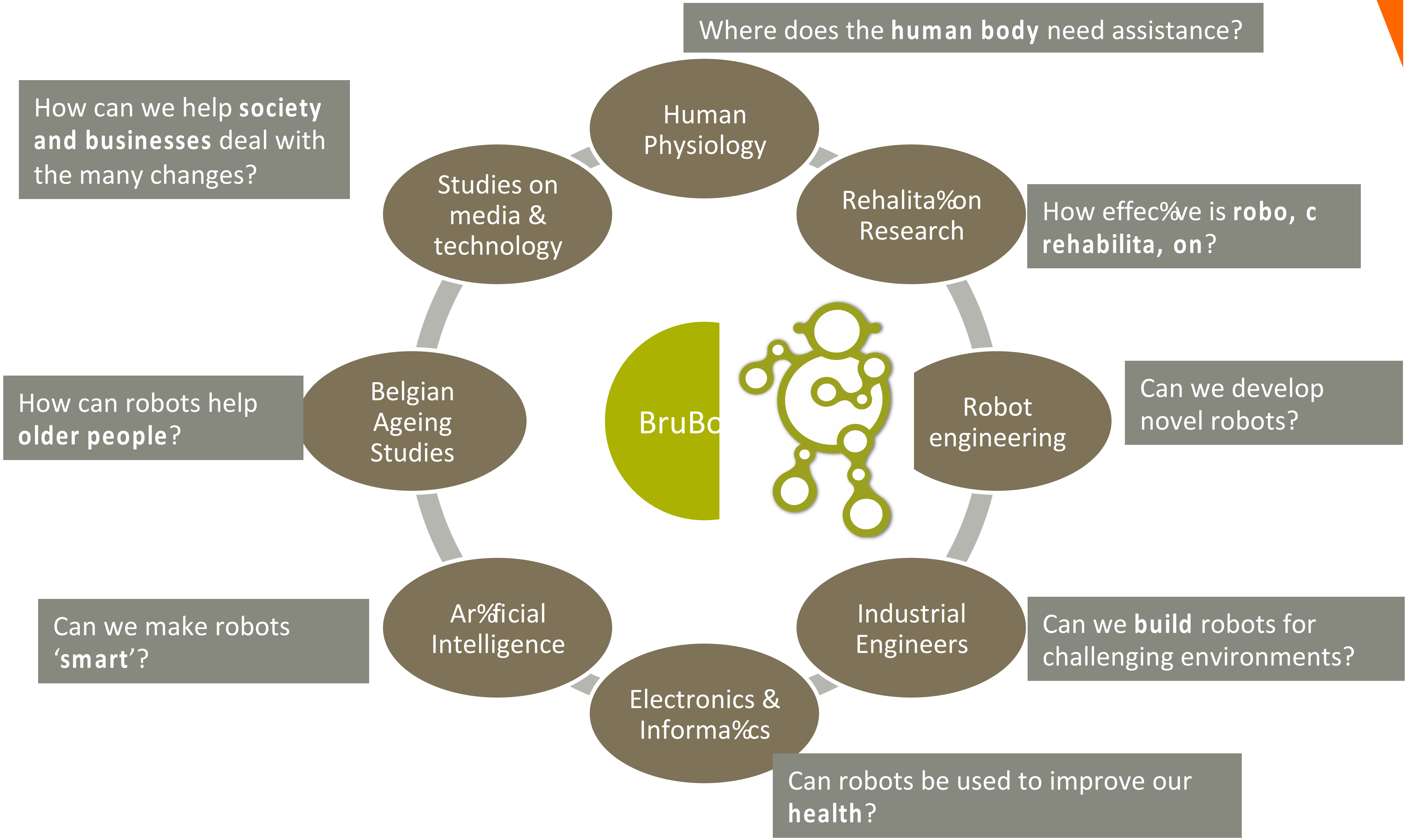
slide Audi Brussels

Amazon

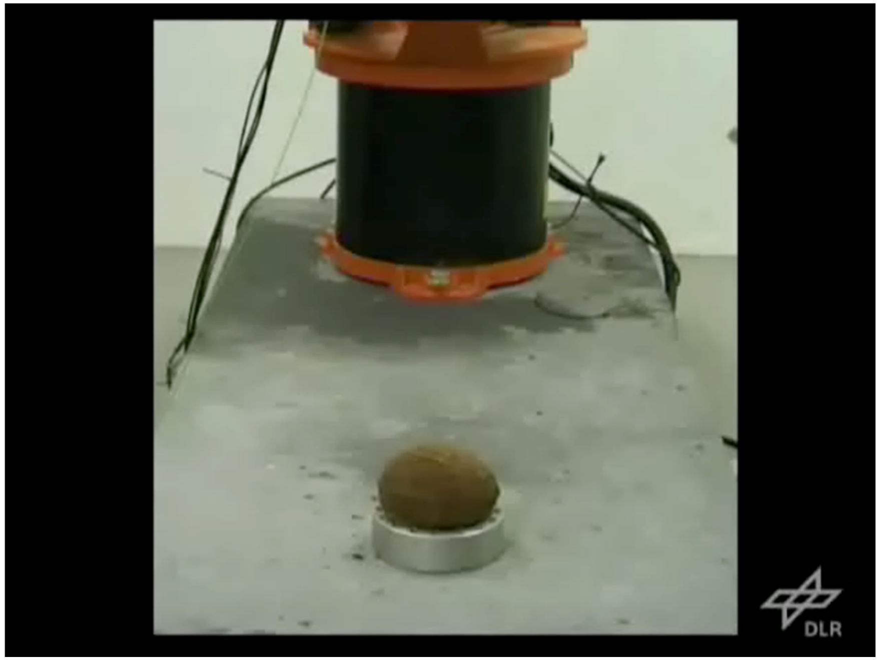
Combine strengths of the human and the robot

Brubotics

Brussels Human Robotic research center



Primary concern is safety



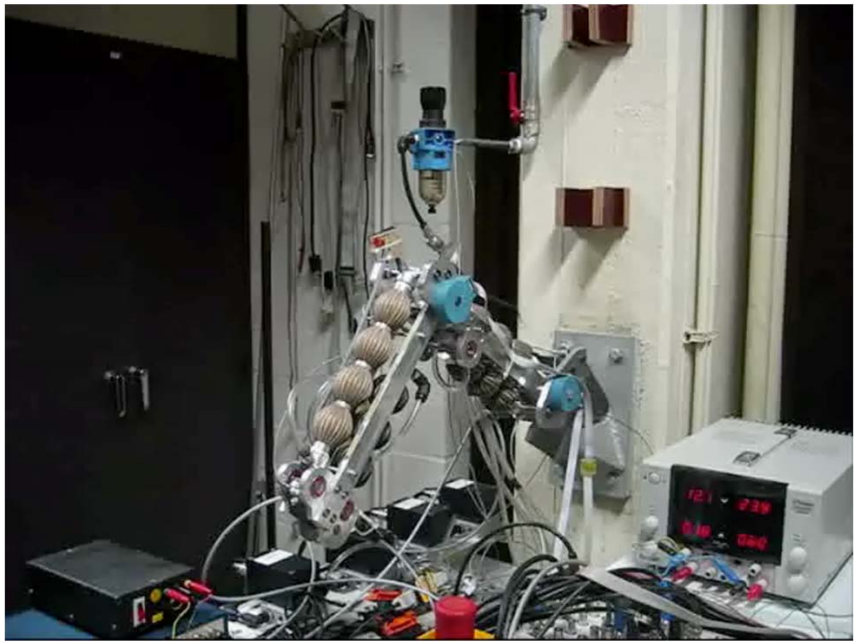
DLR

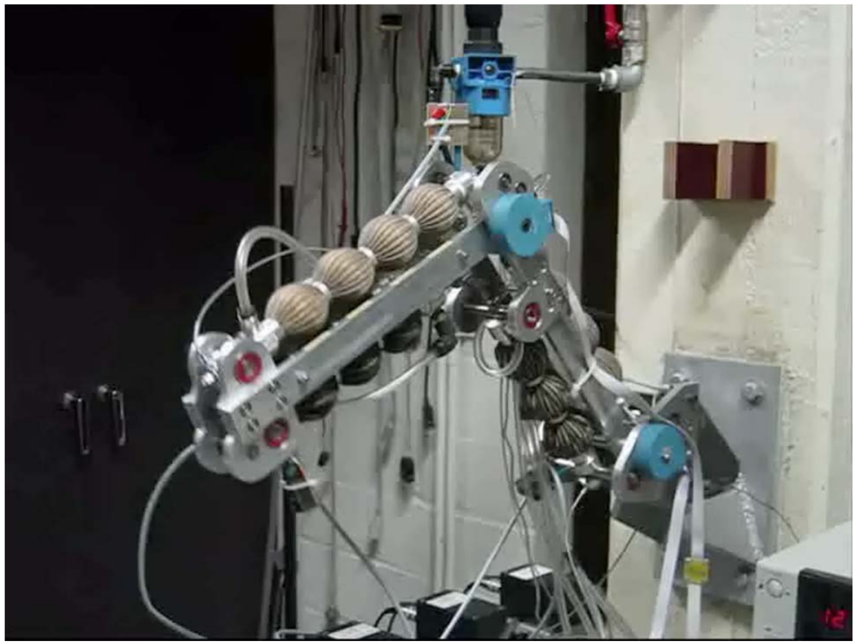
Position controlled robots
—> Torque controlled robots

Active compliance

DLR

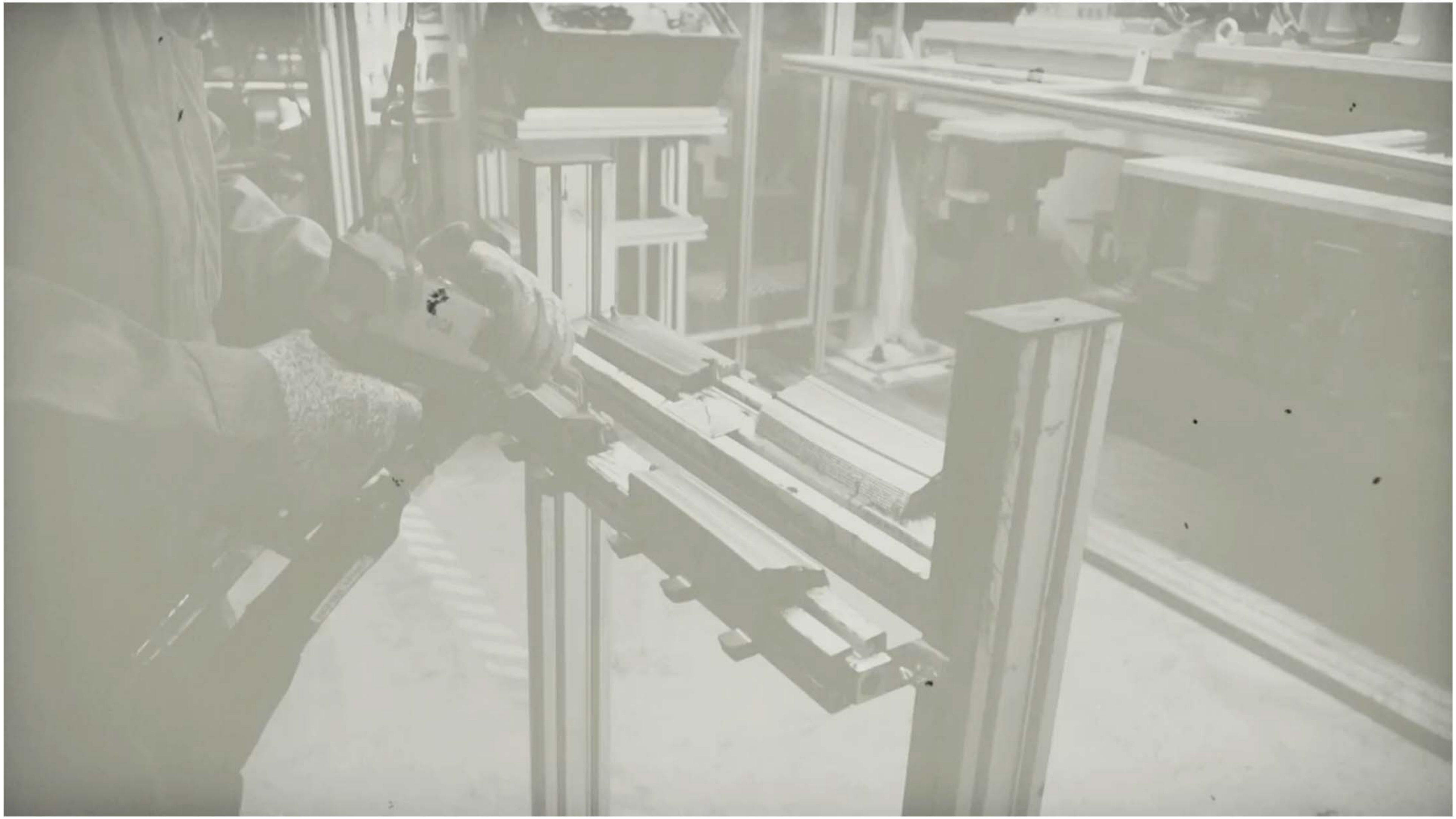
Passive compliance



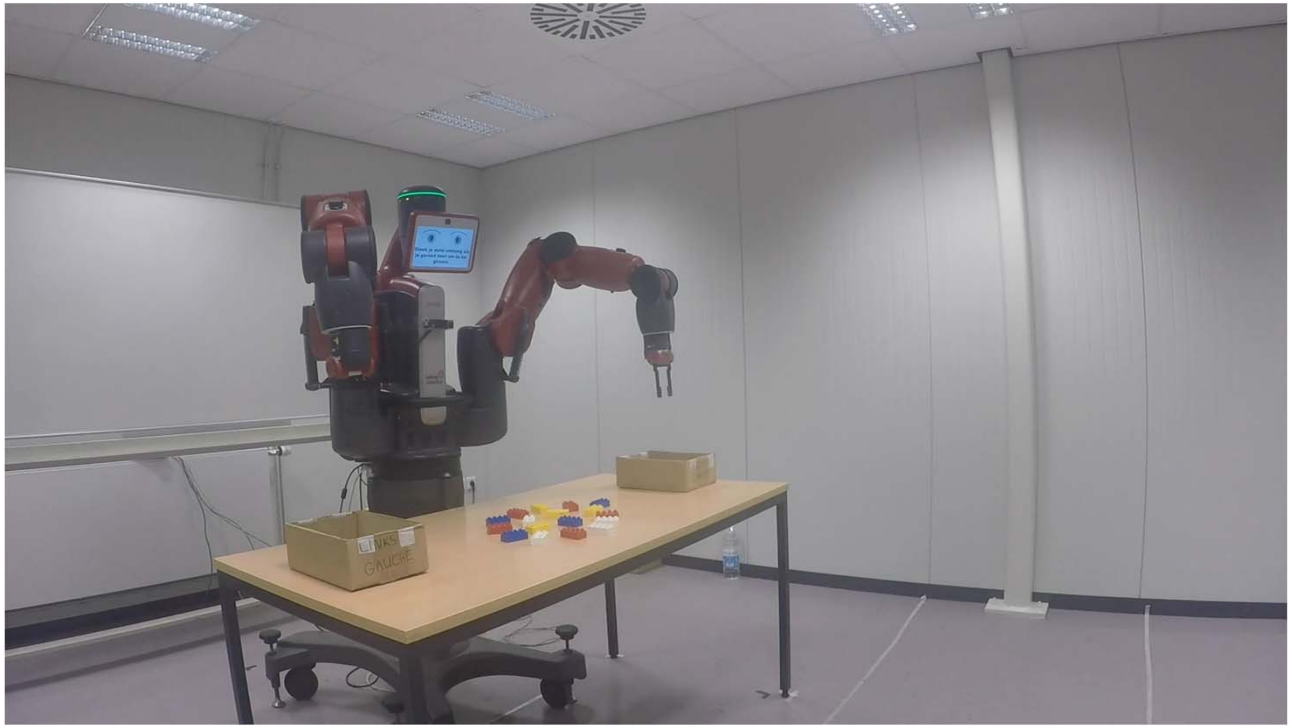


VUB softarm

Use case:
glue operation for reinforcement plate for a roof rack for Audi A1



Study on acceptance of the robot



All factory workers expressed concerns of robots taking over their jobs.

Elprama, S. A., Jewell, C. I. C., Jacobs, A., Makrini, I. El, & Vanderborght, B. (2017). Attitudes of factory workers towards industrial and collaborative robots. In Conference on Human-Robot Interaction (HRI 2017)

A pilot study suggested that factory workers are more willing to accept working with a cobot when it shows more social cues (such as nodding of its head, displaying eyes).

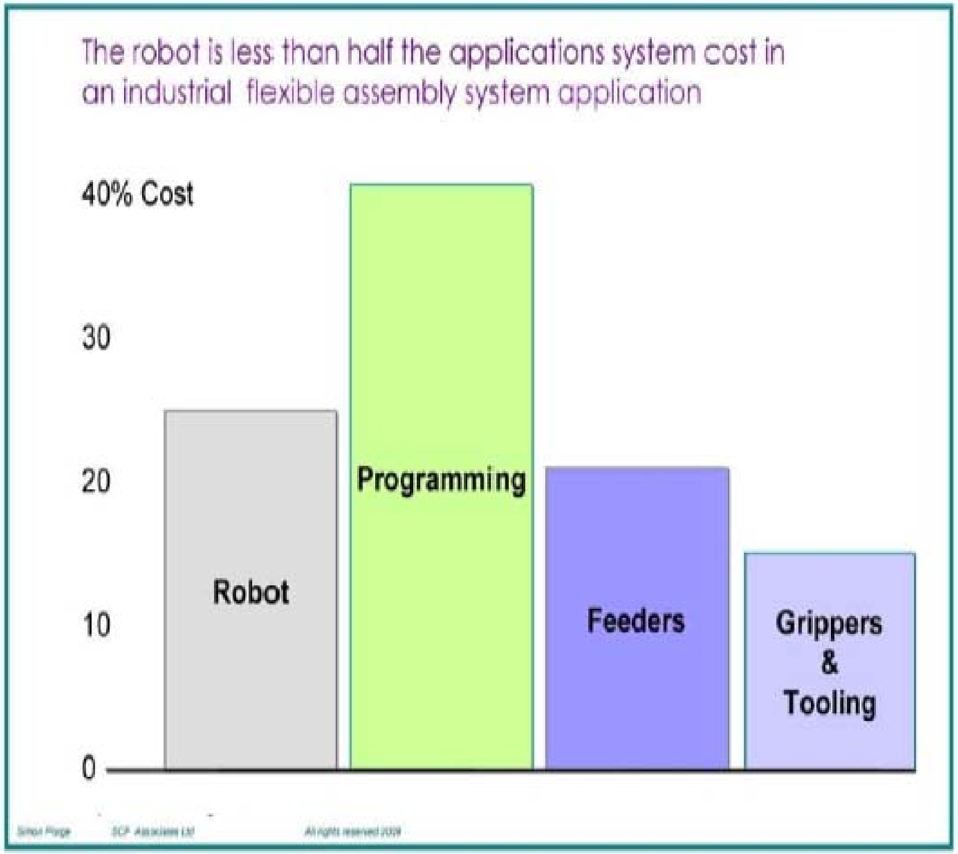
Elprama, S. A., Makrini, I. El, Vanderborght, B., & Jacobs, A. (2016). Acceptance of collaborative robots by factory workers : a pilot study on the importance of social cues of anthropomorphic robots. In Robot and Human Interactive Communication (ROMAN16),

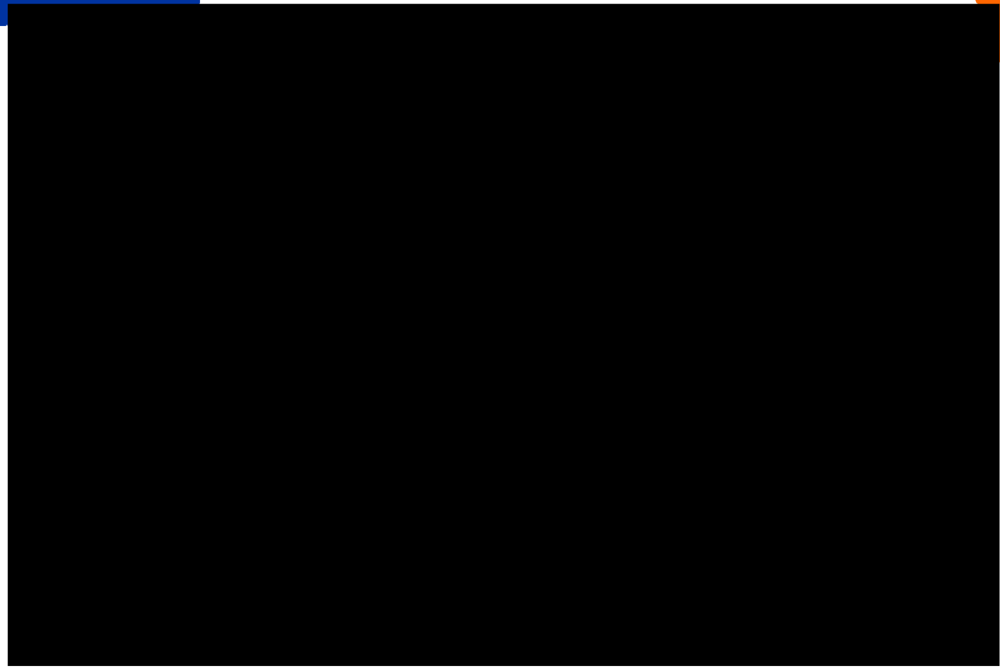
Baby Geert coworking robot

Worker proud to collaborate with the robot “Baby Geert”
20% less glue needed
Improvement quality by 15%

VUB VRIJE UNIVERSITEIT BRUSSEL
imec
UHASSELT KNOWLEDGE IN ACTION
Audi Brussels
SoftKinetic
Melexis
innoviris.brussels
FLANDERS INNOVATION & ENTREPRENEURSHIP
Flanders State of the Art
RoboVision
AMS
imec

Robot programming towards operators





CHAPTER II

SHOW FRANKA WHAT TO DO

Human robot collaboration

Flanders Make SBO Yves

Low payloads - limited range-
low energy efficiency

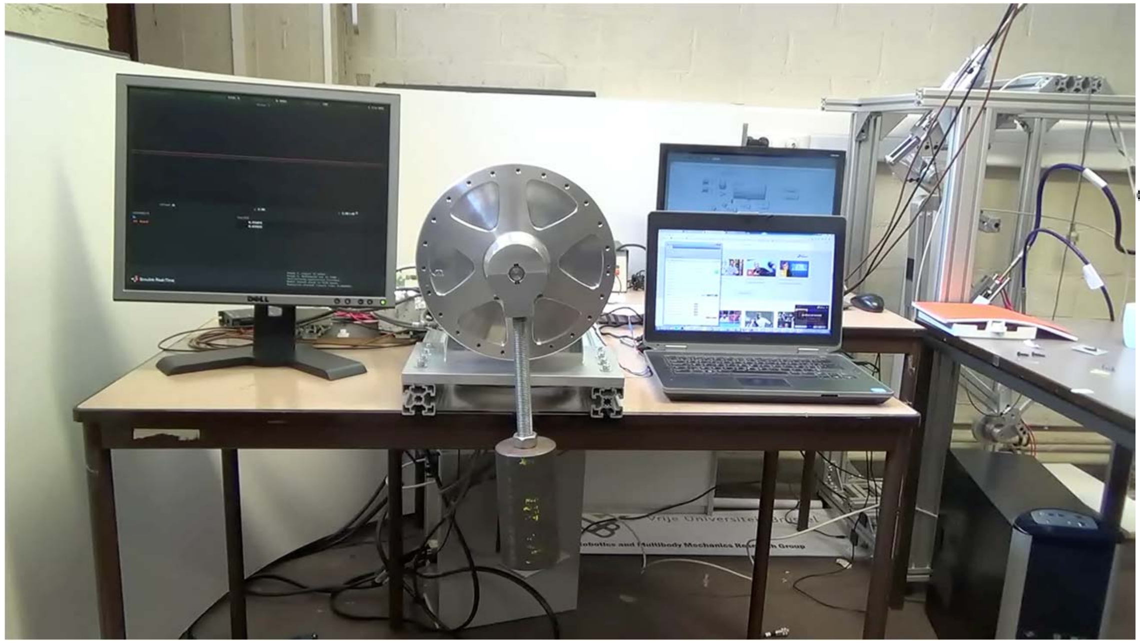
Payload to mass ratio is typically 1-10
Most of energy required is to move/lift its own arm

Sawyer-Franka
few kgs

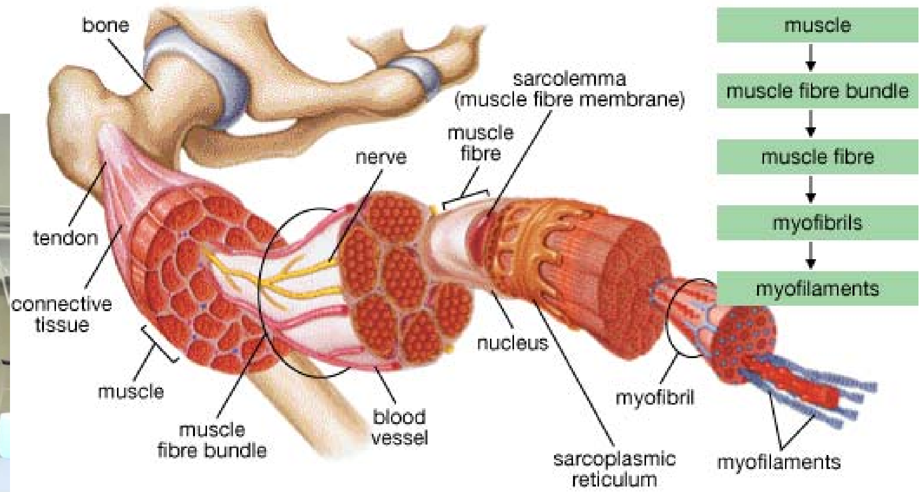
Fanuc CR
max 35 kg
mass= 990kg

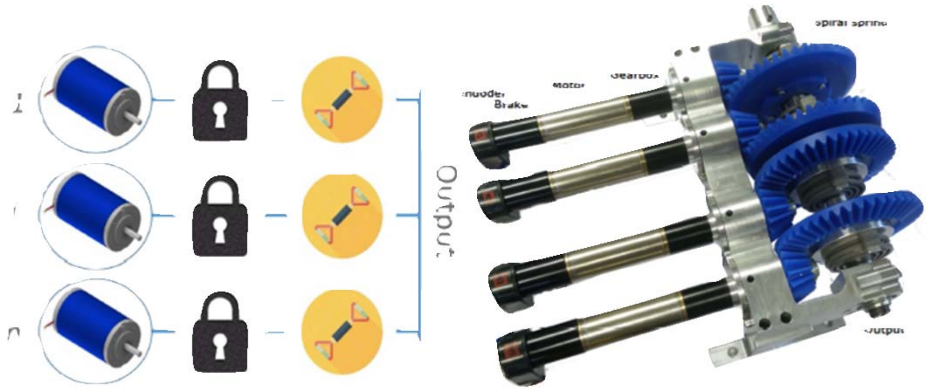
Kuka iiwa
max 14 kg (175 platform)
mass= 375kg

Stronger actuators



VUB-Livedrive



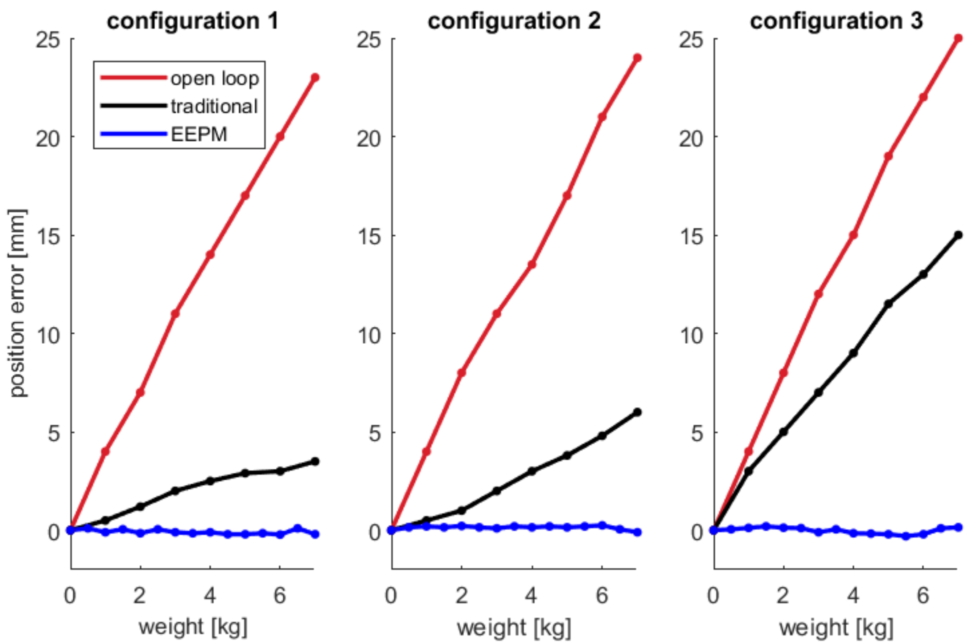


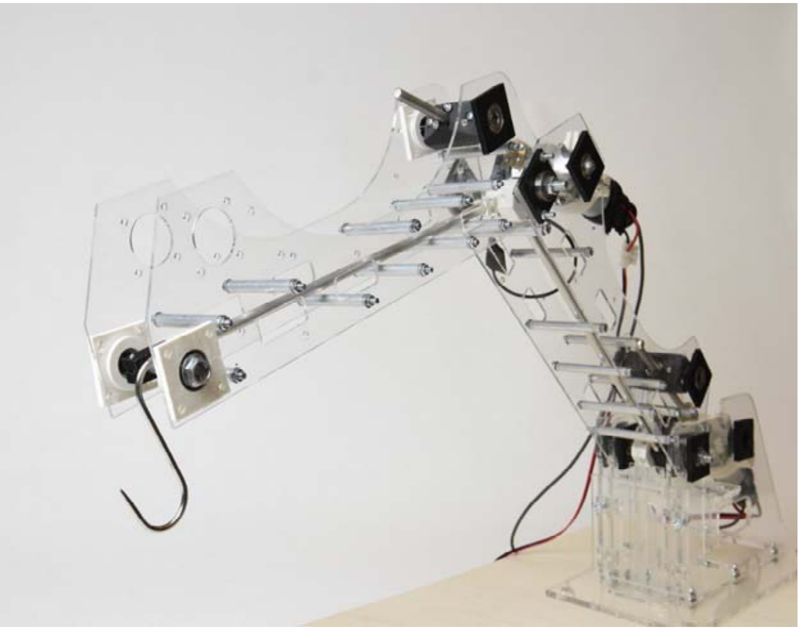
(a) SPEA schematic (b) SPEA prototype

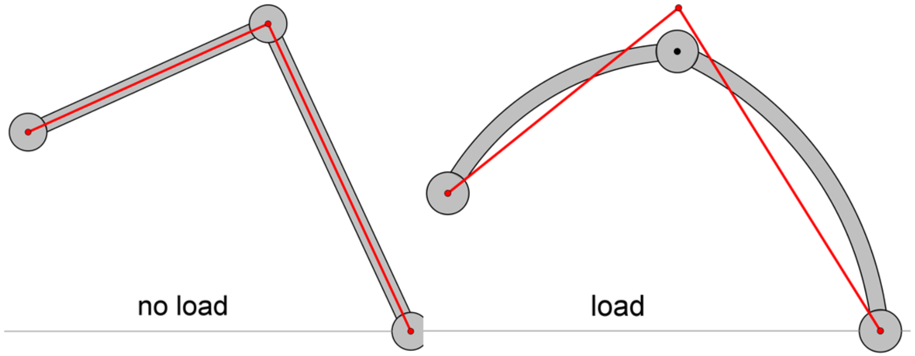
New manipulator arms

Lightweight arms

Payload/mass=2







Other opportunities with e.g. exoskeletons,...

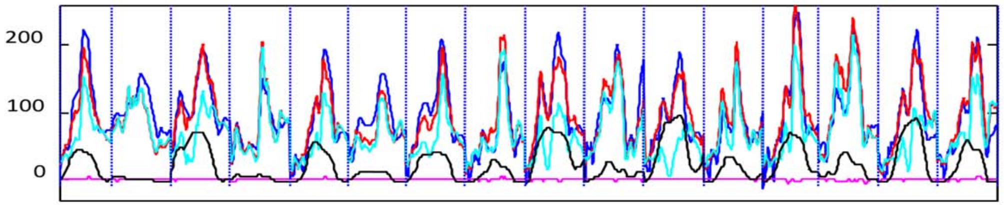
Exoskeletons

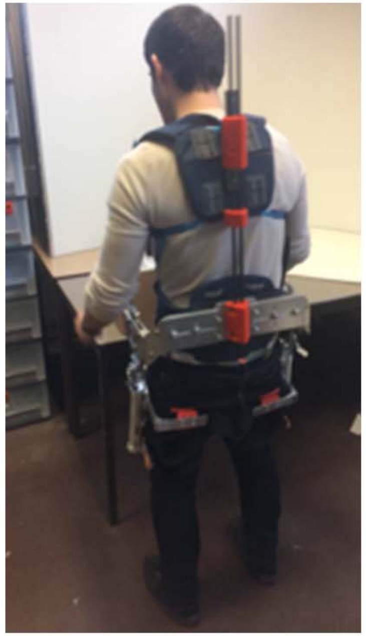
VUB-KUL Mirad

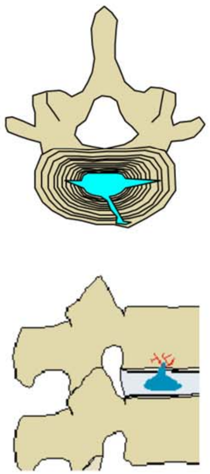
VUB

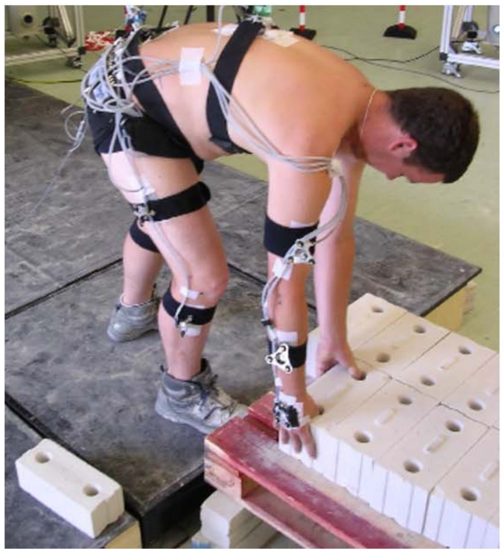
Spexor EU project: Spinal exoskeletal robot for low back pain prevention and vocational reintegration

SPEXOR









EXO4Work SBO

VUB VRIJE UNIVERSITEIT BRUSSEL

KU LEUVEN

EXO4WORK

Wearable Robotic Body Exoskeleton for Workers

VOLVO TRUCKS | Atlas Copco | Audi Brussels | PICANOL why weavers win | suez SITA

BOMBARDIER the evolution of mobility | brussels airport | asco | DAIKIN | profel

BESIX | colruyt group | Universitair Ziekenhuis Brussel | bpost | AXALTA

GREENYARD FOODS | DHL | DEME Dredging, Environmental & Marine Engineering | Qbic | Gemma Frisius Fonds

preparing O&O with industrial prototypes for acceptance and physiological tests

Conclusion

Make humans and robots (cobots-exoskeletons) work together for healthier and better jobs

brubotics®

Brussels Human Robotic Research Center

FLANDERS MAKE
MANUFACTURING INNOVATION NETWORK

erc European Research Council

AGENTSCHAP INNOVEREN & ONDERNEMEN

FWO VLAANDEREN

INNOVIRIS

imec

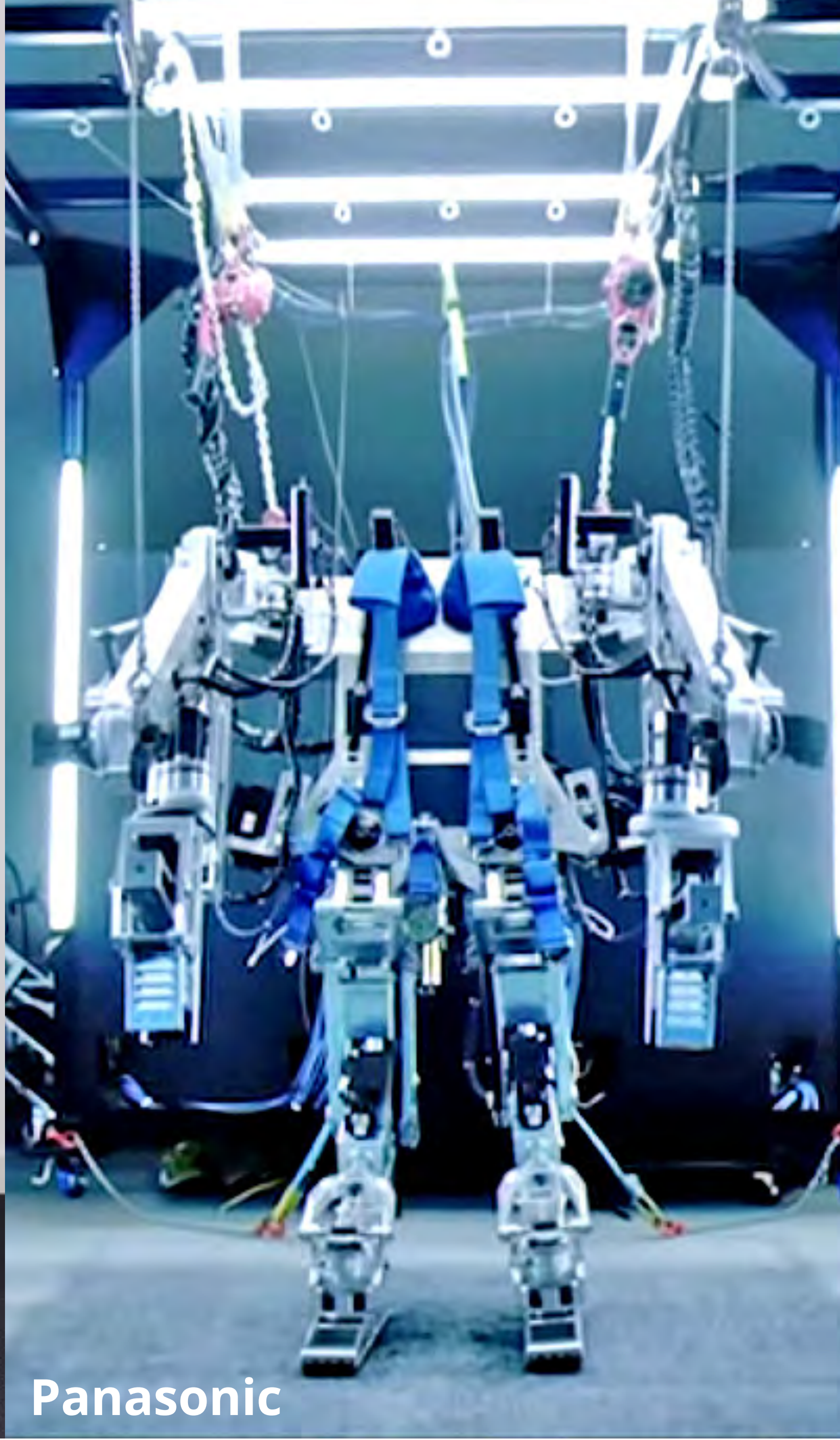
FLANDERS MAKE


laevo
the **wearable tool**
to support
work posture
www.laevo.nl

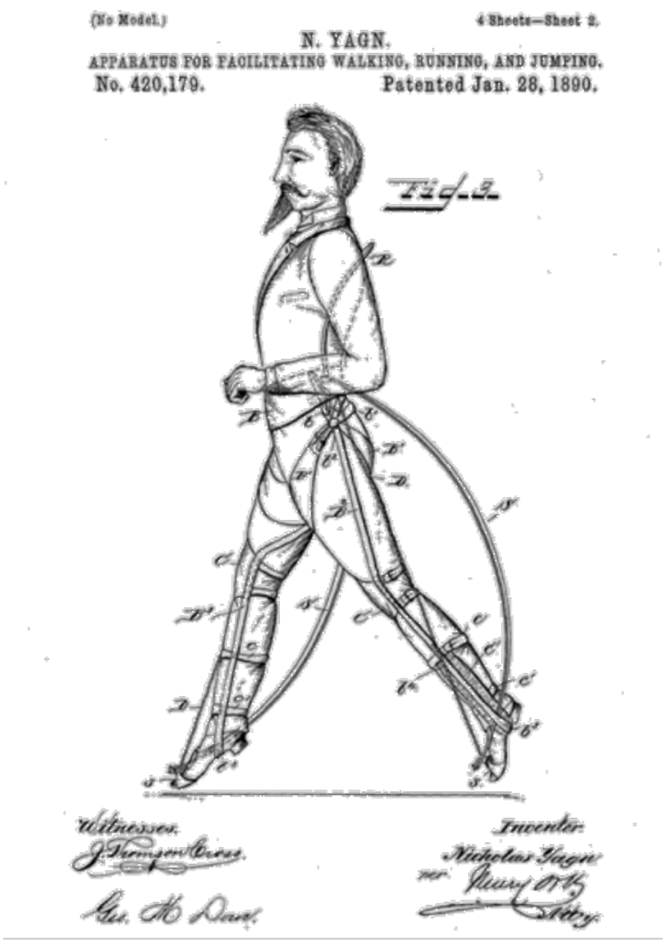
Different goals = Different tech


Ekso


Laevo

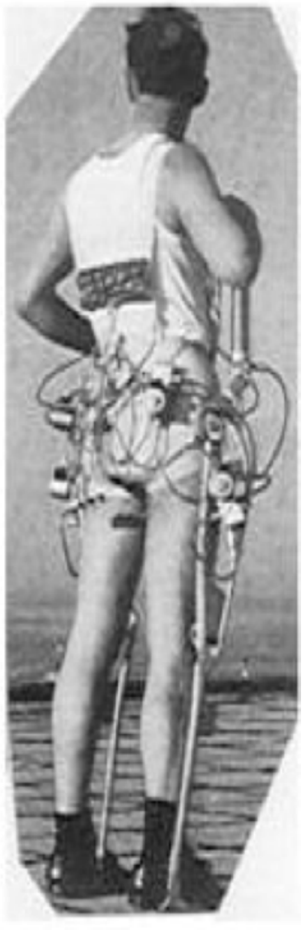

Panasonic

A long history of desire to augment



First patent (1890)

Hardiman General Electric (1965)



Mihailo Pupin institute (1969)

Currently most developed: paraplegic support

Example of emerging solutions: elderly


Walking Assist Device, Honda, Japan


Bodyweight Support Assist, Honda, Japan


Power Assist Suit, Kawasaki, Japan


Panasonic, Japan


Hyundai, Japan


Toyota, Japan


Innophys, Japan


Hexar Systems, Korea


B-temia Keeogo, Canada


PhaseX AB, Sweden


Cyberdyne, Japan

Example of emerging tech: worker support

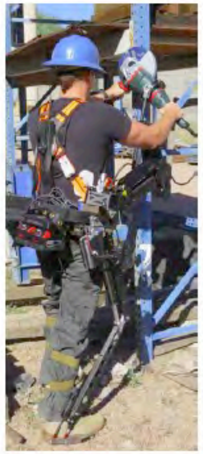
Daewoo, Korea

RB3D, France

Cyberdyne, Japan

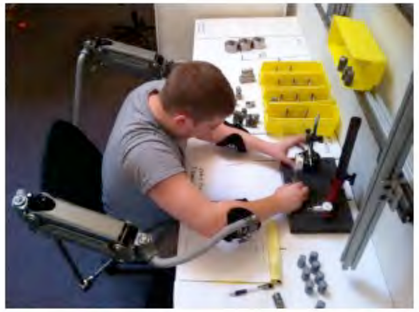
Strong Arm, USA

Fortis, USA



BAE Systems, England

Activelink, Japan



X-Ar Equipois Inc. (USA)

100s of exo-designs, few work in practise

User issues

- learning-curve
- effectiveness
- donning - doffing
- inhibits other tasks
- stigma
- ....

Employer issues

- maintenance
- standardisation
- price
- implementation in process
- fitting multiple users
- ....

User-centred approach: benefits outweigh costs

1 start SPECIFIC

Focus one task

NORMALISE

Become accepted

+ add FUNCTION

Sensing / data collection
Smart on/off
Other body part support
Actuation
Integration in clothes
Integration in tools

Key-enabling Technologies

Mechanical design
Actuators
Sensors
Control
System architecture
Modelling
Design tools

Laevo V2.5 introduction

Our start – 2010 – solve posture, not just lifting

point.one intespring TU Delft

Due to back pain:

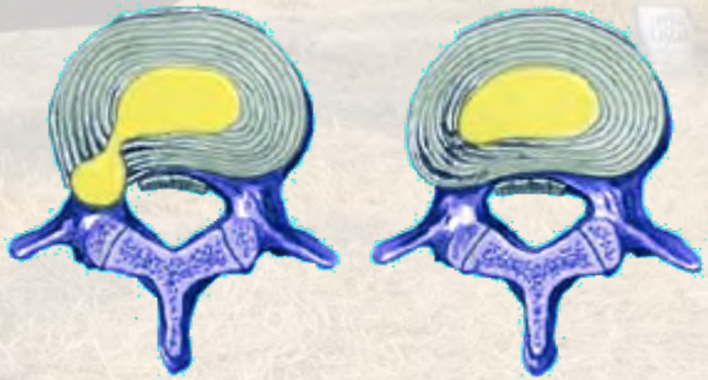
- Total cost in US: **$100 billion /y**
- **25.9 million Americans** losing an average of **7.2 days of work**
- Those worker compensation **claims** usually $40,000-$80,000.

Wearable tools emerge that increase safety and capacity

Exos don’t replace strength training

Silent killer:

- Training load with recovery is healthy
- **Cumulated load with insufficient recovery is damaging**



laevo

V2 exoskeleton

SUPPORT
WORK POSTURE

Up to 50% less load & EMG,

Average 25% less net. torque

all day
all tasks
all movements

users generally report -30% perceived work load

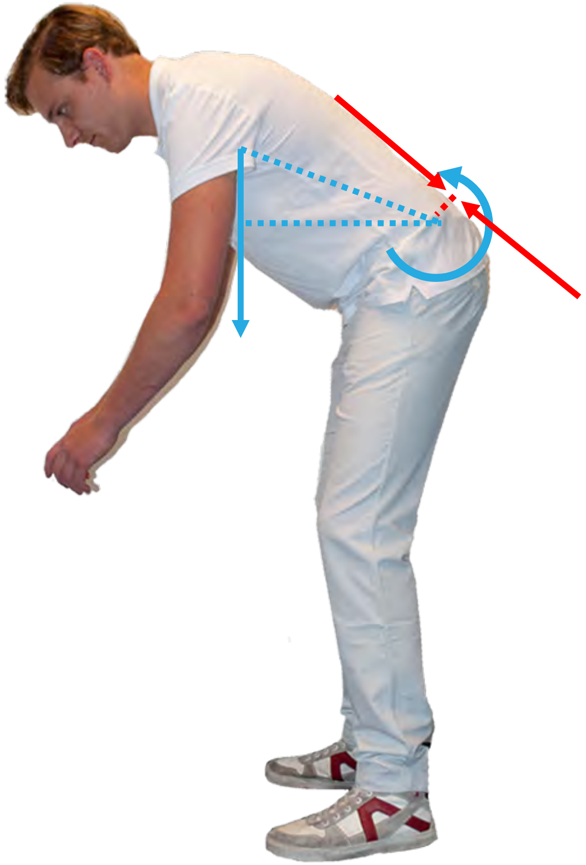
It works!

Burden

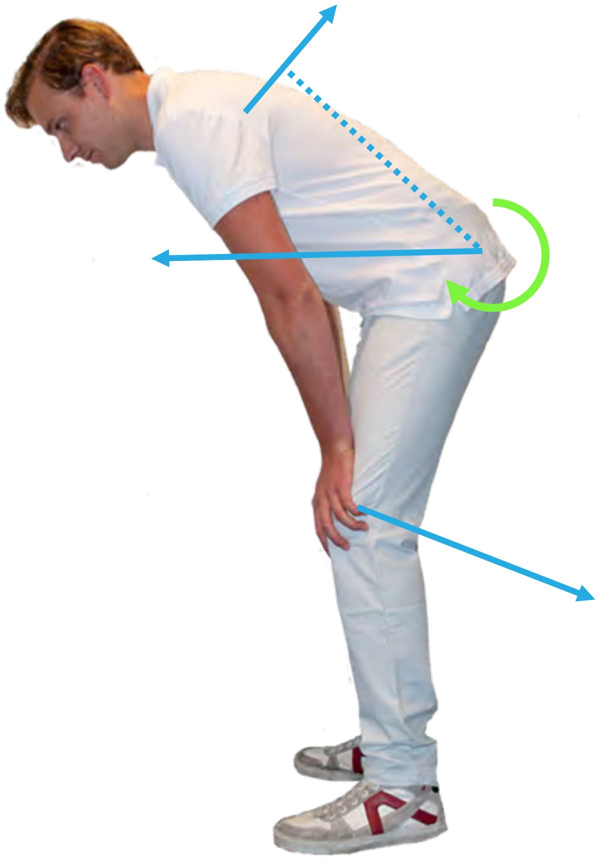
Helps

This too

Biomechanics



Torso on S1/L5

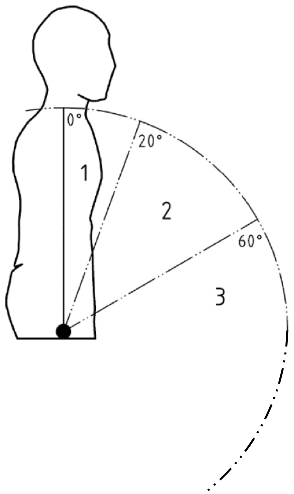


Counter torque

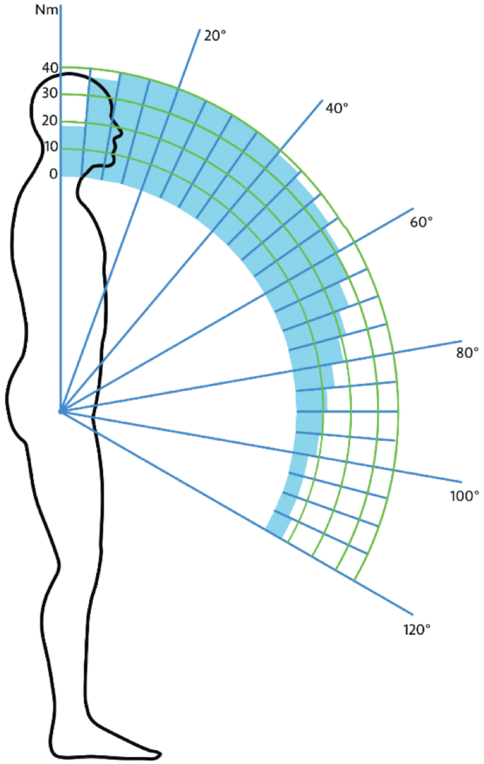
Net-torque is lower

Support emphasis zones: torques (Nm)

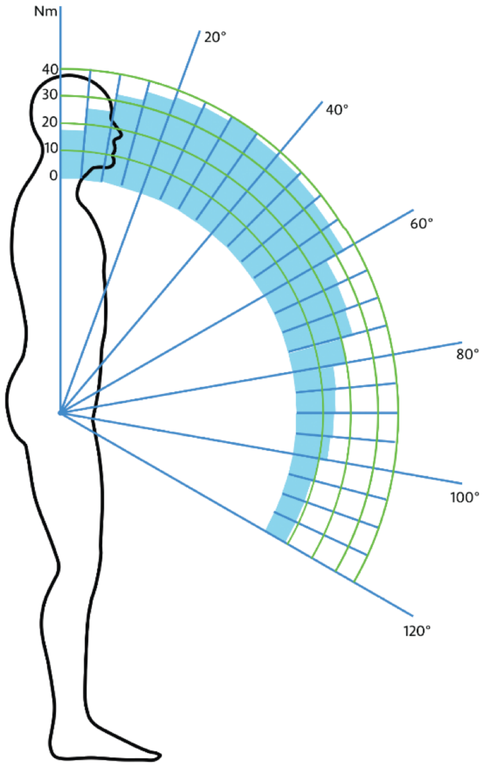
Risk zones



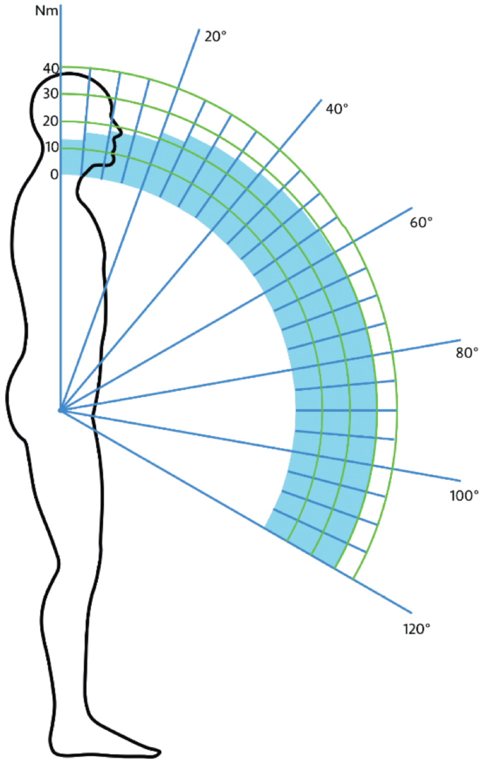
1: 'Surgeons'



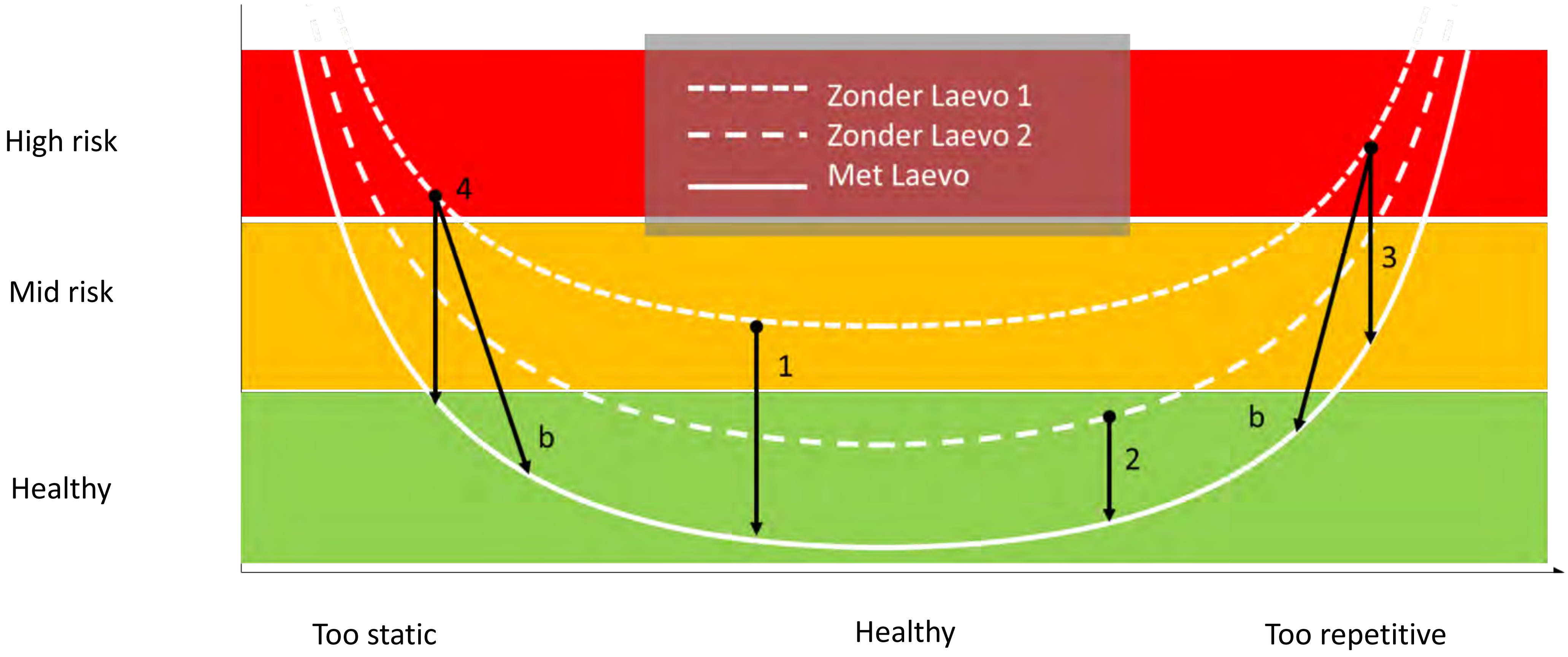
2: 'Table-top' work



3: 'Floor' work



Back load and repetitiveness determines risk



Theoretical effect Laevo

↓ Reduced load/ stress/strain → better motility ← less repetitions

“traffic light’ model: handboek Fysieke belasting

ROOD

Risico op gezondheidsschade

De uitkomst ‘rood’ geeft aan dat er zonder meer sprake is van eer
volgens de normen en wet- en regelgeving verplicht actie te ond

ORANJE

Mogelijk risico op gezondheidsschade

De uitkomst ‘oranje’ geeft aan dat er mogelijk sprake is van een k
aangeraden actie te ondernemen.

GROEN

geen risico op gezondheidsschade

De uitkomst ‘groen’ geeft aan dat er geen sprake is van een knelpu

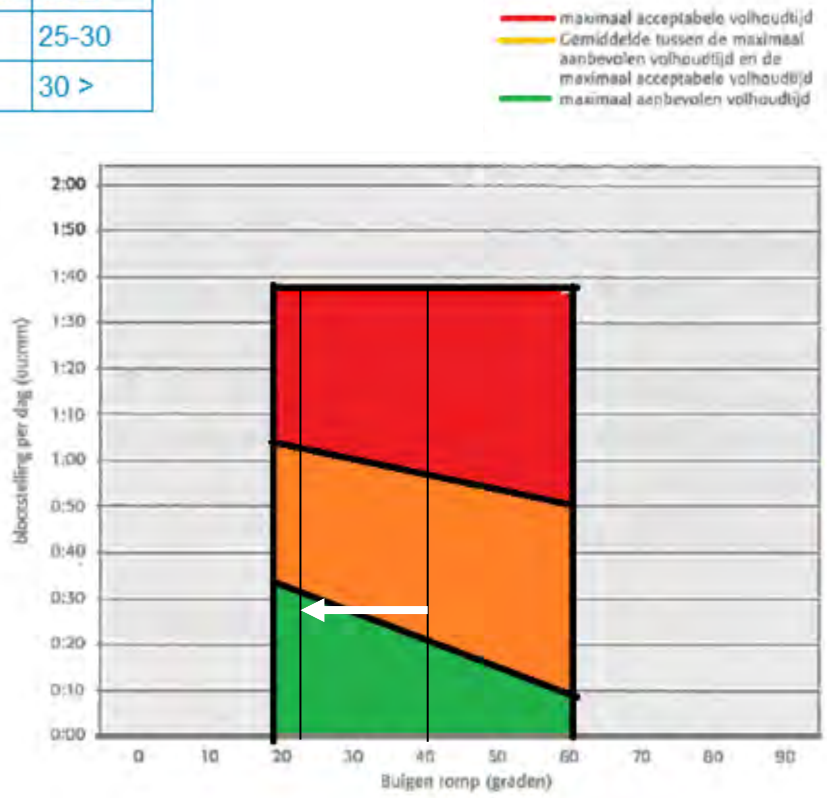
Norms approach: convert to virtual posture

Houding met Laevo vertaald naar houding zonder Laevo met gelijk montent tov L5/S1

aanname zwaartepunt romp boven L5/S1 bij 0 graden flexie

Lichaamslengte	185,00	cm		
Lichaamsgewicht op basis BMI	684,50	N	BMI	20
gewicht hoofd romp armen	342,25	N	Ondergewicht	< 19
Zwaartepunt lichaam boven L5/S1 staand	0,46	m	Gezond gewicht	19-25
Mate van flexie rug tov verticaal met Laevo	40	°	Overgewicht	25-30
Zwaartepunt romp t.o.v. L5/S1 horizontale afstand	0,30	m	Obesitas	30 >
Moment bovenlichaam	101,75	N/m		
Moment Laevo op grond van hoek bovenbeen/romp	40,00	N/m		
Moment totaal	61,75	N/m		
vergelijkbaar met afstand zwaartepunt	0,18	m		
vergelijkbaar met een hoek van zonder Laevo	23	°		
Winst aantal graden bij gelijke belasting qua moment	17	°		

Bron: Willems Ergonomie



Bron: Handboek fysieke belasting

A practical tool

No Batteries

Med. device Class I

Keep working as usual

Sit, Squat, Kneel, Walk

Wear it as a coat

Comfortable, ♀ ♂

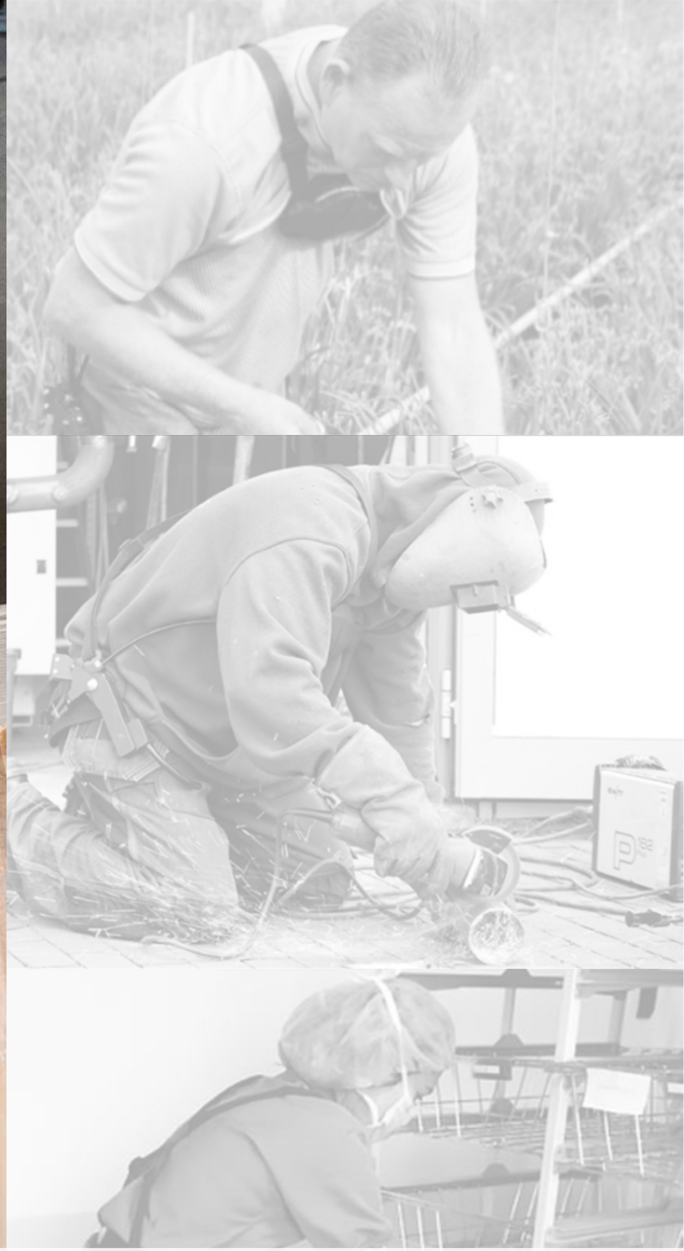
Customizable fit for different uses

Easy fit / sizing

Fine-tuning angle

Interchangeable rods: 4 basic sizes, specials possible in straight/ slim-fit

A solution in many sectors



TO COME:

Everybody wins

Employee

Q of Life

Better work

3x Holding time

30% subjective work load

Getting used to

Employer

Flexibility

-x% Absence

-x% Turnover

+x% Productivity

\+

xx% efficiency

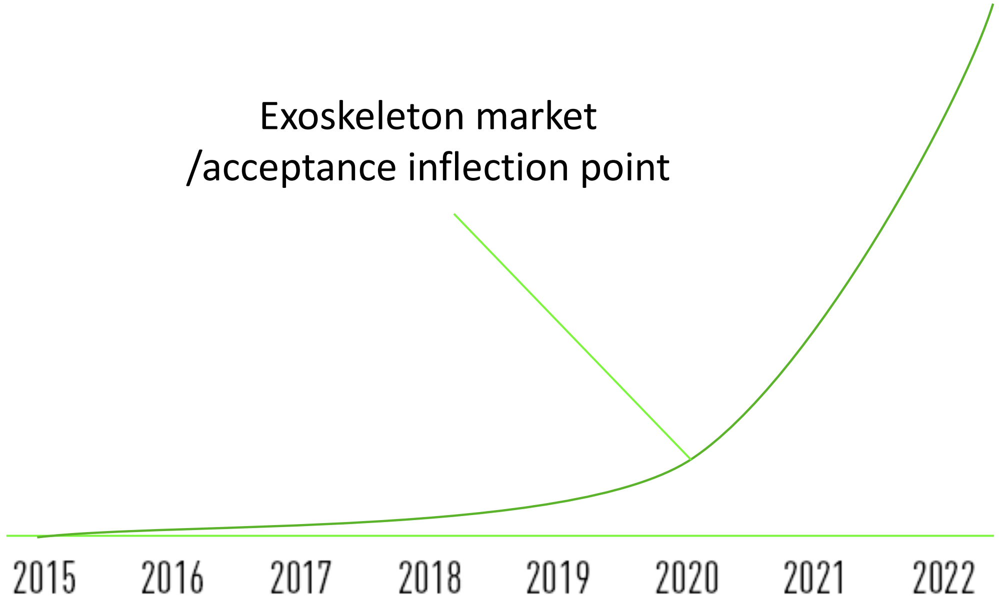
Cost of ownership †

† numbers vary depending per use case

laevo

Anticipating a fast growing demand

Revenues



Founders

Team

…

Key partners

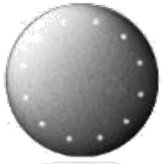
BOERS&CO fijnmetaal groep

achmea

iturri

Future vision: healthcare example

Additional **arm** modules



Sensoring for user feedback

Additional **leg** modules

Integration in Ambulance uniform
- Better looking
- Less obstruction
- Extra protection

Actuation
(super human capabilities, more support during lifting)

SMART
Robotic on/off

laevo
exoskeletons

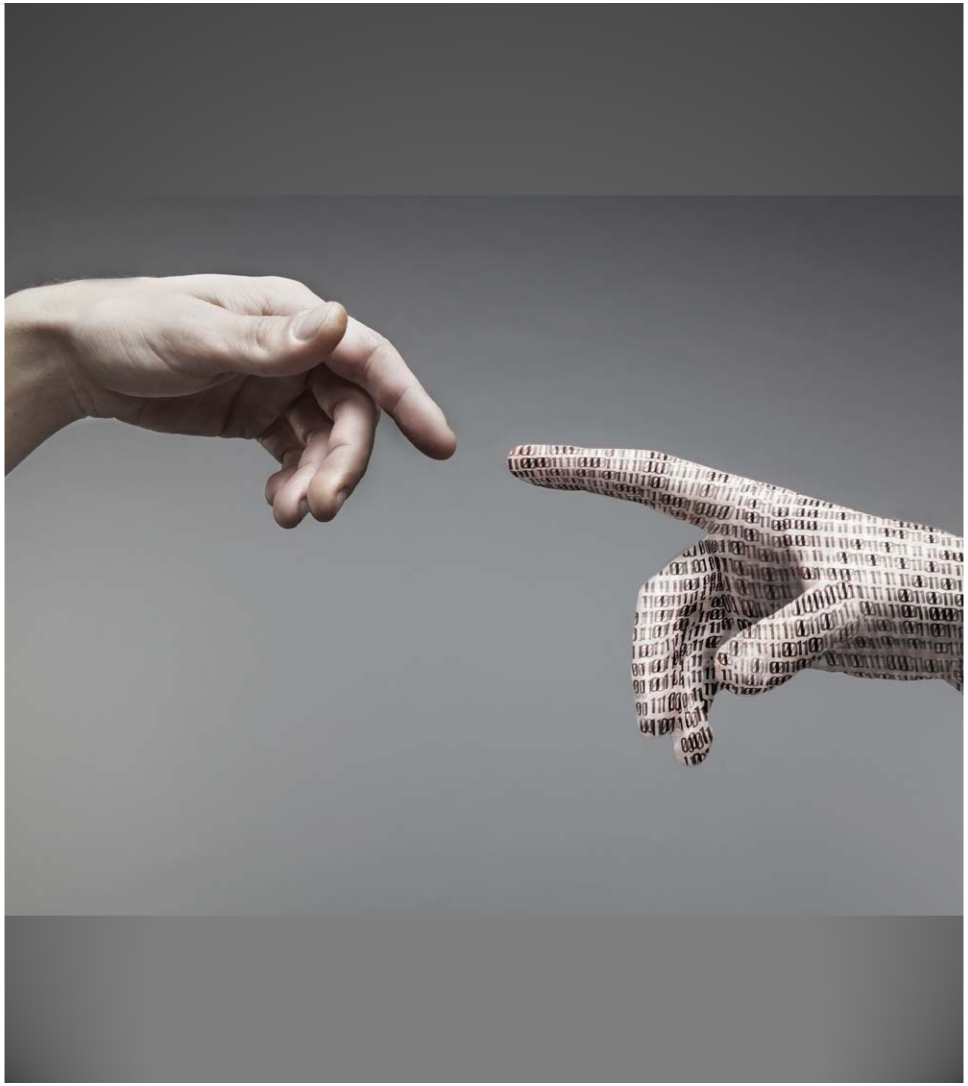
www.laevo.nl
info@laevo.nl

Boudewijn Wisse
CEO
bw@laevo.nl
+316 24 255 244

QUI SOMMES NOUS ?

Technologies Ergonomie Appliquées,
Expert de la **mesure** et de l'analyse du **comportement** de **l'Homme** en **Activité** et de ses interactions avec son **environnement**.

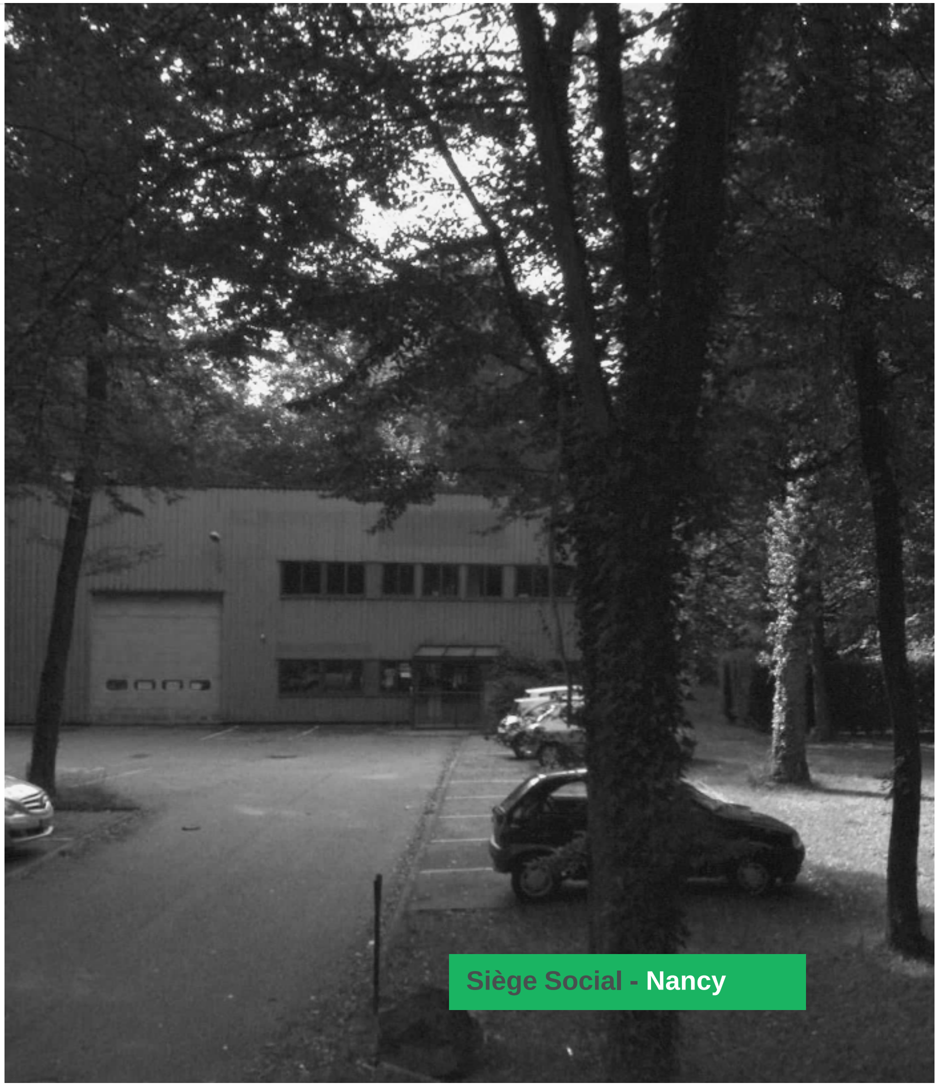
TECHNOLOGIE ERGONOMIE APPLICATIONS



TEA

UN PEU D'HISTOIRE

- Création en 1985 – 32 années d'existence
- 17 personnes :
  - Force commerciale: 6
  - Recherche et Développement : 8
- 7 thèses doctorales
- Transfert de technologie / partenariat INRS
- Nomination aux victoires de la médecine



Siège Social - Nancy

NOS ACTIVITÉS

R&D

Logiciel CAPTIV
Capteurs sans-fil
Transmission sans-fil
Solutions spécifiques

Ventes

Solution CAPTIV (logiciel et matériel)
Capteurs EMG (Delsys)
Capteur EEG (B-Alert / DSI)
Capteur environnement (Bappu)
Capteur Eyetracker (Fovio, Tobii, Dikablis)
Capteur de pression (Teckscan)
Réseau de Revendeurs

Prestation

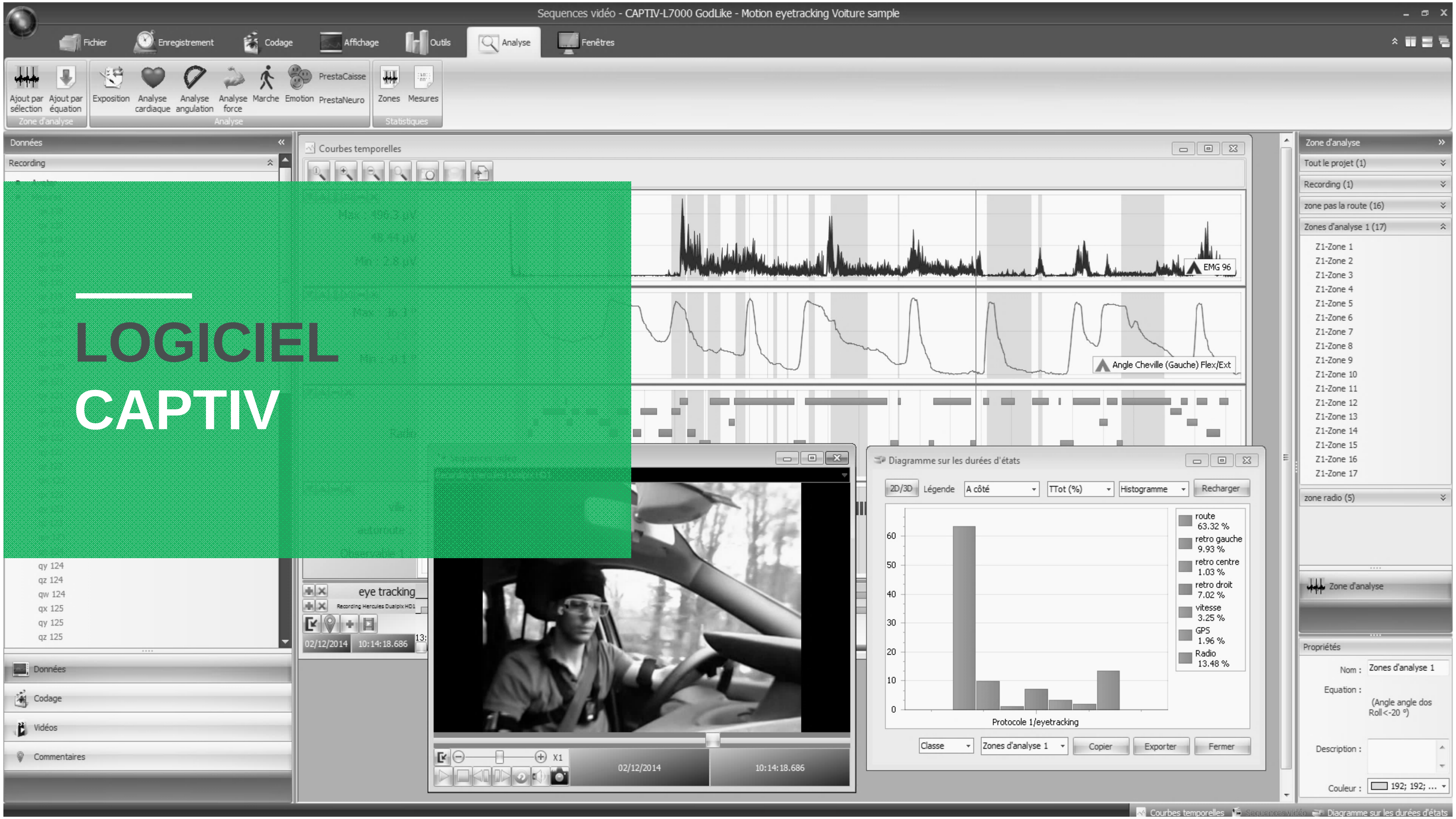
Diagnostics Postes de Travail
Accompagnement
Formation

Présence Internationale

TECHNOLOGIE ERGONOMIE APPLICATIONS

NOS RÉFÉRENCES

LOGICIEL CAPTIV



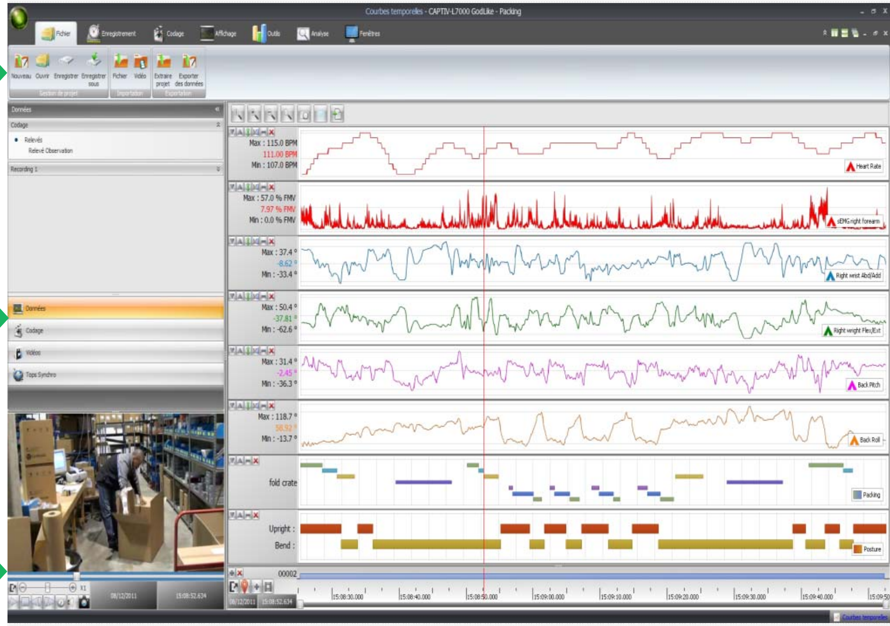
LE CONCEPT

Codage Manuel

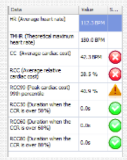
Vidéos (USB ou Camescope)

Capteurs (T-Sens et autres)

Logiciel CAPTIV



Rapports



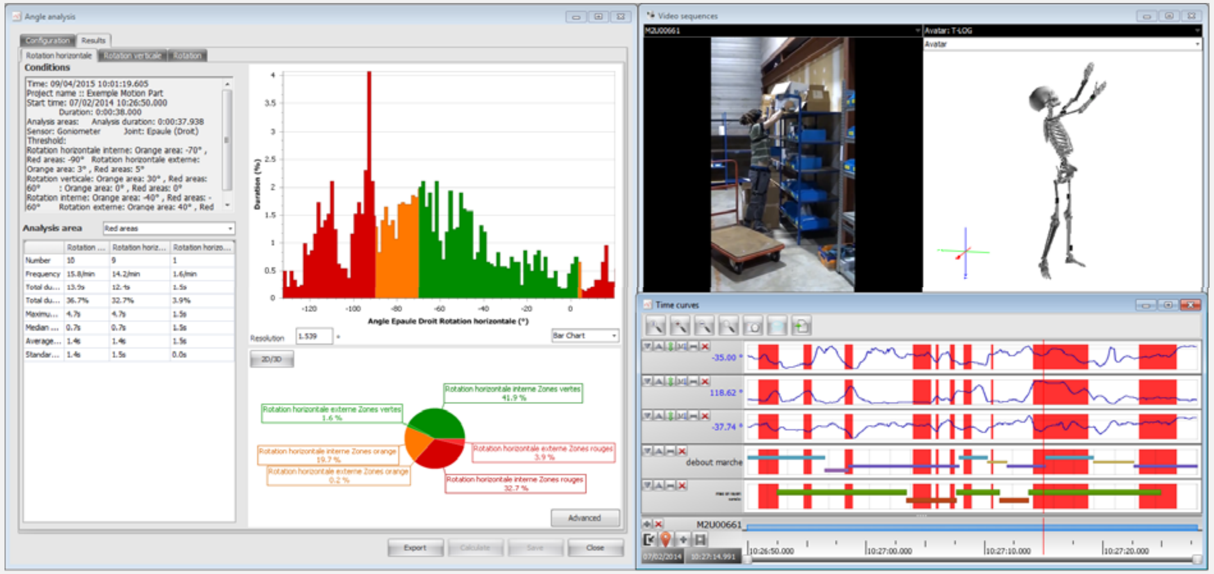
CAPTIV L7000 PREMIER

- Permet d’effectuer des études de poste
- Permet de faire la cartographie des postes
- De valider un nouveau matériel et des prototypes
- Prévenir les risques de TMS
- Etudier l’ergonomie de conception :

- Construction, conception, réalisation de matériel ergonomique.
- Intégration de l’ergonomie dans la construction de bâtiments
- Simulation de l’activité au sein d’une maquette afin d’éviter de devoir procéder à des ajustements ultérieurs au niveau de la structure d’un bâtiment.
- Cela peut faire l’objet de norme comme la norme NF EN « *Méthodologie d’analyse du travail à l’appui de la conception* ».

- Enfin grâce à notre nouvel avatar et son système de colorisation des articulations, il peut s’avérer très pédagogique pour tout enseignement des gestes et postures.

LES ANALYSES SPÉCIFIQUES

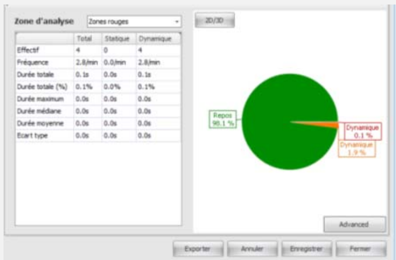


Analyse Angulaire

Analyse des postures du sujet
à partir de seuils de confort

LES ANALYSES SPÉCIFIQUES

Disponible dans la version CAPTIV L7000 Premier

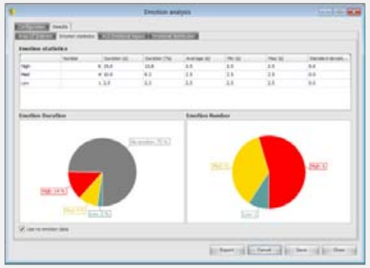


Analyse EMG

Analyse des contractions musculaires à partir de seuils %FMV.

Analyse Fréquence Cardiaque

Calcul du CCR, CCA, etc..
Indicateur Meunier, Frimat, Chamoux



Analyse Arousal

Calcul des arousals à partir du capteur GSR
3 niveaux d'amplitude :
Haut / Moyen / Bas

Facial Coding

Analyse des expressions faciales à partir d'une webcam

NOS CAPTEURS SANS-FIL

LES RÉCEPTEURS

Datalogger T-Log

- Enregistreur embarqué
- Réception de 1 à 32 capteurs sans-fil T-Sens
- 12h d'autonomie
- Enregistrement sur memoire interne

Recepteur T-Rec

- Recepteur Temps-Réel
- Réception de 16 capteurs sans-fil T-Sens
- Distance de réception de 15m
- Triggers in/out

LES CAPTEURS T-SENS

Capteurs T-Sens Psycho/Emotion

CEM (GSR)
Mesure de la conductivité éléctrodermale cutanée

ECG
Mesure de la fréquence cardiaque

Température
Mesure de la température cutanée

Respiration
Mesure de la fréquence et amplitude respiratoire

LES CAPTEURS T-SENS

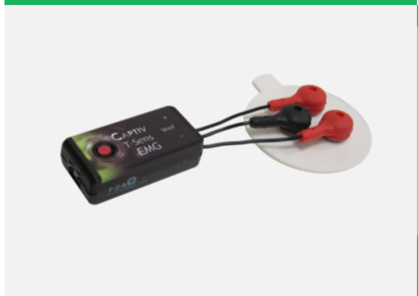
Capteurs T-Sens Physio/Posture

sEMG

Mesure de contractions musculaires

Accéléromètre

Mesure de la vibration dans les 3 axes XYZ



Motion (IMU)

Mesure des angulations articulaires

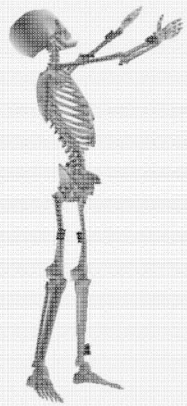
Capteur universel

Convertisseur analogique vers digital 0-3.3V

Permet de connecter un systeme tierce

T-SENS MOTION

Motion (IMU) - Centrale Inertielle



- Mesure des angles, vitesses angulaires et accélérations angulaires
- Système mobile (Datalogger) ou temps-réel vers PC
- Ne nécessite ni caméras ni marqueurs
- Système très résistant aux perturbations magnétiques

LES AUTRES CAPTEURS

LES EYETRACKERS

LES SYSTEMES DÉPORTÉS

Tobii X Serie
Écran, tablette, smartphone

FOVIO
Multi-écran, simulation
véhicule embarqué

Tobii Spectrum
Haute fréquence (600Hz)
Micro-saccade, lecture

LES SYSTEMES EMBARQUES

Tobii Glasses
Environnement écologique
mobile et autonome

Dikablis Glasses
Environnement simulation
Intégration temps réel

Tobii VR
HTC
Oculus CV1
Samsung Gear

EEG B-ALERT

Électrodes Gel

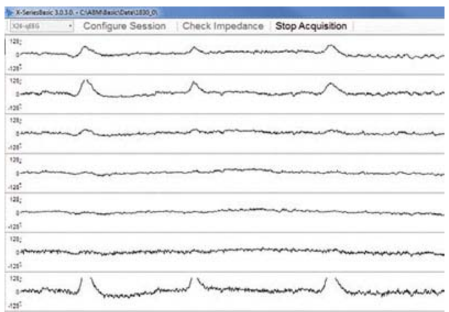
MODÈLES DISPONIBLES

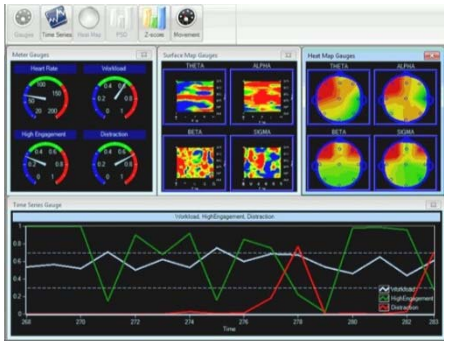
- B-Alert X10 : 10 Électrodes (9 EEG + 1 EMG ou EKG)
- B-Alert X24 : 24 Électrodes (20 EEG + 3 EMG ou EKG)

Transmission sans-fil : 10 mètres de portée

Signal brut, signal décontaminé

Données sur les états cognitifs (engagement, distraction, somnolence, stress, workload)





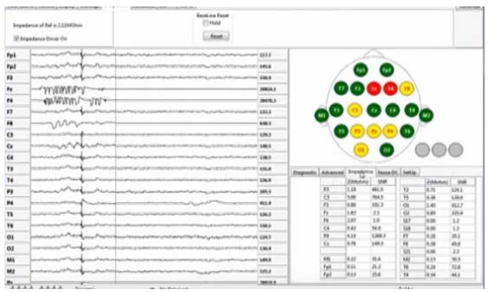
EEG DSI

Électrodes Sèches

MODÈLES DISPONIBLES

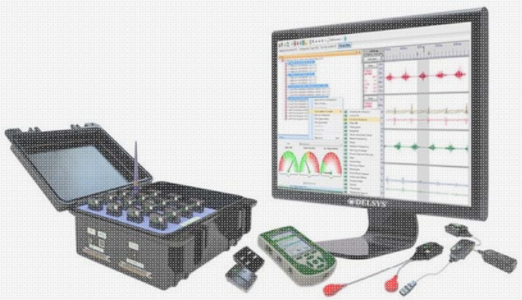
- DSI-7: 7 Électrodes EEG
- DSI-24 : 24 Électrodes (21 EEG + 3 auxiliaires)

Transmission sans-fil : 10 mètres de portée
Signal brut, signal décontaminé
Données sur les états cognitifs (engagement, distraction, somnolence, stress, workload)



EMG DELSYS

EMG Brute – IMU intégrés



- Réception temps réel sans-fil de 1 à 32 capteurs simultanément
- Signal brute EMG jusqu'à 2000Hz de qualité
- IMU intégrés dans chaque capteur (accéléro, gyro, magnéto)
- Intégration avec des systèmes de motion capture vidéo (SIMI, VICON, QUALISYS, CODA)
- Datalogger mobile disponible
- Capteurs hybrides disponibles (EKG, pression, intra-musculaire, gonio)

CAPTEUR BAPPU

Caractéristiques techniques

- Température de l'air,
- Humidité atmosphérique relative,
- Niveau de bruit instantané et moyenné,
- Intensité de l'éclairage (luminosité),
- Fréquence de balayage d'un écran (scintillement),
- Clarté maximale d'un écran,
- Contraste de densité de luminance noir/blanc sur écran,
- Contraste de densité de luminance entre écran et environnement.
- Anémomètre : Vitesse de l'air ambiant

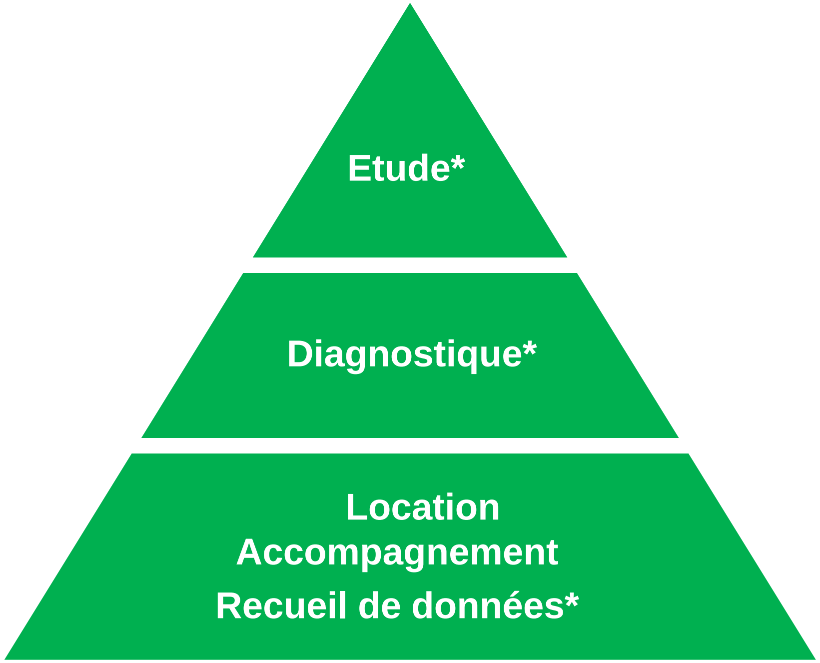
Domaines d'application

Analyse du travail sur écran, en open space - éclairage - bruit - aérologie


PRESTATIONS
&
FORMATION

PRESTATIONS
Ergonomie

OFFRE DE PRESTATIONS



** Les données obtenues sont confidentielles et restent la propriété du client.*

DIAGNOSTIQUE

- Nos experts vous accompagnent pour l'**état des lieux** de postes ou de situation de travail

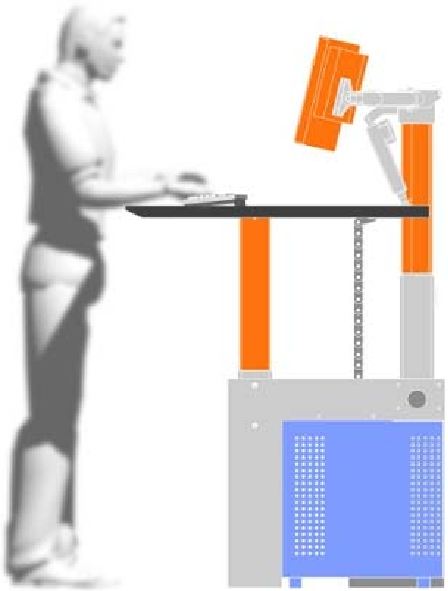
- Thématiques
  - Postures
  - Efforts
  - Pénibilité
  - Gestes répétitif
  - Port de charge

- 1 à 2 de jours sur site

ETUDE

- Mise en place d’un **projet pluridisciplinaires**, avec **accompagnement** à la mise en place de solutions.

- Thématiques
  - Aménagement de postes
  - Sélection d’outils
  - Validation de procédés / de solutions
  - Conception

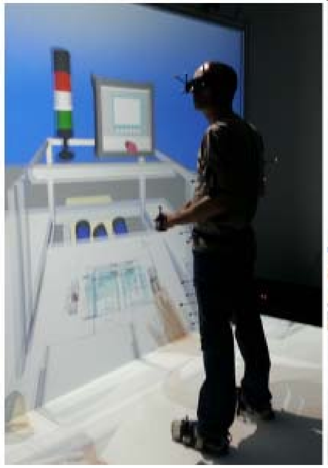


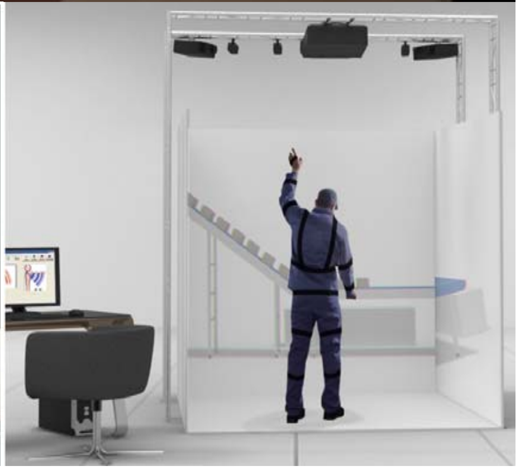
REALITE VIRTUELLE

- Valider l'ergonomie de vos postes de travail en **environnement virtuel immersif**

- Simulation à l'**échelle 1:1** vos postes de travail issus de vos données CAO

- Mesures disponibles
  - ➢ Motion tracking
  - ➢ Mesures physiologiques
  - ➢ Suivi oculaire
  - ➢ Accessibilité
  - ➢ Comportement






Formation
Ergonomie

FORMATION Contraintes musculo-squelettiques

Objectif pédagogique

Former les participants à la mesure des contraintes musculo-squelettiques au cours de l'activité physique de travail.

Public concerné

Médecins et Infirmier(e)s de Services de Santé au Travail, Préventeurs, Ergonomes, IPRP, Ingénieurs et Techniciens QHSE et en Méthodes – Industrialisation, toute personne concernée par la conception du travail, de ses outils, de son environnement ou de son organisation.

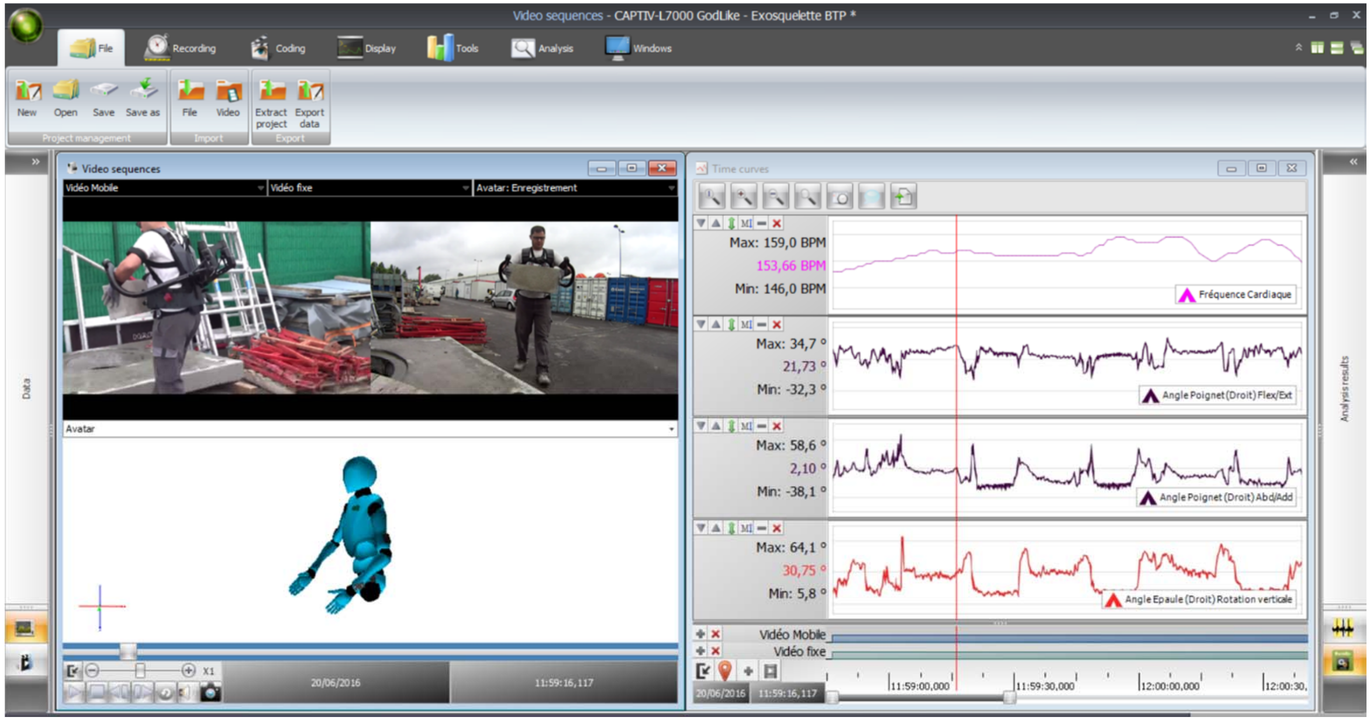
Contenu

- Notions d'ergonomie
- Éléments de physiologie musculaire
- Éléments de biomécanique
- Codage de l'activité de travail
- Mesure de la posture et du mouvement
- Éléments de physiologie cardiovasculaire *(optionnel)*
- Mesure de la fréquence cardiaque *(optionnel)*

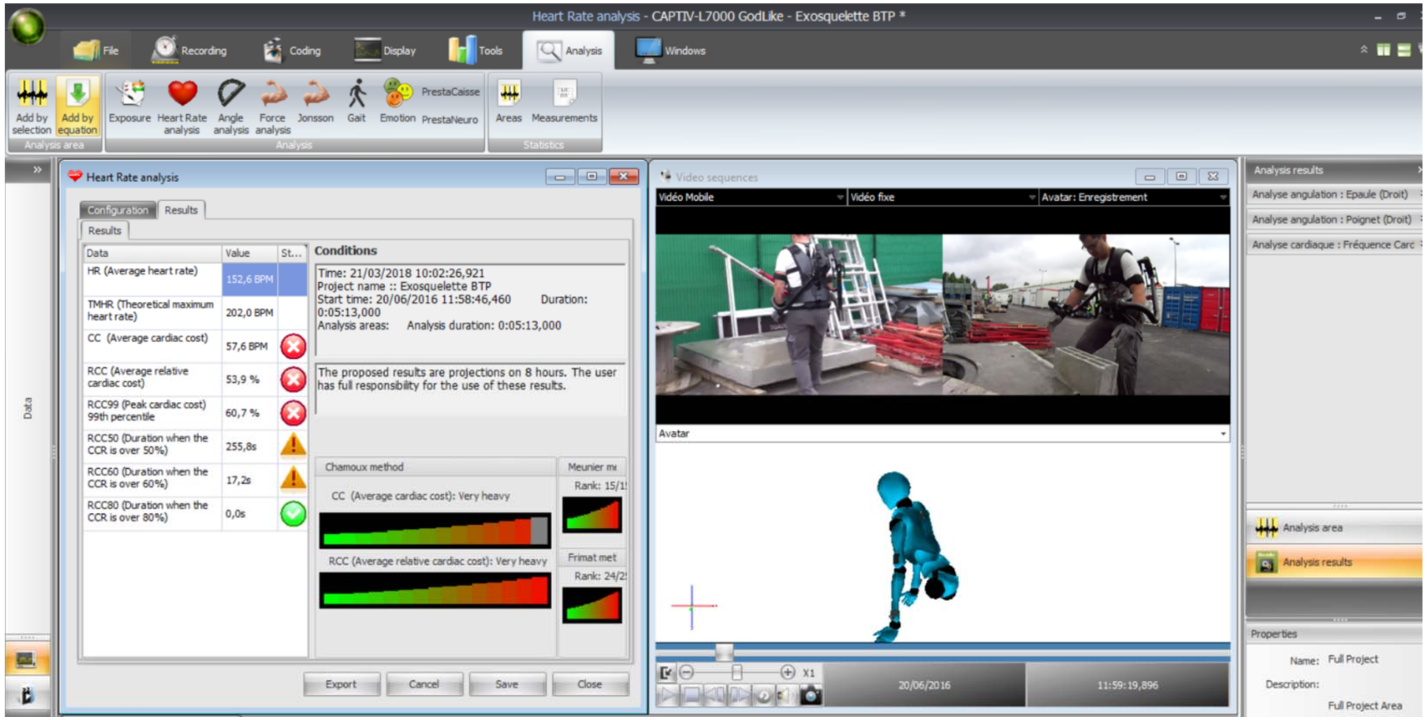
Durée : 2 à 3 jours

* Cette formation intègre l'analyse de cas réels avec le logiciel CAPTIV©, développé par TEA en partenariat avec l'INRS

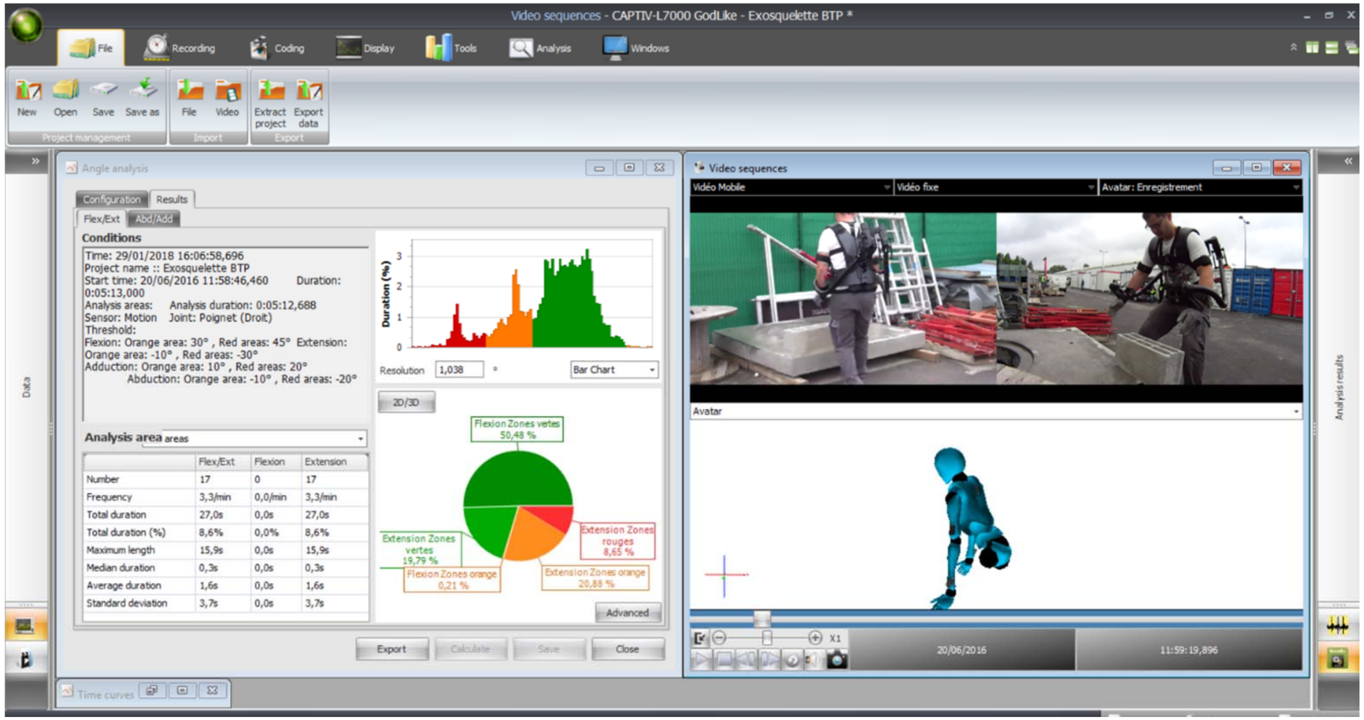
Exemple exosquelette



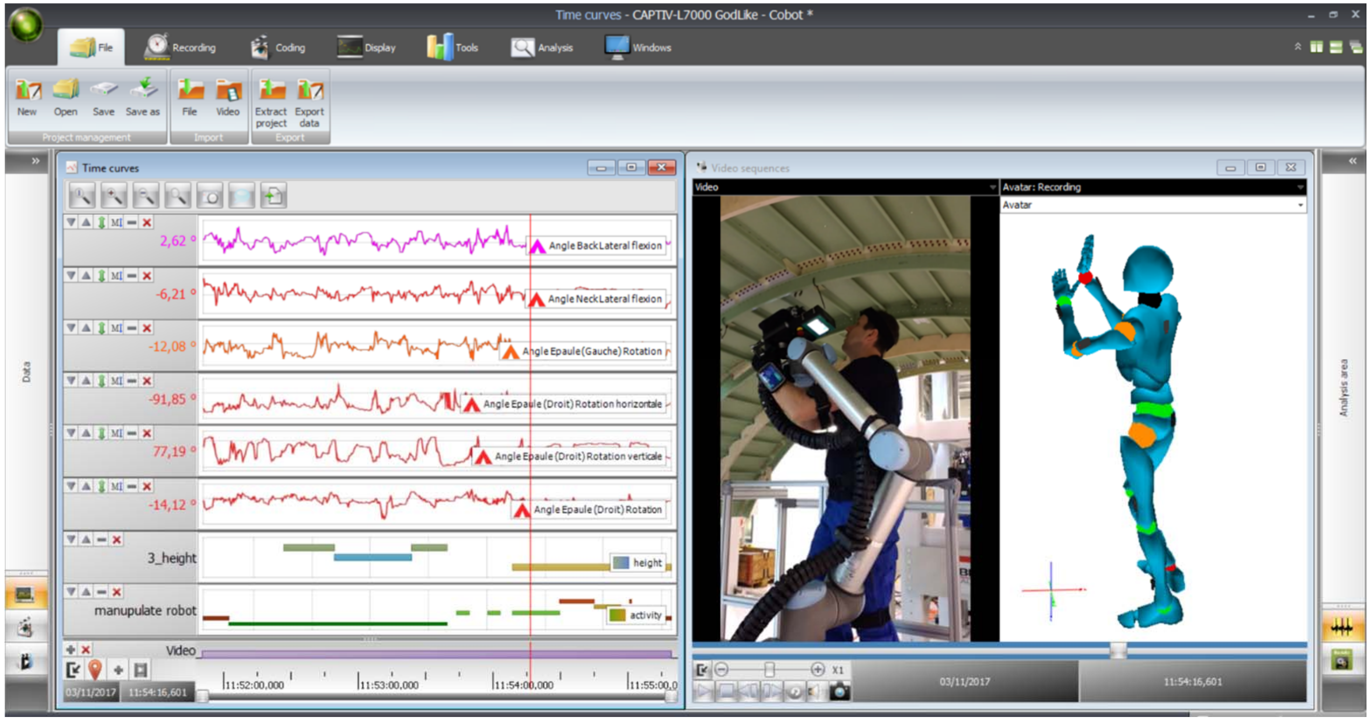
Résultats d'analyse exosquelette



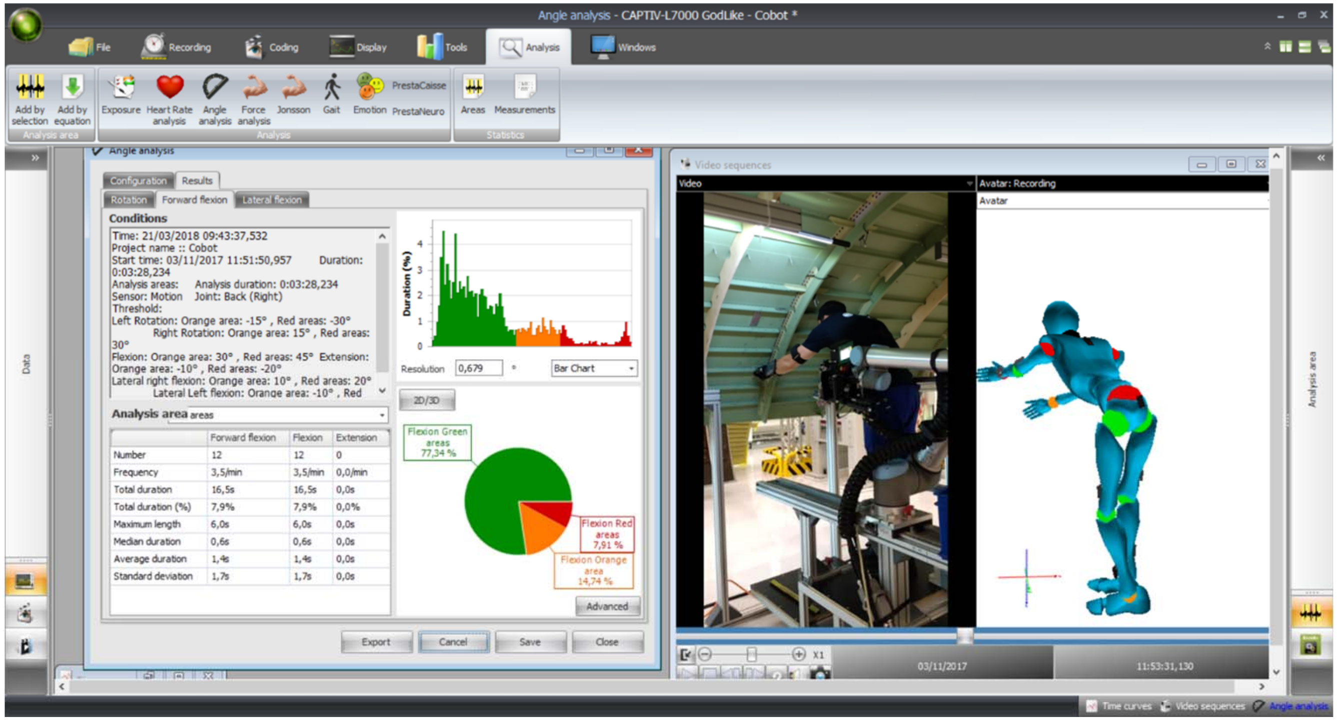
Résultats d’analyse exosquelette



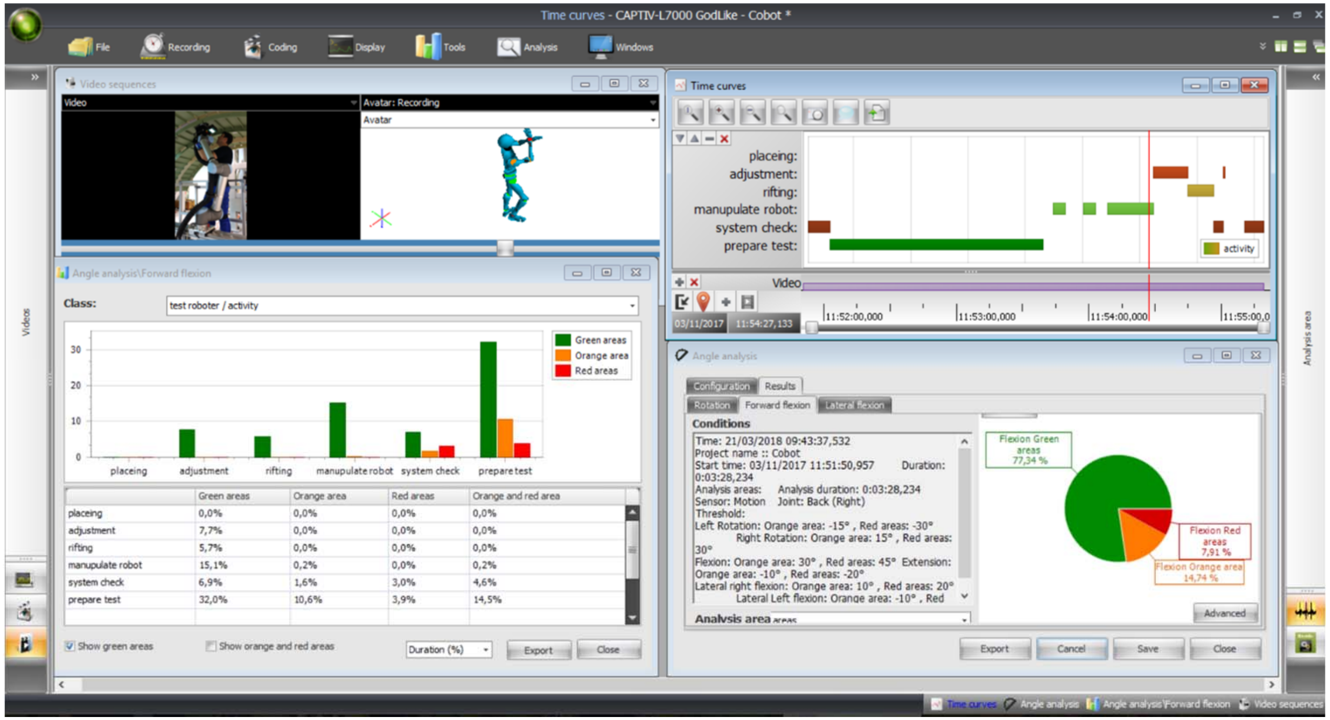
Exemple Cobot



Résultats d’analyse cobot



Résultats d'analyse cobot




CONTACT
Nicolas PERSON
TEA – TECHNOLOGIE ERGONOMIE APPLICATIONS
3 rue du Bois Chêne Le Loup
F54500 VANDOEUVRE-LES-NANCY, FRANCE
www.teaergo.com
contact@teaergo.com