Digital Transformation CoLab

Development of industrial robotic solutions according to a Human-centric approach

Robotics and Ergonomics: The DTx approach

Project Team and Charter

Symbiotic Human-Robot Collaboration in Joint Manufacturing Tasks

DTx CoLab

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Traditional Industrial Robots

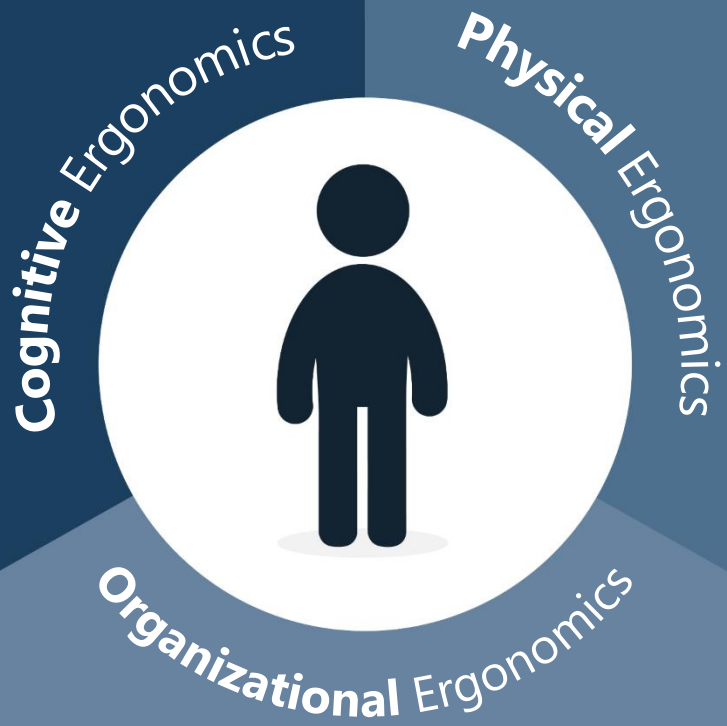
- Worker and robot are separated through guards
- Repeatable tasks of high cadence
- Profitable only with medium to large lot size

Collaborative Robots

- Safe interaction in workspace shared with workers
- Flexible and easily adaptable solution
- Profitable even at a single lot production

Ergonomics & Human Factors (E&HF)

- Perception
- Mental workload
- Decision-making
- Work stress



- Working postures
- Materials handling
- Repetitive movements
- Workplace layout
- Work-related Musculoskeletal disorders (WMSD)

- Work design
- Participatory design

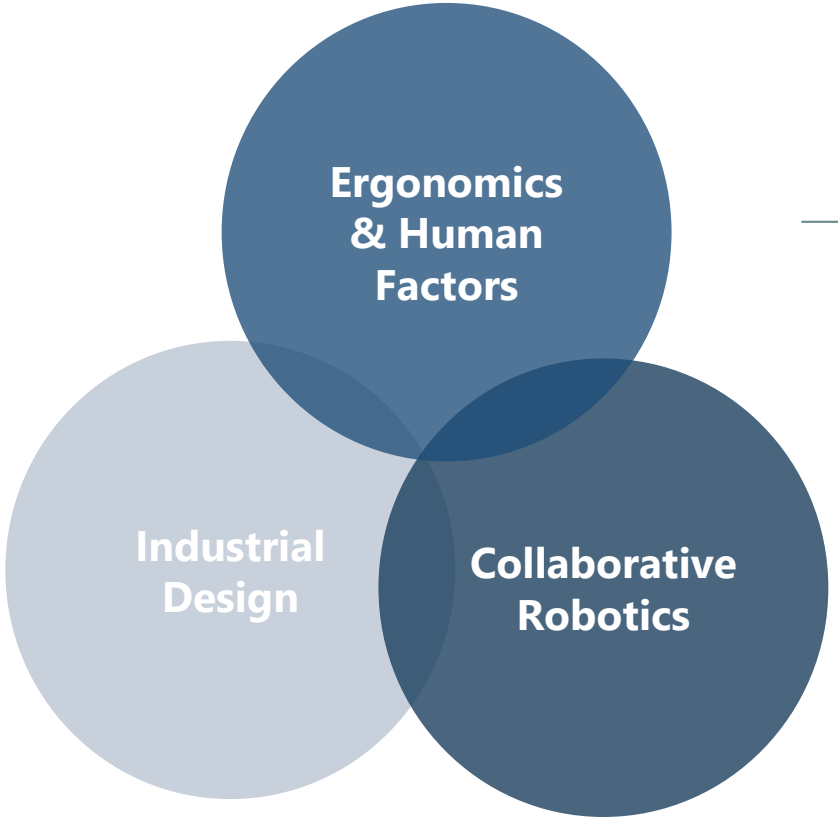
Potential of E&HF and Collaborative Robotics

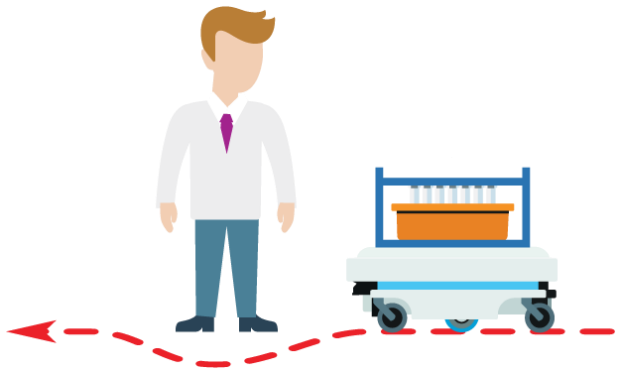
Work-related musculoskeletal disorders (WMSD) in EU [1]

- ≥ 40 million workers affected;
- ~50% of all absences >3 days;
- Total costs €240 billion / year

Human-Robot Collaboration (HRC) to

1. reduce workload;
2. increase productivity:
3. decrease WMSD risk [2, 3].





Sustainable, flexible and Human-centered Design.

[1] Bevan, S.: Economic impact of musculoskeletal disorders (MSDs) on work in Europe, Best Pract. Res. Clin. Rheumatol. 29(3), 356–373 (2015).
[2] Cherubini, A., Passama, R., Crosnier, A., Lasnier, A., Fraisse, P.: Collaborative manufacturing with physical human-robot interaction, Robot. Comput. Integr. Manuf. 40 (2016).
[3] El Zaatari, S., Marei, M., Li, W., Usman, Z.: Cobot programming for collaborative industrial tasks: An overview. Rob. Auton. Syst. 116(April), 162–180 (2019).

Potential of CR & HF

European Commission | Horizon 2020 European Union funding for Research & Innovation

+80M € Funded in H2020 projects involving CR & Ergo

- Shift of focus from **technology-driven** progress to a thoroughly **human-centric** approach
- Technology **maximizes the benefits** for both the **company** and the **worker**

COLLABORATE

"**collaborative assembly** that allocates humans and robots to execute and share tasks **according to their capabilities**"

share work

"**modular** system to **understand** the **environment** and **human actions** through knowledge and sensors"

SHERLOCK UNLOCKING POTENTIALS

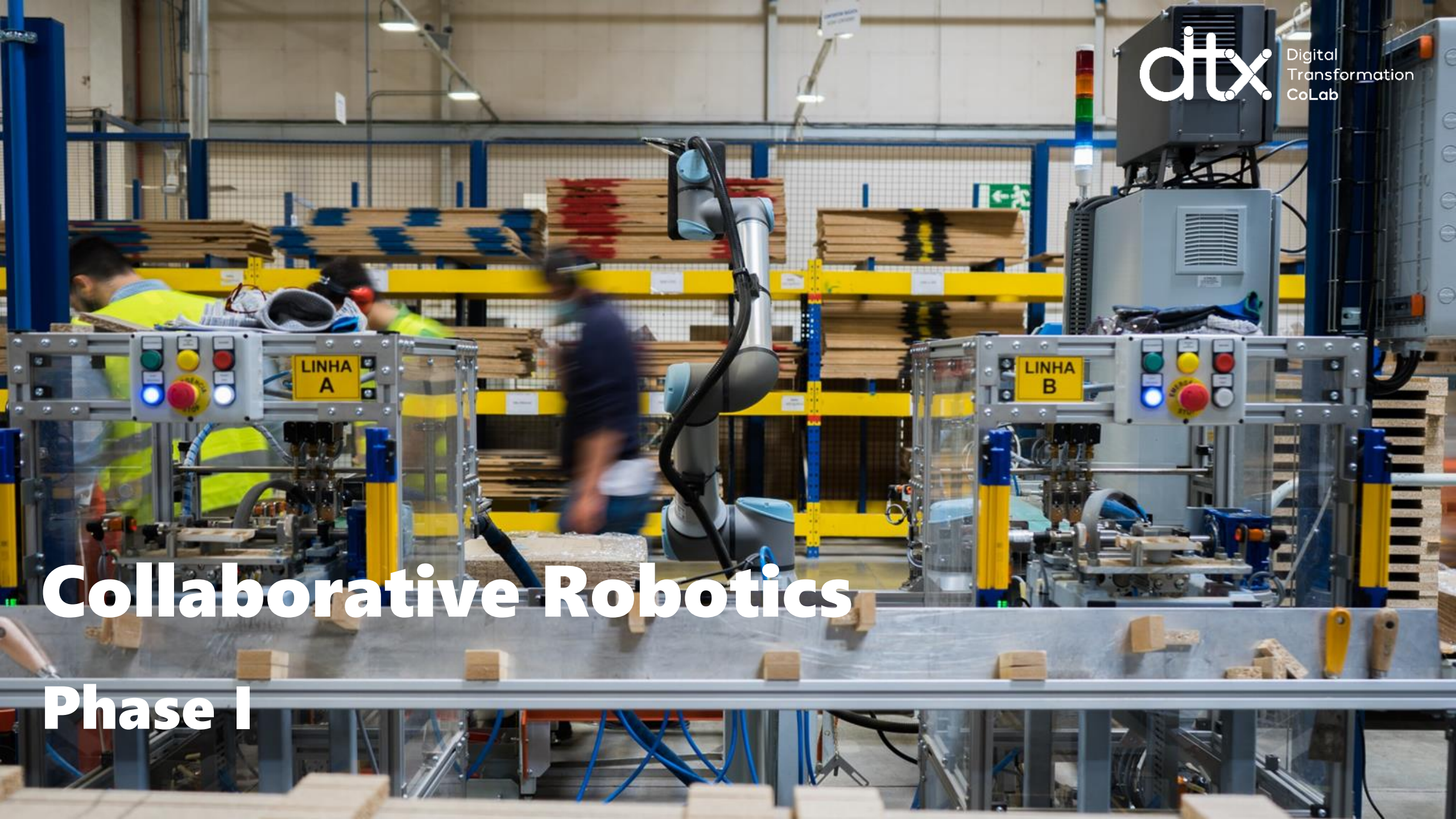
"genuine **HRC** enhanced with **smart technologies** and mechatronic systems - VR, AR, AI"

SYMBIOTIC

"a safe, dynamic, intuitive and cost-effective working environment for **immersive** and **symbiotic collaboration** between humans and robots"

Rossini

"develop a **disruptive**, **inherently** safe **hardware-software platform** for HRC applications in manufacturing.



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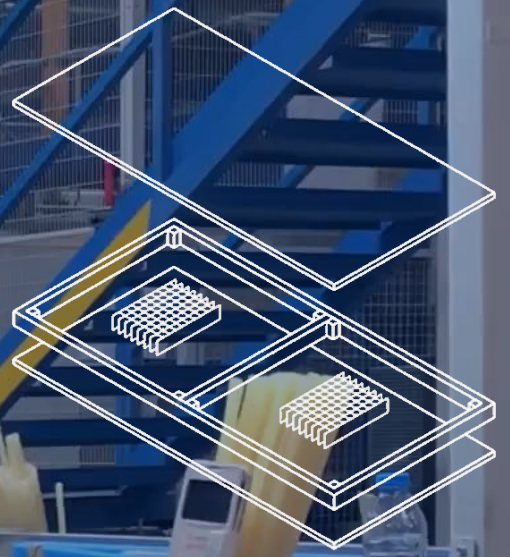
Collaborative Robotics

Phase I

Phase I – Initial Problem



Worst Scoring Tasks

1. Apply glue to the blocks;
2. Fix blocks to the stripes;
3. Transfer stripes to the pallet.

Complaints

1. Musculoskeletal problems;
2. Hot glue burns;
3. Inadequate workstation height.

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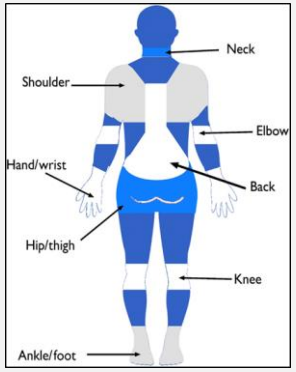
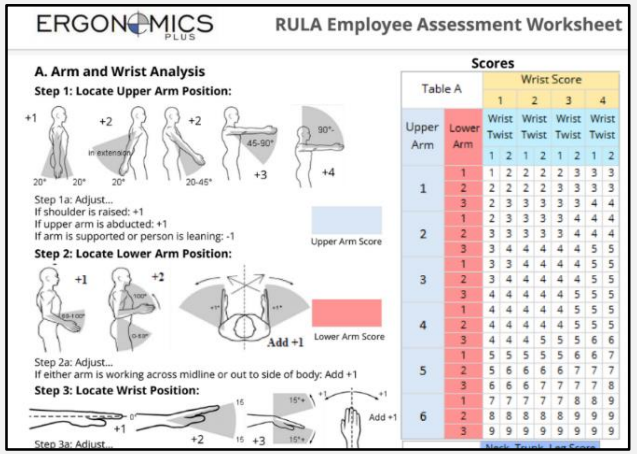
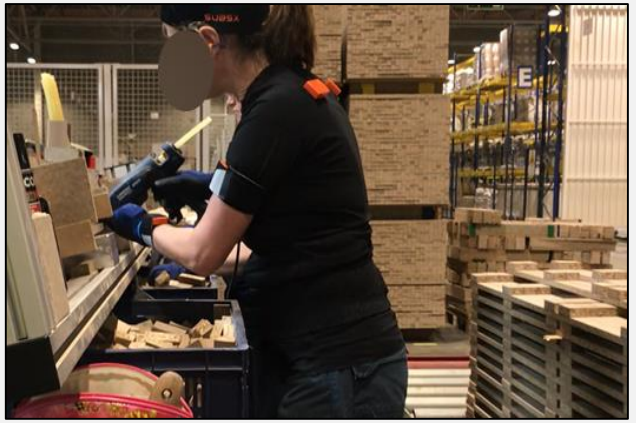
Problem Characterization

- Ergonomic Assessment
  - Rapid Upper Limb Assessment (**RULA**) [1]
  - Revised Strain Index (**RSI**) and Composite Index (**COSI**) [2]
  - Key Indicator Method for assessing physical workload during Manual Handling Operations (**KIM-MHO**) [3].
- Workers' **musculoskeletal symptomology** and **physical exertion** (Mesquita et al., 2010; Borg, 1990).
- **Time-motion study**.
- **Kinematics analysis** (Xsens®).







[1] McAtamney, Lynn, and Nigel Corlett.: RULA: A Survey Method for the Investigation of Work-Related Upper Limb Disorders.. Applied Ergonomics 24 (2): 91–99 (1993).
[2] Garg, Arun, J. Steven Moore, and Jay M. Kapellusch: The Revised Strain Index: An Improved Upper Extremity Exposure Assessment Model. Ergonomics 60(7): 912–22 (2017).
[3] Klussmann, Andre et al.: Risk Assessment of Manual Handling Operations at Work with the Key Indicator Method (KIM-MHO) - Determination of Criterion Validity Regarding the Prevalence of Musculoskeletal Symptoms and Clinical Conditions within a Cross-Sectional Study. BMC Musculoskeletal Disorders 18(1): 1–13 (2017).
[4] Mesquita, C., Ribeiro, J., Moreira, P.: Portuguese version of the standardized Nordic musculoskeletal questionnaire: Cross cultural and reliability. Journal of Public Health 18(5), 461-466 (2010).

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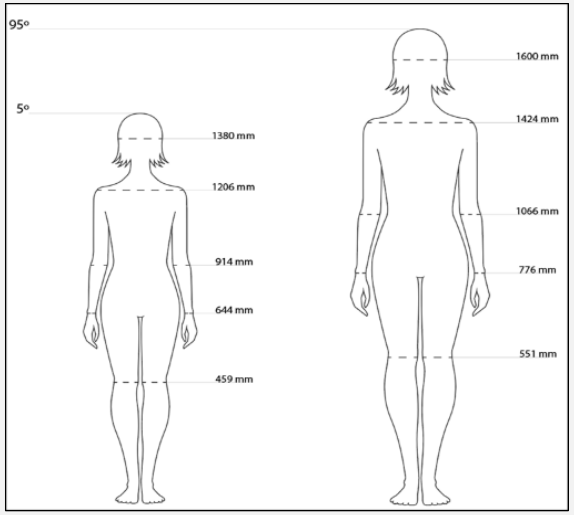
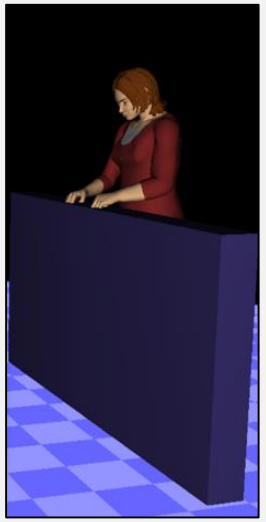
2. Requirements

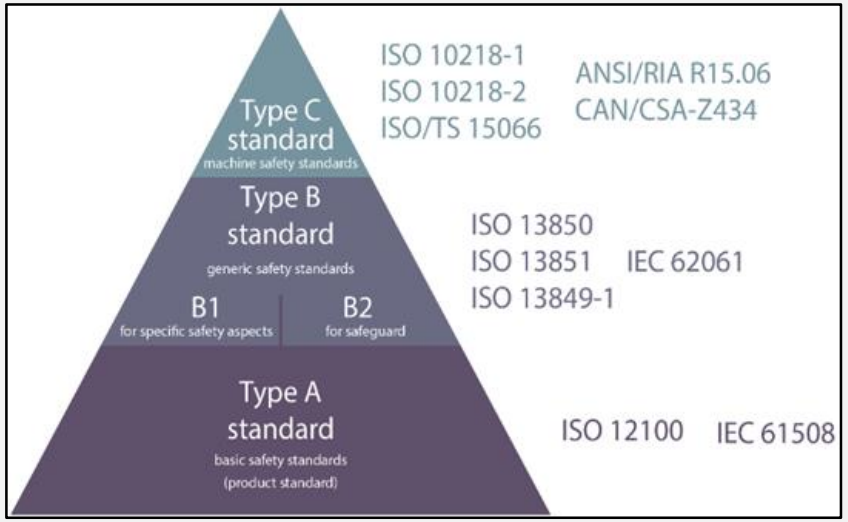
Productivity and **Task allocation** (most critical).

Anthropometric data and **Human simulation** (Jack software – Siemens®).





Safety requirements – International Standards.



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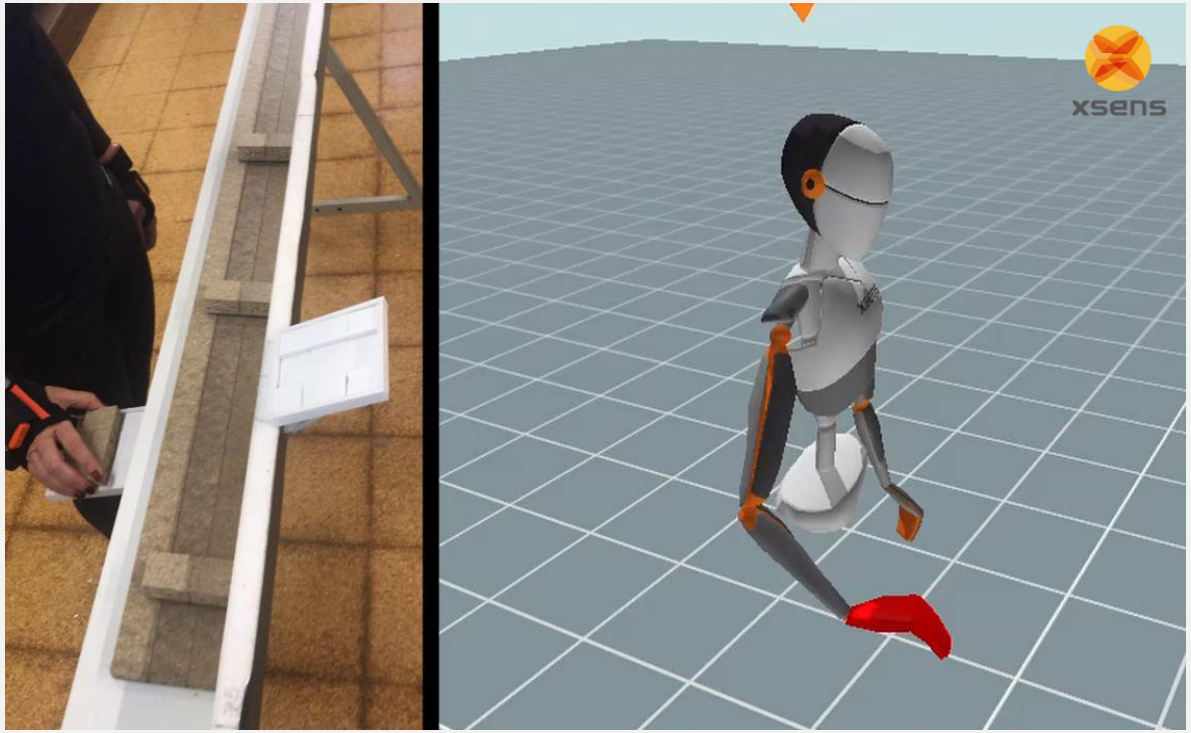
3. Concept & Prototype

- **Tasks simulation** with IKEA workers.
- XSens® technology – **kinematics analysis**.
- **Final design** and definition of system functions.



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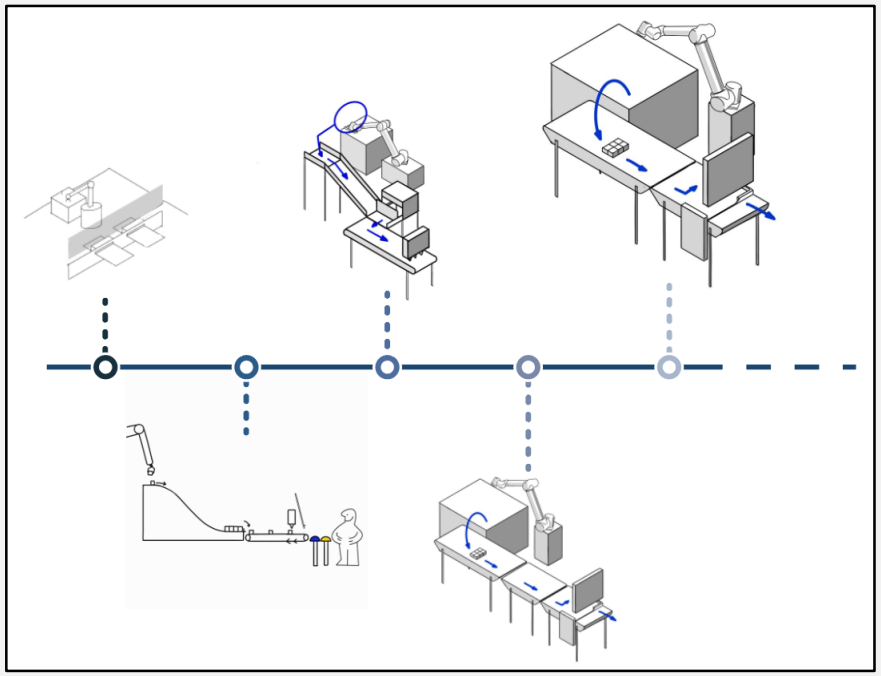
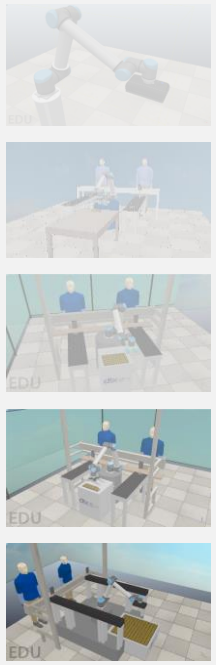
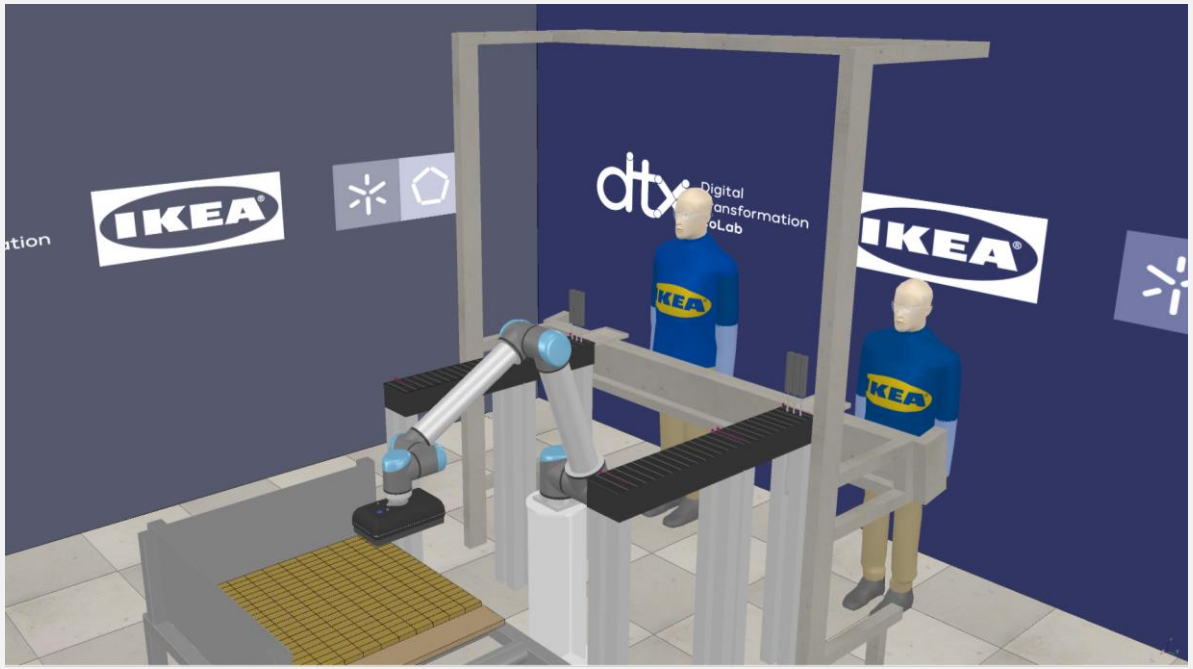
3. Concept & Prototype

- Iterative prototyping to balance requirements and system feasibility
- Task-allocation and flexible product manufacturing
- Fast conceptualization and testing
- Realistic simulation with CoppeliaSim from the creators of V-REP .







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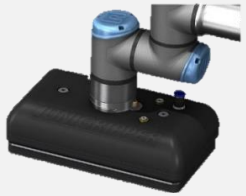
4 Technologies

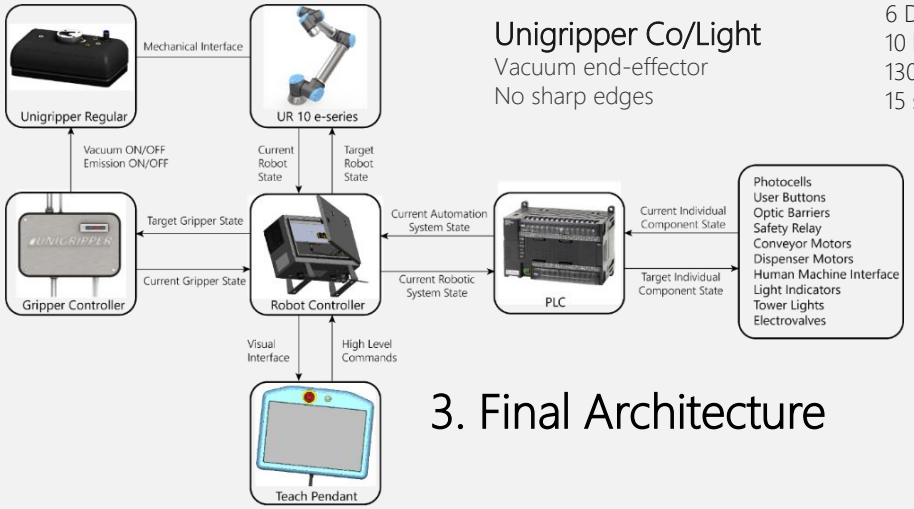
1. Robotic System



Unigripper Co/Light
Vacuum end-effector
No sharp edges

UR 10 e-series
6 DoFs
10 kg payload
1300 mm reach
15 safety functions

3. Final Architecture



2. Automation

Infeed Pallet Indexer

Automatic Glue Dispenser

Multi-Conveyor System

Block Dispenser

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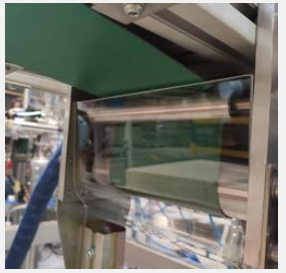
5. Solution

- 1st **COBOT workstation** at IKEA Industry
- Certified, turnkey, and replicable
- Workers' **Co-design** and **Training**

Ergonomic and **Key Performance Indicators** Assessment

Safety Assessment and **Certification**



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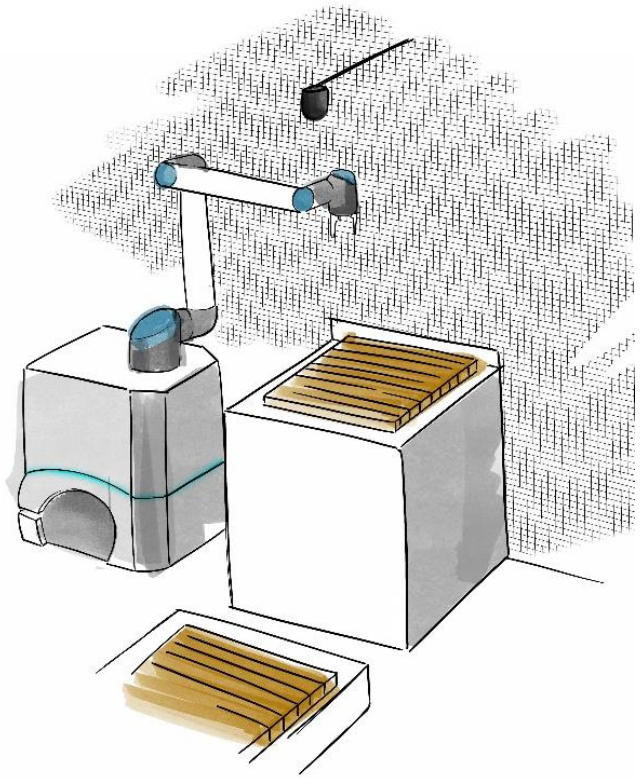
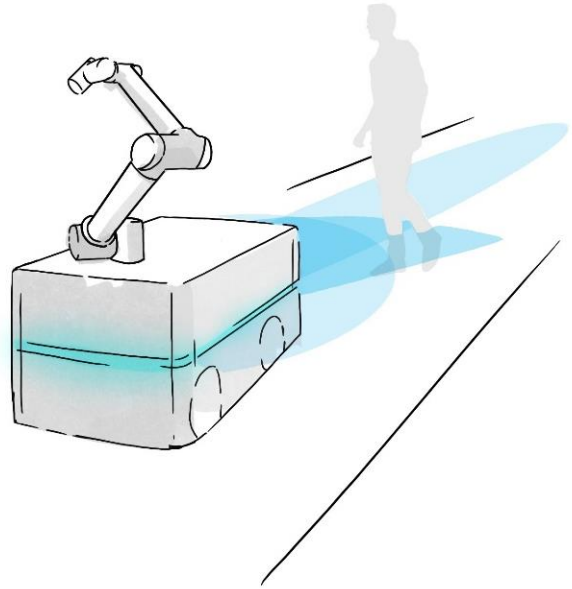
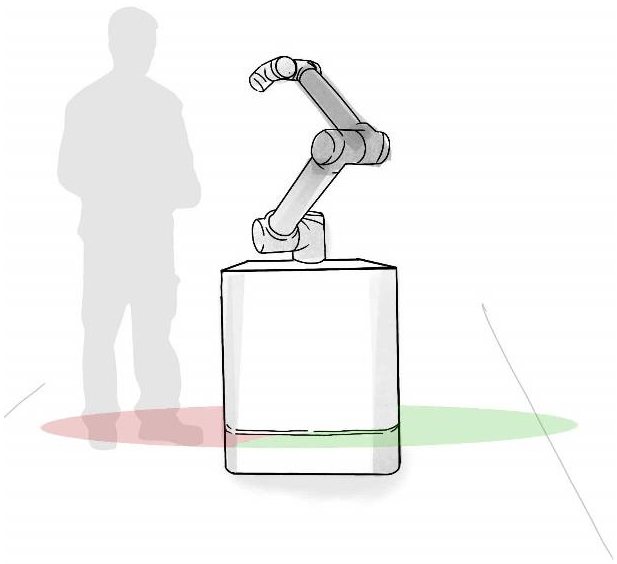
Manual Preassembly Collaborative

Manual		Collaborative
Neglects the workers' **clinical history** and **variability** **Repetitive** and **WMSD prone work**	Description	**First Human-centred** cobot station at IKEA Industry **Certified**, **turnkey**, and **replicable** solution
Frequent occurance of **glue burns** **Strenuous tasks** for the hand-wrist system	Worker satisfaction	Perception of **safety** even without safeguards **Less** musculoskeletal **discomfort** and **easier tasks**
Cycle time of **46.2 seconds** Glue consumption of **792 cm³** per pallet	Productivity	Cycle time of **42.9 seconds** — **7%** less time Glue consumption of **566 cm³** per pallet — **29%** less glue
Risk scores of ergonomic assessments Weighted **RULA** 3.8 **COSI** 41.7	Ergonomics	2.9 Weighted **RULA** 25.3 **COSI** **24%** up to **39%** improved ergonomic scores





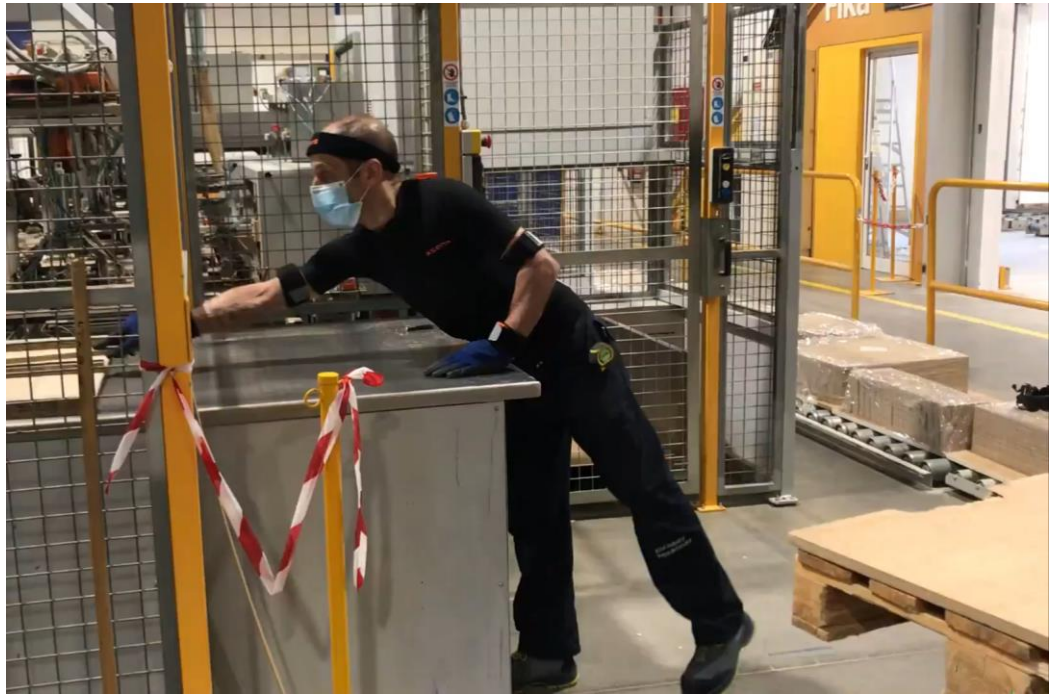


Collaborative Robotics

Phase II

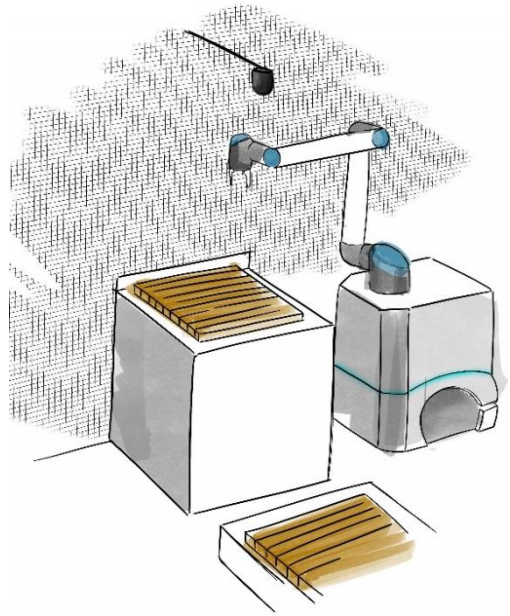
MasterForm Digital Transformation

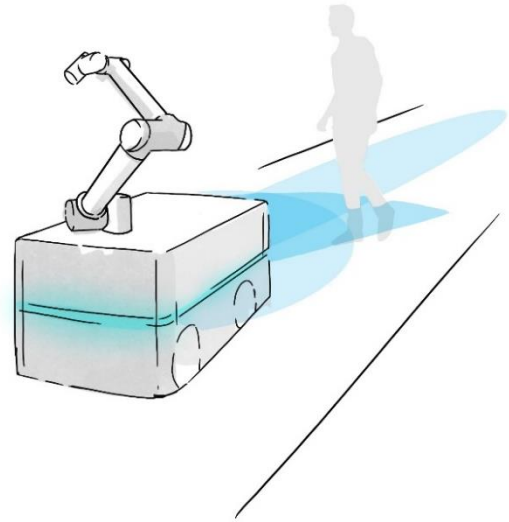
Current Situation

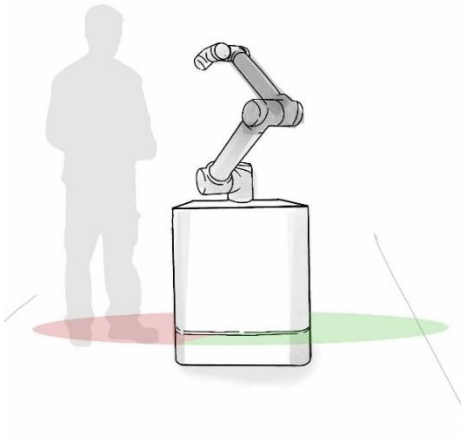


What it can be

- **Mitigation** of **musculoskeletal risk** in manual picking and palletizing, integration of **lean** principles
- **Autonomous** and **Human-aware navigation** between workstations.
- Autonomous **pick-and-place** and quality control.
- **Monitor surrounding** area for intrusion of workers or machines
- Industry-ready, **safety-certified** and fully-integrated **AI-based** Mobile Manipulator.



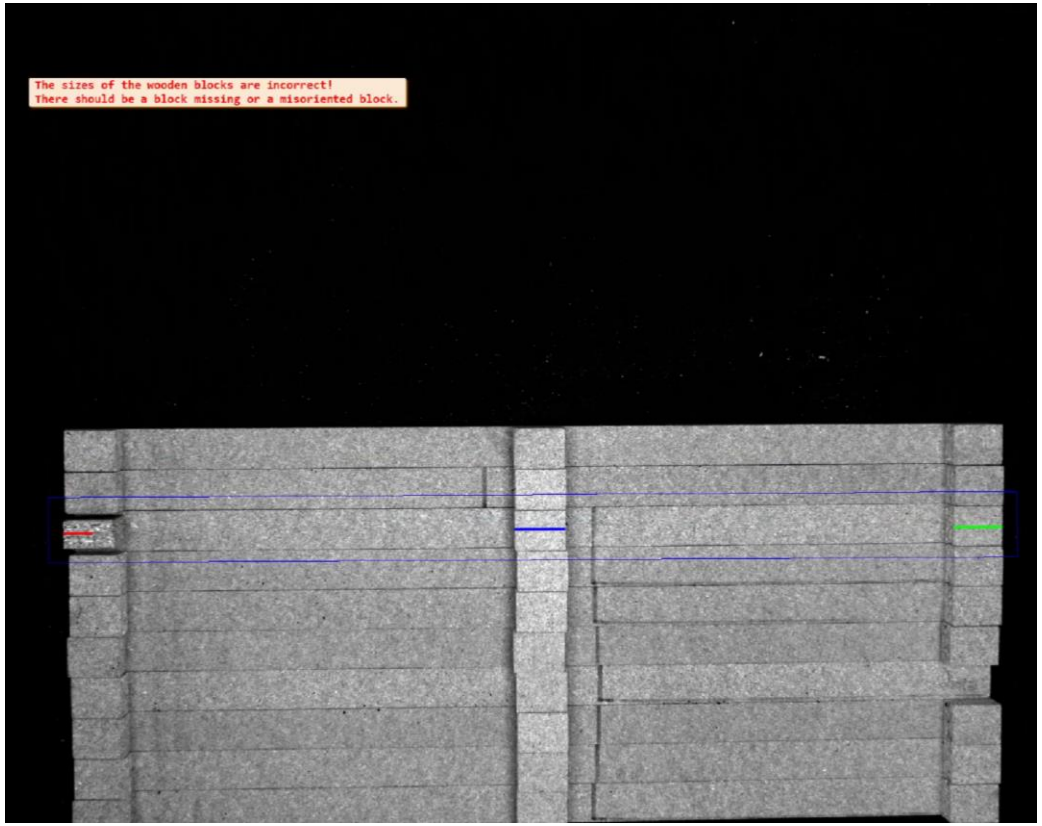




Perception

- Detection of preform type, cadence, and position/orientation
- Quality control – missing blocks and incorrect fixation
- Autonomous collision-free navigation

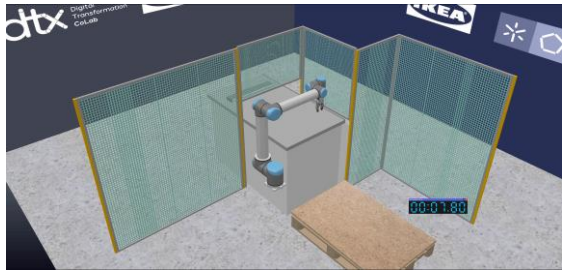
HALCON
the power of machine vision



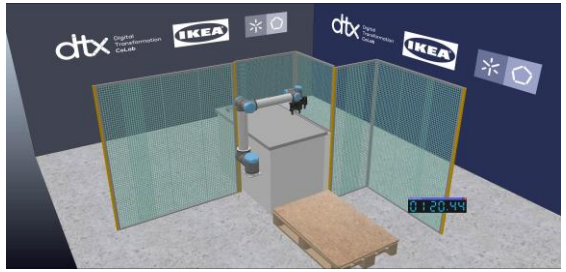
Manipulation

- Integration of UR10e with a collaborative gripper – URSim
- Obstacle avoidance motion planning for static and dynamic scenarios.
- Palletizing application

SD01 Preform 1



TP01S

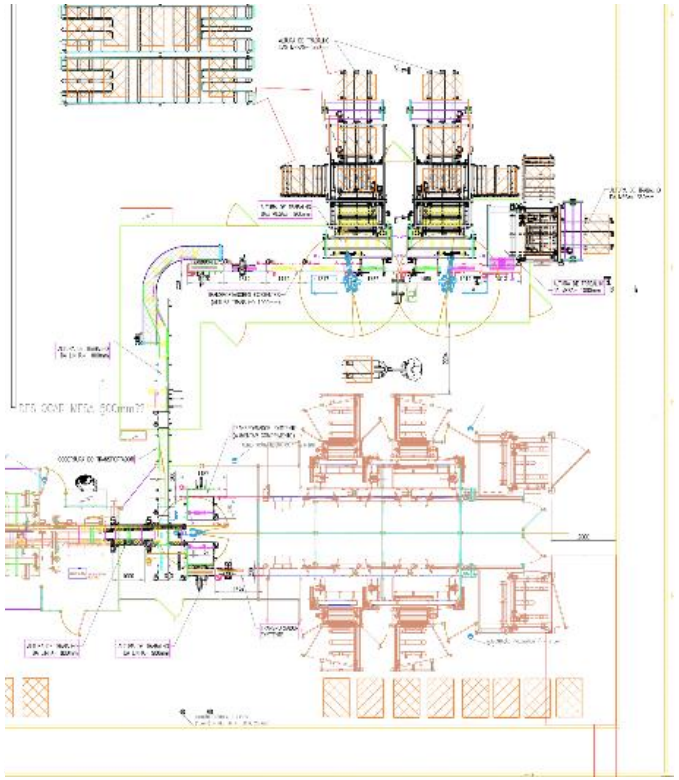


SD01 Preform 2

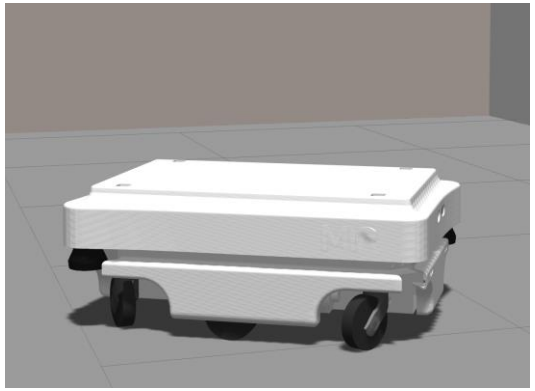
TP02,3,4S

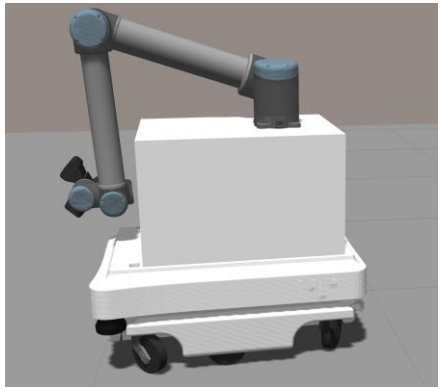
Navigation

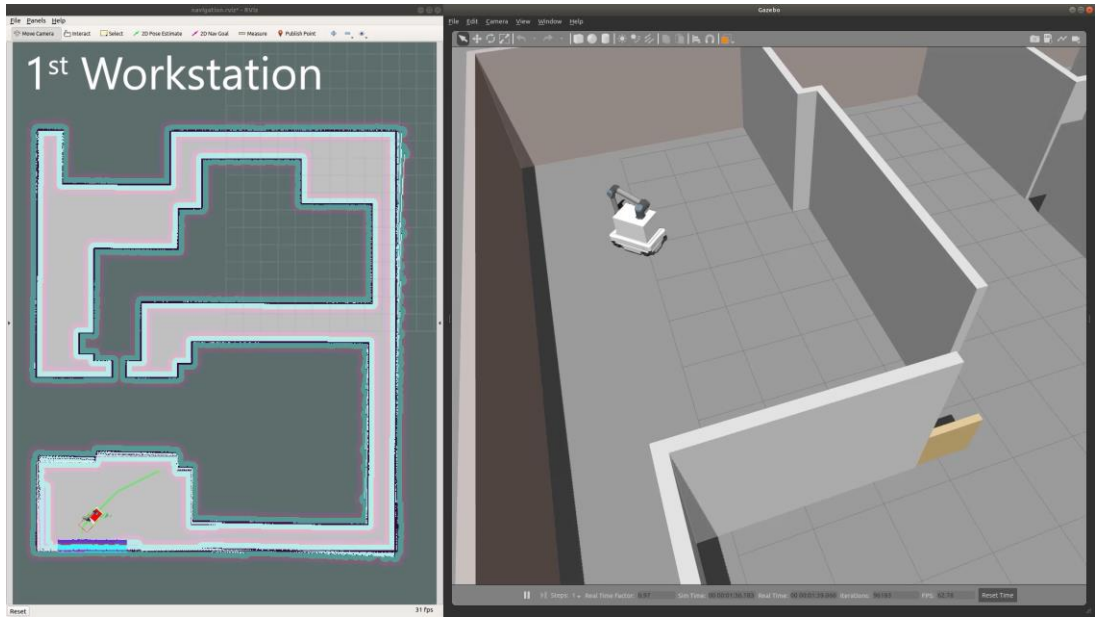
- Mapping real environments in virtual worlds
- Integration of MiR 200 with UR10e
- Dynamic and static obstacle avoidance



Mobile Manipulator







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Outputs

Scientific Publications

1. Faria, C., Vilaca, J.L., Monteiro, S., Erlhagen, W., Bicho, E.: Automatic Denavit-Hartenberg Parameter Identification for Serial Manipulators. In: IECON 2019 - 45th Annual Conference of the IEEE Industrial Electronics Society. pp. 610–617. IEEE, Lisbon (2019).

2. Colim, A., Carneiro, P., Costa, N., Faria, C., Rocha, L., Sousa, N., Silva, M., Braga, .A.C., Bicho, E., Monteiro, S., Arezes, P.: Human-Centered Approach for the Design of a Collaborative Robotics Workstation. In: Arezes, P., Santos Baptista, J., Barroso, M.P., Carneiro, P., Cordeiro, P., Costa, N., Melo, R.B., Sérgio Miguel, A., and Perestrelo, G. (eds.) Occupational and Environmental Safety and Health II. Studies in Systems, Decision and Control. pp. 379–387. Springer (2020).

3. Colim, A., Faria, C., Braga, A.C., Sousa, N., Rocha, L., Carneiro, P., Costa, N., Arezes, P. Towards an Ergonomic Assessment Framework for Industrial Assembly Workstations - A case study. Appl. Sci. 2020, 10, 3048;

4. Faria, C., Colim, A., Cunha, J., Oliveira, J., Costa, N., Carneiro, P., Monteiro, S., Bicho, E., Rocha, L.A., Arezes, P.: Safety Requirements for the Design of Collaborative Robotic Workstations in Europe – a review. In: Arezes P., Boring R. (eds) Advances in Safety Management and Human Performance. AHFE 2020. Advances in Intelligent Systems and Computing, vol 1204. Springer, Cham.

5. Colim, A., Morgado, R., Dinis-Carvalho J., Sousa N. Impact of collaborative robotics implementation in an assembly process: Case study in a furniture manufacturer, Proceedings of 2100 Projects Association Joint Conferences 8 (2020) X-X ISSN: 2183-3060 (Presented)

6. Colim, A., Morgado, R., Dinis Carvalho, J., Sousa, N. Impact of collaborative robotics in human factors and performance. (Submitted)

7. Colim, A., Morgado, R., Carneiro, P., Costa, N., Faria, C., Sousa, N., Rocha, L., Arezes, P. Lean manufacturing and ergonomics integration: defining productivity and wellbeing indicators in a Human-robot workstation. (Submitted)

8. Colim, A., Faria, C., Cunha, J., Oliveira, J., Sousa,N., Rocha, L. Safe design and development of an assembly workstation with collaborative robotics. (Submitted)

9. Cunha, J. G., Faria, C., Colim, A., Oliveira, J., Rocha, L. A., Silva, M., Monteiro, S., Bicho, E. From Handcrafting to a Certified and Ergonomic Collaborative Workstation: the Digital Transformation Process. IEEE International Conference On Intelligence And Safety For Robotics - IEEE ISR2021

Projects

FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA EDUCAÇÃO E CIÊNCIA

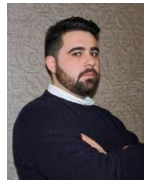
Título do projeto (em inglês)
Project title (in english)
I-CATER – Intelligent robotic Coworker Assistant for industrial Tasks with an Ergonomics Rationale

Completed M.Sc.

João Gaspar Oliveira Cunha
A Collaborative Work-Cell to Improve Worker Ergonomics and Productivity

Rita Martins Morgado
Impacto na produção de células de robótica colaborativa em postos de operação manual

Scholarship Ph.D.



MIT Portugal

Framework for ergonomic assessment in a collaborative robotic system

Ongoing M.Sc.

Skeleton-based Action Recognition in Industrial Settings

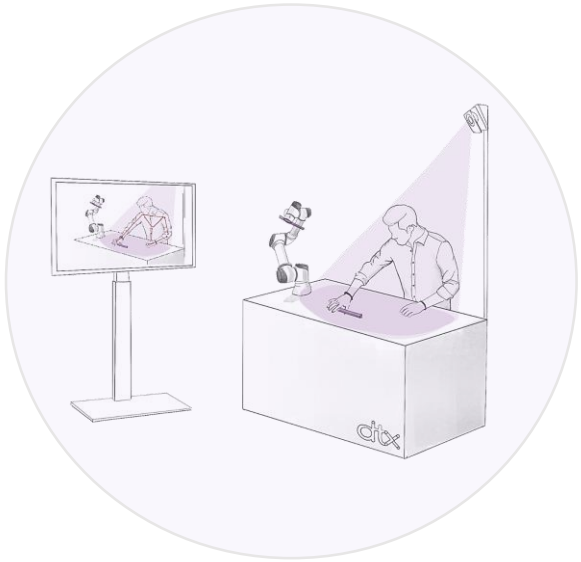
Prospective study for the implementation of collaborative robotics in the manual packaging section of a furniture company

Domain Randomization applied to Collaborative Robotics

Impact of the Implementation of a Collaborative Robot on Human Factors and Production Performance: A Case Study

Competences

1. Create certified **industry-ready** solutions in compliant with European Directives on Human-Machine Interfaces
2. **Human-centered** design of workstations balancing **productivity**, **ergonomics**, and **technical** requirements
3. **Fast-conceptualization** of collaborative workstations in **virtual simulators**
4. **Application of research** with **cutting-edge technologies** for real-world projects
5. Creation of **critical-knowledge** and **disruptive concepts** for DTx associates



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Experiencing the Future

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