

# ADAPTIEVE ROBOT

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BRUBOTICS  
HUMAN ROBOTICS  
RESEARCH CENTER

FLANDERS  
MAKE  
DRIVING INNOVATION IN MANUFACTURING

## CONTENT

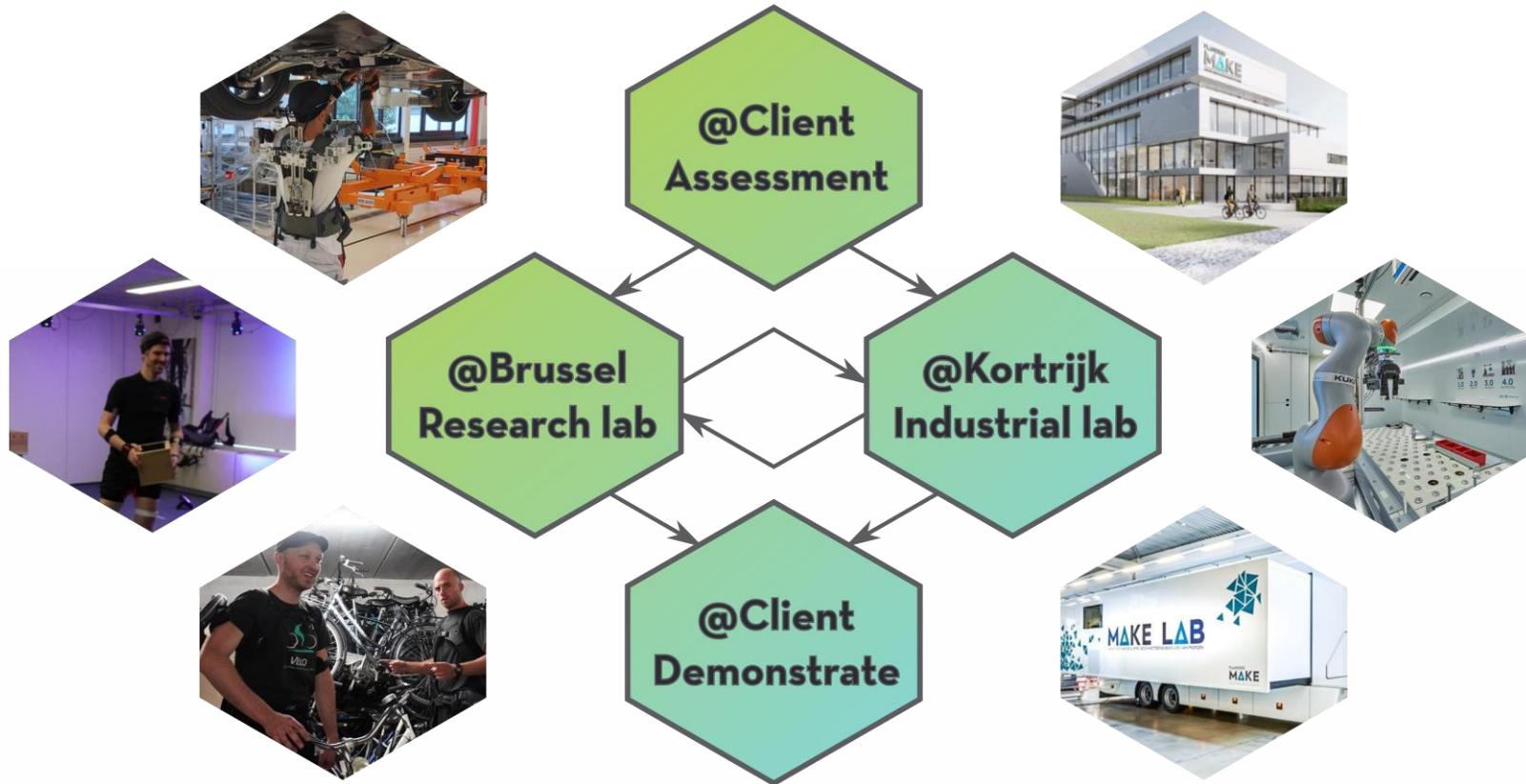
- AugmentX
- EU SOPHIA
- Ergonomic co-manipulation
- Task allocation
- Other applications

# AUGMENTX

- AugmentX opening on January 11, 2024
- Different stakeholders invited: companies, researchers, journalists
- <https://trends.knack.be/kanaal-z/z-nieuws/bekijk-augmentx-bewijst-voordelen-van-exoskelet-op-de-werkvloer/>



# AUGMENTX



- Holistic assessment of labour
- Exploring exoskeletons
  - Qualitative assessment, reporting
  - Quantitative assessment, reporting
- Introduction of collaborative robots
  - Development of use case: Gripper, Sensors, Software, Testing, demonstration ...

# AUGMENTX



# AUGMENTX

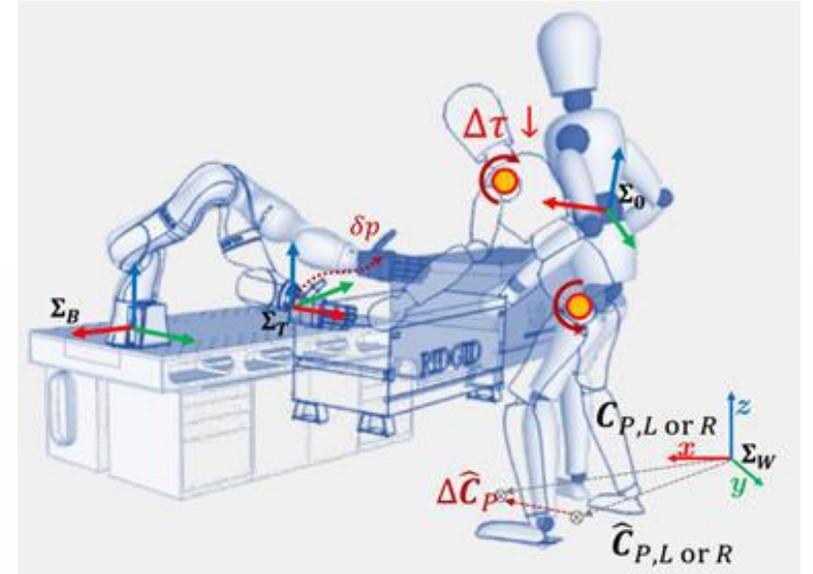


Leverage our expertise to boost the quality and speed of your research.

- Assess human physical and cognitive stress
- Research in exoskeletons
- Synchronisation of third-party measurement devices
- Develop cobot-demonstrators

# EU SOPHIA

- Development of socially cooperative human-robot systems in agile production
- Improve human ergonomics, trust in automation, and productivity in manufacturing environments
- Achieve a reconfigurable, flexible, and resource-efficient production



## EU SOPHIA

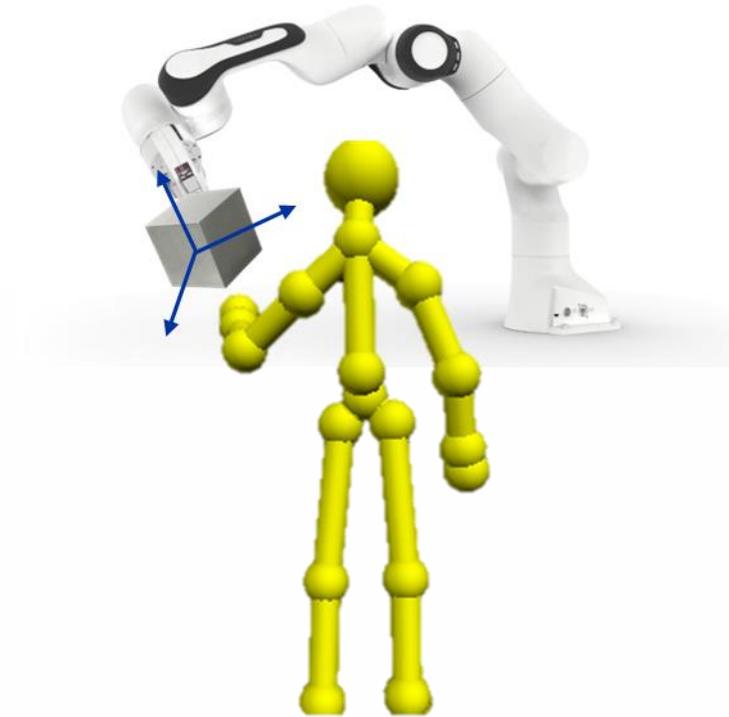


- >150 Publications in high-impact journals and conferences
- 26 exploitable results with 12 innovations selected by the EU's Innovation Radar
- 4 Best PhD thesis (2 national; 1 EU Georges Giralt winner, 1 finalist EU Georges Giralt)
- 7 Best paper awards/finalists
- 4 Patents
- Award of the EU success stories by EU commission
- 3 industrial and 2 healthcare use-cases fully integrated

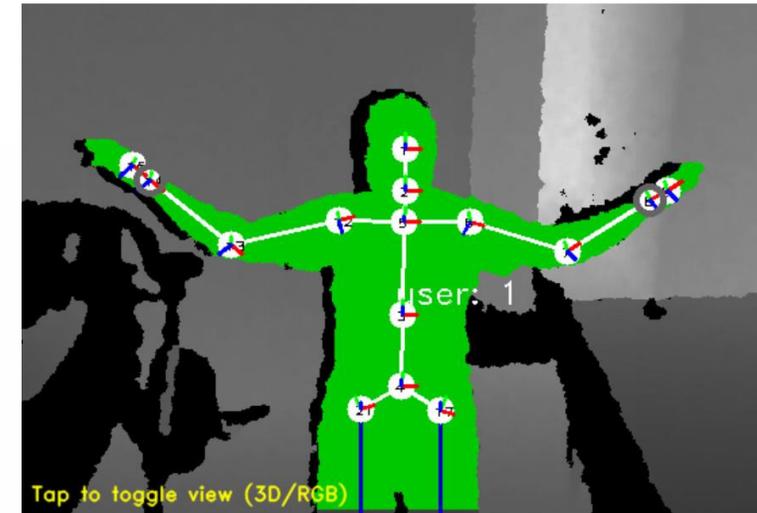
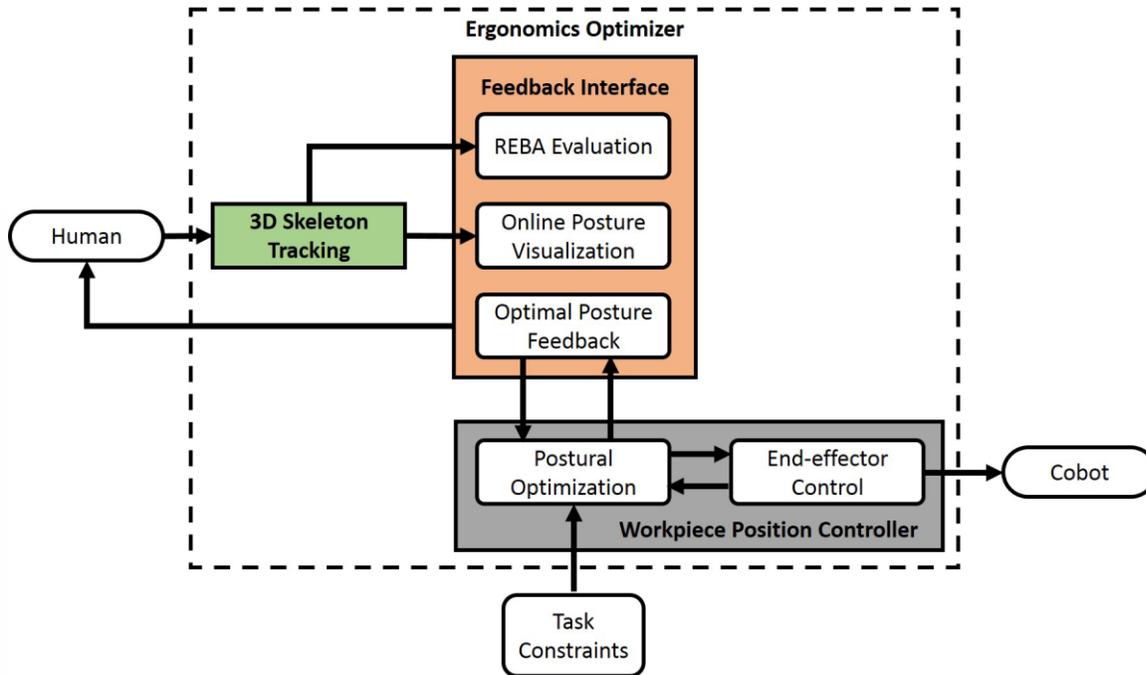
# ERGONOMIC CO-MANIPULATION

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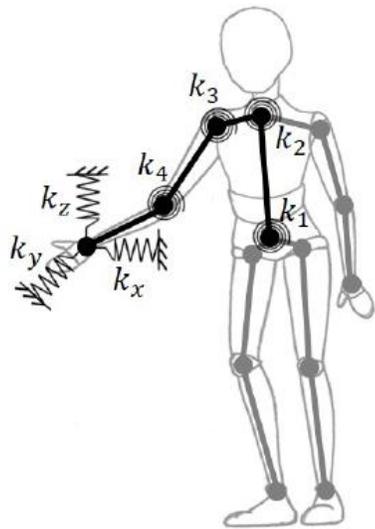
- Cobots assist during human-robot tasks (e.g. non-ergonomic postures like picking objects from low tables).
- The robot can reposition objects/tools for better ergonomic alignment.
- Feedback on posture should be provided when repositioning is not possible



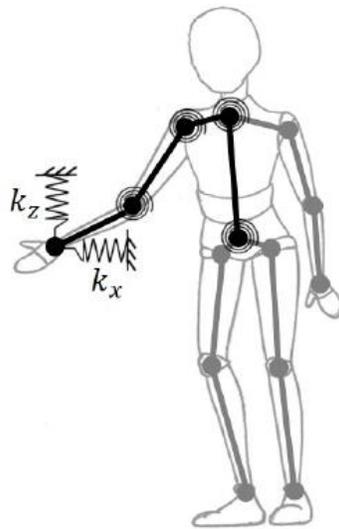
# ERGONOMIC CO-MANIPULATION



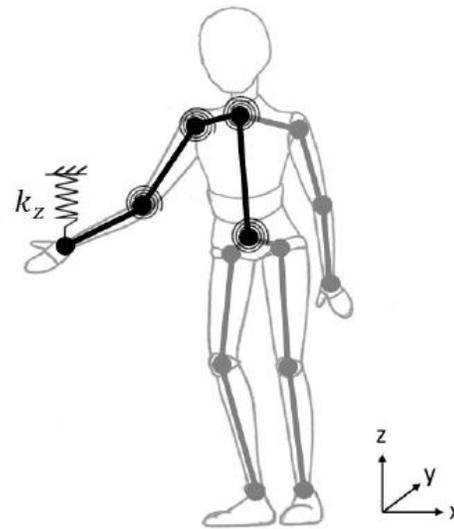
# ERGONOMIC CO-MANIPULATION



(a) Wrist's position locked



(b) Wrists' y and z positions locked



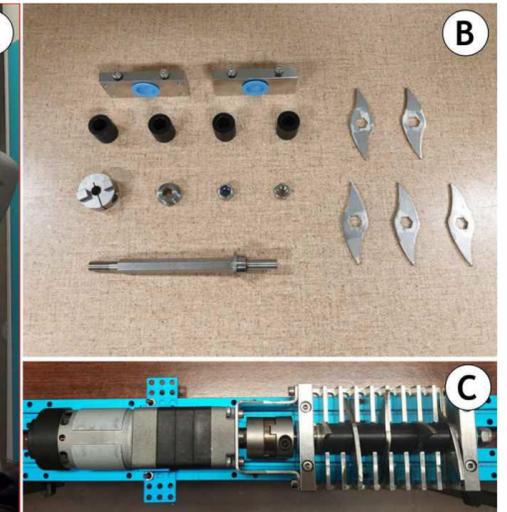
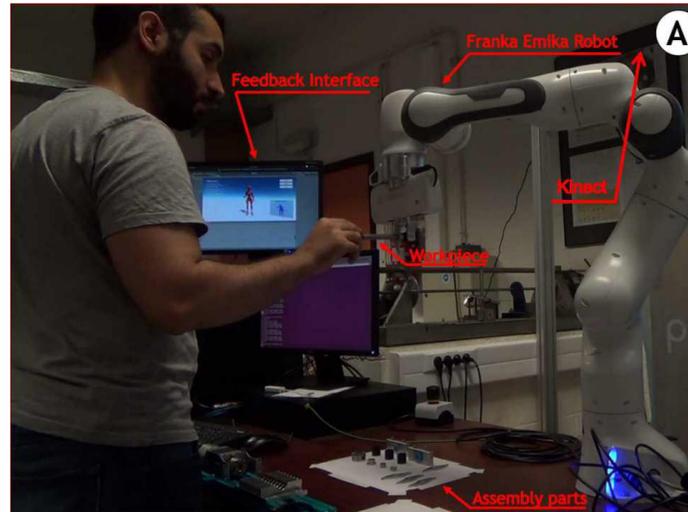
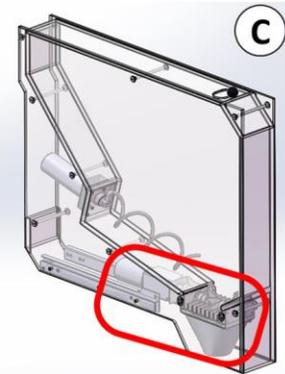
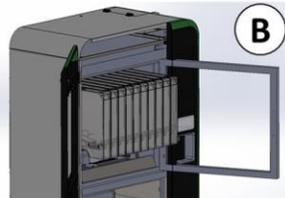
(c) Wrist's z position locked

$$C_h \dot{\Theta}_h + K_h(\Theta_h - \Theta_h^*) = T_h$$

$$T_h = J_h^T F_h$$

$$F_h = \begin{bmatrix} -k_x(x - x_d) - k_{I,x} \int (x - x_d) dt \\ -k_y(y - y_d) - k_{I,y} \int (y - y_d) dt \\ -k_z(z - z_d) - k_{I,z} \int (z - z_d) dt \\ -k_\theta(\theta - \theta_d) - k_{I,\theta} \int (\theta - \theta_d) dt \\ -k_\beta(\beta - \beta_d) - k_{I,\beta} \int (\beta - \beta_d) dt \\ -k_\delta(\delta - \delta_d) - k_{I,\delta} \int (\delta - \delta_d) dt \end{bmatrix}$$

# ERGONOMIC CO-MANIPULATION



# ERGONOMIC CO-MANIPULATION

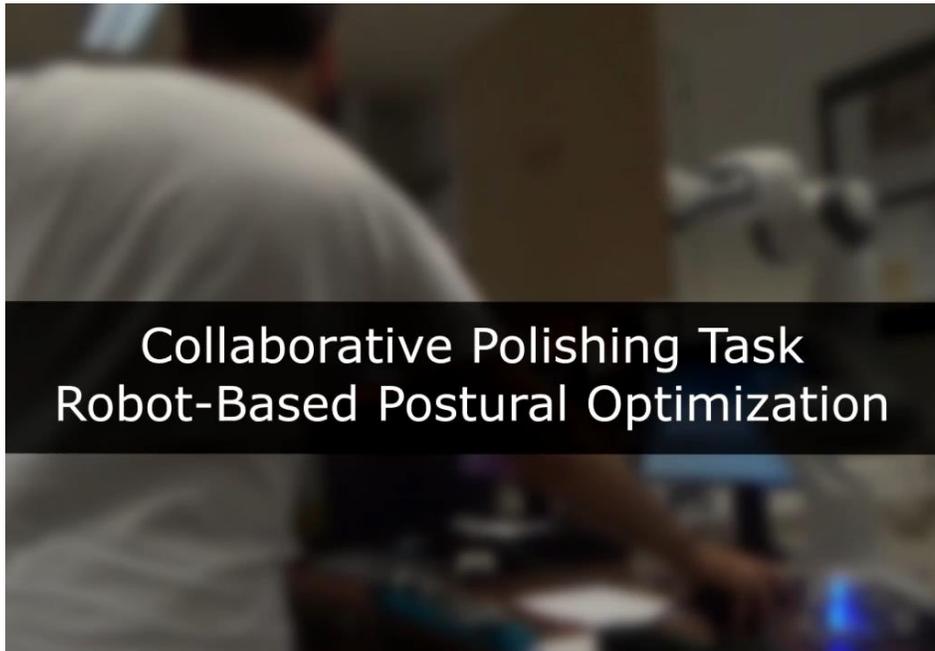
## Postural Optimization for Improved Ergonomics during Human-Robot Collaborative Tasks



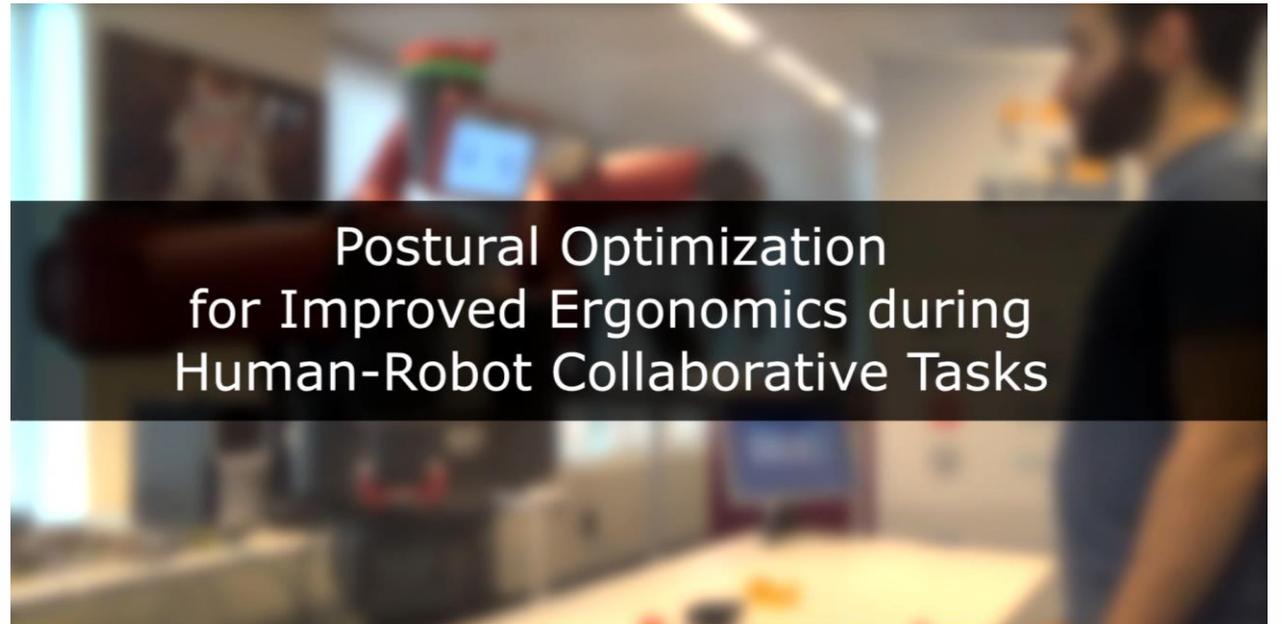
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# ERGONOMIC CO-MANIPULATION



Collaborative Polishing Task  
Robot-Based Postural Optimization

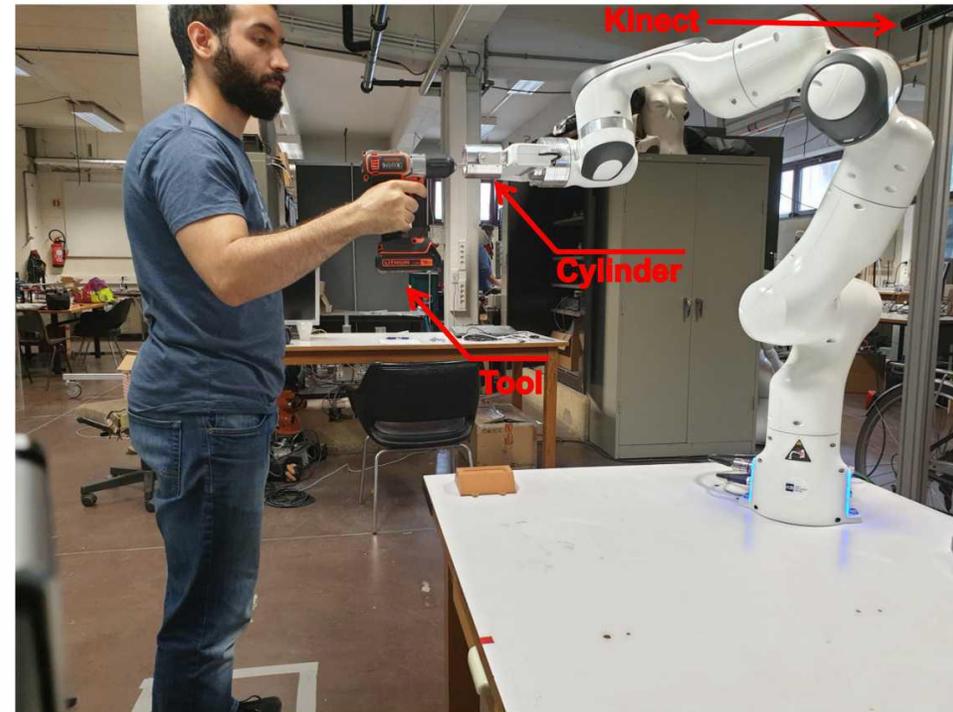


Postural Optimization  
for Improved Ergonomics during  
Human-Robot Collaborative Tasks

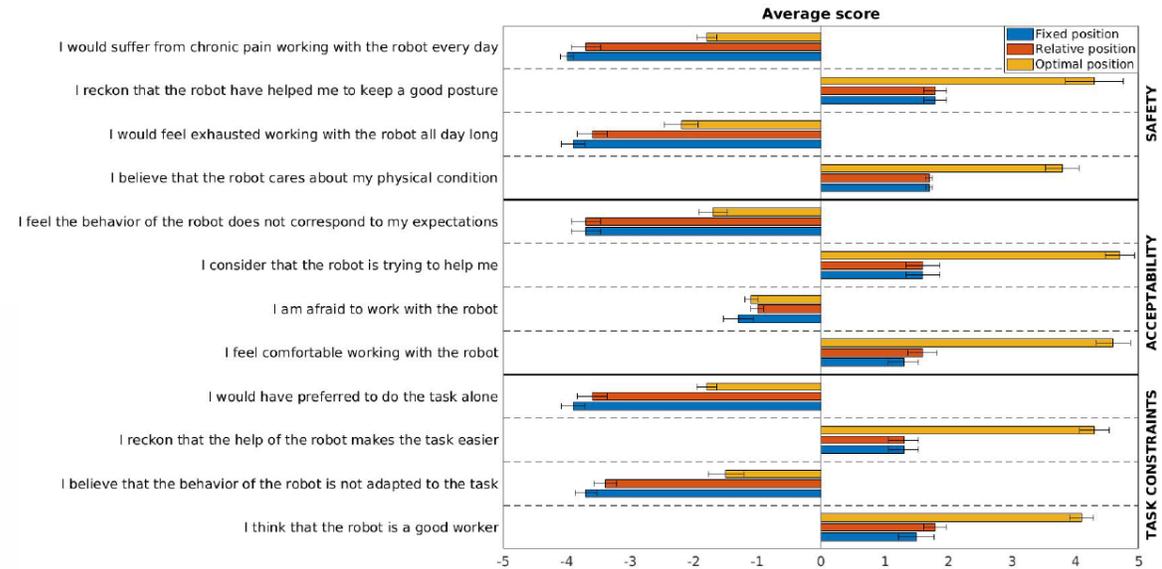
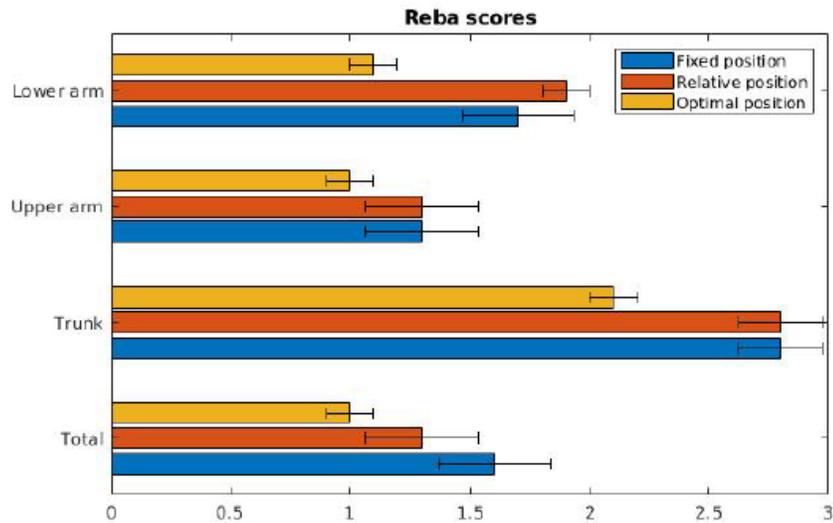


# ERGONOMIC CO-MANIPULATION

- Experimental setup where robot holds a cylinder that is polished by user
- The robot brings the cylinder position to improve the body posture
- User study with 10 participants in three different modes (fixed, relative and optimal)

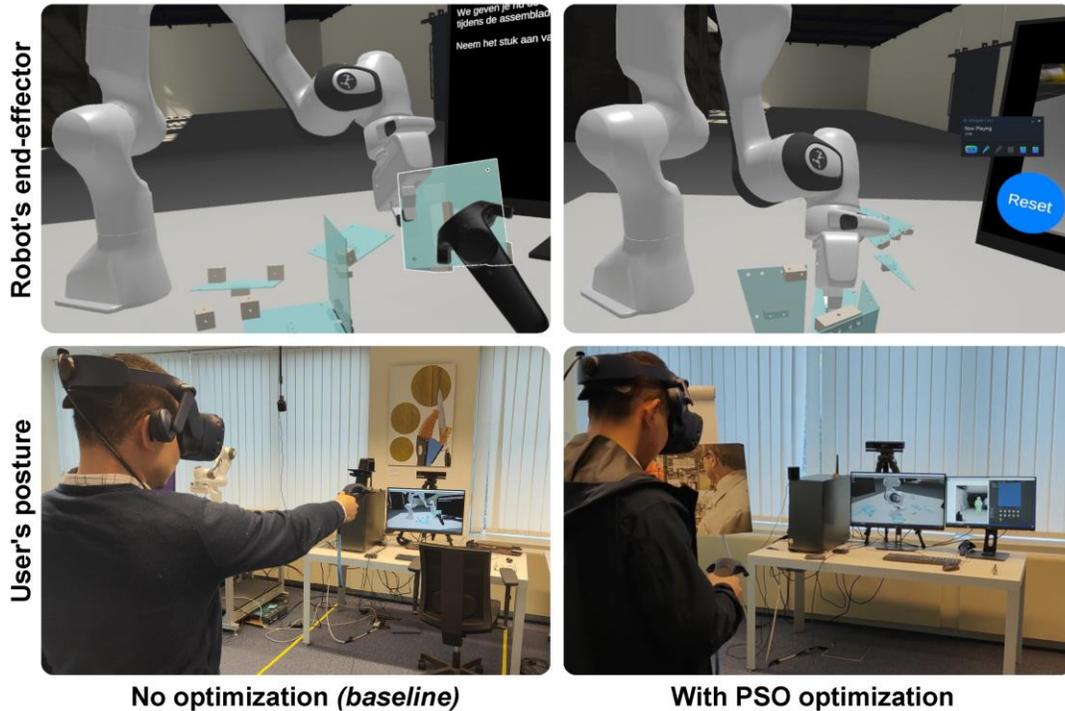


# ERGONOMIC CO-MANIPULATION



- The interaction with the robot was assessed with a questionnaire of 12 questions.
- **Results:**
  - The optimal mode was ranked as the preferred behaviour among users.
  - The total reba score of the optimal mode is about 0.6 lower than in the fixed mode

# ERGONOMIC CO-MANIPULATION

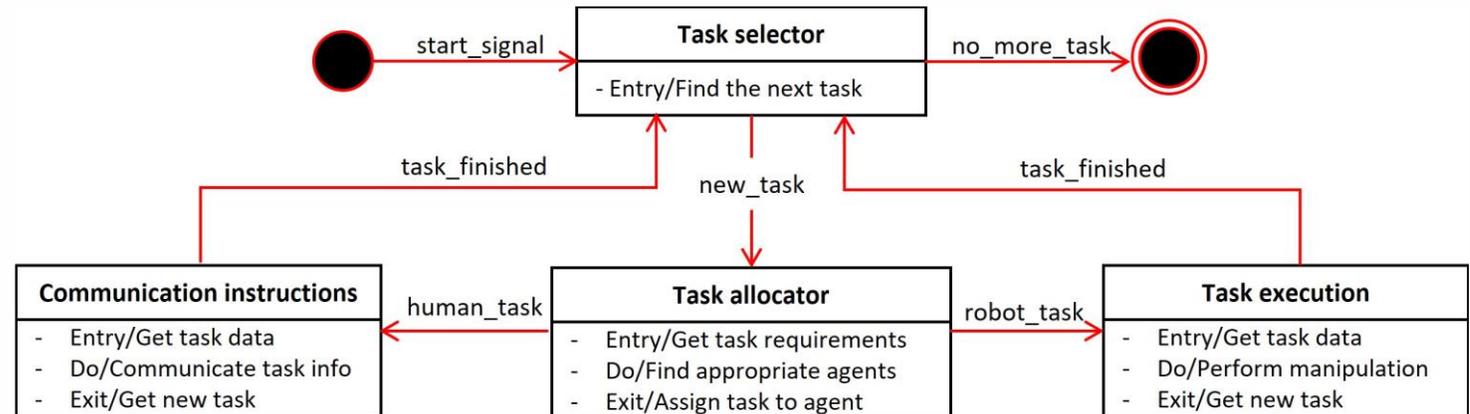


- PSO algorithm optimizes the robot's end-effector placement to reduce user pressure.
- Workspace dimensions (elbow height, robot-to-human distance) are calculated for efficiency and ergonomics.
- Placement ensures minimal robot movement and improved ergonomics, based on REBA standards.
- Robot adjusts its end-effector to enhance user comfort, with ergonomic feedback analyzed.

# TASK ALLOCATION

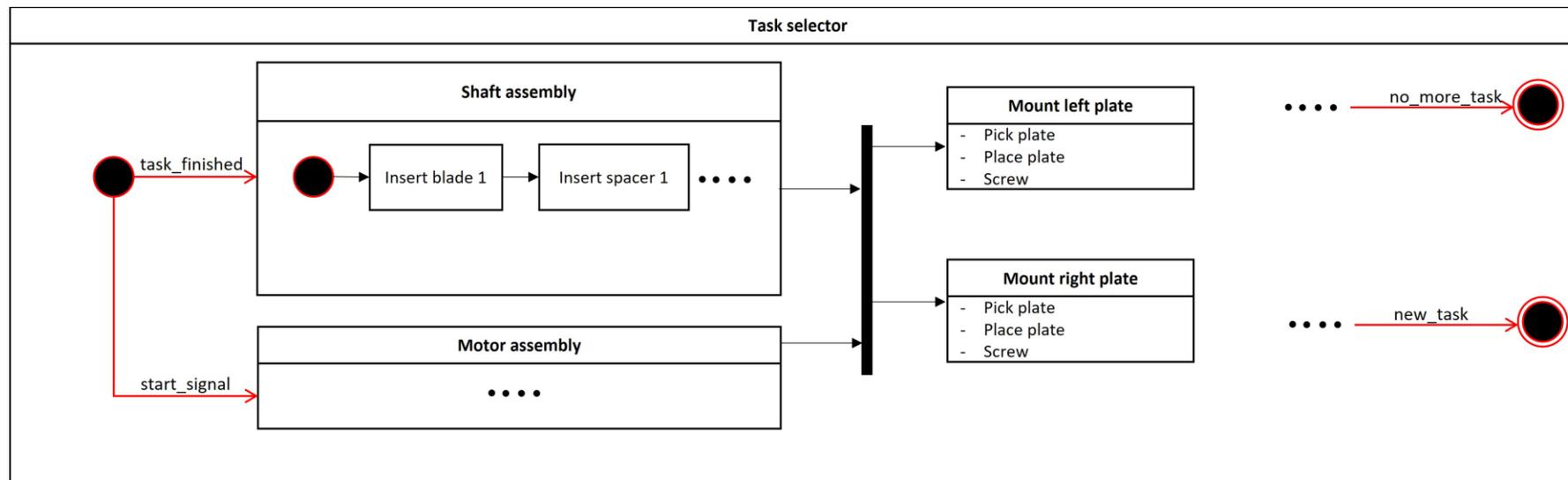
# TASK ALLOCATION

- Tasks are split recursively in sub-tasks until elementary tasks are reached.
- Four modules:
  - Task selector
  - Task allocator
  - Communication instructor
  - Task executor



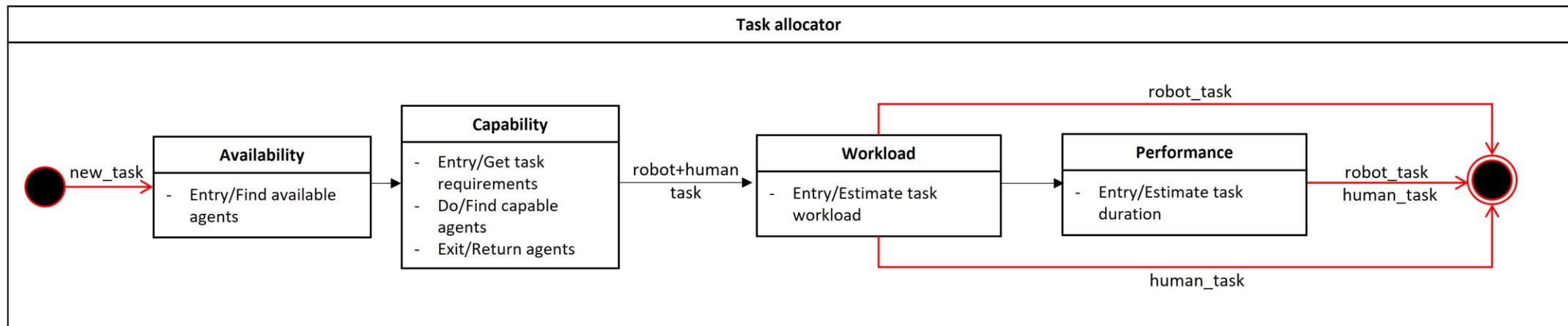
# TASK ALLOCATION

- Task = group of state-machines (sub-tasks).
- Example: shaft assembly is made of the state machines "insert blade 1", "insert spacer 1", etc.



# TASK ALLOCATION

- Allocation of task to the most suitable agent.
- Capability evaluated based on task requirements and agent information.
- Task assignment according to current human workload and agent performances.



# TASK ALLOCATION

Agents' characteristics: payload, speed, reach, equipped gripper type, and gripping force.

Basic objects' characteristics include weight, dimension, position, and current grasping status (1 = grasped, 0 = not grasped).

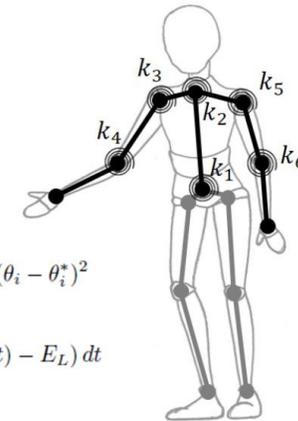
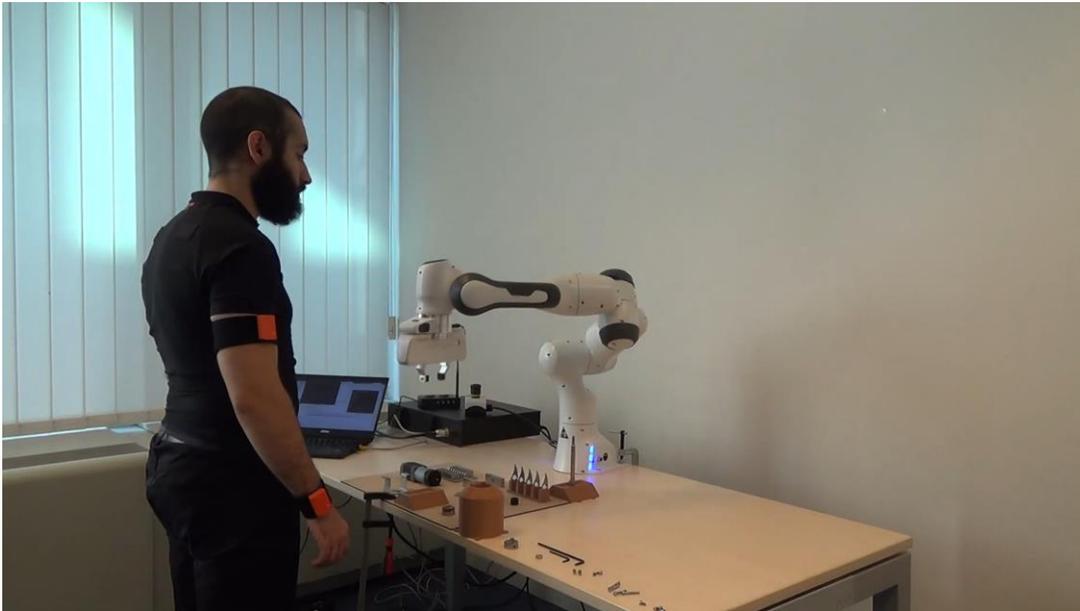
TABLE I: Example of information about agents<sup>1</sup>.

Agent Info	unit
Payload	[kg]
Precision	[mm]
Reach	[mm]
Speed	[mm/s]
Force range	[N]
Gripper type	[-]
Gripping force	[N]

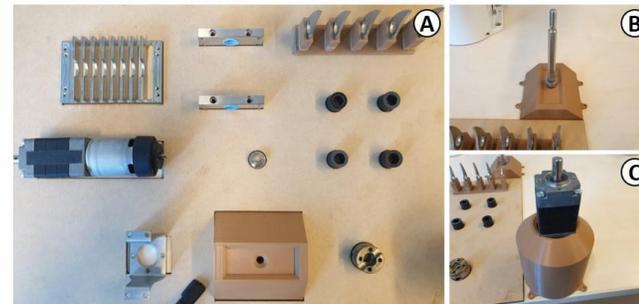
TABLE II: Example of information about objects.

Object Info	unit
Weight	[kg]
Position	[mm]
Dimension	[mm]
Grasping status	[-]

# TASK ALLOCATION



$$E = \sum_i \frac{1}{2} k_i (\theta_i - \theta_i^*)^2$$
$$W = \frac{1}{T} \int_0^T (E(t) - E_L) dt$$

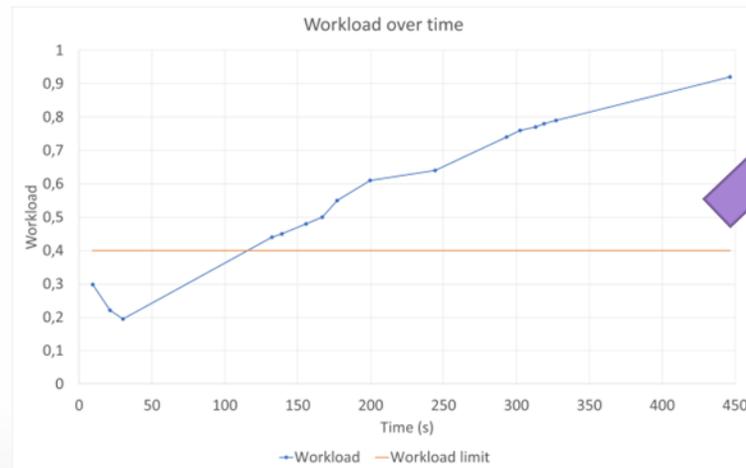


I. El Makrini, G. Mathijssen, S. Verhaegen, T. Verstraten, and B. Vanderborght, "A virtual element-based postural optimization method for improved ergonomics during human-robot collaboration," IEEE Transactions on Automation Science and Engineering, pp. 1-12, 2022.

# TASK ALLOCATION



The workload after assembly is decreased (0.8 vs 0.9) when reducing the workload limit to 0.25.



# OTHER APPLICATIONS

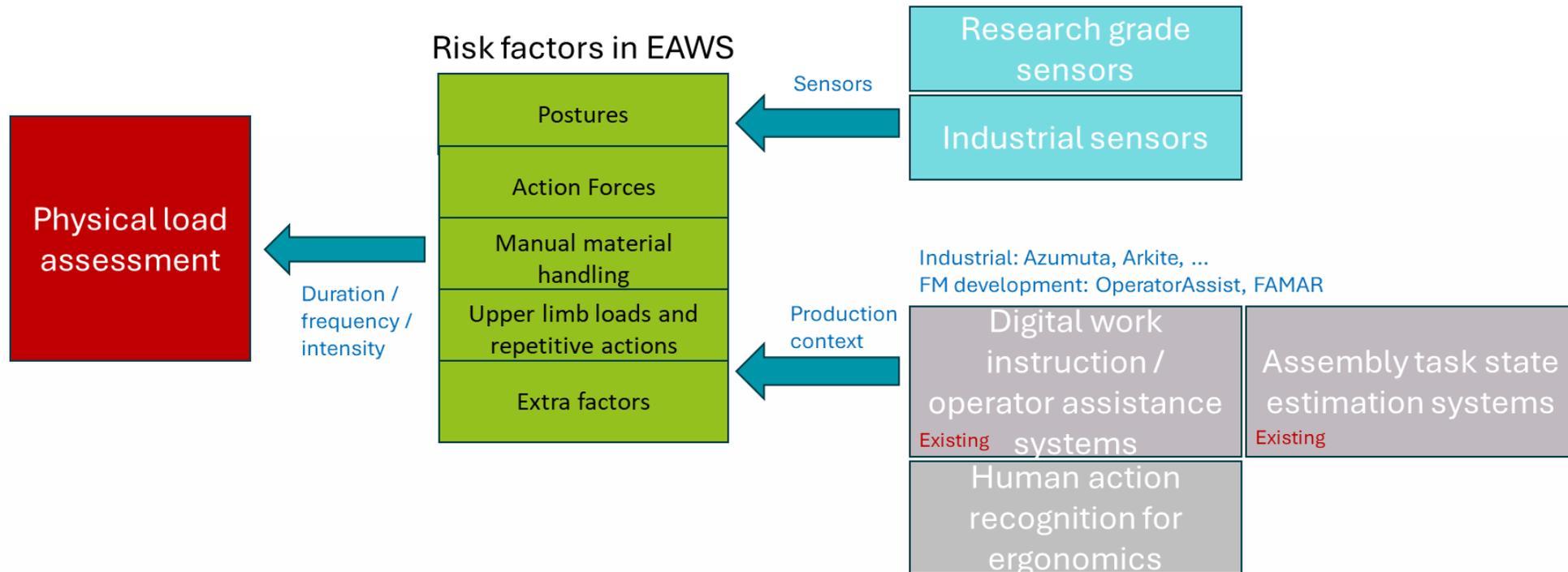
# OTHER APPLICATIONS

The image shows two pages of the 'Ergonomic Assessment Worksheet V1.3.4'. The left page contains a header with identification fields, an overall evaluation section with a color-coded scale (red to green), and a table for 'Punti Extra' (extra points) for various ergonomic factors like posture, force, and repetition. The right page is a detailed table for 'Posture Base' (3D static postures) with columns for different body parts and posture types. Callouts point to specific sections: 'Header' (top left), 'Overall evaluation' (top left, red/green bar), 'Extra points' (middle left), 'Time points for repetitive loads' (bottom left), and 'Section 1: 3D static postures' (middle right, pointing to the posture table).

- **EAWS Score:**
  - Section 1: Working Postures and Movements with Low Additional Physical Effort
  - Section 2: Action Forces of the Whole Body or Hand/Finger System
  - Section 3: Manual Material Handling:
  - Section 4: Repetitive Loads of the Upper Limbs
- Compliant with relevant ISO standards
- Open system: Constantly improved by experts
- Suitable for large and small-scale production

# OTHER APPLICATIONS

## Physical load assessment (PLA)



“Operator pushes a cart of 200kg for 10m on a rough surface while bending mildly forward”

## OTHER APPLICATIONS



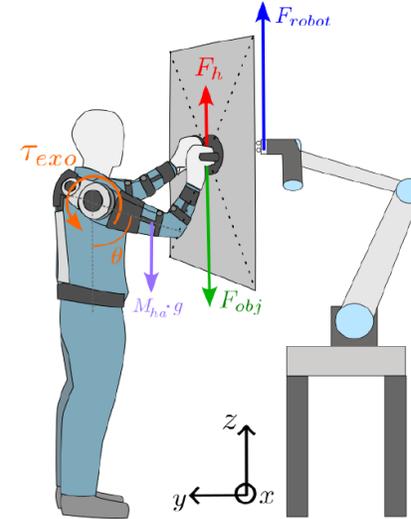
**EAWS Score = 30.0**



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# OTHER APPLICATIONS

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THANK YOU!

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