EMERALD kick-off meeting

Filippo Sanfilippo[1]

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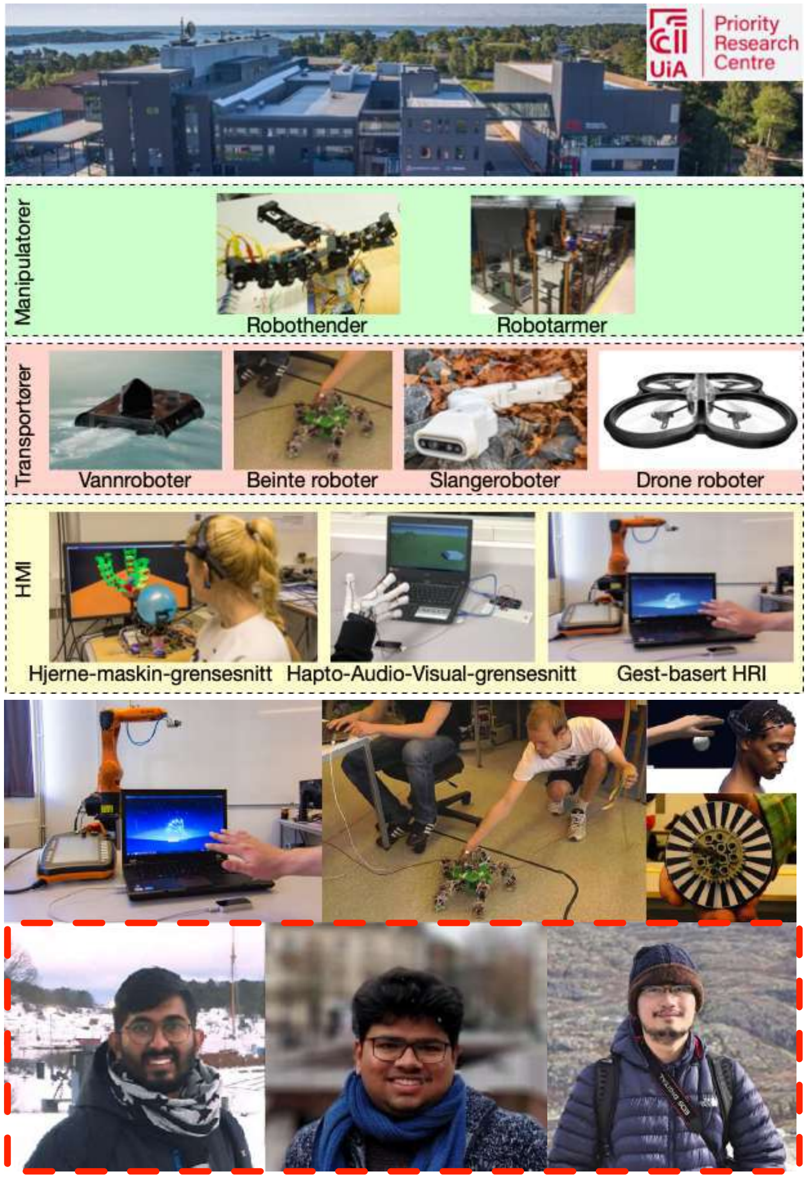
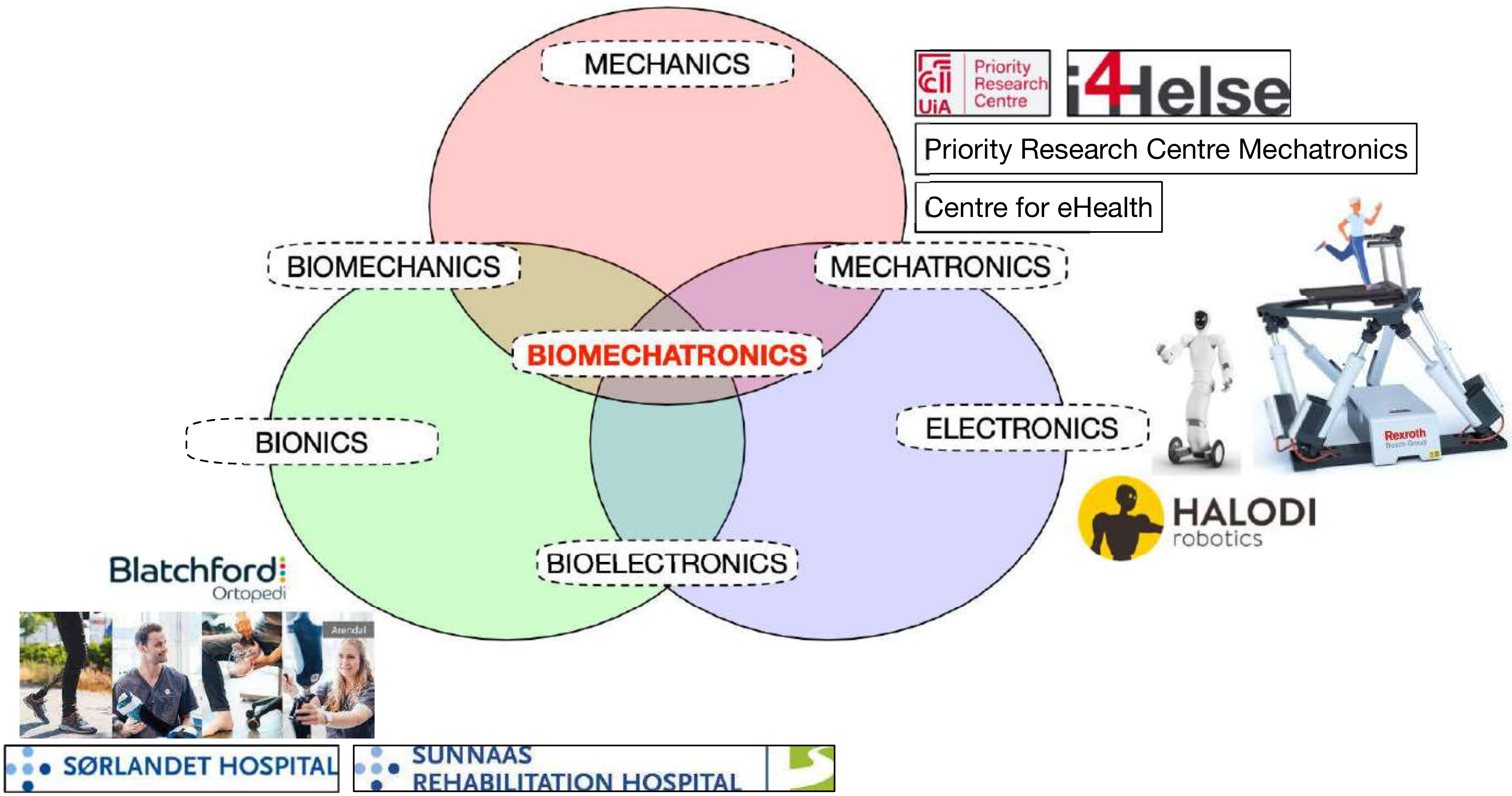
EMERALD kick-off meeting

Top Research Center in Mechatronics, Coboter

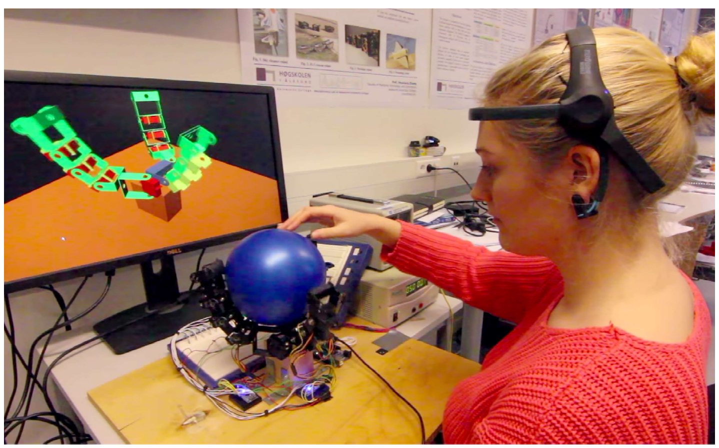


- Dr. Filippo sanfilippo
  - Professor at the Dept. of Eng. Sciences, Faculty of Eng. and Science, University of Agder (UiA)
- Top Research Center in Mechatronics (TRCM)
  - Collaborative Robots (Cobots)
- Centre for Integrated Emergency Mangement (CIEM)
  - Technologies for Augmenting Response Capabilities in Emergency Management Operations
- Research team
  - Student projects/theses (BSc/MSc)
- PhDs and PostDocs supervision
  - PhD stipendiat, Saishashank BALAJI
  - PhD stipendiat, Hareesh Chitikena
  - PhD stipendiat, Hua Minh Tuan
  - 1 PhD, to be hired
- Chair of IEEE Norway Section
- Chair of Robotics & Automation, Control Systems & Intelligent Transportation Systems Joint Chapter
- Treasure of Norsk Forening for Kunstig Intelligens (NAIS).

Biomechatronics



Collaborative robots (cobots)



Collaborative robots (cobots):

- robots intended for direct human robot interaction within a shared space, or where humans and robots are in close proximity.

Challenges:

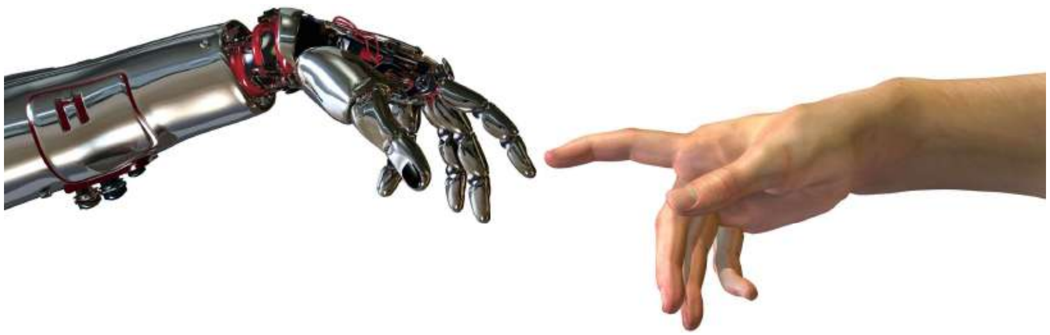
- cobots are advancing from being simple stand-alone manipulators to becoming **autonomous co-workers**;
- **extend robot capabilities in sensing human motions and behaviour**;
- **how robustly we can measure and predict human motions and intentions**.

⇒ trade-off between control and mechanical/software design

[1]

[1] Filippo Sanfilippo, Houxiang Zhang, and Kristin Ytterstad Pettersen. "The New Architecture of ModGrasp for Mind-Controlled Low-Cost Sensorised Modular Hands". In: *Proc. of the IEEE International Conference on Industrial Technology (ICIT2015), Seville, Spain.* 2015, pp. 524–529.

Bio-inspired robotic hands and modular grasping



Mimicking the human hand's ability, one of the most challenging problem in bio-inspired robotics:

- large gap in terms of performances.

Classical approach, analysis of the kinematic behavior of the human hand:

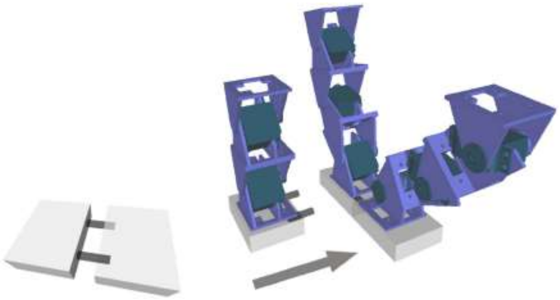
- simplified human hand models with minimum and optimal degrees of freedom[2].

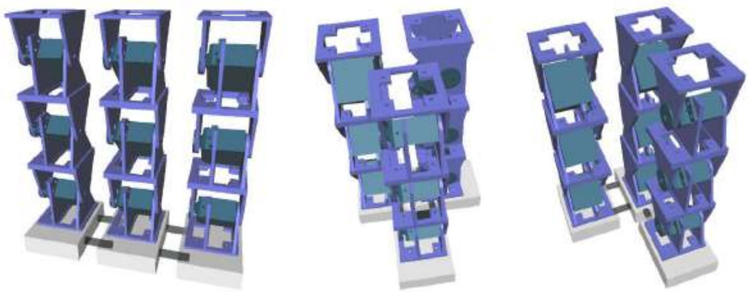
Modular grasping, a promising solution:

- minimum number of degrees of freedom necessary to accomplish the desired task.

[2] S. Cobos, M. Ferre, and R. Aracil. "Simplified human hand models based on grasping analysis". In: *Proc. of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*. 2010, pp. 610–615.

Modular grasping

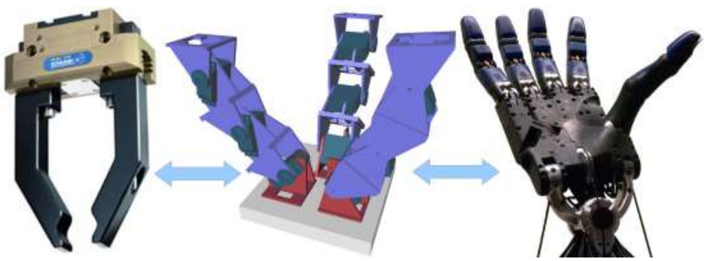




- A trade off between a simple gripper and more complex human like manipulators.
- *Principle of minimalism*: choose the simplest mechanical structure, the minimum number of actuators, the simplest set of sensors, etc.

Modular grasping:

- identical modules are used to build linkages to realise the grasping functions. The modular grasping meets the requirements of standardisation, modularisation, extendibility and low cost[3].



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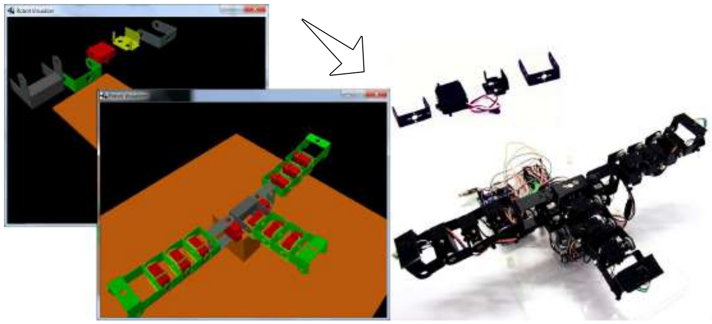
ModGrasp: a rapid-prototyping framework for designing modular hands



ModGrasp:

- Modular Mechanics;
- Modular Hardware;
- Modular Software.

ModGrasp, a rapid-prototyping framework for low-cost sensorised modular hands:

- real-time one-to-one correspondence between virtual and physical prototypes;
- on-board, low-cost torque sensors, 3-D visualisation environment;

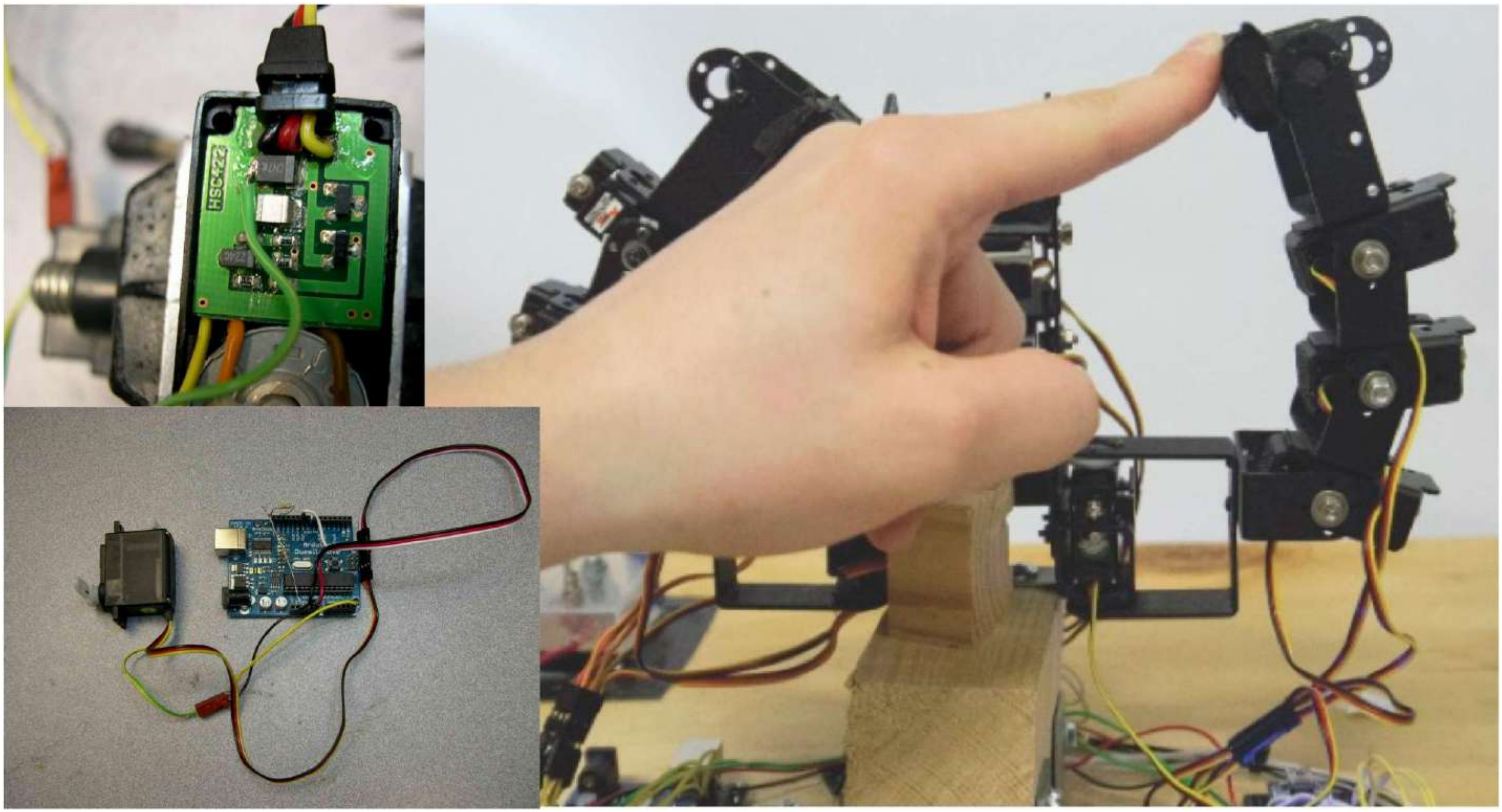
ModGrasp, not only an engineering tool but mostly a scientific tool:

- a framework that can be used to discover new ways of controlling modular hands.

[1,4]

[4] Filippo Sanfilippo et al. "ModGrasp: an Open-Source Rapid-Prototyping Framework for Designing Low-Cost Sensorised Modular Hands". In: *Proc. of the 5th IEEE RAS & EMBS International Conference on Biomedical Robotics and Biomechatronics (BioRob), São Paulo, Brazil.* IEEE RAS & EMBS. 2014, pp. 951–957.

Low-cost torque sensing and joint compliance

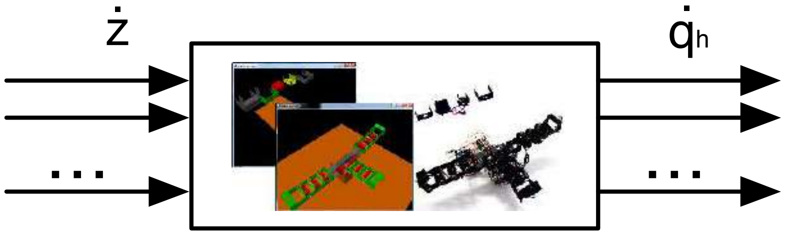


Control approach

[5]

[5] M. Santello, M. Flanders, and J. F. Soechting. "Postural hand synergies for tool use". In: *The Journal of Neuroscience* 18.23 (1998), pp. 10105–10115.

A three-fingered modular manipulator



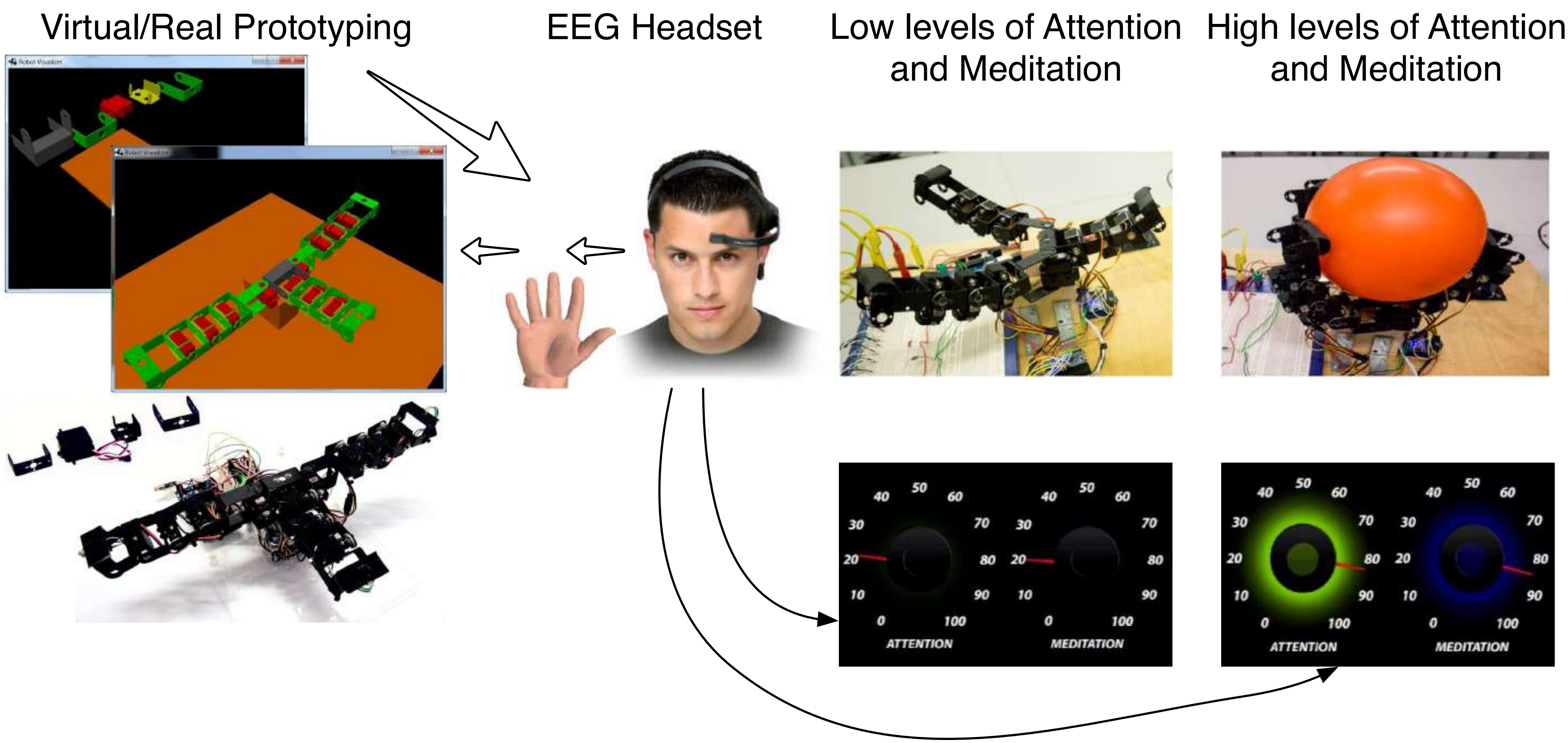
Let $q_h \in \Re^{n_{q_h}}$, with n_{q_h} representing the number of actuated joints. The subspace of all configurations can be represented by an input vector $z \in \Re^{n_z}$ (with n_z denoting the number of inputs and $n_z \leq n_{q_h}$) which parameterises the motion of the joint variables along the *synergies*:

$$\dot{q}_h = S_h \dot{z}, \tag{1}$$

being $S_h \in \Re^{n_{q_h} \times n_z}$ the synergy matrix.

$$S_h = \begin{bmatrix} -0.7 & 0 \\ -0.2 & 0 \\ -0.1 & 0 \\ 0 & -1.6 \\ -0.7 & 0 \\ -0.2 & 0 \\ -0.1 & 0 \\ 0 & 1.6 \\ -0.7 & 0 \\ -0.2 & 0 \\ -0.1 & 0 \end{bmatrix} \begin{matrix} \left.\begin{matrix} \\ \\ \\ \end{matrix}\right\} \textit{Thumb} \\ \left.\begin{matrix} \\ \\ \\ \\ \end{matrix}\right\} \textit{Finger1}. \\ \left.\begin{matrix} \\ \\ \\ \\ \end{matrix}\right\} \textit{Finger2} \end{matrix} \tag{2}$$

Control objective idea



Experimental results

https://youtu.be/XXUXd_352sE

Closing the loop with haptic feedback

https://youtu.be/sT6oxMxvXYE
[6]

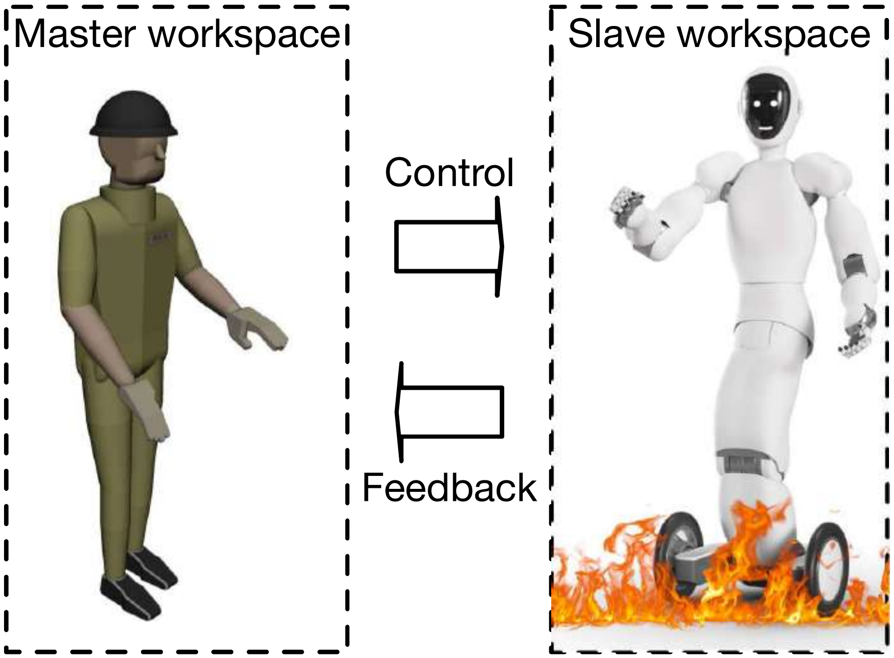
[6] Filippo Sanfilippo, Lars Ivar Hatledal, and K Pettersen. "A fully-immersive hapto-audio-visual framework for remote touch". In: *Proc. of the 11th IEEE International Conference on Innovations in Information Technology (IIT'15), Dubai, United Arab Emirates*. 2015.

Paraplegia

Activities of Daily Living (ADLs)

- Paraplegia is a paralysis starting in the thoracic (T1-T12), lumbar (L1-L5) or sacral (S1-S5) area, which results in the inability to voluntarily move the lower parts of the body.
- However, persons with paraplegia usually possess good functioning of the arms and hands.
- Consequently, for paraplegic patients, teleoperated robotics could provide a formidable improvement in the quality of life.

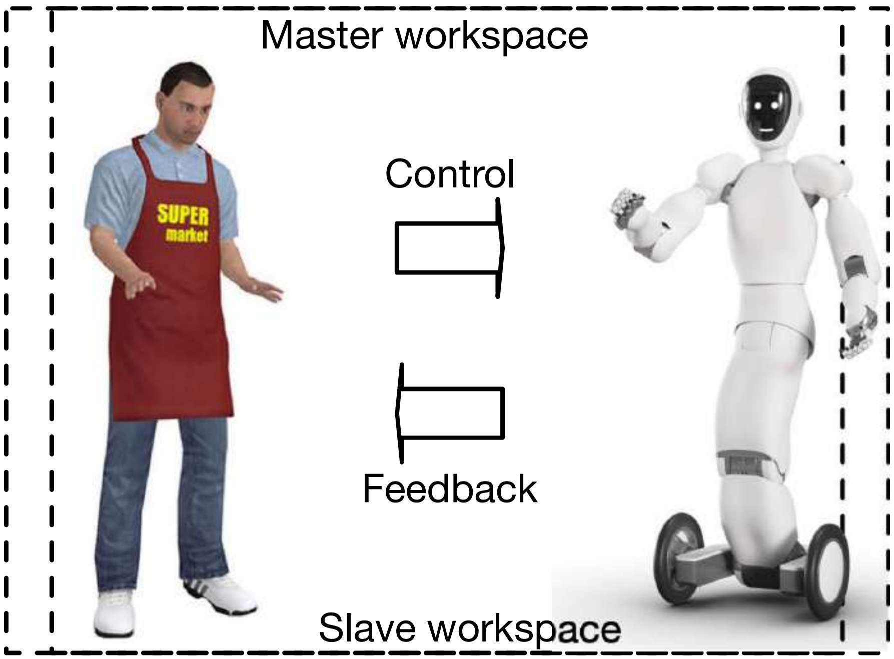
Teleoperated robotics



Teleoperated robotics:

- the operator site where the master and the human operator are located;
- the remote site where the robot, performs the remote task;
- The human is isolated from the working environment and is to be safe at every moment.

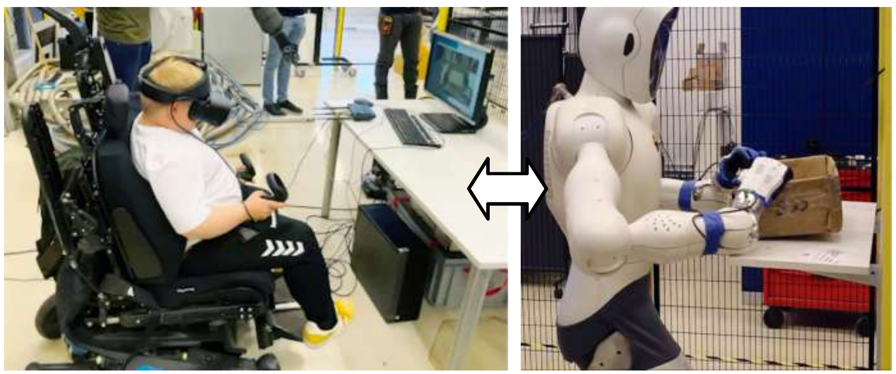
Proprio and teleoperation



Proprio and teleoperation:

- Sometimes both areas, the operator and remote environment are the same, but not at all times.
- The human operator teleoperates the robot whose working environment includes himself or herself.
- This paradigm enables the possibility of adopting teleoperated robotics in a home environment or a work environment.

Mixed reality (MR) Enabled Proprio and Teleoperation of a Humanoid Robot for Paraplegic Patients



[7]

Proposed idea:

- a mixed reality (MR) enabled proprio and teleoperation framework;
- to develop a teleoperated robotic system that will assist paraplegic people with ADLs;
- the adopted humanoid robot is the EVEr3 Humanoid Research Robot from Halodi Robotics;
- the Unity gaming engine and the Oculus Rift S controller are employed for augmenting the patient capabilities.

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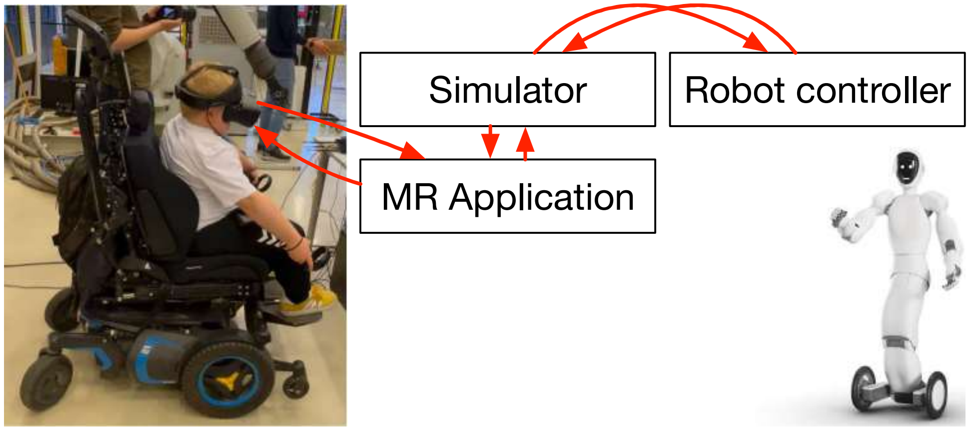
[7] Halodi Robotics. *EVEr3: machine learning ready direct force control self balancing mobile manipulator platform.* https://halodi.com/ever3. [Online; accessed 6-May-2021]. 2021.

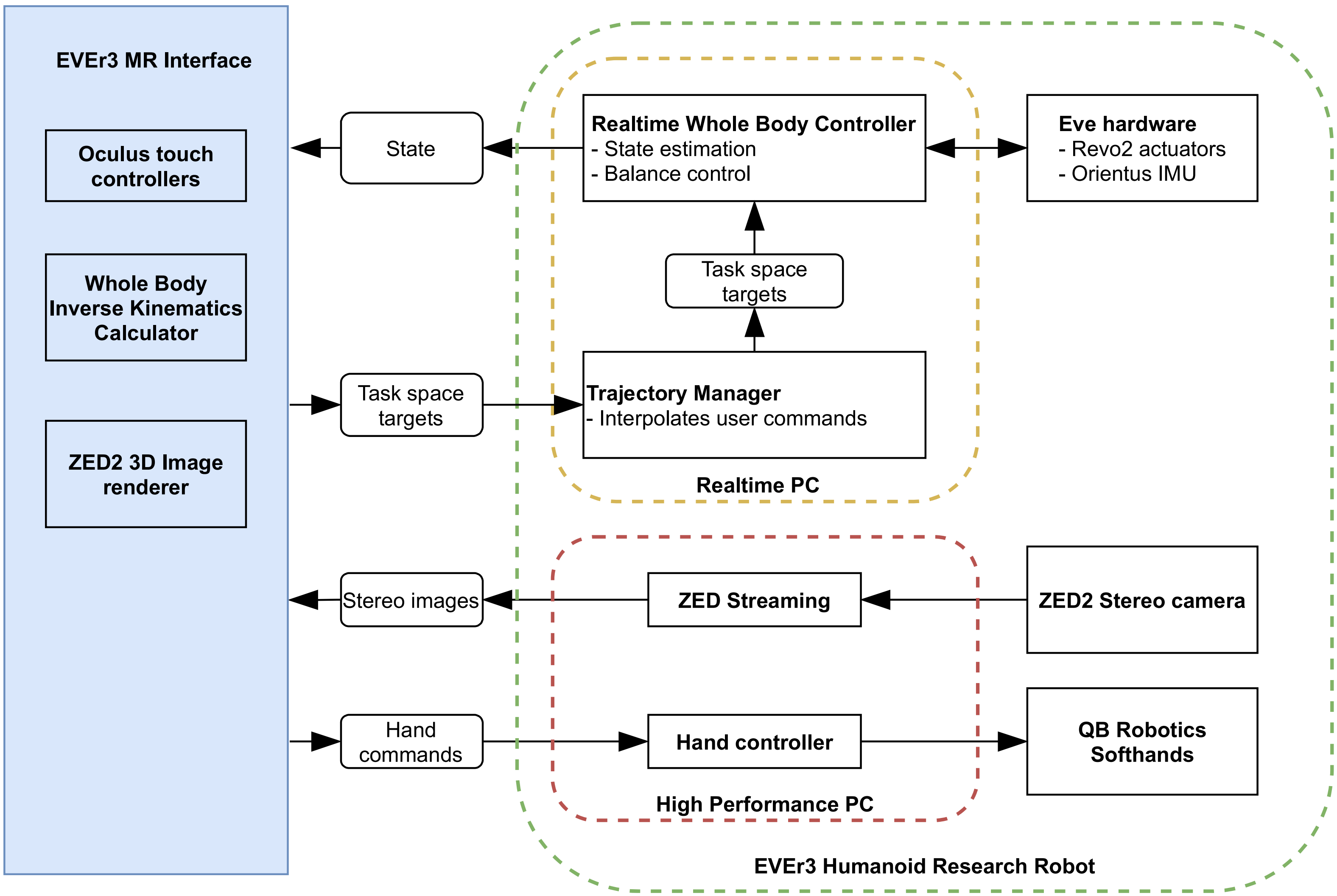
The high-level representation of the framework



The high-level representation of the framework:

- the underlying idea is that the robot operator can provide the desired control inputs from an MR application. The interaction is enabled by a simulator where the robot avatar and the control interface are integrated;
- the control inputs are forwarded to the robot controller to be actuated by the robot.

Proposed framework architecture



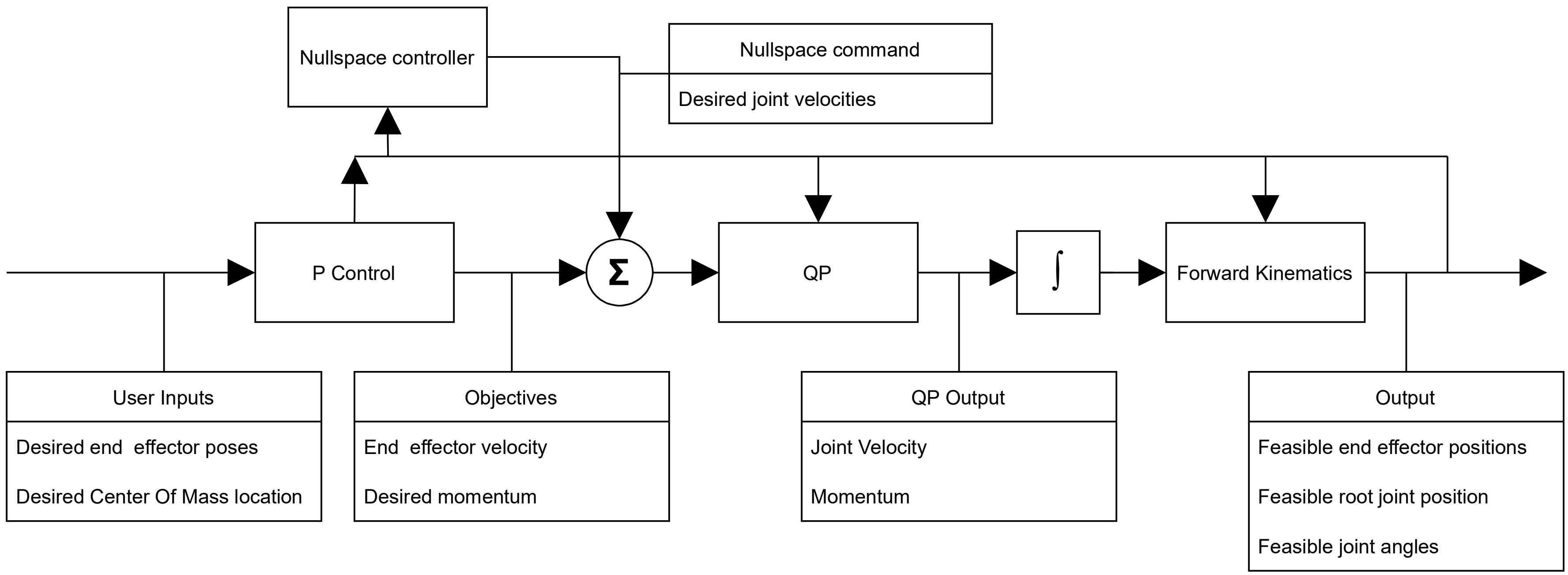
Whole-body inverse kinematics

The inverse kinematics problem is formulated as an iterative Quadratic Program (QP), which optimises for the set of joint velocities v_d that are the closest to the given inputs after the next integration step. The QP is formulated as:

$$\underset{\mathrm{v}_d}{\text{minimise}} \; \frac{1}{2}(J\mathrm{v}_d - p)^T C_w (J\mathrm{v}_d - p) + \frac{1}{2}(A\mathrm{v}_d)^T C_h (A\mathrm{v}_d) + \frac{1}{2} \cdot c_v \mathrm{v}_d^T \mathrm{v}_d, (1) \tag{3}$$

where, $(J\mathrm{v}_d - p)^T C_w (J\mathrm{v}_d - p)$ are the motion tasks. The desired motion tasks p_i, where $i = 1...n$ is the identifier for the task, provide objectives to the optimisation problem in the form of $J_i \mathrm{v}_d = p_i$, where v are the desired joint velocities and J_i is the Jacobian matrix. J is the combination of the task jacobians J_i. The motion tasks are added as an objective with the weight matrix C_w, allowing prioritisation of tasks. $(A\mathrm{v}_\mathrm{d})^T C_h (A\mathrm{v}_\mathrm{d})$ minimises centroidal momentum. $\frac{1}{2} \cdot c_v \mathrm{v}_d^T \mathrm{v}_d$ ensures that the resulting hessian matrix is invertible.

Whole-body inverse kinematics



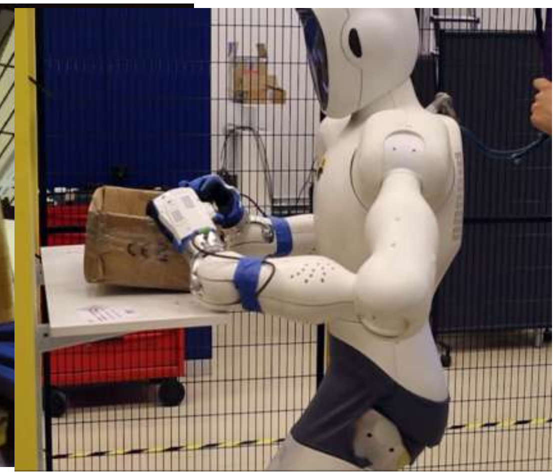
Other essential components

- Real-time Whole-Body Controller. Provides an efficient push recovery and balancing controller that allows the user to be confident in moving the robot without worrying about falling over.
- Trajectory Manager. The trajectory manager receives desired task space commands from the EVEr3 MR Interface and filters those with a first order low-pass filter, before sending them on to the Real-time Whole-Body Controller. The filtering smooths out possible jitters introduced in the network layer, as well as the update rate of the MR application.
- ZED Streaming. Visual sensing is provided using a ZED2 stereo camera mounted in the robot head.
- Hand Controller. The robot has two QB Robotics SoftHands, controlled trough a ROS2 node. The SoftHands have a single actuator and mechanically adapt to grasp a wide variety of objects.

Human Subject Study

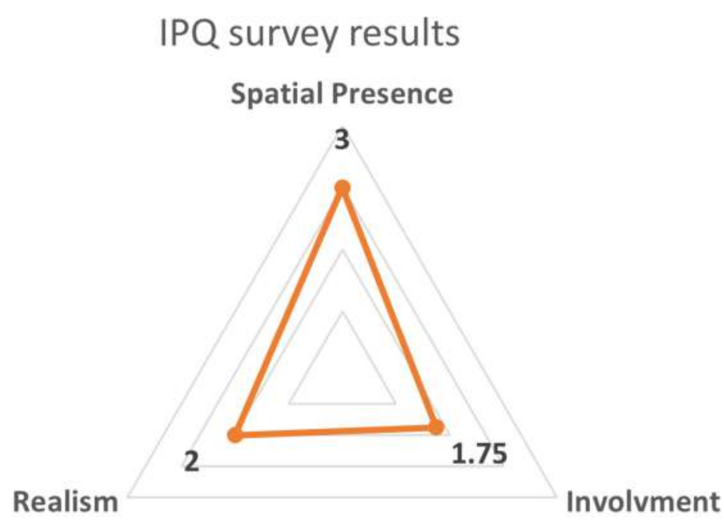
The human subject performing the task.

The EVEr3 MR application.



The EVEr3 Humanoid Research Robot.

Experimental Results



The Igroup Presence Questionnaire (IPQ):

- assesses the sense of presence experienced in a virtual environment (VE);
- it has three sub-scales: a) spatial presence - the sense of being physically present in the VE; b) involvement - measuring the attention devoted to the VE and the involvement experienced; c) experienced realism - measuring the subjective experience of realism in the VE;
- an additional general item assesses the "sense of being there", and has high loadings on all three factors, with an especially strong loading on spatial presence.

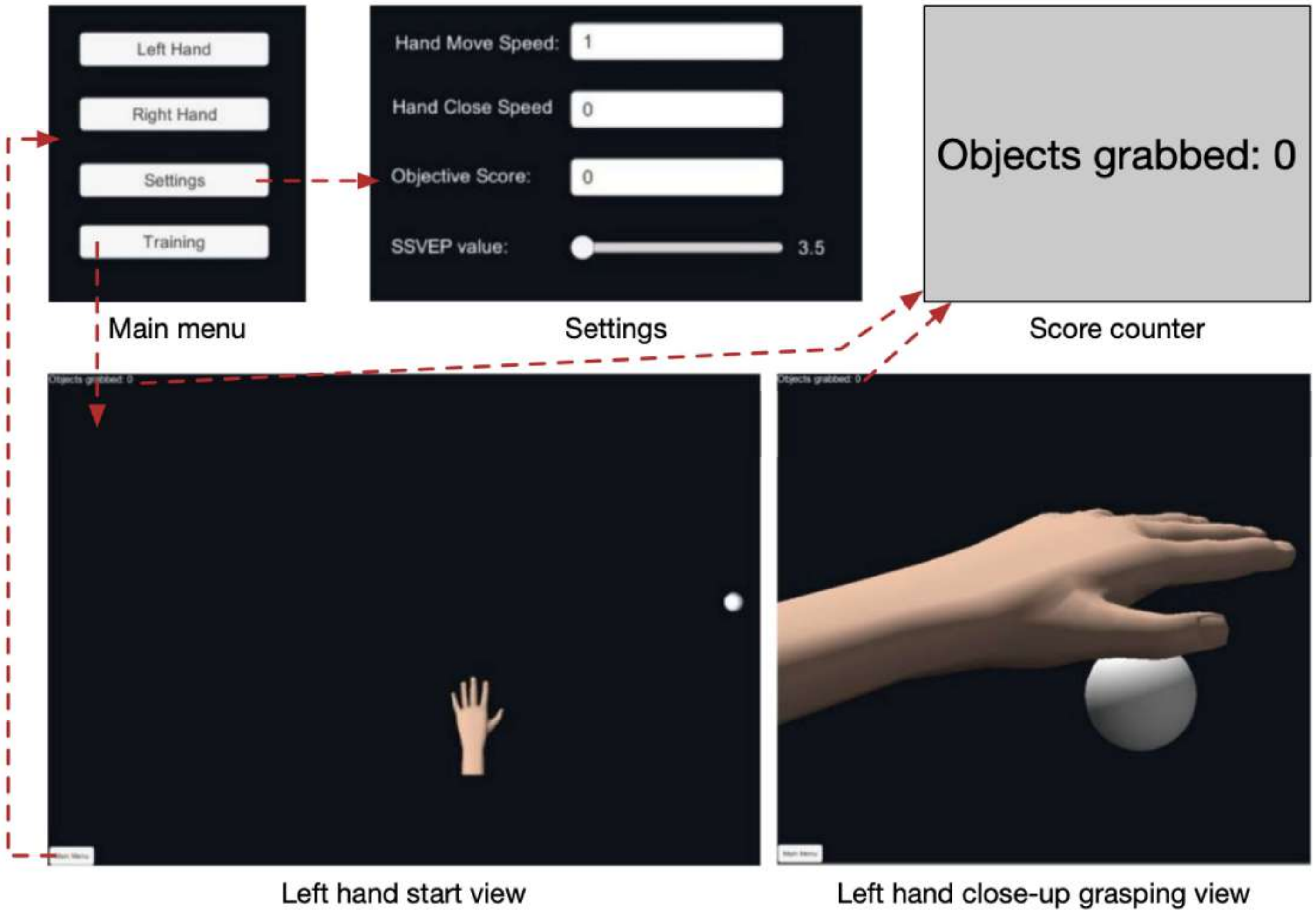
[8]

[8] Shahri M Panahi et al. "Reliability and validity of igroup presence questionnaire (IPQ)". In: (2009).

Demo

https://youtu.be/vZw1Ne-kB5Y

Rehabilitation of Stroke Patients



[9]

[9] Tom Verplaetse et al. "On usage of EEG brain control for rehabilitation of stroke patients". In: *30th European Conference on Modelling and Simulation, Regensburg Germany, May 31st–June 3rd, 2016*. ECMS European Council for Modelling and Simulation. 2016.

Bio-mechatronics course at UiA

UiA Universitetet i Agder

Studier Forskning Samarbeid Om UiA Søk

< Studieplaner

Bio-mechatronics

MAS511-G

Inngår i studieprogram

- Mekatronikk, masterprogram

Anbefalte forkunnskaper

MAS200, MAS105

Læringsutbytte

On successful completion of the course, the student should be able to:

- explain and summarise the motivation, state-of-the-art, ethical issues and future challenges in biomechatronics
- analyze human as a biomechanical system
- understand the critical elements of biomechatronics and their interaction with biological systems

Emnebeskrivelse for studieår
2021-22

Varighet
1 semester

Studiepoeng
7.5

Start
Høst

Studiested
Grimstad

Fakultet
Fakultet for teknologi og realfag

https://www.uia.no/studieplaner/topic/MAS511-G

Thank you for your attention

Contact:

- Professor Filippo Sanfilippo, Department of Engineering Sciences, Faculty of Engineering and Science, University of Agder (UiA), Jon Lilletuns vei 9, 4879, Grimstad, Norway.
  Email: filippo.sanfilippo@uia.no.
- To know more about my research activity, please visit my website at: http://filipposanfilippo.inspitivity.com.

References I

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References II

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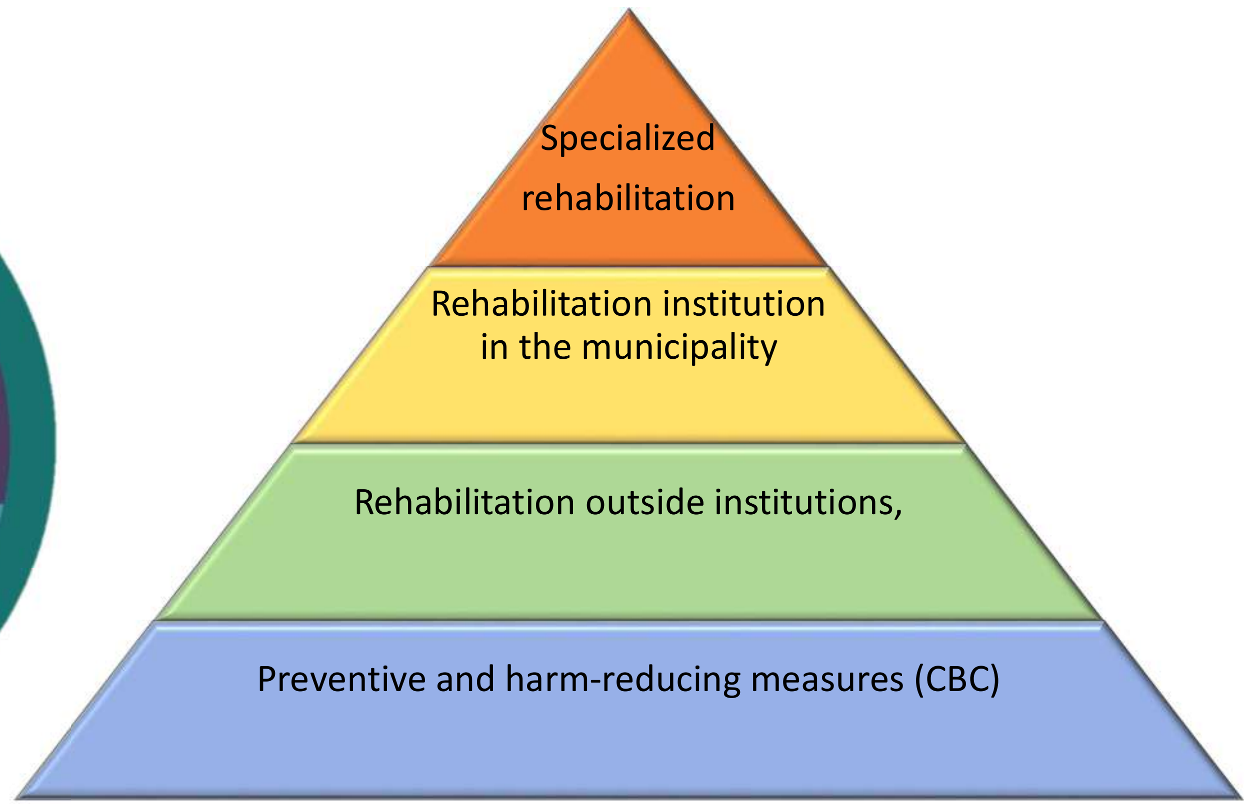
UiA Universitetet i Agder

Morten Ottestad

Head of aplication area assisted Living at
Top Research Centre Mechatronics
Study Program Manager Master Mecatronics

My interesses is
Motion control Hydraulic /electric
Sensors instrumentation an sinnal prossesing
Machine vision
Mobile autonomous system

What is the mission of welfare technology



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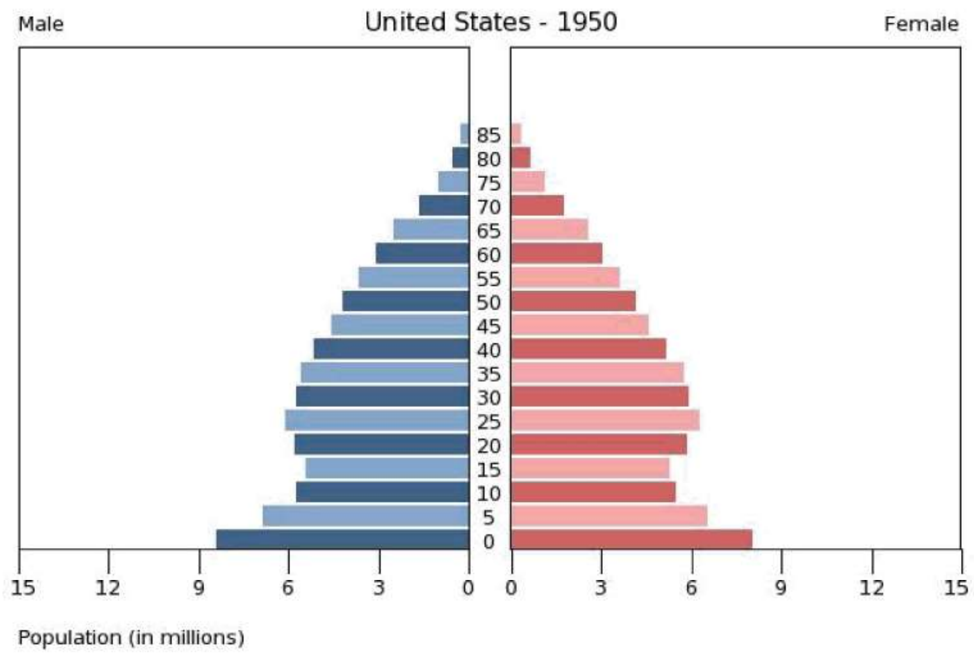
Why welfare technology is more important than before

Demographic development

- The need for increased quality
- The need to increase intensity
- The need for increased volume
- Reduce costs
- Demographic developments
-



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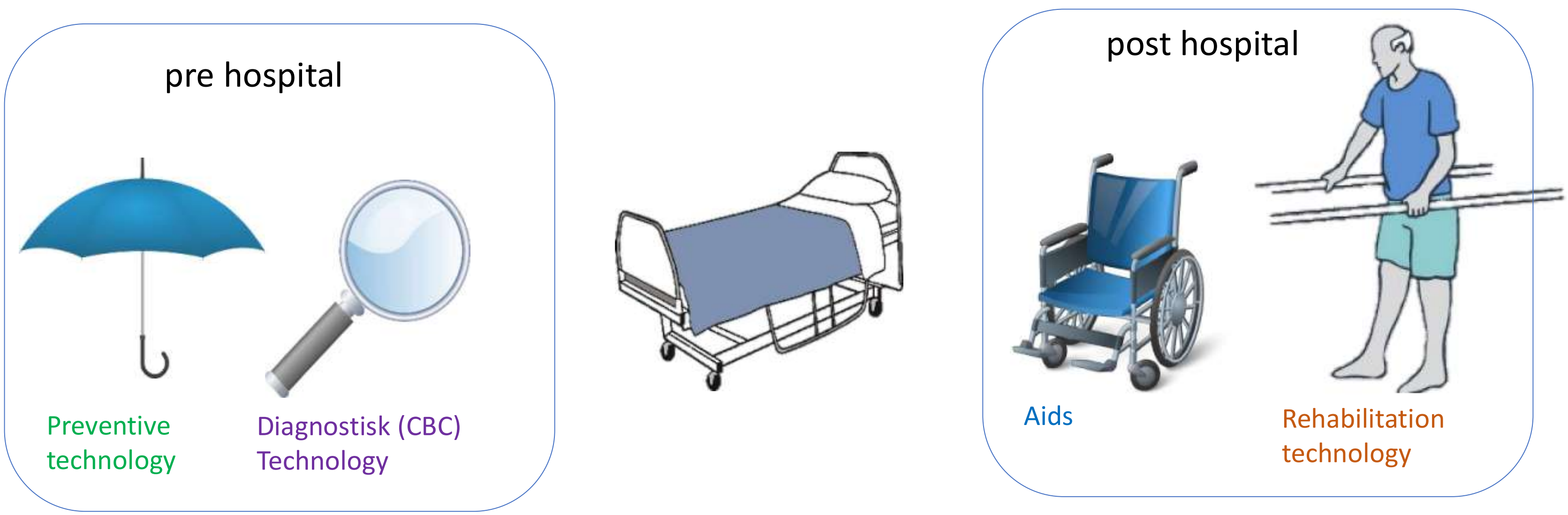
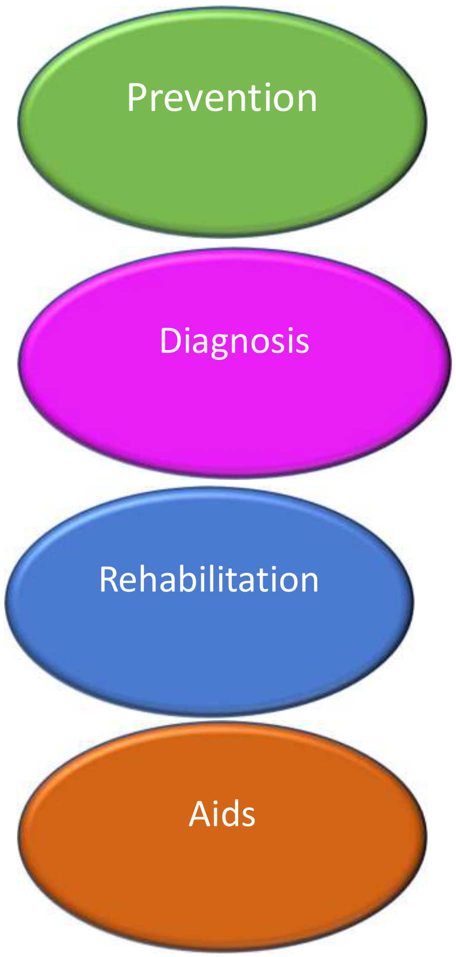
How can mechatronics contribute to the development of welfare technology

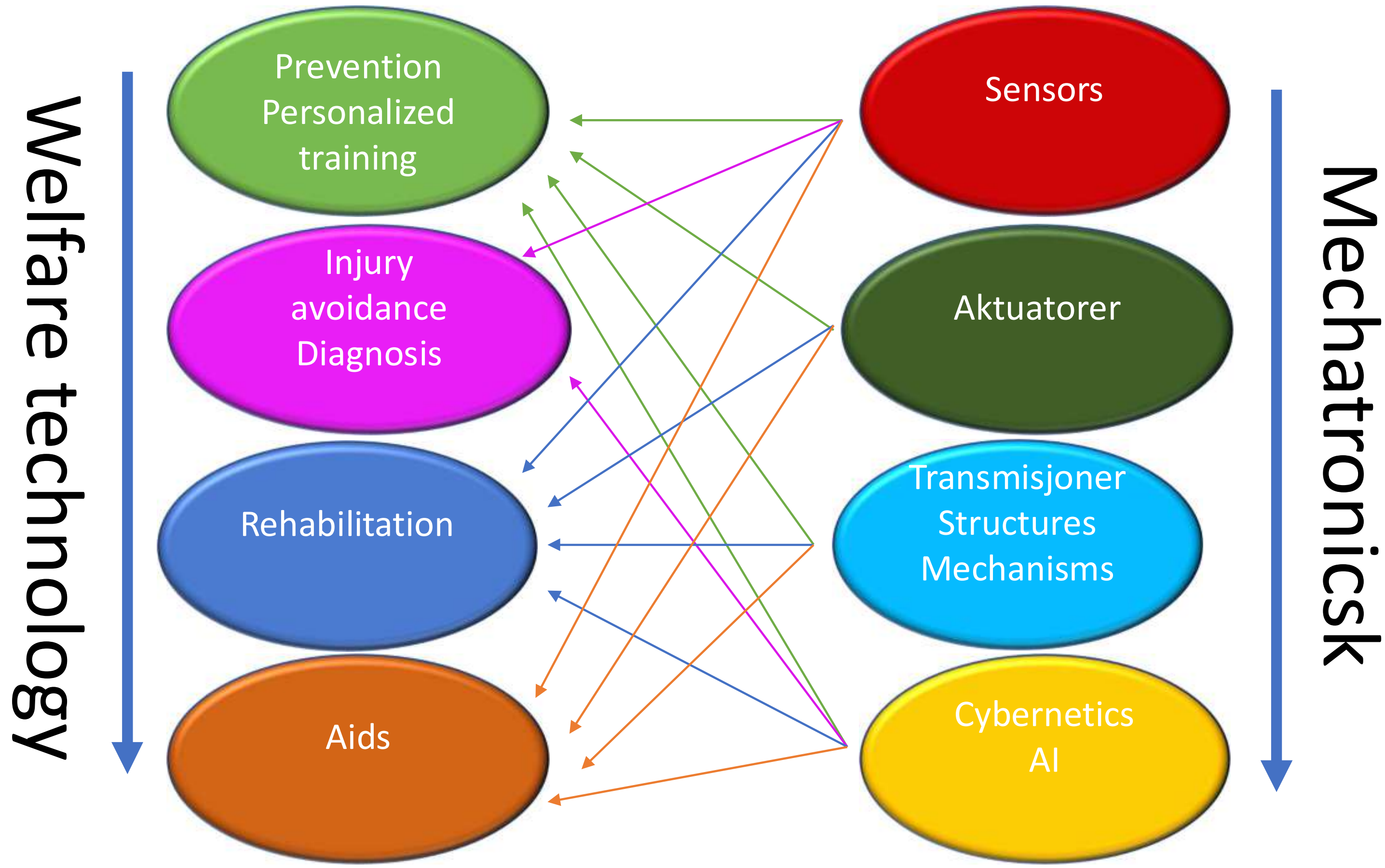


What is welfare technology

- Welfare technology is al the technology witch in one ore another way
- Welfare technology make people more autonomous
-



Welfare technology and mechatronics



Svein Service robot for impassable surroundings

Aids Autonomous Stair Climber

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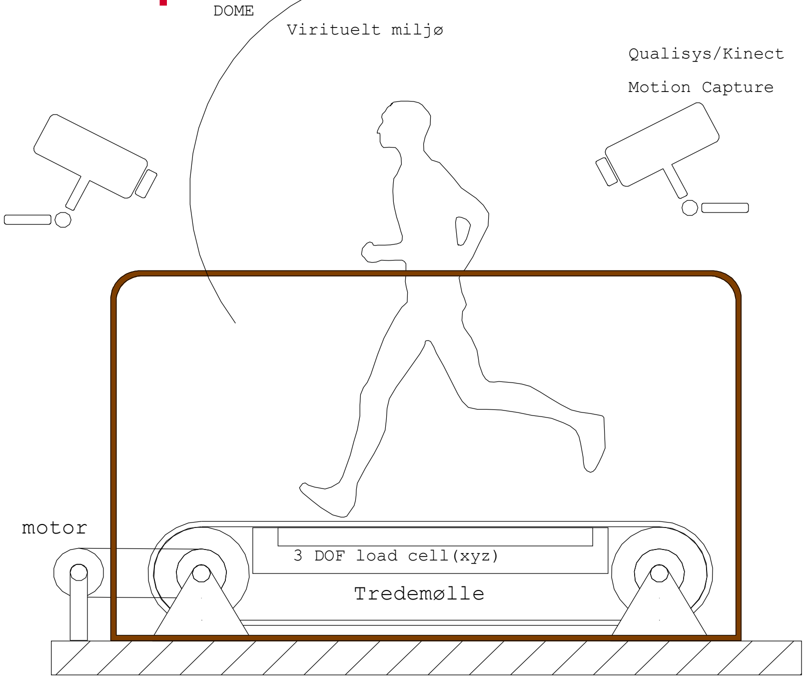
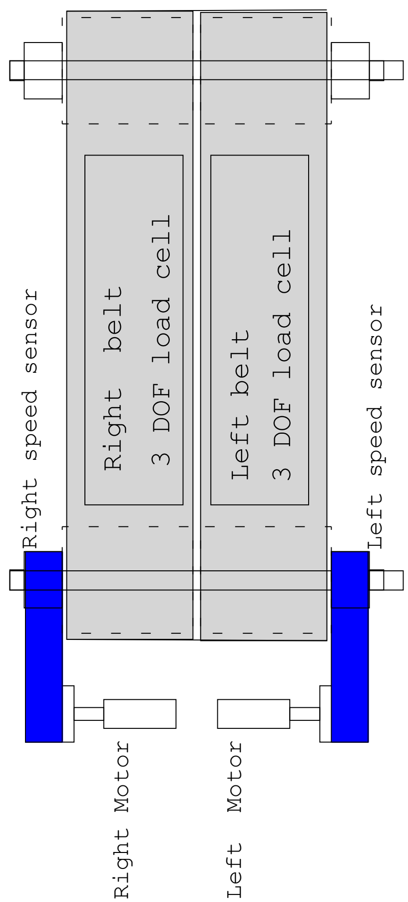
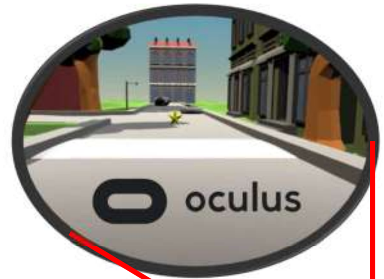
Self-paced treadmill





Norway's most advanced
computer-aided rehabilitation laboratory

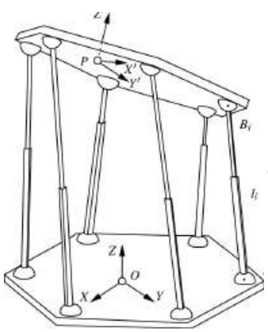
Virtual environment



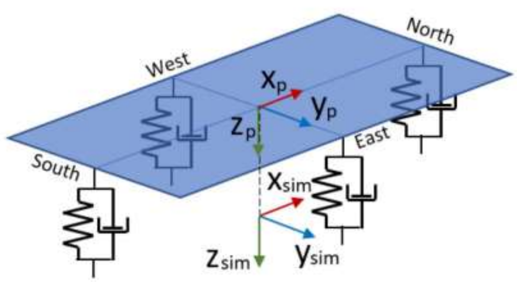
Qualisys motion
capture system

Force plate

Vessel model
Skateboard



Control



Virtuelt terreng modell

unity

Rexroth
Bosch Group

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Dataassistert rehabilitering