- Institution: **University of Belgrade (Serbia)** (100.000 students, ranked top 400 Shanghai University Ranking)

- Faculty: **School of Electrical Engineering** (4.000 students, leading HEI in electrical and computer engineering in Serbia

- Application areas: **Industrial, Service, Healthcare**

- Research interests: **Human-centered and collaborative Robotics and AI**

- Contact: robot@etf.rs / kostaj@etf.rs

- **Assc. Prof. Kosta Jovanović**
- Research: **physical human-robot collaboration, cobots applications**

- **Asst. Prof. Nikola Knežević**
- Research: **human-robot collaboration, AI/ML in robotics**

- **Zaviša Gordić, PhD**
- Research: **industrial robotics, collision detection**

- **Branko Lukić, PhD**
- Research: **VSA, stiffness control, robot control**

- **Maja Trumić, PhD**
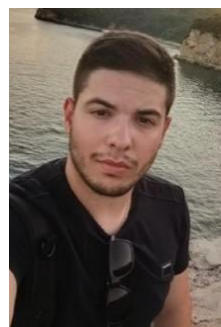- Research: **soft robots, robot control**

- **Filip Bečanović, PhD**
- Research: **human motion analysis, inverse optimal control**

- **Miloš Petrović** PhD student
- Research: **human motion analysis, ergonomy, MoCap**

- **Gorana Milovanović,** PhD student
- Research: **Hu man-machine interfaces**

- **Nikola Ružić,** PhD student
- Research: **ROS, Mobile manpilators**

- **Veljko Todić,** PhD student
- Research: **human-robot interaction in XR**

- **Anastasija Rakic,** PhD student
- Research: **inverse RL**

LABORATORY

UNIVERSITY OF BELGRADE
SCHOOL OF ELECTRICAL ENGINEERING | ETF Robotics

cooperative industrial robot cell
(by ABB, Denso and Siemens)

industrial SCARA robot
(by FANUC)

mobile cobot
(Franka Research III on
Robotnik omniwheel base)

VSA actuators

reconfigurable
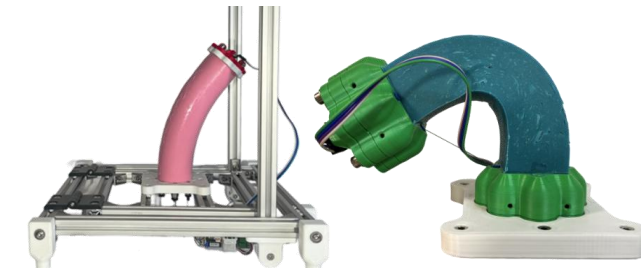soft grippers

F/T sensors

sensors for biomechanics

Franka Emika Panda

AI-powered cobot
with integrated
vision - MAiRA

ABB YuMi

Soft robotics –
lab prototypes

RESEARCH

➤ **CITADELS -** Cultivating Industry 5.0 Talents: Academia-industry collaboration and empowerment through accessible DEep technoLogieS, Funded by *EU Horizon Europe*. *9/2025 – 8/2029.*

➤ **HMI2MARKET -** Upgrading university entrepreneurial infrastructures for human-machine interaction innovations acceleration that foster inclusive employment, injury prevention and social wellbeing in labor-intensive industries, Funded by *EIT HEI*. *4/2025 – 4/2027.*

➤ **MASTER-XR** - Mixed reality ecosystem for teaching robotics in manufacturing, experiment XR4Human-SERVE 5.0, Funded by *EU Horizon Europe* (cascade funding). *11/2024 – 8/2025, shop4cf.eu/oc1*

➤ **NOTRE - Novel methods for improving production innovation potential with examples of senior care-related solutions**, Funded by **InterReg Danube RegionEurope,** *1/2024 – 7/2026, interregeurope.eu/notre*

➤ **BrAIn -** BRinging Artificial INtelligence Towards SMEs, Funded by **InterReg Danube Region,** *1/2024 – 7/2026, danube-region.eu/brain*

➤ **CircuBot -** Modular and versatile collaborative intelligent waste management robotic system for circular e Funded by *Science Fund - Republic of Serbia,* *5/2023 – 4/2025, circubot.etf.bg.ac.rs*

➤ **MUSAE** - a human-centred factory for a future technological sustainable development driven by arts, Funded by *EU Horizon Europe*, *6/2023 – 9/2025, musae.starts.eu*

➤ **DIH-HERO** - Digital Innovation Hubs in Health Care Robotics, Funded by *EU Horizon 2020*, *1/2019 – 12/2023, dih-hero.eu*

➤ **DIH² -** A Pan European Network of Robotics DIHs for Agile Production, Funded by *EU Horizon 2020*, *1/2019 – 6/2023, dih-squared.eu*

➤ **BOWI** - Boosting Widening Digital Innovation Hubs, Funded by *EU Horizon 2020* (funding for widening DIH – Belgrade Robotics Hub). *7/2021 – 6/2023, bowi-network.eu*

➤ **ForNextCobot** - Mechanical Impedance Estimation and Planning for Next Generation Collaborative Robots, Funded by *Science Fund - Republic of Serbia*, *7/2020 – 1/2023, fornextcobot.etf.bg.ac.rs*

➤ **SHOP4CF -** Smart Human Oriented Platform for Connected Factories, experiment BrainWatch, Funded by *EU Horizon 2020* (cascade funding). *11/2021 – 9/2022, shop4cf.eu/oc1*

ETF Robotics

- **Selected journal papers in last 3 years:**

➢ A. Vukicevic, M. Petrovic, P. Milosevic, A. Peulic, K. Jovanovic, A. Novakovic „A systematic review of computer vision-based personal protective equipment compliance in industry practice: advancements, challenges and future directions", *Artificial Intelligence Review* (Springer), 2024.

➢ N. Knezevic, A. Savic, Z. Gordic, A. Ajoudani, K. Jovanovic, "Towards Industry 5.0 - A Neuroergonomic Workstation for Human-Centered Cobot-Supported Manual Assembly Process", *IEEE Robotics and Automation Magazine*, 2024.

➢ N. Knezevic, B. Lukic, T. Petric, K. Jovanovic, "A Geometric Approach to Task-Specific Cartesian Stiffness Shaping", *Journal of Intelligent & Robotic Systems (Springer)*, 2024.

➢ A. Vukicevic, M. Petrovic, N. Knezevic, K. Jovanovic, "Deep learning-based recognition of unsafe acts in manufacturing industry", *IEEE Access*, 2023.

➢ F. Becanovic, V. Bonnet, R. Dumas, K. Jovanovic, S. Mohammed, "Force Sharing Problem During Gait Using Inverse Optimal Control", *IEEE Robotics and Automation Letters,* 2023

➢ M. Trumic, C. Della Santina, K. Jovanovic, A. Fagiolini, "On the stability of the soft pendulum with affine curvature: open-loop, collocated closed-loop, and switching control", *IEEE Control Systems Letters*, 2022

➢ M. Trumic, G. Grioli, K. Jovanovic, A. Fagiolini, "Force/Torque-Sensorless Joint Stiffness Estimation in Articulated Soft Robots", *IEEE Robotics and Automation Letters,* 2022

➢ K Jovanovic, et al. "Digital Innovation Hubs in Health-Care Robotics Fighting COVID-19: Novel Support for Patients and Health-Care Workers Across Europe", *IEEE Robotics & Automation Magazine,* 2021

➢ M. Trumic, C. D. Santina, K. Jovanovic, A. Fagiolini, "Adaptive Control of Soft Robots Based on an Enhanced 3D Augmented Rigid Robot Matching," *IEEE Control Systems Letters, 2021*

➢ M.Trumic, K. Jovanovic, A. Fagiolini, "Decoupled Nonlinear Adaptive Control of Position and Stiffness for Pneumatic Soft Robots", *International Journal of Robotics Research (IJRR)*, 2021

ETF Robotics

Research challenges:

1) **Development and control of new actuators**
   complaint (VSA/antogonistic), bio-inspired

2) **Human motion and behavior pattern analysis and prediction**
   based on MOCAP + wearables sensors (EMG, EEG, IMU)
   more efficent pHRI and improved human ergonomics

3) **New methods for assesment of safe and efficient pHRI**
   with minimal set of sensors – based on signal processing and control
   theory

4) **New robot control methods for safe and efficient pHRI**
   mechanical impedance shapping and control

ETF Robotics
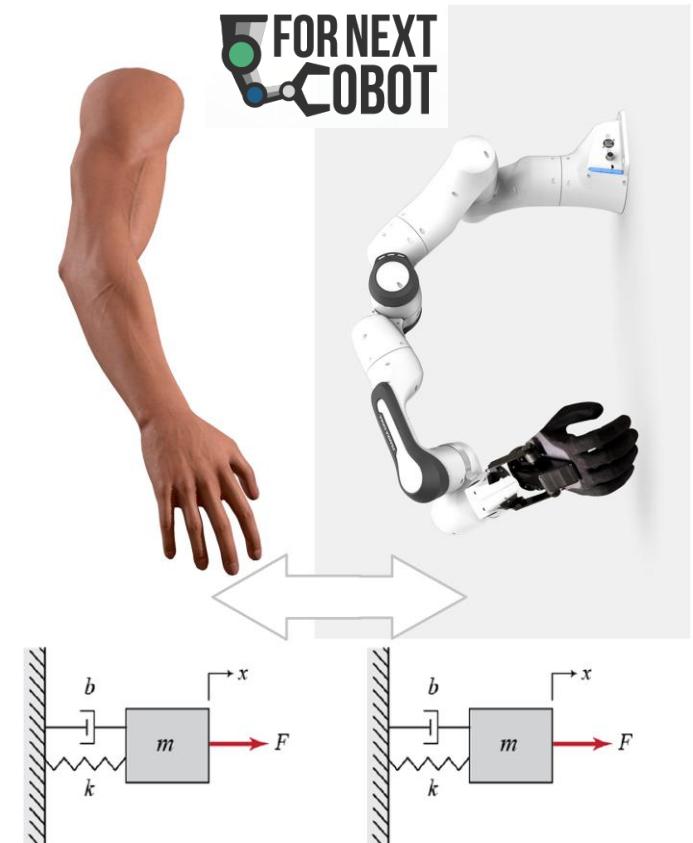
1) Development and control of new actuators

- *Puller-follower* control of antagonistic VSA
  model-based, observable under pulling contraint,
  energy efficient

  The puller-follower control of compliant and noncompliant antagonistic tendon drives in
 robotic systems
  V Potkonjak, B Svetozarevic, K Jovanovic, O Holland
  International Journal of Advanced Robotic Systems 8 (5), 69

- Cascade control of antagonistic VSA
  general approach applicable to various VSA design

  Cascade Control of Antagonistic VSA—An Engineering Control Approach to a Bioinspired
  Robot Actuator
  B Lukić, K Jovanović, TB Šekara
  Frontiers in neurorobotics 13, 69

- Decoupled adaptive control
  robust to parametric uncertainties and closes the loop
  on both position and stiffness

  Decoupled nonlinear adaptive control of position and stiffness for pneumatic soft robots
  M Trumić, K Jovanović, A Fagiolini
  The International Journal of Robotics Research, 0278364920903787

ETF Robotics
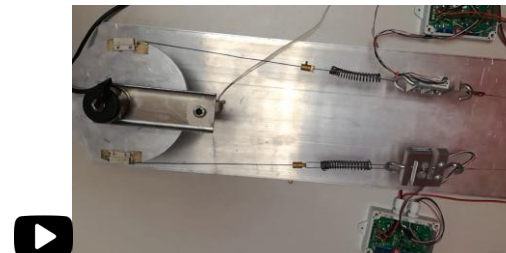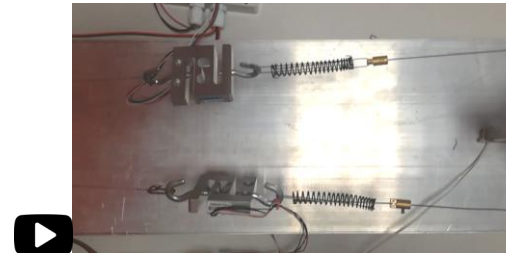
2) Human motion and behavior pattern analysis and prediction

- Development of a comprehensive framework combining vision and wearable sensors (EMG, IMU, F/T)

  use of CNN for assesment of human pose and ergonomics

  Deep learning-based recognition of unsafe acts in manufacturing industry
  AM Vukicevic, MN Petrovic, NM Knezevic, KM Jovanovic
  IEEE Access

  Assessment of the human-robot collaborative polishing task by using EMG sensors and 3D pose estimation
  M Petrovic, AM Vukicevic, B Lukic, K Jovanovic
  International Conference on Robotics in Alpe-Adria Danube Region, 564-570

- Development of methods for predicting people's strategy in the optimal execution of certain tasks

  inverse optimal control (IOC), bilevel optimization, multi criteria assesment

  Force Sharing Problem During Gait Using Inverse Optimal Control
  F Bečanović, V Bonnet, R Dumas, K Jovanović, S Mohammed
  IEEE Robotics and Automation Letters 8 (2), 872-879

  Assessing the Quality of a Set of Basis Functions for Inverse Optimal Control via Projection onto Global Minimizers
  F Bečanović, J Miller, V Bonnet, K Jovanović, S Mohammed
  2022 IEEE 61st Conference on Decision and Control (CDC), 7598-7605

ETF Robotics
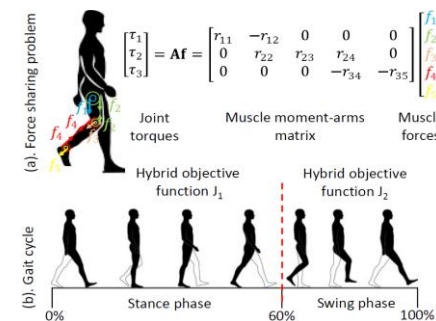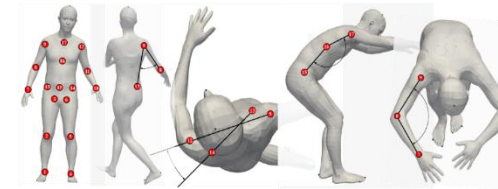
3) New methods for assesment of safe and efficient pHRI

- Interaction detection and understanding of the context of the robot's interaction with the environment (model-based or hybrid) *modified Dynamic Time Warping – mDTW, dynamic modeling*

Collision detection on industrial robots in repetitive tasks using modified dynamic time warping
Z Gordić, K Jovanović
Robotica 38 (10), 1717-1736

A Hybrid Approach to Interaction Detection in Robotics
Z Gordić, K Jovanović
2023 10th International Conference on Electrical, Electronic and Computing ...

- Methods for sensor-less estimation of stiffness in real time adaptive control, unknown inputs observer theory, recursive least squares algorithm

Force/torque-sensorless joint stiffness estimation in articulated soft robots
M Trumić, G Grioli, K Jovanović, A Fagiolini
IEEE Robotics and Automation Letters 7 (3), 7036-7043

An input observer-based stiffness estimation approach for flexible robot joints
A Fagiolini, M Trumić, K Jovanović
IEEE Robotics and Automation Letters 5 (2), 1843-1850

Robust and Decoupled Position and Stiffness Control for Electrically-driven Articulated Soft Robots

Salvatore Pedone, Maja Trumić, Kosta Jovanović and Adriano Fagiolini

UNIVERSITÀ DEGLI STUDI DI PALERMO

dipartimento di ingegneria unipa

UNIVERSITY OF BELGRADE

School of Electrical KAPWING

ETF Robotics

4) New robot control methods for safe and efficient pHRI

- Methods for shaping Cartesian stiffness matrix of a robot
  singular decomposition of the stiffness matrix, optimal
  exploitation of the stiffness space and joint positions, nonlinear
  sequential least square programming optimization

$$K_C = (J(q)K_j^{-1}J(q)^T)^{-1}$$

$$K_C = U\Lambda U^{-1}$$
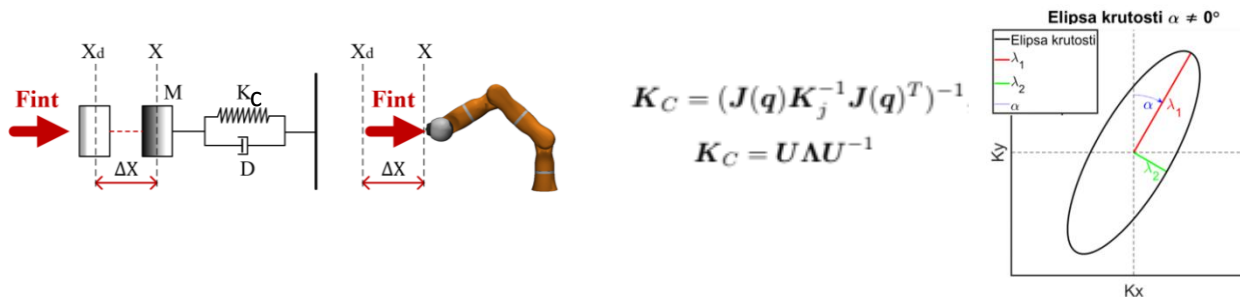
A Geometric Approach to Task-Specific Cartesian Stiffness Shaping
KJ N. Knezevic, B. Lukic, T. Petric
Journal of Intelligent & Robotic Systems 110 (14), 1-11

Online cartesian compliance shaping of redundant robots in assembly tasks
B Lukić, K Jovanović, L Žlajpah, T Petrič
Machines 11 (1), 35

End-Effector Cartesian Compliance Shaping for Redundant Robots

Branko Lukić*, Kosta Jovanović*, Leon Žlajpah** and Tadej Petrič**

*School of Electric Engineering, University of Belgrade, Belgrade, Serbia
**Jožef Stefan Institute, Ljubljana, Slovenia

A Geometric Approach to Task-Specific Cartesian Stiffness Shaping

Nikola Knežević*, Branko Lukić*, Tadej Petrič**, Kosta Jovanović*
*University of Belgrade, School of Electrical Engineering
** Jožef Stefan Institute, Ljubljana

ETF Robotics   **CoBoTaT**

ETF Robotics

Analysis and control of soft inverted pendulum

Challenge: How the physical parameters of a soft robot affect its stability and equilibria? When is zero dynamics stable and when it is not? How to switch from one stable equilibrium to another?

On the stability of the soft pendulum with affine curvature: open-loop, collocated closed-loop, and switching control
M Trumić, C Della Santina, K Jovanović, A Fagiolini
IEEE Control Systems Letters 7, 385-390
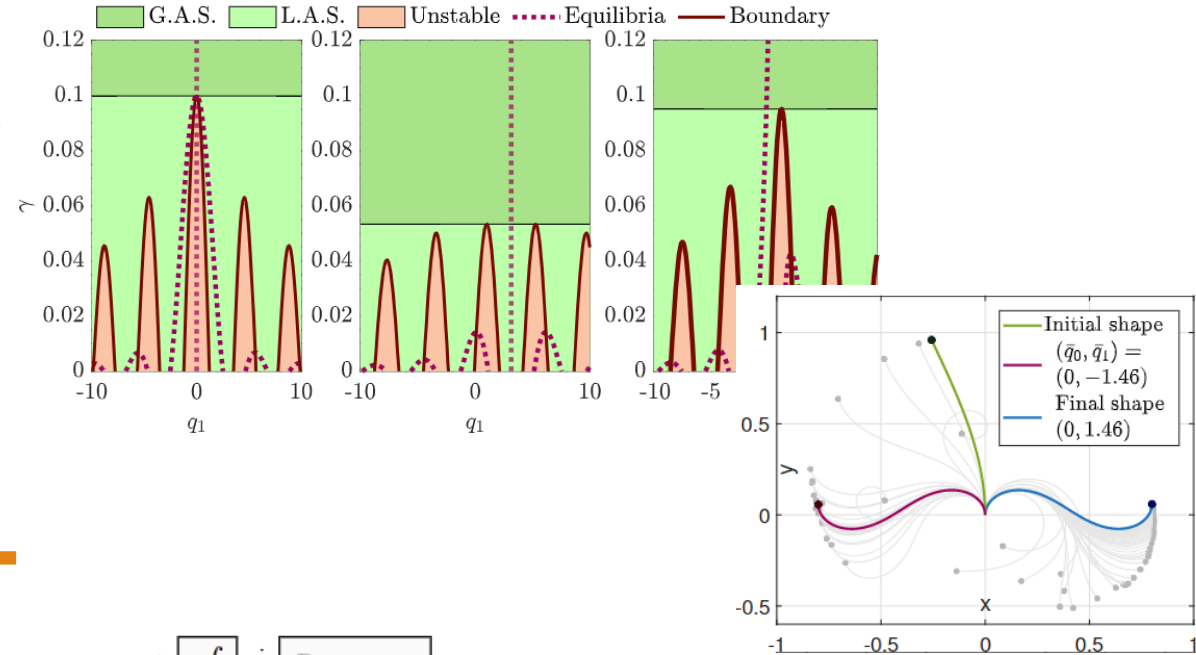
Adaptive control of soft robots

Challenge: How to control a soft robot when its parameters are partially unknown? How to achieve robust tracking of the desired trajectory?

Adaptive control of soft robots based on an enhanced 3d augmented rigid robot matching
M Trumić, C Della Santina, K Jovanović, A Fagiolini
2021 American Control Conference (ACC), 4991-4996

ETF Robotics
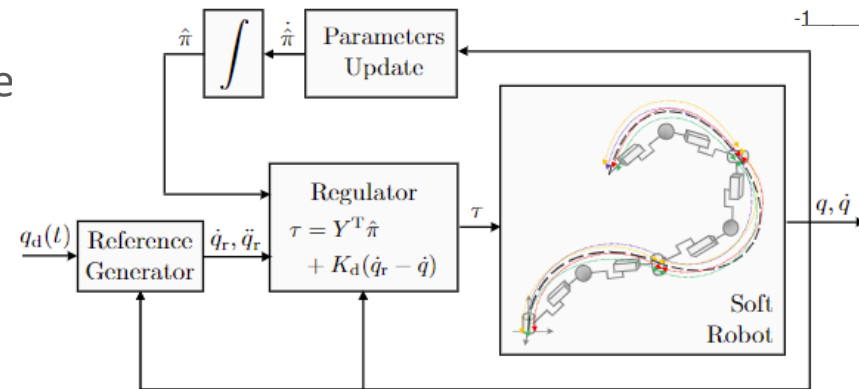
BrainWatch

GALEB Electronics is the biggest producer of fiscal devices and GPS systems in Serbia. However, assembling different products with specific models in low batches requires a high level of worker attention and engagement making the manufacturing laborious.

The objective of the BrainWatch is to increase the productivity of such processes while improving workers' satisfaction by human-centred modular neuroergonomic workcell:

➢ Module 1: physical assistance (**Cobot**)

➢ Module 2: audio-visual assitance (**ADIN** – adaptive GUI),

➢ Module 3: physical assesment (**M2O2P-L** – non-invasive HMI)

➢ Module 4: non-physical (cognitive) assesment (**BrainWatch**),

➢ Module 5: strategic support (expert system - **FLINT**).

Toward Industry 5.0: A Neuroergonomic Workstation for a Human-Centered, Collaborative Robot-Supported Manual Assembly Process
N Knežević, A Savić, Z Gordić, A Ajoudani, K Jovanović
IEEE Robotics & Automation Magazine

https://www.youtube.com/watch?v=w7F1bNlHWi0
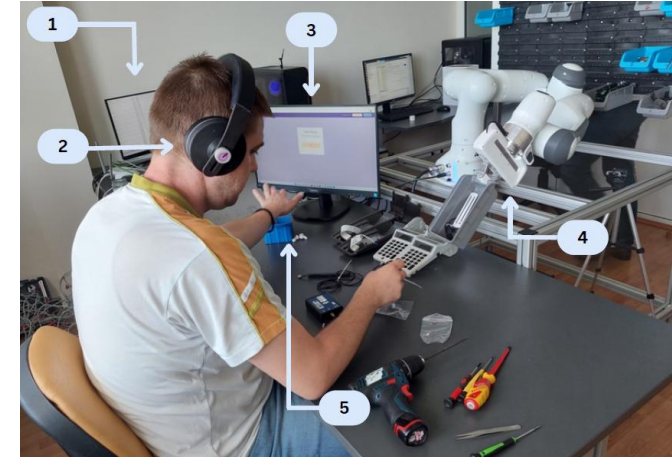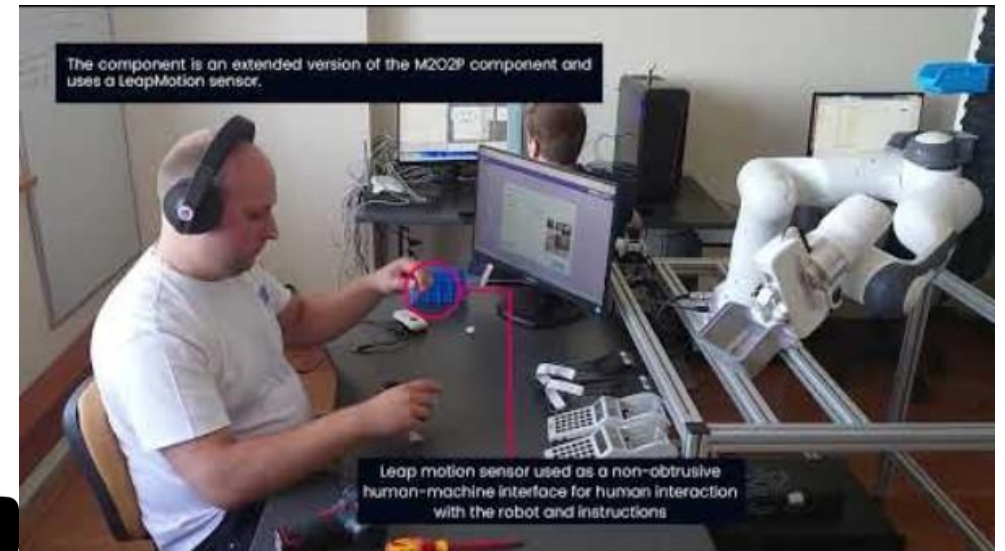
BrainWatch 2.0 – Cobot + XR headset

ETF Robotics

CircuBot - Modular and versatile collaborative intelligent waste management robotic system for circular economy

https://www.youtube.com/watch?v=nuBwZ4MKNFM

CircuBot main features:

➢ A tool for optimal design of collaborative sorting station

➢ Algorithm for fast training for object classification

➢ Computer-vision-based assesment of object demage level

➢ Smart task scheduler for task distribution between agents (cobots and human operators)

Versatile waste sorting in small batch and flexible manufacturing industries using deep learning techniques

Аутори   Arso M Vukicevic, Milos Petrovic, Nebojsa Jurisevic, Marko Djapan, Nikola Knezevic, Aleksandar Novakovic, Kosta Jovanovic

Датум   2025/1/30
објављивања

Часопис   Scientific reports

Trustworty DIH
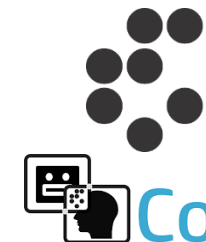
ETF Robotics

ETF Robotics supports industry with the following services:

- Collaborative research
- Proof-of-concept (PoC) lab development
- Return-of-Investment (RoI) study
- Access to funding for innovation actions
- Trainings (robot programming)
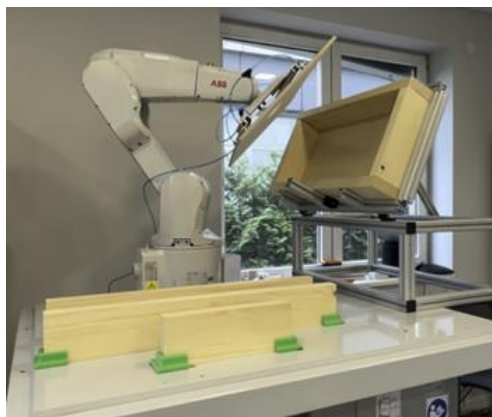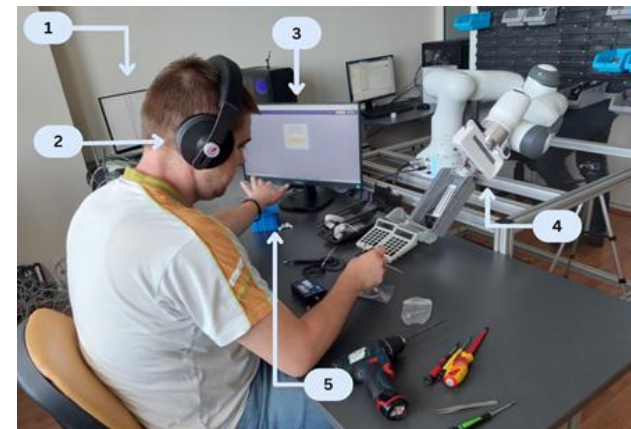- Organizing student competitions / hackathons

> **PoC + RoI**
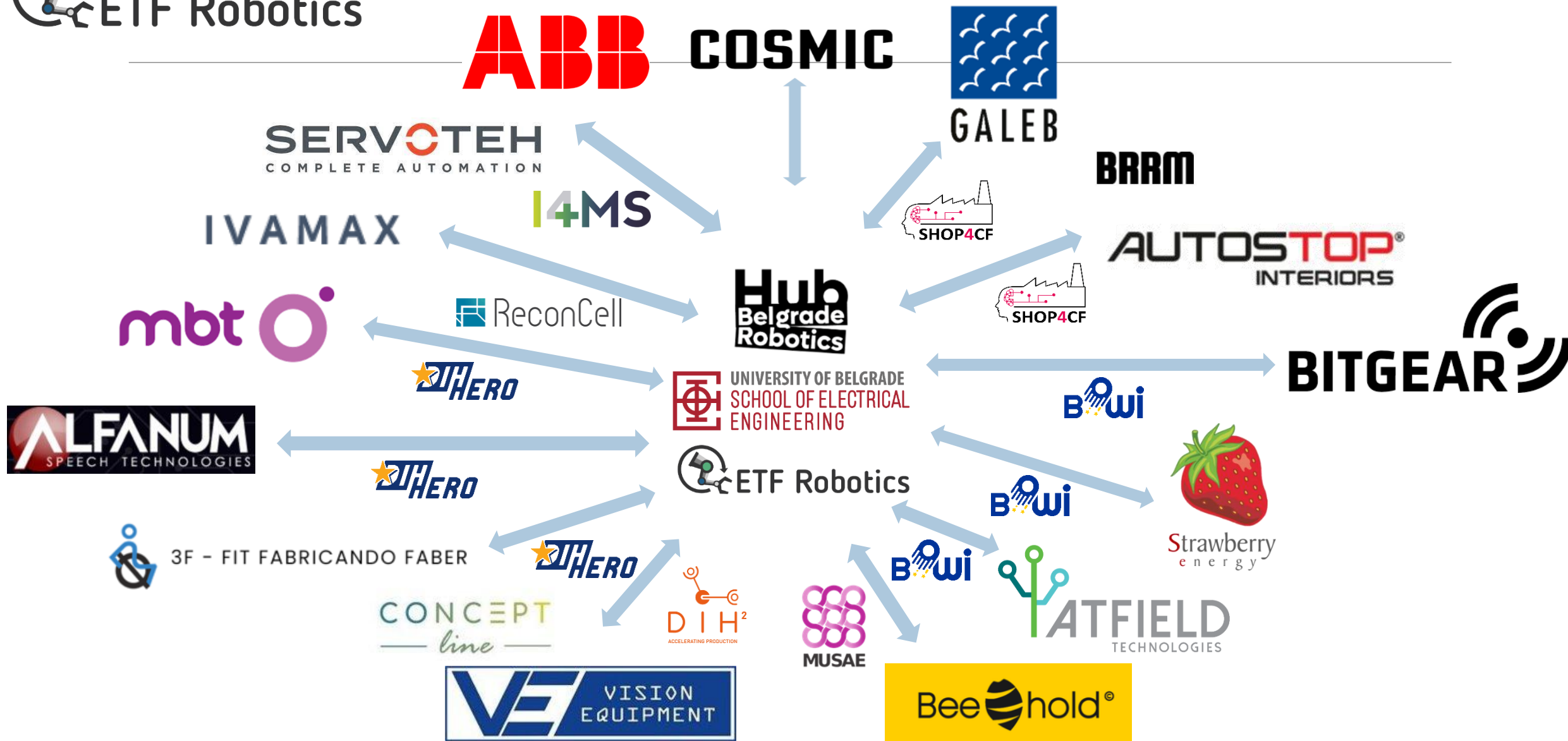> Self-reconfigurable assembly line for IVAMAX

> **PoC**
> Cobot-supported assembly for GALEB

> **PoC**
> Robot panel builder for COSMIC

Trustworty DIH

ETF Robotics

New lab @Palace of Science

new lab

cobot-supported neuroergonomics workstation for Industry 5.0

mobile cobot on omniwheel base

computer-vision and AI for handling moving objects of arbitrary shape

Thank you for your attention!

website: http://robot.etf.rs/

e-mail: robot@etf.rs