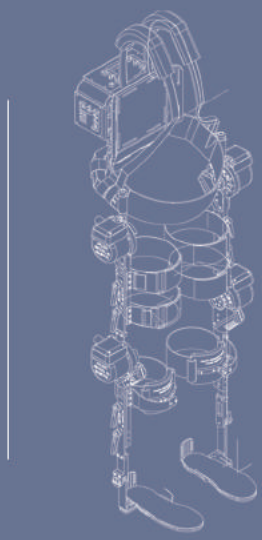
FUM CARE

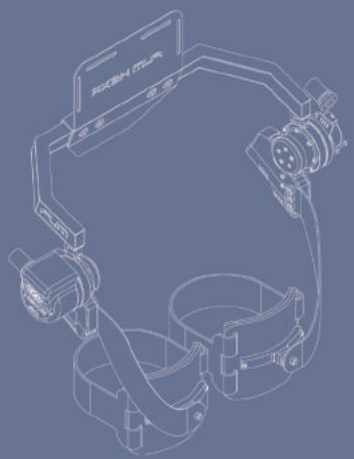
CENTER OF ADVANCED
REHABILITATION & ROBOTICS RESEARCH

FUM Center of Advanced Rehabilitation and Robotics Research (FUM CARE) is dedicated to dynamic research and innovation in all branches of robotics with the aim of advancing technology towards improving the standards of living.

Products

- Medical Robots
- Industrial Robots
- Motion Simulators
- Bio-inspired
- Mobile Robots
- Sensors
- Artificial Intelligence





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Orthopedic Research Center

Medical Robots

FUM-Exoskeleton

The FUM-Exoskeleton is a lower limb wearable exoskeleton robot with a variety of applications, including enhancing strength, mobility, and endurance of people experiencing paralysis and mobility issues after a brain injury, stroke, or spinal cord injury.

- Six anthropomorphic degrees of freedom in hip, knee, and ankle joints
- Hip and knee joints powered by 4 MAXON EC flat motors
- Extensive sensor usage (EMG, IMU, GRF, joint torque sensor, etc.)
- Advanced control system to give full movement control
- Open control architecture allowing implementation of custom algorithms
- Modular design allows users to independently wear the robot
- Weight < 28 kg
- Max speed of 0.8 m/s
- Battery life on a single charge, 1.5 hours continuous walk or 8 hours intermittently
- Adjustable for users of different sizes

FUM-HEXA

The FUM-HEXA is used for the evaluation and rehabilitation therapy of the hip joint. It is designed to help those with weakened leg muscles but who are still able to walk. It is used for patients with arthritis, hip arthroplasty, mobility defects, hemiplegia or those who simply need to walk faster.

- Three anthropomorphic degrees of freedom in each hip joint
- Hip flexion/extension powered by a MAXON EC flat motor
- Extensive sensor usage (EMG, IMU, GRF, joint torque sensor, etc.)
- Assistive torque up to 12 N.m
- Max speed of 1.2 m/s
- Battery life on a single charge, 2 hours of continuous walk
- Open control architecture allowing implementation of custom algorithms
- Record and report patient progress
- Comfortably worn by user
- Adjustable for users of different sizes

FUM-Physio

The FUM-Physio is designed to allow isokinetic, isotonic, isometric and passive exercises. It can be used following knee surgery (ACL reconstruction, cartridge repairs, and arthroscopy), as well as following quads or hamstring tendon repair surgery.

- One DOF Lower-limb rehabilitation robot
- Equipped by EMG recording device
- Ability to record force, angular speed and position
- Integrated with a variety of cognitive games
- Adjustable for users of different sizes
- Ability to simulate hydrotherapy exercises
- Visual feedback for patient motivation

FUM-Hand V

The FUM-Hand V is designed for individuals with upper limb loss to perform daily tasks with ease. Five Independent powered fingers and manual rotating thumb position make it possible to grasp objects with different shapes. EMG-based control makes it easy to control the hand and perform a natural grasp pattern.

- 7 DOF (including wrist movement), 5 motors with Worm gear
- Manual selectable thumb position
- Non back-drivable finger motion
- Ability to absorb collision forces
- Independent finger control
- EMG signals for activation-force feedback sensor
- Innovative control algorithm base on US patent (US10912512B2)

FUM-Hand C-II

FUM-Hand C-II is a cable-driven prosthetic hand with 6 DOF that is designed to help individuals with upper limb loss fulfill everyday activities and improve their life quality.

- 6 DOF - 6 motors
- Motors placed at the forearm-actuation type: Tendons and pulleys
- Independent finger control
- Ability to take shape of different objects
- Uses EMG signals for activation
- Gloves for position feedback and teaching

FUM-Hand III

The quick and precise response of FUM-Hand III alongside its light weight makes it a perfect prosthetic hand for everyday activities. EMG-based prostheses plus innovative force sensor responds to the wearer and allows for a natural grasp patterns. Griping force sensory feedback leads to ability of grasping fragile objects.

- One degree of freedom four bar mechanism
- Non-back driven and worm-gear power transmission
- Adjustable grasp force (0-10 N) and speed (15-260 mm/s)
- Light weight structure (380 g)
- Griping force sensory feedback (FSR)
- Impedance control based on electromyography (EMG)

Industrial Robots

FUM-6R

The FUM-6R articulated robot specialized in handling applications such as machining, assembly, palletizing, arc welding, painting, etc. Open control architecture makes this robot a unique industrial level robot ideal for university research.

- Six DOF
- Max payload: 10 Kg
- Maximum reach: 1.3 m
- Max Cartesian speed: 2.8 m/s
- Repeatability: ±0.015 mm
- Open control architecture
- EtherCat communication protocol

FUM-N6R

FUM-N6R is our 2nd generation six axis articulated robot for heavier payloads applications such as machining, assembly, palletizing, arc welding, etc. Open control architecture makes this robot a unique industrial level robot ideal for industry and university research.

- Six DOF
- Max payload: 16 Kg
- Max reach: 1.6 m
- Max Cartesian speed: 3.5 m/s
- Repeatability: ±0.05 mm
- Open control architecture

FUM-SCARA

The FUM SCARA robot is designed for pick-and-place or assembly operations where high speed and high accuracy top down assembly is required. The light and slim design of this robot plus its load capacity makes it a great fit for tiny work cells.

- Robot type (Series RRR-P); X, Y, Z, ϑ
- Max payload: 5 Kg - Max Cartesian Speed: 7500 mm/s
- Repeatability: 0.05 mm
- Industrial grade control architecture for factory usage
- Simulink Matlab interface
- Open control architecture

FUM-SCARA II

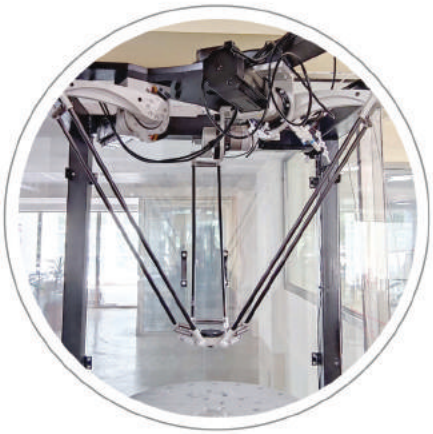
Our second generation industrial grade four axis FUM-SCARA II robot with increased accuracy of up to ±10 microns, linear speeds as high as 7.5 meters per second and small foot print is an ideal robot for demanding assembly operations.

- Robot type (Series RRR-P); X, Y, Z, ϑ
- Max payload: 4 Kg - Max Cartesian Speed: 7500 mm/s
- Repeatability: 0.015 mm
- Industrial grade control architecture for factory usage
- Applications: Pick & Place in the packaging industry, pharmaceutical

Industrial Robots

FUM-Delta

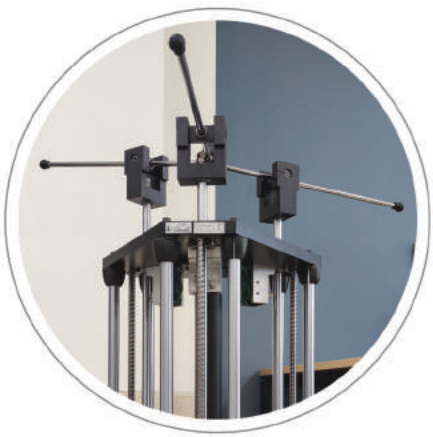
The **FUM-Delta** has accelerations as high as 15 G with a relatively large work envelop. The light weight industrial level robot is ideal for demanding high speed and high accuracy pick and place operations.



- 4 DOF (X, Y, Z, ϑ)
- Acceleration up to 15 G
- Parts picks/min as high as 126
- Payload: 2 kg
- Repeatability: 0.1 mm
- Maximum speed: 7000 mm/s
- Horizontal stroke: 800 mm - Vertical Stroke: 380 mm
- Etherlab communication protocol
- Open control architecture

FUM-3PSP

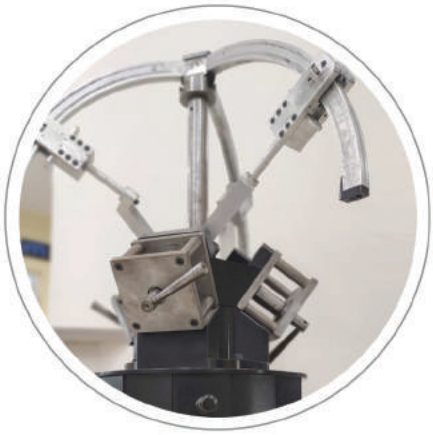
The semi-industrial **FUM-3PSP** is a spatial type parallel manipulator, with three prismatic-spherical-prismatic joints. Its open control architecture plus its inherently safe mechanical design make it ideal for implementing various control algorithms.



- The Semi industrial 3PSP is of type 3-PSP parallel robot
- Selectable three out of six (X, Y, Z, ϑ, φ, λ) degrees of freedom
- Used for orienting a tool and solar panels
- Open control architecture suitable for research applications

FUM-Zippy Wrist

The **FUM-Zippy Wrist** is a fully spherical type parallel robot with a star shaped end effector and three revolute-spherical-prismatic branches 3-RPR. It allows orienting its end-effector in 3 axis.

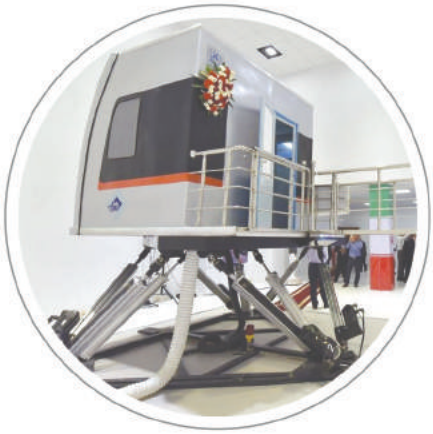


- 3-RPR Parallel robot
- Fully Spherical robot
- Mechanical handles in place of motors for teaching applications
- Applications in orienting objects

Motion Simulators

FUM-Large Stewart

A high payload and high-speed system based on a Stewart platform with 2200 Kg payload capacity. The 6 DoF motion platform is mainly intended for professional applications for flight and driving simulation and entertainment industry. It can also be equipped with the pneumatic weight support system.



Specification						
Motion	**Yaw**	**Pitch**	**Roll**	**Heave**	**Sway**	**Surge**
Position	± 20 °	± 14 °	± 14 °	± 30 cm	± 30 cm	± 30 cm
Velocity	25 °/s	20 °/s	20 °/s	0.45 m/s	0.5 m/s	0.5 m/s
Acceleration	180 °/s^2	180 °/s^2	180 °/s^2	3 m/s^2	3 m/s^2	3 m/s^2

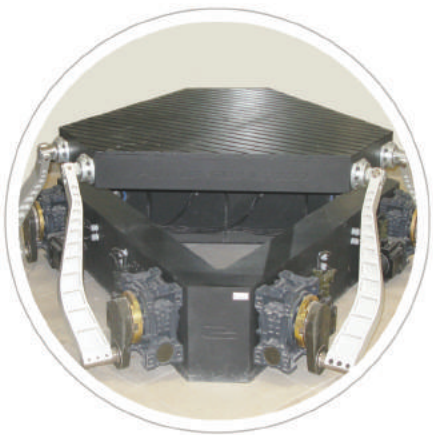
FUM-Stewart m450

With an acceleration of 2G for 450 Kg payloads, this Stewart type platform allows unique and demanding simulation applications. In house custom designed electromechanical linear actuators ensure long life and high repeatability.

Specification						
Motion	**Yaw**	**Pitch**	**Roll**	**Heave**	**Sway**	**Surge**
Position	± 20 °	± 14 °	± 14 °	± 14 cm	± 25 cm	± 25 cm
Velocity	50 °/s	50 °/s	50 °/s	0.5 m/s	1 m/s	1 m/s
Acceleration	500 °/s^2	500 °/s^2	500 °/s^2	2 g	1 g	1 g

FUM-6RSU

The six degrees of freedom, FUM-6RSU (revolute-spherical-universal) parallel robot is ideal for general purpose simulation applications. Its low profile mechanical design allows it to fit in tight spaces and carry a 1000 Kg load with up to 0.6 m/s2 accelerations.



Specification						
Motion	**Yaw**	**Pitch**	**Roll**	**Heave**	**Sway**	**Surge**
Position	± 11.5 °	± 9.3 °	± 9.6 °	± 0.12 m	± 0.12 m	± 0.12 m
Velocity	50 °/s	38 °/s	38 °/s	0.45 m/s	0.66 m/s	0.66 m/s
Acceleration	500 °/s^2	250 °/s^2	250 °/s^2	6.5 °/s^2	6.5 °/s^2	6.5 °/s^2

Motion Simulators

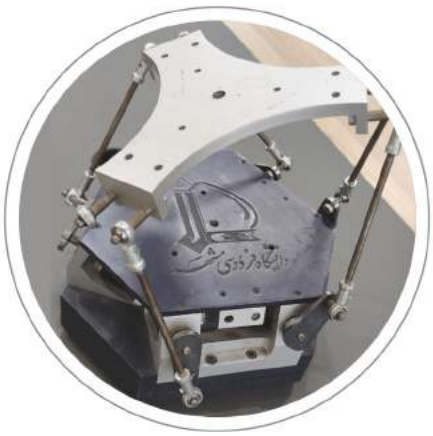
FUM-3RRS

The FUM-3RRS is a low cost industrial level simulator with three degrees of freedom. It can carry 250 Kg weight in Heave, Pitch and Roll directions.

Specification			
Motion	**Pitch**	**Roll**	**Heave**
Position	± 18 °	± 23 °	0.15 - 0.47 m
Velocity	60 °/s	60 °/s	0.26 m/s
Acceleration	250 °/s^2	250 °/s^2	25 m/s^2

FUM-Mini Simulator

The FUM-Mini Simulator is a 6RSS parallel robot, designed for mechanical and biomedical applications. It is only 30 cm in length, widths and height which makes it ideal for teaching and research applications.



Specification						
Motion	**Yaw**	**Pitch**	**Roll**	**Heave**	**Sway**	**Surge**
Position	± 20 °	± 25 °	± 25 °	± 5 cm	± 5 cm	± 5 cm
Velocity	50 °/s	50 °/s	50 °/s	0.5 m/s	0.5 m/s	0.5 m/s

Mobile Robots

FUM-Lawn Mower

The **FUM-Lawn Mower** robot is capable of performing safe and autonomous lawn mowing with minimum user intervention. It incorporates various safety feature such as collisions, lifting and rolling detections which immediately stops the cutting blade.

- Fully autonomous
- Automated blade height adjustment
- High precision GPS system
- Collision safe blades
- Data transfer to remote server
- Flexible programming
- Quiet operation

FUM-VIRUB

The **FUM-VIRUB** is a mobile Trolley UV based Sterilizer disinfection system. It has a stylish design with stainless steel structure. It can be used in various enclosed spaces namely hospitals, office spaces, shopping malls, schools, airports, etc.

- Whole room sanitization
- Application in hospitals, clinics, industry, hotels, public, transportation, etc.
- Disinfecting environment from various microbes, bacteria, and viruses
- 360° UVC light penetration
- Power: 1.08 KW
- Radiation power: 324 W
- Long bulb life: 8000 h
- Weight: 65 Kg
- Size: 80×50×160 cm (l×w×h)

FUM-Handy VIRUB

The **FUM-Handy** VIRUB is a handheld portable UV based sanitizer. It is a light weight and powerful disinfection tool for home, work, and everywhere in between. It kills 99.9% of bacteria and viruses in seconds.

- Disinfecting environment from various microbes, bacteria, and viruses
- Low cost
- Battery operated
- Light weight
- No need for dangerous chemical disinfectants

FUM-Segway

The **FUM-Segway** is a two wheel self-balancing personal transporter. It provides an environmentally friendly alternative to car-based short-distance transportation. It is an excellent example of inverted pendulum applications. Its open control architecture makes it ideal for doing stability and control studies in research or university labs.

- Ability to carry 100 Kg
- Max speed 20 Km/h
- Brushless DC motor
- Open control architecture

Sensors

FUM-EMG

The **FUM-EMG** is a 16-channel board-based device with active electrodes, designed to record electrical signals of the muscles during contraction and relaxation.

- CMRR > 90 dB
- EMG input range: ±25 mV
- EMG bandwidths: 20-500 Hz
- EMG sampling rate: 4370 sample/sec (max)
- Sensor resolution: 24 bits
- Input referred noise: 5uVrms (20-500 Hz)
- Electrode offset toleration: ±250 mv
- Wi-Fi and CAN communication protocols

FUM-IMU

This electronic device can measure and report acceleration,angular rate, and the orientation of the human body by using a combination of accelerometers, gyroscopes, and magnetometers. It comes in wireless and wired versions.

- 9 DOF Inertial Measurement unit
- Data fusion
- Convenient configurations of outputs, output rates, output format and sensor alignment
- Real-time data acquisition and monitoring
- Coordinate calibration in multi-sensor applications
- High speed angle measurement using internal processor
- Fully tested and calibrated
- Wi-Fi data transmission (sample frequency = 100 Hz)

FUM-Smart Insole

As a low-profile wearable device, the **FUM-Smart Insole** contains FSR sensors to measure and analyze vertical interactions between foot and ground. It can provide gait phase detection, and gives gait parameters including center of pressure, vertical ground reaction force, cadence, pas, and balance.

- Maximum thickness: 1.3 mm
- Number of force sensors: 8
- High flexibility for convenient use
- Robust mechanical design
- Wired/wireless versions
- CAN or USB communication protocols

Projects

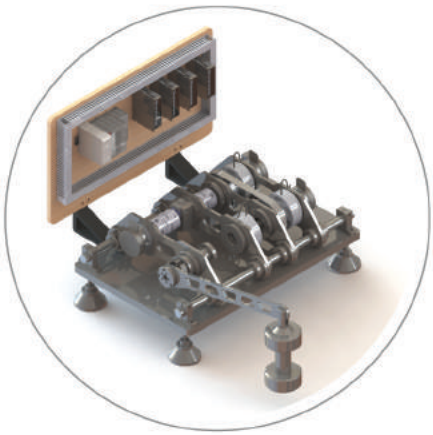
FUM-Driver

In a compact design, the **FUM-Motor Driver** can provide reliable and high precision control of DC motors in all the three torque, speed and position operation modes.

- Accurate control for DC motors (40 V/15 A)
- Efficiency up to 97% at 500W output power
- CAN, isolated USB, and isolated RS-485 ports with dedicated simple communication protocols
- Over current and over voltage protection
- Three operation modes: torque, speed and position
- Field oriented control using both Hall-Effect and Incremental Encoder or with sensor-less estimation

FUM-Test Setup

As its name implies, this **test setup** is launched to simulate the performance of the assistive robots and implement control algorithms in a controlled environment.



- Simulation of human joint movements
- Implementation of various control algorithms
- Identification of motor and gearbox
- Identification of series elastic actuators

FUM-Linear Actuator

The **FUM-Linear** Actuator is designed to provide linear motions for applications that require large output force and high precision such as robots with linear motion or lifting, pulling and pushing heavy objects.

- Max stroke: 330 mm
- Max speed: 0.53 m/s
- Max continues force: 4250 N
- Max instantaneous force: 12750 N
- Available in other combination of strokes, forces, and speeds

FUM-Rotary SEA

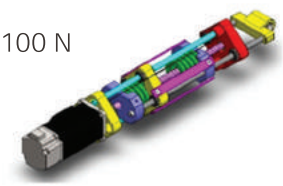
Developed to reduce interface stiffness in rotary motions, **FUM-RSEA** offers certain advantages over rigid actuators including greater shock tolerance, lower reflected inertia, more accurate and stable force control, less inadvertent damage to the environment and the capacity for energy storage.

- Stiffness: 275 Nm/rad
- Max instantaneous torque: 70 Nm or 150 Nm
- Nominal torque: 15 Nm or 54.36 Nm
- Torque resolution: 0.10 Nm

FUM-Linear SEA

With an elastic element attached between the motor and output link, this linear actuator provides several advantages over rigid actuators such as low mechanical output impedance and better force control, tolerance to impact loads, increased peak power output, and energy storage.

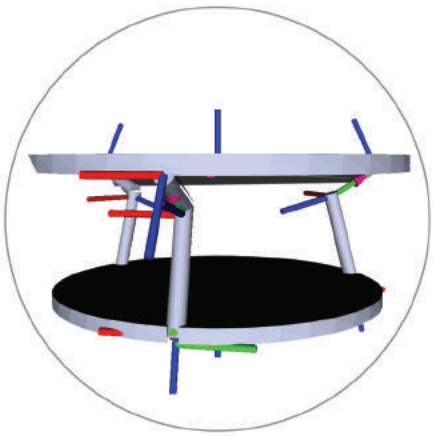
- Stiffness: 8600 N/m
- Max instantaneous force: 2100 N
- Nominal force: 700 N
- Force resolution: 0.3 N



Artificial Intelligence

Intelligent Robot Control

Intelligent control extends the boundaries of systems theory to control unstructured, uncertain, and time varying environments, such as industrial robots and human-robot interaction. Specifically, we combine classical control theories with various paradigms of intelligent systems such as fuzzy logic and neural network to ensure stability and performance despite large unknown dynamics, disturbances, time varying parameters and unmeasured states.



- Use the wide inventory of experimental testbeds such as the FUM-3RRS, Delta, SCARA, 6-RUS, 6R and Stewart platform.
- Robot Operatic System (ROS) is used to integrate various modules and to implement various robot control strategies in real-time.
- Gazebo and unity are used to simulate various robots and their environments.

Competitive Physical Human-Robot Game Play

Human competitive artificial intelligence has already been examined in various mind games such as Go and Chess. The concurrent testing of human-competitive intelligence and physical agility, however, remains a much evading problem since it requires a multidisciplinary approach. Here, we exploit the human-robot interaction in a competitive Ping Pong game through a physical Delta-robot that is powered by a reinforcement learning intelligent design.

- Optimized Delta Robot Hardware for playing Ping Pong games
- Robot Operating System (ROS) to integrate subsystem processes such as vision, learning, and robot control processes
- Real-time image processing for ball and opponent state feedback
- Simulations in Gazebo and Unity software environments for Robot-Robot Learning
- Reinforcement Learning

Human Intention Estimation by Deep Learning Structures

We use end-to-end deep learning structures to estimate human intention and provide better human-robot collaboration using input signals from our various homemade devices such as FUM-Smart Insole, FUM-IMU and FUM-EMG.

- Amputee intention detection for bionic hands based on a unique method (USP: WO2019008497A1)
- Real-time human intention estimation for rehabilitation using exoskeletons by fusion of FUM-imu and FUM-smart insole data
- Support Vector Machine and Linear Regression to estimate human intention using electromyogram signal
- Human motion estimation and gait abnormality using imu sensors

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REHABILITATION & ROBOTICS RESEARCH

Artificial Intelligence

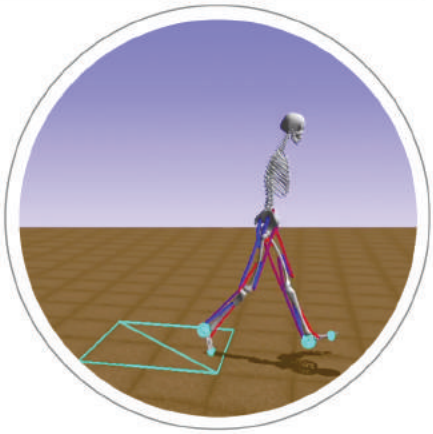
Intelligent Robotic Rehabilitation

Video games are developed for patients to follow their physiotherapy exercises more effectively, more pleasantly while being entertained. The games follow patients' progress and accordingly adapt the level of game difficulty and increase patient engagement with the therapy.

- Progress estimation of patients by an actor-critic network and fuzzy expert system. Custom design fuzzy logic impedance controller simulates in water condition. Rehabilitation games for hemiplegic stroke patients
- Rehabilitation games for various knee injuries such as knee osteoarthritis, ACL as well as knee arthroplasty.

Video Game-Strategies for Physiotherapy

Patient's strength, capabilities and gait are evaluated using intelligent methods and the required rehabilitation level are determined. The Patients' neuro-musculoskeletal model is generated and controlled by artificial intelligence to simulate patients' behaviors. Next, the robot control strategies are tuned for real-time movement rehabilitation.



- Personalized musculoskeletal models of patients
- Use of Strength Index to assist as needed
- Custom design rehabilitation strategies

Human-Robot interaction

We research how to communicate with robots and use new methods to communicate faster and easier with them.

- Movements of magnet embedded amputee hands are translated using deep neural networks in terms of desired hand gestures for a smooth and transparent bionic hand.
- Vision system is used for hand gestures recognition for teaching and commanding our industrial FUM-Delta robot.
- Force sensor attached to the robot end effector is used to allow physical human-robot interaction.

Vision-Based gait analysis

Gait analysis has a wide application in medical, rehabilitation, geriatric care, biometrics, and sports. We use the visual approach with and without the use of markers or depth sensors to detect gait abnormalities and monitor remote physical therapy using deep neural networks and pose estimation models. Additionally, we use vision for:

- 2D and 3D marker or marker-less gait analysis
- Remote rehabilitation monitoring
- Gait abnormality detection using deep neural networks
- Detecting various gait patterns
- Fall detection using deep neural networks
- Quantitative assessment of motion using deep neural networks

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