Friedrich-Alexander University
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ASSISTIVE INTELLIGENT ROBOTICS

FAU

Sensors for Intent Detection 2

Sensors

US

FMG

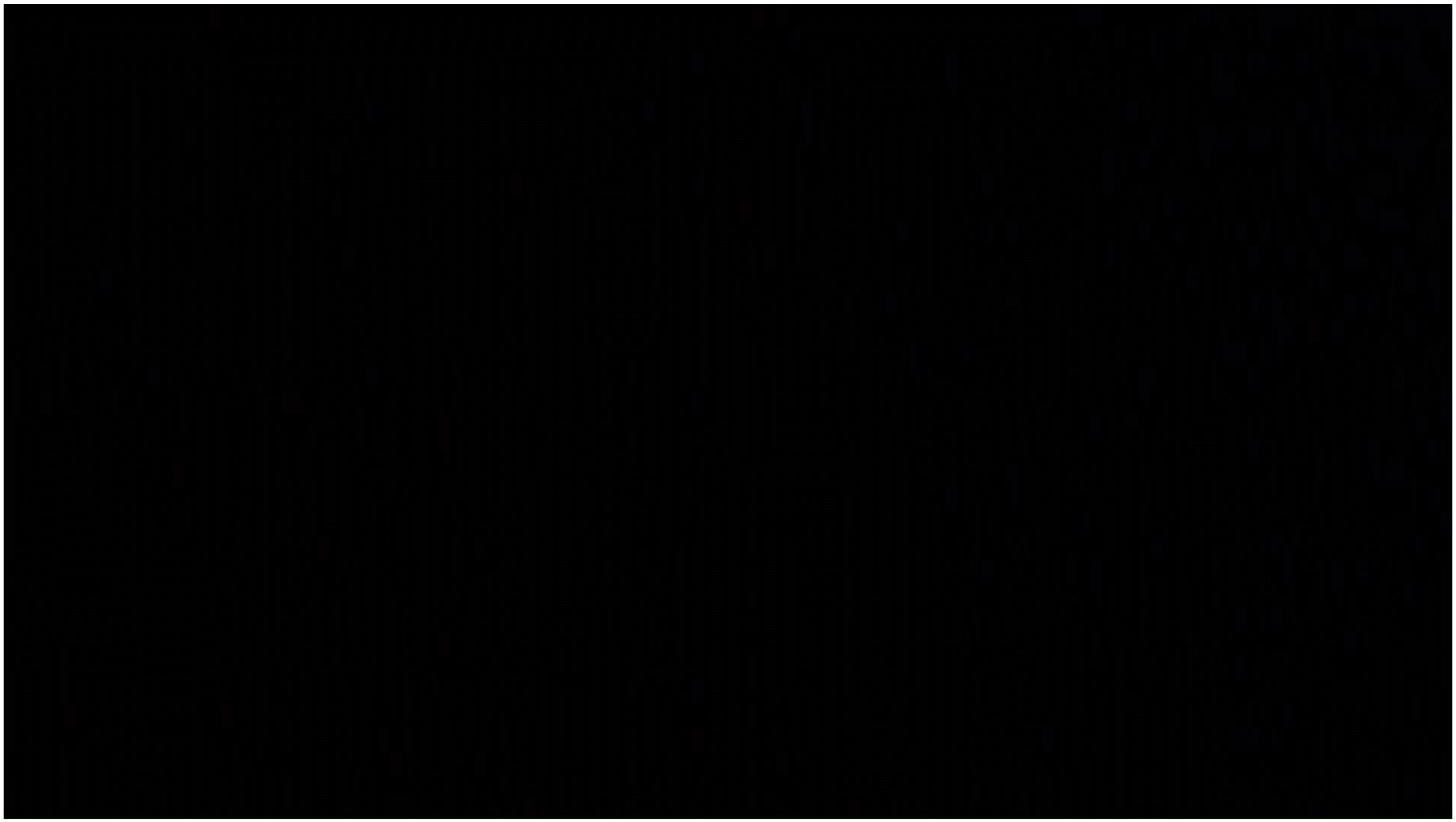
IMU

EIT

force / torque

sEMG / EMG

Ultrasound



Ultrasound

What are the benefits of ultrasound with respect to EMG and FMG?

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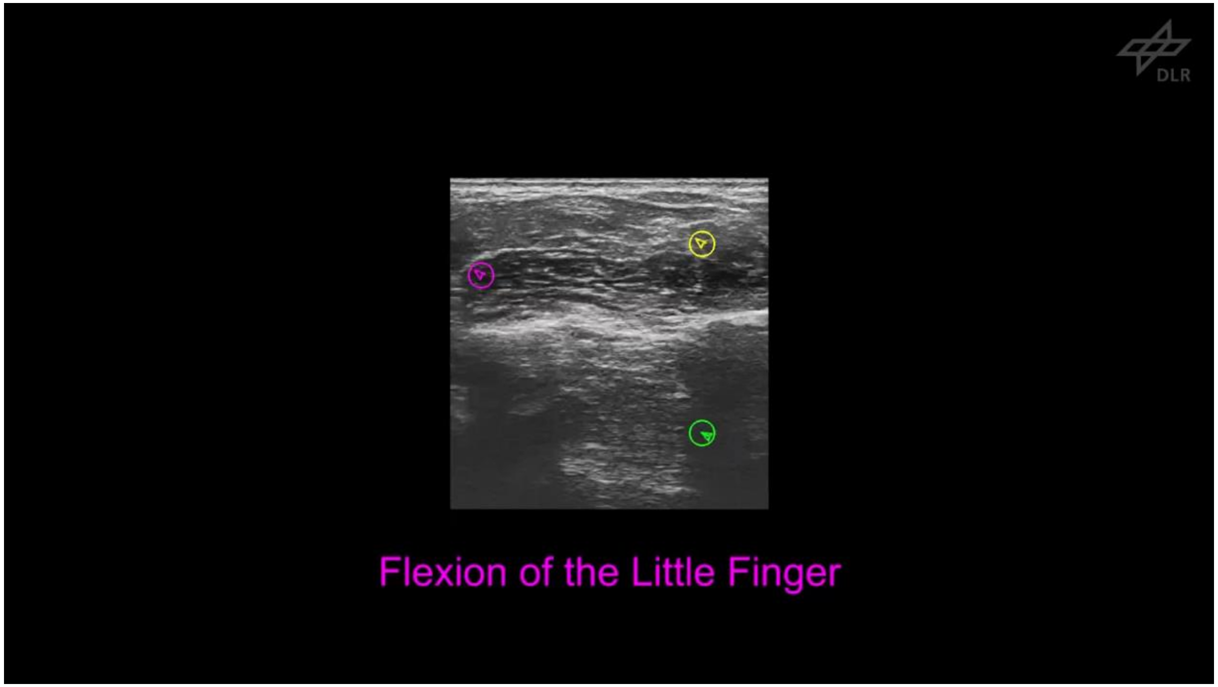


What are the issues of ultrasound?

https://sunrisediagnosis.com/blog/sonography-services-benefit-expectant-mothers-pune/

Pressure

https://diers.eu/de/produkte/

https://blog.xsensor.com/insole-pressure-mapping-and-human-performance

How does the pressure change during a walking cycle?

The image depicts the pressure distribution on the feet during different phases of the walking cycle. The walking cycle is divided into two main phases: the stance phase and the swing phase. Each phase consists of several sub-phases. Here's a breakdown of the terms and the overall image:

Stance Phase:

1.HS (Heel Strike):

1. The moment the heel first makes contact with the ground.
2. Pressure is concentrated on the heel.

2.FF (Foot Flat):

1. The entire foot is in contact with the ground.
2. Pressure distribution spreads across the whole foot.

1.MSt (Midstance):

1. The body's weight is directly over the supporting foot.
2. Pressure is more evenly distributed.

2.HO (Heel Off):

1. The heel lifts off the ground, transferring weight to the forefoot and toes.
2. Pressure shifts towards the ball of the foot and toes.

During a walking cycle, the pressure on the feet varies significantly. Initially, when the heel strikes the ground (heel strike), there is a high pressure on the heel. As the body moves forward, the pressure shifts to the midfoot (midstance) and then to the ball of the foot and toes (toe-off) as the foot pushes off the ground. This dynamic shift in pressure helps in propelling the body forward and maintaining balance during walking

1. **Swing Phase:**

1.TO (Toe Off):

1. The toes push off the ground to propel the body forward.
2. Pressure is concentrated on the toes.

2.IS (Initial Swing):

1. The foot lifts off the ground and moves forward.
2. Minimal to no ground contact, so no pressure distribution shown.

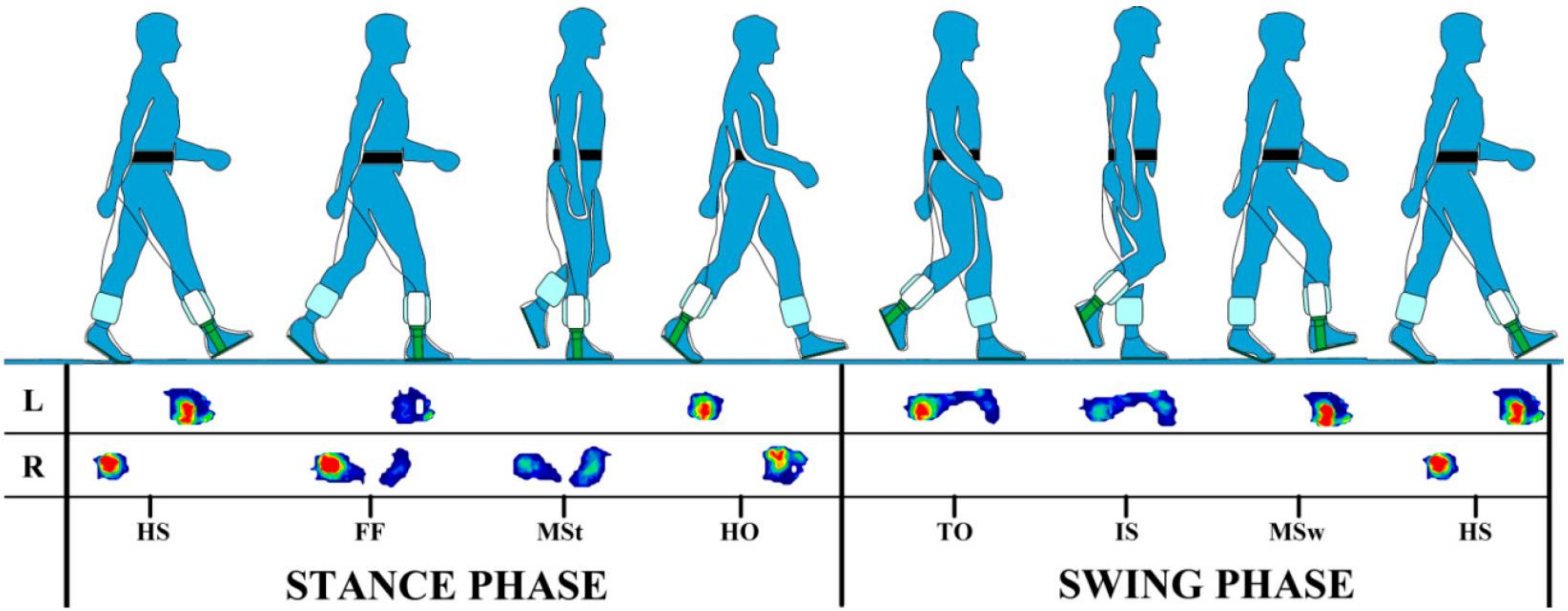
3.MSw (Mid Swing):

1. The leg swings through under the body.
2. The foot is in the air, so no pressure distribution shown.

4.HS (Heel Strike):

1. The heel strikes the ground again, beginning a new cycle.
2. Pressure is concentrated on the heel.

Pressure



Wafai, L.; Zayegh, A.; Woulfe, J.; Aziz, S.M.; Begg, R. Identification of Foot Pathologies Based on Plantar Pressure Asymmetry. *Sensors* **2015**, *15*, 20392-20408.

Pressure

What else can you detect using pressure insoles or pressure plates?

What else can you detect using pressure insoles or pressure plates?

1. Walking cycle - Pressure Distribution Across Sensors
2. Analysis of different regions of the foot: outside, medial, and inside.

3. Temporal data can detect how pressure shifts dynamically during different activities, providing insights into gait cycles and specific movements.

4. How pressure distribution changes during different activities

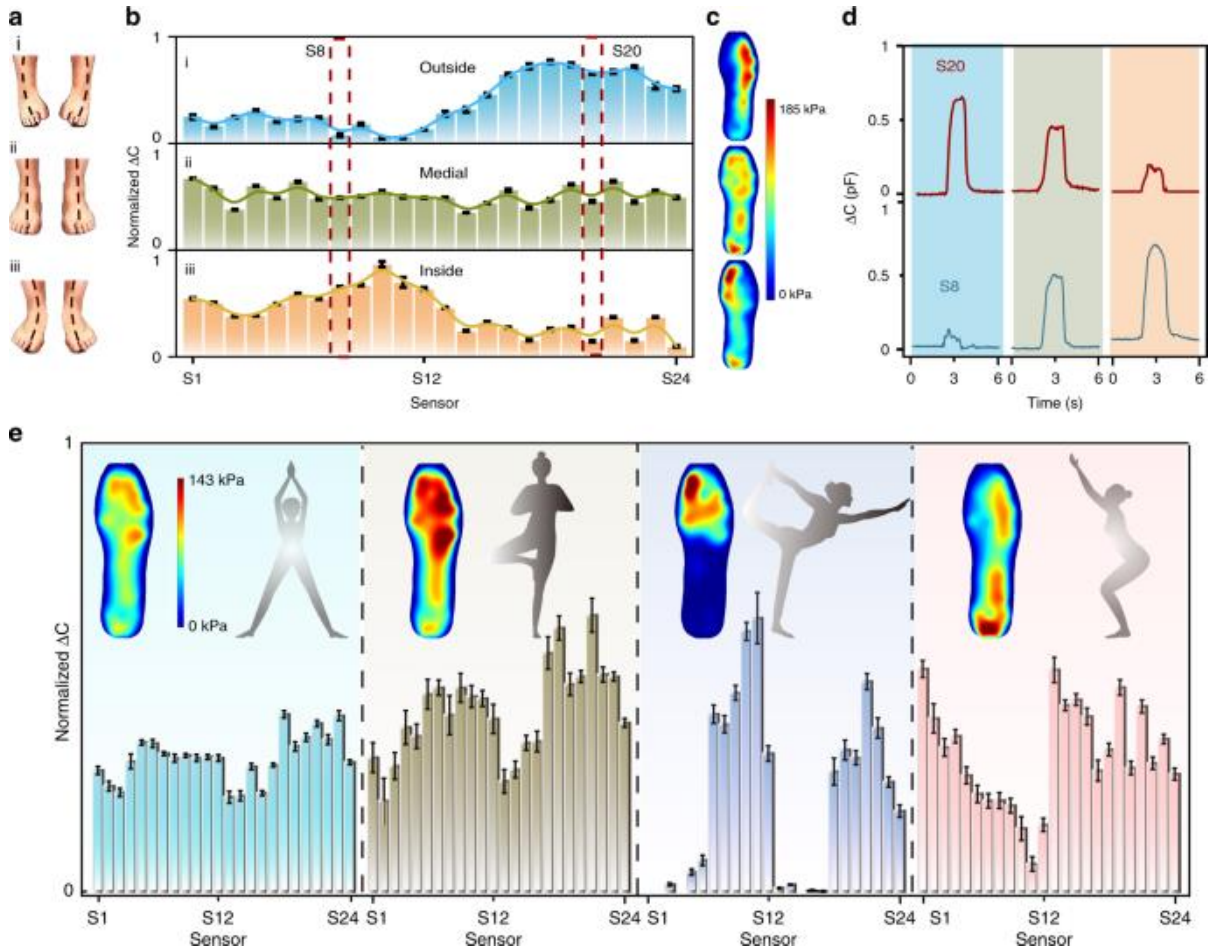
Posture Assessment: Understanding weight distribution to identify and correct postural imbalances.

Athletic Performance Monitoring: Evaluating foot pressure during different sports activities to optimize performance and reduce injury risk.

Rehabilitation Monitoring: Tracking pressure changes to assess the progress and effectiveness of rehabilitation exercises for lower limb injuries.

Check if the patient wants to stop or continue

Pressure



Tao, J., Dong, M., Li, L. *et al.* Real-time pressure mapping smart insole system based on a controllable vertical pore dielectric layer. *Microsyst Nanoeng* **6**, 62 (2020).

Imagine you combine a pressure sensor for the hand with an exoskeleton. Which user groups could benefit from that?

https://pressureprofile.com/body-pressure-mapping/finger-tps

Imagine you combine a pressure sensor for the hand with an exoskeleton. Which user groups could benefit from that?

1.During training if no senses in hand then they could Measure how much pressure is applied and give feedback
2. Harvesting robot

3.Rehabilitation Patients: Those undergoing physical therapy for hand injuries could use the exoskeleton to aid in their recovery and improve strength and coordination.

4.Industrial Workers: Workers performing repetitive or strenuous tasks could use the exoskeleton to reduce fatigue and prevent injuries

How could you use flex sensors to overcome back pain?

to monitor and correct posture

These sensors can detect the bending or flexing of the back and provide real-time feedback to the user
if the user slouches or adopts a poor posture, the device can alert them to correct their posture, thereby reducing the strain on the back muscles and spine over time

Upper back - Thoracic Spine
Lower back - Lumbar Spine
Shoulders
Neck,hips

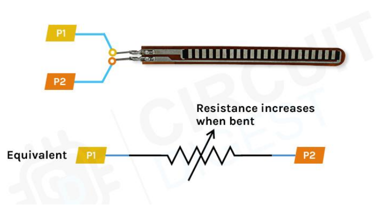
To what kind of wearables could you easily add them?

Straps around the chest

Smart clothing

Fitness trackers

Rehabilitation Devices:
Wearables used in physical therapy to monitor and guide movements during exercises.



Flex Sensors

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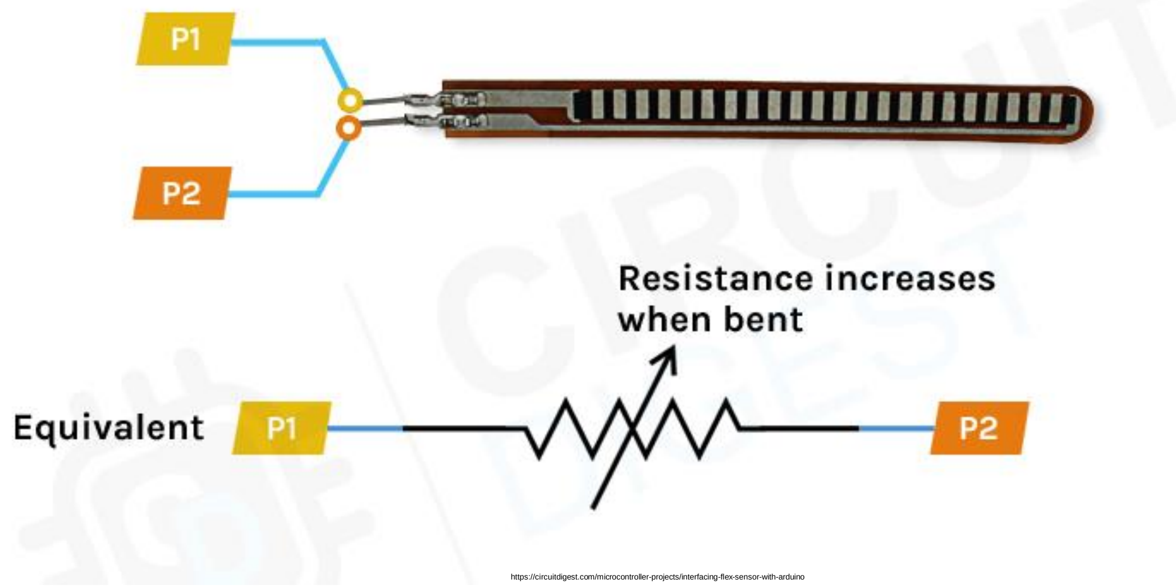

https://circuitdigest.com/microcontroller-projects/interfacing-flex-sensor-with-arduino

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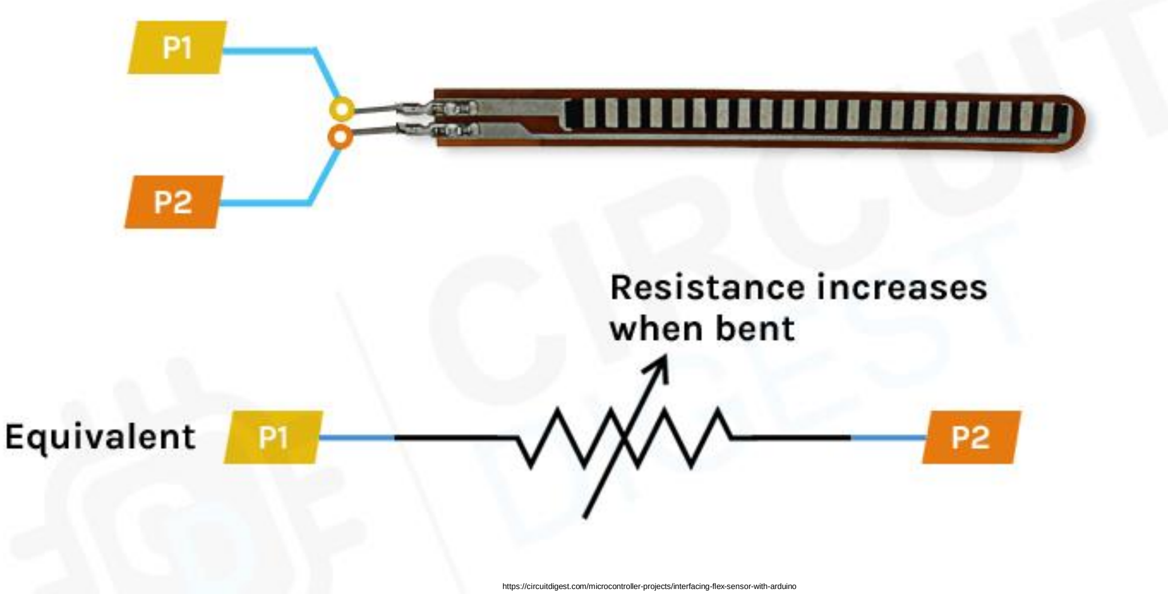

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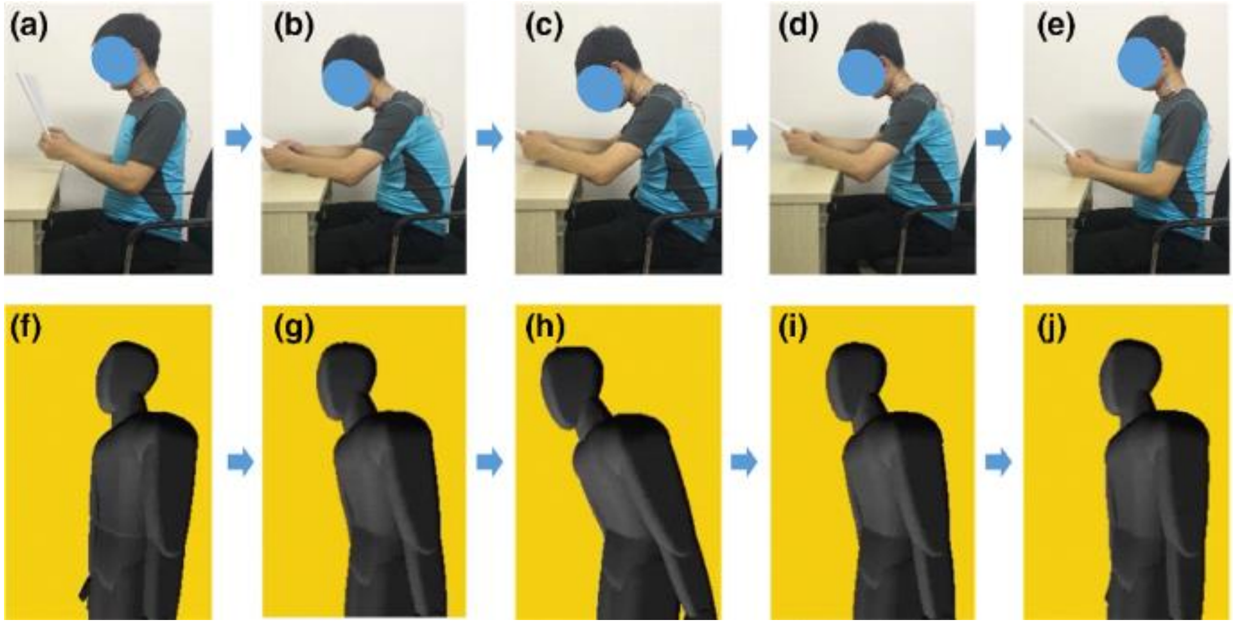

Zhang, J., Zhang, H., Dong, C. *et al.* Architecture and Design of a Wearable Robotic System for Body Posture Monitoring, Correction, and Rehabilitation Assist. *Int J of Soc Robotics* **11**, 423–436 (2019)

Benefits and Drawbacks of External Sensors

Benefits:

Accuracy: External sensors can provide highly accurate and reliable data.

Specialization: They can be specifically designed to measure particular metrics such as pressure, movement, or posture.

Non-Invasive: They do not require any surgical procedures, making them safer and more user-friendly.

Drawbacks:

Bulkiness: External sensors can be cumbersome and uncomfortable to wear.

Cost: High-quality external sensors can be expensive.

Data Management: They often require additional devices or software to collect and interpret the data.

Take time to set up

What sensors might be preferred during rehabilitation? Why?

External – if we are in a clinic, then no human errors
Else use wearable – if we can walk

What kind of sensors does (nearly) every participant already have with him/her?

•Smartphone
Sensors:Accelerometer and Gyroscope**:** Track movement and orientation.
Camera**:** Visual analysis and feedback
Microphone: Voice commands and audio feedback
Proximity and light sensors,IMU

Watches – track sleep,exercise

What is the difference between the sensors used during a session at the physio therapist and at home?

Physiotherapist Sessions:

Sensors: High precision, specialized sensors (e.g., high-resolution pressure plates, professional-grade EMG).

Monitoring: Detailed and comprehensive, under professional supervision.

At Home:

Sensors: Consumer-grade sensors (e.g., smartphone sensors, simple wearables).

Monitoring: Basic monitoring and feedback, focusing on adherence to exercise routines.

Visual Feedback

• Important for telemanipulation • Helps if system is precise but not accurate • Very intuitive • (Most of the time) easy to understand • Humans are pretty used to it from daily life

Haptic Feedback:

Technology Used: Uses devices like vibration motors.

Purpose: Creates physical sensations to mimic touch experiences.

Tactile Feedback:

Technology Used: Uses physical buttons, textures, and other tangible elements.

Purpose: Enhances the sense of touch through real physical elements.

Tactile feedback -
Sensing different materials
Sensing different textures
Haptic feedback - Sensory Feedback: Incorporating tactile sensors in prosthetic limbs to provide feedback about pressure, texture, and temperature. This can help amputees better control and feel their prosthetics, making them more functional and intuitive to use.

Vibration Motors: Embedding small vibration motors to simulate different tactile sensations, enabling amputees to distinguish between different types of surfaces or detect when they are holding an object.

Sensory substitution is a change of the characteristics of one sensory modality into stimuli of another sensory modality.

3 parts: a sensor, a coupling system, and a stimulator. The sensor records stimuli and gives them to a coupling system which interprets these signals and transmits them to a stimulator

External Sensors

1. What are the benefits and drawbacks of external sensors?
2. What sensors might be preferred during rehabilitation? Why?
3. What kind of sensors does (nearly) every participant already have with him/her?
4. How could you make use of these?
5. What is the difference between the sensors used during a session at the physio therapist and at home?

This involves providing feedback to the user through changes in temperature (heat or cold).

Examples:

•**Haptic Devices:** Devices that simulate touch-related experiences by altering temperature, such as feeling warmth when touching a virtual object.

•**Wearables:** Smart clothing or accessories that change temperature to signal alerts or provide comfort adjustments.

•**Virtual Reality:** VR systems that create immersive environments by varying temperature to match the virtual scene.

IMU and prosthetic hand - The IMU could be used to determine the orientation of the prosthesis holding the coffee and this could be used to adapt the orientation of the prosthetic hand if it is moved to overcome spilling.

Filter - **EMG** – frequency for ID - 50-150Hz

A band-pass filter for the range of [50Hz, 150Hz]

A common choice for EMG signal processing is the Butterworth filter due to its flat frequency response in the passband.

FE – Amplitude high -> more force

- Amplitude of the EMG
- Continuous EMG signal over a specific threshold - Ensures that the muscle activity stays above a certain level for a sustained period, which is crucial for stable and controlled actions, such as holding a paper cup without deforming it.
- Frequency Content of the EMG Signal

- Determine the intent from the features in EMG-If the amplitude of the EMG if over an specific threshold a
- If the amplitude of the EMG is below a specific threshold b (in case someone wants
- Continuous EMG signal (95% of the values) in the threshold range [a,b] over more than 2s
- 0-1 second: Sharp rise in the EMG signal.
- 1-2 seconds: Amplitude fluctuates as the grip is adjusted.
- 2-10 seconds: Steady amplitude, maintaining a consistent level of muscle contraction.

How could you use shared autonomy to grasp the paper cup using the IMU as input?

The human moves the hand to the paper cup and the hand. Once it is grasped, the prosthesis autonomously tries to keep it at a reasonable orientation to overcome spilling.

- Euler angles: might lead to singularities
- Rotation matrix: higher computation effort

Damage check

Temp and force sensors help

- Stimuli generated - Pressure on the prosthetic hand, with a pressure sensor at the fingers
- Deformation of the paper cup, with a camera

How could you preprocess the data from the temperature sensor?

You could use subsampling and define the threshold if you e. g. measure more than 75°C it belongs to bin 4. It is a 3 in the interval]75°C, 50°C]. And so on…

classify temperature readings into predefined bins or categories based on thresholds

preprocessing involves transforming and categorizing continuous temperature readings into discrete categories

DIY:

Prosthetic Limb Control:
Functionality Indication: Audio cues can signal the status of different functions (e.g., gripping strength, mode switching).
Error Notification: Alerts when something goes wrong or if adjustments are needed.
Sensory Substitution:
Tactile Information: Audio feedback can represent tactile sensations such as texture, temperature, and pressure by mapping these sensations to specific sounds or tones.
Environmental Awareness: Sounds can provide information about surroundings, helping amputees navigate safely.

In what situations is audio feedback helpful?

Accessibility: For individuals with visual impairments, audio feedback provides essential information that they cannot obtain visually.

Environmental Constraints: In dark or low-visibility environments, audio feedback ensures that users can still receive necessary information.

When is audio feedback superior to visual feedback?

Attention Management: Audio feedback can capture attention more effectively in scenarios where visual attention is divided, such as driving or multitasking.
Mobility and Portability: Audio feedback is more practical when users are on the move and cannot constantly look at a screen.
Alerting and Alarming: For critical alerts, such as emergency alarms or timer notifications, audio feedback is more effective in grabbing immediate attention.
Situational Awareness: In environments where maintaining situational awareness is crucial, like during sports or while operating machinery, audio feedback provides essential information without the need to divert visual focus.

Where is audio feedback used in our daily life?

Smartphones: Ringtones, message alerts, and voice assistants (e.g., Siri, Google Assistant).
Home Appliances: Beeps from microwaves, washing machines, and dishwashers indicating the end of a cycle.
Vehicles: Audible signals for seatbelt reminders, turn signals, and parking sensors.
Computers and Gadgets: Error beeps, notification sounds, and startup chimes.
Public transport: Announcements

How could you use audio feedback for assistive devices?

Screen Readers: For individuals with visual impairments, screen readers convert text on a screen into speech, allowing them to navigate and interact with digital content.
Auditory Alerts: Devices can use sounds to alert users to changes or important events, such as medication reminders or changes in health metrics.
Voice Commands: Assistive devices can be controlled using voice commands, providing an interactive and accessible way for users to manage technology.
Environmental Sensors: Devices that detect obstacles or changes in the environment (e.g., for the visually impaired) can provide audio cues to navigate safely.
Feedback for Wearables: Wearable devices, such as fitness trackers, can use audio feedback to inform users about their progress or health status without requiring visual confirmation.