SmartEdge

Use Case 5b: Healthcare: Digital Rehabilitation

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HES-SO

SMARTEDGE Project

Grant No. 101092908

https://www.smart-edge.eu/

Objectives

- Demonstrate a prototype that can accommodate **dynamic** and **self-organizing** wearables to support head and neck digital rehabilitation
- Integrate **a stream of data from wearable sensors** placed on various body parts.
- Facilitate continuous **home-based physiotherapy** through **near real-time feedback** and **data analytics**.
- Digital rehabilitation, particularly for chronic conditions and post-surgical recovery, is increasingly **favored over traditional methods.**

Motivation

- Traditional physiotherapy heavily relies on the **manual skills** and **episodic observation of therapists**.

- **Normally effective** but these methods are limited by scalability, accuracy, and the capacity to personalize treatment based on comprehensive data analysis.

- There has been a recent trend towards **integrating digital tools into rehabilitation practices**, such as **wearable sensors**, **3D cameras**, and **data analytics**, to enhance patient monitoring and therapy personalization

Challenges: Architecture

- **Near Real-time Analysis:** Provide real-time data processing and feedback due using distributed sensing and data orchestration.

- **Semantic-Based Orchestration:** Utilize semantic information to determine system actors (nodes) and their corresponding roles, resolving challenges in managing a diverse range of devices and sensors.

- **Dynamic Adaptation and Scalability:** Dynamically reconfigure the system when a device or sensor fails.

- **Enhanced Personalization:** Provide highly personalized therapy options tailored to individual patient needs.

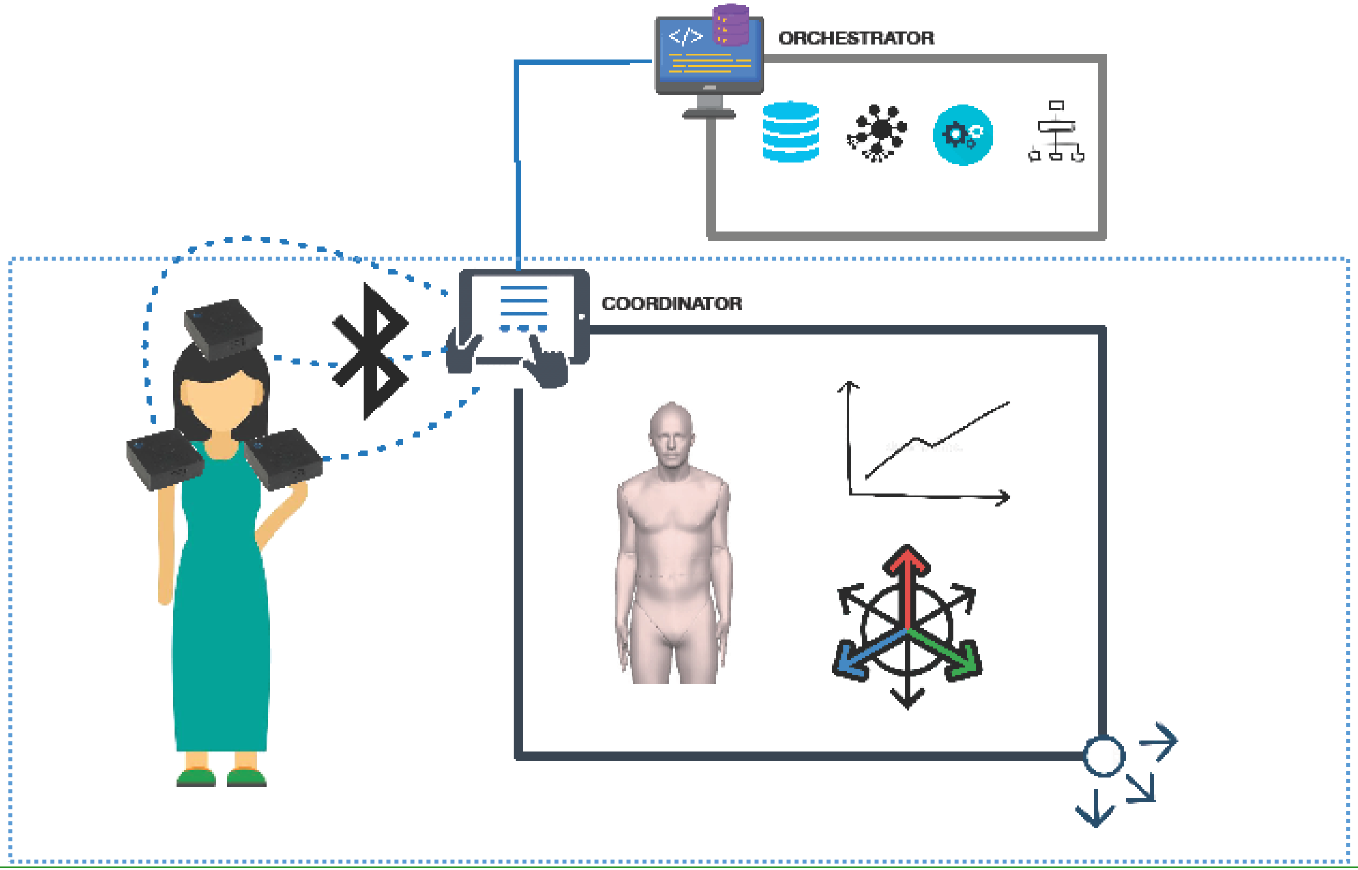
Stage 1

- How can we provide a near real-time feedback to the user for physical rehabilitation?

- Build a mobile application using Flutter with a body model.

- Apply the stream of sensor data onto the model.

Stage 1

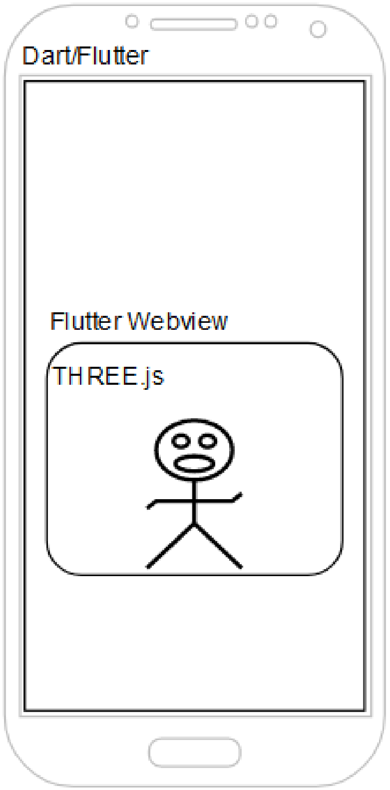


Stage 2

- How do we make it work with Flutter?

- Unfortunately Flutter can not render 3D models natively (yet).

- But it can render WebGL provided we have a web interface.



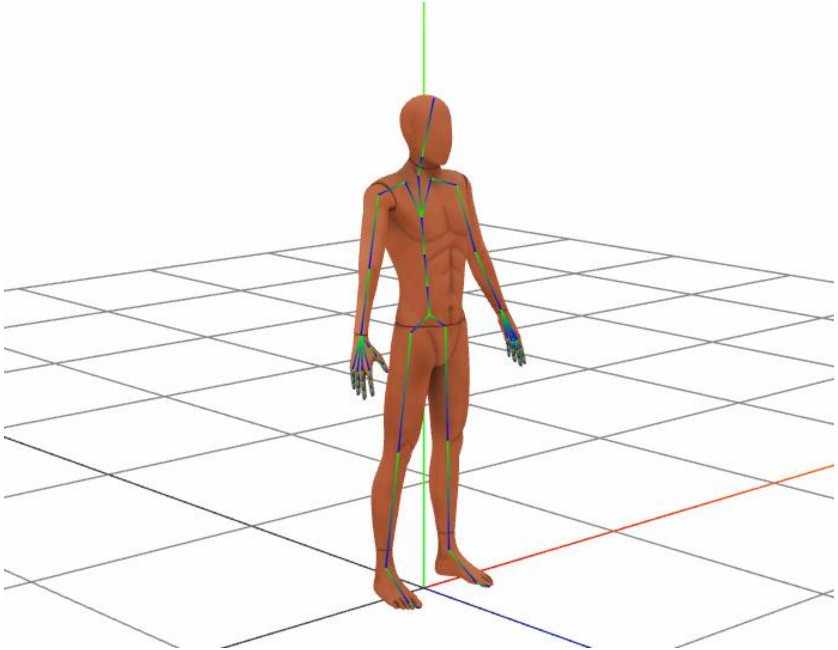
Stage 2

- First, we need a WebGL based 3D model viewer using web technologies.

- We use THREE.js and Maximo model.

- Use webpack (or alternatives) to compile a single html/js file

- We can host the web file internally using the WebViews (mobile embedded browsers)



Stage 3

- How do we make the model replicate the users’ movement?

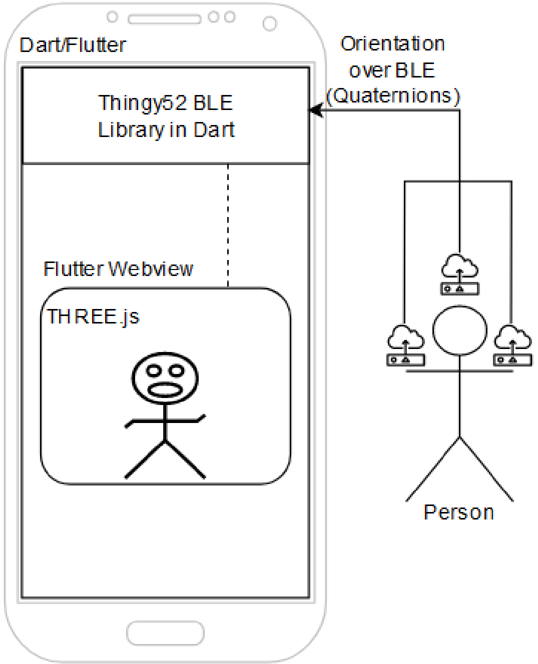
- We use sensors (Thingy52)

- 9-axis inertial motion unit (IMU) and Bluetooth Low Energy

- Accelerometer, Gyroscope and Compass

Stage 3

- Put the sensors on the **users' head** and **shoulders**.
- **Continously stream data** from the sensors using the bluetooth addresses.
- Notification services via **Bluetooth Low Energy**.
- Observe the data coming from the sensors.

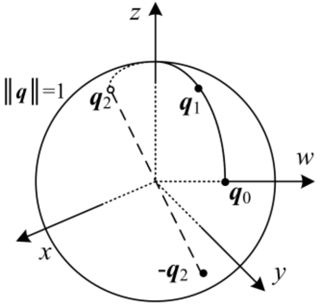


- **Quaternions** are mathematical objects used **to represent rotations in 3D space**, offering a way to smoothly interpolate and combine rotation.

- The sensor outputs quaternion information (its orientation) at 100 Hz

- $q_{relative}$ is the total displacement in orientation, represented by another quaternion.

- q_{new} is the final orientation of the model after the relative rotation is applied



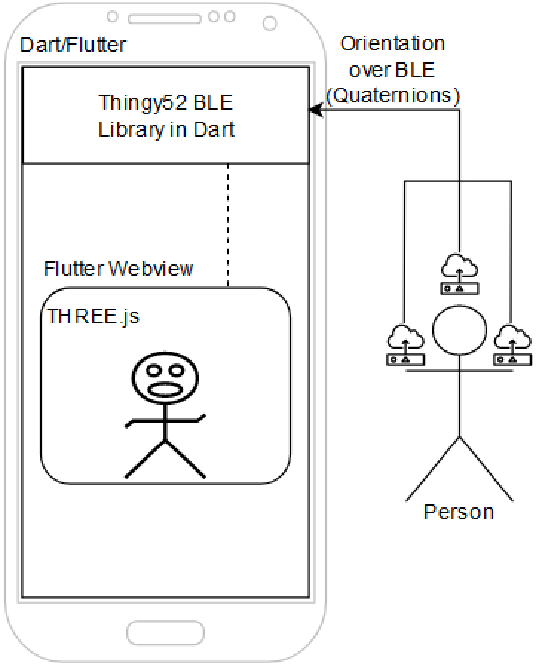
$$q = w + xi + yj + zk$$

$$q_{\text{relative}} = q_0^{-1} \cdot q_{\text{current}}$$

$$q_{\text{new}} = q_{\text{relative}} \cdot q_{\text{model}}$$

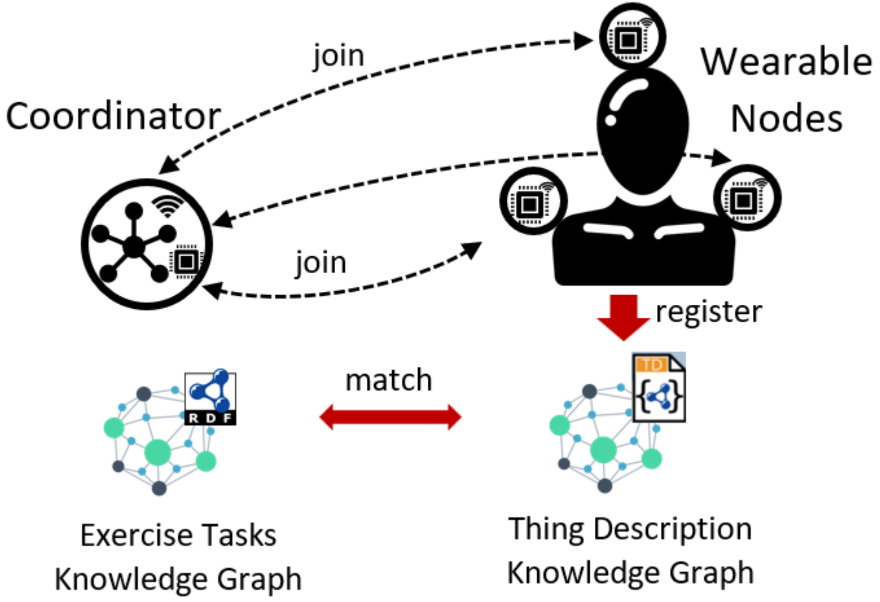
Stage 4

- How do we use the data from the sensors on the model?
- Apply the **orientation delta** to the model.
- The orientation is applied to the model via **assumptions of the human body**.
- With the constraints **we estimate** if the user has made **a correct or false move**.
- Collect the data for future analysis.



Towards distributed semantic knowledge:

- The Coordinator:
  - queries the system requirements of the exercise from **the orchestrator,**
  - is **aware of the capabilities** of the sensors,
  - **matches the capability** of the sensors and **the exercises** during discovery.
- The Sensor:
  - broadcasts its name and capabilities (TBD),
  - shares information on how to use its output (TBD).

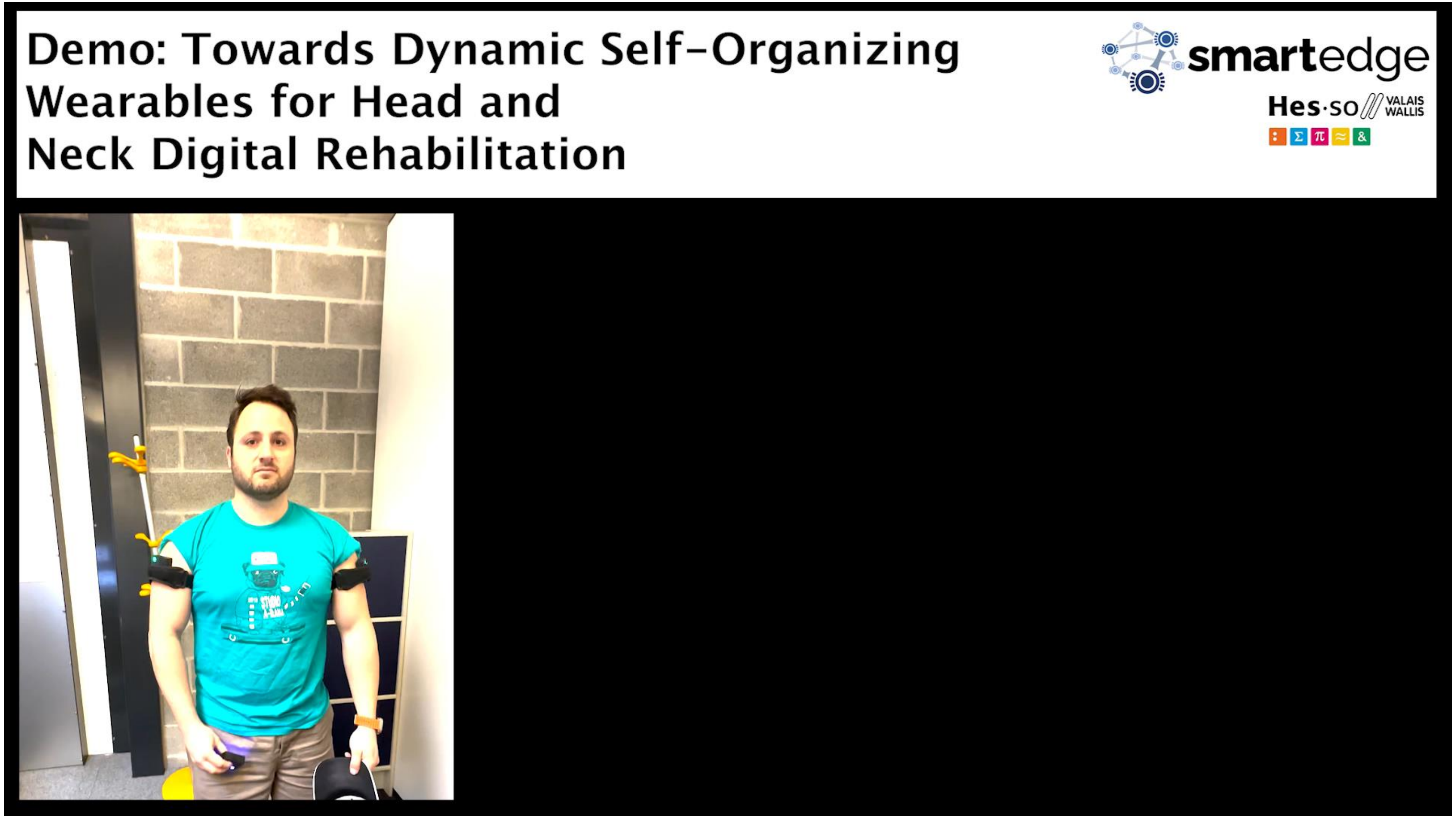


Stage 5

```
{ "@context": { "schema": "http://schema.org/", ...  },
  "@id": "http://hevs.ch/exercise1",
  "@type": "schema:PhysicalTherapy",
  "name": "Movement control tests",
  "description": "Active cervical flexion and extension tests",
  "video": "https://www.youtube.com/watch?v=uKjSvHtylUo",
  "bodyLocation": "cervical spine", "procedureType": "Noninvasive",
  "howPerformed": {
    "@id": "http://schema.org/howPerformed",
    "text": "The patient flexes the cervical spine so that the chin moves ..."},
  "schema:exercisePlan": {
    "@type": "ExercisePlan", "schema:repititions": 3,
    "schema:activityDuration": 120, "schema:activityFrequency": 5 },
  "schema:observes":   {
    "@type": "QuantitativeValue",
    "schema:measuredProperty": "oum:Acceleration",
    "schema:marginOfError": "...",  "schema:measurementMethod": "..." }    }
```

```
"events": {
    "accelerometer": {
      "title": "Accelerometer",
      "description": "Get the current accelerometer data",
      "forms": [ {
          "op": [ "subscribeevent" ],
          "href": "uuid:EF680406-9B35-4933-9B10-52FFA9740042" } ]   }  }
```

Stage 4


Demo: Towards Dynamic Self-Organizing
Wearables for Head and
Neck Digital Rehabilitation
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Stage 6

Future work

- Nodes should **acquire functionality** from the knowledge graph.
- An **Exercise (E)** is composed of **Functionalities (F)** which are made of **Operations (Op).**
- All operations have a **mapped functionality** in the node library.

Assume;

$$Exercise = \{F_1, F_2, \dots, F_n\}$$

$$F_i = \{Op_1, Op_2, \dots, Op_n\}$$

Implement;

$$Exercise = \{ShowModelToUser, LogMoves \dots\}$$

$$F_1 = \{connectDevice, parseMotion, applyMotion\}$$

DeviceDescription.yaml

Future work

- Push the knowledge further toward the edge.
- Take experiments with physiotherapists for a proof of concept.
- We still need to incorporate heterogenous sensors.
- Enrich the knowledge graph with personalization.

Recap

- We created a Flutter-based mobile application for exercise monitoring and real-time feedback.

- By utilizing **decentralized knowledge**, we will try to **combine heterogenous sensor** capabilities in exercises.

- Multi-modality is particularly important in complex tasks and verification of sensor inputs.

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