When your Digital Twin falls ill

ITEA Cyber-Physical-Metaverse in Healthcare

Johan Plomp

26/05/2026 **VTT – beyond the obvious**

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- Digital twins in healthcare
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- Human sensing background
- Project examples
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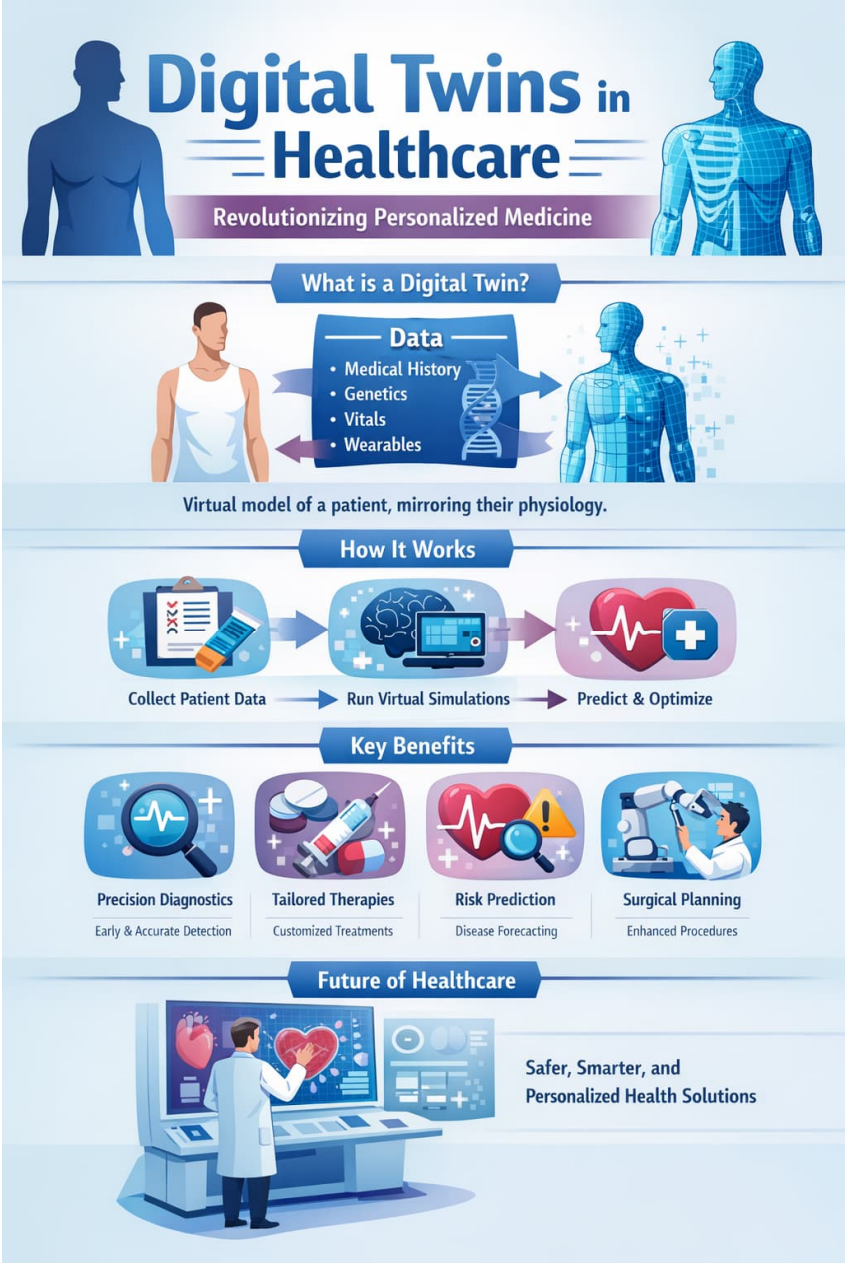
  - DistriMuSe (Chips JU)
- Living and dying with a digital twin
- Next – your digital twin makes friends

Digital twins in healthcare

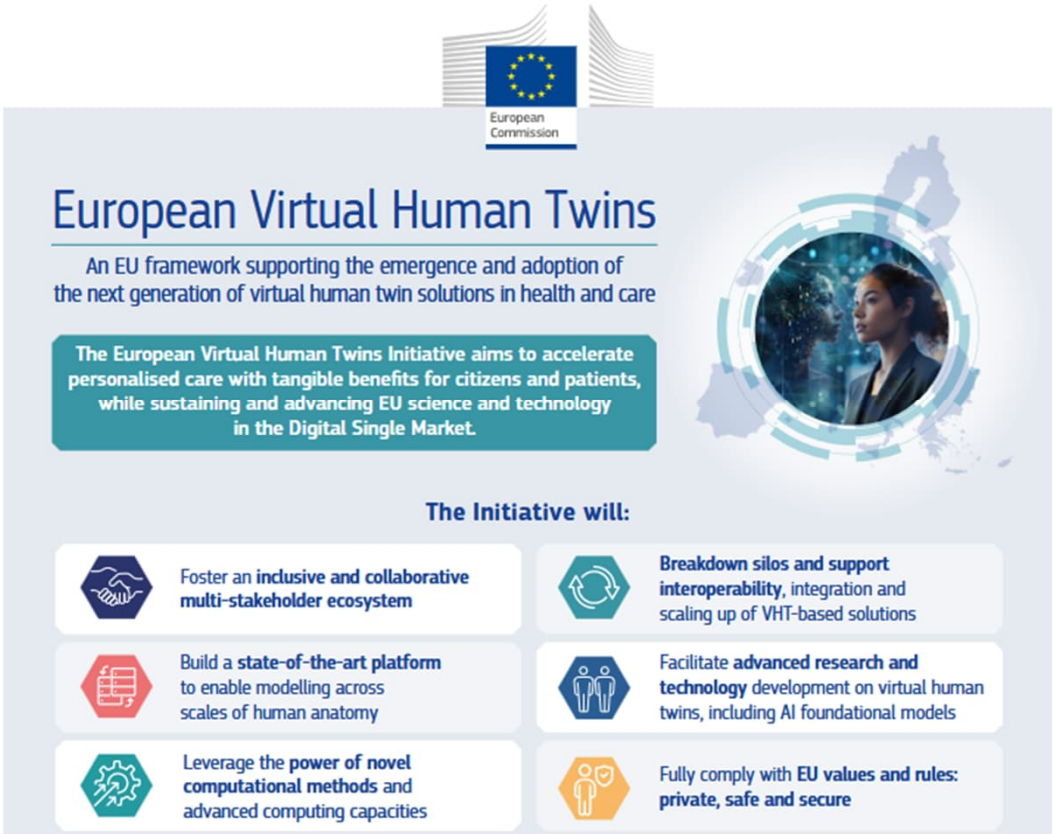
- A digital twin can be used in healthcare for:
  - *Modeling human physiology*
    - *Limited to specific organ or full body*
    - *Level of detail may vary*
    - *Can focus on physical (surgical planning), biochemical or functional aspects*
    - *May specialise e.g. for drug response*
  - Modeling mental state
    - E.g. stress under heavy loads
  - Modeling population health
    - Including e.g. simulation of effects of pandemics or polution
  - Modeling medical devices
    - Device digital twins are used also in industry
  - Modeling care processes
    - Hospital management
    - Care paths for specific diseases
  - In-silico clinical trial design



EU backed work towards virtual human twins

Virtual Physiological Human (VPH)
Society for in-silico medicine - https://vph-society.org/

https://zenodo.org/records/14769224



https://www.virtualhumantwins.eu/

How to train your digital twin

- Initialising – modelling the person
  - The initial model includes all relevant knowledge of the person at the start of use
  - The model can consist of existing ”physical” models and ML models
  - Models are often parametrised generic models, which are adjusted to fit the person’s features
    - Transfer learning
  - Measurements, imaging etc can be used to obtain the person’s physiological parameters
- Maintaining the digital twin state
  - Keeping the model up to date is necessary for continuous monitoring applications
    - ”Single use” models can also be useful, e.g. for simulations
  - Regular measurements allow to have the digital twin to be updated at all times
    - Interval may vary:
      - Yearly health check-ups
      - Streaming measurements from wearables
    - Scope of measurements may be smaller than initially
      - ”easy to measure” physiological data maintains digital twin state and other parameters are estimated from the input

50 Years of Health Monitoring Evolution

Key Trends in Human Health Monitoring (1970s–2020s)

1970s–1980s
Clinical Physiological Monitoring

ICU & Hospital Settings

1990s
Point of Care Monitoring

Portable Medical Devices

2000s
Wearable Diabetes Monitoring

Continuous Glucose Meters

2010s
Wearable Activity & Smart Watches

Fitness & Health Tracking

2020s
Elderly Monitoring

Home & Remote Care

2020s

1970s — 1990s — 2000s — 2020s →

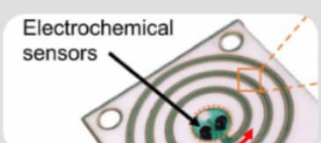
From Hospital to Home | From Devices to Wearables

VTT Health: Towards Personalized and Holistic Healthcare

CONTINUOUS REAL-TIME HEALTH MONITORING

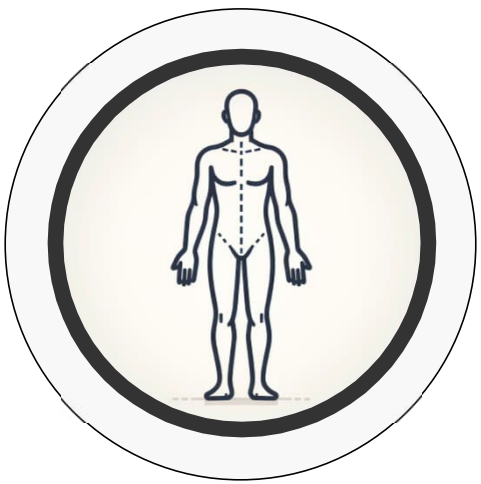
Vital signs
- ECG
- PPG
- Blood pressure
- O_2 Saturation
- Respiratory rate

Metabolism
- Lactate, Glucose
- Electrolytes



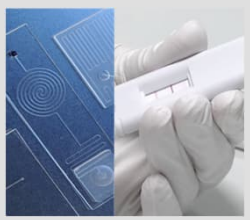
Cognitive state
Multiple biosignals, Incl.eye movements

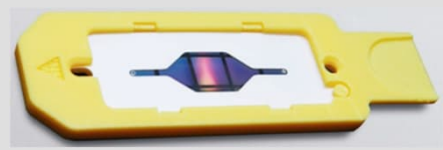
Medical-grade health assessment capabilities, expanding clinical monitoring outside hospitals

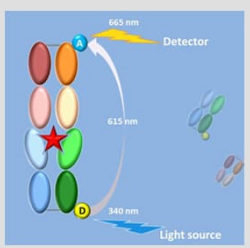


AI models for health assessment and decision assistance

TARGETED HIGH-SENSITIVE MOLECULAR DIAGNOSTICS







Diagnostic platforms and photonics readers.
Novel antibodies to detect:
- Hormonal balance
- Infections
- Cancer

MULTIMODAL DATA INTEGRATION & AI

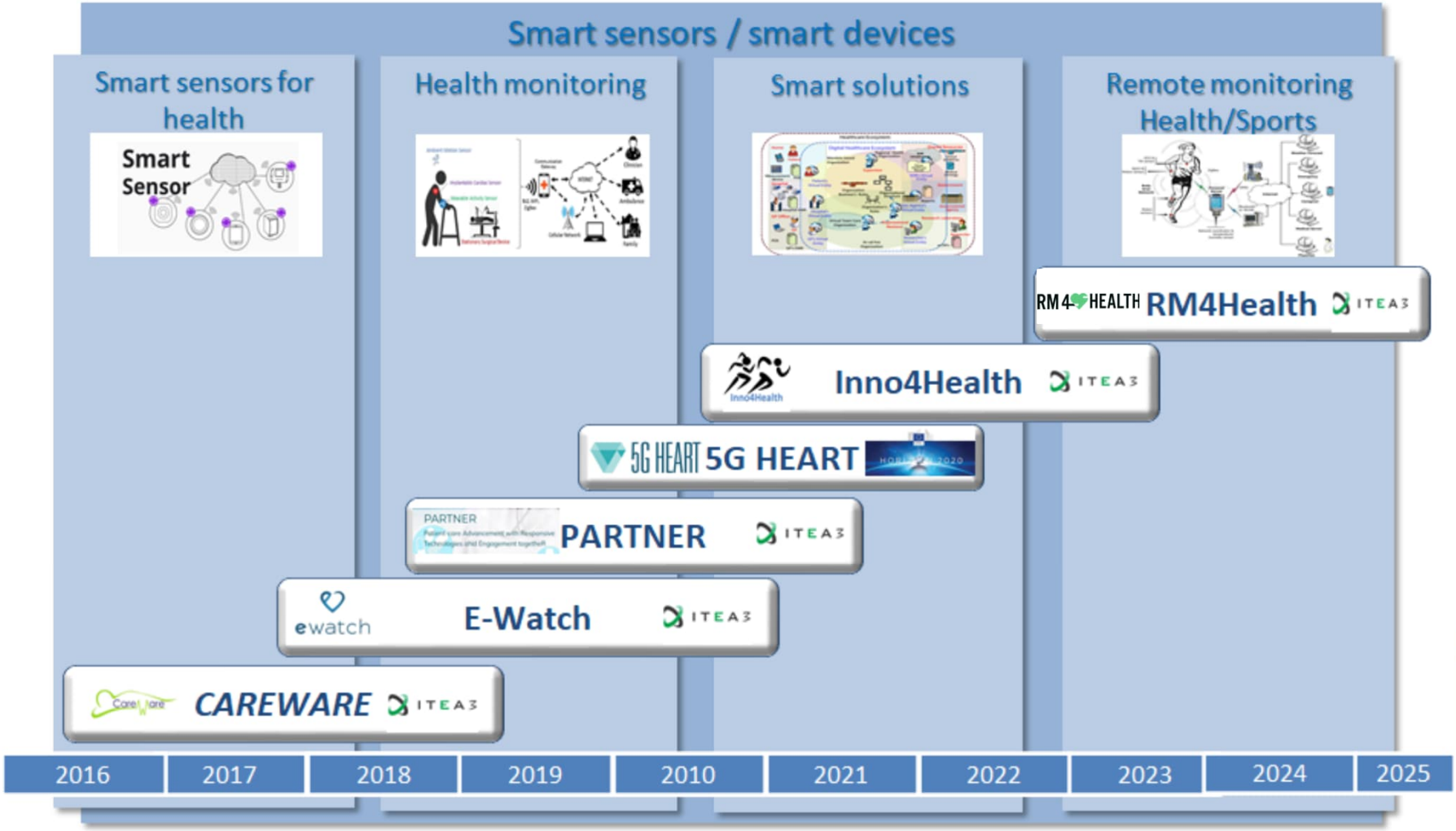
Trustworthy health twin
- Edge AI
- Federated data analyses

AI-assisted signal processing

COMPLEMENTARY HEALTH DATA

- Exposome
- Genome
- Medical history

Development of project topics in ITEA (examples)



RM4Health – Remote monitoring in health and sports (ITEA)

- To make use of existing wearables and develop new **wearable solutions** for selected **metrics** (blood pressure, core body temperature) and use these as data sources for further innovations on data integration and algorithm development to turn these **physiological measurements** into **clinical insights** supporting the selected **use cases**.
- To advance the **remote monitoring platforms** to allow partners to use them as solution for continuous data collection of wearables and devices used by patients and athletes, for developing advanced algorithms and data models, and for **connecting with apps and dashboards** for particular use cases, patient groups and athletes.
- To create **digital twins for patients and athletes** which can continuously track the status of their physiological performance.
- To use the data-driven insights to develop **care and training programs**, with, e.g., dashboards, alerts and recommendations to participating patients and their health providers, or athletes and their coaches.

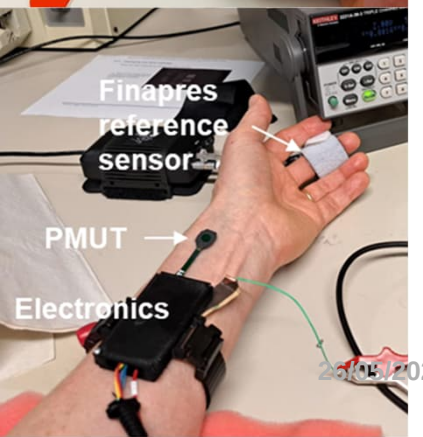
	Partners
NL	**Philips**, Evalan, TU Eindhoven, Catharina Hospital, Maxima Medical Center, Sportbizz
ES	HI-Iberia
FI	Everon, Polar, VTT, University of Turku, Nokia, Emfit
PT	Wiseware, ISEP, University of Porto Faculty of Medicine

https://rm4health.eu/

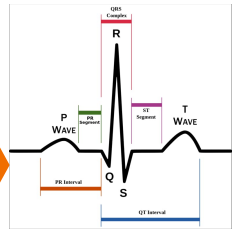
RM4Health use cases

UC1: Remote monitoring for post-operative care for surgery patients and for telerehabilitation of chronic heart failure patients
UC2: Detection of respiratory diseases in children through the analysis of the digital stethoscope signal
UC4: Early detection of heart failure decompensation
UC5: Remote Monitoring 4 Elderly Daily Activities
UC6: Exercise monitoring for sports and rehabilitation
UC7: Innovation for physical fitness and performance assessment in athletes

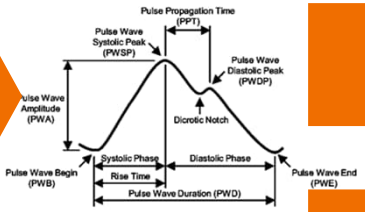
VTT sensors and envisioned digital twin



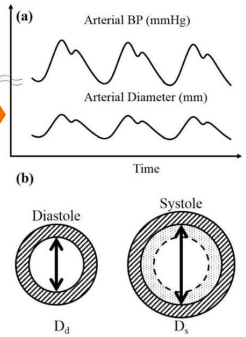
ECG



PPG



Artery diameter

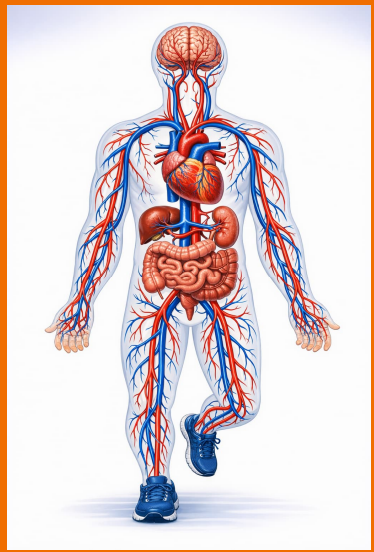


Signal morphology

Timing

Patch location

Hemodynamic ”Digital Twin”



HR, HRV

PAT, PB, CO

SVR

Subject phenotype

Ambient

Distributed multi-sensor systems for human safety and health

O1
- Improved innovative **multimodal sensors and sensor systems** optimised for advanced human observation, measurement, and interaction

O2
- ML-based **data analytics and multi-sensor fusion** for (semi) real-time decision-making

O3
- Supporting **adaptive distribution of computation and algorithms** across available resources from edge to cloud for efficient real-time operation

O4
- Building a comprehensive understanding of **human physical health, mental state, intentions and safety risks**

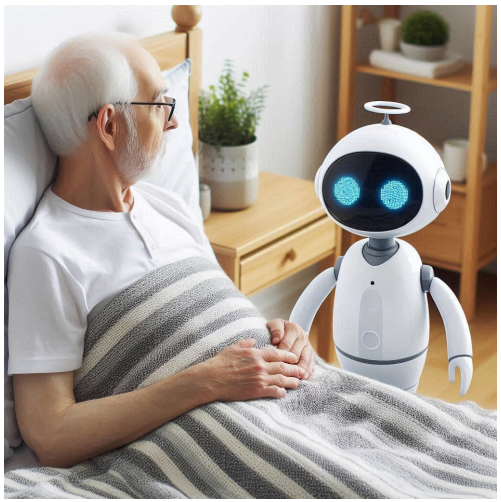
O5
- Validating the technologies in **human-centric use cases** :

1. health and wellbeing monitoring and support;
2. real-time traffic safety enhancement, including for vulnerable road users;
3. safe interaction and cooperation of humans with robots and automated factory systems.

https://distrimuse.eu/

DistriMuse

Domains and use cases



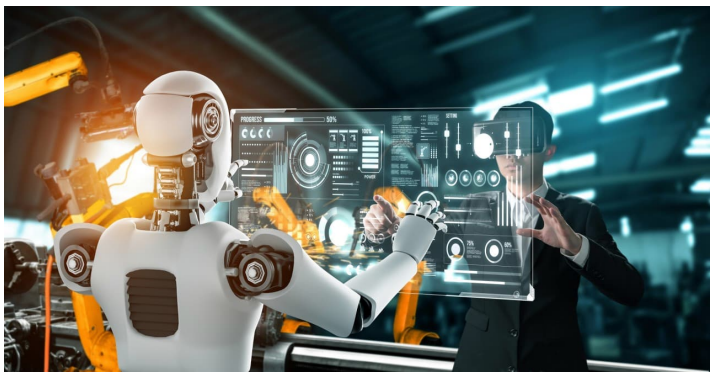
Watching over your health

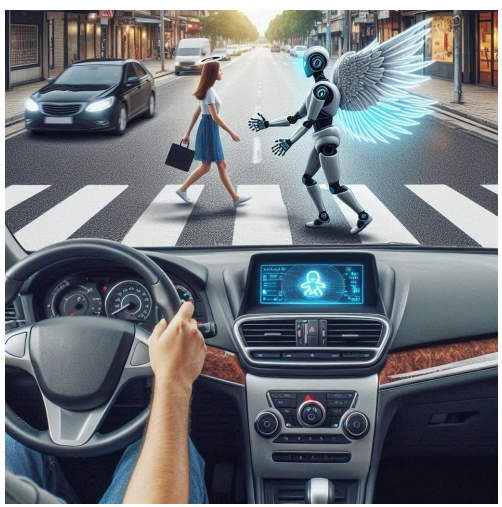
UC1: Continuous hybrid health monitoring

- MCI tracking
- Life-style monitoring
- Sleep monitoring
- Sports performance

Health & Wellbeing

Safe collaboration with robots in factories





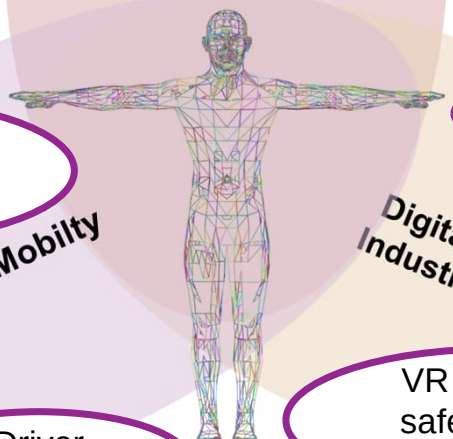
Watching over Pedestrians and cyclists in traffic

Collaborative situational awareness

Mobilty

UC2: Situational awareness for VRU and driver safety

Driver distraction



Digital Industry

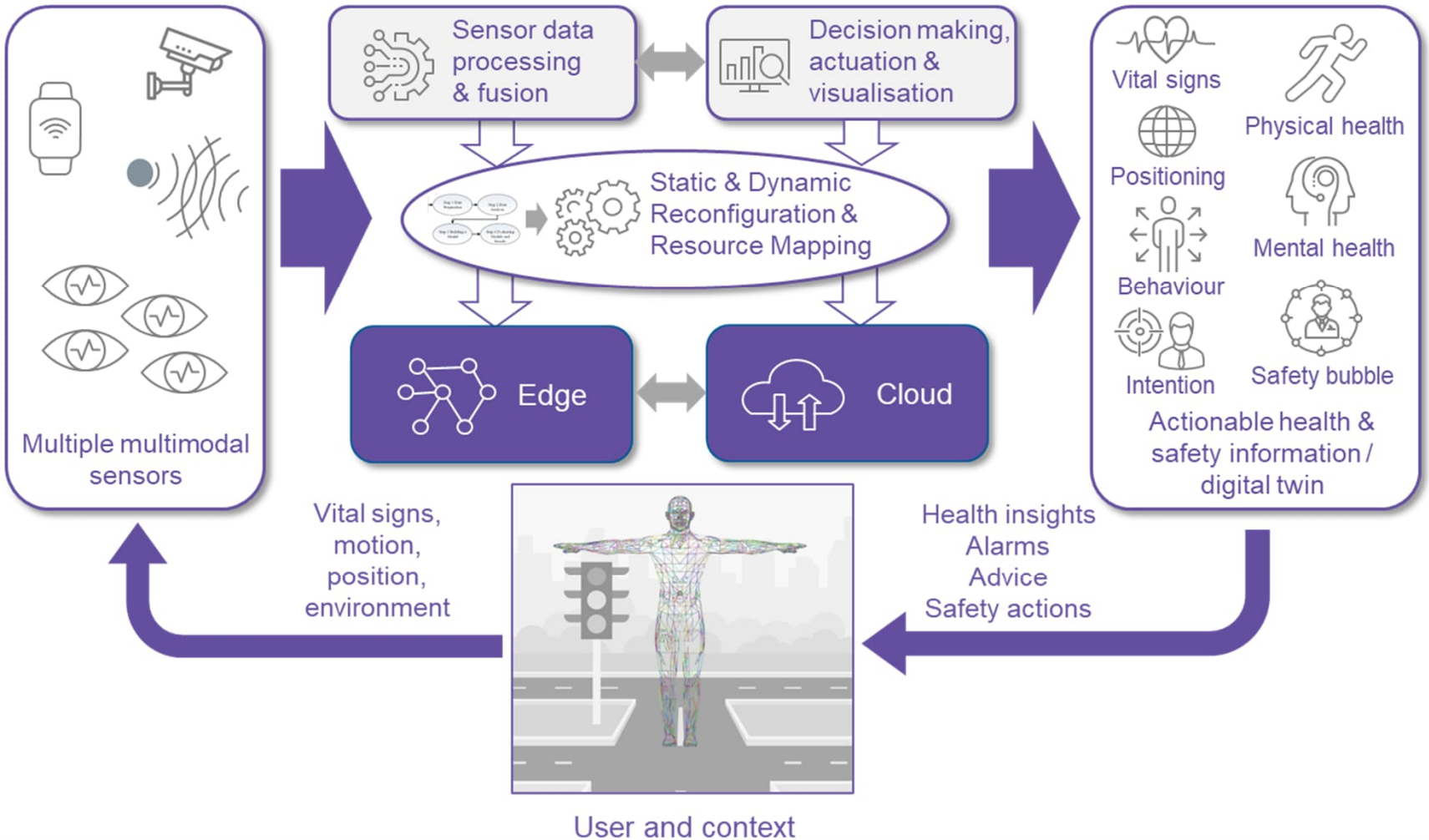
Dynamic human-robot factory management

Adaptive operation in human presence

UC3: Safe interaction and cooperation with robots

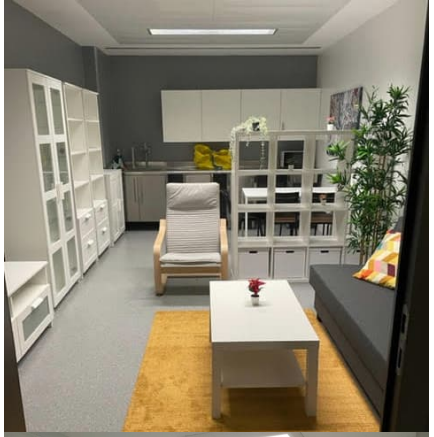
VR model of safe human-robot interaction

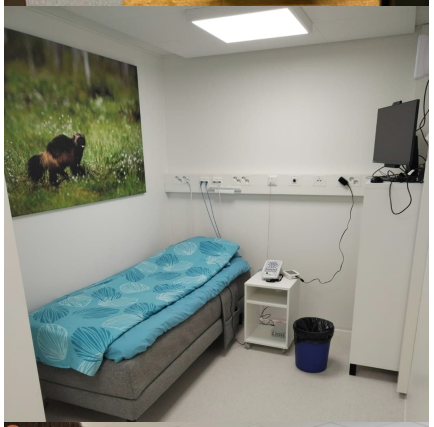
Conceptual architecture



DistriMuSe UC1: Continuous hybrid health monitoring

- *Demo 1.1*: Human **life-style monitoring** which focusses on daily activity monitoring of two main interest groups: **early-stage MCI patients and elderly people** in care facilities and assisted living. The data will be captured using a combination of visual, wearables, radar and other sensors. The developed algorithms and support tools should assist the caregiver in detecting/preventing emergency situation and assure a better follow up.
- *Demo 1.2*: **Sleep Monitoring**, which focusses on the development of less obtrusive methods for the monitoring of sleep and the assessment of sleep disorders. By measuring vital signs in a novel and less obtrusive manner, that can replace measurement methods that are currently part of today's gold standard video-polysomnography setups. As well as the measurement of vital signs (e.g. blood pressure) that are currently not part of gold standard methods due to the obtrusiveness of current measurement setups.
- *Demo 1.3*: **Sports performance and health assessment** focuses on monitoring the physical activity of participants with the overall goal of measuring the activituy and exertion levels and producing estimation of performance levels and maximum effort.



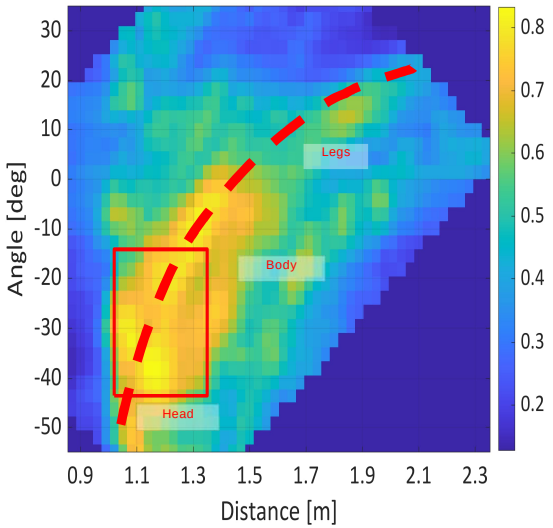


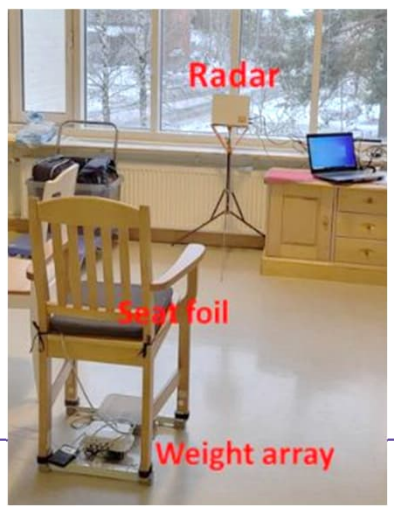
DistriMuSe

VTT

VTT Polarimetric radar for human monitoring

- 60GHz FMCW radar
- Polarimetric imaging
- 4TX and 12 RX channels
- Extracting vital signs
  - HR, BR, HRV
- Used for sleep monitoring and elderly monitoring (gait, TUG)
- VTT hardware





Living and dying with a digital twin

What your twin is like

- Accumulates health data continuously
  - Able to provide history and trends
  - Provides a baseline for diagnostics
    - Never been available before, revolutionised healthcare
- Early detection and risk
  - Detection of subtle changes and adverse trends
  - Assess risks related to lifestyle
- Personalised health
  - Models allows for personalising care and medication
  - Therapy optimisation
- Clinical decision support
  - Allows to simulate / predict outcomes of interventions and treatment
- Health coach
  - Continuously provides advice on life-style including activity, nutrition and sleep
- *Close to a guardian angel?*

When things look bad

- Your twin is not looking good
  - If that is how you feel – it operates properly
- You get annoyed with your twin
  - User acceptance is key!
- Your twin's state does not reflect your health
  - The twin fails to model you correctly and provides wrong indications or advice
  - Can lead to dangerous situations
  - How to ensure correct operation
  - Keep clinical verification in the loop
- Your twin is manipulated or hacked
  - Conspicuous advertisements for specific products
  - Failure to operate properly
  - Ransoms are demanded for its release
- Your twin sells its data
  - The twin represents very personal health and behavioural data – needs to be protected with great care
  - Business with data or (partial) donation for medical science may be possible, but needs proper anonymisation

Next – your digital twin makes friends

- Digital twins are primarily for the benefit of the user
- ”Worn” digital twins are extremely useful for medical research
  - Population health
  - Virtual clinical trials
- What about if digital twins partner up to care for others / a group?
  - E.g. family
  - Nudging
  - Guidance on how to care for a near person

beyond
the obvious

Thank you!

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Infographics generated by Co-pilot