Continuous Health Monitoring for Preventive Medicine

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MHH
Medizinische Hochschule Hannover

Technische Universität Braunschweig

Prof. Dr. Thomas M. Deserno

Overview

- Introduction
  - Motivation
  - Global health and well-being
  - Changing paradigms
- Diagnostic spaces
- Sensors
- Health monitoring
- Summary

© Craiyon: disease

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Motivation: Stroke

- Germany (source: IGES Institute)
  - 280.000 per year
  - 3rd main cause of death
  - € 22,500 direct costs (1st year)
  - € 2.4 billion annually (public insurance)

- Early detection
  - Atrial fibrillation
  - Heart rate variability
  - Mobile ECG

- Problem
  - Heartbeat not noticeable
  - Mobile measurements
    - Sporadically
    - After the event

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WHO Definitions

- Health
  - State of complete physical, mental, and social well-being
  - Not just the absence of disease or infirmity
  - (Global) health & well-being
- Quality of Life (1997)
  - Environmental
  - Behavioral
  - Physiological
  - Psychological
  - Social
  - Spiritual

	Overall Quality of Life and General Health
1. Physical health	Energy and fatigue Pain and discomfort Sleep and rest
2. Psychological	Bodily image and appearance Negative feelings Positive feelings Self-esteem Thinking, learning, memory and concentration
3. Level of Independence	Mobility Activities of daily living Dependence on medicinal substances and medical aids Work Capacity
4. Social relationships	Personal relationships Social support Sexual activity
5. Environment	Financial resources Freedom, physical safety and security Health and social care: accessibility and quality Home environment Opportunities for acquiring new information and skills Participation in and opportunities for recreation/ leisure Physical environment (pollution/noise/ traffic/climate) Transport
6. Spirituality/Religion/Personal beliefs	Religion /Spirituality/Personal beliefs

WHO/MSA/MNH/PSF/97.4

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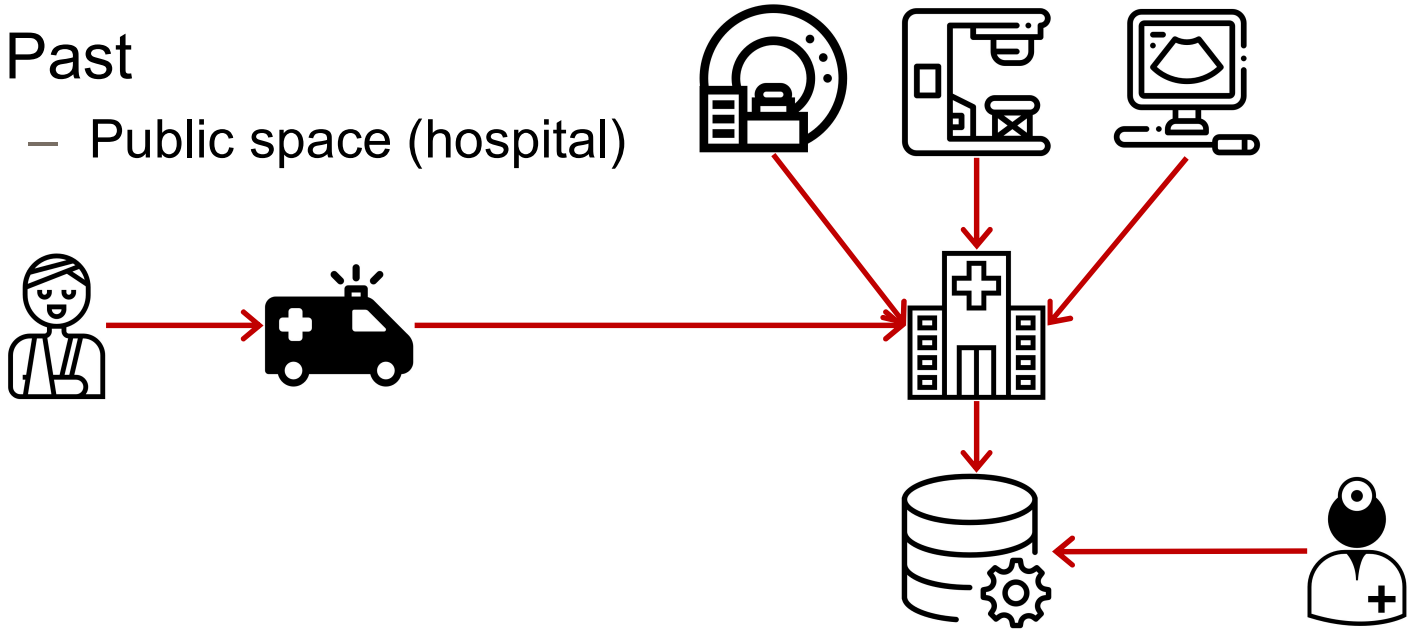
Paradigm Change: Central vs. Decentral Diagnostics

- Past
  - Public space (hospital)



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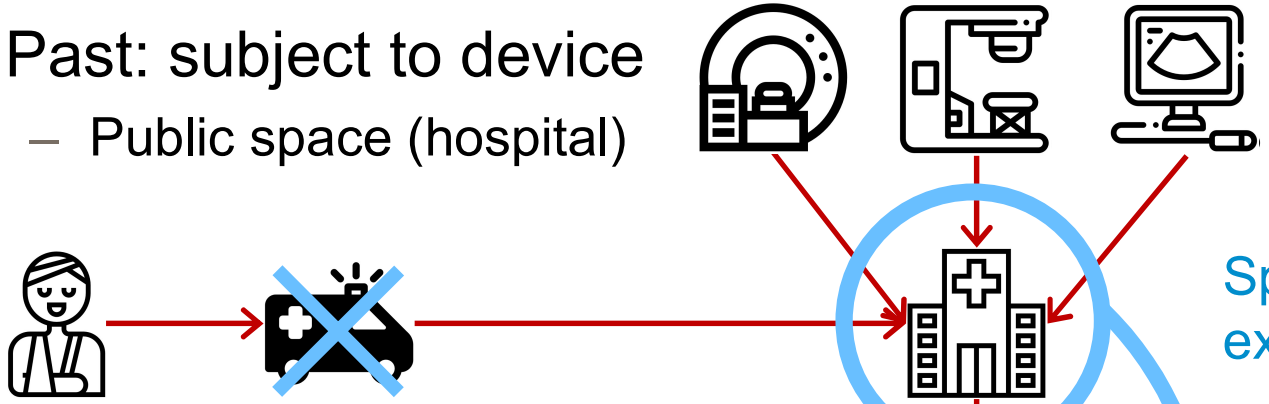
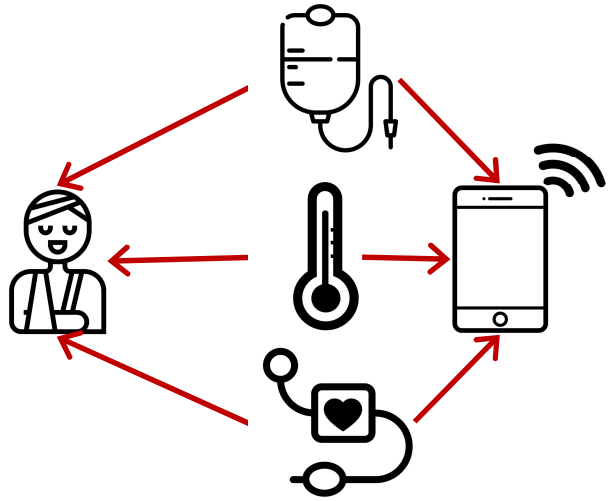
Paradigm Change: Central vs. Decentral Diagnostics

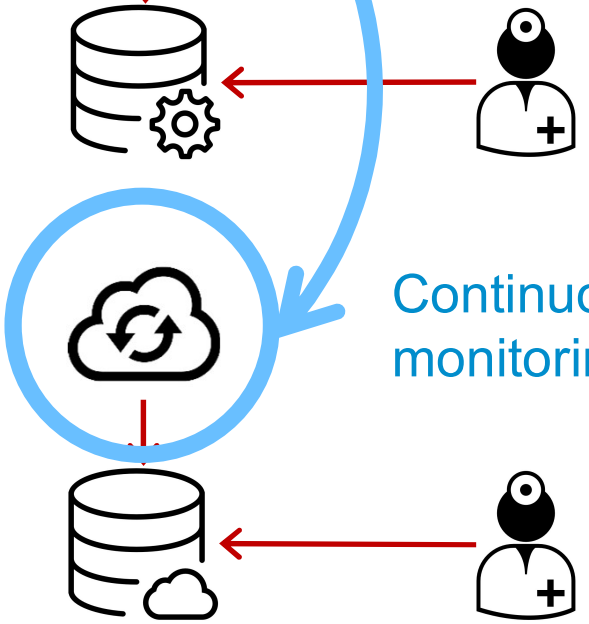
- Past: subject to device
  - Public space (hospital)



Sporadic examination

- Future: device to subject
  - Private space (home, vehicle)





Continuous monitoring

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Paradigm Change: Curative vs. Predictive Health

- Today's medicine
  - Symptoms (illness)
  - Examinations (findings)
  - Diagnose (sporadic)
  - Therapy
  - Recovery

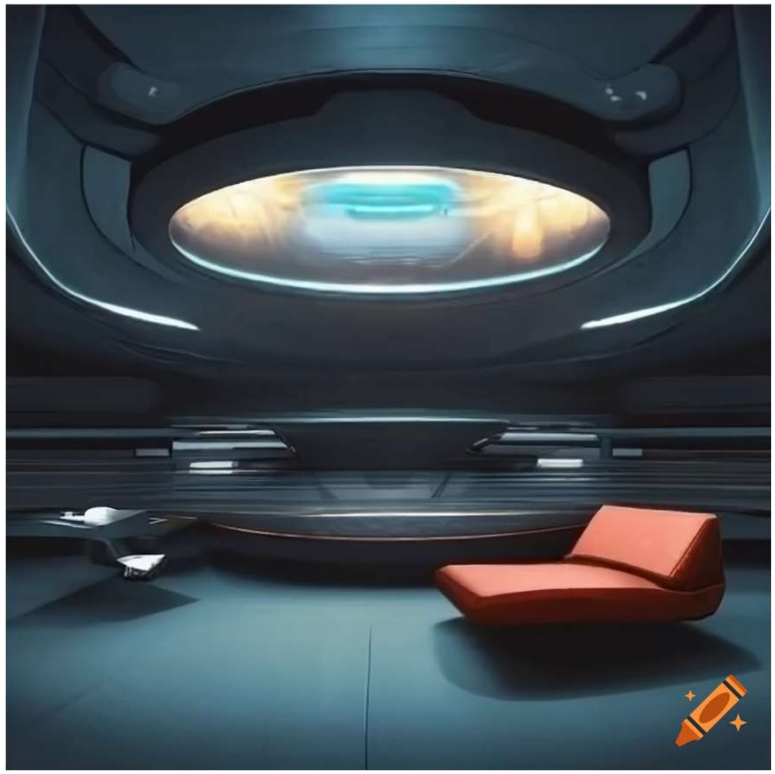
https://www.diako-leipzig.de/

- Continuous health monitoring
  - Findings (continuous)
  - Trend analytics (personal)
  - Prediction (prognostics)
  - Prevention (no therapy)

https://thehealthcareinsights.com/

Overview

- Introduction
- Diagnostic spaces
  - Vehicle
  - Home
- Sensors
- Health monitoring
- Summary



© Craiyon:
photorealistic 23rd century decision chamber with comfy seating and good lighting

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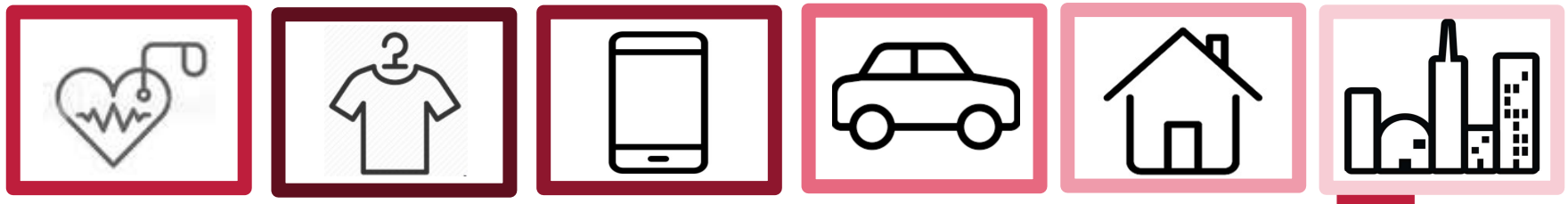
Diagnostic Spaces

- Level
  - Smart implant
  - Smart clothes
  - Smart wearable
  - Smart vehicle
  - Smart home
  - Smart city



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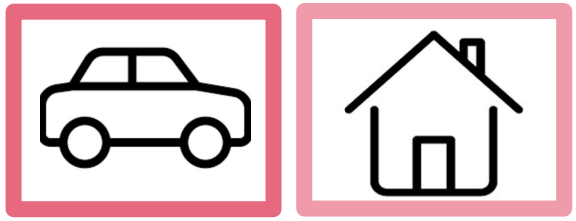
Diagnostic Spaces

- Level
  - Smart implant
  - Smart clothes
  - Smart wearable
  - Smart vehicle
  - Smart home
  - Smart city
- Properties
  - Private
  - Autonomous
    - Power supply



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Vehicle as Diagnostic Space

- PLRI research cars (street legal)
  - Ambient sensors
    - Unobtrusive but close
    - In body contact
      - Seat, instruments
    - No change in behavior

  - CAN BUS system (Controller Area Network)
    - 1987 Robert Bosch GmbH

sensors

MDPI

Review

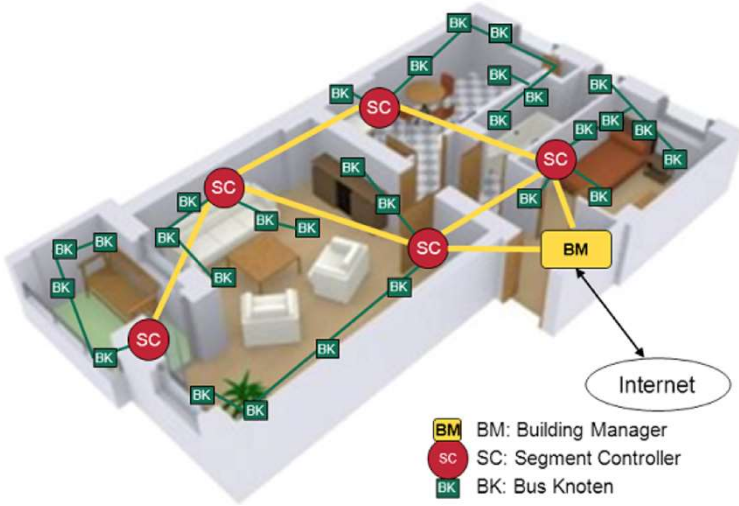
Unobtrusive Health Monitoring in Private Spaces: The Smart Vehicle

Ju Wang *, Joana M. Warnecke, Mostafa Haghi and Thomas M. Deserno

Peter L. Reichertz Institute for Medical Informatics of TU Braunschweig and Hannover Medical School, D-38106 Braunschweig, Lower Saxony, Germany; joana.warnecke@plri.de (J.M.W.); mostafa.haghi@plri.de (M.H.); thomas.deserno@plri.de (T.M.D.)

Home as Diagnostic Space

- PLRI research apartments (City of Brunswick)
  - Ambient sensors
    - Unobtrusive from a distance
    - In the furniture
    - No change in behavior
  - BASIS BUS system (Building Automation by a Scalable and Intelligent System)
    - 2015 TU Braunschweig



- sensors MDPI

Review

Unobtrusive Health Monitoring in Private Spaces: The Smart Home

Ju Wang [1]*, Mostafa Haghi [1], Jonas Schwartze [1,2], Nicolai Spicher [1], Joana M. Warnecke [1] and Thomas M. Deserno [1]

1 Peter L. Reichertz Institute for Medical Informatics of TU Braunschweig and Hannover Medical School; Muehlenpfordtstr. 23, D-38106 Braunschweig, Lower Saxony, Germany.
2 Wohnungsentwicklung und Forschung, Nibelungen-Wohnbau-GmbH; Freyastr. 10, D-38106 Braunschweig,

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Overview

- Introduction
- Diagnostic spaces
- Sensors
  - Environmental
  - Behavioral
  - Physiological
  - Psychological
- Health monitoring
- Summary

© Craiyon:
future city with sensors observing a human

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Environmental Sensors

- Example: smart home
  - 1: PLRI Lab
    - 50 m^2
    - Living area with kitchen, bathroom, bedroom

https://panoxl.de/tour/tubraunschweig/index.html#node513

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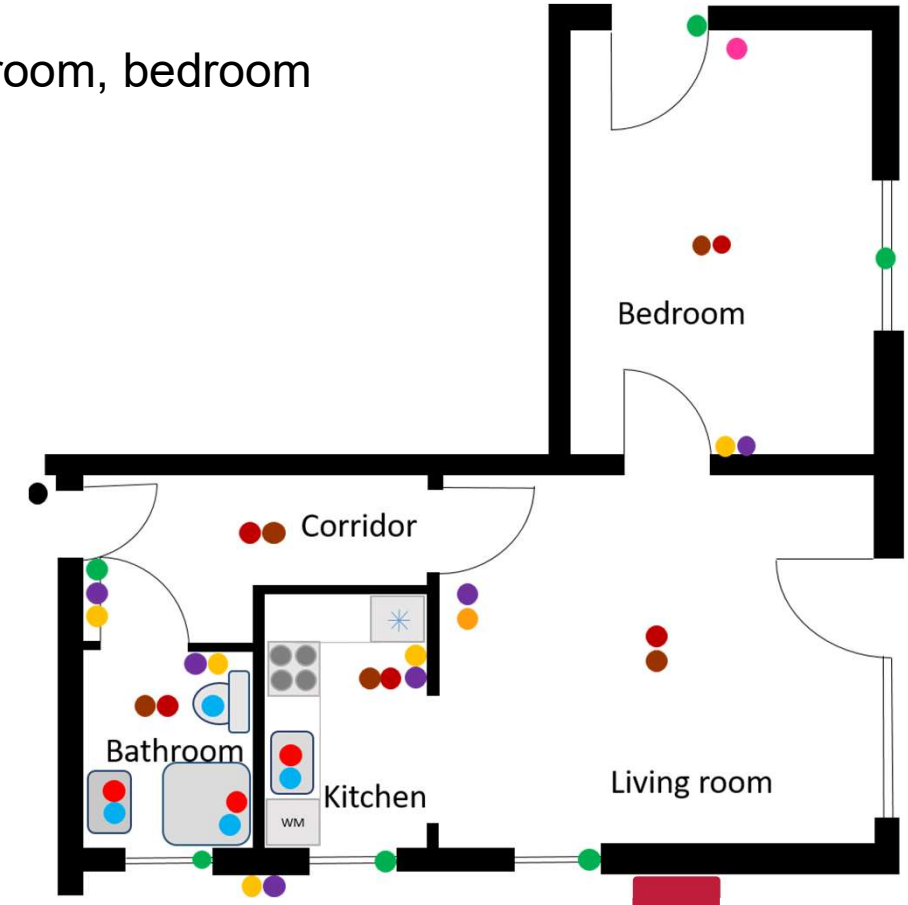
Environmental Sensors

- Example: smart home
  - 1: PLRI Lab
    - 50 m²
    - Living area with kitchen, bathroom, bedroom
  - 6: City of Brunswick

Nibelungen Wohnbau GmbH

- Sensors
  - Movement
  - Opening, closing
  - Cold, warm water
  - Luminance
  - Temperature
  - Humidity
  - Power consumption
- Similar: smart vehicle



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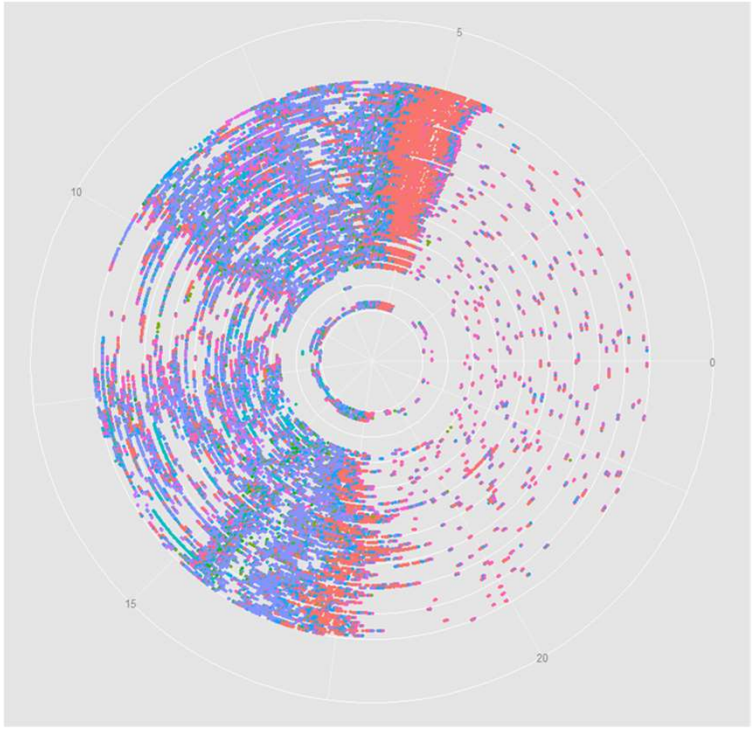
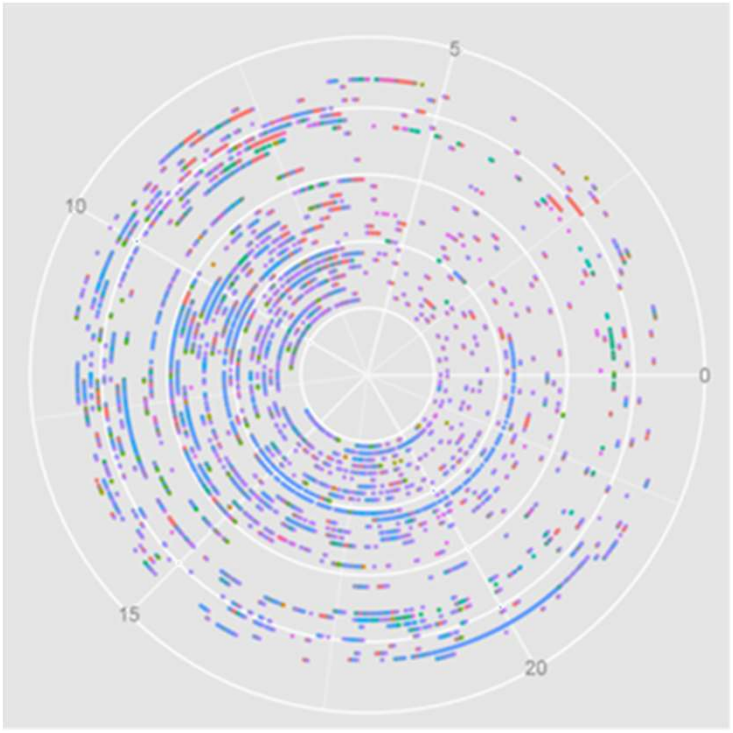
Behavioral Sensors

- Example: apartment usage
  - Regular daily rhythm (healthy)
  - Irregularity (pathological)





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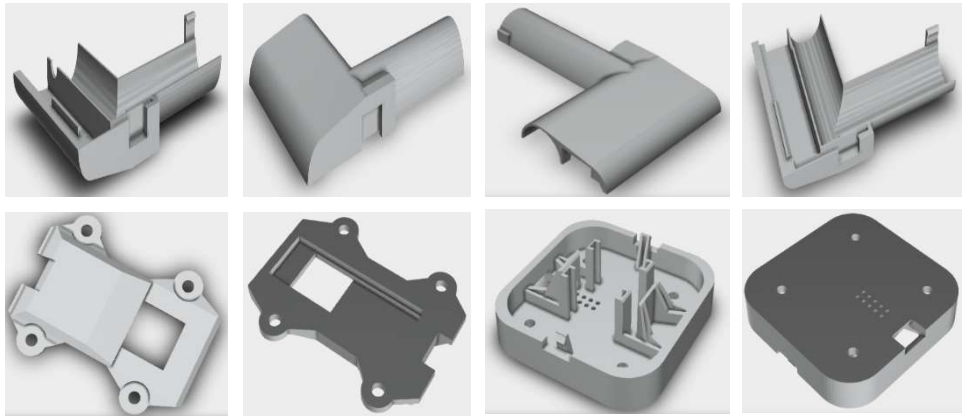
Physiological Sensors

- Vital signs
  - Body temperature
  - Heart rate
  - Respiratory rate
  - Blood pressure
  - Oxygen saturation
  - End-tidal CO_2
- Other parameters
  - ECG
  - Electro-dermal activity
  - Glucose
  - Urine
  - …



Physiological Sensors

- Example: Image-based monitoring
  - Face detection
  - Color change
  - Heart rate

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Psychiological Sensors

- Electrodermal activity
- Image-based monitoring
  - Fear

https://www.thearrowdrivingschool.com

  - Anger

https://www.budgetdirect.com.au

  - Happyness

https://www.papertransport.com

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Overview

- Introduction
- Diagnostic spaces
- Sensors
- Health monitoring
  - Redundant
  - Hybrid
  - Personalized
  - Livelong & one health
- Summary

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future city with sensors observing a human

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State-of-the-art

- Open questions
  - Which sensors for which parameter in which space?
  - What reference data for training of AI?
  - How to distinguish?
    - Measurement error vs. pathological signal?
- Answers
  - Redundant systems
    - Different sensor types for *same* parameters
    - Robustness by signal fusion
  - Hybrid systems
    - Fusion of parameters from *different* domains
    - Robustness by additional knowledge
  - Personalized systems
    - Modular concept
    - Individual configuration

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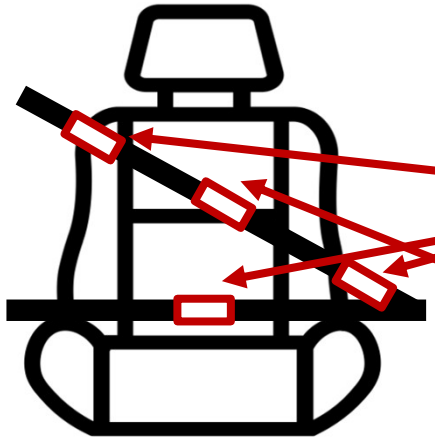
Redundant Systems

- Example: PLRI research cars



RGB & Radar/Lidar
- Heart rate
- Respiratory rate
- Stress level

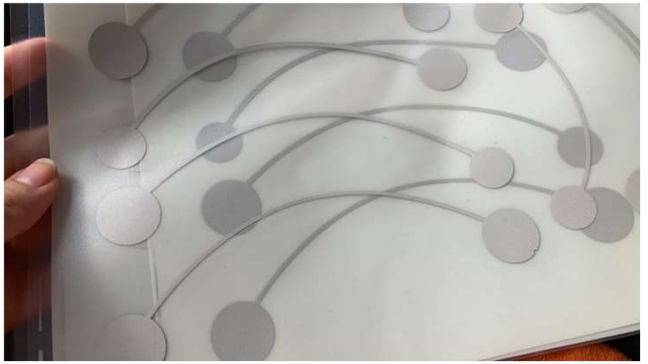
ECG
- Heart rate
- Respiratory rate

PPG
- Heart rate
- Respiratory rate

EDA
- Stress level

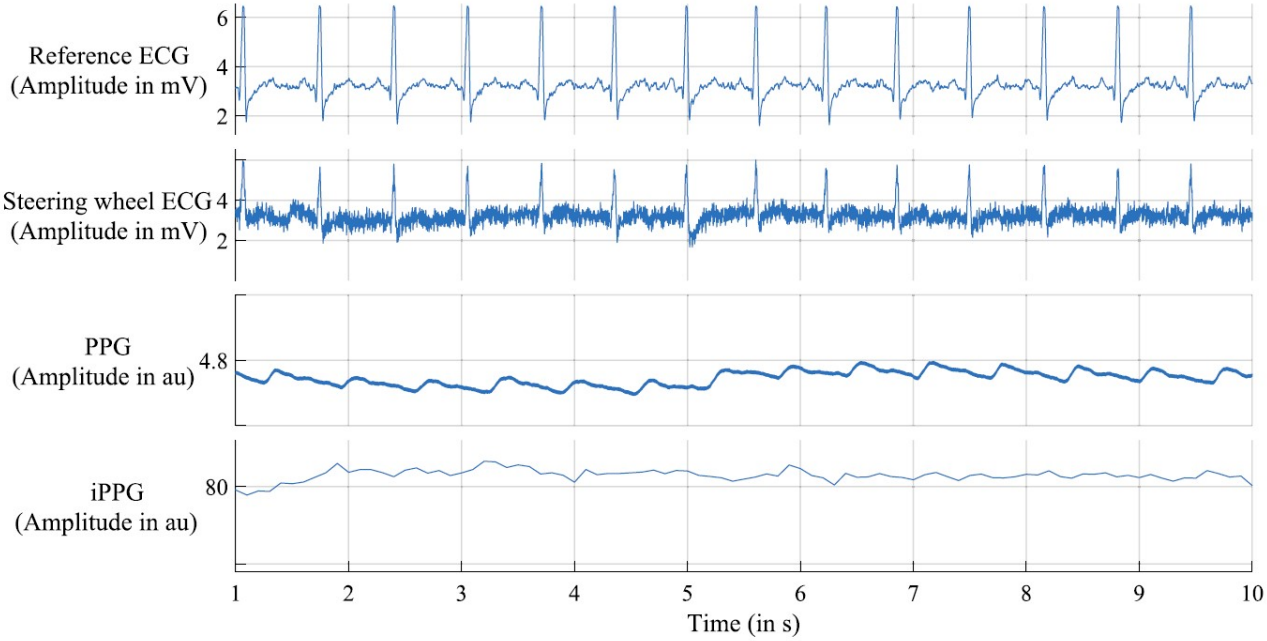
BCG
- Heart rate
- Respiratory rate

PCG
- Heart rate



Redundant Systems

- Example: heartbeats



scientific reports

OPEN

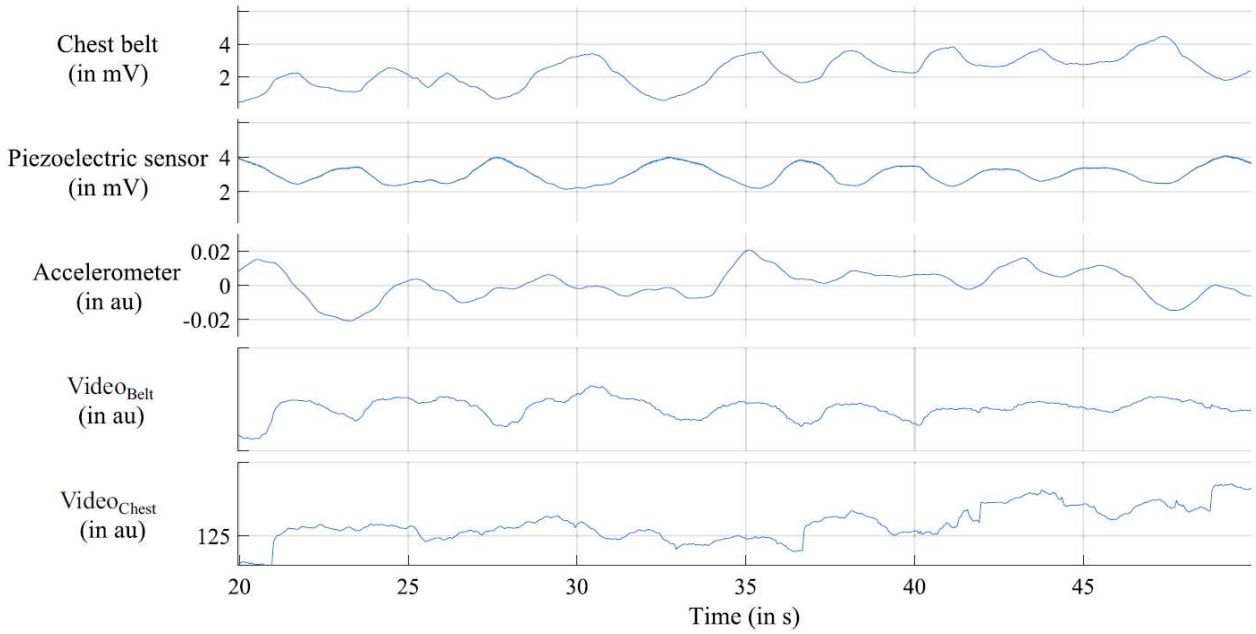
Check for updates

Robust in-vehicle heartbeat detection using multimodal signal fusion

Joana M. Warnecke[1,2✉], Joan Lasenby[2] & Thomas M. Deserno[1]

Redundant Systems

- Example: respiratory rate



scientific reports

Check for updates

OPEN

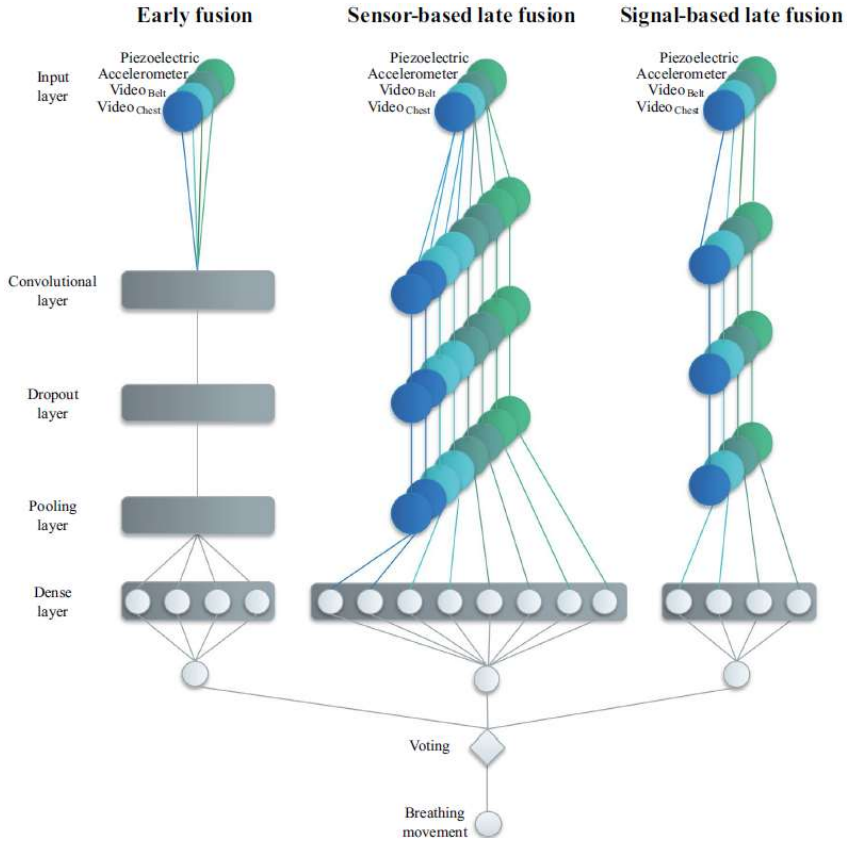
Robust in-vehicle respiratory rate detection using multimodal signal fusion

Joana M. Warnecke[1,2✉], Joan Lasenby[2] & Thomas M. Deserno[1]

Redundant Systems

- Signal fusion
  - Early
  - Late
    - Signal-based
    - Sensor-based
  - Hybrid
- First results
  - Heart rate

Approach	ECG (%)	PPG (%)	iPPG (%)	Mean$_P$ (%)
Early Fusion	44.33	**57.25**	48.50	50.02
Signal-based late fusion	49.98	**51.27**	50.38	53.43
Sensor-based late fusion	**50.10**	49.41	45.35	49.95
Hybrid algorithm	48.10	**52.09**	47.71	**55.44**

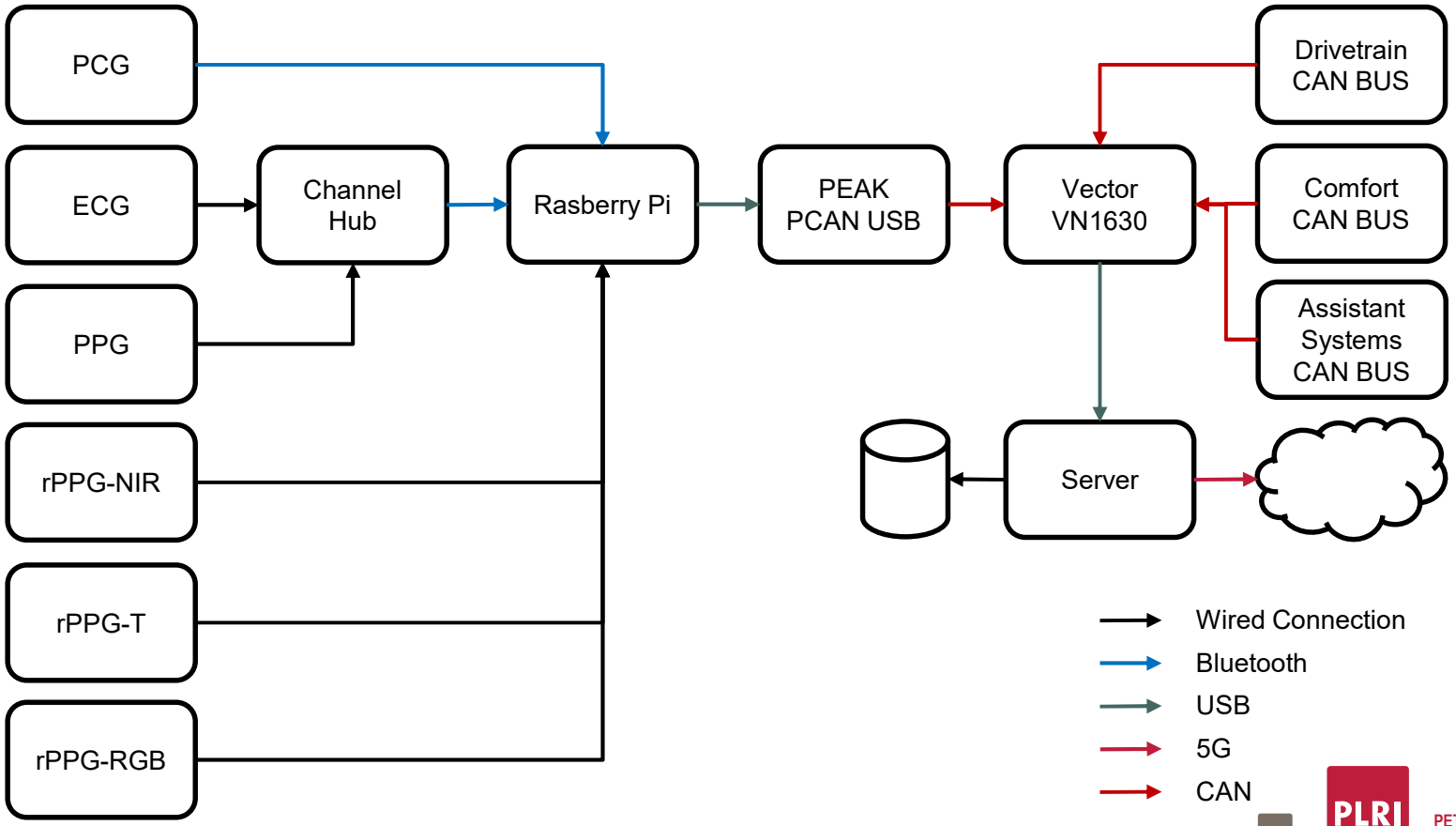


  - Respiratory rate

Approach	Piezo [%]	Acc [%]	Video$_{Belt}$ [%]	Video$_{Chest}$ [%]	Mean$_P$ [%]
Early fusion	49.08	49.16	49.66	**53.38**	50.15
Signal-based late fusion	49.10	55.79	51.80	49.51	61.98
Sensor-based late fusion	49.10	49.19	**53.58**	51.40	61.99
Hybrid fusion	48.82	49.17	**53.31**	52.21	**62.01**

Hybrid Systems

- Example: PLRI research cars
  - Physio CAN BUS
  - Car CAN BUS



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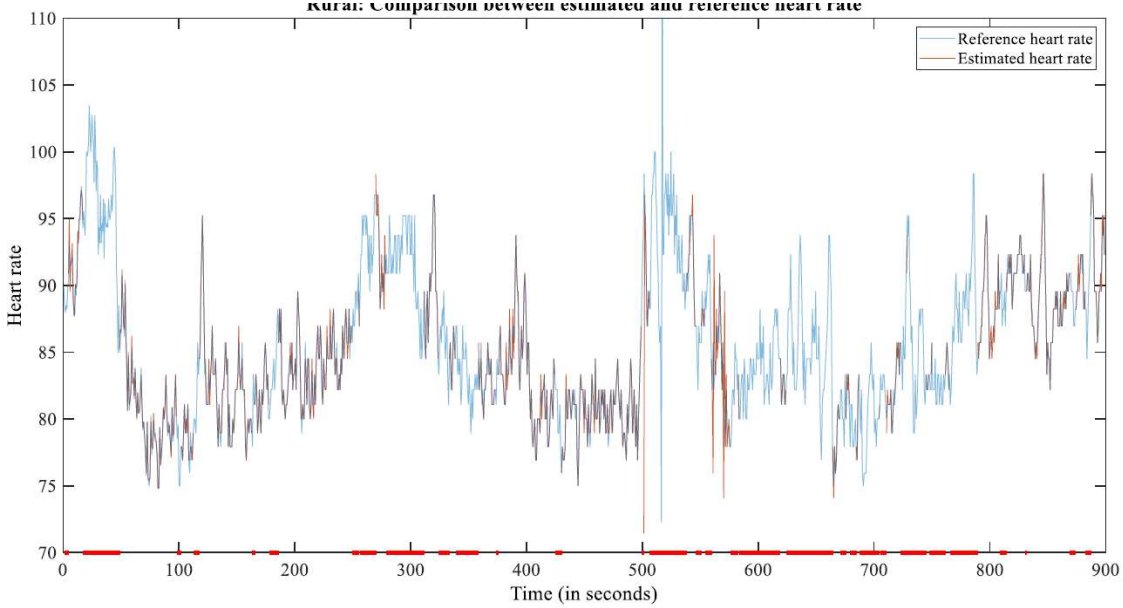
Hybrid Systems

- Example: PLRI research cars
  - Steering wheel ECG



  - Reliable heart rate
    - ~ 50 % of the time

sensors

MDPI

Article

Printed and Flexible ECG Electrodes Attached to the Steering Wheel for Continuous Health Monitoring during Driving

Joana M. Warnecke [1,*], Nagarajan Ganapathy [1], Eugen Koch [2], Andreas Dietzel [2], Maximilian Flormann [3], Roman Henze [3] and Thomas M. Deserno [1]

Hybrid Systems

- Example: Motion analysis for capacitive ECG

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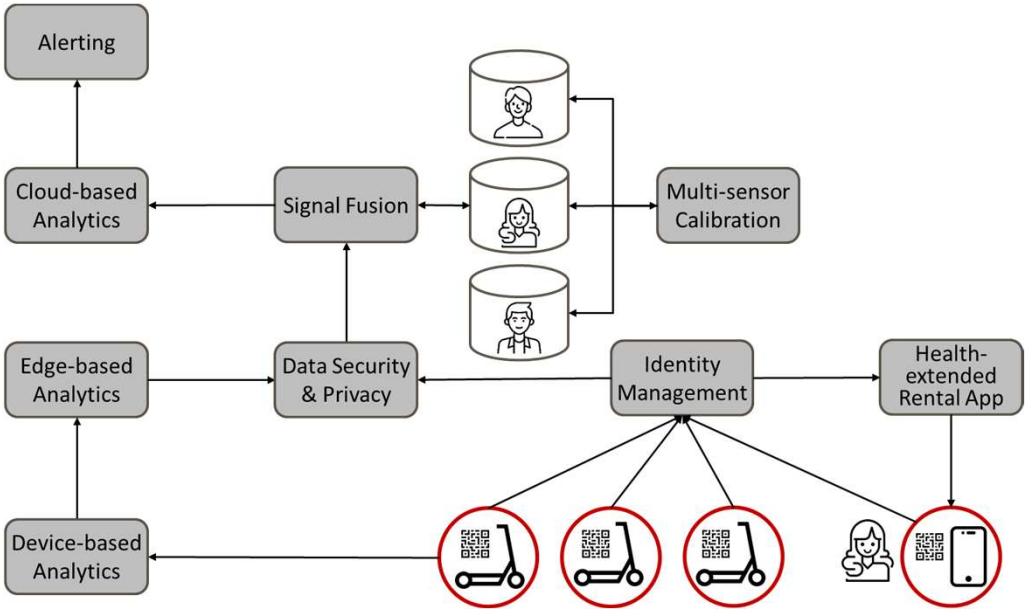
Personalized Systems

- Modular concept
  - Sensors & add-ons
  - One platform
  - Different apps
- Individual configuration
  - Hardware
  - Add-ons
  - Apps
- Example
  - Rental eScooter
  - Smart city (Non-private)



URI: https://hdl.handle.net/10125/106805
978-0-9981331-7-1
(CC BY-NC-ND 4.0)

HICSS

Continuous Health Monitoring on Shared Mobility Devices: A Health-eScooter Prototype

Joana M. Warnecke [1], Christian Baumgartner [2], Michael H. Breitner [3], Dominique F. Briechle [4], Thomas M. Deserno [1], Maximilian Heumann [3], Martin Johns [5], Alexander Picker [1], Andreas Rausch [4], and Lars Wolf [6]

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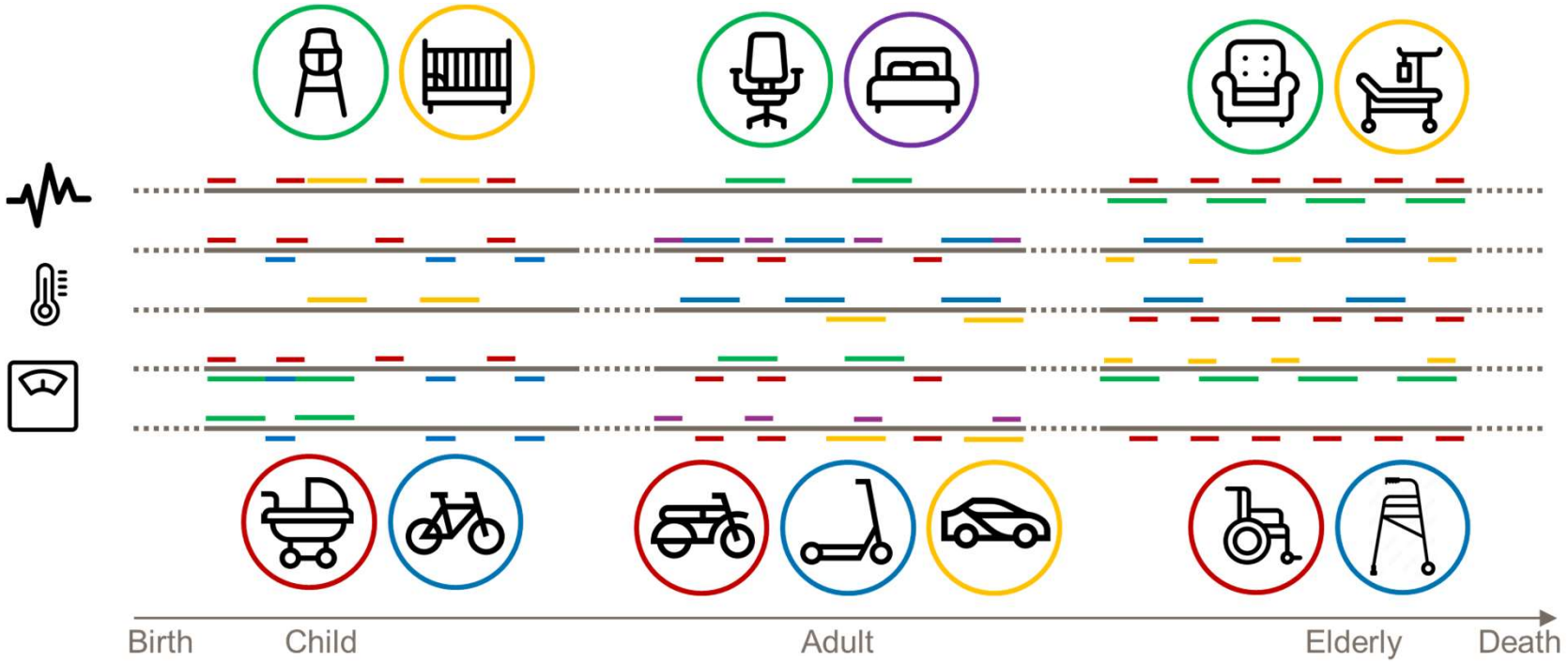
Vision

- Lifelong Health Monitoring



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  - Changing paradigms
  - Take home messages

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realistic photo of a young girl feeding a beagle puppy in a flower garden

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Changing Paradigms

Medicine

- Decentral vs. central diagnostics
- Continuous monitoring vs. sporadic examinations
  - Private & shared diagnostic spaces
  - Stationary & mobile
- Prognostics & prevention vs. illness & therapy

Medical Informatics (eHealth)

- PLRI ~ 1970
  (Peter L. Reichertz)
  - The right information
  - At the right time
  - At the right place
- PLRI ~ 2020
  (Thomas M. Deserno)
  - The right prediction
  - Long before the event
  - Personalized for each individual

Take-Home Messages

- *Health* is more than not being ill
- *Smart home* is more than light control by apps
- *Smart car* is more than autonomous driving
- *Diagnostic spaces* for continuous monitoring on private & shared devices
  - Learn individual situation (adaption)
  - Monitor long time (years/decades)
  - Detect (lingering) changes
  - Alert early
  - Help in emergencies
- Future: *One digital health* for combined monitoring of
  - Humans
  - Animals
  - Environment

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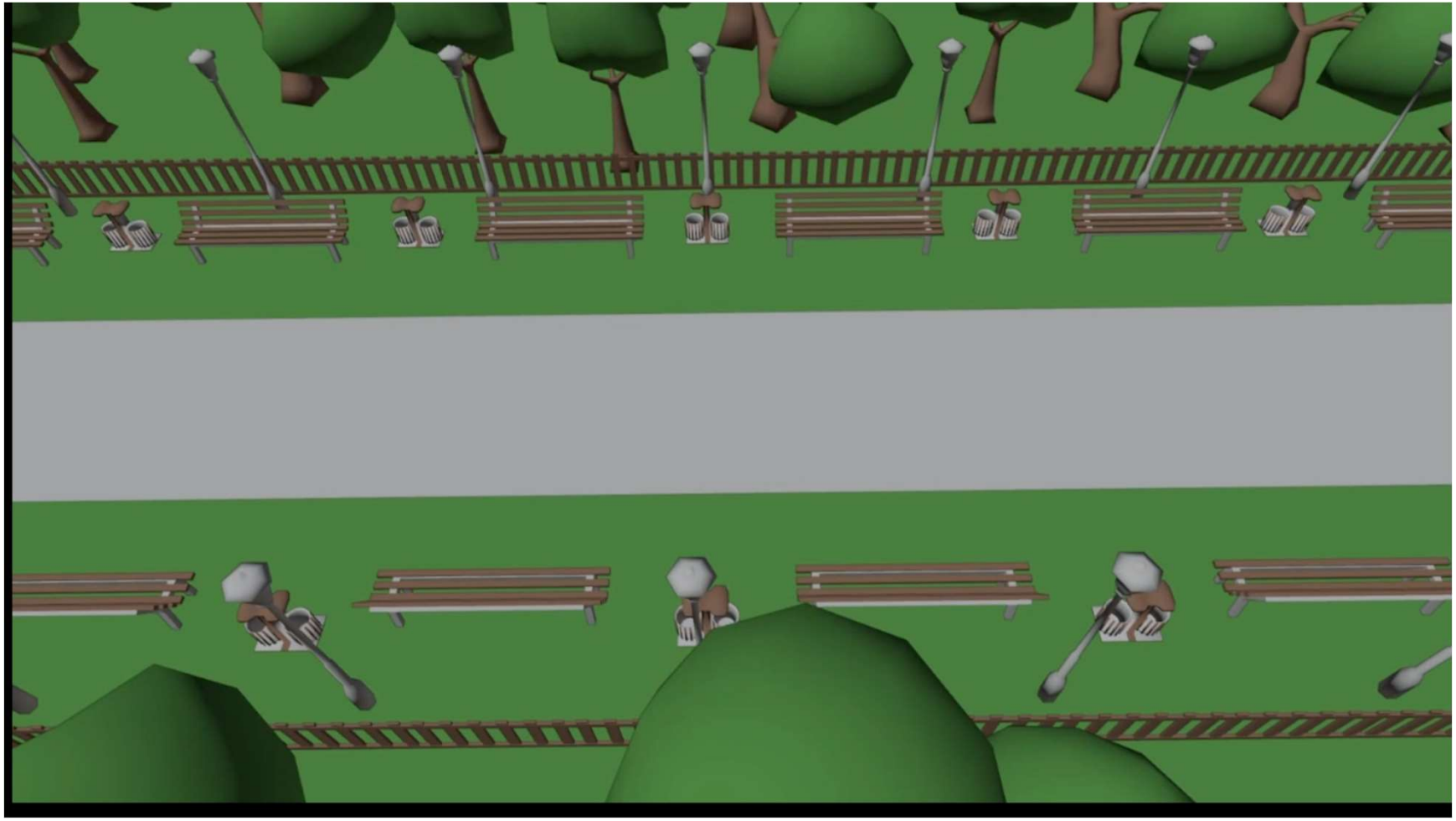
Future: One Digital health

- Interacting data of humans, animals & environment



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