ZENTRUM ASSISTIVE TECHNOLOGIEN
ZAT RHEIN RUHR

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Rhine-Waal University of Applied Sciences

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A Reference Architecture for Pro-Adaptive Cognitive Assistive Technology

Thomas Nitsche

Hochschule Niederrhein, Germany

thomas.nitsche@hs-niederrhein.de

A Reference Architecture for Pro-Adaptive Cognitive Assistive Technology

Sebastian Hauscheid[1], Sarah Buscher[2], Sinan Yavuz[1], Jordan Schneider[3], Michał Stolarz[3], Andre Frank Krause[2], Robin Grashof[1], Oviya Rajavel[3], Swathy Satheesan Cheruvalath[3], Teena Chakkalayil Hassan[3], Christian Ressel[2], Nele Wild-Wall[2], Edwin Naroska[1], **Thomas Nitsche[1]**

Centre for Assistive Technologies Rhine-Ruhr

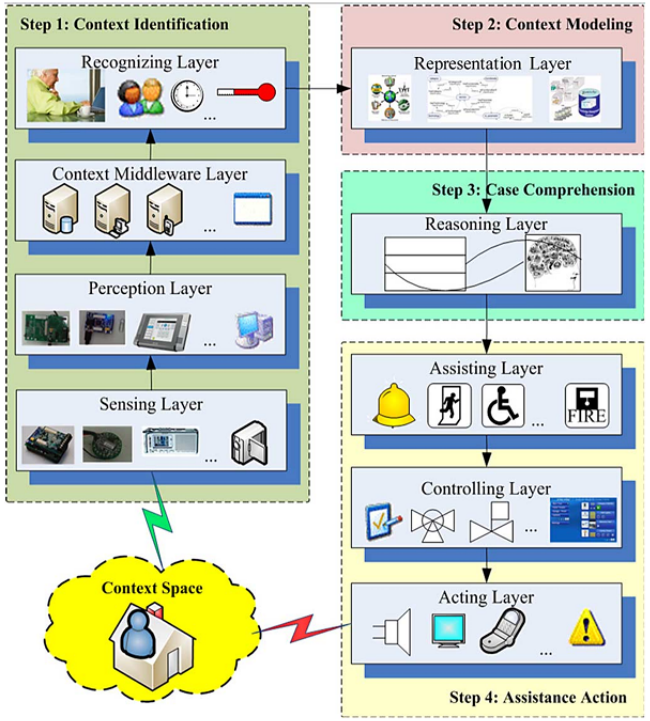
1. Hochschule Niederrhein University of Applied Sciences, Krefeld, Germany
2. Rhine-Waal University of Applied Sciences, Kamp-Lintfort, Germany
3. Bonn-Rhein-Sieg University of Applied Sciences, Sankt Augustin, Germany

Introduction

Assistive Technology (AT)

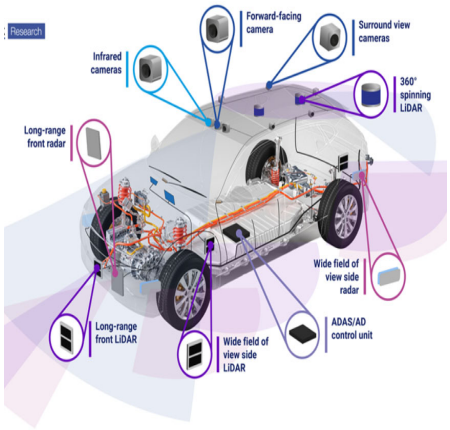
Assistive technology

- provides situational **support** for human actions
- based on context and behavioral data
- delivered precisely when it is needed or explicitly requested



Example applications

- Home care
- Workplace support
- Rehabilitation, medical



Example AT [7]

Cognitive Assitive Technology (CAT)

Support for humans in specific activities and in everyday life, e.g.

- Monitor parameters & activities
- Act as reminder
- Inform users of threatening szenarios

Cognitive impairments poses particular challenges, e.g.

- Data protection/privacy requirements
- Acceptance
- Disease-specific limitations
- Progression of disease (e.g. as in Parkinson)

Aim

- Provide a reference architecture for pro-adaptive cognitive AT (Pro-CAT)
  - Reduce reduplication effort, proven solutions & compatibility between systems
  - Especially,
    - Architecture handling (AI)-models at run-time
    - Framework for pro-adaptive components
  - Basis for future Pro-CAT
- Explictly handling privacy components

Pro-Adaptive Cognitive Assistive Technology (Pro-CAT)

- Most existing ATs remain primarily reactive
  - Adapting only to current context (or explicitly configured parameters)
  - → inflexibly to automatically adapt to changing user requirements

- Pro-Adaptive CAT
  - Extends this paradigm
  - Explicitly considering temporal dynamics & longitudinal trends
  - → anticipate future changes in user abilities
  - → proactively adjust assistance strategies

Levels of Adaptablity of Assistive Technology

Analogous to technology-readiness levels and levels of driving autonomy

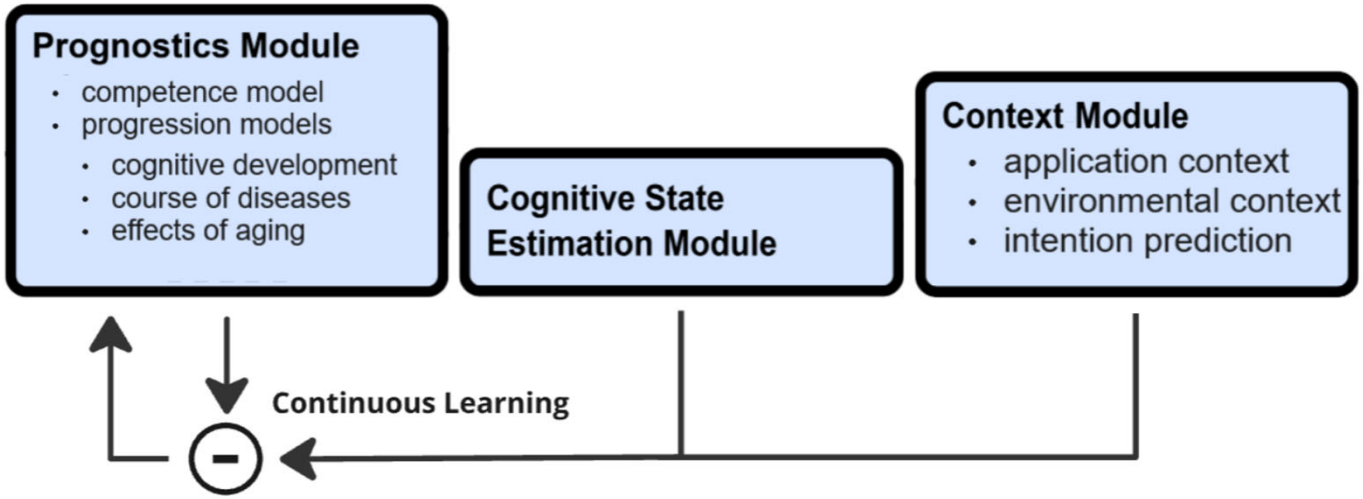
1. **Static** AT: Assistance is available to the degree defined by the manufacturer of the AT.
2. **Adaptiv**: The extent of assistance is adapted based on current sensor data.
3. **Personalizable**: Users can manually adapt the AT to their specific needs and requirements.
4. **Auto-individualizing**: The AT adapts to the user automatically based on past observed behavior and sensor data.
5. **Pro-adaptiv**. Combination of (2-4). Moreover, the AT adapts to meet the user's (future) needs based on anticipated conditions that are derived from past and current sensor data.
   - (e.g., aging or disease related changes in the user's capabilities).

Highest Level: Pro-Adaptive Cognitive AT

- Continuously evaluate user's situational data & learning over (longer) time
- Prediction of user's (cognitive) capabilities & assistance required in the future
  - → **Adaption to future needs**
  - Provide more support (if abilities degrate ⇓) or less (if abilities improve ⇑, skills learned)
  - Train user before condition worsen
- Advantages
  - Sustained personalisation
  - Improved long-term usability
  - Ability to proactively adjust assistance strategies (in response to predictable changes in user capabilities)

Enabling Pro-Adaptive CAT

- Prognostics module predicts changes in relevant abilities
- Cognitive state estimator
- Context module infers user intentions
- Continuous Learning → updates models over time for individualized AT



Pro-CAT Architecture

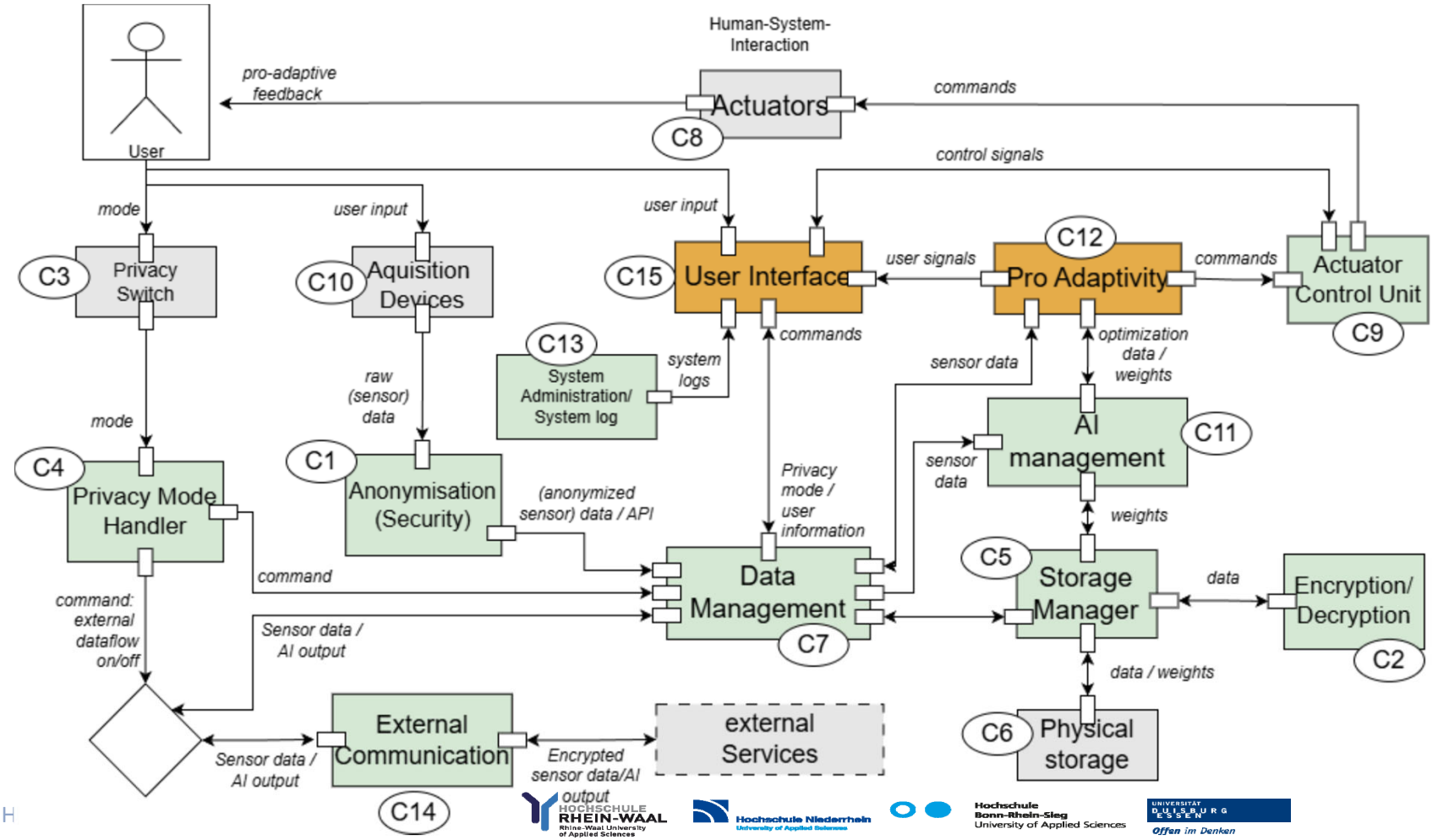
Requirements of AT

- **Detection** of disease-related symptoms & monitoring → (sensor) **data**
- (Local) **storage** → support long term tracking & AI-based digital twin of the patient
- (Sensor) **data processing**
- Provide **assistance** (based on capabilities)
  - **adapted to specific user's needs** → avoid over-assistance)
- Usability (cf., symptoms-related limited interactions) → UI adaptive & configurable
- Enable **local computing** (→ low latency, **privacy**-preserving)
- Additionally: cloud-integration (→ external resources & services)
- Additional security measures (anonymization, data encryption)

Components

- C1: Anonymization (Security)
- C2: Encryption / Decryption
- C3: Privacy Switch
- C4: Privacy Mode Handler
- C5: Storage Manager
- C6: Physical Storage
- C7: Data Management
- C8: Actuators
- C9: Actuator Control Unit
- C10: Acquisition Devices
- C11: AI Management
- C12: Pro-Adaptivity
- C13: System Administration / System Log
- C14: External Communication
- C15: User Interface

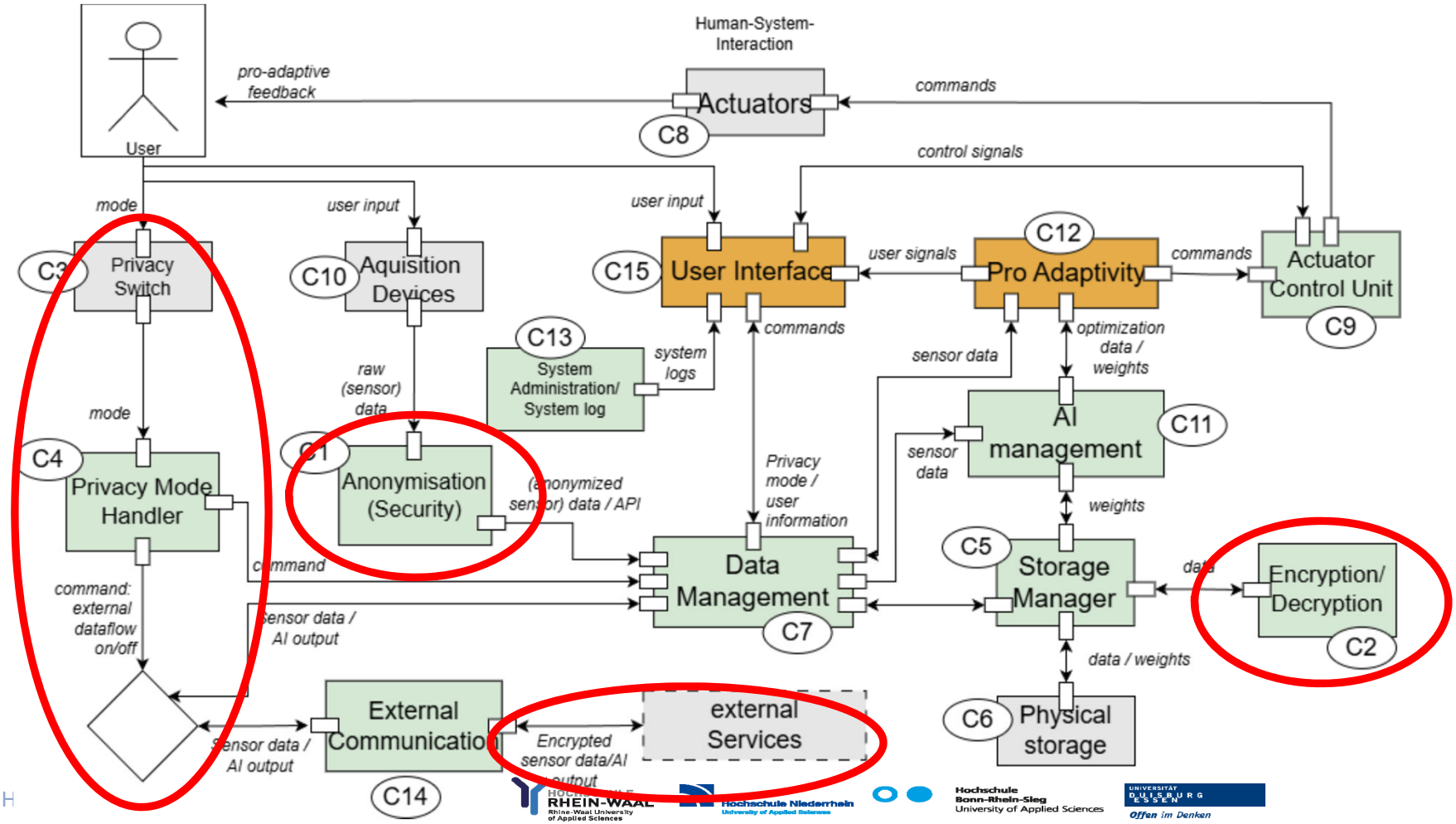
Proposed Reference Architecture



Discussion & Evaluation

- Privacy-by-Design
  - Privacy Switch & Privacy Mode Handler → enables explicit user control & systematic policy enforcement
  - Explicit Anonymization & Encryption → implement privacy by design

Privacy by Design



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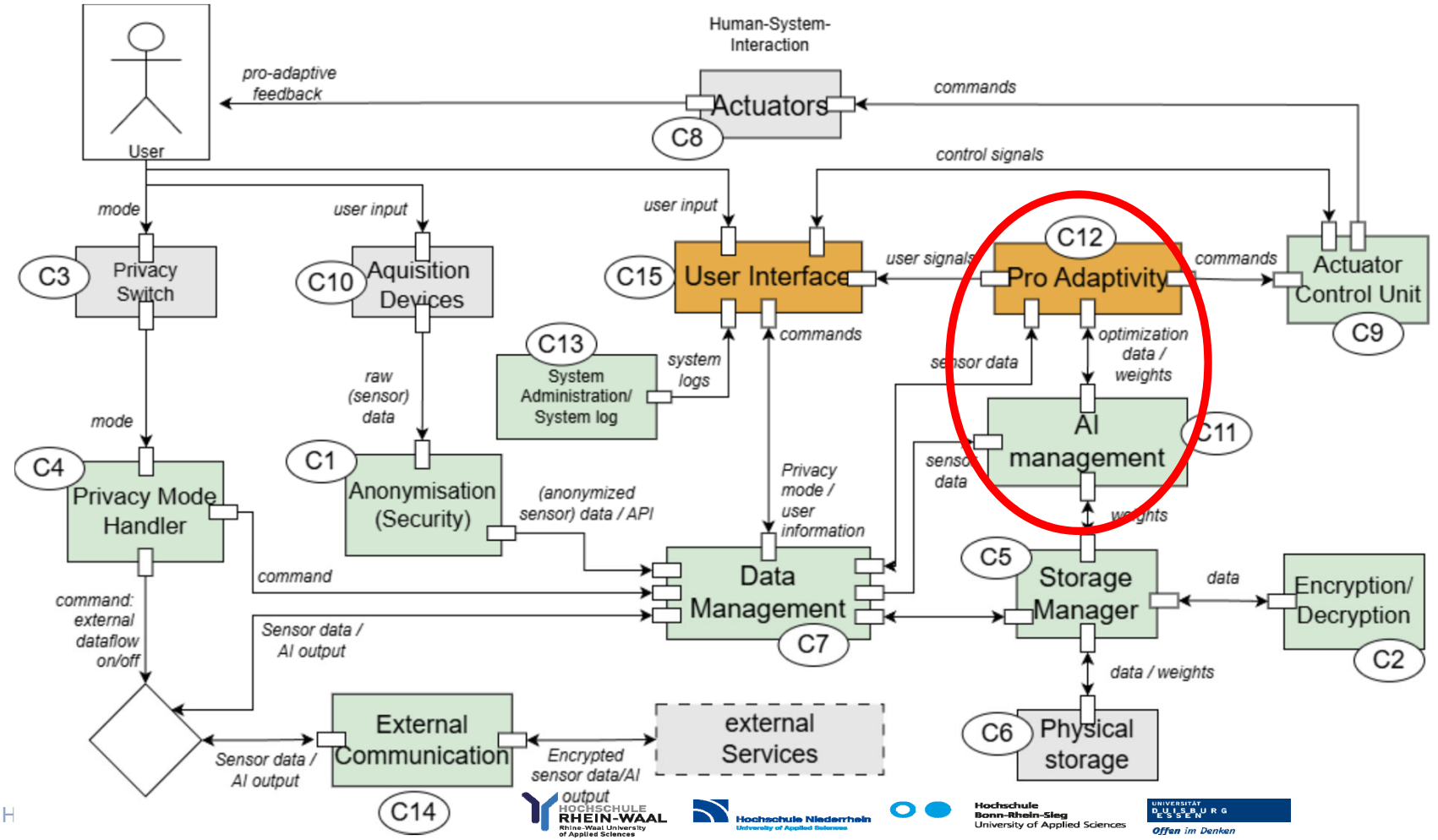
- Pro-Adaptivity
  - Distinct capability (implemented through interaction between AI Mgt. & Data Mgt,
  - Supported by
    - Data integration from diverse sources
    - Allowing model updates
    - Supporting closed-loop feedback (observed outcomes → model optimization)

Pro-Adaptivity



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- Limitations
  - Conceptial validation
  - Operationalization of Pro-Adaptivity

Conclusion

- Modular, privacy-by-design **reference architecture for Pro-CAT**
  - Proposed architecture addresses key limitation of existing ATs
    - Explicitly supporting longitudinal adaption to predicable changes in user capabilities
    - Contrast to purely reactive ATs: enables **pro-adaptive behaviour**
  - Clear separation of concerns
  - **Common conceptual basis** for pro-adaptive ATs
  - **Explicit treatment of privacy and Pro-Adaptivity** as architectural concerns
    - → supports both trustworthy data handling & continuous personalization
    - Supports both local, privacy-preserving operation & optional cloud-based services
- Concept of **levels of adaptability** of ATs

Future Work

- Monitoring, evaluation and user studies
  - Evaluate in different szenarios
  - Currently working on, dementia support, ADHD support, (cognitive) training, …
- Prognostic module and temporal modeling
  - Specify how prognostics & longitudinal user modelling are realized
- Example application szenario (ADHD support) → see next talk in this session
- **Workshop „Towards Pro-Adaptivity in Human-Computer-Interaction“**
  - **https://www.uni-due.de/kowi/mukom/workshops_muc2026**
  - You want to contribute/discuss further? → Call for Papers will appear soon

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Hochschule Niederrhein

Prof. Dr. Thomas Nitsche
Hochschule Niederrhein
thomas.nitsche@hs-niederrhein.de

Thank you!

Questions?

HOCHSCHULE RHEIN-WAAL Rhine-Waal University of Applied Sciences

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