Leveraging Mobile Interaction with Sensor-Driven and Multimodal User Interfaces

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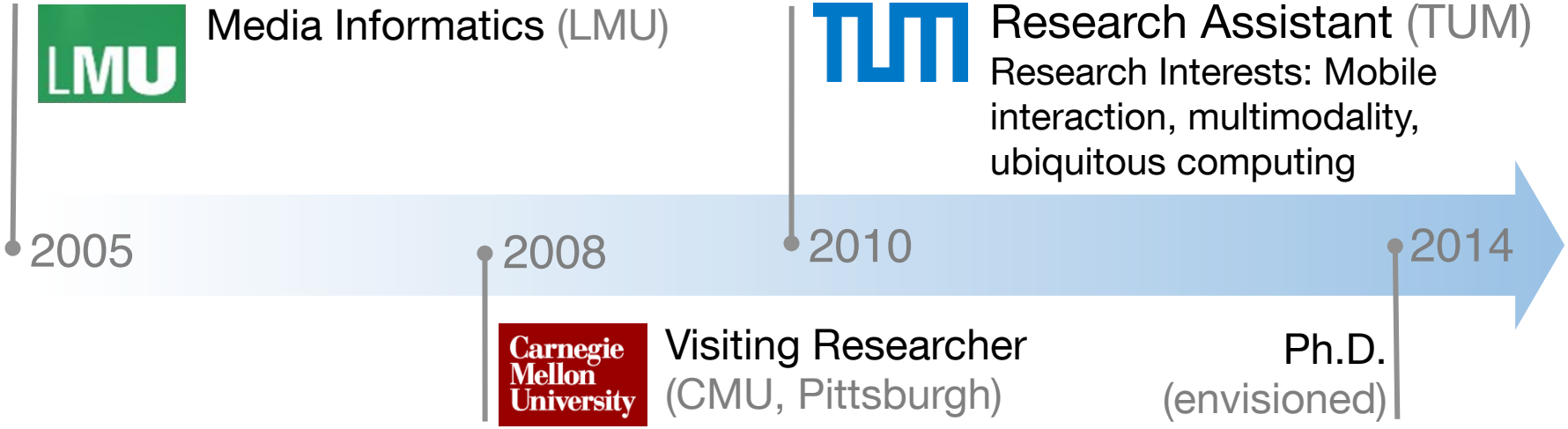
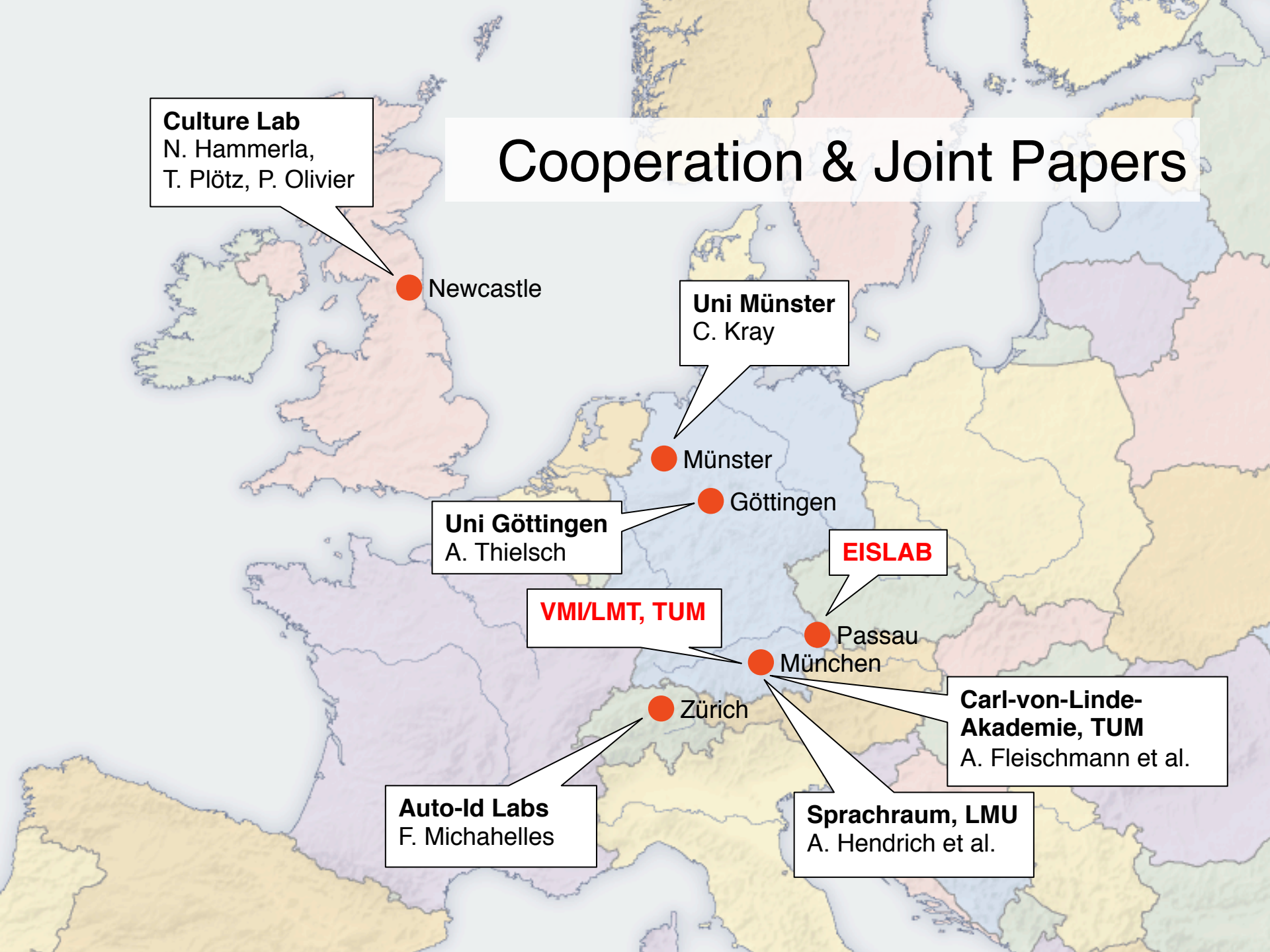
29.07.2014

My Road towards the Ph.D.



- **Publications**
  - First author of 14 peer-reviewed publications (8 full papers), among others at CHI (2x), PerCom, NordiCHI, MUM
  - Co-author of over 40 publications with research group
- **Supervised theses (as responsible advisor)**
  - 13 Master & bachelor theses, Diplom- & Studienarbeiten

Cooperation & Joint Papers



Motivation

- **Challenges of Mobile Interaction**
  - Increasing functionality → increasing complexity
  - New target groups (e.g., elderly people)
  - New application areas (e.g., health and fitness)
- **Trend: Ubiquitous Computing**
  - Usage in different contexts and under different conditions
- **Multimodality** as proposed solution
- Need for research:
  - Design space for mobile multimodal interaction (previously: desktop, selected use cases)
  - Investigation in light of new trends and use cases
  - Support from scratch, all stages of the development process

Terms

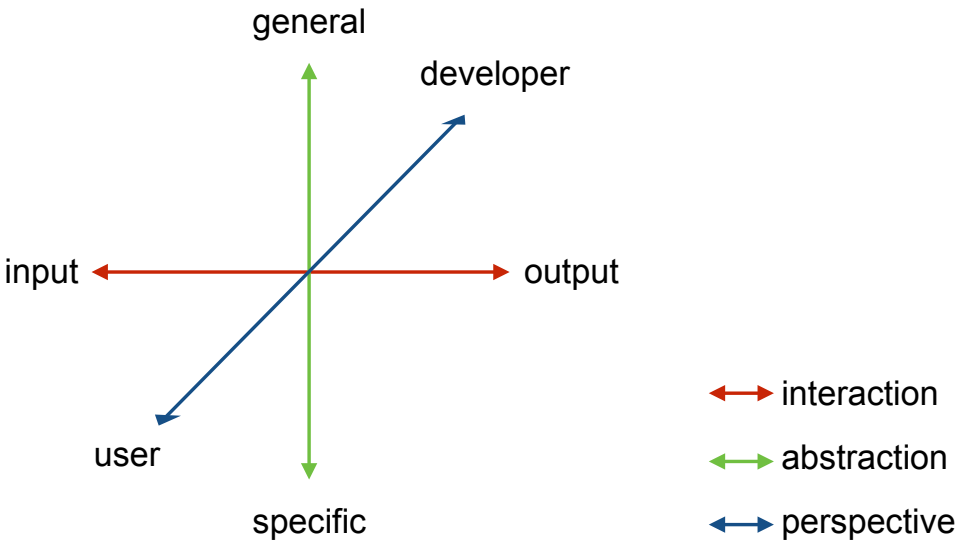
- **Multimodal Interaction**
  - input and output involving more than one modality
  - independently or combined, in parallel or sequentially
- **Sensor-Driven Interaction**
  - communication with a system initiated or mediated by information acquired from sensors
- **MUSED** (*MU*ltimodal and *SE*nsor-*D*riven) **user interface**
  - focusing on the relationship between the above terms
  - multimodality is (partly or entirely) realized by device-internal sensors
  - notion of term „modality“ as (sensor-driven) interaction paradigm
  - implicit and explicit character of user interaction

Goals

- **Make multimodality usable (end users) and accessible (developers)**
- Improvement of existing applications and use cases
  - Naturalness (Bunt 1998)
  - Efficiency (Oviatt 1999)
  - Robustness (Oviatt 1997)
  - Adaptivity (Quek et al. 2002)
  - Diversity (Lemmelä et al. 2008)
  - Popularity (Oviatt 1997)
- Facilitation of completely novel applications
  - Examples are given in the thesis (*Chapters 3-5*)
- Systematic approach to overcome existing problems (*Chapters 6 & 7*)
  - End user's perspective
  - Developer's perspective

Research Questions

Analysis of multimodal systems using three dimensions



Selection of research questions

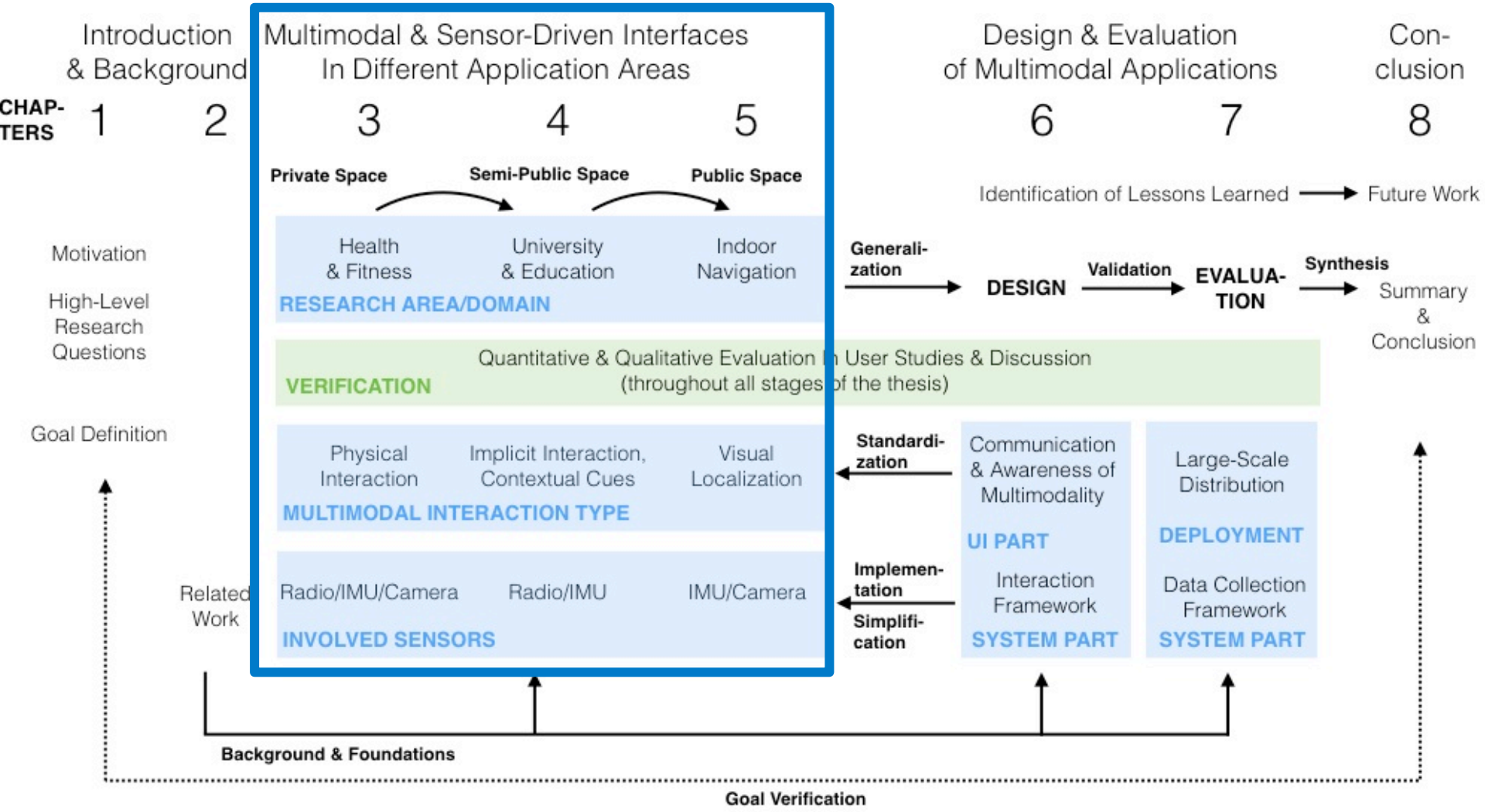
- What are **advantages** and **potential problems** and challenges of multimodality and sensor-driven interaction?
- How can **mobile interaction benefit** from multimodality?
- How can the **development process** of multimodal applications be better supported?
- What are pitfalls in the **evaluation** of multimodal (and in general novel) interaction methods?

Major Contributions

- Deeper understanding of multimodality and its benefits in different application areas
- Conception of a model for multimodality, supporting input as well as output, in everyday & special cases
- Creation of a multimodality programming framework
- Appropriate UIs for behavior definition & awareness
- Discussion of appropriate evaluation methods

→ Support of complete development process

→ All findings informed and grounded by user studies & evaluations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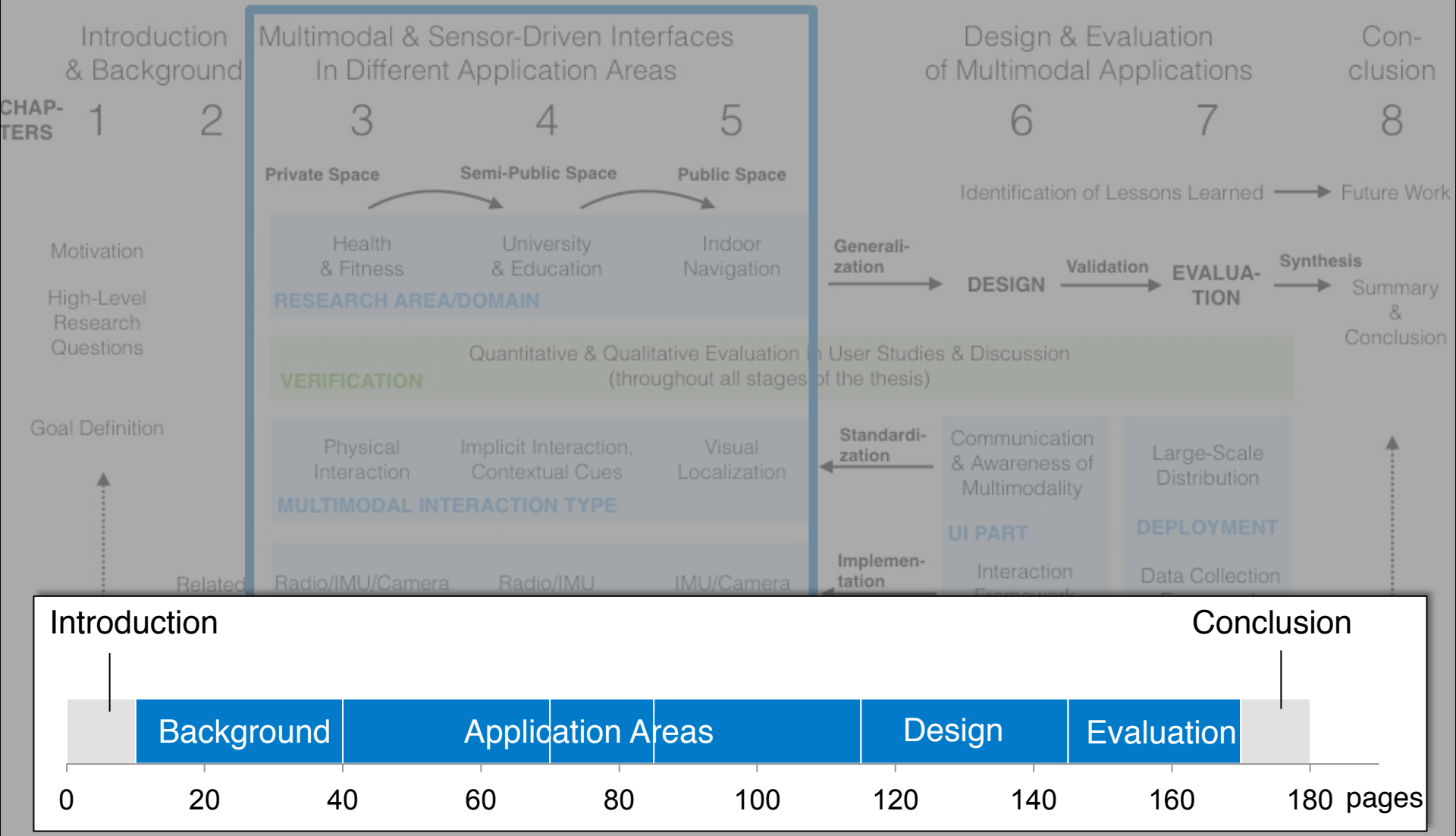
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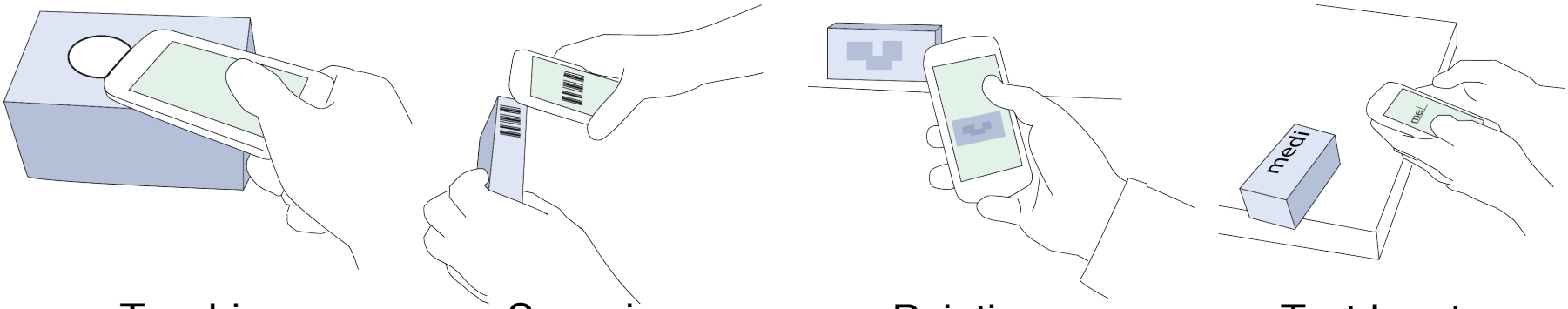
Health & Fitness, Activities of Daily Living (ADL)

- Motivation for support in ADL area
  - Aging society, multi-morbidity, problems with daily tasks
  - Tomorrow's *best agers* are technology-affine (but: need for adaptations, good usability, …)
  - Scenario: Medication package identification

- Motivation for support in health and fitness area
  - Sedentary lifestyle, lack of free time → need for ubiquitous training, keeping up long-term motivation
  - self-monitoring trend, smartphones are always at hand, but: usability is important (cf. wearable sensors)
  - Scenario: Personal fitness trainer

MobiMed: Investigated Interaction Modalities



Touching
(radio tags,
e.g. NFC or RFID)

Scanning
(visual tags,
e.g. bar codes)

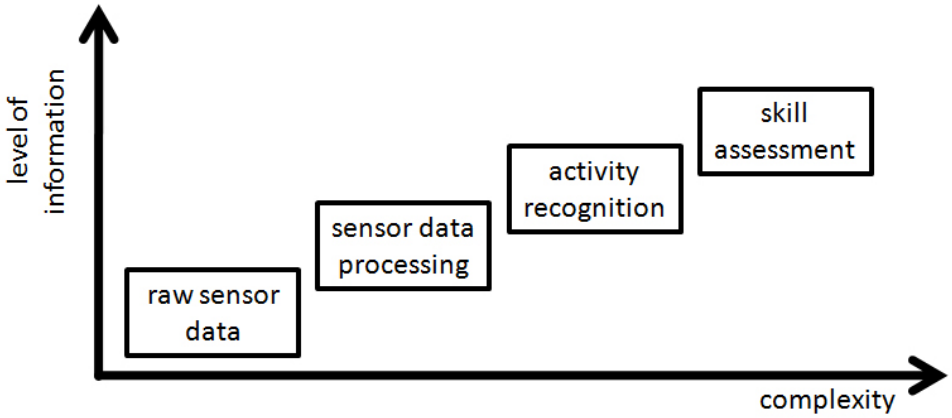
Pointing
(tag-less
vision-based
identification)

Text Input
(e.g. name, ID, …)

- Evaluation
  - Online study (149 participants)
  - Lab study (16 participants)
  - Proposed modalities more efficient and popular than baseline

GymSkill

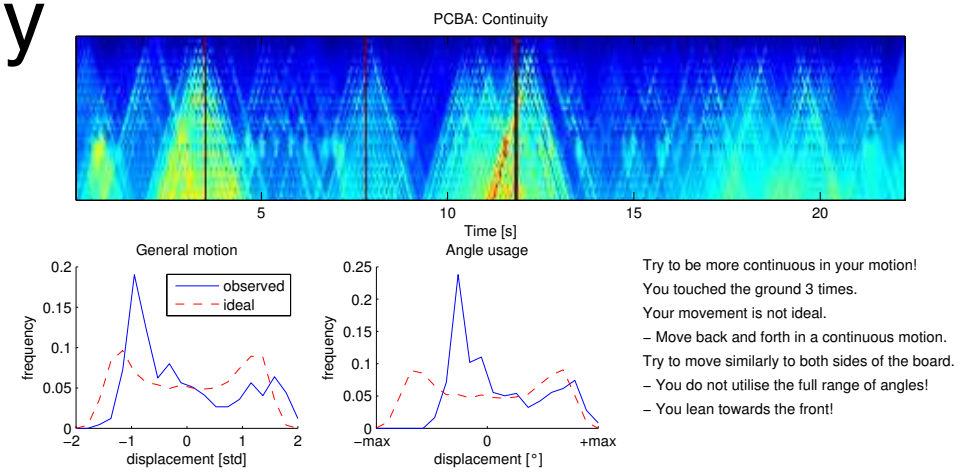
- "Personal trainer" based on phone sensor data ("physical interaction modality")
- Touch modality (NFC) for configuration
- Continuous supervision **and** assessment
- Individualized advice and motivation
- Minimization of injury risk
- Scenario: Rocker board exercises



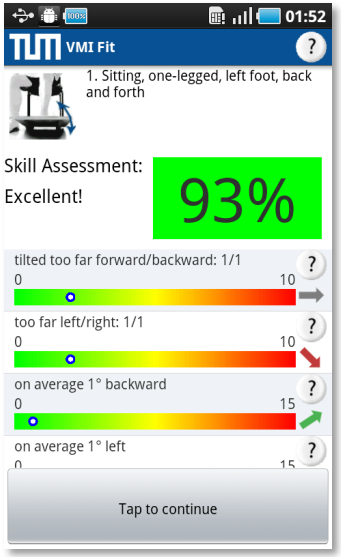
A. Möller et al., *GymSkill: A Personal Trainer for Physical Exercises*, Proc. PerCom 2012
M. Kranz, A. Möller et al., *The Mobile Fitness Coach: Towards Individualized Skill Assessment Using Personalized Mobile Devices*, PMC 9:2, 2013

GymSkill: Methodology

- Training data collection (ground truth)

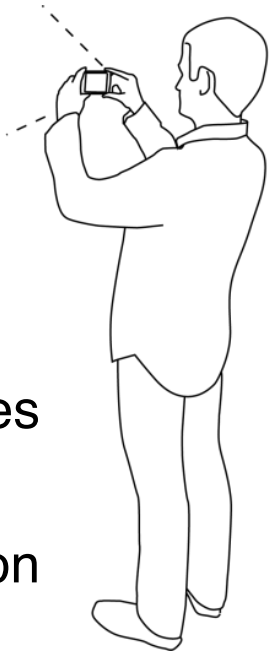


- Iteration 1: Principal Component Breakdown Analysis (PCBA)
  - Visual feedback after training
  - Global and local motion quality
- Iteration 2: Criteria-Based Assessment
  - On-device analysis
  - Sub-scores on individual performance aspects



- Study suggested long-term motivation through feedback

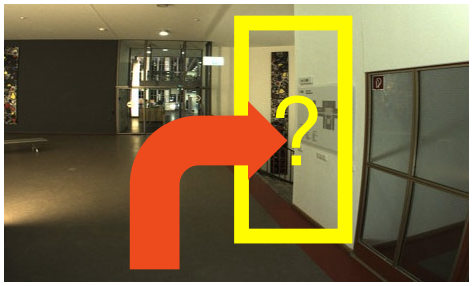
Indoor Navigation



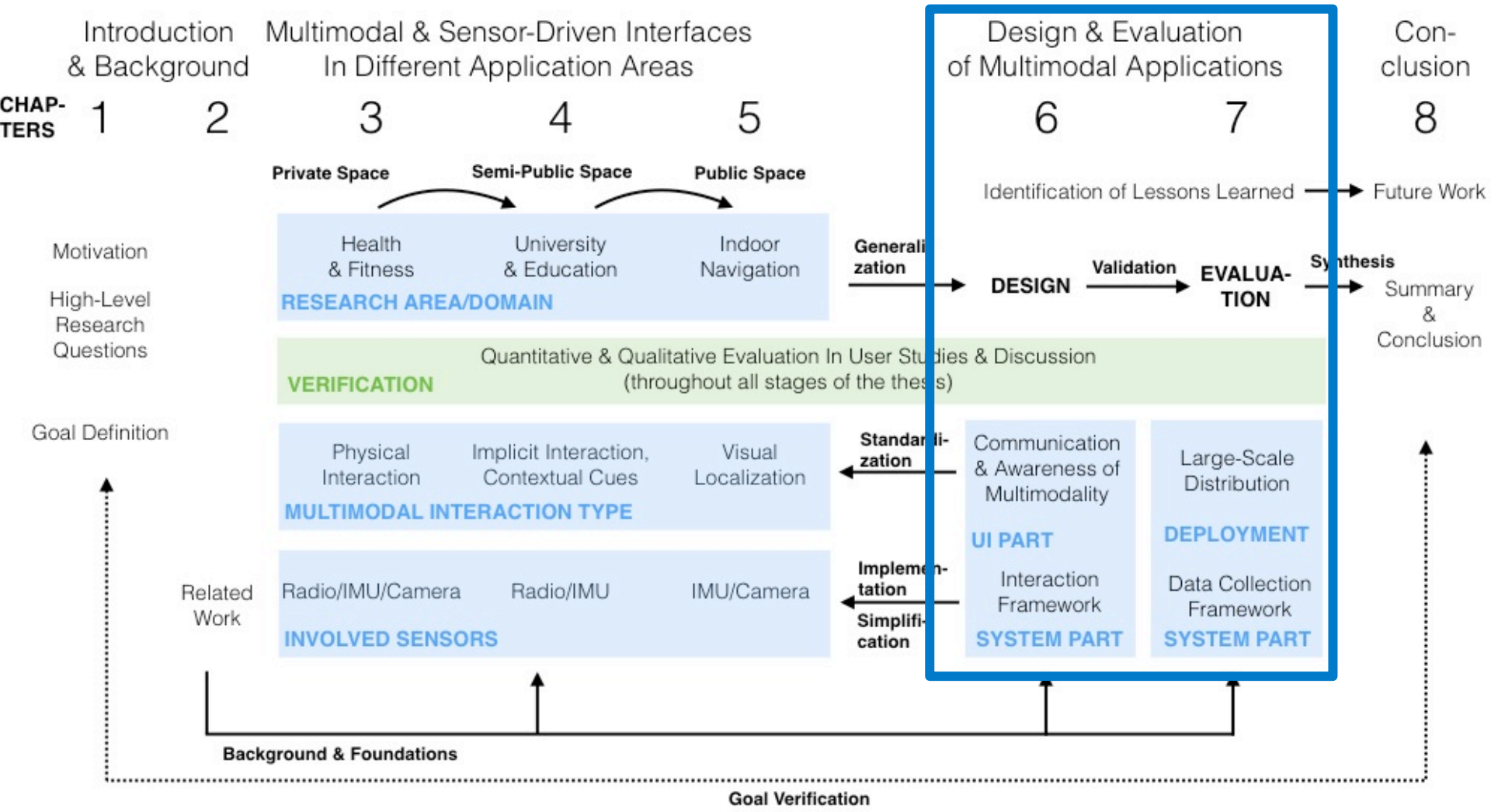
- Example for interaction in public space (generalization of university scenario as semi-public space)
- **Vision** as input modality for indoor localization
  - Camera records environment and extracts visual features
  - Matching with reference database
  - Advantageous compared to alternative indoor localization techniques (WLAN, Infrared beacons, visual markers)
- Iterative improvements and evaluation of interaction concepts
  - Online study
  - Multiple Real-world studies

A. Möller et al., *Experimental Evaluation of User Interfaces for Visual Indoor Navigation*, Proc. CHI 2014
A. Möller et al., *A Mobile Indoor Navigation System Interface Adapted to Vision-Based Localization*, Proc. MUM 2012

Interaction Concept



- *Augmented Reality* View for intuitiveness, but:
  - Wrong overlays when localization is inaccurate
  - Permanent re-localization required
  - Uncomfortable camera pose
- *Virtual Reality* as alternative
  - 360° panorama images, embedded instructions
  - Re-localization only from time to time
  - More comfortable pose
  - More robust with regard to localization failure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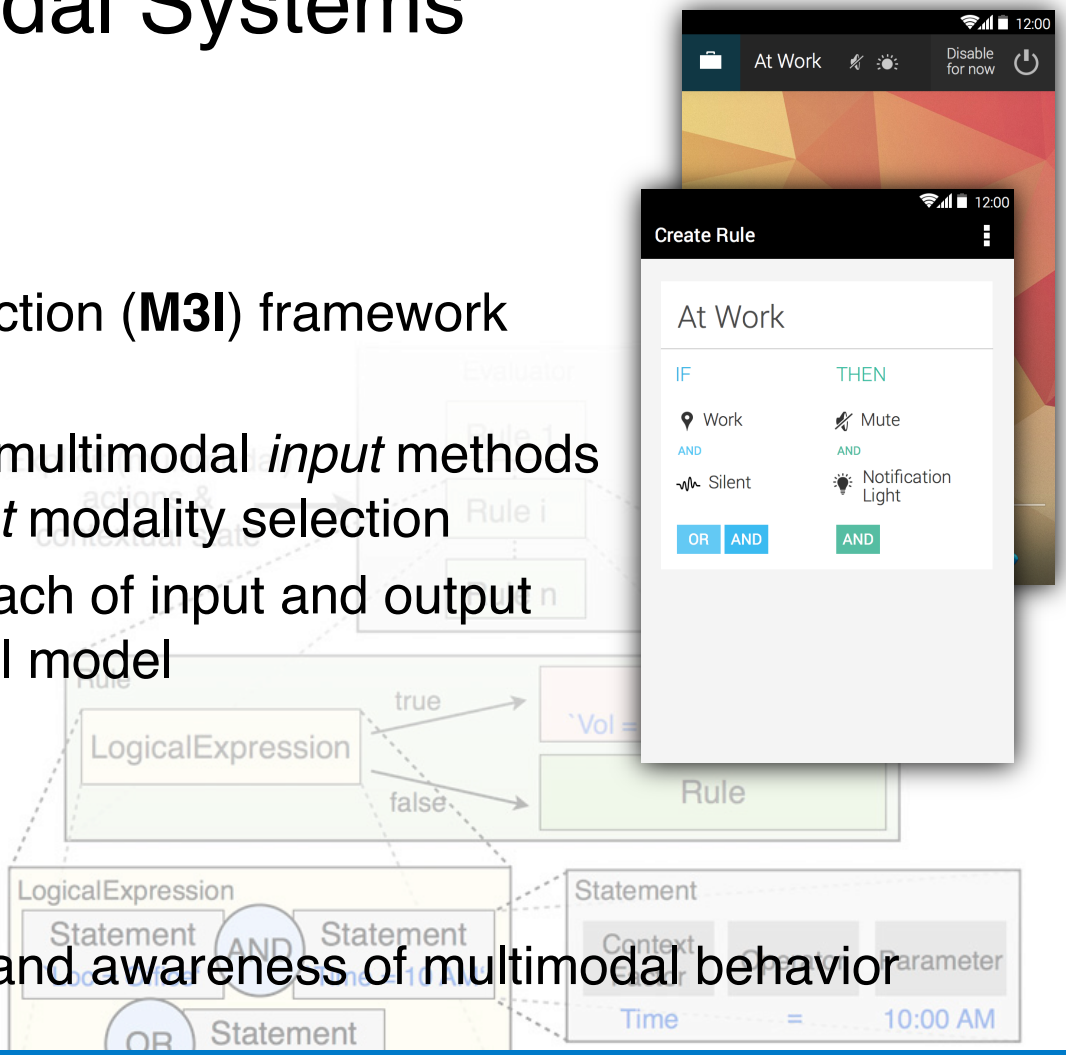
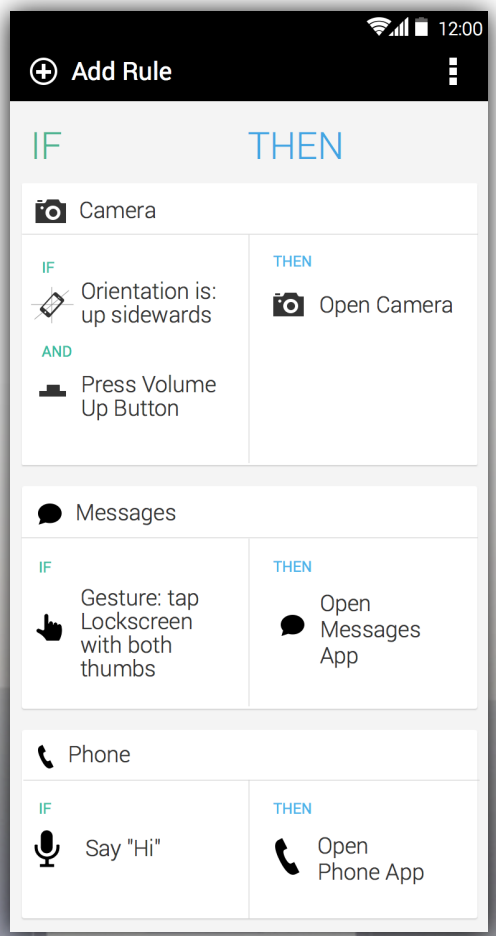
Designing Multimodal Systems

- **Developer perspective**
  - Problems in status quo
  - **M**obile **M**ulti**M**odal **I**nteraction (**M3I**) framework as explicit contribution
  - Implementation of novel multimodal *input* methods and context-based *output* modality selection
  - Rule-based wiring approach of input and output supporting human mental model
- **End user perspective**
  - Current modality usage
  - Requirements analysis
  - UI concepts for defining and awareness of multimodal behavior



Conducted Studies

- **Laboratory Study**
  - Comparative evaluation of rule creation interfaces (efficiency, effectiveness, satisfaction)
  - Comparative evaluation of rule awareness notifications (efficiency, effectiveness, satisfaction)
  - Explorative study of multimodal input methods
- **Field Study**
  - Long-term usage and acceptance
  - Insights on created rules



Evaluating Multimodal Systems

- **Research question**: Which evaluation methods are adequate for multimodal systems?
  - High degree of interactivity and interdependence of real world
  - Informed by own research experiences

Laboratory Evaluation: Wizard of Oz	**Field Evaluation**: Logging and self-reporting	**App Stores** for large-scale deployment
Used for: indoor navigation & multimodal interface studies	Development of a self-reporting tool Used for: MobiDics study, multimodal interaction study, self-reporting behavior analysis	Focus on update behavior and implications on research apps

Conducted Studies

- **Investigation of Self-Reporting**
  - Comparison of self-reporting modes (voluntary, interval-based, event-based) with regard to accuracy, change over time, influence on reporting frequency
  - Scenario: usage of mobile applications
  - Deduction of guidelines for long-term study setups
- **App Stores as data source for "Research in the Large"**
  - Study of update behavior with own Android app (install base: 3000+ users)
  - Implications for research applications

Image source: Apple.com

A. Möller et al., *Investigating Self-Reporting Behavior In Long-Term Studies*, Proc. CHI 2013
A. Möller et al., *Update Behavior in App Markets and Security Implications: A Case Study in Google Play*, LARGE 2012

Next Steps

- Finalize Writing Up Thesis
- Envisioned Finish Date: September 2014

Thank you for your attention!

Questions & Discussion