Leveraging Mobile Interaction with Sensor-Driven and Multimodal User Interfaces

Andreas Möller
Betreuer: Prof. Dr. Matthias Kranz

Doktorandenseminar an der LMU München
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My Road towards the Ph.D.

- **Media Informatics (LMU)**
  - 2005
- **Research Assistant (TUM)**
  - Research Interests: Mobile interaction, multimodality, ubiquitous computing
  - 2008
  - 2010
- **Visiting Researcher (CMU, Pittsburgh)**
- **Ph.D. (envisioned)**
  - 2014

- **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
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 (MUltimodal and SEnsor-Driven) 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)
- 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

- Adaptivity (Quek et al. 2002)
- Diversity (Lemmelä et al. 2008)
- Popularity (Oviatt 1997)
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
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
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., *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

Applicability and utility of very specific multimodal interfaces and associated benefits

For each domain

- Concepts
- Implementations
- Evaluation in user studies
- Lessons learned for specific domain

Next step:

- Design multimodal systems (user’s and developer’s perspective)
- Evaluate multimodal systems (methods, experiences, guidelines)

Identification of Lessons Learned

DESIGN → Validation → EVALUATION

Communication & Awareness of Multimodality

UI PART

Interaction Framework

SYSTEM PART

Large-Scale Distribution

DEPLOYMENT

Data Collection Framework

SYSTEM PART

Summary & Conclusion

Future Work

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Designing Multimodal Systems

**Developer perspective**
- Problems in status quo
- **Mobile MultiModal Interaction (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)
  - Exploratory 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

Used for: indoor navigation & multimodal interface studies

**Field Evaluation:** Logging and self-reporting

Development of a self-reporting tool
Used for: MobiDics study, multimodal interaction study, self-reporting behavior analysis

**App Stores** for large-scale deployment

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

A. Möller et al., *Investigating Self-Reporting Behavior In Long-Term Studies*, Proc. CHI 2013
Next Steps

- Finalize Writing Up Thesis
- Envisioned Finish Date: September 2014
Thank you for your attention!

Questions & Discussion