Software Development
Challenges for
Ubiquitous Augmented Reality

GI Workshop
Virtuelle und Erweiterte Realität

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Summary

- **Ubiquitous augmented reality** is the convergence of augmented reality and ubiquitous computing.
- This convergence allows several promising applications.
- Building such systems presents software engineering challenges:
  - **Uncertainty**: users’ mobility changes availability of distributed devices
  - **Ill-defined requirements**: interaction metaphors are being researched and users’ preferences change
  - **Near-real-time performance**: needed to create convincing AR experience
- These challenges must be addressed by the development process, the software architecture and the run-time infrastructure.
Ubiquitous Augmented Reality

- Convergence of two interaction technologies
- Augmented reality: larger range, more devices, more users
  - classical AR: track position and orientation, superimpose virtual objects into view
  - more devices for input (multi-modality) and output (multi-media)
  - greater range: mobile AR, outdoor AR
  - many users: collaborative AR
- Ubiquitous computing: richer, natural interaction techniques
  - computing technology in environment without thinking about it as such
  - applications in home, workspace; user focuses on other activities
  - other users bring new devices, providing new services
  - goal: enhance and augment the real world
- Convergence Investigated by several groups (e.g. Klinker, Schmalstieg, Butz)
A Definition of UAR

- **Augmented Reality (Azuma)**
  - combines real and virtual
  - is interactive in real time
  - is registered in three dimensions

- **Ubiquitous Computing (Weiser)**
  - makes computers available throughout the physical environment
  - makes them effectively invisible to the user
  - augments the real world

- **Ubiquitous Augmented Reality (proposed definition)**
  - augments the real world with virtual information
  - is interactive in real time
  - is spatially registered
  - is available throughout a large physical environment
  - allows both immersive interaction and unobtrusive assistance
Relevance: Applications

- Navigation

- Construction and Maintenance
Relevance: Applications (2)

- Games

- Collaborative design

- Hospital, intelligent campus, exploration, team action…
Challenges in Software Development

• Workable solutions to some problems in AR are available
  – e.g. commercial optical tracking; scene graph rendering engines
  – Convincing static AR systems can be built (e.g. in surgery)

• Ubicomp applications are becoming more numerous
  – but low degree of immersivity and interactivity

• But: building UAR systems is an unsolved problem

• One reason: software engineering challenges
  – **Uncertainty**: dynamically combine distributed software components
  – **Ill-defined requirements**: young field; users’ preferences change
  – **Near-real-time performance**: needed to create convincing AR experience

• Those are the challenges I am investigating in my dissertation
  – …although, of course, there are many others.
Uncertainty

Problem: At system run time, which software components should be combined, and how?

Forces:

• Distributed, interdependent hardware devices
  – Mobile and stationary (handheld, room-based tracker)
  – Computing, network, input, output

• Changing availability of devices
  – Users move about
  – Limited sensor range

• Changing context influences components and system structure
  – Use devices that are “close” to the user (in position, or in context)

• Incomplete knowledge of software components
  – stepwise deployment, different administrative domains
Ill-Definition

Problem: What should the system do, anyway?
Forces:

• New and changing technology
  – Interaction metaphors are still being researched
  – Difficult for users to imagine

• Many people and many disciplines involved
  – Different users have different preferences
  – Different disciplines have different languages

• Requirements elicitation is difficult
  – Users involved in real-world tasks; computers of secondary interest

• New applications
  – Users will want to recombine deployed components in different ways
Performance

Problem: System must deliver near-real-time performance in large distributed environment

Forces:

• Immersivity for convincing AR user experience
  – Low overall lag between head tracking and 3D rendering; 20ms
  – High update rate, 30 fps

• Scalability in ubiquitous computing environment
  – Many users must have access to same sensor data
  – Users’ mobile devices should collaborate

• Many data and communication types
  – Video streams, sensor data streams, semantic events, transactions…
Towards a Solution

UAR Software Development Problems

- Ill-definition
- Uncertainty
- Performance

- Development process
- Software architecture
- Run-time infrastructure

- affects
- affects
- affects

- Must balance forces in different aspects of software development
- Tradeoffs—e.g. dynamic adaption can degrade real-time performance
Conclusion

• Ubiquitous augmented reality is a promising field
• There are fundamental problems to be solved in how to develop software for it
• The three problems of...
  – uncertainty
  – ill-definition
  – performance

...affect the choice of...
  – software architecture
  – middleware, run-time infrastructure
  – development process

...and should be considered carefully in planning them.
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Thank You for Your Attention!
Any Questions?

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