Ubiquitous Tracking for Augmented Reality

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Overview

• Why we need Ubiquitous Tracking
• Formal model
• Implementation concepts
• DWARF-based implementation
• Simulation environment
• Conclusions & Future work
Why we need Ubiquitous Tracking

**Bringing AR to intelligent environments:**

- AR applications extend their range of operation
  - Mobile AR
  - Powerful wearable devices
- Ubicomp applications extend their immersivity
  - “Natural” interaction benefits from accurate location information
- Combining tracking requirements from ubicomp and AR allows to use AR interaction in ubiquitous environments
Why we need Ubiquitous Tracking

**Enhancing AR tracking technology:**

- No single sensor is perfect for all AR applications
  - Sensor fusion gains attention
  - Reusable solutions required
- Tracking technologies tend to build upon each other
  - Initialization problem for natural feature tracking
  - Stabilize results of absolute by relative tracker
What is Ubiquitous Tracking?

- Abstraction Layer between location sensors and applications
- Gathers all available spatial relationships from sensors
- Provides inferences to deduce “best” possible spatial relationship between arbitrary objects in the system
  - Semantics of “best” is application dependent
  - Existing inferences (i.e. filter and fusion components) have to be integrated
Definition of Terms

- A spatial relationship between two objects can be expressed in terms of multiple parameters (e.g. any dimension of position, orientation and their derivatives)

- A sensor performs a measurement of some physical property and computes an estimate of some spatial relationship parameter

- A locatable is an object whose spatial relationship to some reference coordinate system is estimated by a sensor

- An inference is an estimate of a spatial relationship computed from single or multiple estimates of spatial relationships
Formal Model

- **Goal**: uniform modelling of all spatial relationships
  - Handle estimates of diverse sensor classes
  - Handle inferences (i.e. filtering data, sensor fusion)
- **Approach**: directed *spatial relationship graph*
  - Describe spatial relationships as functions of time
  - Functions yield estimates of spatial relationship characterised by attributes
Formal Model: Inferring Knowledge

- Integrate existing inferences (e.g. Kalman Filter fusing two sensors) by adding new edges to SR graph

- Provide generic inferences by using transitivity property of spatial relationships
  - Search path in SR graph between relevant nodes
Formal Model: Challenges

- Directed graph: non-trivial inversion of edges
- Timing issues: measurements made at discrete points in time, demand for estimates in continuous time
- Should map onto real implementation without too many restrictive assumptions
- For this purpose: handle dynamic changes in availability of spatial relationships
Implementation Concepts

- **Layered Architecture:**
  - Spatial relationship data moves from sensors to applications through filters inferring new spatial relationships
  - Set of filters built and connected on demand according to application’s needs

- **Data flow graphs**
  - Flow of data through filters can be modeled as a graph
  - Assumption: form of data flow changes seldom compared to spatial relationships
DWARF-Based Implementation

- DWARF is a distributed peer-to-peer middleware, modelling AR applications as set of distributed services
- Extension of DWARF middleware to allow generic Ubitrack inferences
- Resulting data flow consists of a set of services:
  - Sensor services encapsulate hardware devices
  - Inference services aggregate data (on multiple levels)
  - Application services consume data
Simulation Environment

• Large-scale Ubitrack environments are not yet ready
  – Limited amount of sensors

• Ubitrack simulation environment allows to generate artificial multi-sensor tracking data
  – Test Ubitrack implementation by comparing results to simulation ground truth

• Generation of simulated images of scenes for feeding vision-based trackers
Conclusions

• Automated reusable sensor fusion is a prerequisite for bringing AR applications into large intelligent environments
• Formal model allows automated handling of large multi-sensor setups
• DWARF-based implementation shows feasibility of approach
Future Work

- Build large-scale setups for real world applications
- Incorporate sensors using different representations of spatial relationships (e.g. cell-based trackers)
- Exploit Ubitrack for natural feature trackers
- Autocalibrate parts of Ubitrack setups
Thank you.

- Any questions?