Ubiquitous Tracking for Augmented Reality

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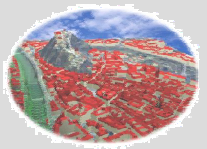
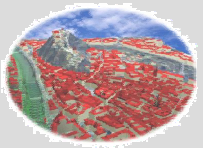


Overview

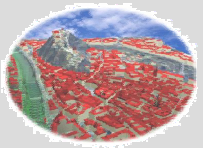
- Why we need Ubiquitous Tracking
- Formal model
- Implementation concepts
- DWARF-based implementation
- Simulation environment
- Conclusions & Future work



Why we need Ubiquitous Tracking

Bringing AR to intelligent environments:

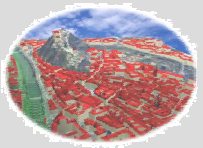
- AR applications extend their range of operation
  - Mobile AR
  - Powerful wearable devices
- Ubicomp applications extend their immersivity
  - “Natural” interaction benefits from accurate location information
- Combining tracking requirements from ubicomp *and* AR allows to use AR interaction in ubiquitous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



Why we need Ubiquitous Tracking

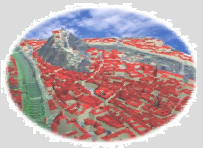
Enhancing AR tracking technology:

- 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



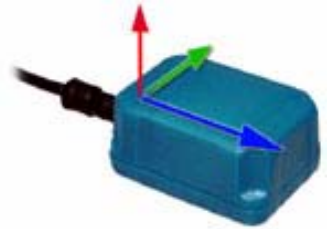
What is Ubiquitous Tracking?

- 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

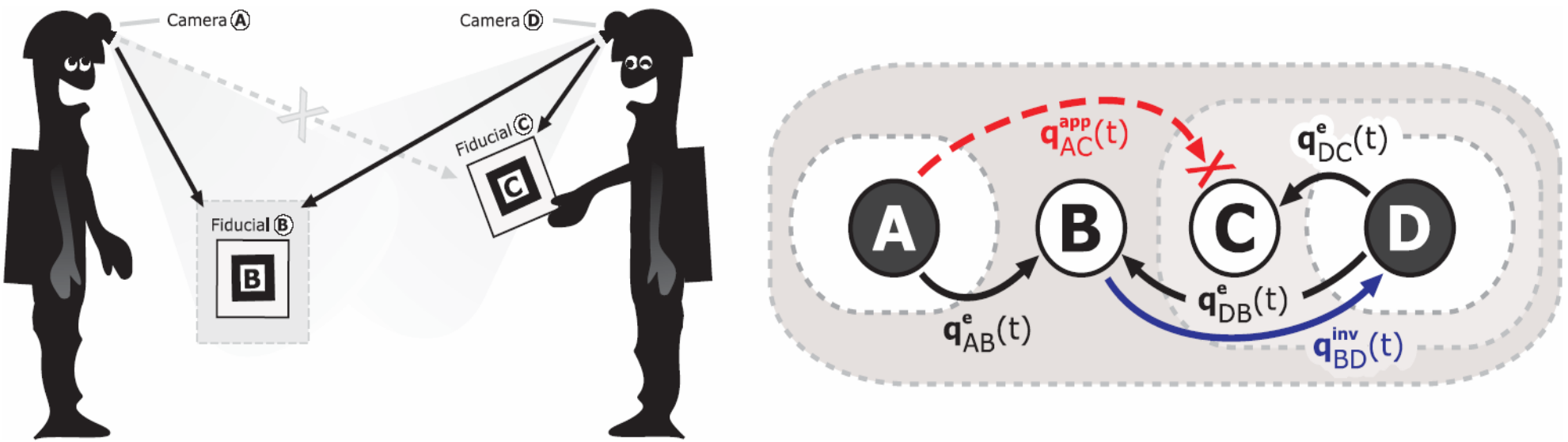


Definition of Terms

- 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



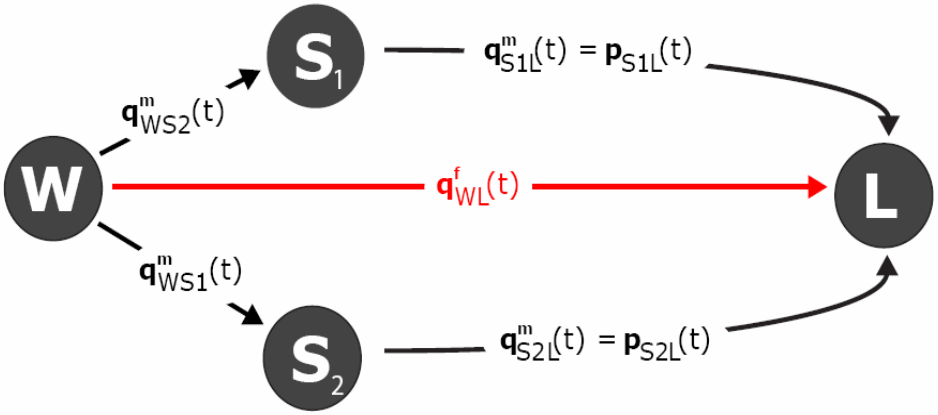
Formal Model



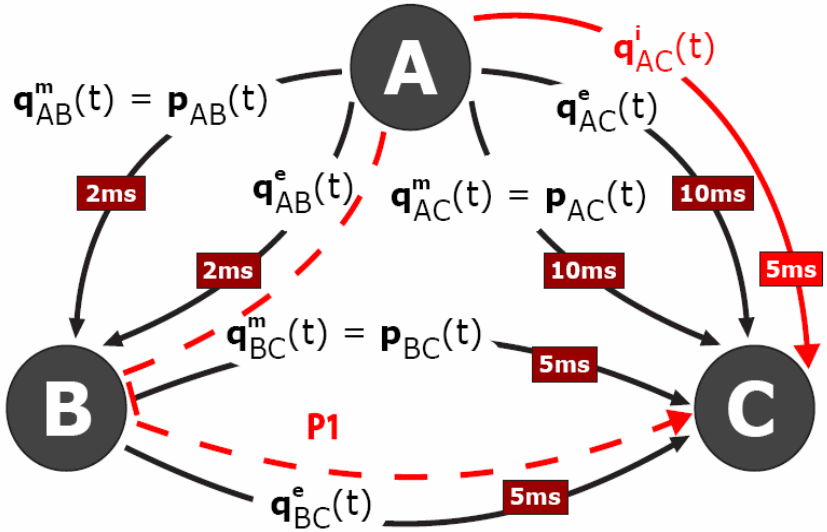
- Goal: uniform modelling of all spatial relationships
  - Handle estimates of diverse sensor classes
  - Handle inferences (i.e. filtering data, sensor fusion)
- Approach: directed ***spatial relationship graph***
  - Describe spatial relationships as functions of time
  - Functions yield estimates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

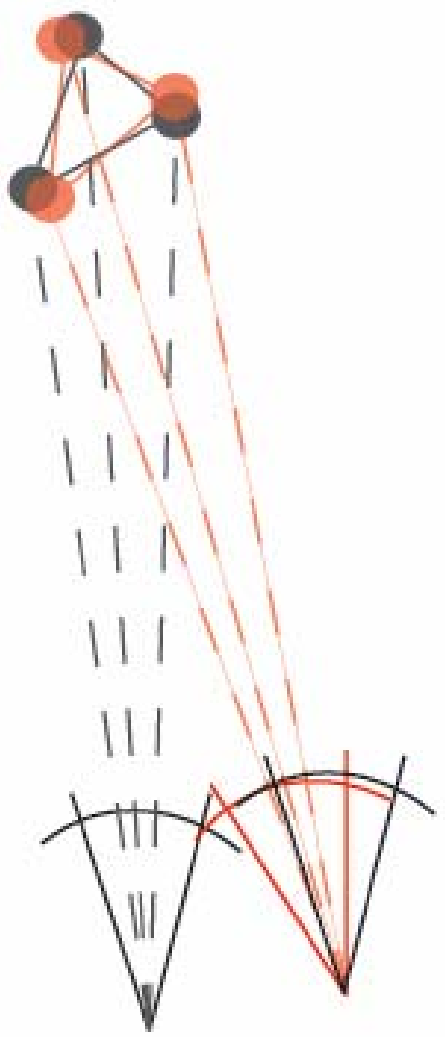


- Provide generic inferences by using transitivity property of spatial relationships
  - Search path in SR graph between relevant nodes



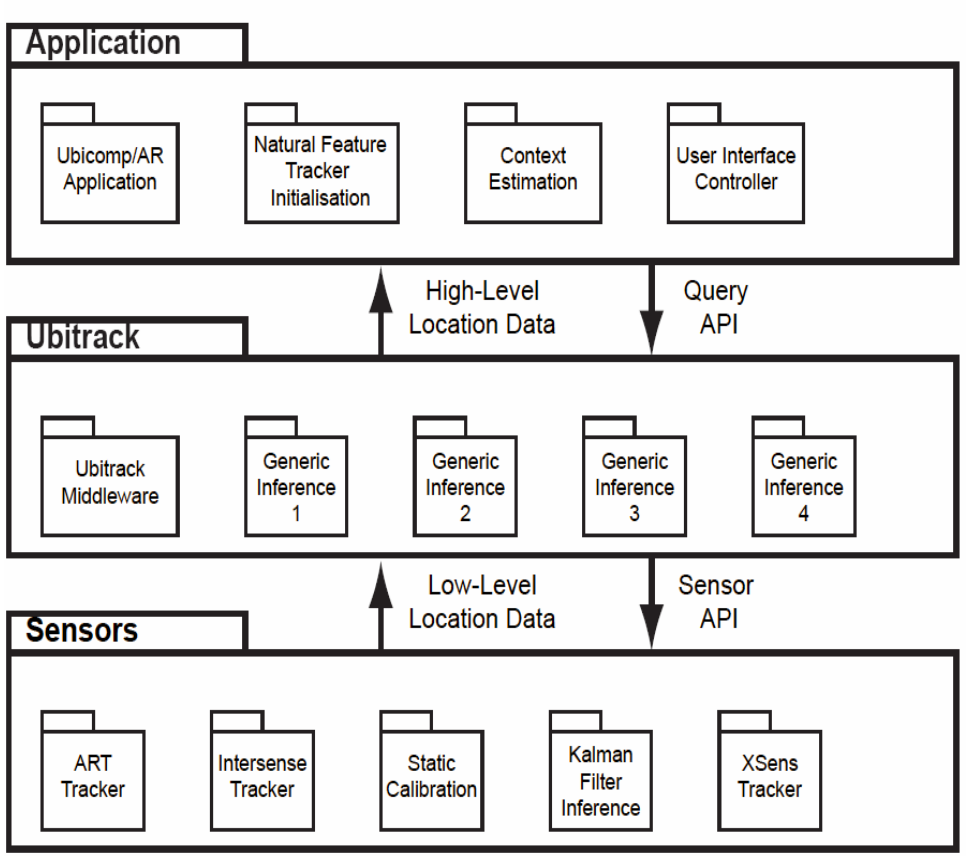
Formal Model: Challenges

- 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



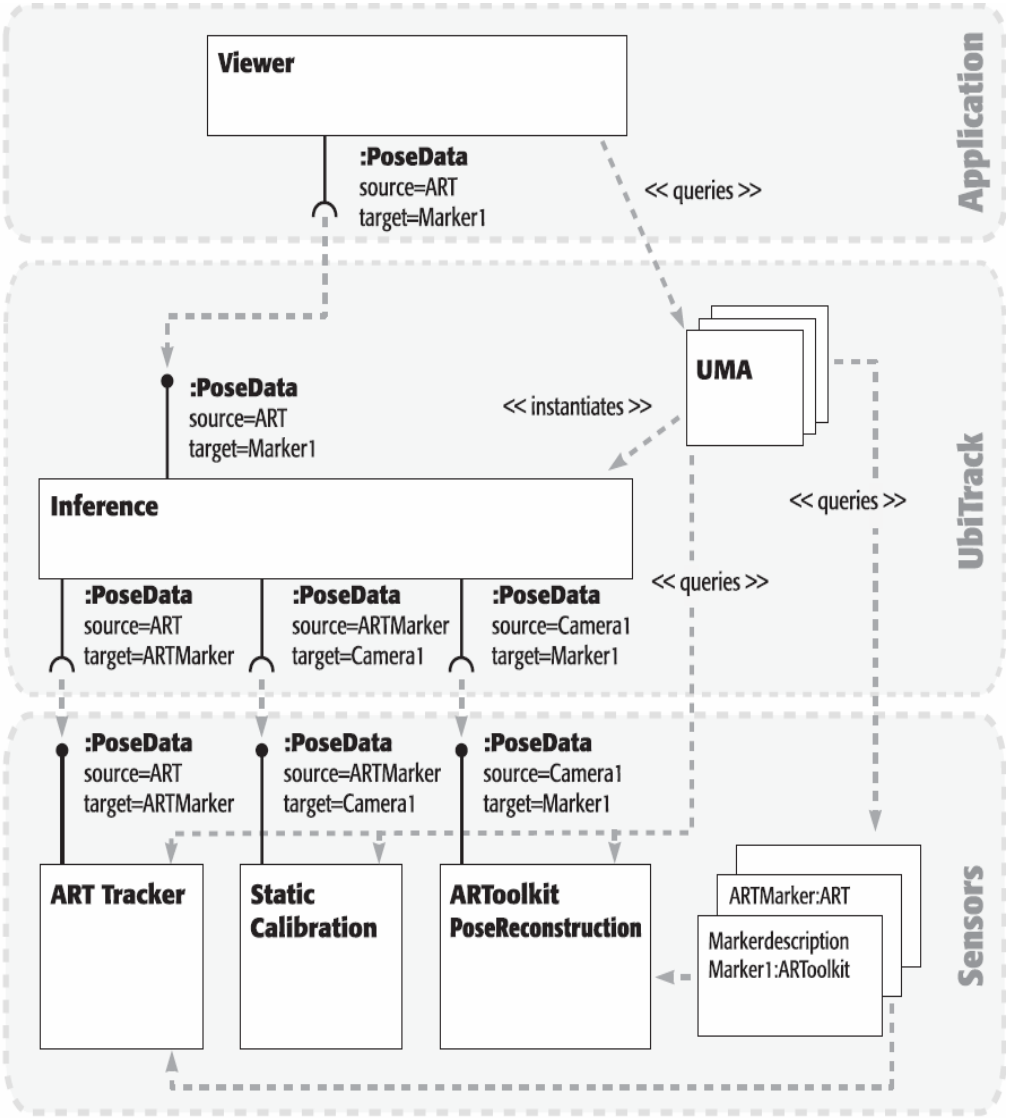
Implementation Concepts

- 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



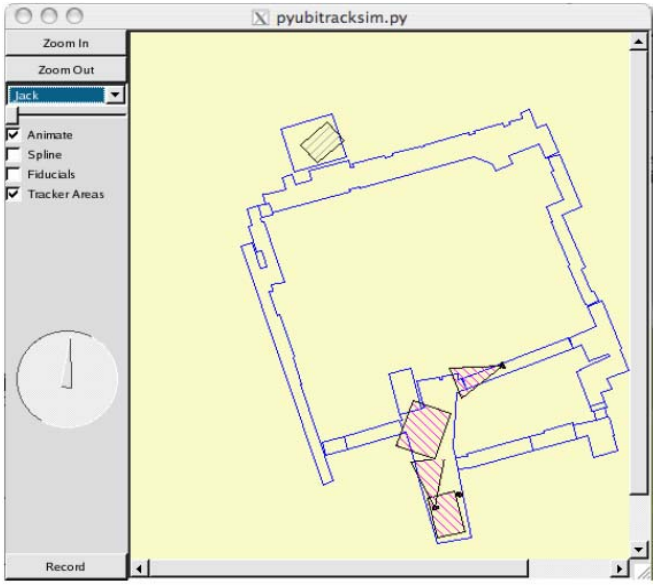
DWARF-Based Implementation

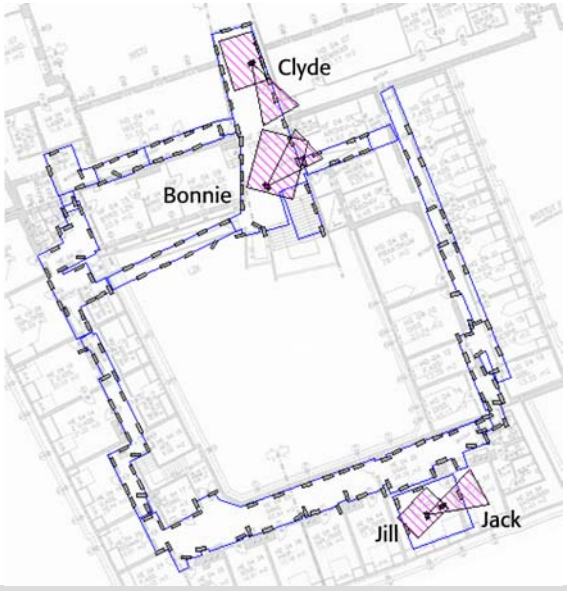
- DWARF is a distributed peer-to-peer middleware, modelling AR applications as set of distributed *services*
- Extension of DWARF middleware to allow generic Ubitrack inferences
- Resulting data flow consists of a set of services:
  - Sensor services encapsulate hardware devices
  - Inference services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



Simulation Environment

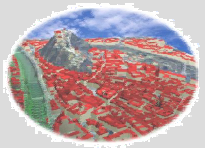
- Large-scale Ubitrack environments are not yet ready
  - Limited amount of sensors
- Ubitrack simulation environment allows to generate artificial multi-sensor tracking data
  - Test Ubitrack implementation by comparing results to simulation ground truth
- Generation of simulated images of scenes for feeding vision-based trackers





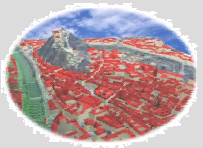
Conclusions

- 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?