MiddleWare for Sensor Systems – keeping things Open

Ken Moody

Computer Laboratory, University of Cambridge
Overview of the talk

the Opera group and what we do - past and present activities

why we're at this Workshop – TIME-EACM and CareGrid

fundamental problems of (sensor) data interpretation

volume of data, how and where to cope with it, audit and reliability

timeliness, feedback and stability – too hard for TIME-EACM

presenting relevant information as the context changes
**OPERA Group**

part of the *Systems Research Group* (SRG) in the Computer Laboratory

- *Jean Bacon, Ken Moody* (Faculty)
- *about 6 RAs, and 12 PhD students* at present

*MiddleWare* for wide-area application support

- *event-based systems* (CEA - Cambridge Event Architecture, 1995)
- *Role-Based Access Control* (service-based, parametrised roles)
- *scalable publish/subscribe system* (*HERMES*)
- *Trust-based systems* (*SECURE - EU Framework 5* grant)
- *public-sector* applications (*police, health, now transport*)
Why we're at this Workshop ...

Current research grants

**TIME-EACM** (EPSRC WINES program)

*Transport Information Monitoring Environment*

umbrella framework supported by Boeing

– *Event Architecture and Context Management*

5-group consortium, Cambridge and Birkbeck, + BT

Opera group (CL)  *generic event-architecture*

Digital Technology Group (CL)  *sensor deployment*

Richard Gibbens (CL)  *transport data analysis*

Bill Fitzgerald (CUED)  *audio-sensor interpretation*

Niki Trigoni (Birkbeck)  *sensor data management*

main thrust of **TIME-EACM** to realise sensor-data as information

**CareGrid** – aspects of Trust in health-care monitoring (with Imperial C)
ASIDE – *how I got into Database ...*

with Alan Macfarlane – starting in 1972 – 25-year project

*parish records of Earls Colne 1400-1750* – 13 million English words

mark-up language + editor for *syntax* and *simple semantic categories*

*intelligent algorithms* for data interpretation (i.e. medieval Latin readers)

realise marked text as a semantic network – store in a relational database

high-level query language via relational algebra – *original text available*

demographic model – *people* and relationships, property, court records

not actually *people* – just the *names of people* – *grounding problem*

raw data – *intelligent algorithms* – information base – *grounding*
Converting data to information in the context of a sensor network

thrust of **TIME-EACM** is to deploy traffic sensors incrementally

fixed infrastructure and wireless networks, including mobile sensors

information bases available to applications, including mobile clients

*intelligent algorithms* to convert *data* to *information*

statistical and information theoretic approaches

– *hidden Markov Models*, *e.g.* for speech recognition

– *Bayesian networks*, *e.g.* for classification

other approaches based on models at the information level

potential bulk of sensor data – where to carry out information fusion

requirement for event data archive – *audit* and *replay*
Relevant recent PhD dissertations

Middleware support for context-awareness in distributed sensor-driven systems

Eli Katsiri  (DTG - then LCE in CUED)  Computer Lab TR 620

Examples of the approaches mentioned already

- *hidden Markov Models*,  e.g.  for identifying movements
- *Bayesian networks*,  e.g.  for predicting the location of users

Separate approach based on  *Temporal First-Order Logic*

- *Horn clause productions*,  inferring high-level predicates  (*CLIPS*)
- *maintaining state-based high-level predicates*  (*SPASS*)

*SCAFOS*  –  application development for the  *active BAT*  environment

- *infers state-level predicates*  from  *sensor-level predicates*
PhD dissertation  (Runner-up in the BCS DD series)

Ontology based Visual Information Processing

Chris Town  (AI group in CL, with John Daugman of *iris* fame)

Frame and sequence analysis via specific components
- *low-level blob trackers*,  *e.g.*  for identifying movements
- *expert witnesses*,  *e.g.*  for identifying texture types (*skin, metal*)

Higher-level description via an Ontological Query Language  *OQUEL*
- classification of static images  (*e.g.*  photograph collections)
- scene and sequence analysis by tracking multiple blobs
- *performance enhancement by data fusion of video and BAT sensors*

Fusion experiments allow a combination of sensor sources to support the same high-level scene descriptions through  *OQUEL*
- the results are encouraging rather than overwhelming
Thought for the day

“You might want to say a little about how machine learning is used to tie together the different feature detectors and classifiers. The main value of using an ontology is twofold: as a human readable specification of a problem domain and as hierarchical prior that allows one to train a Bayesian Network or similar learning framework to integrate different sources of evidence (sensors, detectors, classifiers etc.).”

Chris Town
Integrating sensor networks

Event Communication and Composition

Application

aggregation, inference, storage, control

sensor clusters

Context models

Event Databases

device control
devices

event flow
control flow
Timeliness, feedback and stability

outside the scope of \textit{TIME-EACM} – \textit{walk before you try to run}?

Nyquist Theorem, need \textit{hard real-time} guarantees

intention is to support real-time sensor data feeds – \textit{latency} matters

\textit{distributed systems} require sophisticated handling of \textit{time}

\textit{control applications} need \textit{guarantees} and \textit{proofs} of stability properties

target applications are such \textit{soft real-time} tasks as route planning

future control support implies an \textit{event data archive} – \textit{audit} and \textit{replay}

\textit{Boeing} are particularly interested in support for \textit{control applications}
Supporting context-sensitive applications

clients above *TIME-EACM* may be mobile—*motion-sensitive needs*

clients may have limited bandwidth/energy—*resource-aware views*

whose responsibility is it to support context-sensitive views?

*important*—but outside the initial scope of *TIME-EACM*

—must be aware of requirements as the architecture evolves

target applications are such *soft real-time* tasks as route planning

—these will often be *context-aware*

—important to consider *use-case* higher-level applications