Decentralized Probabilistic World Modeling with Cooperative Sensing

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Arjan Peddemors
INCA Group
Telematica Instituut / Novay
Enschede, The Netherlands

Eiko Yoneki
Computer Laboratory
University of Cambridge
Cambridge, United Kingdom
Mobile Phone Penetration

- Nov. 2007 (according to Informa)
  - 3.3 billion subscriptions
  - 6.6 billion world population

Interesting Times in the Mobile Device Market...
Mobile Phones – Open Platforms – Software getting more important

iPhone App Store

Android Market
Mobile Phones –
More and more sensing capabilities

- Wireless (network) interfaces
  - Cellular
  - 802.11
  - Bluetooth
  - RFID / NFC
- Geographical location (GPS)
- Acceleration
- Temperature
- Light
- Audio
- Video
- Touch
Large scale sensing

- High number of mobile device owners (on world scale)
- Device close to its owner most of the time
- New powerful devices
- Take off of mobile internet
- Many sensors per device

Great opportunity to sense the world around us on a very large scale!
- Continuously
- Collectively
- Individually
What if…

• ...we store all information received from all the sensors on these personal mobile devices continuously?

• ...we use this data to build a probabilistic world model – individually and collectively – to capture static features (objects) and dynamic features (behavior) of our environment?
Then we can…

- Know at which location resources are available
  - E.g. where a person has access to WLAN networks while traveling
- Know where and when people are likely to meet
- Detect unusual situations
  - E.g. sense that a person is close to people he has not met before or only in another setting
  - E.g. sense that a road is blocked
- Predict upcoming events
- …
Bottom-up Modeling

• Finding frequent patterns in the stream of data coming from the sensors that perceive our surrounding
  – General, not application specific

• Predefined structure
  – Incorporating primitives like roads, buildings, people, cars, artifacts, etc
  – Building and maintaining such a structure is a very large endeavor
  – Hard to identify unanticipated relationships between occurrences

• Bottom-up structure does not have these disadvantages
Lots of data! Lots of processing!

- Example: CoSphere experiment (feb/march 2007)

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- Much more data expected from other types of sensors

CoSphere trial data: http://cosphere.telin.nl/trial/, retrieved on 2008-09-02
Example: prediction of future network visibility
(mobile device perspective)

- Forecasting visibility event based on already seen (other) visibility events
- These other events act as ‘predictors’
- Use the best predictor when multiple are available
Example: prediction of future network visibility (mobile device perspective)

- Does it help to take the visibility of other infrequently seen networks into account? YES
Example: prediction of future network visibility 
(mobile device perspective)

• Does it help to use information from one network 
  interface (one sensor) to predict events on another 
  network interface (another sensor)? YES, but…
  – The case for almost all participants
  – ‘Inter-tech’ prediction contributes more than ‘intra- 
    tech’ prediction

• What do we learn from this?
  – Use as much sensor data a possible
  – Sensor data fusion works
Probabilistic World Modeling
Example: compositional hierarchies

atoms can be combined without limit

each chunk corresponds to a specific pattern of atoms

structured part-of relationships

chunks

atoms

Figure taken from Karl Pfleger’s PhD defense presentation, http://www.ksl.stanford.edu/people/kpfleger/, retrieved on 2008-09-02
Probabilistic World Modeling
Example: compositional hierarchies
Probabilistic World Modeling
Example: compositional hierarchies
Collective Effort

- By sharing the models built on individual nodes (mobile devices), we may
  - Increase the overall model accuracy
  - Use the observations of others in environments unknown to individual nodes

- We propose to take a decentralized P2P approach
  - No centralized role that may interfere with privacy
  - Exchange of model data with those that are most relevant
  - Opportunistic data exchange, when nodes (peers) are near, using short range wireless networks
Discussion (many open issues)

- Semantic ‘gap’: how can we bridge the gap between the probabilistic model and application logic
- Difference in sensor quality and calibration may interfere with collective model building
- Difference in hierarchy building between individual nodes may make model data exchange difficult
- Uncertain whether a generic model is capable of supporting a wide range of applications
Discussion (many open issues)

- Temporal patterns evolve at widely varying rates
- Computing resources
- Opportunistic spread of model data
- Privacy
Summary

- Personal mobile device
  - Exciting platform to do large scale sensing and modeling of the world around us

- Probabilistic world modeling
  - Open and promising field of research
  - Bottom-up, no need for predefined structure
  - Helping to find collective and individual patterns of behavior

- Opportunistic data exchange
  - P2P based

- This is a truly multidisciplinary effort!