Location Based Services
Stop Searching, Let Information Find You

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This presentation describes joint work with

- Alan Walendowski
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- Michael Roberts
- Bob Price
- Kurt Partridge
- Tracy King
- Ellen Isaacs

- Ji Fang
- Nicolas Ducheneaut
- Maurice Chu
- Ed H. Chi
- Mark Newman
- Victoria Bellotti
- and others …
8-12 Nov 2008, San Diego, Hilton Resort

• A world class city with great climate
• Exciting plenary speakers
• Conference banquet at Sea World
• Demonstrations reception
• Social and networking opportunities

The program needs you!

Papers, Notes: April 18, 2008
Panels Proposals: May 2, 2008
Workshop Proposals: May 2, 2008
Doctoral Colloquium: July 18, 2008
Posters, Demos, Videos: July 18, 2008
About PARC

  - *Xerox corporate research laboratory*
  - *Inventions*: Ethernet, Graphical User Interfaces, Laser Printer, Ubiquitous Computing

- **PARC (2002-present)**
  - *Subsidiary of Xerox Corporation*
  - *Open business model*: funding from Xerox, government grants, patent and technology licensing, and client-sponsored research
  - *170 researchers*: computer scientists, psychologists, ethnographers, sociologists, linguists, electrical engineers, materials scientists and physicists
Ubiquitous Computing is no longer a dream …

Bridging Physical and Virtual Environments

Computation pervades the environment, furniture, clothing, phones, …

1978

1990s

Today and beyond
... but an all too ubiquitous problem.
“Seams” Disrupt User’s Goals

■ Controls are not ready-to-hand
  – Applications have to be launched
  – Variety of interfaces must be learned
  – Controllers are not always with you (laptops, remotes, handhelds, etc.)

■ Technical boundaries must be managed
  – Multiple formats, protocols, networks, VPN, etc.
  – Multiple accounts, service subscriptions, etc.
  – Multiple physical locations of data, versions, etc.

■ Information overload requires manual searching, filtering, managing versions, etc.
Controlling Information Environments
not managing devices and networks

Behavior modeling

Lightweight & Implicit User Interaction

Seamless Interaction

Device & Data Infrastructures
**Obje™ Interoperability**  
*Infrastructure to enable seamless interoperation*

- Consumers: “Why can’t they all just get along?”
- Obje data source “teaches” how to play data
  - Reduces time to market of new functionality (e.g., media codecs, media types, evolving DRM mechanisms, etc.)
  - Reduces consumer barrier to new purchases (increased value from network effects)

Without Obje, new formats cannot be used by old devices
Objen™ Interoperability
Infrastructure to enable seamless interoperation

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**Obje™ Interoperability**
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New Obje-enabled High Definition Player

Old Obje-enabled Digital Display

New HD Format Video

New HiDef codec

Sensed Context

New Security

New Services...

...
Location, location, location

- Local theaters
- Traffic
- Broadcast stations
- Tourist attractions
- Directions
- Geo-cached media
- Restrooms
- Bars
- Reminders
- Asset tracking

- Find Friends and Family
- Weather
- Stores
- Restaurants
- Rendezvous with others
- Historic landmarks
- Pick-up sports games
- Events
- Recommendations from others
Outline

- Intro
- Location Sensing Technologies
  - Overview
  - GPS
- Location Based Services
  - Asset Tracking
  - Distributed group awareness
- Location Based Media Services
  - Photos
  - Advertising
  - Guide books
  - PARC’s Magitti
- **Books**

  - Kolodziej & Hjelm, 2006
  - Kuepper, 2005

- **Conferences & Workshops**

  - **Location Technologies**: LoCA (Location and Context Awareness), PLANS (Position, Location And Navigation),
  - **Geographic Information Systems**: GIS, GIR, O’Reilly Where 2.0
  - **Applications & Systems**: Pervasive, Ubicomp, CHI (Human Factors in Computing Systems)
  - **Mobile Technologies & Applications**: HotMobile (nee WMCSA), MobiSys, WoWMoM
Location Sensing Technologies

- Chris Heathcote: 35 ways to find your location

- dGPS: 2m-5m
- WAAS: 2m-25m
- AGPS: 10m-50m
- GPS: 10m-75m
- WAAS: 2m-25m
- TV: ~50m
- IP Address: 2km+
- Cell tower: 50m-2km
- Cell TDOA: 30m-50m
- UWB, Ultrasound <20cm

- Beacons (Bluetooth, RFID, Ultrasound, IR): ~1-50m
- Computer Vision: <1m

- Wifi: 5-20m
- Indoor/outdoor
- Outdoor only
Global Positioning System

- **GPS** is owned and operated by the US government.
- Constellation of 24 orbiting satellites (~26,560 km altitude).
- First Block 1 developmental satellite launched 1978.
- Position determined by **multilateration**.
  - Distances estimated from time difference of arrival and position of at least 4 satellites (usually 6 or more).
- GPS provides 24-hour, all-weather navigation and timing capability to terrestrial, airborne and spaceborne users.
- Funded purely through US federal taxes—signals available “free of charge”.
- European version called Galileo is currently in deployment.

**Public value:**
- Recreation
- Aviation
- Defense
- Electric utilities
- Internet timing
- LBS
- Surveying
- Agriculture
- Financial
- Precise Timing
- Scientific Research

Curtis Hay, 2005
GPS Accuracy: ~10-30m

**Satellite factors**
- Broadcast ephemeris (estimated satellite position and velocity)
- Clock errors
- Constellation geometry
- Anomalies and maintenance
- Selective Availability (disabled)

**Atmospheric factors**
- Ionosphere effects
- Troposphere (weather)
- Video

**Ground factors**
- Sky visibility
- User motion
- User environment (urban, heavy foliage, etc.)
- Signal reflections (multipath)
- Interference (unintentional or otherwise)
- Receiver design
  (noise figure, sensitivity, software bugs, design limitations, etc.)
GPS Urban Canyons

The number of GPS satellites available in central London (red = less than 4, yellow = 4 to 10, green = more than 10)

(source: Transport for London)
GPS Adoption in Mobile Phones

- Sprint & Verizon: 80% of phones GPS-enabled [Kolodziej & Hjelm 2006]
- **e911** – enhanced 911 for wireless
  - Required accuracy:
  - 300m accuracy for 95% of calls
  - 100m for 67%

- Many handsets have better accuracy
  - AGPS: 10-50m accuracy
  - Location is calculated by network service providers – uses up-to-the-minute atmospheric data

- **Smart mobile device shipments hit 118 million in 2007, up 53% on 2006**
  - Symbian leads with 65% share, ahead of Microsoft on 12%, RIM on 11%, Apple on 7%, and Linux at 5%
Indoor Location

- **ActiveBat**
  - Ultrasonic mechanism
  - Accurate up to 3cm
  - 1.2m spaced receivers
  - Much research dedicated to power management, dealing with ultrasonic reflections
  - http://www.cl.cam.ac.uk/research/dtg/attarchive/bat/

- **Ubisense**
  - Startup formed by ActiveBat researchers
  - Uses UWB instead of ultrasonic
    » Less accurate, but no clicking
From Position to Place

- Convert GPS coordinates …
  - 37.4062983333333, -122.1472033333333,

- To “Place”
  - “Work”, “School”, “Home”, …

- [Ashbrook and Starner, 2003]
  - System clusters, user assigns labels to clusters

- Indoor Places
  [Aipperspach 2006]

- Predestination
  [Krumm, 2006]
Developer Pointers

- Wifi: SkyHook, Navizon
  - Use a database of known wi-fi/cell radio transmitters to derive your location
- Multi-source: Yahoo FireEagle, SkyHook Loki
- OS-level APIs
  - NMEA 0183 serial protocol
  - Microsoft's "GPS Intermediate Driver"
    » wraps classes around the NMEA protocol and adds events
  - JSR 179 Location API for J2ME
  - Symbian Location Acquisition API
Location-Based Services
Asset Tracking

- Money
- Automobiles
- Aircraft
- Shipments
- People (emergency, hospital staff, parolees, ...)

- WCA Location-Based Services SIG

Locating And Managing Assets
March 25th 2008, 4:00pm - 6:00pm, at PARC

c.f. “Spime”

Source: The North River Consulting Group
Friend Awareness: Awarenex

- Awareness
  - Finding a good time to make contact
  - Non-disruptive approach and leave-taking mechanisms

- Integrated communication
  - Making contact easy

- Ubiquity
  - Multiple clients
  - Shows location

Awareness nexus

[Tang et al. 2001]
LOOPTLOOPT
Location Awareness through the ages

# isthere <userid>
# campon <userid>
# talk <userid>

UNIX, ‘80s

Montage, ‘94

Peepholes, ‘96

ICQ, ‘96

AIM, ‘97

Intellisync, ‘05

Awarenex, ‘01

Hubbub, ‘02

Intellisync, ‘05

loopt, ‘07

More to come…
Beyond Context Awareness: Behavior Modeling Anticipates Needs

- Applications that proactively assist the user or influence actions
  E.g., route calls, adjust environment, retrieve relevant info, suggest specific exercise, influence user behavior, etc.
- Targeting information to what is on the user’s mind

**User Goals, Intentions and Desires**
- Preference Model
  - Taste, interests
- Behavior Model
  - Past actions
- Context Model
  - Environment, situation
- Personal Info
  - Calendar, email

**Applications**
- Information Retrieval
- Advertising
- Community Monitoring
- Spatial/Time patterns
- Time Tracking
- Power Savings
- Support of Science
- Group Default Behavior
- Group coordination
- Better usability
- Health monitoring
Rhythm model detects recurring events that are not in person’s calendar

start and end of day, lunch, availability during meetings, commutes, ...

Descriptive and predictive model using expectation maximization from observed events.

[Begole et al. CSCW 2002, UIST 2003]
Example with Location Transition

Starts work from home very early Monday mornings, then commutes to office.
Location-Based Media Services
GeoCoding Photos

- Location embedded in image EXIF data
Yahoo! ZoneTag

Take a picture — Instant upload to Flickr with location tags

Now for Nokia N73, N95 and other S60 3rd edition phones!
Social GeoTagging

- **STAMPS**: System for TAgging Messages, Post-Inferential Semantics

- **Socialight**
  - Leave messages, media clips in specific locations
  - Favorite restaurants, stores, etc.
  - Update facebook, other social net apps
  - Users can create “channels” and author a series of location-based media posts
Photosynth
AudioAura

- [Mynatt, et al. 1998]
- Audio version of ambient display, localized to a particular place
  - E.g., stop by an office and receive a personalized audio cue about how recently the inhabitant was there

Figure 2: The Audio Aura System
Location-based Advertising
Shopping Assistants

- Asthana, et al. 1994
- Ubisense Demo

MediaCart, to be in stores in 2008
Museum Guides

*sotto voce*, parc, 2001

Shared audio within a group
Magitti: Stop searching – let information find you

- Replace tedious mobile searching with personalized recommendations

- Information and suggestions based on
  - Current Situation
  - Past behavior
  - Personal preferences

- Information targeted on Leisure Activities
  - Eat, Shop, See, Do, Read

Service engagement with Dai Nippon Printing Co, Ltd
[Bellotti, Begole, et al. CHI 2008]
Conceptual Architectural Context:

Time, Location, etc.

Restaurants, stores, events, etc.

Preferences: Sushi, Bookstores, etc.

Mobile Device

Feedback (selections, ratings, visits)

Consumer

Local Area

Model Preferences

Infer Activity

Filter and Rank Database Items

Recommendation Server
Personal Preferences
- Explicit preferences
- Rating of items inspected
- Analysis of content read
- Behavior; where/when/what

What you like

Filtering and Ranking

Context
- Time
- Location
- Email analysis
- Calendar analysis

What you are doing now

History
- Prior population patterns
- User Queries
- User Locations

Activity | Venue         | Utility |
---------|---------------|---------|
EAT      | Straits Cafe  | 0.77    |
EAT      | Fuki Sushi    | 0.64    |
EAT      | Evvia         | 0.60    |
EAT      | Tamarine      | 0.57    |
DO       | Sam’s Salsa   | 0.39    |
EAT      | Bistro Elan   | 0.38    |
BUY      | Apple Store   | 0.33    |
EAT      | Spalti       |         |
Demonstration

- Demo setup
  - Not emulated; software is running on the mobile device
  - Database and server running on laptop

- PARC prototype
  - Palo Alto content database of local restaurants, shops, parks, and other events and venues
Recommendable Items
Restaurant Reviews
Store Descriptions
Parks Descriptions
Movie Listings
Museum Events
Magazine Articles...

Personal Preferences
- Explicit preferences
- Rating of items inspected
- Analysis of content read
- Behavior; where/when/what

Context
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What you like

Filtering and Ranking

Activity
Venue
Utility

<table>
<thead>
<tr>
<th>Activity</th>
<th>Venue</th>
<th>Utility</th>
</tr>
</thead>
<tbody>
<tr>
<td>EAT</td>
<td>Straits Cafe</td>
<td>0.77</td>
</tr>
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<td>Fuki Sushi</td>
<td>0.64</td>
</tr>
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<td>0.60</td>
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<td>Spalti</td>
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What you are doing now

Eat
Buy
See
Do
Read

Context

Personal Preferences

Activity
Venue
Utility

Filtering and Ranking

History

Context

Activity
Venue
Utility

Filtering and Ranking

Personal Preferences

Activity
Venue
Utility

Filtering and Ranking

History

Activity
Venue
Utility
Predicting Activities from Population Priors

When there is no user-specific data, prior population data is used

Mobile-phone Diaries

Code each respondent’s activities over 7-day week

<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Day of Week</th>
<th>Time of Day</th>
<th>Activity Type</th>
<th>Start Time</th>
<th>End Time</th>
<th>Start Day</th>
<th>End Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>TA05</td>
<td>Mon-Thu</td>
<td>11:00</td>
<td>Group Activity</td>
<td>11:00</td>
<td>11:30</td>
<td>Monday</td>
<td>Thursday</td>
</tr>
<tr>
<td>TA06</td>
<td>Mon-Thu</td>
<td>12:00</td>
<td>Personal Care</td>
<td>12:00</td>
<td>13:00</td>
<td>Monday</td>
<td>Thursday</td>
</tr>
<tr>
<td>TA07</td>
<td>Mon-Thu</td>
<td>13:00</td>
<td>Personal Care</td>
<td>13:00</td>
<td>14:00</td>
<td>Monday</td>
<td>Thursday</td>
</tr>
<tr>
<td>TA08</td>
<td>Mon-Thu</td>
<td>14:00</td>
<td>Personal Care</td>
<td>14:00</td>
<td>15:00</td>
<td>Monday</td>
<td>Thursday</td>
</tr>
<tr>
<td>TA09</td>
<td>Mon-Thu</td>
<td>15:00</td>
<td>Personal Care</td>
<td>15:00</td>
<td>16:00</td>
<td>Monday</td>
<td>Thursday</td>
</tr>
<tr>
<td>TA10</td>
<td>Mon-Thu</td>
<td>16:00</td>
<td>Personal Care</td>
<td>16:00</td>
<td>17:00</td>
<td>Monday</td>
<td>Thursday</td>
</tr>
<tr>
<td>TA11</td>
<td>Mon-Thu</td>
<td>17:00</td>
<td>Personal Care</td>
<td>17:00</td>
<td>18:00</td>
<td>Monday</td>
<td>Thursday</td>
</tr>
<tr>
<td>TA12</td>
<td>Mon-Thu</td>
<td>18:00</td>
<td>Personal Care</td>
<td>18:00</td>
<td>19:00</td>
<td>Monday</td>
<td>Thursday</td>
</tr>
<tr>
<td>TA13</td>
<td>Mon-Thu</td>
<td>19:00</td>
<td>Personal Care</td>
<td>19:00</td>
<td>20:00</td>
<td>Monday</td>
<td>Thursday</td>
</tr>
<tr>
<td>TA14</td>
<td>Mon-Thu</td>
<td>20:00</td>
<td>Personal Care</td>
<td>20:00</td>
<td>21:00</td>
<td>Monday</td>
<td>Thursday</td>
</tr>
<tr>
<td>TA15</td>
<td>Mon-Thu</td>
<td>21:00</td>
<td>Personal Care</td>
<td>21:00</td>
<td>22:00</td>
<td>Monday</td>
<td>Thursday</td>
</tr>
<tr>
<td>TA16</td>
<td>Mon-Thu</td>
<td>22:00</td>
<td>Personal Care</td>
<td>22:00</td>
<td>23:00</td>
<td>Monday</td>
<td>Thursday</td>
</tr>
<tr>
<td>TA17</td>
<td>Mon-Thu</td>
<td>00:00</td>
<td>Personal Care</td>
<td>00:00</td>
<td>01:00</td>
<td>Monday</td>
<td>Thursday</td>
</tr>
<tr>
<td>TA18</td>
<td>Mon-Thu</td>
<td>01:00</td>
<td>Personal Care</td>
<td>01:00</td>
<td>02:00</td>
<td>Monday</td>
<td>Thursday</td>
</tr>
</tbody>
</table>

Aggregate all data

Hourly activity report:
- Who
- What
- Where
- When
- Info used & desired
- Photo

Predict...

... probability of each activity type
Predicting Activities from Email/SMS

- How well do messages suggest activity?
  - We examined a public set of 10,000 SMS messages from National University of Singapore students, similar to the Magitti target demographic
  - Approximately 11% of the messages contain information related to leisure activities

  tomorrow what **time** you be in school? think me and shuhui meeting in school **around 4**. then duno still can **see movie** or not because duno if a rest want **meet for dinner**.

- Keywords and linguistic structures are identified and sent to the activity inference mechanism

  ACTCAT=MOVIE, EAT :: ACTTIME=2007/05/26 16:00 :: UNCERTAINTY=10 minutes :: TENSE=FUTURE
Predicting Activities from Learned User Patterns

Venue

Likelihood: 50% 50%

12:00 to 1:00

1:00 to 1:00

Hector’s Cafe

Astrid’s Grocery

Dave’s Donuts

Context History

<table>
<thead>
<tr>
<th>Time</th>
<th>Location</th>
<th>Visit</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:57-12:45</td>
<td>37°26′39″ -122°9′38″</td>
<td></td>
</tr>
<tr>
<td>1:22-1:31</td>
<td>37°23′11″ -122°9′02″</td>
<td></td>
</tr>
</tbody>
</table>

Weekly Behavior Patterns

<table>
<thead>
<tr>
<th></th>
<th>Monday</th>
<th>Tuesday</th>
</tr>
</thead>
<tbody>
<tr>
<td>…</td>
<td>…</td>
<td>…</td>
</tr>
<tr>
<td>12:00 to 1:00</td>
<td>$</td>
<td>$</td>
</tr>
<tr>
<td>Grocery Cafe</td>
<td>…</td>
<td>Grocery Cafe</td>
</tr>
<tr>
<td>1:00 to …</td>
<td>…</td>
<td>…</td>
</tr>
</tbody>
</table>
Location, location, location

- LBS is growing as location technologies become more prevalent
- Early days with multimedia in LBS
- Location data enables Behavior modeling for new capabilities
  - Content recommendation
  - Automatic Media Programming
- Come to WCA LBS SIG:
  - Tuesday, January 22nd 2008, 4:00pm - 6:00pm