
# Adaptive Computing

## Research Portfolio

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# Vision

The Adaptive Computing group works on ubiquitous computing, user modeling and interaction with a view of making the life of ordinary people easier through easy-to-use digital services.

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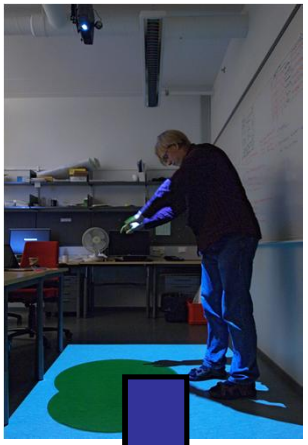
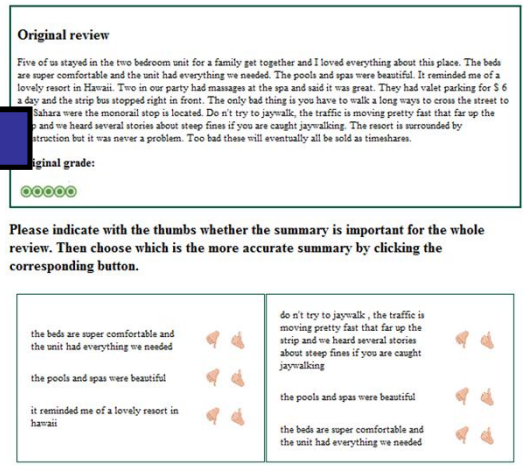
Real-World Interaction



Mobile User Modeling


Services

Intelligent IR




Mobile Localization

Mobile Sensing

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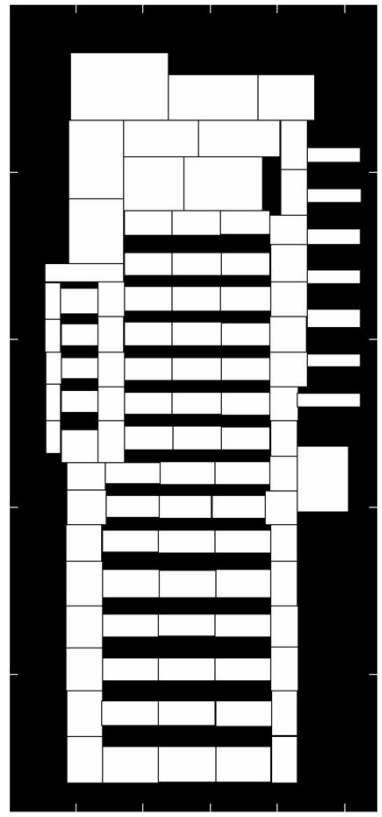
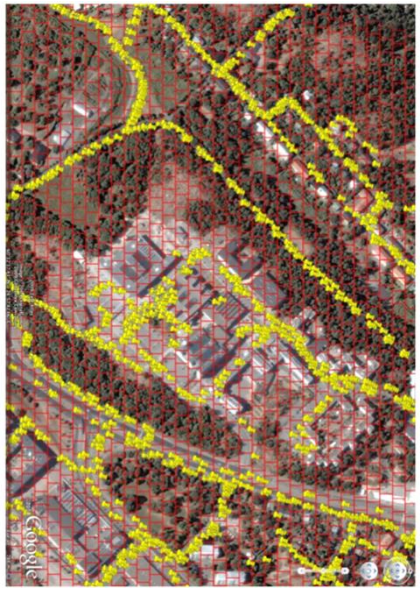
# Mobile Localization

- Goal: enable ubiquitous (i.e., everywhere and at all times) positioning directly on mobile devices
- Focus areas:
  1. On-Device Positioning: Enable creating and updating radio maps directly on a mobile device.
  2. Facilitating Deployment: Reducing the effort needed for calibration, facilitating WLAN access point deployment, etc.
  3. Ubiquitous Positioning: Enable seamless switching of positioning models between different environments.

# Localization Algorithms

- Probabilistic Hyperbolic Localization
  - Probabilistic modeling of signal strength differences between pairs of access points for positioning
  - KLD adapted particle filter used for tracking
  - Installed within two large-scale supermarkets
- On-device GSM localization
  - World represented using a grid, signal variations within grid cells modeled using Gaussian distributions
  - Accuracy: Median < 150m, 95% < 450m
  - Radio maps can be created and updated on a mobile device, multiple clients can share maps



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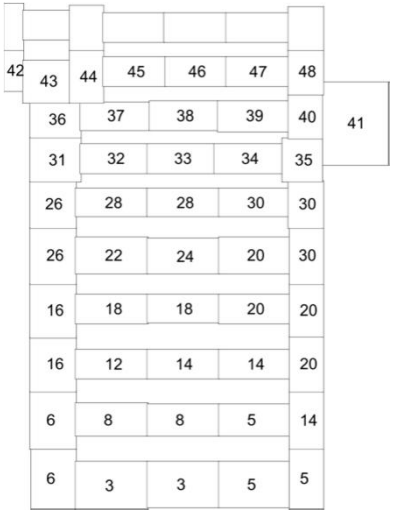
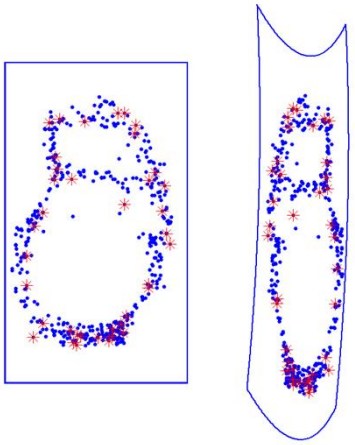
# Facilitating Deployment

- AWESOM: Automatic partitioning of spaces
  - Divide a geographic area (indoors or outdoors) into clusters/cells that are spatially co-located and have similar signal characteristics
  - Can also be used to suggest locations for adding new access points




- Signal Interpolation for Calibration
  - Construct a non-linear mapping of WLAN signals using ISOMAP and use measurements from selected anchor points to control the shape of the mapping
  - Can recover the structure of the environment and the resulting mapping can be used to predict signal values at locations with no measurements



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# Selected Publications


- P. Nurmi, S. Bhattacharya, J. Kukkonen: "*A grid-based algorithm for on-device GSM positioning*." Proc. 12th ACM International Conference on Ubiquitous Computing (Ubicomp, Copenhagen, Denmark, September 2010). ACM Press, 2010, 227-236.
- T. Pulkkinen, P. Nurmi, "AWESOM: Automatic Discrete Partitioning of Indoor Spaces for WiFi Fingerprinting", Proc. 10th International Conference on Pervasive Computing (Pervasive 2012, June 2012, Newcastle, UK).
- T. Pulkkinen, T. Roos, P. Myllymäki, "Semi-supervised learning for WLAN positioning", Proc. International Conference on Artifical Neural Networks (ICANN, June 2011).

# Mobile Sensing

- Goal: collect rich and personally meaningful sensor data from mobile devices in a non-obtrusive way
- Focus areas:
  1. Context Inference: Infer high-level context information from sensor data, preferably on-device.
  2. Energy-Efficiency: Ensure that meaningful sensor data can be collected and communicated in a way that does not drain the battery of the client rapidly.

# Context Inference

- Semantically meaningful locations
  - Analyze location traces to determine areas where the user regularly spends time
  - DPCluster: algorithm that models places using infinite Gaussian mixture models
  - Evaluation with 12 datasets: accuracy 74%, recall 68% (f-score 0.71)
- Co-Presence Detection (ongoing)
  - Use mobile phones to detect when people are interacting together.
  - Based on similarity of WiFi signal environments between different devices. Works robustly regardless of sensor variations
  - Focus on structured indoor environments, such as campuses and offices


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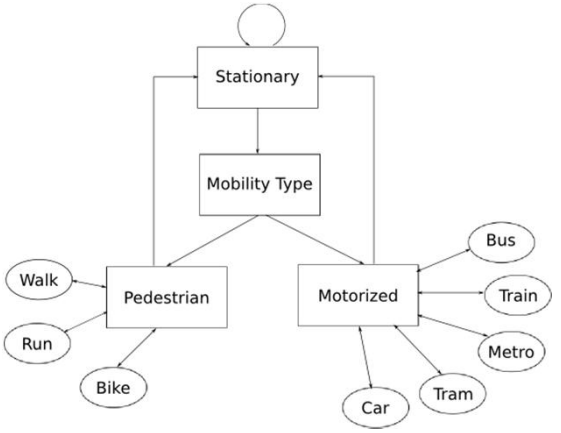
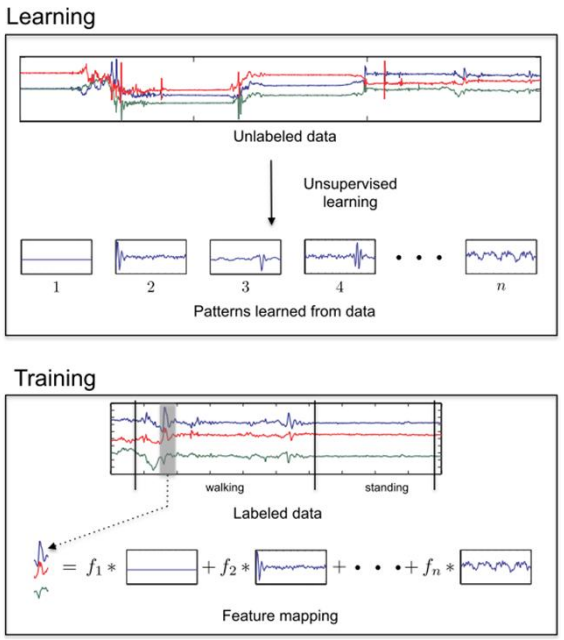
# Activity Recognition

- Transportation mode detection (ongoing)
  - Focus on detection of transportation modes using different modalities (GPS, GSM, acc.)
  - Application areas: movement models for positioning, tools for supporting green transportation behavior etc.
- Feature Learning (ongoing)
  - Activity recognition using automatically learned basis vectors instead of feature engineering
  - Reduces effort needed to construct activity classifiers and enables to automatically analyze (class) structure in data

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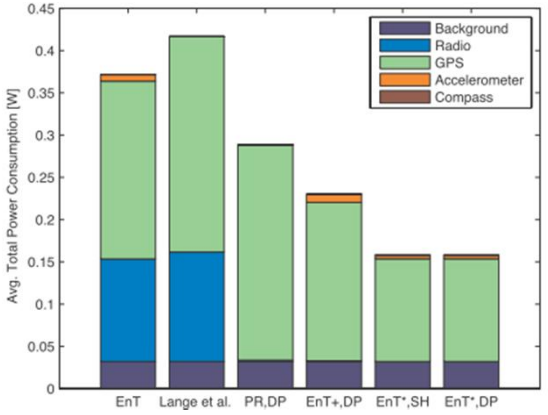
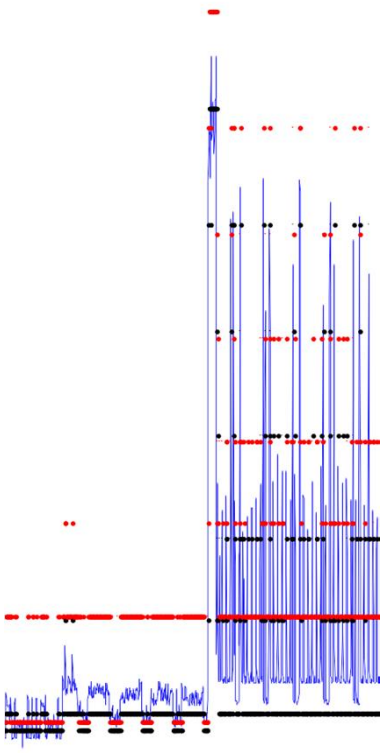
# Energy-efficiency

- On-device Position and Trajectory tracking
  - Position updates determined considering movement (acc.), heading (compass) and position changes (GPS)
  - Trajectory simplification used to determine when to update position information
  - Trade-off between power consumption and tracking accuracy
- Empirical Energy Modeling (ongoing)
  - Probabilistic modeling of energy consumption of individual sensors and sensor combinations
  - Enables deriving a mean estimate of power consumption, as well as determining a confidence interval for estimates



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# Selected Publications


- J. Kukkonen, E. Lagerspetz, P. Nurmi and M. Andersson: “BeTelGeuse: A Platform for Gathering and Processing Situational Data.” IEEE Pervasive Computing 8 (2009), 49–56
- P. Nurmi and S. Bhattacharya: “*Identifying meaningful places – the nonparametric way.*” Proc. 6th International Conference on Pervasive Computing (Pervasive 2008, Sydney, May 2008). LNCS 5013. Springer-Verlag, Berlin, 2008, 111–127.
- M. B. Kjaergaard, S. Bhattacharya, H. Blunck, P. Nurmi, "*Energy-efficient Trajectory Tracking for Mobile Devices*", Proc. 9th International Conference on Mobile Systems, Applications and Services (MobiSys, June-July 2011).
- P. Nurmi and J. Koolwaaij: “*Identifying meaningful locations*.” Proc. 3rd Annual International Conference on Mobile and Ubiquitous Systems: Networks and Services (Mobiquitous, San Jose, July 2006), IEEE Computer Society, 2006.


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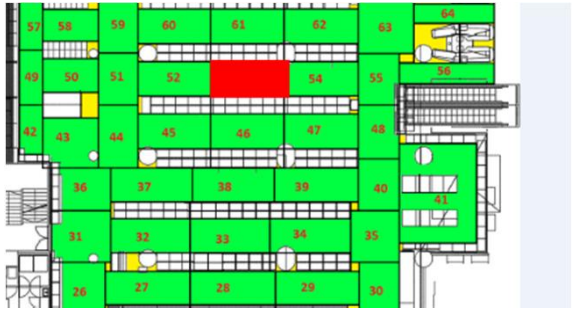
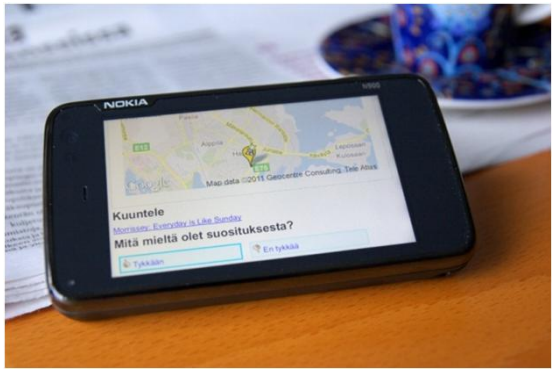
# Mobile User Modeling

- Goal: Enabling mobile applications to provide access to more relevant information by modeling the interests, needs and goals of the user
  1. Recommender systems: provide users of mobile devices with access to relevant or otherwise interesting (e.g., serendipity) information
  2. User profiling: analyze sensor and interaction data to obtain fine-grained information about the user's needs and interests

# Recommender Systems

- Natural Language Recommendations
  - Personalized special offers: identify relevant special offers based on the contents of a customer's shopping list
  - Product recommendations: recommend useful and interesting products based on shopping list entries
- Location-based recommendations
  - User study evaluating effects of location-awareness and personalization on advertising effectiveness
  - Location-based media recommendations in an urban culture festival

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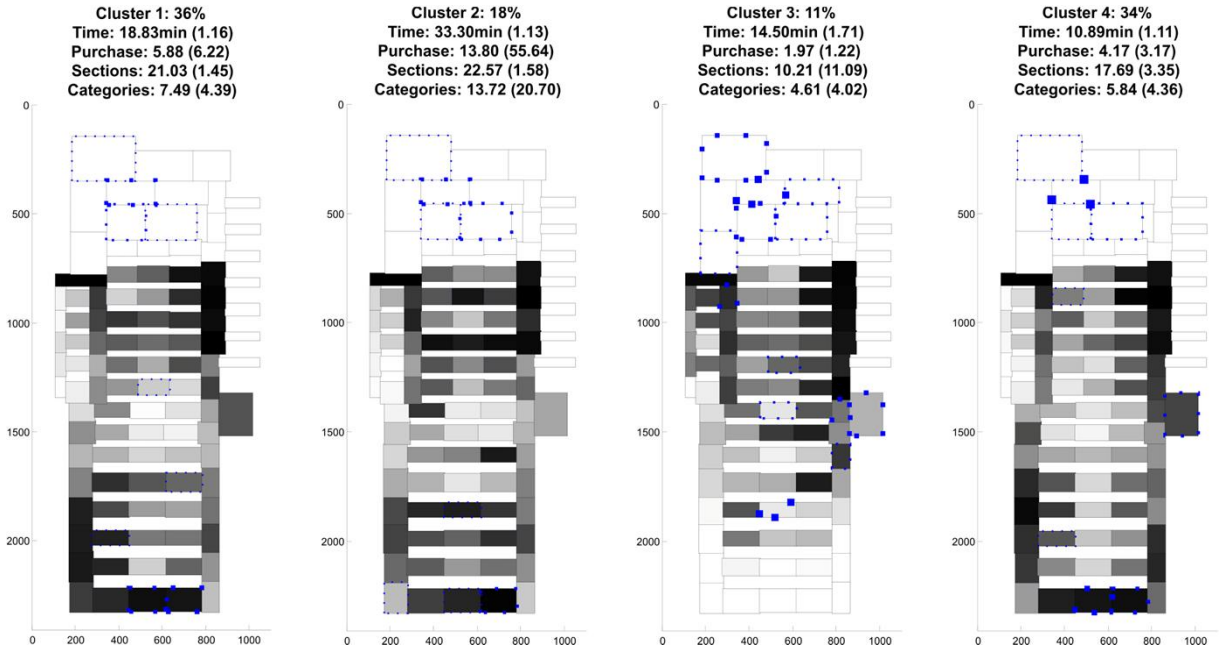
# User Profiling

- Path study: detecting shopping styles (ongoing)
  - 102 shopping routes + receipts from a large-scale supermarket
  - Temporal and spatial information correlate strongly with purchase behavior ➔ potential for classifying users into shopping styles
  - Cluster analysis indicated 4-5 clearly distinct shopping styles / behaviors, currently looking into online prediction of s. style

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# Selected Publications

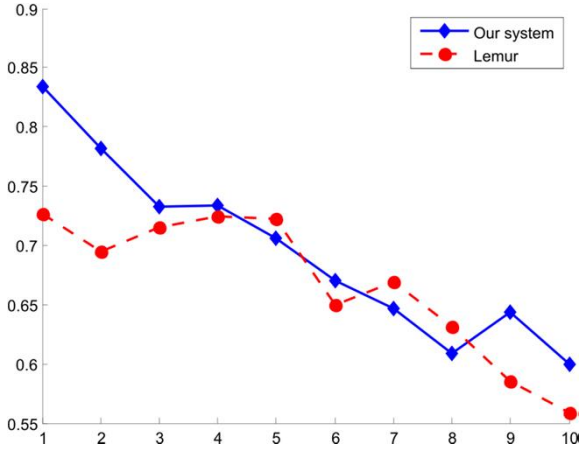

- **P. Nurmi**, **A. Forsblom** and **P. Floréen**: "*Grocery Product Recommendations from Natural Language Inputs*." Proc. 1st and 17th International Conference on User Modeling, Adaptation and Personalization (UMAP 2009 , Trento, Italy, June 2009), LNCS 5535, Springer-Verlag, Berlin, 2009, 235-246.
- **A. Forsblom, P. Nurmi**, P. Åman, L. Liikkanen, "Out of the Bubble – Serendipitous Event Recommendations at an Urban Culture Festival," Proc. 2012 Conference on Intelligent User Interfaces (IUI'12, Lisbon, Portugal, February 2012=
- L. Du, W. Buntine, **P. Nurmi**: "*Bayesian networks on Dirichlet distributed vectors*". Proc. 5th European Workshop on Probabilistic Graphical Models (PGM, Helsinki, Finland, September 2010), 2010, 33-40.
- **F. Boström**, **P. Nurmi**, **P. Floréen**, **T. Liu**, **T.-K. Oikarinen**, A. Vetek and P. Boda: "*Capricorn - an intelligent user interface for mobile widgets*." Proc. 10th International Conference on Human Computer Interaction with Mobile Devices and Services (MobileHCI'08, Amsterdam, the Netherlands, September 2008), 327-330.

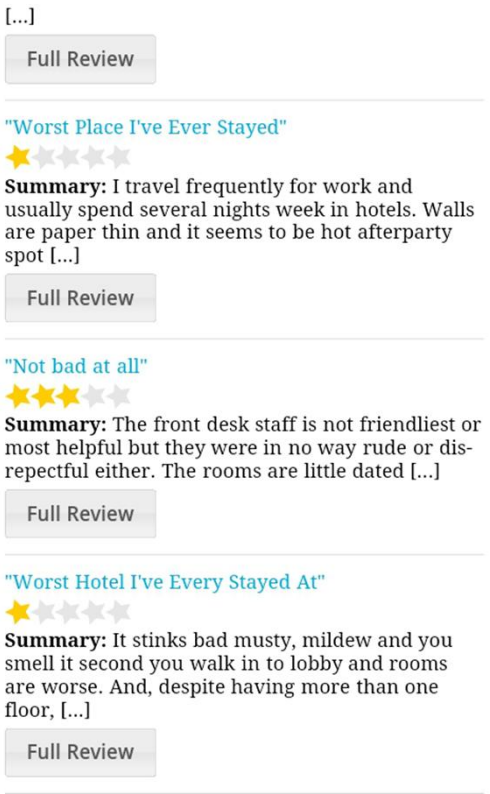
# Intelligent IR

- Goal: enable mobile interactions from limited verbal input and provide means for more effective browsing of information on mobile devices.
  1. Mobile search: enable people to find relevant information more easily, current focus on specific application domains, particularly retailing.
  2. Decision support systems: facilitate decision making on mobile devices by providing means for making better informed devices faster.

# Intelligent IR

- Grocery product search
  - Grocery retrieval engine that maps items on the user's shopping list to products
  - Ranking combines textual match with product popularity
  - Product hierarchy used to assist search
  - 85% accuracy at rank 1
- Sentiment summarization (ongoing)
  - Facilitate browsing of customer reviews on mobile devices by extracting the most meaningful sentence from a review
  - Combines a feature selection metric with sentiment summarization techniques

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# Selected Publications


- **T. Vähäkangas, J. Pyykkö**: “VisciPad: Peeking Into a Collaborative Creative Writing Project in Elementary Schools,” Proc. 10th International Conference on Creating, Connecting and Collaborating through Computing (C5-12, University of Southern California, CA, January, 2012).
- **P. Nurmi**: “*Perseus – a personalized reputation system.*” Proc. IEEE/WIC/ACM International Conference on Web Intelligence (WI, Fremont, California, November 2007), 798-804.
- **P. Nurmi, E. Lagerspetz,** W. Buntine, **P. Floréen, J. Kukkonen**: “*Product Retrieval for Grocery Stores.”*, Proc. 31st ACM Conference of the Special Interest Group on Information Retrieval (SIGIR, Singapore, July, 2008), ACM, 2008.
- **P. Nurmi**, **E. Lagerspetz**, W. Buntine, **P. Floréen**, **J. Kukkonen** and P. Peltonen: “*Natural language retrieval of grocery products.*” Proc. ACM 17th Conference on Information and Knowledge Management (CIKM, Napa Valley, California, October 2008), 1413-1414.


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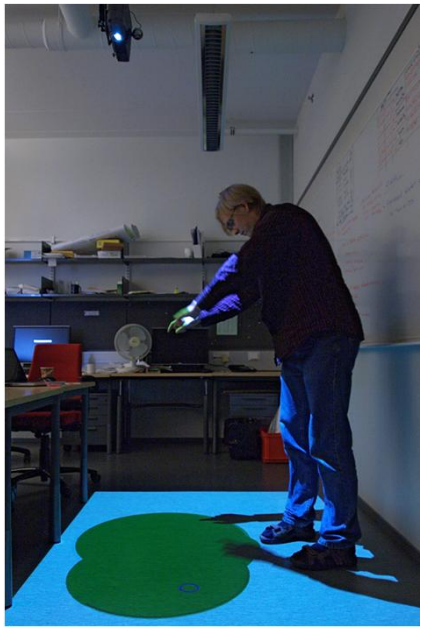
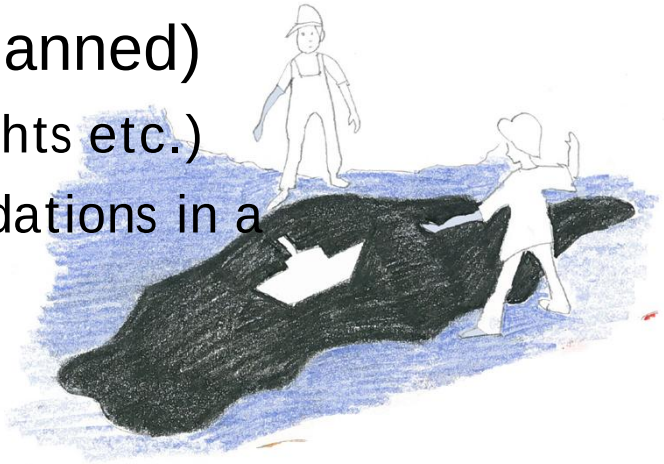
# Interaction Techniques

- Intelligent interaction techniques for supporting ambient and mobile interaction
  1. Ambient interfaces: display persuasive feedback, support learning, provide new means for interacting with recommendations
  2. Mobile interaction: focus on specific application areas, currently retailing and navigation systems

# Ambient Interfaces

- UbiLight: projector based interaction technique (ongoing)
  - Image projected to the floor, camera and projector mounted on the ceiling
  - Interaction based on gesture tracking (camera or Kinect)
  - Focus on educative content, evaluate whether the interface can enhance learning
  - E.g., prevent oil spill from reaching the shore
- Ambient persuasive interfaces (planned)
  - Peripheral displays for the home (lights etc.)
  - Interfaces for visualizing recommendations in a store environment





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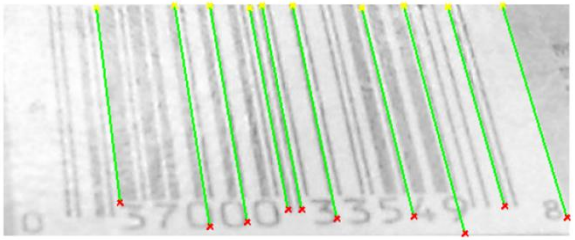
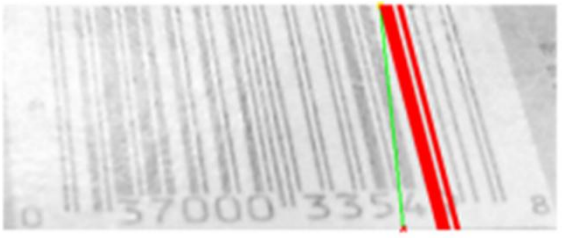
# Mobile Interaction: Vision-Based Interfaces

- Camera-based AR
  - Markerless tracking of the camera pose
  - Recognize the shelf that the camera is pointing at
  - Based on SIFT + bag of keypoints algorithm
  - Currently 40% accuracy (baseline 8%)

- Mobile barcode detection (ongoing)
  - Use computer vision techniques to recreate barcodes from mobile camera pictures
  - Contrary to scan-lined based techniques, insensitive to partial reflections that block the camera view and to curved surfaces





# Mobile Interaction: Navigation Systems

- Influence of landmarks on user attention
  - Can we influence what people register from their environment by selection of landmarks?
  - User study comparing two instruction types with different visual demands
  - Increased visual demand decreases efficiency, but does not improve environmental recall


- Auditory interaction (ongoing)
  - Voice personality and gender influence people's attributions of computer generated speech
  - User study investigating whether type of voice influences navigation performance
  - Matching gender + personality a safe bet, but voice quality matters even more

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# Selected Publications


- **P. Nurmi**, A. Salovaara, **S. Bhattacharya**, **T. Pulkkinen**, G. Kahl: "*Influence of landmark-based navigation instructions on user attention in indoor smart spaces*". Proc. 2011 Conference on Intelligent User Interfaces (IUI, Palo Alto, CA, February, 2011)
- **S. Bhattacharya**, **T. Pulkkinen**, **P. Nurmi**, A. Salovaara, "*MONSTRE: A Mobile Navigation System for Retail Environments*", Proc. International Workshop on Smart Mobile Applications (SmartApps, June 2011).
- **P. Nurmi**, **A. Forsblom**, **P. Floréen**, P. Peltonen, P. Saarikko: "*Predictive Text Input in a Mobile Shopping Assistant: Methods and Interface Design*." Proc. 13th International Conference on Intelligent User Interfaces (IUI, Sanibel Island, Florida, February 2009), 435–438.
- **J. Uitto**: "*Vision Based Indoor Positioning in a Retail Environment*", M.Sc. Thesis, Department of Computer Science, January 2011.


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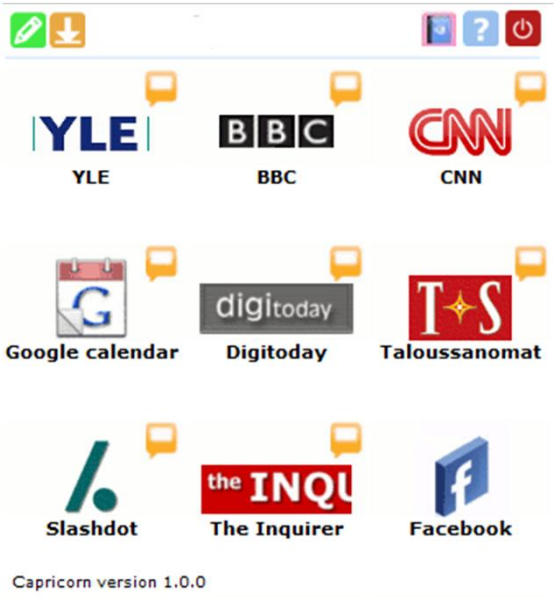
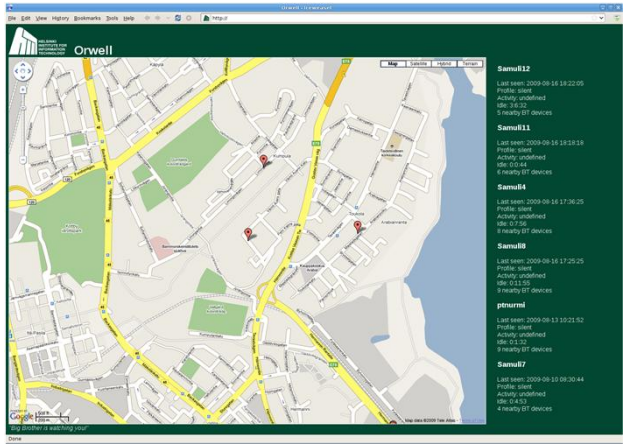
# Selected Other Work

## BeTelGeuse

## Capricorn




## Orwell

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# Contact Information

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Publications: www.hiit.fi/adapc/publications

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