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A Picture of Present Ubicomp Research Exploring Publications from Important Events in the Field

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Abstract. In this work we use a dataset of papers published in top conferences focused on ubiquitous computing (ubicomp) to provide an overview and analysis of recent ubiquitous computing research performed internationally and in Brazil. The contributions of this study are twofold. First, we extracted useful information from our dataset such as representativeness of authors and institutions, and the formation of communities. Second, we analyzed all papers published between 2010 and 2011 in all top international conferences, creating a taxonomy of recent ubicomp research performed internationally. After that we mapped SBCUP papers (Brazilian ubicomp conference) according to this taxonomy, which enables the comparison of international and national research. This study is useful to guide novices in the field and it also provides experienced researchers with facts enabling the discussion of ubicomp research.

Key words: Ubiquitous computing, scientific network, collaboration network, Pervasive, Percom, Ubicomp, SBCUP, taxonomy, characterization.

Introduction

The future world envisioned by Mark Weiser considers a computing environment in which each person is continually interacting with many wireless interconnected devices (Weiser, 1993). A fundamental aspect of this world will be ubiquitous computing (ubicomp or pervasive computing), as named by Weiser.

As a good research area, ubicomp gave us more questions than answers (Weiser *et al.*, 1999), and many of them are still open (Caceres and Friday, 2012). There are many researchers around the world working on different aspects of those ubicomp challenges, including Brazilians. Today there are three notable international conferences[1] (TOPint group) devoted primarily to the area: Ubicomp[2] (the oldest one, now in its 14th edition), Pervasive[3], and Percom[4]. The Brazilian event dedicated to this field is SBCUP[5], which is in its 4th edition.

The ubicomp community, not only in Brazil, is in its infancy. In this case it is natural to have many newcomers to this community. With that in mind, this paper provides an overview of recent ubicomp research conducted abroad and in Brazil.

The contributions of this work are twofold. First, we collected information about all papers published in Ubicomp, Pervasive and Percom, and performed a data mining process, extracting statistics such as most productive authors and institutions. We also analyzed the collaboration among authors identifying, for instance, the formation of communities. Second, we analyzed all papers published in 2010 and 2011 in the TOPint group, creating a taxonomy of recent ubicomp research. We used this taxonomy

[1] Based on the conference ranking maintained by Microsoft: http://academic.research.microsoft.com
[2] International Conference on Ubiquitous Computing.
[3] International Conference on Pervasive Computing.
[4] International Conference on Pervasive Computing and Communications.
[5] Simpósio Brasileiro de Computação Ubíqua e Pervasiva.

to discuss the research being performed in Brazil by analyzing SBCUP papers and, thus, to compare recent research results.

The rest of this work is organized as follows. Section "Related Work" describes the related work. Section "Ubicomp in Numbers" presents statistics about authors, papers and institutions related to papers published in the aforementioned conferences. Section "Representativeness of Authors and Institutions" discusses the representativeness of authors and institutions. Section "Collaboration Network" analyzes the author's collaboration network. Section "Recent Ubicomp Research" presents the taxonomy of recent research on ubicomp performed abroad and in Brazil. Finally, Section "Conclusions" concludes the paper.

Related Work

Related to the first part of our work, i.e., statistics and analysis, we can cite the following studies. In Maia *et al*. (2012) the authors collected some data from all papers published between 1983 and 2012 in the SBRC[6]. With that dataset, they built an author's collaboration network, which was analyzed using complex network metrics. The studies of Procópio *et al.* (2011) and Freire and Figueiredo (2011) also built and analyzed a collaboration network. The first one considers authors from SBBD[7]. Besides applying complex network metrics, they also presented some statistics about SBBD. The second one considers two collaboration networks: global (composed of all authors who published in a paper listed in DBLP) and Brazilian (subset of the previous network, composed only of authors from Brazil). Besides the characterization of basic information on those networks, they created a metric, called ranking, which was used to measure the importance of individuals, as well as groups. Kaye (2009) presented statistical aspects of CHI and its sister conferences.

Bazzan and Argenta (2011) studied the main features of the social network created by the Program Committee members of conferences sponsored by the Brazilian Computing Society. The relationships between nodes of this network were established according to co-authorship data extracted from the DBLP Computer Science Bibliography database. The authors show that social network does not fit any well-established pattern when compared to other networks discussed in the literature. Nascimento *et al*. (2003) analyzed the SIGMOD co-authorship graph, finding, for instance, that the SIGMOD community is a small world network.

Regarding the second part of our work (taxonomy of recent research), the closest study, to the best of our knowledge, is the work performed by Satyanarayanan (2001). That paper introduces a taxonomy and the way research problems in pervasive computing relate to those in mobile computing and distributed systems. Our taxonomy differs from Satyanarayanan (2001) because its concern is to present research that has been published recently in top events. As discussed in Section "Recent Ubicomp Research", many problems discussed in Satyanarayanan (2001) are being studied today, such as energy and location aware systems.

Ubicomp in Numbers

This section presents the dataset used throughout this work and several statistics for the conferences considered.

Dataset

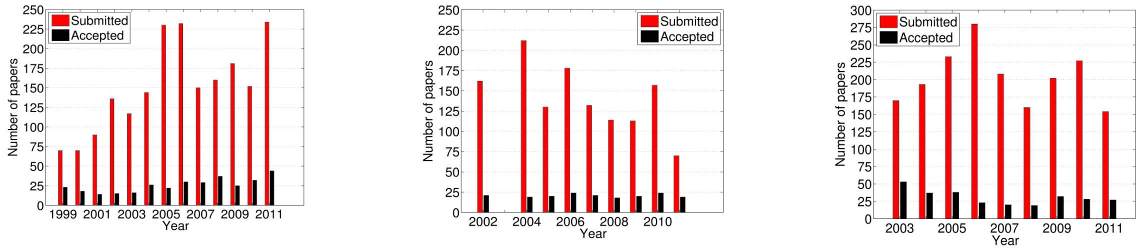
We collected all articles published in all editions of Ubicomp, Pervasive, Percom (group called TOPint), and SBCUP, from the first edition until the edition held in 2011 (main track only for all events, not including, for example, demos). For each paper we collected: title, year of publication, authors, and their respective institutions and location.

We are not considering the SBCUP dataset in all statistics and analysis because sometimes it does not make much sense due to its small size.

Analysis of Publications

Organized by Karlsruhe University in Germany, the first edition of Ubicomp, called International Symposium on Handheld and Ubiquitous Computing (HUC), occurred in 1999. In 2001, the word 'Handheld' was omitted and the symposium began to be called Ubicomp. In 2011, the event was in its thirteenth

[6] Brazilian Symposium on Computer Networks and Distributed Systems.
[7] Brazilian Symposium on Databases.



(a) Papers per year – Ubicomp (b) Papers per year – Pervasive (c) Papers per year – Percom

Figure 1. Papers per year in TOPint conferences.

edition. It is organized in full papers sections and notes, workshops, posters, panels, live demonstrations, video presentations, doctoral colloquia, and tutorials. Considering the submission and acceptance of full papers at the Ubicomp conference, the average acceptance rate is approximately 19%, as shown in Figure 1a. The Pervasive conference has a similar scope of Ubicomp and the first edition occurred in Switzerland in 2002. The acceptance rate of full papers is about 16%, as shown in Figure 1b. Both conferences have similar standards and criteria for acceptance.

The Percom conference presents advances in the field of pervasive computing and communications. The first edition was held in the USA in 2003. Considering full papers in the Percom conference, the average acceptance rate is of approximately 16%, as shown in Figure 1c.

Authors have published 397 papers in 13 editions of Ubicomp, 308 papers in nine editions of Percom, and 203 papers in nine editions of Pervasive. This amounts to a total of 908 papers and 2,239 unique authors. In SBCUP we have 41 papers and 103 authors (77% in just one edition).

Percom, Pervasive and Ubicomp publish by year an average of 34 (standard deviation σ=9), 22 (σ =3) and 30 (σ=8.78) papers, respectively, while SBCUP publishes 14 papers on average. Figure 2a shows the evolution of published papers in the TOPint group. Percom decreased from 54 to 27 papers in the last year. On the other hand, Ubicomp increased from 23 in 1999 to 50 papers in 2011. Pervasive keeps stable in almost all editions – the maximum was 27 papers in 2008.

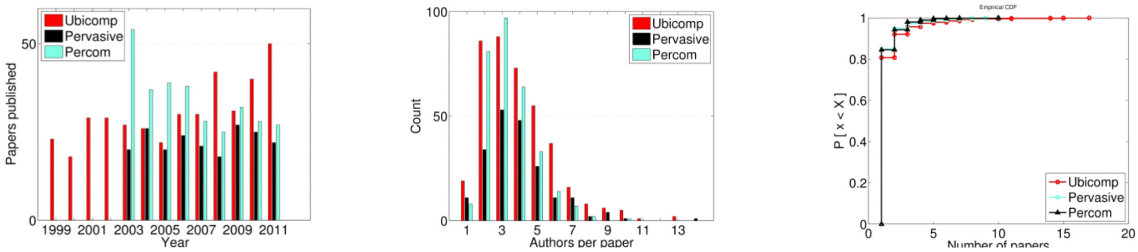
Figure 2b shows that almost 50% of the papers published were written by two or three authors (439 out of 908 papers). The number of authors has decreased over the years. In fact, after 2006, there was no paper published by a single author in TOPint. Ubicomp holds the record of number of authors per paper: two articles with 13 authors.

The CDF of the number of papers per authors in TOPint is presented in Figure 2c. Around 80% of the authors published only one paper in all conferences, 98% of authors published at most five papers, 0.013% published between six and ten papers and 0.007% published more than 10 papers. The top three authors in the TOPint group are Gregory D. Abowd, Anind K. Dey and Shwetak Patel.

Considering all papers from the TOPint group, most of the publications come from the USA (20%), and in the second to the fifth positions we have, respectively, the UK (5.4%), Germany (3.6%), Japan (2.3%), and Switzerland (2.3%). Brazil is the only country from Latin America, with just one paper. A curious fact is that the only Brazilian author (first author of a paper published in 2011 at Ubicomp) does not have ubiquitous computing as his main research area.

Analysis of Authors

The TOPint group has a total of 2,548 authors distributed as follows: 1,103 in Ubicomp, 613 in Pervasive, and 832 in Percom. However, some authors have published in more than one conference, and, thus, we have a total of 2,239 different authors. In that universe, 1,954 authors published only in one of the three conferences, 256 authors in two conferences, and 26 in all of them. Figure 3 shows the intersection between authors and conferences. Each circle represents a conference (with its authors), and the graph also shows the intersections between them. We see a major interest in Pervasive and Ubicomp, with 169 authors in common. We believe this occurs because Percom is a broader conference in computer networks, while Pervasive and Ubicomp focus on ubiquitous computing.



(a) Publications per year. (b) Authors per paper. (c) Publications per author.

Figure 2. Percom, Pervasive and Ubicomp in numbers.

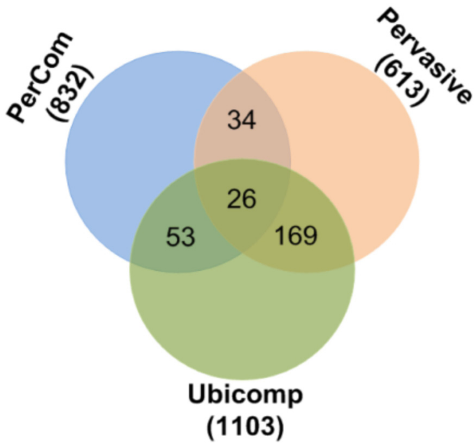


Figure 3. Intersection of authors in the TOPint group.

The authors Anind K. Dey, Gregory D. Abowd and Shwetak Patel published at least one paper in nine editions of Ubicomp. Another interesting fact is that Shwetak Patel published in nine consecutive editions of Ubicomp. Gregory D. Abowd has the largest number of publications in Pervasive (seven), all consecutive, followed by Gaetano Borriello, Gerhard Troster, and Shwetak Patel (each one with six publications). In Percom, Lionel Ni has the largest number of publications (seven). It is interesting to note that Lionel Ni has no involvement in Ubicomp or Pervasive, and the top publishers of these conferences did not publish in Percom (except for Gerhard Troster with one paper in 2010). Among the top publishers, Abowd and Patel have twelve joint publications, and Abowd and Dey have two joint publications.

Figure 4a presents the number of authors by their streak length of publications per year. Most authors published a maximum of two years in a row. This is in accordance with the information observed in Figure 2c (most authors publish just one paper). Figure 4b considers the longest period of absence of publications by a given author, i.e., the maximum period between two publications. Most of the returning authors have a two-year maximum of absence.

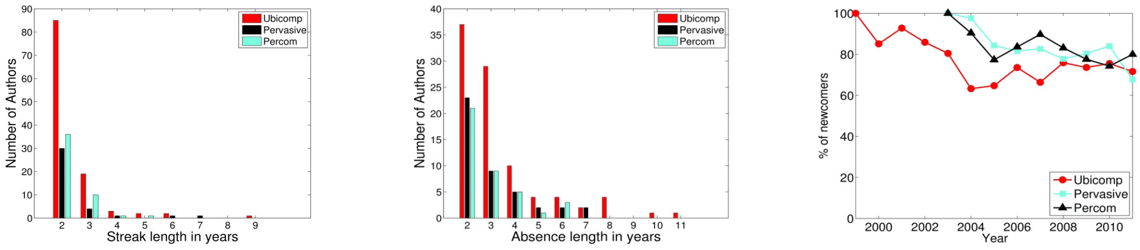
Figure 4c shows the fraction of newcomers per year. Obviously, in the first edition of a conference the percentage of newcomers is 100%. It is interesting to see in Figure 4c that in every edition of the TOPint group there are, at least, 63% of newcomers.

This indicates that the number of returning authors is small, as we could observe previously in Sections “Analysis of Publications” and “Analysis of Authors”. There are different conjectures for this fact. One of them is that there are few people who dedicate most of their time to research ubiquitous computing issues. Most of the authors might have their main research in other related areas, such as Artificial Intelligence, and occasionally work with some ubiquitous computing problems.

Representativeness of Authors and Institutions

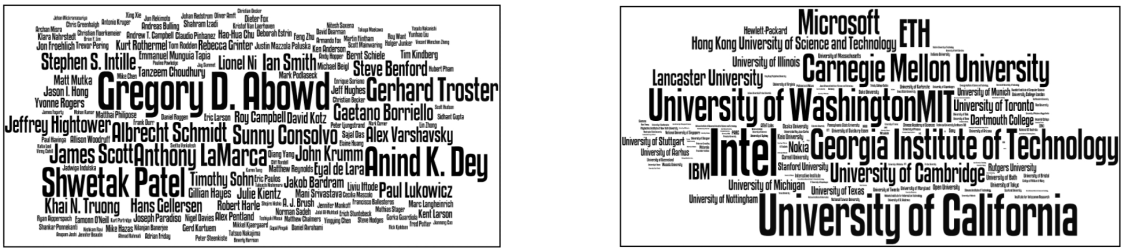
Figures 5a and 5b depict the occurrence of authors and institutions in the TOPint group, respectively. In this analysis authors and institutions are counted just once by paper. Gregory D. Abowd is the author who published the largest number of papers (Figure 5a), and Universities of California and Washington, and Intel are the most productive institutions (Figure 5b). In SBCUP, both the South region (UFRGS, UCPel, Unisinos, UFSM) and North region (UFAM, and FUCAPI) have a strong participation.

Figure 6 displays the institutions according to their occurrence in papers (institutions are counted just once in each paper), considering Ubicomp, Pervasive and Percom individually



(a) Uninterrupted (b) Absence (c) Newcomers

Figure 4. Participation of authors..



(a) Cloud of authors (b) Cloud of institutions

Figure 5. Representativeness of authors and institutions.

(Figures 6a, 6b, 6c, respectively). Most productive institutions depicted in Figure 5b (TOPint conferences) are not necessarily the most productive when we consider each conference individually. Analyzing the results, it is possible to perceive a stronger correlation between top institutions from Ubicomp and Pervasive than top institutions from Percom. For example, the University of Washington is one of the most productive institutions in the Ubicomp and Pervasive conferences, but not in Percom. The most productive institution in Percom is the Hong Kong University of Science and Technology. This might be an indication that Ubicomp and Pervasive tend to accept studies in more similar areas.

Collaboration Network

A natural process when conducting research is to form groups and establish partnerships (e.g., by affinity) in order to improve a work or to share experiences. In this regard, we identified the main institutions that collaborated with each other in the TOPint group. Ubicomp has 40% of papers with collaboration (more than one institution), Pervasive 38% and Percom 32%.

In the rest of this section we represent the scientific collaboration network of the TOPint group as a graph. In this network, nodes represent authors, while an edge between two nodes indicates a joint publication between authors. In Section “Connected Components” we discuss the connected components, and in Section “Communities Visualization” we identify some communities of authors.

Connected Components

Figure 7a presents the evolution in the number of connected components over the years. In the first editions of Ubicomp, Pervasive, and Percom, the network had 21, 19, and 46 connected components, respectively. After five editions, Ubicomp, Pervasive, and Percom had 80, 71, and 144 authors, i.e., an increase of 280%, 273%, and 213%, respectively. In 2011, Ubicomp, Pervasive, and Percom had 128, 89, 178 components, i.e., an increase of 60%, 25%, 23%, respectively. In this way, the number of components had a significantly greater increase in the first years. Furthermore, the number of components in Percom is much higher than in Ubicomp and Pervasive.

Figure 7b shows the evolution of the biggest connected component (BCC), and the second biggest connected component (SBCC). In

(a) Ubicomp

(b) Pervasive

(c) Percom

Figure 6. Representativeness of institutions per conference.

the second half of that period, BCC starts to increase much more than SBCC, for both Ubicomp and Pervasive. This does not happen for Percom, where BCC does not increase significantly in any edition. Authors who were supposed to increase BCC may end up increasing the number of new components (Figure 7a).

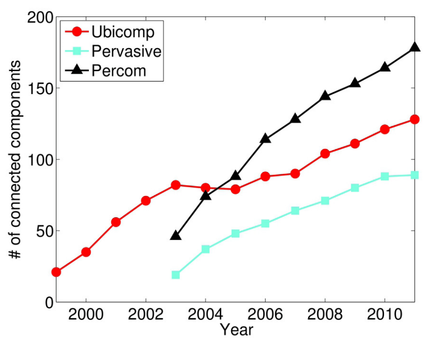
Communities Visualization

One of the most relevant characteristics of graphs representing real systems is the structure of communities. For such identification, we grouped the final network (total) of the TOPint group and applied the *k*-clique community algorithm, according to Palla *et al.*, 2005. A community is defined as the union of all clicks of size *k* that can be reached through adjacent *k*-cliques (two *k*-cliques are adjacent if they share *k* nodes).

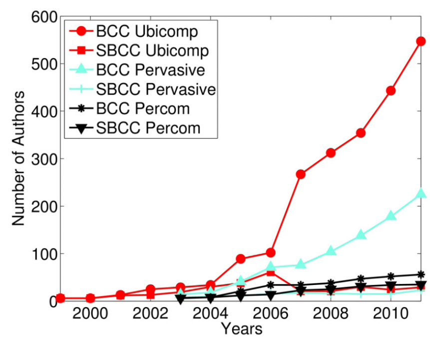
Figure 8 depicts communities with members connected to universities. If an author was affiliated to more than one institution throughout his/her history, we considered all recorded affiliations. We found 66 communities (using *k*=3). Figure 8 shows only the four biggest communities (due to space limitations) with 29, 16, 14 and 12 authors. Figure 8a (biggest community) shows that authors from the University of Washington, and Intel are very popular in this community.

Recent Ubicomp Research – Taxonomy

In order to provide a snapshot of the research being conducted in the field of ubicomp, we did a careful reading of the abstract, introduction, conclusion, and, in some cases, other sections as well, of papers published in the TOPint group editions of both 2010 and 2011. This study gave us an overview of the present research in the area, leading to our proposed taxonomy. We do not intend to say that we offer a complete view of recent research, but we do believe it is a good approximation about recent research topics. This taxonomy is very useful for two reasons. First, it can guide



(a) Number of components



(b) Size of biggest component

Figure 7. Connected components.

(a) 29 authors

(b) 16 authors

(c) 14 authors

(d) 12 authors

Figure 8: Four biggest communities – visualization by universities.

novices in the field. Second, it can be used to compare and discuss the ubicomp research performed in Brazil.

We identified seven categories (see Figure 9), named: Context-aware; HCI Evaluation; Invisible Computing; Innovative Technology; Resource Limitation; Privacy/Security; and Software Design. Sometimes a paper can belong to more than one category, but we consider its dominant entry. Categories have subcategories. They were created when we identified at least three papers related to a "specialization" of the category. This is a way to highlight topics that are receiving considerable attention, which could indicate a research trend or a hot topic. Figure 9 also shows the number of papers found in each category. For instance, category Invisible Computing has 23 papers (15 of them were classified in a subcategory, which means that the remaining eight papers were not sub-categorized).

In the next sections we describe all categories of the taxonomy. In order to increase the readability, we did not cite all papers analyzed.

Context-Aware

Context is defined by Dey and Abowd (2000) as any information that can be used to characterize the situation of an entity. An entity can be a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves. The category named "Context-aware" groups studies that use context to automatically adapt a service behavior according to the current context, such as environmental conditions or location. This is a very active and important field in pervasive computing with a considerable number of studies.

There are papers related to context information modeling (Chen, 2011) that propose a hybrid approach to resolve context inconsistencies. The authors Degeler and Lazovik (2011) introduced Context Consistency Diagrams, a data structure for reasoning about situations with incomplete knowledge of the environment and context conflicts that cannot be unambiguously resolved.

Context-aware applications use sensing and inference to attempt to determine users' contexts and to take appropriate actions. However, they are prone to uncertainty, and this may compromise the trust users have in them (Lim and Dey, 2011). We also found studies that are focused on providing intelligibility about how context-aware applications work to improve users' impressions of them. The authors Lim and Dey (2011) investigated the impact of intelligibility on understanding and user impression of applications with varying certainty. Lim and Dey (2010) proposed a toolkit to obtain eight types of explanations from the most popular decision models of context-aware applications.

Some papers were classified in two subcategories:

A-Recognition: This category groups studies that derive high level context information from raw data (provided by sensors). This action is

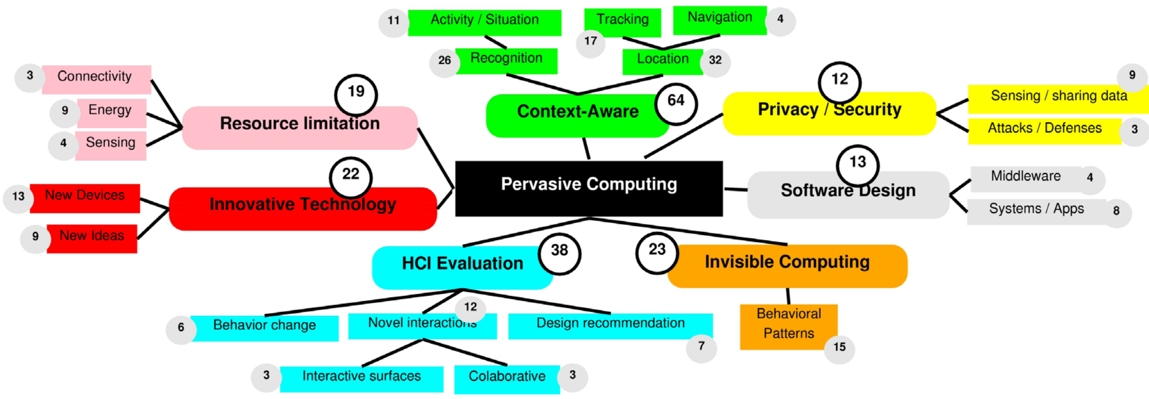


Figure 9: Taxonomy of recent research on ubicomp - Top international conferences.

called recognition, interpretation or inference. We classified many studies in this category, including proposals that focus on emotional/psychological state recognition. Healey *et al.* (2010) performed a study on emotion recognition. Rachuri *et al.* (2010) presented a mobile sensing platform capable of recognizing some user's psychological states, for social psychology studies based on mobile phones. There are also studies related to voice recognition. Amft (2010) proposed an unsupervised speaker identification system for personal annotations of conversations and meetings. Studies related to situation recognition such as Lovett *et al.* (2010) proposed a real-time data fusion method that combines the calendar with location and social network data to improve the representation of reality, which is not given by the calendar alone. Another example is the work of Zhuang *et al.* (2011). Many other papers focus on recognition. Steinhoff and Schiele (2010) showed the promise of dead reckoning using solely a device placed freely in a trousers' front pocket. Larson *et al.* (2011) presented an algorithm to detect coughs from the audio stream of a mobile phone. Some of the studies of this category were classified in a specific subcategory:

A.1-Activity: By "activity" we mean physical human activity. Activity recognition is receiving considerable attention by researchers. Albinali *et al.* (2010) presented a technique to improve upon state-of-the-art energy expenditure estimation in physical activities. In Förster *et al.* (2010) the authors proposed and evaluated a dynamic hand gesture recognition system, based on wearable motion sensors. Maekawa *et al.* (2010) showed how to recognize activities of daily living (ADLs) with a designed sensor device, which is equipped with heterogeneous sensors such as camera, microphone, and accelerometer attached to a user's wrist. Helaoui *et al.* (2011) proposed a method for recognizing interleaved and concurrent activities.

B-Location: Location is powerful context information, typically available in mobile devices with an embedded GPS. Location enables a wide range of new services and poses many research issues. Yang *et al.* (2010) provided a study of the accuracy of two existing methods for cell tower localization using wardriving data. Based on a cell-phone trace analysis, Calabrese *et al.* (2010) showed that the origins of people attending an event are strongly correlated to the type of event. Kranz and Schmidt (2010) discussed the Digital Enhanced Cordless Telecommunications and its potential for positioning and localization. Bentley *et al.* (2011) presented a service that allows videos to be saved in user-specified real-world locations, and then serendipitously discover the location of a story as people approach them. Some papers were classified in two other subcategories:

B.1-Tracking: Tracking of mobile entities (living being or objects) is a fundamental building block for location-based services. For instance, to deliver a warning message to a car about an accident on the road, the system needs to keep track of the cars on that road to check which car should receive the message. This category is composed of proposals that focus mainly on algorithms or mechanisms to track mobile entities. Becker *et al.* (2011) showed how to use hand-off patterns from cellular phone networks to identify which routes people take through a city. Weinschrott *et al.* (2011) introduced mechanisms using mobile devices such as smartphones to track mobile objects. The main contribution of Scellato *et al.*

(2011) was a method to perform location prediction based on nonlinear time series analysis of the arrival and residence times of users in relevant places. Higuchi *et al.* (2011) proposed a cooperative algorithm to localize mobile nodes.

B.2-Navigation: This subcategory is composed of studies that focus on methods and techniques to help user's navigation. Pielot and Boll (2010) investigated the concept of tactile waypoint navigation to overcome existing limitations in commercial pedestrian navigation systems. Minamimoto *et al.* (2010) proposed a local map generation algorithm that could be used in the recognition of an accident site in an emergency situation. Hoseinitabatabaei *et al*. (2011) presented an approach to determine a user's facing direction with a mobile phone, regardless of the mobile phone's orientation.

HCI Evaluation

This category of studies presents investigations of the use of new or existing ubicomp technologies to help the design and deployment of future ubicomp applications, devices or systems. This is a relevant and very active field in the field of ubicomp, as we can see from the amount of related papers. Dey *et al.* (2011) presented an investigation about the users' proximity to their mobile phones. Boesen *et al.* (2010) evaluated the ways in which Location-Based Services are changing domestic relationships.

Truong *et al.* (2010) evaluated a proposed task-centered battery interface (TCBI) for mobile devices. The goal of TCBI is to help users to better understand how different applications affect battery usage. Dillahunt *et al.* (2010) proposed a set of open research questions and design recommendations for technologies that may affect and be affected by the conflict between stakeholders around energy use. Betz (2010) studied how maintenance workers deal with repair-related information, how this information is related to objects and places and to which extent those objects can be seen as boundary-objects for the involved groups of actors. MacMillan *et al.* (2010) performed a large scale trial of a game and also presented some evaluation techniques to be applied in that case.

We categorized some papers in three subcategories:

A-Behavioral Change: This subcategory is composed of studies that propose and/or evaluate mechanisms to provide user behavior change (e.g., make healthier meal choices). Rogers *et al.* (2010) presented an evaluation of the potential of embedded displays (designed to give information in subtle and playful ways) to nudge people to change their behavior. Grimes *et al.* (2010) presented a field study evaluation of a mobile game in which players learn how to make healthier meal choices. In the line of e-health, Oliveira *et al.* (2010) presented a mobile social game that engages users to be more compliant in taking their daily medication.

B-Design Recommendation: This subcategory is composed of proposals that focus on providing guidance and recommendations on designing or deploying pervasive technologies. Poole *et al.* (2011) provided guidance for introducing ubiquitous computing technologies in institutions with established norms and rules. Clinch *et al.* (2011) reflected on how a digital signage system is used in detail (content and use related practices) and provided a set of lessons for designers of future ubicomp public display systems.

C-Novel Interactions: This subcategory groups research projects that propose or evaluate new types of interaction (e.g., touch interaction). Related to touch interaction, Bonner *et al.* (2010) presented an eyes-free gesture-based text entry system for multi-touch devices. Related to haptic interaction, Linden *et al.* (2011) designed an immersive theater experience to raise awareness and question perceptions of 'blindness'. A multimodal experience was created, comprising ambient sounds and narratives and an assortment of themed tactile objects, intended to be felt. They also designed a novel haptic device to enhance their discovery of a pitch-black space. As an example of a new proposal, Bulling and Roggen (2011) investigated the feasibility of using eye movement analysis to recognize visual memory recall processes of people looking at familiar pictures or unfamiliar pictures. They also introduced cognition-awareness and cognitive context as new paradigms in ubiquitous computing. Some studies were classified in two other subcategories:

C.1-Interactive Surfaces: This subcategory groups studies related to interactive surfaces (tangible user interfaces). They merge input and output into a single space, enabling designers to go beyond simple touch interactions, to integrate physical objects as interactive tools on the surface. Costanza and Shelley (2010) evaluated the impact of Tangible User Interfaces on users' everyday environments through two tangible interfaces. Hincapié-Ramos *et al.* (2011) explored an alternative for integrating everyday objects and tabletops called mediated tabletop interaction. Åkerman *et al.* (2010) also proposed a solution that belongs in this category.

C.2-Collaborative: This subcategory is composed of papers that enable interaction of people to create and share context on pervasive devices. Willis and Poupyrev (2010) presented a system that allows people to create and share drawings directly from a regular mobile phone. Perring *et al.* (2010) evaluated a collaborative workspace table prototype.

Invisible Computing

Traditional computers consume much of our attention and separate us from what is happening around us. Weiser believed that in the ubicomp world computation could be integrated with common objects used for everyday work practices, rather than forcing computation to be a separate activity (Krumm, 2009). Invisible computing is essential to the ubicomp visions and is related to technologies that require minimal interaction from users. This section is composed of studies dedicated to this challenge.

We classified 23 papers in this category. Bidot (2011), for example, presented an approach to aggregate and use devices that support the everyday life of human users in ambient intelligence environments. Some of them were classified in a specific subcategory, named: Behavioral Patterns.

A-Behavioral patterns: To achieve invisible computing, a fundamental step is the understanding of people and system behavioral patterns. For example, location patterns can be used to automatically program home thermostats. The papers in this subcategory focus mainly on user behavioral pattern identification, modeling, and prediction. Lathia and Capra (2011) demonstrated how automated fare collection records reveal the hidden behaviors of individuals and their behaviors responses to travel incentives. Zhang *et al.* (2011) aimed to discover anomalous driving patterns from taxis' GPS traces, targeting applications such as the automatic detection of taxi driving frauds or road network change.

Madan *et al.* (2010) used mobile phones to identify behavior changes reflected in mobile phone sensors, when individuals suffer from common colds, influenza, fever, stress and mild depression. Choujaa (2010) performed a study about the prediction of mobile phone users' activity.

Innovative Technology

We would like to emphasize that every work listed in this taxonomy presents innovation in its field. The category "Innovative Technology" is composed of studies that focus mainly on original devices or visionary conceptual ideas for ubiquitous computing. All the studies identified in this category (22 papers) were categorized into two groups:

A-New Devices: This group presents the design of novel devices. Usually the new device is presented through a prototype. Wei *et al.* (2011) presented a dining table embedded with interactive subsystems that augment and transport the experience of communal family dining to create a sense of coexistence among remote family members. Cohn *et al.* (2010) presented a sensing solution for automatically identifying gas use. Cheng *et al.* (2010) described a new on-body capacitive sensing approach to derive activity-related information.

B-New Ideas: This category is composed of papers that present new ideas that do not demand the design of new devices. In other words, they rely on existing devices (e.g., popular devices) to offer new services. For example, the study by Ho *et al.* (2011) proposed a thermal-based power meter system that uses thermal imaging to track disaggregated appliance usage. Gupta *et al.* (2011) described a sensing approach that turns ordinary compact fluorescent light bulbs into sensors of human proximity. Du *et al.* (2011) utilized consumer depth cameras (Kinect style) to allow non-expert users to scan their personal spaces into 3D models. Kuznetsov *et al.* (2011) argued for expanding the current landscape of sensing to include living organisms, such as plants and animals, along with traditional tools and digital devices.

Resource Limitation

This category is composed of studies that focus mainly on common resource limitations present in many ubicomp devices, like smartphones. Katmon and Ryan (2011) proposed a replication scheme that dynamically creates and releases replicas on client nodes during runtime, with the goal of improving response time performance. Qin *et al.* (2010) proposed a VANET-WSN system to overcome the inherent limitations of a pure VANET-based system.

This category is further classified in three subcategories:

A-Energy: The studies in this subcategory present new techniques to improve energy savings and analyses of energy-related issues. Musolesi *et al.* (2010) presented the design, implementation and evaluation of several techniques to optimize the information uploading process for continuous sensing on mobile phones. Pyles *et al.* (2011) exploited, during runtime, the silence periods of a VoIP call to save smart phone Wi-Fi energy. Ramos *et al.* (2011) proposed a Low Energy Assisted Positioning solution that can save up to 80% of GPS energy consumption in typical trajectory-based service scenarios. Xu *et al.* (2010) presented an energy-efficient RFID inventory algorithm. Rice and Hay (2010) examined the power consumption of two handsets and showed in detail the energy used by particular actions.

B-Connectivity: In certain situations, the service may lack continuous network connectivity, such as in a mobile environment. This group of studies deals mainly with this issue. Yang and Wu (2011) studied the problem of intermittent connected passive RFID networks. Razafindralamboo *et al.* (2010) presented a distributed algorithm for adaptive infrastructure deployment in two-tiered intermittent connected networks. And finally Pitkanen and Karkkainen (2010) explored mobile web access using asynchronous messaging via WLAN hotspots.

C-Sensing: A given event may be more difficult to observe by using just one device. On the other hand, when other people collaborate with their devices (e.g., sensor-enabled cell phones) this can be simpler. In this category there are studies related to participatory sensing (Burke *et al.*, 2006; Silva *et al.*, 2012), but this same category could be appropriated to group studies related to opportunistic sensing (Campbell *et al.*, 2006). Reddy *et al.* (2010a) and Lee (2010) explored user participation incentive in participatory sensing applications. Reddy *et al.* (2010b) discussed how to develop a recruitment framework to enable organizers to identify well-suited participants for data collections, based on geographic and temporal availability and behavior.

Privacy/Security

Today there are many possibilities to create, store and transmit several kinds of sensed data, including GPS location, videos, and photos. This brings new types of services and also many challenges related to the privacy and security of those personal data. This category (12 papers) is classified in two subcategories:

A-Sensing/sharing data: The sensing of personal data is possible through the use, for example, of smartphones or smart environments, like a smart house (e.g. the tracking of energy consumption by a smart grid system). Increasing the amount of data stored and/or transmitted through the Internet, or another network, increases the need for securing the privacy of this data (Stajano, 2004). While people may benefit from services that make use of sensed data (e.g., location), it is important to consider the privacy risks of such services. This category is composed of studies that are mainly focused on those issues. Wiese *et al.* (2011) explored which features of interpersonal relationships influence sharing. Toch *et al.* (2010) presented a study about location sharing privacy preferences of users. De Cristofaro *et al.* (2011) presented an architecture geared to privacy-sensitive applications where personal information is shared among users. Brush *et al.* (2010) explored people's concerns about privacy related to personal data provided from location-based services.

B-Attacks/Defenses: This category is composed of studies that are more concerned with proposing or discussing methods for attacking and defending personal data. Kostakos *et al.* (2011) aimed to answer two questions related to targeted location-sharing privacy attacks. Peddinti and Saxena (2011) examined the level of privacy protection provided by the current query obfuscation techniques against adversarial location service providers. Finally, Saxena *et al.* (2011) presented a novel approach for authenticating multiple RFID tags.

Software Design

This category is composed of studies that focus on pervasive software design (e.g., approaches and models). Harrington and Cahill

(2011) presented a model-driven approach to apply planning and optimization algorithms in pervasive computing applications. All other studies of this category were classified in two subcategories:

A-Middleware: This subcategory is composed of studies that are focused on providing and discussing a middleware or framework to ease the development of pervasive systems. Ding *et al.* (2010) proposed a framework for adaptive software that supports the online reconfiguration of each concern in the adaptation loop. Chowdhury *et al.* (2010) presented a middleware for supporting energy-efficient, long-term remote health monitoring. Kang *et al.* (2010) presented an active resource orchestration framework for mobile context monitoring.

B-Systems/Apps: This subcategory contains studies concerned mainly with current pervasive applications or systems. Pham and Paluska (2010) proposed a tool that takes a step towards easing the development of ubicomp systems by reducing several debugging pain points. Lu *et al.* (2010) presented a mobile multiparty voice communication system that allows drivers to socialize with each other while driving. Nachman *et al.* (2010) proposed a system to manage diabetes that considers energy expenditure monitoring, diet-logging, and analysis of health data. Luyten (2010) presented an approach and tool that makes it possible to create an intuitive user interface for exploring and controlling the environment.

Ubicomp Research in Brazil

In this section we present the classification of studies published in SBCUP between 2010 and 2011 (Figure 10) using the proposed taxonomy that was presented in details in previous sections. As shown in Figure 10, the most representative category is software design (52% of all papers), and the second one is context-aware (19% of all papers). In the classification performed for international studies, i.e., papers from abroad presented at SBCUP, the most representative category is context-aware (35% of all papers), and the second one is HCI evaluation (20% of all papers). Notice that we have not been able to classify studies in the HCI evaluation category considering papers from SBCUP. Another relevant observation is that in some categories, for instance invisible computing, we did not find enough papers to create subcategories that were previously identified. We believe that these observations may be interesting for two reasons. First, there are many opportunities for Brazilian researchers acting in related fields, such as HCI or security, to start addressing new issues brought by ubicomp, for instance development and evaluation of new forms of user interaction. Second, they may guide newcomers to start his/her research in less explored areas.

Conclusions

This work presented an overview and analysis of recent ubicomp research. Based on datasets of top conferences in ubicomp we showed relevant information, such as representativeness of authors and institutions and communities formed by authors. In the analysis of all papers published in top conferences in the ubiquitous computing area, we proposed a taxonomy of recent ubicomp research. Besides that, we also discussed the Brazilian ubicomp research based on the proposed taxonomy. We believe that this work can be useful to guide

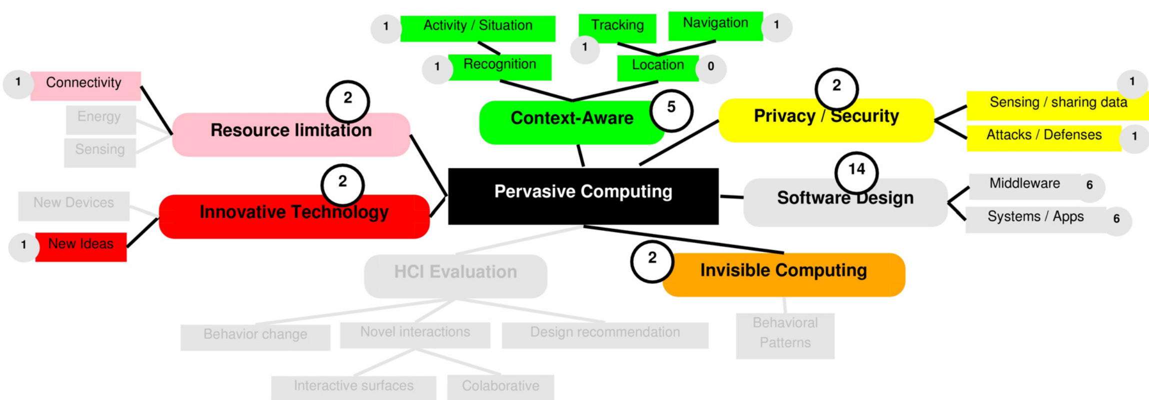


Figure 10. Taxonomy of recent ubicomp research , considering publications in SBCUP (Brazilian conf.).

newcomers to this field, as well as for experienced researchers as it provides facts to enable discussion about the field.

In terms of future work, it is interesting to keep analyzing recent papers in the field to maintain the taxonomy updated. For this purpose the use of crowdsourcing tools may be a good option.

References

ÅKERMAN, P.; PUIKKONEN, A.; HUUSKONEN, P.; VIROLAINEN, A.; HÄKKILÄ, J. 2010. Strangers – In the Wild Study of Ad Hoc Social Communication by Drawing. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, pages 193–202, 2010. http://dx.doi.org/10.1145/1864349.1864390

ALBINALI, F.; INTILLE, S.; HASKELL, W.; ROSENBERGER, M. 2010. Using wearable activity type detection to improve physical activity energy expenditure estimation. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Copenhagen, 2010. *Proceedings*... Copenhagen, p. 311-320. http://dx.doi.org/10.1145/1864349.1864396

AMFT, O. 2010. Collaborative Real-Time Speaker Identification for Wearable Systems. In: IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Mannheim, 2010. *Proceedings*... Mannheim, p. 180-189. http://dx.doi.org/10.1109/PERCOM.2010.5466976

BAZZAN, A.; ARGENTA, V. 2011. Network of collaboration among PC members of Brazilian computer science conferences. *Journal of the Brazilian Computer Society*, **17**(2):133-139. http://dx.doi.org/10.1007/s13173-011-0033-7

BECKER, R.A; CACERES, R.; HANSON, K.; MENGLOH, J.; URBANEK, S.; VARSHAVSKY, A.; VOLINSKY, C. 2011. Route classification using cellular handoff patterns. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings*... Beijing, p. 123-132. http://dx.doi.org/10.1145/2030112.2030130

BENTLEY, F.R.; BASAPUR, S.; CHOWDHURY, S.K. 2011. Promoting intergenerational communication through location-based asynchronous video communication. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings*... Beijing, p. 31-40. http://dx.doi.org/10.1145/2030112.2030117

BETZ, M. 2010. The Secret Life of Machines – Boundary Objects in Maintenance, Repair and Overhaul. *In:* INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING, Helsinki. 2010. *Proceedings*... Helsinki, p. 174-191. http://dx.doi.org/10.1007/978-3-642-12654-3_11

BIDOT, J. 2011. Using AI Planning and Late Binding for Managing Service Workflows in Intelligent Environments. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Seattle, 2011. *Proceedings*... Seattle, p. 156-163. http://dx.doi.org/10.1109/PERCOM.2011.5767580

BOESEN, J.; RODE, J. A.; MANCINI, C. 2010. The Domestic Panopticon: Location Tracking in Families. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Copenhagen, 2010. *Proceedings*... Copenhagen, p. 65-74. http://dx.doi.org/10.1145/1864349.1864382

BONNER, C.; BRUDVIK, J.; ABOWD, G.; EDWARDS, W. 2010. No-Look Notes: Accessible Eyes-Free Multi-touch Text Entry. *In:* INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING, Helsinki, 2010. *Proceedings*... Helsinki, p. 409-426. http://dx.doi.org/10.1007/978-3-642-12654-3_24

BRUSH, A.J.; KRUMM, J.; SCOTT, J. 2010. Exploring End User Preferences for Location Obfuscation, Location-Based Services, and the Value of Location. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Copenhagen, 2010. *Proceedings*... Copenhagen, p. 95-104. http://dx.doi.org/10.1145/1864349.1864381

BULLING, A.; ROGGEN, D. 2011. Recognition of visual memory recall processes using eye movement analysis. *In:* INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings*… Beijing, p. 455-464. http://dx.doi.org/10.1145/2030112.2030172

BURKE, J.; ESTRIN, D.; HANSEN, M.; PARKER, A.; RAMANATHAN, N.; REDDY, S.; SRIVASTAVA, M. B. 2006. Participatory sensing. *In:* WORKSHOP ON WORLD-SENSOR-WEB, Boulder, 2006. *Proceedings*… Boulder, p. 117-134.

CACERES, R.; FRIDAY, A. 2012. Ubicomp systems at 20: Progress, opportunities, and challenges. *IEEE Pervasive Computing*, **11**(1):14-21. http://dx.doi.org/10.1109/MPRV.2011.85

CALABRESE, F.; PEREIRA, F.; LORENZO, G.D.; LIU, L.; RATTI, C. 2010. The Geography of Taste: Analyzing Cell-Phone Mobility and Social Events. *In:* INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING, Helsinki, 2010. *Proceedings*... Helsinki, p. 22-37. http://dx.doi.org/10.1007/978-3-642-12654-3_2

CAMPBELL, A.T.; EISENMAN, S.B.; LANE, N.D.; MILUZZO, E.; PETERSON, R.A. 2006. People-centric urban sensing. *In:* INTERNATIONAL WORKSHOP ON WIRELESS INTERNET, New York, 2006. *Proceedings*… New York. http://dx.doi.org/10.1145/1234161.1234179

CHEN C. 2011. Hybrid Context Inconsistency Resolution for Context-Aware Services. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Seattle, 2011. *Proceedings*... Seattle, p. 10-19. http://dx.doi.org/10.1109/PERCOM.2011.5767574

CHENG, J.; AMFT, O.; LUKOWICZ, P. 2010. Active Capacitive Sensing: Exploring a New Wearable Sensing Modality for Activity Recognition. *In:* INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING, Helsinki. 2010. *Proceedings*... Helsinki, p. 319-336. http://dx.doi.org/10.1007/978-3-642-12654-3_19

CHOUJAA, D. 2010. Predicting Human Behaviour from Selected Mobile Phone Data Points. *In:* ACM INTERNATIONAL CONFERENCE. ON UBIQUITOUS COMPUTING, Copenhagen, 2010. *Proceedings*... Copenhagen, p. 105-108. http://dx.doi.org/10.1145/1864349.1864368

CHOWDHURY, A.R.; FALCHUK, B.; MISRA, A. 2010. MediAlly: A Provenance-Aware Remote Health Monitoring Middleware. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Mannheim, 2010. *Proceedings*... Mannheim, p. 125-134. http://dx.doi.org/10.1109/PERCOM.2010.5466985

CLINCH, S.; DAVIES, N.; FRIDAY, A.EFSTRATIOU, C. 2011. Reflections on the long-term use of an experimental digital signage system. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings*... Beijing, p.133-142. http://dx.doi.org/10.1145/2030112.2030132

COHN, G.; GUPTA, S.; FROEHLICH, J.; LARSON, E.; PATEL, S. 2010. GasSense: Appliance-Level, Single-Point Sensing of Gas Activity in the Home. *In:* INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING, Helsinki. 2010. *Proceedings*... Helsinki, p. 265-282. http://dx.doi.org/10.1007/978-3-642-12654-3_16.

CONTANZA, E.; SHELLEY, S. 2010 Ubicomp to the Masses: A Large-scale Study of Two Tangible Interfaces for Download. *In:* ACM INT. CONF. ON UBIQUITOUS COMPUTING, Copenhagen, 2010. *Proceedings*… Copenhagen, p. 173-182. http://dx.doi.org/10.1145/1864349.1864388

DE CRISTOFARO, E.; DURUSSEL, A.; AAD, I. 2011. Reclaiming Privacy for Smartphone Applications. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Seattle, 2011. *Proceedings*... Seattle, p. 84-92. http://dx.doi.org/10.1109/PERCOM.2011.5767598

DEGELER, V.; LAZOVIK, A. 2011. Interpretation of Inconsistencies via Context Consistency Diagrams. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Seattle, 2011. *Proceedings*... Seattle, p. 20-27.

http://dx.doi.org/http://10.1109/PERCOM.2011.5767588

DEY, A. K.; ABOWD, G. D. 2000. Towards a Better Understanding of Context and Context-Awareness. *In:* WORKSHOP ON THE WHAT, WHO, WHERE, WHEN, AND HOW OF CONTEXT-AWARENESS, Netherlands, 2000. *Proceedings*... Netherlands, p. 304-307. http://dx.doi.org/10.1007/3-540-48157-5_29

DEY, A.K.; WAC, K.; FERREIRA, D.; TASSINI, K.; HONG J-H.; RAMOS, J. 2011.Getting closer: an empirical investigation of the proximity of user to their smart phones. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings*... Beijing, p. 163-172. http://dx.doi.org/10.1145/2030112.2030135

DILLAHUNT, T.; MANKOFF, J.; PAULOS, E. 2010.Understanding Conflict Between Landlords and Tenants: Implications for Energy Sensing and Feedback. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Copenhagen, 2010. *Proceedings*... Copenhagen, p. 149-158. http://dx.doi.org/10.1145/1864349.1864376

DING, B.; WANG, H.; SHI, D.; CAO, J. 2010.Taming Software Adaptability with Architecture-Centric Framework. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Mannheim, 2010. *Proceedings*... Mannheim, p. 145-151. http://dx.doi.org/10.1109/PERCOM.2010.5466983

DU, H.; HENRY, P.; REN, X.; CHENG, M.; GOLDMAN, D.; SEITZ, S.; FOX, D. 2011. Interactive 3D modeling of indoor environments with a consumer depth camera. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings*... Beijing, p. 75-84. http://dx.doi.org/10.1145/2030112.2030123

FÖRSTER, K.; BIASIUCCI, A.; CHAVARRIAGA, R.; MILLÁN, J.R.; ROGGEN, D.; TRÖSTER, G. 2010. On the Use of Brain Decoded Signals for Online User Adaptive Gesture Recognition Systems. *In:* INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING, Helsinki, 2010. *Proceedings*... Helsinki, p. 427-444. http://dx.doi.org/10.1007/978-3-642-12654-3_25

FREIRE, V.; FIGUEIREDO, D. 2011. Ranking in collaboration networks using a group based metric. *Journal of the Brazilian Computer Society*, **17**(4):255-266. http://dx.doi.org/10.1109/SBSC.2010.18

GRIMES, A.; KANTROO, V.; GRINTER, R.E. 2010. Let's play!: mobile health games for adults. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Copenhagen, 2010. *Proceedings*... Copenhagen, p. 241-250. http://dx.doi.org/10.1145/1864349.1864370

GUPTA, S.; CHEN, K.; REYNOLS, M.; PATEL, S. 2011. LightWave: using compact fluorescent lights as sensors. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings*... Beijing, p. 65-74. http://dx.doi.org/10.1145/2030112.2030122

HARRINGTON, A.; CAHILL, V. 2011.Model-Driven Engineering of Planning and Optimisation Algorithms for Pervasive Computing Environments. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Seattle, 2011. *Proceedings*... Seattle, p. 172-180. http://dx.doi.org/10.1109/PERCOM.2011.5767582

HEALEY, J.; NACHMAN, L.; SUBRAMANIAN, S.; SHAHABDEEN, J.; MORRIS, M. 2010. Out of the Lab and into the Fray: Towards Modeling Emotion in Everyday Life. *In:* INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING, Helsinki. 2010. *Proceedings*... Helsinki, p. 156-173. http://dx.doi.org/10.1007/978-3-642-12654-3_10

HELAOUI, R.; NIEPERT, M.; STUCKENSCHMIDT, H. 2011. Recognizing Interleaved and Concurrent Activities: A Statistical-Relational Approach. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Seattle, 2011. *Proceedings*... Seattle, p. 1-9. http://dx.doi.org/10.1109/PERCOM.2011.5767586

HIGUCHI, T.; FUJII, S.; YAMAGUCHI, H.; HIGASHINO, T. 2011. An Efficient Localization Algorithm Focusing on Stop-and-Go Behavior of Mobile Nodes. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Seattle, 2011. *Proceedings*... Seattle, p. 205-212. http://dx.doi.org/10.1109/PERCOM.2011.5767587

HINCAPIÉ-RAMOS, J.; TABARD, A.; BARDRAM, J. 2011.Mediated tabletop interaction in the biology lab: exploring the design space of the rabbit. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings*… Beijing, p. 301-310. http://dx.doi.org/10.1145/2030112.2030153

HO, B.; KAO, H.; CHEN, N.; YOU, C.; CHU, H.; CHEN, M. 2011. HeatProbe: a thermal-based power meter for accounting disaggregated electricity usage. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings*... Beijing, p. 55-64. http://dx.doi.org/10.1145/2030112.2030121

HOSEINITABATABAEI, S.A.; GLUHAK, A.; TAFAZOLLI, R. 2011. uDirect: A novel approach for pervasive observation of user direction with mobile phones. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Seattle, 2011. *Proceedings*... Seattle, p. 74-83. http://dx.doi.org/10.1109/PERCOM.2011.5767597

KANG, S.; LEE, Y.; MIN, C.; LEE, J.; RHEE, Y.; SONG, J. 2010. Orchestrator: An Active Resource Orchestration Framework for Mobile Context Monitoring in Sensor-rich Mobile Environments. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Mannheim, 2010. *Proceedings*... Mannheim, p. 135-144.

http://dx.doi.org/10.1109/PERCOM.2010.5466982

KATMON, N.; RYAN, C. 2011. Adaptive client side object replication for response time improvement in pervasive environments. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Seattle, 2011. *Proceedings*... Seattle, p. 164-171. http://dx.doi.org/10.1109/PERCOM.2011.5767581

KAYE, J. 2009. Some statistical analyses of CHI. *In:* EXTENDED ABSTRACTS ON HUMAN FACTORS IN COMPUTING SYSTEMS, New York, 2009. *Proceedings*... New York, p. 2585-2594. http://doi.acm.org/10.1145/1520340.152036

KOSTAKOS, V.; VENKATANATHAN, J.; REYNOLDS, B.; SADEH, N.; TOCH, E.; SHAIKH, S.; JONES, S. 2011. Who's your best friend?: targeted privacy attacks in location-sharing social networks. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings*... Beijing, p. 177-186. http://dx.doi.org/10.1145/2030112.2030138.

KRANZ M.; SCHMIDT, A. 2010. A Comparative Study of DECT and WLAN Signals for Indoor Localization. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Mannheim, 2010. *Proceedings*... Mannheim, p. 235-243. http://dx.doi.org/10.1109/PERCOM.2010.5466970

KRUMM, J. 2009. *Ubiquitous Computing Fundamentals*. 1st ed., Boca Raton, Chapman & Hall/CRC, 328 p.

KUZNETSOV, S.; ODOM, W.; PIERCE, J.; PAULOS, E. 2011. Nurturing natural sensors. *In:* ACM INT. CONF. ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings*... Beijing, p. 227-236. http://dx.doi.org/10.1145/2030112.2030144

LARSON, E.C.; LEE, T.; LIU, S.; ROSENFELD, M.; PATEL, S. N. 2011. Accurate and privacy preserving cough sensing using a low-cost microphone. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings*... Beijing, p. 375-384. http://dx.doi.org/10.1145/2030112.2030163

LATHIA, N.; CAPRA, L. 2011. How smart is your smartcard?: measuring travel behaviours, perceptions, and incentives. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings*… Beijing, p. 291-300. http://dx.doi.org/10.1145/2030112.2030152

LEE, J. 2010. Sell Your Experiences: A Market Mechanism based Incentive for Participatory Sensing. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Mannheim, 2010. *Proceedings*... Mannheim, p.60–68. http://dx.doi.org/10.1109/PERCOM.2010.5466993

LIM B.Y.; DEY, A.K. 2011. Investigating intelligibility for uncertain context-aware applications. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings*... Beijing, p. 415-424. http://dx.doi.org/http://10.1145/2030112.2030168

LIM, B.Y.; DEY, A.K. 2010. Toolkit to Support Intelligibility in Context-Aware Applications. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Copenhagen, 2010.*Proceedings*... Copenhagen, p. 13-22. http://dx.doi.org/10.1145/1864349.1864353

LINDEN, J.; ROGERS, Y.; OSHODI, M.; SPIERS, A.; MCGORAN, D., CRONIN, R.; O'DOWD, P. 2011. Haptic reassurance in the pitch black for an immersive theatre experience. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings...* Beijing, p. 143-152. http://dx.doi.org/10.1145/2030112.2030133

LOVETT, T.; O'NEILL, E.; IRWIN, J.; POLLINGTON, D. 2010. The calendar as a sensor: analysis and improvement using data fusion with social networks and location. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Copenhagen, 2010. *Proceedings*... Copenhagen, p. 3-12. http://dx.doi.org/10.1145/1864349.1864352

LU, H.; STEPHEN, S.; PRAVIN, S.; JAMES, B.; LIVIU, I. 2010. Ad-hoc Voice-based Group Communication. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Mannheim, 2010. *Proceedings*... Mannheim, p. 190-198. http://dx.doi.org/10.1109/PERCOM.2010.5466977

LUYTEN, K. 2010. Pervasive Maps: Explore and Interact with Pervasive Environments. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Mannheim, 2010. *Proceedings*... Mannheim, p. 227-234. http://dx.doi.org/10.1109/PERCOM.2010.5466973

MADAN, A.; CEBRIAN, M.; LAZER, D.; PENTLAND, A. 2010. Social sensing for epidemiological behavior change. *In:* ACM INTERNATIONAL CONFERENCE. ON UBIQUITOUS COMPUTING, Copenhagen, 2010. *Proceedings*... Copenhagen, p. 291-300. http://dx.doi.org/10.1145/1864349.1864394

MAEKAWA, T.; YANAGISAWA, Y.; KISHINO, Y.; ISHIGURO, K.; KAMEI, K.;SAKURAI, S.; OKADOME, T. 2010. Object-Based Activity Recognition with Heterogeneous Sensors on Wrist. *In:* INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING, Helsinki, 2010. *Proceedings*... Helsinki, p. 246-264. http://dx.doi.org/10.1007/978-3-642-12654-3_15

MAIA, G.; GUIDONI, D.; SILVA, T.H.; SOUZA, F.S.H.; MELO, P.; SOARES, C.; ALMEIDA, J.; LOUREIRO, A. 2012. Análise da rede de colaboração do simpósio brasileiro de redes de computadores e sistemas distribuídos: 30 edições de história. *In:* SIMPÓSIO BRASILEIRO DE REDES DE COMPUTADORES E SISTEMAS DISTRIBUÍDOS (SBRC), Ouro Preto, 2012. *Proceedings*... Ouro Preto, p. 14-27

MCMILLAN, D.; MORRISON, A.; BROWN, O.; HALL, M.; CHALMERS, M. 2010. Further into the Wild: Running Worldwide Trials of Mobile Systems. *In:* INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING, Helsinki. 2010. *Proceedings*... Helsinki, p. 210-227. http://dx.doi.org/10.1007/978-3-642-12654-3_13

MINAMIMOTO, S.; FUJII, S.; YAMAGUCHI, H.; HIGASHINO, T. 2010. Local Map Generation using Position and Communication History of Mobile Nodes. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Mannheim, 2010. *Proceedings*... Mannheim, p. 2-10. http://dx.doi.org/10.1109/PERCOM.2010.5466999

MUSOLESI, M.; PIRACCINI, M.; FODOR, K.; CORRADI, A.; CAMPBELL, A. 2010 Supporting Energy-Efficient Uploading Strategies for Continuous Sensing Applications on Mobile Phones. *In:* INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING, Helsinki. 2010. *Proceedings*... Helsinki, p. 355-372. http://dx.doi.org/10.1007/978-3-642-12654-3_21

NACHMAN, L.; BAXI, A. BRATTACHARYA, S.; DARERA, V.; DESHPANDE, P.; KODALAPURA, N.; MAGESJKUMAR, V.; RATH, S.; SHAHABDEEN, J.; ACHARYA, R. 2010. Jog falls: a pervasive healthcare platform for diabetes management. *In:* INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING, Helsinki. 2010. *Proceedings*... Helsinki, p. 94-111. http://dx.doi.org/2010.10.1007/978-3-642-12654-3_6

NASCIMENTO, M.A.; SANDER, J.; POUND, J. 2003. Analysis of Sigmod's co-authorship graph. *SIGMOD Rec*., **32**(3):8-10. http://dx.doi.org/10.1145/945721.945722

OLIVEIRA, R.; CHERUBINI, M.; OLIVER, N. 2010. MoviPill: Improving Medication Compliance for Elders Using a Mobile Persuasive Social Game. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Copenhagen, 2010. *Proceedings*... Copenhagen, p. 251-260. http://dx.doi.org/10.1145/1864349.1864371

PALLA, G.; DERÉNYI, I.; FARKAS, I.; VICSEK. T.2005. Uncovering the overlapping community structure of complex networks in nature and society. *Nature*, **435**(7043):814-818. http://dx.doi.org/doi:10.1038/nature03607

PEDDINTI, S.T.; SAXENA, N. 2011.On the limitations of query obfuscation techniques for location privacy. *In:* ACM INT. CONF. ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings...* Beijing, p. 187-196. http://dx.doi.org/10.1145/2030112.2030139.

PERRING, T.; LYONS, K.; WANT, R.; MURPHY-HOYE, M.; BALOGA, M.; NOLL, P.; BRANC, J.; BENOIST, N. 2010. What Do You Bring To the Table? Investigations of a Collaborative Workspace. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Copenhagen, 2010. *Proceedings…* Copenhagen, p. 183-192. http://dx.doi.org/10.1145/1864349.1864389

PHAM, H.; PALUSKA, J.M. 2010. PerViz: Painkillers for Pervasive Application Debugging. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Mannheim, 2010. *Proceedings*... Mannheim, p. 208-216. http://dx.doi.org/10.1109/PERCOM.2010.5466975

PIELOT, M.; BOLL, S. 2010. Tactile Wayfinder: Comparison of Tactile Waypoint Navigation with Commercial Pedestrian Navigation Systems. *In:* INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING, Helsinki, 2010. *Proceedings*... Helsinki, p. 76-93. http://dx.doi.org/10.1007/978-3-642-12654-3_5

PITKANEN, M.; KARKKAINEN, M. 2010. Opportunistic Web Access via WLAN Hotspots. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Mannheim, 2010. *Proceedings*... Mannheim, p. 20-30. http://dx.doi.org/10.1109/PERCOM.2010.5466997

POOLE, E.S.; MILLER, A.D.; XU, Y.; EIRIKSDOTTIR, E.; CATRAMBONE, R.; MYNATT,E.D. 2011. The place for ubiquitous computing in schools: lessons learned from a school-based intervention for youth physical activity. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings*... Beijing, p. 395-404. http://dx.doi.org/10.1145/2030112.2030165

PROCÓPIO, P.S.; LAENDER, A.H.F.; MORO, M.M. 2011. Análise da rede de coautoria do simpósio brasileiro de bancos de dados. *In:* SIMPÓSIO BRASILEIRO DE BANCO DE DADOS, Florianópolis, 2011. *Proceedings*... Florianópolis.

PYLES, A.; REN, Z.; ZHOU, G.; LIU, X. 2011. SiFi: exploiting VoIP silence for WiFi energy savings in smart phones. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings*... Beijing, p. 325-334. http://dx.doi.org/10.1145/2030112.2030157

QIN, R.; LI, Z.; WANG, Y.; LU, X.; ZHANG, W. 2010. An Integrated Network of Roadside Sensors and Vehicles for Driving Safety: Concept, Design and Experiments. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Mannheim, 2010. *Proceedings*... Mannheim, p. 79-87. http://dx.doi.org/10.1109/PERCOM.2010.5466988.

RACHURI, K.K.; MASCOLO, C.; RENTFROW, P.J; LONGWORTH, C. 2010. EmotionSense: A Mobile Phones based Adaptive Platform for Experimental Social Psychology Research. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Copenhagen, 2010. *Proceedings*... Copenhagen, p. 281-290. http://dx.doi.org/10.1145/1864349.1864393

RAMOS, H.S.; ZHANG, T.; LIU, J.; PRIYANTHA, N.; KANSAL, A. 2011 .LEAP: a low energy assisted GPS for trajectory-based services. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings*... Beijing, p. 335-344. http://dx.doi.org/10.1145/2030112.2030158

RAZAFINDRALAMBOO, T.; MITTONO, N.; VIANA, A. C. 2010. Adaptive Deployment for Pervasive Data Gathering in Connectivity-Challenged Environments. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Mannheim, 2010. *Proceedings*... Mannheim, p. 51-59. http://dx.doi.org/10.1109/PERCOM.2010.5466992

REDDY, S.; ESTRIN, D.; HANSEN, M.; SRIVASTAVA, M. 2010. Examining Micro-Payments for Participatory Sensing Data Collections. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Copenhagen, 2010. *Proceedings*... Copenhagen, p. 33-36. http://dx.doi.org/10.1145/1864349.1864355

REDDY, S.; ESTRIN, D.; SRIVASTAVA, M. 2010. Recruitment Framework for Participatory Sensing Data Collections. *In:* INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING, Helsinki. 2010. *Proceedings*... Helsinki, p. 138-155. http://dx.doi.org/10.1007/978-3-642-12654-3_9

RICE, A.; HAY, S. 2010. Decomposing power measurements for mobile devices. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Mannheim, 2010. *Proceedings*... Mannheim, p. 70-78. http://dx.doi.org/10.1109/PERCOM.2010.5466991

ROGERS, Y.; HAZLEWOOD, W.R.; MARSHALL, P.; DALTON, N; HERTRICH, S. 2010. Ambient Influence: Can Twinkly Lights Lure and Abstract Representations Trigger Behavioral Change? *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Copenhagen, 2010. *Proceedings*... Copenhagen, p. 261-270. http://dx.doi.org/10.1145/1864349.1864372

SATYANARAYANAN, M. 2011. Pervasive computing: vision and challenges. *Personal Communications*, **8**(4):10-17. http://dx.doi.org/10.1109/98.943998

SAXENA, N; UDDIN, M.B.; VORIS, J.; ASOKAN, N. 2011. Vibrate-to-unlock: Mobile phone assisted user authentication to multiple personal RFID tags. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Seattle, 2011. *Proceedings*... Seattle, p. 181-188. http://dx.doi.org/10.1109/PERCOM.2011.5767583

SCELLATO, S.; MUSOLESI, M.; MASCOLO, C.; LATORA, V.; CAMPBELL, A.T. 2011. NextPlace: a spatio-temporal prediction framework for pervasive systems. *In:* INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING, San Francisco, 2011. *Proceedings*... San Francisco, p. 152-169. http://dx.doi.org/10.1007/978-3-642-21726-5_10

SILVA, T.H.; DE MELO, P.O.V.; ALMEIDA, J.M.; LOUREIRO, A.A.F. 2012. Uncovering Properties in Participatory Sensor Networks. *In:* INTERNATIONAL WORKSHOP ON HOT TOPICS IN PLANET-SCALE MEASUREMENT, Lake District, 2012. *Proceedings…* Lake District, p. 33-38.

STAJANO, F. 2004. Will your digital butlers betray you? *In:* ACM WORKSHOP ON PRIVACY IN THE ELECTRONIC SOCIETY, New York, 2004. *Proceedings*…New York, p. 37-38.
http://dx.doi.org/10.1145/1029179.1029191

STEINHOFF, U.; SCHIELE, B. 2010. Dead Reckoning from the Pocket - An Experimental Study. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Mannheim, 2010. *Proceedings*... Mannheim, p. 162-170.
http://dx.doi.org/10.1109/PERCOM.2010.5466978

TOCH, E.; CRANSHAW, J.; DRIESLMA, P.H.; TSAI, J.; KELLEY, P.; SPRINGFIELD, J. CRANOR, L.; HONG, J.; SADEH, N. 2010. Empirical Models of Privacy in Location Sharing. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Copenhagen, 2010. *Proceedings*... Copenhagen, p. 129-138.
http://dx.doi.org/10.1145/1864349.1864364.

TRUONG, K.N.; KIENTZ, J.A.; SOHN, T.; ROSENZWEIG, A.; FONVILLE, A.; SMITH, T. 2010. The design and evaluation of a task-centered battery interface. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Copenhagen, 2010. *Proceedings*... Copenhagen, p. 341-350.
http://dx.doi.org/10.1145/1864349.1864400

WEI, J.; WANG, X.; PEIRIS, R.; CHOI, Y.; MARTINEZ, X.; TACHE, R.; KOH, J.T.; HALUPKA, V.; CHEOK, A.D. 2011. CoDine: an interactive multi-sensory system for remote dining. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings*... Beijing, p. 21-30.
http://dx.doi.org/10.1145/2030112.2030114

WEINSCHROTT, H.; WEISSER, J.; FRANK, D.; ROTHERMEL, K. 2011. Participatory Sensing Algorithms for Mobile Object Discovery. In: IEEE INT. CONF. ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Seattle, 2011. *Proceedings*... Seattle, p.128-135.
http://dx.doi.org/10.1109/PERCOM.2011.5767577

WEISER, M. 1993. Some computer science issues in ubiquitous computing. *ACM Communications*, **36**(7):75-84.
http://dx.doi.org/10.1145/59544.159617

WEISER, M.; GOLD, R.; BROWN, J.S.1999. The origins of ubiquitous computing research at parc in the late 1980s. *IBM Systems Journal*, **38**(4):693-696.
http://dx.doi.org/10.1147/sj.384.0693

WIESE, J.; KELLEY, P.; CRANOR, L.; DABBISH, L; HONG, J.; ZIMMERMAN, J. 2011. Are you close with me? Are you nearby?: investigating social groups, closeness, and willingness to share. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings*... Beijing, p. 197-206.
http://dx.doi.org/ACM.10.1145/2030112.2030140

WILLIS, K.; POUPYREV, I. 2010. Pixels: Exploring Social Drawing on Mobile Phones. *In:* INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING, Helsinki. 2010. *Proceedings*... Helsinki, p. 391-408.
http://dx.doi.org/10.1007/978-3-642-12654-3_23

XU, X.; GUT, L.; WANG, J. 2010 Negotiate Power and Performance in the Reality of RFID Systems. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Mannheim, 2010. *Proceedings*... Mannheim, p. 88-97
http://dx.doi.org/10.1109/PERCOM.2010.5466989

YANG, J.; VARSHAVSKY, A.; LIU, H.; CHEN, Y.; GRUTESER, M. 2010. Accuracy characterization of cell tower localization. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Copenhagen, 2010. *Proceedings*... Copenhagen, p. 223-226.
http://dx.doi.org/10.1145/1864349.1864384

YANG, Z.; WU, H. 2011. Mobile Node Rostering in Intermittently Connected Passive RFID Networks. *In:* IEEE INTERNATIONAL CONFERENCE ON PERVASIVE COMPUTING AND COMMUNICATIONS (PERCOM), Seattle, 2011. *Proceedings...* Seattle, p. 111-119.
http://dx.doi.org/10.1109/PERCOM.2011.5767575

ZHANG, D.; LI, N.; ZHOU, Z.; CHEN, C.; SUN, L.; LI, S. 2011. iBAT: detecting anomalous taxi trajectories from GPS traces. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings*… Beijing, p. 99-108.
http://dx.doi.org/10.1145/2030112.2030127

ZHUANG, J.; MEI, T.; HOI, S.C.H; XU, Y-Q; LI, S. 2011. When recommendation meets mobile: contextual and personalized recommendation on the go. *In:* ACM INTERNATIONAL CONFERENCE ON UBIQUITOUS COMPUTING, Beijing, 2011. *Proceedings*... Beijing, p. 153-162.
http://dx.doi.org/10.1145/2030112.2030134

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