Location-based Crowdsourcing: Extending Crowdsourcing to the Real World

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ABSTRACT
The WWW and the mobile phone have become an essential means for sharing implicitly and explicitly generated information and a communication platform for many people. With the increasing ubiquity of location sensing included in mobile devices we investigate the arising opportunities for mobile crowdsourcing making use of the real world context. In this paper we assess how the idea of user-generated content, web-based crowdsourcing, and mobile electronic coordination can be combined to extend crowdsourcing beyond the digital domain and link it to tasks in the real world. To explore our concept we implemented a crowdsourcing platform that integrates location as a parameter for distributing tasks to workers. In the paper we describe the concept and design of the platform and discuss the results of two user studies. Overall the findings show that integrating tasks in the physical world is useful and feasible. We observed that (1) mobile workers prefer to pull tasks rather than getting them pushed, (2) requests for pictures were the most favored tasks, and (3) users tended to solve tasks mainly in close proximity to their homes. Based on this, we discuss issues that should be considered during designing mobile crowdsourcing applications.

Authors Keywords
crowdsourcing, mobile phone, context, location

Categories and Subject Descriptors
H.5.3 [**Group and Organization Interfaces**]: Collaborative computing, Evaluation/Methodology, Organizational design; H.5.2 [**User Interfaces**]

INTRODUCTION
Over the years the World Wild Web (WWW) has evolved beyond being a platform for retrieving information only but has become a ubiquitous medium supporting various forms of communication, peer-to-peer interactions, shared collaboration, and the creation of user-generated content. Many projects emerged over the past years whose success is based on the contributions of a huge number of people. Wikipedia is a prominent example, which utilizes the broad knowledge of a massive number of people on the Internet. OpenStreetMap is another example where many users, living in different geographical regions, contribute, share, and process their location tracks to make a comprehensive online map. These are just two of many examples where a large number of people, who are often part of a community, make small contributions, which led to a completely new type of applications that would have been hardly imaginable before the pervasive availability of the WWW.

With the ubiquity of interactive mobile devices providing location awareness and network connectivity we expect this trend to accelerate. People carry their phones with them the entire day, providing them the opportunity to contribute at any time. We imagine that new forms of contributions (e.g., real-time media and tasks that require physical presence) will become accessible similar to knowledge work and information sharing in the WWW. Smart mobs [15] and dynamic ride sharing services are current examples that involve physical presence in order to complete a task.

One specific form of harvesting wisdom of the crowd and contributions from users is crowdsourcing, as introduced by Jeff Howe [6]. The concept describes a distributed problem-solving and product model, in which small tasks are broadcasted to a crowd in the form of open calls for solutions. As a strategic model, crowdsourcing tries to attract interested and motivated crowds capable of providing the required solutions in return for incentives (mainly small amounts of money). Often, such so-called crowd workers gather in online communities consisting of experts, small businesses, and other volunteers working in their spare time. As a result, problems can be addressed very quickly, at little cost, and the task provider might exploit a wider range of talents [9]. Tasks are normally initiated by a client and are open either to anyone or to particular communities. The solution may be submitted by individuals as well as by a group. In comparison with ordinary "outsourcing", a task or problem is outsourced to an undefined public rather than to a specific body. Crowdsourcing is effective in areas where the task can be easily described to humans and where these tasks are easier to do for humans than for computers, e.g., perception tasks and tasks involving creativity.

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We argue in this paper that mobile crowdsourcing offers great potential and new qualities when considering and exploiting the context of the user, e.g., his location. Mobile phones are ubiquitous in many parts of the world. Nowadays most devices provide not only means for communication and interaction, but they typically are enhanced with a range of different sensors (e.g., camera, GPS, accelerometer), hence making it possible to easily extract context information. When additionally considering that the WWW and data services are becoming more common on mobile phones, we envision such devices being the upcoming platform for crowdsourcing. We believe that mobile, and especially location-based, crowdsourcing has the potential to go beyond what is commonly referred to as "traditional" (digital) crowdsourcing by bringing it to the real world. Therefore we exploit both the seekers' and the solvers' physical location. We focus especially on tasks that go beyond the provision of digital content with no clear limitation on how they are being solved.

We conducted two field studies that focus on the evaluation of constraints and challenges that affect the crowd workers' behavior. We found out that location (and hence the opportunity to retrieve tasks in the vicinity) has a crucial impact when it comes to assigning tasks by the crowd workers. Nowadays time is scarce. Thus most users preferred quick-to-solve tasks in close proximity, which required minimal effort. This is backed up by the fact that crowd workers in the study tended to choose tasks, which could be solved through physical interaction, e.g., taking a photo.

The contributions of this paper are as follows: (1) We introduce the architecture and implementation of a prototype system, which supports mobile crowdsourcing based on location information. (2) In a qualitative user study among 18 participants we explore novel aspects of crowd working and how location-awareness may facilitate and impact on the crowd working process. (3) We present design guidelines, helping developers of context-aware crowdsourcing applications to enhance functionality and uptake among potential crowd workers.

This paper is structured as follows: we start with a brief overview of related works before presenting our concept in more detail. Then we explain the implementation and architecture of our prototype system. We describe the evaluation and report the results of our user study before finally outlining and discussing our design suggestions.

BACKGROUND AND RELATED WORK

The Internet has become an essential platform for seeking and sharing information, communication, presentation, and collaborating for many users. This is facilitated by many applications, platforms, and services that are provided on the Internet. For many of these systems it is essential that Web users actively participate in generating content and providing services. Such applications and platforms that rely on the active contribution of the Web community are the center of the Web 2.0 phenomena.

The contribution to services happens in different ways. In the following we discuss user-generated content and crowdsourcing in more details, as they have been the inspiration for the implemented platform.

User-Generated Content

The creation of content can be discriminated in explicit and implicit content generation. It can be generated on the initiative of the contributor (e.g., adding a new entry in Wikipedia), based on a coordinated call (e.g., someone asks for the clean-up of an article, someone initiates a call to read chapters in librivox[1]), or on request from a potential web user (e.g., a request in a forum).

Explicit content generation describes the process in which a number of web users individually produce content. The content production may be carried out independently or as a part of a coordinated effort. In both cases the central value is in the collective result. Wikipedia, an online encyclopedia, is an example, which is created based on entries added by a large number of web users. Similar examples are product reviews, experience reports, and recommendations provided by customers for others in online shopping platforms. Such collections are sometimes seen as making use of the wisdom of the crowd. There have been recent researches that assess how to best harness the wisdom of the crowds [9] [4]. Explicitly generated content requires effort by the user and typical incentives are peer recognition or immaterial or material benefits, such as payments or vouchers. In [12] the authors investigate how financial incentives impact the performance.

In contrast, implicit user-generated content describes content that is generated by implicit human computer interaction [16]. A prime example is a news website that provides a category "most popular articles" or an online shop with a top 10 of sold articles. Here users generate content (in these cases recommendations) by their actions (reading, downloading, and buying). What is interesting with regard to implicit user-generated content is that there is no extra effort required for the user in order to contribute this content, nevertheless there might be a cost associated (e.g., the loss of privacy). Looking to mobile technologies an example of implicitly generated content is the route someone takes from one location to another. If this is tracked, then the data can become a resource for others, as evident in OpenStreetMap[2]. While collecting the tracks happens implicitly, the post-processing is an explicit wiki-based creation of street maps with meta-information. In this case, both an implicit and an explicit approach are used. For us these examples highlight the power of mobile crowds combined

[1] www.librivox.org (accessed January 2010)

[2] www.openstreetmap.org (accessed January 2010)

with the WWW to create new resources. Commercial systems like HD-traffic[3] information use coarse location data from cell phones to provide high quality traffic information.

In our work we have looked at different types of user-generated content and aimed at designing the platform to include as many types as possible. We see many crowdsourcing tasks as explicit requests for specific user-generated content.

Games and Content Generation

There are several examples where games are successfully used to create content. Von Ahn *et al*. have shown that labeling images can be packed and provided to the users in a playful way [19] [18]. A side effect of playing the game is then the assignment of tags and labels to images. In this approach the game itself is already the incentive for contributing the content. We can imagine that it is feasible to create mobile games where users on the move through physical space would create meaningful and valuable information. An example could be running from location A to B with the condition to cross as few roads as possible.

Another popular type of game is Geocaching [13] [5]. Many of the motivations are not conflicting with the idea of exploiting the information people create while looking for Geocaches. In many cases players already provide photos of the location where they found the cache. This also coincides with our results discussed later where people favored photo-taking tasks.

Smart Mobs and Ridesharing

Content generation and crowdsourcing tasks are so far restricted to the digital domain. From our perspective coordinated actions in the physical world such as Smart Mobs [15] or ride sharing supported by digital technologies hint a further direction of location and context-based crowdsourcing. The idea of a flash mob is that people use digital technologies and coordinate an action. If the action has a clear goal this is then considered as a smart mob. By bringing a number of people at a specific point in time to a certain location a political statement can be made, a street can be blocked, or an advertising campaign can be started.

With current mobile devices a new generation of ride sharing systems is investigated [8]. We see that ride sharing is essentially a crowdsourcing task in the physical world. It is context dependent (time and location) and may have a number of side conditions (e.g., only travelling with a person with more than 5 years driving experiences).

Crowdsourcing

Crowdsourcing on the WWW has gained popularity over recent years. There are several websites available serving as a platform to distribute crowdsourcing tasks. The characteristic of crowdsourcing tasks is that they are typically difficult to solve by computers and easily accomplished by humans. Examples of such tasks are the tagging of images, e.g., images of garments for an online catalog. Here the aim is to get a representative set of keywords so that users can find what they are looking for. Other domains are natural language processing, summarization, and translation. There is no clear limitation to what type of tasks can be solved through crowdsourcing, as long as they can be described in the system and the answer can be provided over the Internet. In most cases small amounts of money as compensation are provided to the users.

Crowdsourcing on the World Wide Web

Currently there are several websites available that are based on the concept of crowdsourcing. Amazon's Mechanical Turk[4] is a web-based marketplace for works requiring human intelligence in which anybody can post their tasks and specify prices for completing them. iStockPhoto[5] is a web-based company offering huge collections of images uploaded and sold by photographers. Clients seeking stock images purchase credits and start buying the stock images they want. Another example is Innocentive[6], which allows companies with specific R&D needs to share their challenges and specify awards among scientists dispersed all over the world. The solvers can submit their solutions through the Web, which go under review by the seeker. Also CambrainHouse[7], built on crowdsourcing foundations, collects, filters, and develops the software ideas coming from the crowds. Artists or anyone with spare creativity can submit their T-shirt designs in Threadsless[8], a clothing company collecting votes from the community and producing the top rated designs. In [7] it is explained how the power of Web 2.0 technologies and crowdsourcing approach are used to create new approaches to collecting, mapping, and sharing geocoded data.

Furthermore, there are researches that investigated various features of crowdsourcing systems. In [2] essential features of a crowdsourcing system and the precise relationship between incentives and participation in such systems are discussed. The authors reported that rewards yield logarithmically diminishing returns with respect to participation levels. In [1] authors studied Google Answer and found out that questions offering more money received longer answers. Yang *et al.* [20] explored the usage of the site "Taskcn", a Chinese site where users submit solutions for various tasks and the winner earns a monetary reward. They found out that while new users are choosing unrealis-

[3] www.tomtom.com/hdtraffic/ (accessed January 2010)

[4] www.mturk.com (accessed January 2010)

[5] www.istockphoto.com (accessed January 2010)

[6] www.innocentive.com (accessed January 2010)

[7] www.cambrianhouse.com (accessed January 2010)

[8] www.threadsless.com (accessed January 2010)

tically, those who are used to the site pursue a more profitable strategy by better balancing the magnitude of the rewards with the likelihood of success. Also Manson and Watts [12] investigated the effect of compensation and performance on Amazon's Mechanical Turk platform and reported that increasing financial incentives increases the quantity of works done by participants but not necessarily the quality of them. In [11] a crowd translator is demonstrated that collects speech data from the crowd through the mobile phones, which is used to build a high-quality speech recognition system.

In the described projects, tasks are location-independent and can be performed on any PC or mobile phone with Internet connectivity. However, there are certain situations where the problems are location-based and physical presence of a person for solving them is required. In our work we focus on location-based problems and on how crowdsourcing can be used to share and solve tasks that are inherently contextual. We fill in the gap between the seekers and a mobile crowd with a location-aware crowdsourcing platform and share tasks based on the solvers' location.

Mobile Crowdsourcing

Various research papers explored crowdsourcing based on the use of mobile phones. Eagle [3] developed *txteagle*, a mobile crowdsourcing system that enables people to earn small amounts of money by completing simple tasks such as doing translation, transcription, and filling out surveys by using their mobile phones. *Askus* is a mobile platform for supporting networked actions [10] that allows specifying tasks, which are then matched by the system to specific persons based on profiles. Such profiles may include geographic location. In contrast to our platform, *Askus* is pushing tasks actively based on a positive match rather than providing an open call addressed to crowd workers present at this location. *Fashism*[9] is an online community that uses phones as a bridge between the physical and digital world. It provides an easy way for customers to get comments on their fashion style while doing shopping by sending a dressing-room photo to the community and getting votes and comments back from the crowds in real time. Google uses crowdsourcing to accumulate the road congestion data and provide the traffic conditions. A user's phone running Google Maps[10] for mobile phones sends bits of data back to Google anonymously, describing how fast he is currently moving. The combination of the data provided by the crowds supply a good overview of live traffic conditions. *Ushahidi* is an open-source platform from Kenya, which allows for crowdsourcing crisis information by letting participants submit information on violence through text messaging using a mobile phone, email, and the Web [14].

In contrast to these examples we deliberately aim at exploiting the users' physical location and context. Additionally we investigate how the results of a crowdsourcing task can go beyond the provision of digital content.

CROWDSOURCING BEYOND THE DIGITAL

When offering tasks to be solved by crowd workers, the person offering the task (in the following also referred to as the *seeker*) defines the product or result that is requested. Typically the seeker has little or no information about the potential crowd workers (*solvers*) that will carry out the task. Hence the description of the task is most critical to achieve the desired result. If tasks are beyond the digital domain and can only be solved in a certain situation it is crucial that the tasks are suggested to seekers who are likely to find themselves in such a situation. The system design needs to include means for matching potential crowd workers in the right location and at the right time with a described task. We believe that certain niches might evolve where crowd sourcing becomes remarkably relevant and successful, especially among certain communities.

In the following we describe several scenarios that focus on tasks, which should be performed in a certain context in the real world and away from the desktop. Such tasks are characterized by the need to be performed in a specific location only, or require the presence of a certain context to solve it.

Scenario 1: Recommendation on demand

John is on his way home from work. On the train he sees an advertisement for a point-and-shoot camera he is interested in. The shop is on his way home but would require a short detour, so he uses mobile crowdsourcing to get information about the availability of the favored camera in this specific store. He is interested in some specific tangible qualities that can be easily assessed while holding the camera in his hands but would be hard to retrieve from a photo. As he trusts the judgment of a fellow customer more than the information he would get from the sales personal, he puts up the task for a crowd worker who just happens to be there.

Scenario 2: Recording on demand

Mary has a very important lecture today at university. The lecturer will discuss the sample questions for the final exam with the students. In the morning she sprains her ankle and hence she cannot go to university. As she knows that many students will attend the lecture, she puts out the task of recording the lecture into the crowdsourcing platform. She specifies the lecture, time, and location of what she would like to have recorded. A few minutes later she gets a positive feedback from Alex who has taken on the task and has a good reputation (completed many tasks and has been highly rated for them). Later, she receives audio and video files of the lecture as well as copies of Alex's notes.

[9] www.fashism.com (accessed January 2010)

[10] www.google.com/mobile/products/maps.html (accessed January 2010)

Scenario 3: Remotely looking around
Sarah lives in New York and she is excited about a new job found in Munich. She will be there for six months and an estate agent has provided her some offers. On the Internet she finds the description of an apartment with some photos of its interior. Unfortunately, the offers did not include any photos and further information about the surrounding area. Using mobile crowdsourcing, she specifies a task and asks for more information on the area including photos. A nearby crowd worker who takes the task provides her a couple of pictures (captured with his mobile phone) of the street, some shops as well as a nice café.

Scenario 4: Real-time weather information:
Bob lives an hour's drive from some great skiing resorts. As his meeting finishes before noon he decides to take the afternoon off in order to go skiing. He is not sure where to go – on the website all resorts state great conditions and perfect snow. From the webcams he cannot really see many differences. He decides to ask the crowds in his three most favorite places about the skiing conditions and crowdedness. Within a few minutes he gets back information from other skiers that provide him with the information.

Scenario 5: Translations on demand
John is in China for two weeks. He decides to buy a very traditional souvenir for his parents. So he goes to downtown and finally finds one. But unfortunately the guys in the store cannot speak English and John does not speak Chinese and so he needs help. With the mobile crowdsourcing platform he searches for someone nearby who can help him in translating English to Chinese.

These scenarios show that crowdsourcing in the real world may offer a new quality. All tasks mentioned above are location-dependent and finding a person in close proximity is a crucial prerequisite. However, the tasks differ fundamentally in their time constraints, task duration, and in the way they are solved by the crowd worker. The time constraints range from minutes up to a day and similarly the duration of the tasks from seconds to several minutes.

A LOCATION-BASED CROWDSOURCING PLATFORM
To investigate the potential of location-aware crowdsourcing we developed a prototype platform to easily create and distribute tasks among crowd workers. The platform consists of three components: (1) A web interface where seekers can upload arbitrary tasks associated with geographical information, (2) a server including a database for storing the tasks, which is responsible for distributing the tasks to potential crowd workers, and (3) a client application on mobile phones for the crowd workers, which pulls available tasks from the database based on the given location. Figure 1 depicts the system architecture.

By providing such a platform we aim at bringing together all kinds of people regardless of their background, skills, and place of residence. So we are able to virtually offer seekers requesting any task at any time and anywhere.

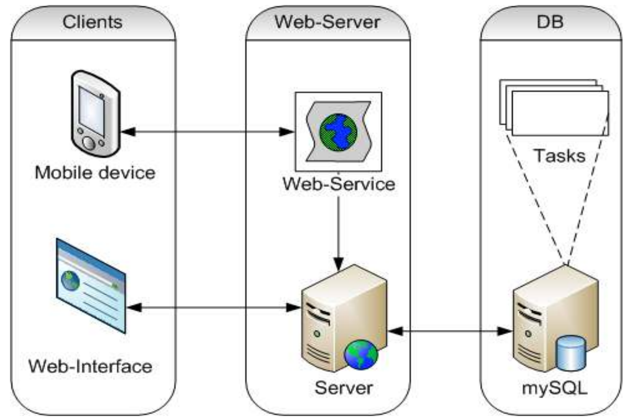


Figure 1: System architecture

Server
The server side is a PHP-based platform consisting of a MySQL database and several web services used by the web platform and the mobile client. The database includes a collection of all tasks defined in the system through the web platform. Each task is specified by a set of properties, which is then used to distribute it among the crowd. In Table 1 we provide a brief overview of the most important properties, which can be specified for each task. All tasks are associated with geographical information (*Location*), which is reused in the matching process to assign tasks to workers based on their current location.

The *Priority* field of a task may be assigned to one of the three following priorities: priority 1 (which is the highest one) means that the task is time-critical and solutions have to be submitted within a pre-defined time period. This amount is being specified in the *Expired* property. Further, tasks with priority 1 are reserved for one solver only. Priority 2 tasks are not time critical (meaning that there is no specified deadline for submitting a solution), but the task is reserved to only one solver. Priority 3 tasks cannot be reserved and users should submit the solution when they sing up for them.

Web Platform
To distribute tasks to the crowd we provide an AJAX-based web platform, which on one hand allows seekers to upload arbitrary tasks and distribute them in the community and on the other hand allows solvers to search and download tasks.

Hence, we provide two different areas for seekers and solvers. The seekers' area includes an overview of all tasks they previously specified (both solved and unsolved) where they can easily track their tasks and find out if a task was downloaded and when. We opted not to provide the names of the solvers in the prototype for privacy reasons – however we plan to integrate synonyms in the future to be able to provide a recommendation system. Further, seekers can create new tasks to be solved. All properties of the tasks

Description	A detailed description of the required task sent to the crowd worker
Location	The geographical location (longitude, latitude) for the task, e.g., a shop
Vicinity	Specifies a radius around the task location in km. This indirectly influences the amount of crowd workers receiving this task
Reward	Specifies the incentive if a crowd worker accepts to solve this task
Priority	Specifies the priority of the task
Expired	Allows for specifying a time interval in which a crowd worker has to submit the task solution. This is important for time-critical tasks
Assigned	The time a user accepted to work on the task
Solution	The solution of the task as entered by the crowd worker
Submission	The time the solution was submitted by the crowd worker

Table 1: Task's properties specified by the seeker

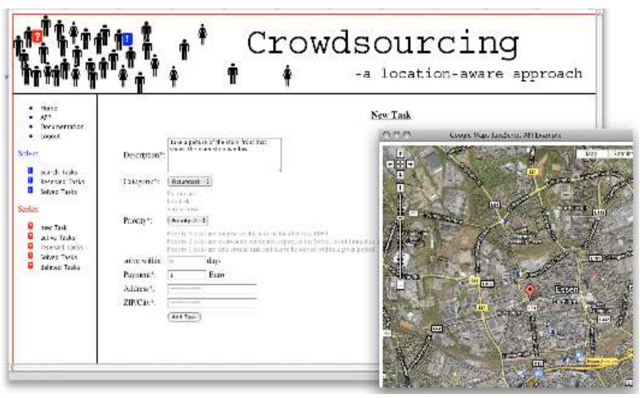
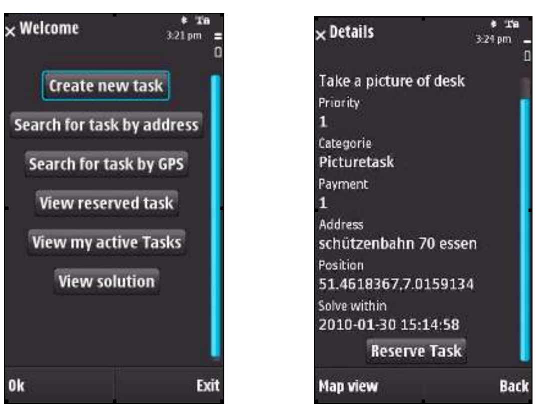


Figure 2: The web client: seekers can define new tasks in database and use Google Maps to specify the location.



(a) (b)

Figure 3: The mobile client screenshots: (a) Main menu where users can search tasks. (b) A sample task retrieved from the database.

have to be provided completely before they are stored in the database and made available to potential solvers. For simplicity, seekers are not required to enter the geographic coordinates of a task but can use a nearby postal address based on which the correct coordinates are calculated. It is also possible that seekers specify the task's location on Google Maps from where the geographical data are extracted (Figure 2). The solvers' area includes an overview of all tasks they assigned themselves (both solved and not yet solved tasks). Besides submitting a task via the mobile client, solvers may also enter the solution to their task via the web interface. However this feature was not used during the evaluation.

Mobile Client

We developed a JME-based mobile application, which can be used both by seekers and solvers. For solvers, the application lets users retrieve tasks from the database based on given locations. The location can be retrieved either by using an (internal or external) GPS receiver or by providing a postal address (street and zip code/city), which is then converted into geographical coordinates on the server. Additionally a Google Maps view is provided to the users to specify their location and retrieve tasks. This setup allows for retrieving tasks not only based on the current location but also based on other locations, which crowd workers potentially might visit in the near future (e.g., on the way home). Additionally, users can use this feature indoors where GPS devices do not work properly.

When it comes to working on a task, two different modes of the mobile application can be distinguished: the assignment mode and the solution mode. In the *assignment mode* the crowd worker can browse and preview available (location-based) tasks based on the given location. Once he decided to work on a task, he may assign himself the task. Based on the *Priority* property, the task may be unavailable to other workers for the period of time specified in the *Expired* property. If the user does not submit his task during this period, the task is released and become available again to all crowd workers. It is also possible to assign more than one task at a time (however we limited the amount of parallel tasks to two for the study). In the *solution mode*, workers can submit their solutions for assigned tasks. In the current version, the submission can be based on texts and pictures. During the design process of the user interface, we focused on keeping the interface simple. Hence, we use a wizard interface to guide users through the different steps of assigning, solving, and submitting the tasks. Figure 3 shows screenshots from the mobile clients.

When using the mobile client as a seeker, the user may create new tasks and publish them to solvers by uploading them onto the server. This allows seekers to create tasks at any time, e.g., while being in transit. The location of the task can be set independent of the current location.

USER STUDY

To gather data on the users' crowdsourcing behavior, we conducted two user studies. To obtain reliable results we wanted users to act in their natural environment. Hence, we opted to do field studies in a familiar setting that is at home, at work, and in the city center of users' hometowns.

Initial Study

Due to the complex setup und amount of influencing factors, we decided to run a pre-study for gaining initial insight in potential challenges as well as a better understanding of the users' crowdsourcing behavior.

Demographics

For the study we recruited nine volunteers via mailing lists, from our courses, and friends. In total, four males and five females participated in the study. Participants were employees (3), students (4), and interns (2), with an average age of 27 years. Prerequisites to participate were that the subjects went to office or the university campus minimum once per working day, and had to own a mobile phone.

Study Setup

To simulate location-based crowdsourcing we asked the participants during the recruiting process to provide us their home and office address, which we used to define different tasks in the database. We divided the tasks into two different dimensions: location and type of tasks. For the *location* we had (1) tasks at/nearby the users' home location, (2) tasks at/nearby the users' office locations, and (3) tasks in the city center of their hometown. For the *types* of tasks, we distinguished between (1) photo tasks, which required using the phone's camera, (2) informative tasks, which required the user to type in some information into the application, and (3) action tasks, which required the user to perform a certain kind of action (see Table 2).

For each participant we then created two different tasks per location and per task type, resulting in an initial set of 6 tasks per user (54 altogether). Then we "refilled" the task list daily based on the tasks the participants opted to complete. There was no restriction for the participants solving tasks and they were free to solve as many as they wanted. We assigned geographical coordinates and a vicinity of 2km to each task based on the location where we wanted the task to be solved. Table 2 shows a sample set of tasks for one participant for a day. Based on the current location maximum just six tasks were visible at the same time.

For those participants who had a mobile phone equipped with GPS and compatible with our application we helped them with the installation and testing. The other participants were provided with Nokia N73 phones where we had preinstalled the application. Since our application allows for extracting tasks based on both geo-graphical coordinates and postal addresses, we divided the participants into two groups. We asked the first group to only retrieve tasks using the GPS receiver in the first week whereas the other group started with address-based selection. After one week,

	Photo Task	Informative Task	Action Task
Home	Take a photo of the closest mailbox	Check the price for a 8GB *iPod Nano* in the nearby electronic store	Send an email to the user study instructor telling him how many bottles of wine you have at home
	Take a photo of your refrigerator	Check how many of the laptops on sale are left at the discounter market	Buy a small bottle of coke from the store around the corner
Office	Take a photo of the coffee machine	Check the departure time of the next bus	Bring a cup of coffee to your colleague next door
	Take a photo of your desktop	Count the number of colleagues currently at their desks	Call the office of the user study instructor
City center	Take a photo of the central post office	Check the opening hours of the Apple store	Buy some milk chocolate

Table 2: A task table for one participant on the 3rd day

groups changed the retrieving mode, which could be verified based on the log data. After the two-week study, participants were asked to fill in a final questionnaire.

Results

The experience we gathered during the initial study showed that location-based crowdsourcing has potential for many application areas. From 50 tasks in the database 30 have been accomplished in the end. Based on the study, the questionnaire, and the analysis of our log data we extracted the following key findings:

Users prefer address-based task selection: Our questionnaire revealed that more than three quarters of the participants preferred to retrieve tasks using postal addresses. There are three potential reasons for this: First, both connecting an external as well as activating an internal GPS device puts a burden that many users are not willing to accept. Second, users were often indoors or in public transportations when selecting tasks using the GPS receiver does not work properly. Third, tasks were mainly situated in places people lived in and were familiar with, which made address-based selection an easier option.

Picture tasks are most popular: Interestingly taking pictures was the most popular task among the participants. Obviously most participants could easily handle using the camera of the mobile phone and preferred this task against more time-consuming informative tasks (due to the need to type in the solution) and the action tasks.

Tasks were mainly solved at or close to home: Based on the results from the questionnaire and an analysis of the solved tasks we found out that the favorite location where users worked on their tasks was at or close to their homes (45% of the tasks).

Tasks are solved after work: When analyzing the times users assigned themselves tasks, we found out that there are peaks in the morning (25% of the tasks were assigned between 6am and 9am, most likely on the way to work), during lunch time (21%), and after 5pm (40%). Interestingly, tasks assigned in the morning were not solved immediately, but mainly after work (81% of all solutions were submitted after 3pm). Thus, we conclude that people tend to download tasks whenever they are free (on the way to work, during breaks, on the way home) and potentially plan to solve the tasks on their way home. This is also supported by the fact that tasks close to home are mainly solved in the study. Further, this might also explain why users favored address-based selection, since retrieving tasks at locations different from the current one is only possible with address-based selection in our implementation.

Response times vary: When analyzing the response times (the time between assigning a task and submitting the solution), we found that 40% of the tasks were solved within the first 3 hours, 70% within 15 hours, and 90% within 20 hours. This implies that mobile crowdsourcing works very well within a time frame of one day – however for time-critical tasks, further investigation is necessary.

Second Field Study

Based on the result of the pilot study where we mainly gathered qualitative feedback, we conducted a second field study with 9 participants, aiming at providing empirical evidence for our findings. The participants were recruited from mailing lists and none had participated in the first study. The participants used their own mobile phones and SIM cards. Their phones had an integrated camera (hence all participants could solve picture tasks), and we made sure that the application was compatible with each phone.

Demographics

The participants of the second study were three females and six males with an average age of 26 years. Six participants were university students with various majors (computer engineering, economics, applied informatics, education science) and the other three were employees. Further, five participants had surfed the WWW via their mobile phones before and five had at least once installed an application on their mobile phones. Only one of the participants had experience with crowdsourcing platforms (Amazon Mechanical Turk).

Study Setup

The study ran for a week with a similar setup as the initial study, however we made minor changes. To provide an even more natural environment, we asked the participants to use their own mobile phone. We invited participants to our lab and after explaining the study to them we installed and tested the application on all phones.

The tasks used over the course of the study were similar to the initial study. However, since we found out that users completed most tasks in close proximity of their daily whereabouts, we asked the participants to provide us a frequent visited address in addition to their home and office addresses, e.g., their parents' or friends' addresses to better simulate a real-world scenario. The given addresses were used to define different tasks in the database (see Table 2). Since most of the tasks in the first study were solved after 3pm, we decided to refill the task tables for each participant in the evenings. As compensation we paid each participant 20 Euros.

In the first study we found out that users were hardly interested in using GPS data for retrieving tasks, hence we disabled this feature for this study and asked all the users to search for tasks by postal address only. Similar to the first study, there was no limitation on solving tasks and they could decide whenever they wanted to use the system. After a week we asked the users to fill in an online questionnaire, which included questions related to the crowdsourcing platform and a System Usability Scale (SUS) test.

Results

During this study 55 out of 110 tasks we provided in the system beforehand were completed successfully (average per participant = 6.1, SD = 2.4). Based on qualitative and quantitative feedbacks from the questionnaire and the log files we derived the following results (results are based on a 5-Point Likert scale, 1 = don't agree at all, 5 = fully agree; given percentages are based on ratings of 4 or 5):

Informative tasks are as popular as Picture tasks: from all accomplished tasks, 23 were Picture tasks, 21 were Informative tasks, and 11 were Action tasks. The popularity of those two types of tasks is also verified by the participants' answers in the questionnaire: 89% of all users agreed or fully agreed to prefer Picture tasks, 89% answered to prefer the Informative task, and 11% to prefer Action tasks. This shows that Informative tasks were equally interesting for the users even though they had to enter texts as solutions making those tasks more complex than Picture tasks.

Time-critical tasks are out of interest: from 55 completed tasks, 30 tasks had priority 3, 20 tasks had priority 2, and just one task had priority 1. This indicates that solving time-critical problems through the location-based crowdsourcing platform cannot be achieved easily because crowd workers prefer tasks without temporal constraints.

Solution should be achievable in 10 minutes: based on the questionnaire results the preferred amount of effort users were willing to take for solving a task is up to 10 minutes (88%). This also supports the previous finding since Picture and Informative tasks can, in general, be considered to be less time consuming than Action tasks. Put in other words, this is an indicator for time intensive tasks being less popular and it might be hard to find crowd workers for solving such tasks.

Tasks are still solved after work: when it comes to the time the tasks' solutions were submitted, we realized that 64% of the tasks were solved after 1pm (most likely after work). Additionally, based on the questionnaires' results, 55% of the participants preferred to use the system in the afternoon and 11% at night (see Figure 4).

Midday breaks are good times to search for task: based on the questionnaire, 45% users tended to search for tasks during midday breaks such as lunchtime or between the lectures and 33% on the way home.

Solving a task can take up to one day: the analysis of the response time (the time between assigning a task and submitting the solution) revealed that 57% of the tasks were solved within 10 minutes, 66% within two hours, and 95% within one day. This supports the finding of the initial study that mobile crowdsourcing works well within a maximum time frame of one day.

Home and surrounding areas are the most favorite places for solving tasks: interestingly, based on the results 66% of the accomplished tasks were retrieved at home and 61% of the solutions were submitted at home. Based on the questionnaire, 77% of the participants tend to solve tasks at home or close to it, 55% around the locations they visited frequently (e.g., downtown, clubs), and 44% around the location they daily went to for shopping.

Voluntary tasks have lower chance: the questionnaire revealed that 77% of the participants had done the task just because of the money, only 22% did it for having fun.

Users search for tasks in their current location: we asked users if they searched for tasks in their current locations or locations which they plan to visit during a day. Based on the results, 88% wanted to search tasks in their current location and 22% also wanted to search tasks in locations where they are going to visit during the day.

The SUS score from the survey was 79.44, which indicates that users were comfortable with the application.

DISCUSSION

Based on the user studies and the survey, the findings indicate that the design choices made for the types of tasks as well as for the means and time of delivery will impact how well location-based crowdsourcing will work. One shortcoming of the study was that tasks were not user-generated but self-designed. Yet, we envision only a minor impact on the solver's behavior even for different tasks.

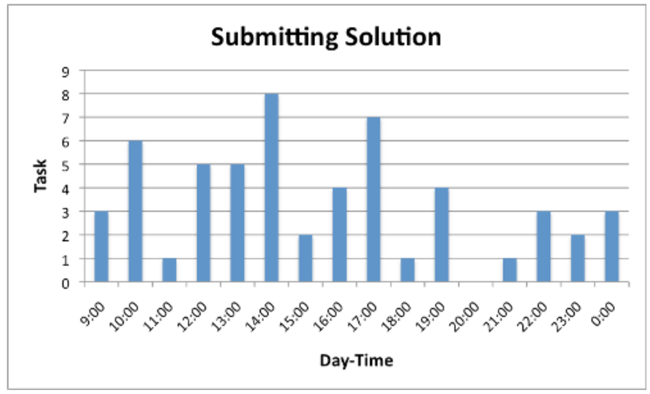


Figure 4: Tasks submitted over the course of a day.

Challenges

We discovered the following challenges:

Users prefer to retrieve tasks by themselves: Users are willing to enter locations by themselves and having control over addresses used while interacting with the system. One main reason can be privacy issues, which is an important aspect in location-based systems.

Provide means for easily choosing the task location: In many cases the locations where users assign themselves tasks are not necessarily the places where they solve them. Hence, an application should enable the user to choose any location, preferably close to their home. Here it might be helpful to provide a map of the surrounding area where users could easily click on a location. Additionally, the frequent locations users visit (e.g., parents' or friends' home, clubs...) have potential for distributing tasks. Hence, history of locations where users used the system and searched for tasks should be taken into account for dealing out tasks. Being able to assign oneself tasks over the course of a day seems to be a helpful feature with good uptake.

Provide means for specifying priorities: Users prefer working on tasks in the after hours, although they tend to search for tasks during the midday breaks or on the way home. Hence, this is where the response time is likely to be short. However this means that seekers setting up tasks in the morning might have to wait the entire day for a result. We suggest using priorities and timer mechanisms for time-critical tasks.

Minimal effort for the crowd worker: We realized in the user studies that tasks requiring minimal efforts are in favor among users. Users mostly want to download a task and solve it afterwards and they tend to send up to 10 minutes to solve a task. Taking pictures was most popular, most likely due to the fact that no typing was required. Nevertheless, Informative tasks were also in the users' favor, since they needed to type very short text. The same might be true for audio and video recording, when the application's interface provides an easy way of using those features. Hence, it is a good strategy to break up tasks into minimal parts with short solutions.

Privacy

Working on location-based tasks raises severe privacy concerns, since from both the location where a user assigns himself a task (e.g., an address) as well as from the task description (e.g., check the opening hours of the post office) the current location of the user can be derived. However, this is not an implementation issue but rather a conceptual problem, which cannot be entirely solved on the system side. Possible options are not to associate the solution submission-time with a task (which only allows to derive an interval in which a user was at a certain location) and to provide users a way to manually enter their current location in an abstract way, such as a zip code or an address in the proximity.

CONCLUSION

In this paper we investigated how crowdsourcing can be extended beyond the digital domain. Based on a discussion of different approaches for content generation, that is explicitly and implicitly, we have proposed an approach for location-based crowdsourcing. To explore the opportunities we created a prototype for location-based mobile crowdsourcing consisting of a web and a mobile client. Through these clients, people of the crowd (solvers) can search for tasks and submit solutions that have a link to the real world.

We evaluated the system in two field studies with 18 participants. The results show the feasibility of location-based crowdsourcing and highlight important aspects. In the discussion we addressed discovered issues and presented recommendations for design and improvement of a mobile crowdsourcing platform. When designing location based crowdsourcing systems and mechanisms for distributing tasks among the crowd the following aspects are crucial for its success and should be supported by the system: chosen location (at best close to the crowd workers home), the type of task (most favorite tasks are taking photos), and the time of day (preferably after work).

As a future work we plan to enhance our applications with video and audio features. Further, it might be interesting to take additional types of users' context into account. We believe that "targeting" tasks might increase the potential of crowdsourcing if the client application is able to learn, e.g., routes the user takes as well as types of tasks and locations he prefers or frequently visit. Finally, we plan to explore how the crowdsourcing application impacts on the uptake and the user behavior among communities (e.g., people might agree to solve tasks without incentives, or provide higher quality results).

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