Capturing context: Mobile and pervasive game-play in participatory sensing

By Bleumers, L. (iMinds-SMIT, Vrije Universiteit Brussel)

Abstract

In participatory sensing (PS), people participate in data gathering and analysis of their surroundings through the use of mobile devices and web services. Often PS campaigns involve concerned citizens. In this paper, I explore how mobile and pervasive game design and research can inform the design of PS campaigns that appeal to a broad audience.

I discuss the outcome of an analysis of 10 game-based PS cases. Making use of Mitgutsch and Alvarado's Serious Games Design Assessment Framework, I have decomposed each case into its different game components, and consider their mutual alignment and their relationship with participatory sensing (i.e. which contextual data is collected, how it is interpreted and represented).

While some game-based approaches to participatory sensing hold promise, this analysis also suggests that care should be taken so as to not compromise the participatory nature of PS campaigns by adding game components.

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[Header 1] Introduction

Participatory Sensing (PS) is "an approach to data collection and interpretation in which individuals, acting alone or in groups, use their personal mobile devices and web services to systematically explore interesting aspects of their worlds ranging from health to culture" (What is Participatory Sensing?, 2013). For example, D'Hondt and colleagues (2013) asked a citizen-led action group to participate in a campaign that involved measuring noise through mobile devices to create a noise map of their city area. Context clearly matters in PS campaigns, as people are encouraged to literally and figuratively speaking 'make sense' of their environment.

D'Hondt and colleagues' study shows that PS campaigns conducted by a group of concerned citizens can result in high-quality data, given extensive calibration and a clear measurement protocol. When one considers scaling up such campaigns, however, the question is raised how to effectively engage a wider audience. How can we create an experience that is fundamentally interesting, and also ensure that the campaign yields the required data? How can we encourage people to contribute to campaign goals, while respecting their autonomy, skills and privacy?

With regard to PS, it is crucial that participants take measurements accurately and report truthfully. Hence, it has been emphasized that mechanisms for incentivizing people (e.g. monetary incentives or reputation scoring) be put in place (Li *et al.* 2012). Such schemes often fail to acknowledge the possibility of making the activity itself more meaningful for participants.

Mobile and pervasive game design and research may inform the design of playful PS campaigns that appeal to a broad audience. Pervasive games – through the use of technology or otherwise – expand beyond the conventions of typical game play, blurring the boundaries of where, when and with whom a game is played (Montola 2005). In this paper, I explore to what extent this idea has been discussed or implemented, and what can be learned from these rare experiments. The starting point for this review is the collection of PS scenarios[i] described by Goldman *et al.* (2009):

- **Personal reflections on environmental impact and exposure** (p.8): E.g. Individuals monitor, reflect on and change their personal behaviour (such as carbon footprint) based on processed, visualized sensor data

- **Participatory sensing for science and education (**p.10): E.g. Scientists and/or teachers set up a campaign in which people search and observe plant life

- **Grassroots sensing by community groups** (p.12): E.g. Community group sets up a campaign in collaboration with a university to expose pollution in their local neighbourhood

- **Personal health monitoring using mobile phones** (p.14): E.g. Elderly use the sensing technology to share specific health and lifestyle information with their caregivers

- **Distributed sensing for commuters** (p. 16): E.g. Bike commuters gather information that enables them to find safer, healthier, social routes to work

[Header 1] Methodology

[Header 2] Case selection

For each of the aforementioned PS types, I looked for cases that introduce game elements to PS (i.e. gamification) or transform PS into mobile games or pervasive games. To describe our selection criteria more concretely, I searched for cases of which the implementation entails:

1. A mobile game, a pervasive game or form of gamification
2. That involves sensor technology, which the Cambridge online dictionary defines as "a device that is used to record that something is present or that there are changes in something".
3. Through which people explore their environment and knowingly gather, interpret and/or contribute info about it
4. Within the scope of the five defined scenarios

In addition, cases needed to be documented to a sufficient degree. I also allowed cases that were still in a conceptual or prototypical form.

[Header 2] Case search

To find cases that met these criteria, I ran a literature search on the following databases, in addition to a grey literature search on Google and Google Scholar:

- **PubMed**
- **ERIC**
- **PsycINFO**
- **ACM Digital Library**
- **Web of Knowledge**
- **IEEE Xplore**

I searched for sources that referenced to at least one of the search terms of each of the following sets of terms:

- **Set 1**[ii]: Gamification, mobile game, pervasive game, ubiquitous game, treasure hunt, assassination game, pervasive larp, alternate reality game, smart street sports, exergame, playful public performance, urban game, reality game
- **Set 2**: Sensor, sensing, monitor(s)/ing, map(s)/(ping)

- **Set 3**: participatory, grassroots, community, health, wellbeing, commuting, environment, science, education

From the collected cases that met the aforementioned criteria, a final selection of 2 cases per PS scenario was made, which allowed for a comparative analysis.

[Header 2] Analytical framework

I described and analysed each of the cases focusing on the following components: background information (actors involved, development stage, label used to describe the application), participatory sensing involved, the game system, and available user research data. I also specified the source material (literature and websites) from which this information was drawn.

With regard to participatory sensing, I looked at which contextual data is being gathered, and how it is collected, analysed and presented. These three tasks of gathering, interpreting and representing data often involved a combination of technology operation and human effort.

As a lens for looking at the game system (which may be partial in case of gamification), I used an existing framework called Serious Game Design Assessment (SGDA) framework. Mitgutsch and Alvarado (2012) proposed this framework to assess the design of games that were created with a specific purpose beyond entertainment. In essence, it supports the act of examining whether the different game components are balanced and well in line with the purpose of the game.

Aside from the game's purpose, the SGDA framework includes the following components: content (information and feedback given via the game), game mechanics, fiction and narrative (incl. characters and plot), aesthetics and graphics, and framing. To identify game mechanics, I additionally made use of the MDA (Mechanics, Dynamics and Aesthetics) framework (Hunicke *et al.* 2004), a methodological instrument for the creation and study of game design.

As a user researcher, I am particularly interested in the framing component, which encompasses the intended target group (which holds specific skills and interests) and the context of use. I looked for user research data (i.e. positive, negative and neutral issues, and perceived missing features) that were gathered to inform the design process.

[Header 1] Results

A complete list of selected cases can be found in Table 1 below.

Table 1. Overview of the 10 selected cases.

Scenario	Case	Purpose	Participatory sensing
Environmental impact & exposure	Power Agent	Reduce energy consumption	Sensor on power meter Picture taking
	Professor Tanda	Promote environmentally friendly behaviour	Location (Cell ID) Subj. reports (e.g. energy meter)
Science & education	Budburst Mobile	Motivate plant data collection, green space usage and appreciation	Location (GPS) Accelerometer Picture taking
	Black cloud	Foster environmental agency, critical reading and writing	Air quality sensor
Communities & grassroots	Neighbourhood Satellites	Support playful monitoring and awareness of air quality in people's neighbourhood	Air quality sensor Light sensor Accelerometer
	CityWatch	Promote sustainability and connectedness in the city	Picture taking Location tagging
Personal health & wellbeing	'Ere be dragons	Provide an aesthetic experience and make people aware of their body and health	Heart-rate data Location (GPS)
	Wind runners	Encourage daily peak expiratory flow measurement as part of asthma treatment	Spirometer Pressure sensor
Commuting & public transport	Playing in traffic	Promote awareness and help communication between commuters to facilitate traffic	Location (GPS) Accelerometer
	Tripzoom	To understand and influence mobile behaviour on an individual and at city level	Location (GPS) Accelerometer Wi-Fi, …

[Header 2] Scenario 1: Environmental impact and exposure

The pervasive game *Power Agent* (Gustafsson and Bång 2008; Gustafsson *et al.* 2009) was created to stimulate teenagers and their relatives to reduce energy consumption at home. The game introduces a mission-based competition between teams of households to minimize energy consumption. How well players do also depends on cooperation in their team, such as building consensus and jointly devising strategies. The game platform gathers power meter data. A character, Mr. Q, delivers mission information and feedback (e.g. consumption graphics) to players via their mobile phone.

Similarly, *Professor Tanda* (Chamberlain *et al.* 2007) is a pervasive game in which game-play is facilitated by a character, Professor Tanda, who contacts players via their mobile phone. In contrast to Power Agent, people play

individually and play sessions are brief. At certain moments during the day, they receive environmental questions and feedback from Professor Tanda based on their current situation. Through these context-sensitive quizzes, players are encouraged to reflect on their environmental footprint. The developers hope this will result in more environmentally friendly behaviours.

Preliminary user research data on *Professor Tanda* showed that players desired more social interaction and felt score-based content was missing (Chamberlain *et al.* 2007). In *Power Agent*, interview data (see Gustafsson *et al.* 2009) point towards the competition aspect as a primary driver for engaging with the game. Secondarily, participants reported that the motivation to do well in the game and reduce electricity consumption was strengthened through social demand within the team. Together the user research data underline the importance of interaction with other players.

[Header 2] Scenario 2: Science and education

Han *et al.* (2011) included a game feature similar to geo-caching to a mobile application for the PS project BudBurst, i.e. *Budburst Mobile*, to explore new forms of motivating data collection on plants in the context of climate change. Using a smartphone, participants search for plants at specified locations and receive points for finding them. As soon as they have sufficient points, they can establish so-called floracaches themselves. A plant is officially discovered by taking a picture and making an observation. Being able to see other volunteers' pictures was considered an important motivational factor.

Whereas *Budburst Mobile* was developed for scientific research, *Black Cloud* (Niemeyer *et al.* 2009) was conceived within an educational context. In this alternate reality game, created for secondary school students, air quality information is gathered through a tailored device not just for data collection, but as part of an empowering discovery process in which students gather and generate knowledge about their neighbourhood and report it across different media forms. This discovery process is framed by the story of the appearance of a black cloud, a mystery which students are asked to help unravel.

The role of narrative clearly distinguishes *Black Cloud* from *Budburst Mobile*. While Niemeyer and colleagues acknowledge the immersive potential of the fictional intrigue built up in the game, they also express concerns about immersing students in an alternate reality space where teachers and designers control the process. They argue that a trade-off needs to be made so that students have sufficient access to information and can act upon it without losing the sense of being part of a playful activity.

[Header 2] Scenario 3: Communities and grassroots

In his master thesis project called *Neighbourhood satellites* (NESA) (2005a), Milicevic created a working game prototype to enable people to collectively monitor air quality in their neighbourhood. A sensing device, equipped with an accelerometer and air quality and light sensors, functions as a game controller. A monitor displays game actions and status. A notebook carried in a backpack runs the game in which players collect samples and avoid getting

virtually overwhelmed by pollutants. The activity was intended as a challenge as well as a pastime that makes citizens aware of their environment.

Milicevic's small-scaled project in which he envisioned people eventually assembling sensing devices themselves contrasts strongly with *CityWatch*, which results from collaboration between a city council, university and a major developer (CityWatch n.d.; Wong 2013). Dublin's city residents can download a smartphone app and report positive and negative events or resources by location tagging. Points are given and subtracted for correct and inaccurate tagging respectively and rewards can be gained individually or collectively. What citizens report is combined with fixed sensor and open government data. This is visualized in a public city map, tagged with text and pictures.

Aside from the scale difference, *CityWatch* and *NESA* differ in terms of the extent to which game-play and sensing are connected. The sensing device in NESA is used to control the game through a direct relationship between sensing activity and action in the game space. The anecdotal user evidence (Milicevic 2005b) shows that this requires mastering skill. In the CityWatch case, however, the sensing activity itself is framed as an achievement that is immediately rewarded with points (if deemed authentic).

[Header 2] Scenario 4: Personal health and wellbeing

The project *'Ere be dragons* is an artistic, playful take on making people aware of their own physical health. Boyd Davis *et al.* (2006) describe how they equipped people with a pocket PC rendering a virtual environment that was mapped on their physical location (via GPS data) and condition (i.e. heart rate). Emphasizing discovery and make-believe, they steered away from competitive game formats. Trying out their concept at public events, they found that participants enjoy the real-time mapping but also that, in multi-player mode, some players spontaneously seek out competition.

Wind runners was created by researchers for asthmatic children to support adherence to their medical treatment plan, namely measuring peak expiratory flow (Nikkila *et al.* 2012). Like *'Ere be dragons*, one cannot play without bio-sensing. However, in *'Ere be dragons*, sensing accompanies the entire playful experience, whereas in *Wind Runners* it precedes it, providing necessary resources to play. At the start of the game, players blow air into a spirometer, which fills up a virtual air reservoir in the game. This resource is used to overcome obstacles while navigating through the mobile platform game.

'Ere be Dragons intentionally targets an audience that is not invested in improving their health. On the contrary, *Wind runners* aims to reach an audience that is dealing with a health condition, is likely to be aware of it, but may need help in following a medical regimen and coping with an illness. The latter case may demonstrate that even when people are invested with a particular cause that requires sensing, incorporating game components can still add meaning to the monitoring activity. Nikkila and colleagues (2012) report plans for user testing in their paper that could help to confirm this.

[Header 2] Scenario 5: Commuting and public transport

With the game concept, *Playing in Traffic*, Chan (2011a; 2011b) explores the possibilities of a pervasive game for cyclists and car drivers on their daily commutes. Based on a visual ethnography, Chan identifies commuting as a mainly individual experience, with limited awareness and understanding of other (types of) road users. Chan proposes to get people to play a multiplayer game with role-playing aspects in line with their interests. Referring to Bartle's MMORPG player archetypes (1996, in Chan 2011b), he suggests that explorers for instance could advance in the game by deviating from the routes they frequent. To achieve this, the game would minimally rely on location data.

The *Tripzoom* case (Holleis *et al.* 2012) is part of a European FP7 project focusing on urban mobility management. It is aimed not only at individuals and communities, but also at city administrators, and third party service providers. In the envisioned use case, citizens can gain insight on their mobility patterns through a mobile application, and also receive challenges tied to these patterns. Meeting the challenges is rewarded with points, which can be exchanged for benefits. City representatives would have access to a dashboard application, which allows them to monitor mobility patterns on a city-scale, and provide and adjust incentives to influence transport behaviours.

Placing the player centrally, Chan aims for reflective experience, rather than persuasion, a process of self-discovery rather than instant gratification and improved efficiency. As such, his concept differs from cases such as *Tripzoom* and Waze. *Waze* gives drivers up-to-date road information based on passively collected GPS data and active member contributions (e.g. accident reports). Waze uses points, leaderboards and badges (PLB) to encourage such contributions. This PLB-approach is also evident in *Tripzoom*.

[Header 2] Cutting across scenarios: Coherence

Following the SGDA Framework, I considered how well each case's described characteristics are in line with one another and with the intended aim of the application. In this section, I will elaborate on possible cohesiveness issues, rather than discussing these per case.

A first important observation in this respect is that overall coherence may be challenged when the case originates from a large consortium of partners. Indeed, partners may have different expectations concerning what constitutes a desirable outcome. Given that they are also likely to have different roles in creating and implementing the application, this may lead to an imbalance in the overall game system if this process is not carefully managed.

Secondly, the relationship between the PS process and game-play may vary in strength depending on the role that data collection has in the game. In some cases, the relationship appears strong. Here the sensor device functions as a game controller (e.g. *NESA*), it yields building blocks for story creation (e.g. *Black Cloud*), or it provides game resources (e.g. *Wind runners*). In other cases, it seems weaker. There, the act of sensing is framed

as an achievement and rewarded, with more or less demand on players (resp. *Budburst Mobile* and *CityWatch*). Finally, there are cases where sensing only results in personalization of game challenges (e.g. *Professor Tanda*) or where sensing takes place during game-play but does not have a fixed role in it (e.g. picture taking during *Power Agent* missions).

Thirdly, I considered how the cases' framing (incl. target group and intended usage setting) fitted other case components. Observed efforts or failures to obtain a good fit include allowing participants to choose a difficulty level, tailoring game mechanics to player types, and delivering age-appropriate fiction. When user research was available to ensure a match, it was mainly evaluative in nature. Mostly, it is part of an iterative prototype testing process where evaluation becomes more large-scaled as the prototype matures. Only in one case, *Playing in Traffic*, user research was mentioned to have occurred at the start of the design process to inform it.

Finally, misalignment between purpose, the PS activity, and delivered content can occur. Sometimes, it appears to be assumed that access to contextual data will make players more aware about their situation and understand it. Moreover, that they will want to change their behaviour or environment and take action. However, many obstacles can obstruct this chain of events. In *Power Agent*, where the purpose is to reduce energy consumption, this concern was taken up in the design. Players are given suggestions on how to reduce energy consumption, they encourage each other, and can learn from one another's strategies (Gustafsson *et al.* 2009).

[Header 1] Discussion

In this paper, I presented, compared and discussed a series of cases in which participatory sensing was gamified, or embedded within a mobile or pervasive game. To analyse these cases, I applied the Serious Games Design Assessment Framework that was put forth by Mitgutsch and Alvarado (2012) as a lens to critically assess the design of games with a purpose beyond entertainment.

[Header 2] Looking beyond the current study

The SGDA framework appears a meaningful tool, not only to assess existing game products but also to facilitate discussion and maintain cohesion within design research projects leading up to gaming or gamification prototypes. This is acknowledged by the framework's authors: "The framework can be used as a constructive structure for additional (serious) game criticism, assessment and evaluation and it might even structure design and prototyping processes." (p.127, Mitgutsch and Alvarado 2012).

When using the SGDA framework for prototyping, I believe user research would be critical to ensure that a match between the target group and the application is not based on mere assumption, but on actual field data. User research could have a function beyond evaluation, feeding knowledge about the intended audience and usage context into the design and technological research to inform and trigger new design ideas. In future work, I would like to explore how user research could be meaningfully linked to the framework.

Whereas the current study looked at cases that are purposeful by design, it would be valuable to extend the analysis towards game-based applications that could or that are already being repurposed for participatory sensing. One could call this a study of purposeful play as opposed to games that are purposeful by design.

Finally, this study revealed that in many cases participation in sensing involves than people becoming data collectors. Often, a change is envisioned on an individual, collective or environmental level where the gathered data is used to demonstrate a change process to participants, which is also hoped to sustain engagement with the given service. Future work needs to address this feedback loop. When and how do people want access to data representations? Would this be different for people who are already invested in the envisioned change versus those that are primarily interested in playing?

[Header 2] Adopting a critical perspective

Chatzigiannakis *et al.* (2011) posit participatory and opportunistic sensing as two extremes: "With participatory sensing users consciously opt to meet an application request. A participatory approach incorporates people into significant decision stages of the sensing system, such as deciding what data is shared and to what extent privacy mechanisms should be allowed to impact data fidelity. With opportunistic sensing, users may not be aware of active applications; their devices are utilized only when required." (p.105).

For the studied cases, at the very least one can find instances where there is a fine line between participatory and opportunistic sensing. Participants can be highly aware of one type of data being collected, when it is central to game-play and represented visually, but oblivious to other forms of ‘silent sensing’. They may get so caught up in the game that they lose sight of what is being tracked. Or non-participants, innocent bystanders, may unknowingly become the subject of participatory sensing.

A case such as *Tripzoom* combines different data streams, both from participatory and opportunistic sensing (e.g. parking camera surveillance). Its city dashboard where city representatives would monitor the effect of their incentives easily evokes a dystopian vision where both the city and its citizens are programmed and people can only find solace in cheating the system.

Rather than getting lost in technological pessimism, I believe the message should stick that ensuring privacy and autonomy in PS campaigns, game-based or other, cannot be reduced to mobile device owners opting in to share certain data, accepting a list of terms and conditions. People must be kept aware of the contextual data they gather and shown how knowledge about this context may matter to them, but also to other stakeholders.

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[i] Goldman *et al.* (2009) described a comprehensive set of hypothetical PS scenarios which they deemed feasible in the nearby future (p.7).

[ii] Montola *et al.* (2009) discuss different types of pervasive games, the name labels used in their work informed the search term delineation in set 1.