Integrating game elements for increasing engagement and enhancing User Experience in a smart city context[1]

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Abstract. This paper outlines an ongoing project (MITOS), which aims to customize and deploy a software platform providing advanced transportation services in the city of Santander, Spain. The system will be presented with a focus on the design framework and the rationale for evaluating User Experience in such a framework.. Concepts for Future Internet environments, such as participatory sensing, game-inspired practices, and ad hoc social networks, will be employed toward this purpose. A set of experiments will be conducted, aiming to qualitatively and quantitatively evaluate the deployed system and assess the impact that its services have on the city, on its citizens / commuters, and on their attitudes towards public transportation use. The project is expected to provide methodological insights on the design and evaluation of interactive location-based systems in hybrid urban contexts. The impact of the system will be manifold and fully aligned to all dimensions related to the impact of the SmartSantander project: environmental, transportation, societal and research / technological. The deployed platform will be available to the city for further experimentation and commercial exploitation, thus being a sustainable system that can affect the activities of the citizens even after the end of the SmartSantander project.

Keywords. Smart cities, environmental sensing, location-based services, game-like urban activities

Introduction

ICTs are today being recognized as one of the most important factors towards the creation of smart, sustainable cities with high-quality living, and have been applied in areas as diverse as education, crime prevention, energy-saving and public transport. In the area of urban mobility in particular, the utilization of mobile and location-based technologies is considered to be one of the most efficient ways of enhancing a city's

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smart transport infrastructure, on account of the prevalence of GPS-and Internet-enabled smartphones. Citizens equipped with smartphones can act as nodes in a network of sensors which provides data related to the city's transportation services. Additionally, dedicated sensors may be employed in order to provide data such as position of vehicles, availability of parking space, traffic density, atmospheric conditions, etc. We are, therefore, talking about a hybrid sensor ecosystem, in the sense that it combines both human and non-human agents as two distinct yet interrelated sources of city-related data.

This paper outlines a research project, funded under the FP7 framework, which aims to enhance the User Experience of an advanced transportation services platform through *gamification*, i.e. by incorporating simple game elements and mechanics within the very design of the platform [26-27]. This decision was based on the hypothesis that a non-game platform that provides affordances for gameful experiences will support users' overall engagement and value creation. As has been frequently reiterated in the last years, gamified designs encourage technology adoption, motivate user behavior and enhance user satisfaction [28-29]. This is because game-like activities and ludic interfaces tend to make technology more engaging, by encouraging users to adopt desired behaviors, by taking advantage of humans' psychological predisposition to engage in game and by leveraging people's natural desires for competition, achievement, self-expression and enjoyment [30-32]. In the application described in this paper, gamification is employed primarily for motivating the users to use the application, but also as a means of increasing randomness and even providing a convenient entry point for possible future additions, e.g. a narrative structure[3].

More specifically, the project's goal is to motivate citizens to commute more by using public transport and to participate in the collection of related data (traffic, incidents, environmental conditions) by utilizing the aforementioned technologies, as well as to enrich the system with subjectively meaningful location-specific content. By providing the system with information about the transportation conditions in certain locations, citizens may feel they get involved in a common goal. By enriching specific locations with meaningful comments, various forms of social interaction amongst some of these citizens may emerge, ultimately leading to an improvement of the social use and appropriation of these technologies and the appearance of novel forms of social behavior which are worth investigating in a systematic and rigorous fashion. The ultimate aim of the project is to foster bottom-up community intelligence and active citizen participation in urban matters.

1. Overview of the *SmartSantander* project and the MITOS experiment

The main goal of the MITOS (Multi-Input TranspOrt planning System) research project is the creation of a European experimental test facility for the research and experimentation of architectures, key enabling technologies, services and applications for the Internet of Things (IoT) in the context of the smart city[4]. The project work team has designed, implemented and deployed all required infrastructure for enabling smart

[3] On a methodological side note, it is important to note that gamification may alter the activity it is applied onto from the user's perspective; a "gamified" application has incorporated game elements into its structure, and these elements may need to be taken into account when evaluating non-game-related aspects of the application. In other words, the practice of gamification may assume the status of the "third variable".

[4] www.smartsantander.eu

city services in the city of Santander and some other facilities across Europe. The project considers the deployment of sensors in Belgrade, Guildford, Lübeck and Santander. The middleware services developed provide all functionality required so that experimenters can deploy their services or algorithms and draw interesting conclusions regarding smart city services, IoT features etc.

As part of this project, an experiment for Intelligent Transportation Services in the context of the Smart City will be designed and performed. The services and applications deployed and demonstrated in the context of MITOS will be:

- A Web portal for transportation information that will be essentially used as a city guide for citizens or tourists. The core functionality provided by the portal will be:
  - Location-based services such as traffic heat-maps, geocoding, visualization of points of interest (POIs), search for transportation information, incident notification, location-aware advertising, parking availability, real-time pollution and temperature information, etc.
  - Optimal-routing for multi-modal transportation. Route planning will rely on dynamic data (either collected from sensors or generated by users).
- A mobile application for advanced transportation services. The application will provide all type of information required by commuters and will enable intuitive ways for searching routes and geo-referenced information based on the personal preferences or abilities of the user. Moreover, it will be used for participatory sensing purposes, complementarily to the existing participatory sensing application.

The MITOS platform will exploit existing sensor sources in order to deliver advanced services to the end users. These sources are:

- A participatory sensing application: users will act as sensors that provide relevant traffic and travel information in the form of free text or predefined messages (e.g. “heavy traffic”, “too much noise”, etc.) and/or image[5]. This strategy is expected to reduce the total amount of messages requiring moderation, thereby reducing the moderator’s workload. They will be able to report incidents and traffic congestion. In this sense, the act of gathering data on the city’s everyday functioning becomes a more decentralized process.
- Environmental data: data stemming from environmental sensors deployed in the smart city (noise, temperature, CO/ CO_2 emissions) will be used in order to evaluate the environmental improvements resulting from the increased use of public transportation as well as current environmental conditions in the city.
- On-street parking space availability. The existing street sensors will be used in order to assist commuters in their trip planning and facilitate combined mobility modes (e.g., car and bus) by offering information on parking availability.
- Traffic intensity estimation. The existing traffic data will be fed into the platform in order to enable better and more accurate transportation guidance to citizens.

[5] This strategy is expected to reduce the total amount of messages requiring moderation, thereby reducing the moderator’s workload.

- On-vehicle devices (GPS) will be also interfaced to the platform in order to provide accurate arrival and inter-arrival times of public transport.

Several algorithmic issues are considered during the setup of the experimental platform. For example optimized routing and trip-time estimation algorithms are involved which have been already applied to other cases [24]. Moreover, the system will be able to take into account user preferences or limitations in order to deliver personalized route selection.

2. Application functionality

The main concept behind the MITOS project, in order to provide advanced transportation services, is not only to deploy data derived from the existing sensor and middleware infrastructure available in Santander, but also to engage citizens in participatory sensing practices. This methodology is considered to contribute to the accuracy and the quality of the services offered by the system, as it provides commuters with accurate information about incidents and issues pertinent to the transportation, as well as to the environmental conditions of the city. As a means of making the system more appealing and fun to use, the central design principle of MITOS is to incorporate game-like features in certain aspects of everyday transportation and at the same time support the emergence of ad hoc social networks.

The MITOS project features a game-like activity taking place in real time throughout the city of Santander. The game is persistent; it is always going on, and users can participate whenever they wish. The MITOS system, largely making use of an existing software platform developed by Mobics in Athens, Greece, is designed to encourage gameplay while on the move, so that commuters can easily participate. Therefore, two types of users may be distinguished in the MITOS system: *mobile* and *desktop*. The former use an application on their mobile phones, whereas the latter connect via a desktop computer. A map displays all active mobile users as they move around in the city. Desktop users have access to the whole city map, where the positions of all active users are updated in real time. Desktop users can see events recorded in the entire city area, while mobile users can see a limited number of users and events based on proximity. Users may alternate between desktop and mobile mode.

MITOS utilizes an achievement and task-reward system as a means of encouraging the use of the application. The basic goal of the game is to gather as many points as possible. Points will be translatable to several kinds of tangible rewards, such as free bus tickets or special offers by affiliated shops. Each action in the context of the game corresponds to a specific point value. Thus the possibility of collecting points acts as an incentive for increased usage duration and frequency. Though players do not directly compete against each other, a number of high-scoring players will be rewarded on a daily basis; an optimal number of rewarded players will be sought, so that being rewarded is neither a remote possibility (when only one user is rewarded) nor a certainty (when the reward criteria are too lax, leading to practically everybody wining). Similarly, the most active user of MITOS system during the course of one week will be nominated for a reward of greater value. However, this is a game with no winners and losers in the traditional sense; participation increases the possibility of gaining points, which increases the amount of benefits attained, and even the users who are last in the

standings will have won at least some points – assuming they performed at least one game-relevant action.

In general, players are encouraged to use the public means of transportation and plan their itinerary consulting the MITOS system maps. The maps offer multimodal routing and additionally integrate data provided by a network of sensors, as well as messages posted by users on the platform and relevant geolocated content. MITOS' deployed sensors give information about temperature, CO_2 levels, humidity, noise, number of available parking spaces, etc. Users can access the maps beforehand, while on desktop mode, so as to have a general idea of the traffic situation in the whole city and accordingly decide on the best route; alternatively, they can have a focused view of the surrounding area via the mobile app while on the move.

The main form of communication provided by the MITOS system is text-based. A number of predefined text messages (e.g. "heavy traffic", "accident" etc.) are available, in order to expedite the process of reporting traffic-related issues. Alternatively, users may compose their own message (up to 140 characters). Employing the aforementioned tools, participants can report incidents they witness while on the move. Additionally, mobile users can act as "environmental sensors" by providing coarse-grained environmental data (e.g. perceived temperature or sound levels), thus supplementing the detailed information attained by sensing devices located in various parts of the city. They may also take pictures or record video and tag it on specific locations. Participants earn points for each of these actions. Desktop users can also contribute to the exchange of messages, gaining points as well. In such a way, indirect and asynchronous communication among the two functionalities is sustained through the MITOS system.

3. Evaluation

3.1. Objectives: Operationalizing User Experience

The deployed system will be evaluated against both objective and subjective criteria. The former pertain to technical and system-related parameters, whereas the latter are focused on the users' underlying psychological and cognitive processes during system use. The subjective aspect of the evaluation revolves around the concept of User Experience (UX), widely recognized today as one of the most important success factors in developing interactive applications.

Following Hassenzahl & Tractinsky [13], we take UX to be a dynamic process influenced by a variety of factors that can be grouped into three main categories: "user's state and previous experience", "system properties", and the "usage context". Taking *user state and previous experience* to be one of the determining factors influencing UX means considering variables such as a person's previous engagements with technology, motives for using the product, current mental and physical resources, as well as expectations about the system before its actual adoption. A user's experience is also influenced by the *properties of the deployed system* and the user's perceptions of them. "Properties" in this context refers to properties designed into the studied system (e.g. functionality, responsiveness, aesthetics, designed interactive behavior), the properties that the user has added or changed in the system or that are consequential of its use (e.g. content uploaded by the user), as well as the brand or manufacturer image (e.g. sustainability, coolness). Thirdly, the overall UX from interacting with a system is

largely determined by the *context in which it is being used.* UX is context-dependent, meaning that it may change when the context changes, even if the system does not change – thus using an intelligent transport platform in a bus packed with people may be different than using it before entering one's car to drive into the city. The social context also matters, since usage will not only be influenced by what the user is doing but also by who else is present and what their relations are. Overall, context in the UX domain refers to a mix of social context (e.g. being with other people), physical context (e.g. using a product on a desk vs. in a bus on a bumpy road), task context (the surrounding tasks that also require attention), and technical and information context (e.g. connection to network services, other products).

User experience is also fundamentally recognized as being *subjective* in nature and related to an individual's perception and thought with respect to a system. It is also broadly understood as being broader than *satisfaction*, (itself considered one of the aspects of usability [15]), in the sense that it covers more intricate, even latent, symbolic, epistemic, and affective dimensions that cannot be reduced to a mere usability and satisfaction analysis.

Based on these assumptions and the extant literature on the topic [2-7, 12-13, 16-18, 21-23], we have arrived at a number of tentative UX meta-dimensions that serve as the building blocks of the ongoing MITOS research project. More specifically, UX from the MITOS system usage will be evaluated in terms of the following dimensions, each to be analyzed in terms of its components:

- *Functionality and utility:* the usefulness of the system to the users' customary everyday activity.
- *Usability and performance:* the system's objectively (e.g. metrics such as error rate, time to complete tasks etc.) and subjectively (e.g. self-report via questionnaires) assessed ease of use. Cognitive aspects, i.e. the efficiency of the system in terms of cognitive requirements (e.g. attention, memory), are also included in this dimension. Relevant variables include task-goal achievement, efficiency, effectiveness, learnability, understandability, memorability, etc.
- *Emotional impact:* subjective, affect-based evaluation of the system's use (commonly referred to as "user satisfaction"), encompassing perceptions about the product itself and the quality of experience derived from using it. Variables typically associated with this dimension include pleasantness, enjoyment, confidence, trust, intention to use, restriction, liberation, stimulation, identification, evocation, expressiveness, novelty, connectivity, competence

3.2. Research Questions

The specific research questions that underline the focus of the research project are aligned with the basic tenets of our holistic operational definition of UX that encompasses contextual, social dynamic and affective aspects, besides the most pragmatic and functional attributes that are being measured in most usability studies (e.g. [19]). The first set of questions aims to identify the key elements of the overall user experience with the MITOS System, and includes questions such as:

- What are the key elements of the overall User Experience with the MITOS system and how does it compare with users' pre-usage expectations?
- What are the primary influences and determinants of user adoption of the system?
- How do different game elements affect the user experience?
- What benefits and what functional shortcomings do users see in the system?
- To what extent are users able to achieve their goals with effectiveness and efficiency?
- Which factors seem to affect the usability of the system, either positively or negatively?

The second set of questions goes beyond system functionality to explore social interaction and urban space perception. Indicative questions include:

- Do users gain value from other, non-functional and more "social" or epistemic aspects of the system?
- Do users attach value to the collective sensing and content-generating activities on which the reward system is based?
- Did spontaneous social interaction and meaningful social behavior emerge during navigation as a result of having used the system?
- What are the effects of location-awareness on individual behavior and social interaction?
- Are there changes in how users perceive of the urban space and inter-city mobility, as a result of using the MITOS platform together with the SmartCity infrastructure?

3.3. Methodology

Given the flexibility of the concept of UX, an evaluation methodology that relies solely on quantitative methods is bound to be inadequate if the aim is to provide a thorough and holistic view of a system's use. Therefore, *mixed research designs* provide an optimal array of methods by virtue of combining the precision and clarity of quantitative measurements with the breadth, depth, and versatility of qualitative methods.

Additionally, for the purposes of our study the design framework has been divided in three distinct stages: pre-use, during use, and post-use. While the core of user experience will be the actual experience of usage, this does not cover all relevant UX concerns. People can have indirect experience *before* their first encounter through expectations formed from existing experience of related technologies, brand, advertisements, presentations, demonstrations, or others' opinions. Similarly, indirect experience extends *after* usage, for example, through reflection on previous usage, or through changes in people's appraisals of use [25]. We will proceed to explain the rationale and techniques of each method used.

The sample size is yet to be specified. However, qualitative methods will by necessity be applied to a small sample size. Quantitative methods, such as post-usage questionnaires, are more suitable for administration to a larger sample size. Lastly, since data regarding aspects of the users' activity will be captured by the system, the sample size for this particular category of data will be higher than that of the other

methods described in this section. Essentially, the total population of users of the application will be providing data automatically.

3.3.1. Pre-use methods

The following research techniques aim to provide indications of users' expectations of the system and projections regarding its impact on their experience of the surrounding environment. The combined objective of using these research techniques is to enable *real-time in-field* observation of users and recording of their experience *as* they perform tasks with the system, therefore to bring the evaluation into the context rather than relying only on retrospective evaluations. This approach will not only provide indications as to the complexities faced during actual system use, but it will also yield "thicker" data of an ethnographic nature that can complement self-report post-usage and pre-usage data.

3.3.1.1. Input survey

Before the system is put into use and during the initial phase of system design, an e-mail survey will be conducted with potential system users with the aim of drawing useful user-centered insights that may inform designers during the system design process, but also may provide useful input to evaluation researchers during the design of the research protocol. Participants will be selected randomly from within the total population of Santander residents (long- or short-term) who are mobile phone users.

3.3.1.2. General survey

A general survey will be conducted to gather data on subjective pre-adoption perceptions, beliefs, expectations and attitudes of potential MITOS users. Questions included in the pre-use survey will cover the following: demographics (gender, age, occupation, educational level, etc), patterns of public transportation usage (frequency and primary purpose of using public transportation, frequency of planning a trip using web or mobile services, access to personal vehicle, etc.), past use and familiarity with technology (experience using various information technology devices, computers, Internet, smart phones, use of applications, accessibility to various devices, etc.), pre-adoption expectations from both MITOS and SmartSantander, pre-adoption perceptions and assumptions concerning the system's value (functional, epistemic, social), as well as primary motivations for using the system and participating in the research project. This pre-use survey will also help in the process of screening participants and selecting a representative subset of subjects to take part in the post-use phase of the evaluation process. It will also guide the customization of questions for subsequent research protocols (surveys, interviews, focus groups, observation).

3.3.1.3. Think Aloud exercise

The Think Aloud approach [20] is useful in giving access to spontaneous users' reactions in their first encounter with the system. Before starting data collection, the system will be demonstrated to participants, who will be encouraged by researchers to apply the Think Aloud approach and verbally express their spontaneous thoughts while trialing the platform on their devices. Their interaction behavior with the system will be filmed for the analysis (the camera focusing only on their hands and the mobile device and recording their verbal commentary without showing their face). Each participant's verbal descriptions will be coded into different themes which will be aligned with the research questions and the operationalized definitions of the research framework.

3.3.2. During-use methods

Logging data, Staged Usage Situations and Experience Sampling will be three different techniques for data collection during the actual usage of the MITOS system. To date, the evaluation of UX has been mainly conducted with qualitative methods that focus on an applications' usability. These studies are typically conducted within a limited time span in controlled laboratory environments, conditions that do not resemble users' natural daily environments. The results of such evaluations may help to discover the mobile application's serious and immediate usability issues in a design, but they may not help to uncover issues that are relevant to real-life situations in the world outside the lab.

3.3.2.1. Data logs

Logging has been used in several usability studies to keep track of what is happening during the experimental use of technological systems. In our study we will mainly use logging as a support for the qualitative observations made during the test, but some data, such as time to complete, number of turns, exchange of data such as text messages and multimedia content, will be subject to statistical analysis as well. Subsequent analysis of logging data may yield metrics such as number of errors per user, average time for task completion, usage frequency etc. Additionally, information in traffic conditions and parking availability can be straightforwardly collected by sensors already installed. While the data collected from server logs are high in ecological validity, they do not really provide access to how users think and feel about their encounter with the system. Staged Usage Situations and Experience Sampling will be deployed to address the need for a more contextualized depiction of actual system use.

3.3.2.2. Staged usage situations

This method lies in exposing randomly selected users with concrete problem-centered tasks via a series of hypothetical mobility situations to see how they respond while using the system "out in the wild". A number of usage situations will be developed to match the whole range of possible system responses in action and the different dimensions that make up the UX construct. Fully disclosed researchers will follow selected users during experimental sessions, having the roles of Observers (taking notes on the observed behavior), Facilitators (setting up the infrastructure & helping with usability issues), and Partners for informal conversations (soliciting feedback, probing and discussing intelligent questions to elicit users' spontaneous, on-the-spot experiences with the system). An advantage of this method is that events in the environment may trigger the discussion – something which may also be a weakness in case the external events are disturbing. After each session, users will be asked to write down evaluative statements about the contexts of use and their interactions and experiences with the service. Research data drawn from this technique will reveal goal-related aspects which represent primarily the semantics of the system that convey meaning in the conversation between the user and the system. They will also try to capture a user's mental mode and what is sometimes referred to as the user's conceptual model. Ideally, a user's mental model matches the user model the designer has created [11].

3.3.2.3. Experience sampling method

This method is based on occasional mini-surveys, which can be administered to system users through their mobile devices over specific time intervals, after particular events,

or at random [14]. Participants will be asked to report about their experience real-time, through prompts for feedback and subjective ratings, while they are "in the field" using the system in naturalistic settings. Questions will mostly be of a yes / no type, appropriately designed to be quickly replied by pressing a few keys and should focus on user experience from the application, the smart city infrastructure, social context, mobility level, etc. To limit the obtrusiveness of this method, participants will be given the option to disable such prompts.

3.3.3. Post-use methods

Post-use methods can be both qualitative (e.g. focus groups, questionnaires featuring open-ended questions, etc.) and quantitative (questionnaires, analysis of logged data etc.). Interesting clues regarding the users' spatial experience and navigation of an environment will also be provided by analysing the routes followed by the users. More specifically, we will be conducting post-use surveys, complemented with one-to-one interviews and group discussions. These are all self-report data collection techniques aiming to capture UX through rich subjective descriptions and evaluations, at a cumulative, reflective level (not possible through logging or observational data). Research questions will be designed to elicit subjective evaluations of the overall UX and its constituting dimensions (pragmatic, emotional, cognitive), but also to reveal areas of difficulty, patterns of use, intention to use, motives and suggestions for improvement.

While questionnaires will be used to gather data for quantitative analysis, semi-structured interviews (having a set of pre-defined questions but allowing for follow-up questions and discussions depending on the user's answers) will allow us to clarify inconsistencies and identify causalities and relations specific to each particular user. The flexibility of the semi-structured interview approach will further enhance user's "freedom" in verbalizing his experience from having used the MITOS system and allow researchers to make the most of the idiographic approach for understanding the meaning of contingent, unique, and subjective phenomena of quality of experience for each particular user. Given a population of users, an analysis could then be conducted within this for MITOS application, or between populations of users of different mobile applications. The same semi-structured approach will be applied in the "group interviews" (focus-groups) which will be conducted with MITOS users after they have used the system.

As far as data analysis is concerned, both qualitative and quantitative analytical techniques will be used. Data gathered from survey questionnaires (both pre-usage and post-usage surveys) will be analyzed quantitatively, while data gathered from interviews, focus groups and open-ended questions in questionnaires, in situ observations and micro-blog comments and images uploaded by users themselves, will be analyzed qualitatively. However, it may be the case that qualitative data drawn mostly from interviews will be quantified and subjected to quantitative analysis, while quantitative data could be used for generalizing qualitative findings. The interplay between qualitative and quantitative methods is compatible with the mixed methods design on which this project is based.

The combined use of qualitative and quantitative frameworks serves the mutual validation and convergence of the results arising from different evaluation methods (triangulation). In other words, results gathered from post-use methods will be analyzed to validate the findings from data collected through pre-use and during-use research.

Qualitative data collected through interviews, focus groups and in situ observation, will be correlated against findings from quantitative data collected through surveys and patterns gleaned from data logged in the application and service infrastructure. Correlated data will be used to generalize the UX with the system.

The above-discussed methods probe different aspects of the mobile usage situation. On the whole, the use of several methods in combination is necessary in order to obtain a good understanding of the user experience. Although longitudinal methods are good for existing technology, they tend to be difficult to use in the design process due to time limitations. Instead, one often has to probe potential future use by shorter tests and design appropriately designed experimental activities. In doing so, it is important to use a variety of methods, and to make use of both qualitative and quantitative approaches.

4. Future work

At present, system design is being finalized and technological development is at the finishing stages. The project will continue with a field experiment for the purpose of evaluating of UX factors in the context of a location-based game-like activity incorporating the elements described in sections 1 and 2. Rich and varied data, both quantitative and qualitative, are expected to be extracted as a result of this activity. A mixed methods perspective will be adopted for data analysis, since an optimal combination of quantitative and qualitative methods is necessary for a holistic and accurate investigation of mobile UX [8-9].

The conclusions that will be arrived at as a result of the field experiment are expected to reinforce our understanding of the role of citizens / commuters as providers of information on traffic, transportation, and environmental conditions, illuminate the dominant factors and underlying processes that influence mobile UX, and clarify the process of social behavior as affected by the use of mobile media.

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