ContextKing

Virtual Kingdoms in Real Life

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Abstract—**Mondial pervasive games feature the earth's surface as the game board on top of which players travel around the globe like virtual pawns in the game. ContextKing is a game that makes extensive use of sensory inputs from the real world to create a whole new game experience within a user's social network. We discuss the management and utilization of sensor data, the actual game setup, its adoption and usage in real-life, and present observations made in the course of ContextKing's deployment.**

Keywords – mondial, pervasive, context-aware, virtual, game

I. INTRODUCTION

In human communication, our senses play a very important role. Inputs from our five senses go along and characterize the actual communication between people. In human computer interaction, computers lack these senses and therefore respond without taking into account any sensory inputs. For desktop computing, the adverse effect of this limitation might be less critical, because the context in which the interaction takes place is partially known. However, for the interaction between a human and a mobile phone, knowledge about the context is of utmost importance. A computing device having knowledge about surrounding information is commonly referred to as being *context-aware*: it has the capability to sense and process the context in which the interaction takes place.

Context has many dimensions. Using context was initially (during the years of 1998–2001) perceived as adapting the application to the user's current location [1]. Today, it has grown into a multi-dimensional web of data that can be collected by hardware sensors, built-in (or connected to) the mobile phone. Already applied sensors include acceleration and rotation sensors, radio beacon discovery (e.g., Bluetooth and Wi-Fi), sports sensors measuring heart rate and walking speed, ecology sensors to detect dust and pollution, light as well as temperature sensors, and many more showing up in numerous consumer electronics in a little while.

Sensed context can be utilized to enhance mobile devices and services in different ways. On the one hand, context information may be treated as the main application content, for instance to record a skating track to share it with friends or within a carpool application to match people based on their recorded commuting patterns. On the other hand, context may adapt the behavior of the application, for rotating pictures based on the current orientation or to select the most appropriate profile based on the situation (loud if in a noisy environment, silent if in a business meeting).

In this paper, we describe the use of sensory inputs to adapt the core behavior of a well-known game: the *Settlers of Catan* [2]. In this board game, players can build villages, cities and infrastructure by using what their territory yields: stone, wheat, wool and wood. Both, the territory selection and the harvest are defined by throwing the dice. In ContextKing,[1] we transferred these basic principles into a virtual world in the mobile space, with the territory and the harvest being defined by the overall presence of the game community in a specific location.

The remainder of this paper is organized as follows. Section II highlights the underlying system infrastructure. The game concept is explained in Section III. Our approach in abstracting from raw context sources is explained in Section IV. Section V discusses the most important observations from the game evaluation and elaborates on lessons learned. Related work is then presented in Section VI, followed by concluding remarks.

II. EMBEDDED GAMING

As a true context-aware game, ContextKing needs sensor data from the player's actual environment. Therefore, it has been built on top of a generic Context Management Framework (CMF) [3]. The CMF represents a network of interconnected components realized as Web Services to allow for the collection, aggregation and distribution of diverse types of context information. This client-server infrastructure enables complex computations in the network and lightweight mobile applications at the same time. A system overview is given in Figure 1.

The core of the CMF is formed by a number of management components that provide the essential infrastructure for services such as secure authentication, a component repository as well as a simplified access to distributed context sources. Additional context components encapsulate and provide access to various data sources. To give an example, one component, the so-called LocationProvider, tracks the user's movements, either based on cell-tower information or GPS, while other components within the framework may use long-term historic location data to derive personal commuting patterns and to provide these as aggregated context information. We refer to [3] for an

[1] https://www.iyouit.eu/portal/contextking.aspx

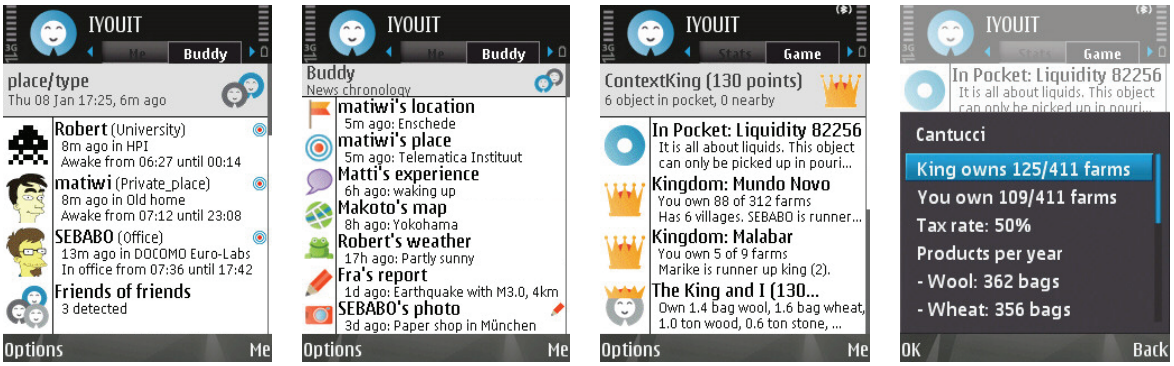

Figure 2: IYOUIT mobile client

elaborate description of the CMF, whereas an overview of the spectrum of context data can be found in [4].

The prime application area of the CMF is the mobile space. Context-aware mobile applications are meant to realize intelligent mobile services that adapt to the user's situation. ContextKing is an instance of the latter but cannot be seen as a detached, pure mobile gaming application. In fact, ContextKing is a distinct part of our mobile implementation on top of the CMF called IYOUIT. [2] This application treats contextual information as the main content for real-time sharing of personal experiences with friends and family members, for context tagging of multimedia and for automatic life blogging [4]. The central place in IYOUIT to keep in touch with friends is the so-called buddy tab, as depicted in Figure 2. IYOUIT can also be connected to a broad range of user generated content services, including Flickr, [3] Twitter, [4] YouTube[5] and Dopplr. [6] The mobile client runs on standard mobile phones and provides access to valuable context information such as a user's current location or the built-in accelerometer. IYOUIT and ContextKing do not only share the same technological basis on which they have been built. Both are strongly intertwined in providing certain incentives by using either one or the other.

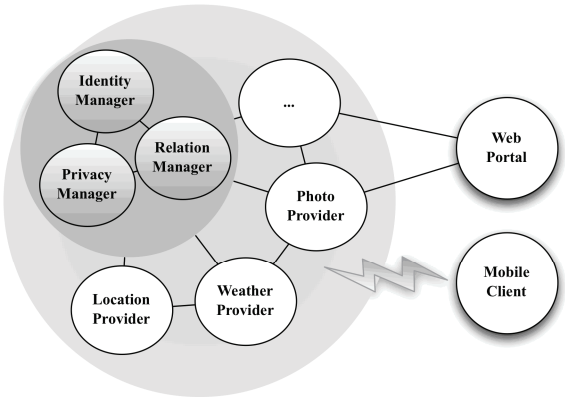

Figure 1: Context Management Framework

By using IYOUIT and collecting context data in the real world, e.g. by making pictures or updating ones presence status, the user's virtual role within ContextKing is automatically updated and changed for the better. The other way round, playing ContextKing requires the user to provide real time context data within IYOUIT, therefore contributing valuable information to the IYOUIT user community.

IYOUIT has been released to the public in June 2008 and can be downloaded from its Web portal, free of charge. It is an alpha release of a scientific demonstrator in the field of context awareness. Its community counts more than 900 users, mainly from Europe, North America and Asia. From the application usage we learned that people like to share and collaborate [5], especially if they are rewarded with some attention. But more than that, people also like to compete. This element of competition was shown in

- trying to be in an area first to measure the GPS location of yet unknown GSM cells (later also used for location determination in IYOUIT),
- ranking buddies according to the current outside temperature, to see who enjoys the warmest weather,
- making pictures to convey messages or to proof something,
- being in the office longer, or going to bed later than your buddies usually do,
- having visited more countries than any of your buddies.

To increase the number of occasions for competition, we added a virtual gaming layer to reality where unbridled competition can take place. The element of competition is realized within the virtual layer where the state of the game is influenced by sensory inputs from the real world. We decided to enrich a well known board-game concept and replace the element of luck, the dice, by actions that people perform in the real world. Instead of a combination of strategy and luck, the game then becomes a combination of strategy and reality. For ContextKing, we borrowed the principle game concept from

[2] http://www.iyouit.eu
[3] http://www.flickr.com
[4] http://www.twitter.com
[5] http://www.youtube.com
[6] http://www.dopplr.com

the Settlers of Catan [2] and added some real world context information from the mobile application IYOUIT.

III. GAME CONCEPT

In ContextKing, the earth is subdivided into small regions with an average size of 10×10 kilometer. Each of those regions is called a farm. Players may become farm owners by being the most frequently present player in that region in the recent past. Farms are grouped per real-world country, and as soon as a player obtains most farms in a country, he can found a kingdom and eventually become king. As a king, he has certain privileges, including personalizing a kingdom, giving it a new name, determining the tax rate and collecting taxes from other farm owners.

Each farm either produces a certain amount of wool, wheat, wood or stone, of which a certain percentage can be raised as tax. While the type of product is determined by chance, the population density determines the amount of products per year. The more players stay in a region the more fruitful the ground may be. If a user is the only one in a certain region, he will quickly obtain the farm, however, with a throttled production rate. The more players can be found in a region, the harder it is to obtain the farm, but it will be more valuable, too. The default tax rate is 25%, which means that a quarter of the harvest remains in the king's possession with the rest being allocated to the farm owner. Figure 3 shows an example of a kingdom with the products it yields and the infrastructure that has already been built.

Once a player owns a kingdom he can use the collected products to build roads, houses, bakeries, churches and villages. Each piece of infrastructure has its own cost:

- a road costs 1 ton of stone and 1 ton of wood,
- a house costs 1 ton of stone, 1 ton of wood and 2 bags of wool,
- a bakery costs 1 house, plus 2 bags of wheat and 1 ton of wood,
- a church costs 1 house, plus 2 tons of stone, 2 tons of wood and 1 bag of wheat,
- a village is a group of 4 houses, a bakery and a church, plus a road to connect to other villages.

Infrastructure is built in a certain kingdom and stays in that kingdom, even when another player dethrones the current king. However, the builder is rewarded with one point for creating any type of infrastructure. The overall goal of the game is to obtain as many points as possible.

When a player does not have the required amount of a certain resource, products may also be exchanged with the bank. The initial exchange rate is 1:1, but in case there is high demand for a specific product, the exchange rates for that product become worse. Table 1 shows the exchange rates for all products after playing the game for four months.

To bring stability into the game play and to avoid an undesirably high frequency of kings being dethroned again as soon as the runner-up king obtains only one additional farm, we introduced the concept of a bonus farm: one for each village in the country that belongs to the ruling king. This way it becomes harder for a just dethroned king to get his kingdom back, because he needs to obtain as least as many additional farms than the number of villages in that kingdom.

From	wool	wheat	wood	stone
To wool		49:5	27:10	43:10
To wheat	5:23		10:29	5:9
To wood	1:1	26:5		23:10
To stone	5:9	29:10	5:6	

Table 1: Product exchange rates

On the other hand, the game should not be too static so that players quickly obtain settled positions and thus become hard to defeat. An additional factor that needs to be carefully considered is the fact that obtaining new farms actually requires physical travelling, even though most people spend most of their time in only very few cities. For that reason, we added four additional notions to allow for a more dynamic game play: the notion of resistant regions as states or provinces where the presence of the king is too low and the tax rates too high, the notion of farm attacks, the notion of disasters, and the notion of virtual objects.

A. Resistant regions

Resistant regions are smaller in size –usually around the size of a province or a state– and more in number compared to regular kingdoms, and are hence easier to obtain. Resistant regions emerge when the tax rate determined by the king is too high given his presence in that region. As a result, those regions are split off from the originating kingdom, and behave like a kingdom in itself, and the taxes in the resistant region flow to a new king gaining power. In case the original king obtains the required number of farms again, the resistant region will be newly merged with the mother kingdom.

B. Farm attacks

The concept of attacking farms has been introduced to allow players to obtain farms without going there physically. Instead, they will have to pay with a certain amount of products from their inventory. Players can only attack farms located nearby farms they already own, or farms in kingdoms they have visited at least once. This way, players cannot found their own kingdom in places where nobody from the game community has ever been. Farm attacks do not have a 100% success rate: the odds are determined by comparing the product inventory of the attacking and the defending player. The more products the defender owns, the less likely it is that an attack against his farms will succeed. Successful farm attacks yield points for the attacking player.

C. Disasters

In an ever-ongoing game where each player's possession increases with every harvest, it is essential to implement a counter force as well. Besides a general decay rate to simulate events like theft, misuse or quality loss, we introduced the concept of disasters triggered by events in the real world. These events include regional storms and earthquakes as reported by IYOUIT's WeatherProvider. Every time a disaster occurs, it can destroy farms or products of players active in the affected area.

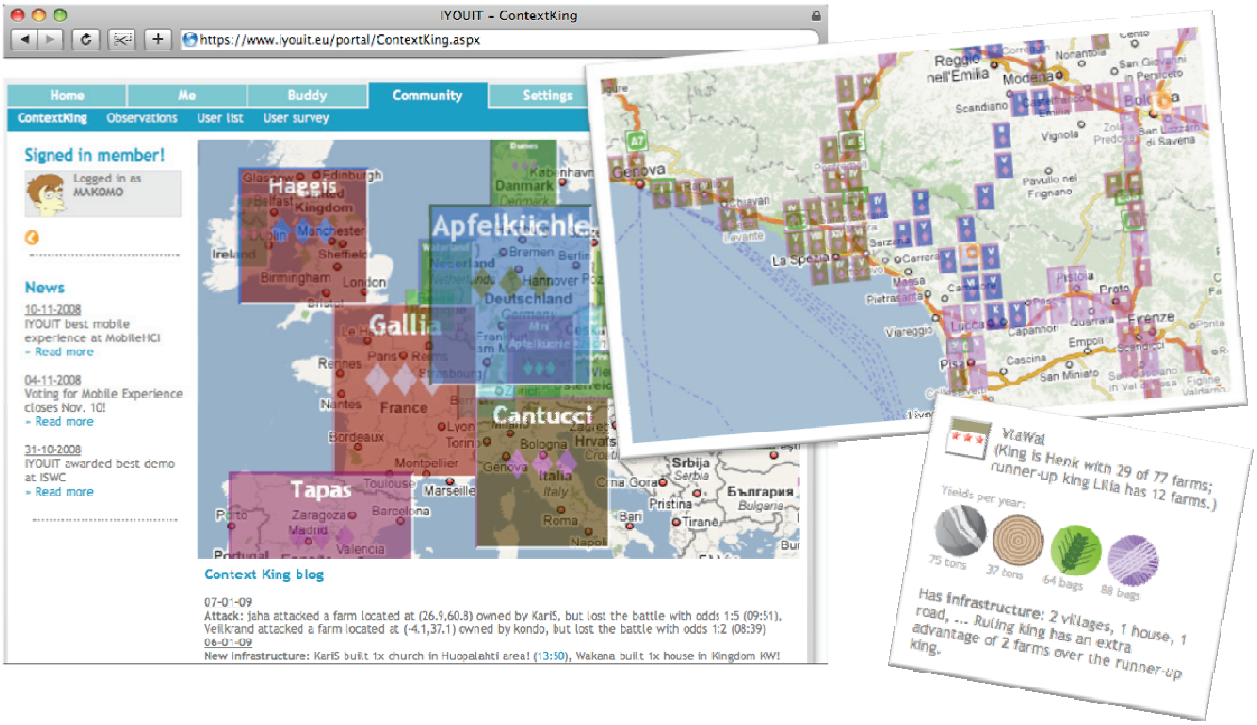

Figure 3: ContextKing Web portal

D. *Virtual objects*

A fourth way to increase game dynamics is by introducing valuable (virtual) objects. These objects can be created in a certain location to be picked up by other players, as long as a certain context condition is fulfilled. Once the objects are picked up, they can be handed over to other players or dropped off, again depending on the current context of the user. Depending on how difficult the conditions are, the player is rewarded with points either on pick up, hand over, or drop off. Figure 4 shows an example description for a virtual object in ContextKing.

The context conditions are chosen freely by the creator of the object. The conditions will be evaluated each time a player tries to pick up, drop off or handover an object, using the latest relevant context state as gathered by IYOUIT. For pickup and handover, additional spatial conditions apply to ensure that the player is in the proximity of the object's location for pick up, and in the close vicinity of a buddy for handover.

Virtual objects come in many flavors: some are beneficial (e.g. in generating some amount of stone for every newly discovered Bluetooth device), others might have a more thievery character (they steal products from the male population and hand those over to the female population); some are viral (they jump over when people are together for at least four hours in a happy mood), others are aware of the environment (jump on with high temperatures, and jump off when it starts getting colder).

Every player can create a formal virtual object definition and submit it to the game engine. Additional constraints apply because it must be prevented that a player creates objects that may only be picked up by the player himself, thus earning points in an undesired way. Therefore, the object creator can not pick up his own objects, and we apply validity checks on the rewarded points in an object definition. To summarize, points will be rewarded for building infrastructure in a kingdom, successful attacks of farms and for the interaction with virtual objects (depending on the object's definition).

Liquidity 7523

It is all about liquids. This object can only be picked up in pouring rain, dropped when walking along a river, and passed when you drink something together. Let this object travel as agile as a drop of water!

Category: theme, profit
Value: 1 point when in possession
Yields: 2 points on drop off

History: Picked up by Caroline
on 6/19/2008 11:06:18 AM
in Enschede (52.22955, 6.89699)

Conditions

For pickup:	weather/condition equals rain
For handover:	experience/drinking equals coffee experience/drinking (for the new owner) equals tea
For drop off:	location/river exists

Figure 4: Virtual object definition

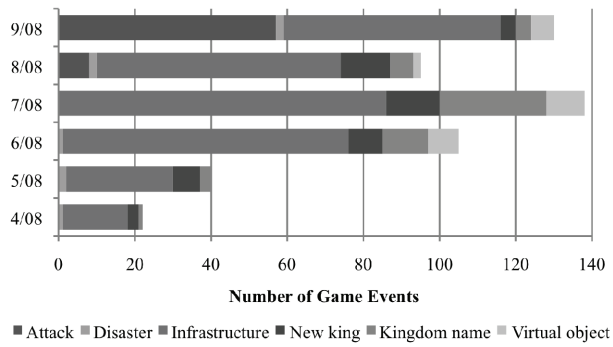

Figure 5: Game usage

The current game state may also be observed via ContextKing's Web portal (cf. Figure 3). Here, all players can browse the game history, observe other players and their progress and take appropriate actions if necessary. In contrast, the mobile client (cf. Figure 2) is mainly used to review the current game state, to attack farms and to build new infrastructure.

IV. RICH CONTEXTUAL DESCRIPTIONS

Rich contextual descriptions contribute to a more interactive and worthwhile game play. However, a broad range of context information cannot be obtained directly from sensors, but has to be derived from the combination of multiple context streams. A player's current activity is one of these richer contextual representations used in the game, either for the description of virtual objects (e.g., object handover only when commuting), or for weighting the value of a kingdom according to the activities of its inhabitants. Activities may include working behind a desk, doing sports, drinking beer with friends, relaxing on the sofa, et cetera. Deriving activities like these in an automatic fashion is far from straightforward. To this end, we have developed the SituationProvider, which gathers various types of lower-level context information to derive new knowledge by the combination and analysis of different context streams. These higher-level context types are, in turn, made available within the framework.

The general approach of making sense of lower-level data is to define a meaningful abstraction layer for selected pieces of information. This context abstraction process takes place in each component, where raw data (e.g., temperature values from a weather source) is mapped to qualitative concepts (e.g., "warm day") potentially making use of additional data and background knowledge (e.g., location, date and historical temperature measurements). We developed a set of core ontologies formulated in the Web Ontology Language (OWL) [6], a formalism currently under development for the upcoming Semantic Web, to give concepts a well-defined meaning for our application domain. The place ontology, for instance, provides descriptions of a hierarchy of spatial concepts that are bound to personal regions of interests of each ContextKing user. Likewise, the social network of users is represented within the social ontology, therefore providing means to semantically describe personal relationships within the user community. Besides, we modeled ontologies for events, meteorological data, as well as temporal descriptions. A detailed description of this abstraction process is published elsewhere [3].

Having linked data to concepts within ontologies, the SituationProvider can gather these qualitative representations without having to deal with potentially vast amounts of quantitative sensor data. The situation ontology in turn allows to semantically describe real-world situations like "working", being in a "meeting" or being on "holiday", to name only a few. In applying logic-based reasoning mechanisms originally developed in the field of Artificial Intelligence [7], all gathered pieces of information fed into the situation ontology, can be classified with respect to the defined situational descriptions [8]. For instance, being in a place typed as "office" during "office hours" with "colleagues" in close proximity, a "business meeting" situation can be automatically deduced. This classification is a continuous process, resulting in a personal segmentation of the player's day into distinct activities. This personal "activity schedule" is again made available as context information to the ContextKing game, and hence it can be used as an intuitive concept, for instance as part of the rule definitions of virtual objects.

V. OBSERVATIONS

In total, 161 players, distributed over 51 kingdoms holding 3968 farms, play ContextKing. The top 5 countries are Germany (863 farms), Finland (437 farms), Italy (410 farms), United States (398 farms) and the Netherlands (343 farms). The game holds 311 virtual objects in all populated areas. Figure 5 depicts an overview of the game community's activity, before and after the public introduction in June 2008, showing a significant increase in game activity. The possibilities to attack farms and to adjust tax rates have been introduced in August 2008.

These (later introduced) features helped to keep the balance between reality and virtuality in the game: too much virtuality makes ContextKing less unique and fun to play; too much reality results in a slower game that is more difficult to play. This balance is one of the greatest challenges in mondial pervasive games, especially if pervasiveness is taken seriously. With hundreds (or even thousands) of mondial players, chances are fairly low that nearby buddies are playing in exactly the same time slot. In this respect, asynchronous player interaction and attractive game history visualizations are very important. The setting of ContextKing with a mondial playground and 24/7 availability is essentially different from games that are played in a limited geographic area in a specific time slot where players meet in a certain location to play a game, like PacManhattan[7] or Monopoly Live. [8]

Wearability is an issue in any context-aware game. We have selected a setup where the phone is the only wearable object, as opposed to wearing backpacks full of sensors (as in PacManhattan), head mounted displays, or sensors mounted to vehicles (as in Monopoly Live). This is especially important because of the true pervasive 24/7 character of ContextKing. The game is meant to be played during normal life, and should

[7] http://www.pacmanhattan.com
[8] http://www.monopolylive.com

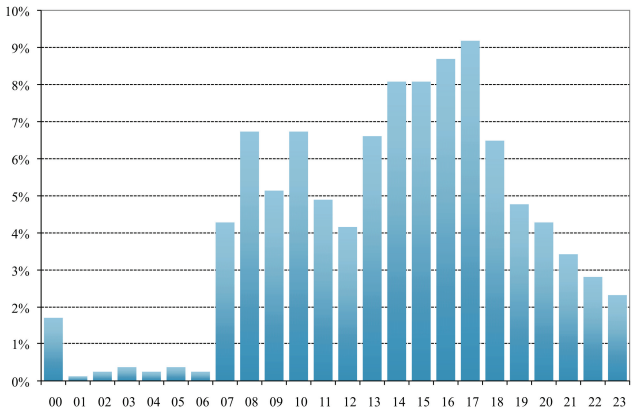

Figure 6: Game interactions over the day

not disturb the usual habits and patterns of the players. Continuous sensing using the mobile phone makes battery life a real issue though: most batteries last barely two days. Table 2 shows the perceived and estimated lifetime of the battery of the top 5 players.

All 5 top players use standard but high-end phones like the Nokia N95 or E90. On average, all users recharge after 58 hours, some players even every 31 hours. Usually they do not fully discharge their batteries, but recharge as soon as the battery level is low, typically during the night.

Usually a pervasive 24/7 game is not played for long consecutive periods of time, but rather every once in a while, when the user has time to play. Users often indicated that they played while travelling, commuting or waiting for something else. This roughly corresponds with the peek usage (shown in Figure 6) between 5 and 6 p.m. (commuting time). There is a smaller peek in the morning, again commuting hours, followed by a decreased usage during lunchtime. This indicates that (for most players) real food is more important than a virtual game.

Also worth mentioning is the fact that most players actually like to exchange thoughts about the current game state. To support our users in doing so, the game engine automatically pushes the most important events to external 3rd party community services, including Twitter (cf. Figure 7). This way, micro-blogs are used to let the world know what is going on in ContextKing. As a side effect, services like Twitter may also trigger some interest in the game in other communities.

Figure 7: ContextKing messages

Name	Estimated life time (h)	Recharge after (h)	Number of recharges
Player 1	26.9	18.2	525
Player 2	41.8	29.5	361
Player 3	45.3	35.3	257
Player 4	64.8	44.4	224
Player 5	47.2	28.7	184

Table 2: Battery performance

VI. RELATED WORK

Location-based game development started in 2000 with early games like BotFighter [9], where real-life location measurements were used in a virtual fighting game for the first time. Back then, the main communication channel was SMS, to transfer player actions in the game.

In 2001, Groundspeak GeoCaching[9] started off [10] with the idea of hiding physical objects in the real world and a Web portal to exchange hints to find them. Today more than 660.000 of such caches are hidden worldwide with a flourishing community of cachers, many of them equipped with a mobile application, such as Trimble Geocache Navigator [10] that enables them to download nearby cache descriptions and to find these using GPS. In 2004, games like PacManhattan [11] were developed where players exchanged location in real time via a data network in downtown Manhattan, and took roles of either Pacman or one of the ghosts. Pacman had to avoid the ghosts in the streets of Manhattan, while collecting as much virtual candy as possible. In 2005, HotPotato [12] introduced the use of presence information as part of the game [11][12]. While a player was holding a potato, it heated up, and the player had to pass it on to a non-player to cool. The goal was to avoid being burned. More recently, games like CitizenMob [13], Hasbro Monopoly Live[13] and PerBlue Parallel Kingdom[14] were developed. In Monopoly Live, players can buy streets in London City and get paid every time another player in a cab passes through their streets and vice versa. Both CitizenMob and Parallel Kingdom are role-playing games using GPS information to position players and objects on a map. Players have to maintain and control their virtual presence in these games.

Although the quality and the overall experience of mondial pervasive games has improved significantly over time, the use of real world sensory inputs is usually limited to location and proximity only. In ContextKing, a broad range of contextual information of the player is used to enhance the game play. Events from the real world like storms or earthquakes have a real impact in the game. Other sensors like acceleration or rotation sensors are used as input to deduce a player's activities

[9] http://www.geocaching.com
[10] http://www.geocachenavigator.com
[11] http://www.pacmanhattan.com
[12] http://www.sics.se/hotpotato
[13] http://www.monopolylive.com
[14] http://www.parallelkingdom.com

in the SituationProvider. The entire range of context information influences the behavior of the kings, their kingdoms as well as their assets in the game.

VII. Conclusions

We have presented ContextKing, a multi-dimensional context-aware game that adds a virtual layer to daily life in which people can satisfy one of their prime necessities of life: competition. In our opinion, using location and proximity information only in a pervasive, ever ongoing game is not enough. Most players (in the ContextKing community) are on the move only about 15% of their time, but the game should also be attractive and dynamic in the remaining 85% of the time. We exploit a broad range of contextual information in the game, which makes the game interesting, stronger linked to real life, and a more dynamic experience. The context information used in the game should be intuitive and easy to understand. Therefore, we automatically derive sketches of the player's current situation by abstracting from raw sensor data.

From a developer's point of view, we believe that mondial pervasive games should provide open architectures to allow for a plug and play approach as soon as new sensors become available on a significant share of modern mobile phones. We expect that open, extendable games will have a longer life expectancy than hermetically sealed ones, allowing players to play and influence their own truly pervasive game.

ContextKing is built on top of an open architecture (CMF), and can easily be extended with new contextual information. However, the utilization of context information should not come at the expense of carrying more devices than only the mobile phone. This is essentially required for a pervasive game that is being played in daily life.

The current development of mobile phones shows a trend of embedding more and more sensors into devices, also including near-field communication for interacting with tags. Our intention is to let ContextKing grow into a game that is played in a significant portion across the globe. Currently, it has some coverage in 51 countries, but still 75% of the game play takes place in only a few countries. We plan to further promote the interaction between the king and the virtual inhabitants of his country. Current activities derived from contextual information are also meant to characterize a kingdom's importance in the game. The rationale behind this is the fact that only the minority of players can become king by definition, yet the game play should be worthwhile for the majority of non-king players, too. Farm attacks and virtual objects are one approach, but we believe that the game can still be improved in this respect.

To learn more about how the game is played in different contexts, we also plan to accomplish a profound user study. Dedicated questionnaires will be combined with automatically recorded usage data (from the mobile phone as well as the Web portal) to evaluate the actual game setup and to further assess our initial observations.

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