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ORIGINAL ARTICLE

Living virtual history

A mobile game around the world

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Abstract Mondial pervasive games feature the earth's surface as the game board with players traveling around the world 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 context data, the principal game concept and its adoption and usage within the community.

Keywords Virtual reality · Mobile gaming · Pervasive computing · Context awareness

Preface

Iniquitously taken by the cruel emperor Gorhan, I set forth to recapture my land in the far north. The ***journey*** *was long and exhausting, but eventually crowned with success.* (Meister-Li from home, Fri. 21:56)

Meister-Li seems to become indefeasible. Let us join our forces and ***attack*** *this sole ruler!* (Daniele, Sun. 10:11)

I am on your side, ready to stand the fight. However, my resources are low, the recent ***harvest*** *has been rather poor. A* ***thunderstorm*** *has struck most of my* ***wheat*** *savings.* (Findebär, happy but starving, Sun. 13:15)

Just dropped a few of my ***Rainman objects*** *nearby the river Isar to rebuild my infrastructure in* ***Kingdom Haggis****. I am willing to do my bit in this strike-back.* (Curtis, working, Mon. 13:34)

Excerpt from "The History of Kingdom Haggis"

1 Introduction

Interweaving the real world with concepts borrowed from traditional board games in a dynamic, ever-ongoing game in the virtual space is what makes ContextKing[1] [1] a novel type of mobile game. By linking selected pieces of information from the user's actual surrounding with virtual concepts in the game, creativity can be stimulated and incentives to further participate in the game are given. Human imagination is a truly powerful and inevitable ingredient in every game play, whose importance cannot be overestimated.

We describe the use of sensory inputs to adapt the basic principle 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, we transferred the game concept into the mobile space, with the territory and the harvest being defined by the overall presence of the game community in a specific location. The

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[1] https://www.iyouit.eu

board game is literally replaced by the earth with real users all over the world representing the pawns in the game. Surrounding information like the current location of a user, local weather information or upcoming events in his personal calendar directly influences the story line in the game. The mobile handset provides a gateway into the virtual space with (partial) knowledge about the surrounding information. Such a computing device 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 [3]. 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 a little while.

2 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, whose owner is the player with the highest presence in that region. Farms are grouped per real-world country, each representing a kingdom in the game. Having collected most farms in a kingdom, a player eventually becomes the king. The kingship comes along with certain privileges, including the right to name the kingdom, to choose the flag, to determine the tax rate, and to charge taxes from farmers in the kingdom. On certain ferry routes, players may also become owner of a sea region and are thus being assigned with the status of pirates that have similar rights as kings.

Each farm produces a certain amount of wool, wheat, wood or stone, of which a certain percentage is raised as tax by the ruling king. The type of product is assigned by the system, whereas the amount of products per year (the harvest) is determined by the population density of the game community. A low population density results in less valuable farms that are fairly easy to obtain, a high population density results in precious farms that are more difficult to obtain.

Kings are allowed to build infrastructure in the kingdom, to be paid with harvested products, similarly as in the Settlers of Catan. They can build roads, houses, bakeries, churches and villages, and are in turn rewarded with game points for each additional construction. Since the costs for building infrastructure varies depending on its type and the wealth of a given kingdom, the king might have to trade a certain amount of resources either with other players or the bank. The latter operates according to basic economic principles: a higher demand for a certain product results in higher costs and thus worse exchange rates. At the same time, more new farms are automatically being allocated to produce the given product in answer to high demands.

ContextKing's Web portal, as shown in Fig. 1, allows for browsing the game history and for observing other players' progress to take appropriate actions if necessary. The mobile client application (shown on the right side of Fig. 1) has been designed as a mobile game controller to sense the environment, to review the current game state, to attack farms and to build new infrastructure.

To find the right balance of a dynamically adapting, interactive game play on the one hand and a consistent, comprehensible behavior on the other hand turned out to be one major challenge in the course of ContextKing's deployment. Here, a deciding factor that needs to be carefully considered is that obtaining new farms actually requires physical traveling, even though most people tend to spend most of their time in only a very limited geographical area. Typically, players of ContextKing spend 91% of their time in their personal top 3 frequently visited cities. For that reason, we introduced four additional notions to allow for a more dynamic game play: the notion of resistant regions to challenge the ruling king, the notion of farm attacks to obtain farms without physical traveling, the notion of disasters, and the notion of virtual objects that can be collected by each player.

2.1 Resistant regions

Resistant regions are usually as large as provinces or states, thus smaller than regular kingdoms and therefore 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. In case the original king obtains the required number of farms again, the resistant region will be merged with the mother kingdom again.

2.2 Farm attacks

The concept of attacking farms has been introduced to allow players to obtain farms without having to travel. Instead, they will have to pay with a significant amount of harvested 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 prevents the creation of kingdoms in places where nobody from the game community has ever been. Farm attacks do not have

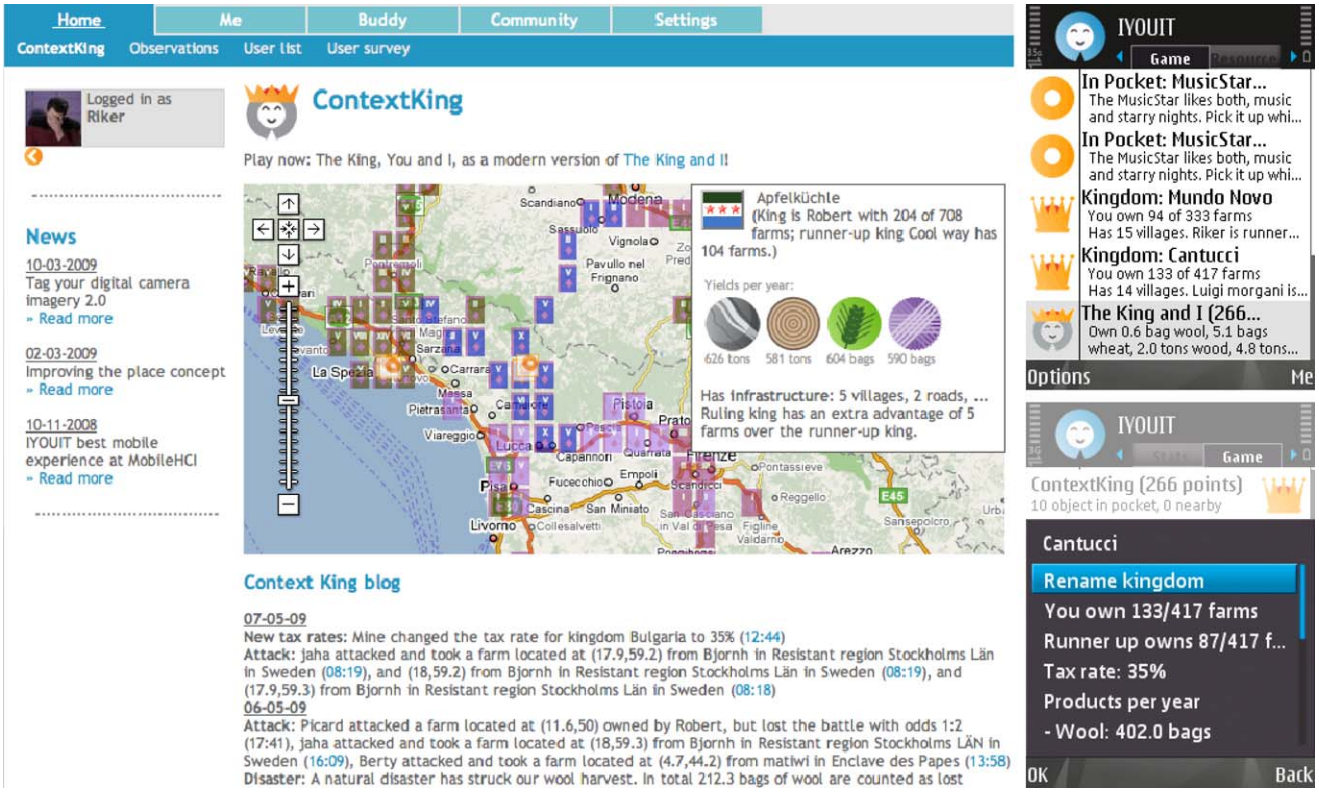

Fig. 1 ContextKing on the Web and the mobile client

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 attacks against his farms will succeed. Successful farm attacks yield points for the attacking player.

2.3 Disasters

In an ever-ongoing game where each player's possession increases with every harvest, a counter force is essentially required 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 based on local weather data. Every time a disaster occurs, it can destroy farms or products of players active in the affected area. Disasters clearly link real-world events recognized by the mobile handset to the virtual game play. In case of disasters this effect is mostly negative, but one might also think about positive events, such as an increased income for the king whenever his citizens are happy, or when they are listening to cheerful music.

2.4 Virtual objects

A fourth possibility to increase game dynamics is to introduce valuable (virtual) objects. These objects can be created in a certain location to be picked up by other players, but only if they are in a certain situation (or context). 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 player(s). Depending on the object's definition, the player is rewarded with points either on pick-up, handover, or drop-off. An exemplary virtual object specification of an object that can only be picked up while it is sunny is shown in Fig. 2 using XML syntax.

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 hand over an object, using the latest relevant context state as gathered from the sensors connected to the mobile phone. For pick-up 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 wool if the player is in rural areas), 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 listen to the same music genre), others are aware of the environment (jump on with high temperatures, and jump off when it starts getting colder).

```
<?xml version="1.0" encoding="utf-8"?>
<virtualObject id="1226">
  <name>Ideal 80687</name>
  <description xml:lang="en">This virtual object comes along with you while on the sunny side of life. You may
  hand over this precious object to someone who commented on your pictures or drop it somewhere in high
spirits.
  </description>
  <creator>1080</creator><value>1</value>
  <category>theme</category><category>happiness</category>
  <history userid="1080" long="11.49" lat="48.15" timestamp="2008-10-06T13:54" action="created" />
  <history userid="1086" long="11.50" lat="48.14" timestamp="2009-04-21T15:46" action="pickup" />
  <condition value="sunny" operator="eq" expression="user/weather/meteo/condition/cond" action="pickup" />
  <condition value="photo" operator="eq" expression="user/comment/contexttype" action="handover" />
  <condition value="happy" operator="eq" expression="user/experience/mood" action="dropoff" />
  <yields value="2" period="handover" item="point" />
</virtualObject>
```

Fig. 2 Virtual object definition

Not only the game developers, but also players can create new virtual objects by submitting a formal virtual object definition to the game engine via the Web portal. Additional validity 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.

3 Infrastructure

As a true context-aware game, ContextKing needs sensor data from the player's actual environment. To gather this data, a mobile client application called IYOUIT has been developed for Nokia Series60 devices [4]. IYOUIT is capable of accessing a multitude of sensors on the mobile handset and represents the game controller in ContextKing. With it, most features of the game can be operated and the current game state can be reviewed. Due to the limited resources and computing power available on the device, the actual processing of the gathered information must be accomplished in the network. Therefore, IYOUIT has been built on top of a generic Context Management Framework (CMF) [5]. 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 schematic representation is given in Fig. 3, highlighting the mobile client and its role as the data collecting unit as well as the CMF and its connection to services in the Web 2.0 domain.

The core of the CMF is formed by a number of management components that provide the essential infrastructure for services such as secure authentication, privacy control, 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 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 aggregated context information like personal commuting patterns [6] or important places [7].

3.1 Context abstraction

Meaningful context information can often not be obtained directly from sensors. In fact, the aggregation of lower-level sensor data to higher-level contextual descriptions is accomplished by 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 or relaxing on the sofa, to name only a few. Activities like these are derived in an automatic fashion by combining raw data with ontological models and the subsequent application of classification-based reasoning methods [8]. The inferred higher-level context items 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 networked component, where raw data (e.g., temperature values from a weather source) is mapped to

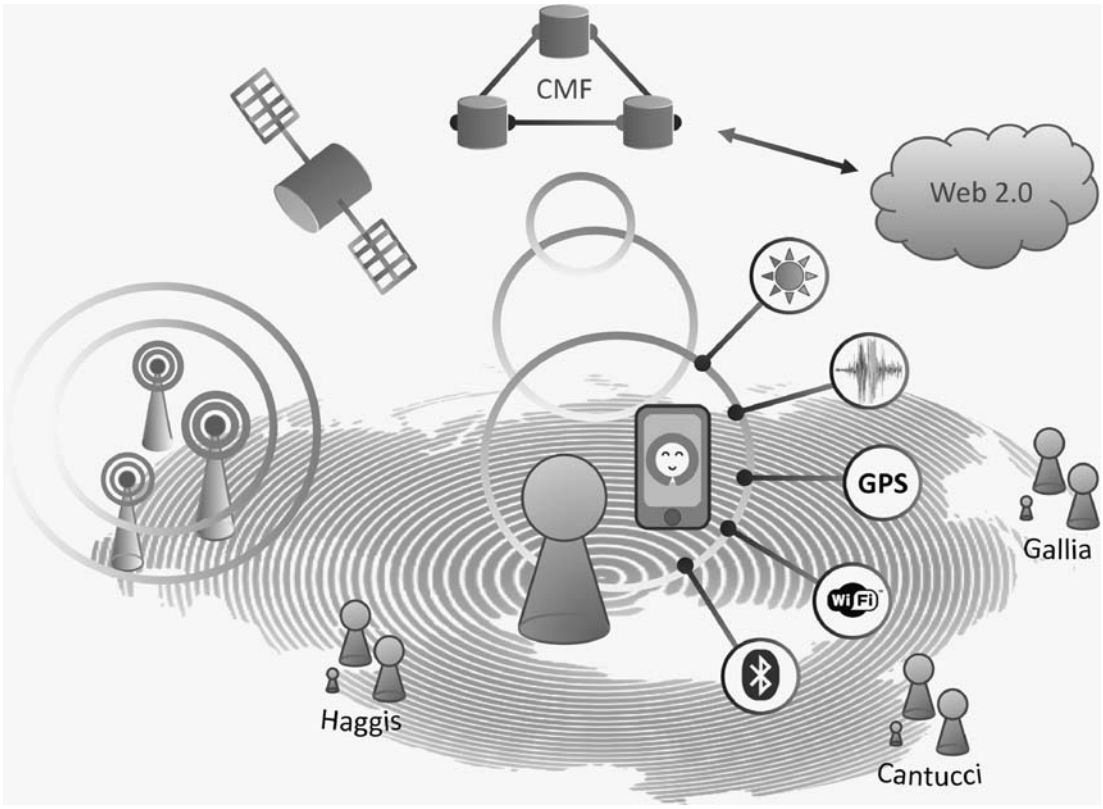

Fig. 3 Facets of ContextKing

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) [9], 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 (e.g., "office", "home" or "bar") 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 (e.g., "friend", "husband" or "colleague") within the user community. Besides, we modeled ontologies for events, meteorological data, as well as temporal descriptions.

Having linked data to concepts within ontologies, qualitative representations can be gathered 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 [10], all gathered pieces of information are fed into the situation ontology to be classified with respect to the defined situational descriptions [11]. 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 within ContextKing, and can thus be used as part of the rule definitions of virtual objects.

3.2 Storytelling

From time immemorial, telling stories has always been the most common way of expressing one's imagination. In ContextKing, storytelling can, from a technical perspective, be seen as the final step in the process of context abstraction. Each player may transform game events and real personal experiences into small textual descriptions, annotated with multimedia objects (like sounds, pictures, and videos). Chronologically sequenced descriptions are combined to eventually form stories of kingdoms and all game events taking place in that particular kingdom (cf. the example given in the Preface).

Fig. 4 ContextKing messages on Twitter and Facebook

Each player that has been associated with a game event can currently adjust stories. To influence the storyline, ContextKing provides certain event keywords such as "attack" or "harvest", to be included as part of the description. These keywords are automatically generated based on real context data collected by IYOUIT, and may also reflect global facts such as earthquakes or personal events like a business trip. This way, and by living virtual history, the game community transfers simple event logs into lively history books full of user generated content.

Through the connection of the CMF infrastructure with various popular social networking sites such as Facebook or Twitter, fragments of these stories can be posted as self-contained micro-blogs or notes, respectively (cf. Fig. 4). In addition, graphical representations of game states (e.g. visualizations of virtual objects in Google Maps) complement textual descriptions to further combine context information gathered from the user's actual surrounding with principal game concepts and the user's personal online presence. As a side-effect, ContextKing's integration into multiple Web 2.0 communities also invites other people to join the game community.

4 Related work

Location-based game development started in 2000 with early games like BotFighter [12], 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[2] [13] started off 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 catchers, many of them equipped with a mobile application, such as Trimble Geocache Navigator[3] that enables them to download nearby cache descriptions and to locate caches using GPS. In 2004, games like PacManhattan[4] were developed to let players exchange location information 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[5] introduced the use of presence information as part of the game [14, 15]. 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 [16], Hasbro Monopoly Live[6] and PerBlue Parallel Kingdom[7] 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 an impact on the game play. Other sensors like acceleration or rotation sensors are used as input to deduce a player's activities. The entire range of context information influences the behavior of the kings, their kingdoms, as well as their assets in the game.

[2] http://www.geocaching.com

[3] http://www.geocachenavigator.com

[4] http://www.pacmanhattan.com

[5] http://www.sics.se/hotpotato

[6] http://www.monopolylive.com

[7] http://www.parallelkingdom.com

Fig. 5 ContextKing's worldwide coverage

5 Summary

We have presented ContextKing, a multi-dimensional context-aware game that adds a virtual layer to daily life. Players create their own stories by mixing virtual elements with happenings in the real world to share these with others online. The game play in ContextKing is automatically influenced by a multitude of sensed context information. The broad range of contextual information allows ContextKing to become a virtual sphere that is unobtrusively intertwined with the real world. However, raw sensor data cannot be directly used to meaningfully influence the game play. Instead, it needs to be processed to derive abstract descriptions of the player's current situation. Current trends in the further development of mobile phones indicate that more and more sensors are being integrated in the near future. To keep up with the technological development, mobile pervasive games must be built on extensible architectures to support new sensors that will be available on a significant share of modern handsets. ContextKing is built on top of an open architecture (CMF), and can easily be extended with new contextual information.

Our intention is to let ContextKing grow into a game that is played in a significant portion of countries around the world. At the time of writing, ContextKing is played in 55 countries, as indicated in Fig. 5. Here, Northern America as well as Central Europe can be identified as regions with the highest game activity over the past twelve months. In total, the number of farms increased from 2000 in June 2008 to over 5000 in April 2009. Resistant regions can be found in 17 of 55 countries, with 246 players distributed over 76 kingdoms. Most players use high-end mobile phones and according to the game statistics tend to be active mostly between 8 and 9 AM, and between 5 and 6 PM, which corresponds to common commuting hours. Similar observations have been made in other pervasive 24/7 games, which are usually not played for long consecutive periods of time, but rather every once in a while. The possibility to participate in the game at any time is an important prerequisite for any ever-ongoing game.

In ContextKing, each individual player may have an impact in game play, no matter how long or how often the game has been played. The history of ContextKing is constantly rewritten through all players' activities in daily life. Their measured behavior is automatically used as input for the game and provides the basis for the interaction with virtual elements such as kingdom attacks, trading, the construction of necessary infrastructure or the collection of valuable objects. All elements in the game keep their own story line as the result of user-generated descriptions based on event keywords provided by the system. Singular story threads are intertwined and eventually grow into rich descriptions of certain game episodes. Through ContextKing's close connection to various Web 2.0 communities, these stories are distributed over the users' social networks and thus provide an uncommon gateway to the game for the majority of people that have not been participating before.

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