Mobile Location-Based Gaming as Driver for Location-Based Services (LBS) – Exemplified by Mobile Hunters

Jörg Lonthoff and Erich Ortner
Technische Universität Darmstadt
Hochschulstraße 1, 64289 Darmstadt, Germany
E-mail: {Lonthoff, Ortner}@winf.tu-darmstadt.de

Keywords: mobility, location-based services (LBS), gaming, acceptance, application system

Received: March 3, 2007

Location-Based Services (LBS) have entered the discussion in the early 1990ies, but they have not yet achieved a real breakthrough. Here, "Mobile Location-Based Gaming" (MLBG) could bring about the change. Location-based services may well achieve wider recognition because of the human play instinct. This work introduces MLBG and the adventure game "Mobile Hunters" – an implemented MLBG that uses the currently available cellular phone network to create a virtual playing field that represents the real world. This innovative way of playing seems strange at first, but it proves to be a helpful step towards context-based value-added services.

Povzetek: Opisana je igrica "Mobilni lovci" na mobilnih telefonih, kot primer novih mobilnih storitev LBS.

1 Introduction

Growing Internet mobility due to various transmission methods such as broadband data transmission get mobile service providers interested in providing services that offer more than voice telephony. Modern cellular phones support GPRS, have a colour display and are usually Java-compliant. This meets the device's requirements for context-based services [18]. As GSM-based cell phones are widely used and – at least in Europe – the GSM-network is available almost everywhere, the context variable "location" seems useful for extending the relevant value-added services. For example, there are services for finding friends in the vicinity (Buddy Alert by Mobiloco – www.mobiloco.de) or, mobile navigation systems for cellular phones (NaviGate by T-Mobile – www.t-mobile.de/navigate).

But there has not yet been a real breakthrough for Location-Based Services (LBS). This is partly due to the costs involved. As yet, mobile network providers do not charge competitive prices for location requests [18]. On the other side, the general recognition of such services poses a central problem for LBS [1]. The possible solution presented in this work uses the human play instinct to achieve greater acceptance. Playing, the use of location-based services will become effortless and people will get interested in such systems. Mobile games are becoming a mass market. If this mass market can be served, prices for location requests will go down – thus providing the solution to a second central issue.

Supported by T-Systems International, in 2005 we developed the adventure game "Mobile Hunters" [9]. The game demonstrates what is possible with LBS and uses the currently available infrastructure mobile network providers offer for creating a virtual playing field. Such a playing field can be adapted to the real world. The object of the game is a hunt. Players can either be a hunter who must find a fugitive or, a fugitive, who has to make sure he is not getting caught. Of course, this hunt will become eventful as there are a variety of obstacles.

This work will first summarize the current state of research in this field and then present "Mobile Location-Based Gaming" (MLBG). Then you will get to know the game "Mobile Hunters". After that, we will discuss the lessons learned from the game and possible further developments will be considered. At the end, a short conclusion will be drawn.

2 Related Work

2.1 Location-Based Services (LBS)

The added value of mobile services opens up opportunities for service providers to address a new dimension of the user: the user's spatiotemporal position. Such services are called Location-Based Services. LBS are based on a variety of localization methods for determining a user's position. In the field of so-called "Context-Aware Computing" [23] LBS provide location information as context references [3].

There are many possibilities of using the location reference in an application system [20, 25]. Unni and Harmon's classification of LBS is consumer-oriented. They divide LBS in information/directory services (e.g. yellow pages), tracking services (e.g. tracking assets), emergency services (e.g. police and fire response), navigation (e.g. route description) and location-based advertising and promotions (e.g. mobile coupons) [28].

All of these LBS are based on mobile positioning. Mobile positioning comprises all of the technologies for determining the location of mobile devices [28]. Basically, there is a difference between indoor and outdoor localization [2]. In the following sections we will focus on outdoor positioning technologies.

A position can be determined in different ways: using network-based technology (the network provides the position) using terminal-based technology (the device provides the position), and hybrid technology (a combination of the former technologies) [22].

Network-based Positioning

GSM networks offer basically six different methods of network-based localization [21]. Cell of Origin (COO) is the simplest mobile positioning technique. It identifies the cell in which a cellular phone is logged on. The positioning accuracy that can be achieved depends on the size of the cellular coverage area, which may range between 25 m and 35 km in diameter. In addition, there are more complex techniques such as Angle of Arrival (AOA), Time of Arrival (TOA), Time Difference of Arrival (TDOA), Signal Attenuation (SA) and the RadioCamera system.

Terminal-based Positioning

Cell of Origin (COO) can also be considered a terminal-based technique, as the desired cell ID can be read out directly from the device (terminal). To do so, however, a reference database is needed, which contains the geographic coordinates stored for each cell ID. The following further terminal-based techniques are available: Enhanced Observed Time Difference (E-OTD) as well as the satellite-based systems such as the global positioning system (GPS), or Assisted-GPS (A-GPS), which works without modifications to the cellular phone network infrastructure, except that the mobile device must possess a GPS receiver.

Hybrid Positioning

Hybrid localization techniques use network-based and terminal-based technology. The Location Trader developed by the Centre for Digital Technology and Management (CDTM) in Munich combines various localization methods. It works in an accumulative way and uses solely information that is open to the public, like cell ID, signal strength and fingerprints of signal patterns. An iterative localization database is built up by using a multitude of users (community). Explicit user interaction, heuristic computation and tabular search and replenish cause the data basis to adjust. Therefore, the goal is to develop a provider-independent localization method, which becomes more precise as more and more users are involved in this system [4].

2.2 Gaming

Mobile games for cellular phones are currently experiencing a growing demand. For the game developers cellular phones are just another platform for porting their console games [18]. There is a strong trend towards more complicated 3D-games. This trend is supported by the current hardware developments, that is, the availability of high-performance cellular phones or smart phones, respectively.

Mobile Games

Games that allow direct communication with remote participants are of great interest (multi-player games). The multi-player games currently on offer can be played using a WAP portal or, locally by two people (infrared) or by several players (Bluetooth).

Games for PDAs (handhelds) are also very interesting. They are usually intended for one player. But games for several players become possible, if infrared, Bluetooth or WLAN are used.

Location-Based Games

But the above mentioned “mobile games” ignore the exciting new possibilities mobile devices like cellular phones provide via their inherent ability to maintain connectivity while on the move. So, one possibility could be to extend the virtual world of a game using location-based information. This extension allows users to play games that incorporate knowledge of their physical location and landscape, and additionally provides them with the ability to interact with both real and virtual objects within the space [18].

In location-based games the movements of a player (in the sense of a geographical change of location) influence the game. Nicklas et al. [15] suggest a classification of location-based games into Mobile Games, Location-Aware Games and Spatially-Aware Games.

As a location reference mobile games require merely one more player who is in the vicinity. The location information itself is not considered in the game. A typical example of this kind of game is "Snake", a game of dexterity for two, which is delivered with the older Nokia cellular phone models. It can be played using infrared or Bluetooth.

Location-Aware Games include information about the location of a player in the game. A typical example might be a treasure quest whereby a player must reach a particular location.

Spatially-Aware Games adapt a real-world environment to the game. This creates a connection between the real world and the virtual world. The MLBG "Mobile Hunters" presented in the following belongs to this category of games.

3 Mobile Location-Based Gaming (MLBG)

3.1 Definition and Delimitation

Mobile Location-Based Games (MLBG) are a special category of Location-Based Games.

Definition: *A MLBG is a location-based game that can run on a mobile device. By using a communication*

channel the game can exchange information with a game server or other players.

Applying this definition, the fields Location-Aware Games and Spatially-Aware Games become relevant. The following figure shows all terms relevant in MLBG.

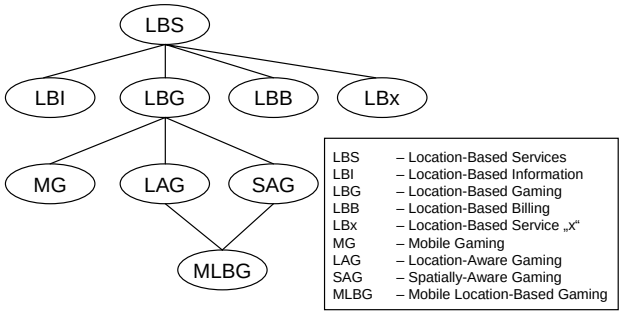

Figure 1. Taxonomy for Location-Based Services.

3.2 Characteristics

Important for MLBG are the type of device used, the communication and network infrastructure it is based on, the way positions are determined and the kind of game.

Devices such as cellular phones, smart phones and PDAs can be used, possibly laptops also. In addition to this rough classification, the device properties can serve for further distinction: the operating system, client programming (JavaVM, Web-Client/WAP-Client), the types of user interfaces available, as well as power consumption and processor power.

The relevant communication media are wide area networks such as WLAN, GSM and UMTS. These technologies vary in range and bandwidth.

In chapter 2 you will find a description of the techniques that can be used for determining positions for MLBG. The accuracy of a determined position depends on the technique used and on the network structure.

When looking at the type of game, two dimensions are of interest: the number of players and the type of game. There are single-player games and multi-player games. You can also play multi-player games alone, if players are simulated. Massive-Multiplayer-Games are a special type of game in which the end of the game is not defined. Players can actively participate in the game for some time and improve their ranking in the community associated with the game. Relevant genres of game would be role-playing games, scouting games, real-time strategy games and shoot-em-up games.

You will find a variety of game collections on the Internet that include MLBG. For example:

- www.smartmobs.com/archive/2004/12/28/locationbased_.html,
- www.we-make-money-not-art.com/archives/001653.php and
- www.in-duce.net/archives/locationbased_mobile_phone_games.php.

There, the distinction is made between cellular phone games, handheld/PDA games and others. The following are typical examples of MLBG: Botfighters by It's Alive (www.botfighters.com – cellular phone, GSM, SMS, J2ME, PC), Treasure Hunt by Treasure Hunt Mobile (www.playtreasurehunt.com - cellular phone/PDA, J2ME, GPS), Supafly by It's Alive (www.itsalive.com/supafly - cellular phone/PC, WAP/J2ME, SMS/MMS) and Seamful Game by Englands Equator Project (PDA, .net, WLAN, GPS).

In newer publications you will find studies [7] and overviews [11, 12, 13, 18] of pervasive games, including MLBG.

3.3 Challenges

One of the main challenges to MLBG is the problem of how to turn "classic" games into MLBG. Nicklas et al. [15] identified four central issues for the adaptation of board games to MLBG:

Adaptation of the playing field

The playing fields of board games are clearly delimited. The real world, in contrast, is continuous. This requires an adaptation of the playing field in the sense of a virtual playing field as an extension of the real world. Here, the unclear delimitation of virtual playing fields proves to be difficult.

Adaptation of the pawn in a game

The pawns that are being moved in a board game correspond to real-life players who are changing their positions in their environment.

The representation of cards or objects

The cards or objects drawn in a board game can be adapted to the virtual world as virtual cards or virtual objects that a player can take.

Adaptation of the moves in the game

Board games are based on rounds. One discrete move is made after another. In MLBG this restriction does not apply, as a player cannot simply remain motionless for one round. Playing rounds or sitting out for some time must be considered in the game concept in such a way that the MLBG can be played in real-time.

When a "classic" game is adapted to a MLBG, it is important to ensure that the point of the game is kept and that the duration of the game is adequate. The hype phases we observe are much shorter with games than with any other service offers. Once a game is considered boring or error-prone, acceptance drops.

Rashid et al. remark that in established game developer conferences, and numerous online discussions, many traditional game developers and executives express their doubts about location-based games [18]. Nevertheless, existing location-based games do contribute to operator revenue. For example, in Sweden, Botfighters made EUR 10 to 100 per person in 2002. Furthermore, the fact that the majority of location-based games launched thus far have generated a considerable amount of public interest, it is likely that they will eventually capture the interest of the less traditional gamers [18].

MLBG are fascinating: "This ability for you to actually use your real world movements to play the game means that you are no more playing a game… You are in the game!" [14].

Another challenge results from the characteristics of mobile networks. In MLBG it may happen that some of the players interrupt the connection for short periods of time. These interruptions must be covered (resuming), for example, using central session management.

4 "Mobile Hunters"

4.1 The Game

We started out with the idea to implement the well-known board game "Scotland Yard", also known as "Hunting Mr. X" [19]. This was difficult because the original game was based on rounds and we needed to change this for the real-time game. Another problem arose when we tried to distinguish the means of transportation. This forced us to modify the conception of the game.

Mobile Hunters is a multi-player game. The creation of a players' community reflects partly the notion of massive multi-player games. To be able to start a game session at least two players must participate. There are two possible roles in the game: One or more hunters and one fugitive. The hunters want to catch the fugitive before the specified playing time (default 30 minutes) is over. The fugitive must try to escape the hunters or, to prove that he is innocent by collecting a number of items (default 3) as proof of his innocence.

After logging on to the Mobile Hunters server with user name and password as authentication, a player can initiate a game. Once a game has been initiated, several more players can enter in the game. If a new player enters in the game, the game server checks whether the potential player's location is within an appropriate distance from the center of the playing field. This ensures that the spatial distance between the players does not become too large. The person who initiated the game decides when the number of players is sufficient and then starts the game. The maximum number of players can be specified.

When the game is started, the game server randomly assigns the roles and informs the players about whether they are a hunter or a fugitive. When the game has been started, the game server randomly distributes all the items for hunters and fugitives on the playing field. After this initialization phase the game begins synchronously on all participating clients and the countdown for the playing time starts. In previously specified intervals (default 1.5 minutes) the current position of the fugitive appears on a map in the hunters' display. In the playing field there are a number of locked (virtual) boxes that players can open if their position is the same as the position of the box (geo-coordinate with specified radius = playing field). Some of the boxes are visible only for hunters. These boxes contain offensive weapons. The fugitive can only see the boxes that contain items for him. These are items for defense or proof of innocence. Table 1 gives an overview of the various items.

A player can attack if one player is located in the same position and the attacker has a weapon. If a hunter attacks another hunter, the person attacked will become incapable of action for some time (default 30 seconds), his client's menu will be hidden. In this attack the attacker loses his weapon. If a hunter attacks a fugitive, the fugitive can defend himself using a matching item for defense. If this happens, the attacker will become incapable of action for some time (default 30 seconds). If the fugitive cannot defend himself, the hunter wins.

The fugitive wins if he is able to find a certain number (default 3) of items that prove his innocence or, if no attack on him was successful during the duration (default 30 minutes) of the game.

Table 1. Overview of the items available for the players.

Recipient	Type	Instance	Purpose
Hunter	Attack		In the boxes the hunter will find offensive weapons he can use to attack the fugitive or, for attacking another hunter to make him incapable of action (e.g. handcuffs).
Fugitive	Proof		In the boxes the fugitive will find items that can prove his innocence (e.g. a theater ticket).

Fugitive	Defense		In the boxes the fugitive will find items he can use to defend himself against attacks by a hunter (e.g. paper clip for defense against handcuffs)

4.2 Fundamental Design Decisions

In the development of "Mobile Hunters", to facilitate acceptance of the game, we only used technologies that have already been accepted in the market and are, or will most certainly be, widely spread,. We chose the GSM network, which is currently most widely used [15, 18], to ensure a wide range of application. Using GPRS, GSM networks support stable IP connections.

The mobile device we chose should not require further hardware (e.g. an external GPS receiver). The devices hardware requirements are at least 200 MHz processor power, 1 MB RAM and a minimal display resolution of 126 x 208 pixels. The software requirements are Java-compliance, a Symbian OS greater or equal version 7.0 in association with Mobile Information Device Profile (MIDP) 2.0 and Connected Limited Device Configuration (CLDC) 1.1. Therefore we opted for the Nokia 6680 cellular phone with an adequate display as playing device [10].

It was essential that the positioning technique would only use the available cellular phone network infrastructure and that it would not be necessary to make modifications to it. Furthermore, it was required that the cell ID could be read out from the cellular phone. This is why Cell of Origin (COO) seemed best suited for Mobile Hunters.

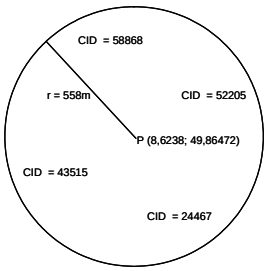

Figure 2. Cellular coverage area of a T-Mobile GSM base station located in Darmstadt, Germany.

COO evaluates the cell ID (CID) to which the cell phone is logged on. The cell ID is connected with the radiation range of a mobile base station. The cellular coverage area has a certain range (r) around the position (P) of the mobile base station. One mobile base station can have several radiation areas (CID), whereby these cells always refer to the same geographic position (P) of the mobile base station's location, mostly denoted in the World Geodetic System 1984 (WGS84) format (s. figure 2) [6].

Thereby the position accuracy depends on the size of the cellular coverage area (approx. 25-100 m in urban areas and up to 35 km in rural areas) [24].

4.3 "Mobile Hunters" Architecture

The implementation is based on a client/server architecture. Communication between the components is realized using the German T-Mobile GSM network. For data transfer we chose GPRS, communication takes place on application level via HTTPS. The Mobile Hunters server is a Java-based game server, which provides the user management and the game management. For determining each player's current position, we use T-Systems' research platform "Permission and Privacy Gateway" (PPGW). The PPGW also provides the Mobile Hunters server with maps of the areas in question. The following figure shows the overall architecture schematically.

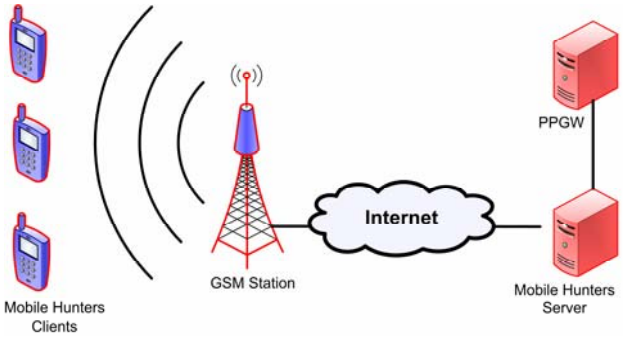

Figure 3. Overall architecture.

4.4 "Mobile Hunters" Client

The Mobile Hunters client (s. figure 4) is the game's user interface. It displays the current map segments and here, interaction with the other players takes place. Players also use the Mobile Hunters client to register and log on.

Figure 4. "Mobile Hunters" client on Nokia 6680.

Current prerequisites are a smart phone with Symbian-OS 7.0 and a J2ME framework. A class implemented in Symbian C++ is needed for reading out the cell ID the mobile device uses. The cell ID is transmitted to the Mobile Hunters server. The server requests the current status in specified intervals (default every 10 seconds). The necessary unique identification of each player is the user name he entered at the beginning of the game.

4.5 "Mobile Hunters" Server

The Mobile Hunters server centrally controls the game. On the server, identification and authentication of the users takes place, as well as the game logic and the communication between PPGW and the clients. Every initialization, as well as the specification of the playing field, happens dynamically on the game server. The server was implemented in Java as an Apache Tomcat application on a Microsoft Windows 2003 Server platform and connected to a Microsoft SQL Server via JDBC/ODBC. This ensures a clear separation of application level and data level. The server establishes the connection to the PPGW for requesting the geographic data of each cell ID used in the game at any time. The PPGW has a reference database where the relevant geo-reference-data for each cell ID are stored. The geographic data that correspond to the cell IDs are returned by the PPGW via an XML-based interface. The server keeps a high-score list to challenge the gaming community. Using a configuration file, the parameters that can be controlled are passed to the server.

5 Lessons Learned

5.1 The Game's Concept

The adaptation of the game's concept to the virtual world turned out to be difficult because of the inaccuracy of positioning. Cell switches occur even if a player does not move. This may happen, for example, if several participants are logged on to a cell and, due to the limits of bandwidth or for reasons of optimization, a neighbouring cell is allocated to the mobile device.

Cellular coverage areas have different sizes: in an urban area approx. 25 m, in rural areas up to 35 km. The homogeneous structuring of a cellular phone network in hexagonal units that is described in literature is not found in practice. The cellular coverage areas of single cells overlap with those of other cells. Large cells cover smaller cells almost completely (s. figure 5). It is still in the discussion whether to exclude cells from the game if they are too large and, from which size on they should be banned.

Figure 5. T-Mobile cells in Darmstadt, Germany.

In the real world it frequently happens that two players are standing side by side, but their mobile devices are logged on to different cells. "Mobile Hunters" is suited for playing in high-density urban areas, because the accuracy of positioning is adequate there. On the outskirts of a town or in rural areas, the game cannot be played due to the current means of positioning and the size of the cells.

For the game Mobile Hunters to be funny and exciting, a game duration of 30 minutes is recommended. The interval in which a fugitive's current position is displayed should be 1.5 minutes, the time a player is incapable of action should be 30 seconds and, the interval in which the cell ID is read ought to be less than one second.

5.2 Hardware and Implementation Experience

A powerful CPU such as the Nokia 6680 is necessary for playing this game. Session handling is essential for playing a MLBG. The user interface's design should be simple, so that no explanations will be necessary.

It is very important to develop the client's code in a way best suited for cellular phones. This means, the "renaissance" of well-tried implementation guidelines like lightweight data structures and prevention of unnecessary procedure calls [10].

Our mobile-specific modeling resulted in a very economic consumption of resources and of handling communication data. In a 30 minute game, only an average of 300 kB data is transferred. Half of that data volume is used for loading the graphics (maps and icons) at the beginning of the game.

In our attempt at optimizing the implementation, another important aspect needed to be considered. It is often the case that, at run-time, 90% of the executed program uses only 10% of the implemented code. It is therefore vital that the code optimization take care of precisely those 10% of the code.

JSME Wireless Toolkit offers a tool called "Profiler". It is ideally suited for finding out, which code is frequently used and can therefore be very helpful for code optimization. You will find a detailed description of

how to use this tool in [26]. The Profiler gives an overview of the entire code execution, as for example the numbers of iterations of a loop or a procedure call.

6 Enhancements

To achieve a higher positioning accuracy based on COO, we are trying to handle cell switches and overlaps by including all cell IDs that the mobile phone receives. This allows us to buffer positions and information can also be evaluated by neighbouring cells. This software-based solution is also known as Enhanced cell ID (E-CID) [28].

A more comprehensive solution would be to use more accurate positioning techniques like GPS, or in future, GALILEO. Assisted GPS (A-GPS) will open up interesting opportunities for mobile network providers.

To play Mobile Hunters globally, that is over great distances an additional virtualization level should be introduced. Using this additional level, each individual player's physical movements could be mapped as relative movements on the virtual playing field. This approach would eliminate the range restrictions of the playing field [27].

It would be a nice feature, if hunters were able to communicate during the game in order to act strategically. Communication between the hunters can become possible by using Instant Messaging or simply by sending text messages (SMS). In this case, another alternative would be Push-to-Talk or voice-telephony. Such communication is very interesting for network operators who want to increase their revenue.

The Mobile Hunters server could be enhanced to become an enabling service, which would provide potential creators of MLBG with the generic functions needed for the implementation of location-based games.

Furthermore, Mobile Location-Based Gaming could be extended by a variety of context parameters and thus reach the higher development stage of Mobile Context-Based Gaming. In addition, MLBG is an interesting medium for advertising and interactive marketing [5, 17].

7 Conclusion

The conclusion we draw is that we have partly succeeded in adapting the real world to a game's virtual world. It is possible to read out the cell ID from a variety of mobile devices using different techniques. However, no standard API is currently available to offer this functionality. This means that anyone who wants to create a game needs to develop a suitable API for every single device, if the game is to be widely used. Only Java-compliant devices with optional package JSR 179 (Location API for J2ME, released 12.07.05) are suitable for location requests. This problem may also be solved by deploying a middleware such as BREW (www.qualcomm.com/brew; [27]) or SNAP Mobile (snapmobile.nokia.com; [8].

The experience gained in the field of gaming also applies to situations in private and business life. Possibly, brand-new application systems useful in every day life can be developed and implemented. In this context "application system" is understood in a comprehensive way for all tasks in user and computer-based information processing [16].

The infrastructure for LBS is available. Now, key issues such as the ownership and management of location-specific data, transaction and data security, as well as consumer privacy are still to be resolved [28]. Gaming is suitable to get a feeling of LBS.

Acknowledgement

Mobile Hunters was developed in a co-operation between the university department "Wirtschaftsinformatik I – Development of Application Systems", computer and information science, in Darmstadt and T-Systems International GmbH. Eight students designed and implemented the game as hands-on training in the field of information science in the winter term 2004/05. Based on this prototype, the "Mobile Hunters" team continued the development and stabilized the software. Here, my special thanks go to the "Mobile Hunters" team (Florian Seeanner, Tilman Laschinger and Michael Wolf) for their extraordinary dedication and to Thomas Leiber of T-Systems International for his invaluable visionary and practical support.

References

[1] Borriello, G et al., 2005, The disappearing computer: Delivering real-world ubiquitous location systems. In: *Communications of the ACM*, Vol. 48, No. 3, pp. 36-41.

[2] Bulusu, N. et al., 2004, Self-Configuring Localization Systems: Design and Experimental Evaluation. In: *ACM Transactions on Embedding Computing Systems*, Vol. 3, No. 1, 2004, pp. 24-60.

[3] Dey, A., 2001, Understanding and Using Context. In: *Personal and Ubiquitous Computing*, Vol. 5, No. 1, pp. 4-7.

[4] Dornbusch, P.; Huber, M., 2003, Generierung von Ortsinformationen durch User-Communities. In: Uhr, W.; Esswein, W.; Schoop, E. (Eds): *Proceedings of Wirtschaftsinformatik 2003 – Medien, Märkte, Mobilität*, Vol. 1, Heidelberg [a. o.], 2003, pp. 175-186.

[5] Han, S.; Cho, M.; Choi, M., 2005, Ubitem: A Framework for Interactive Marketing in Location-Based Gaming Environment. In: *Proceedings of the IEEE International Conference on Mobile Business (ICMB'05).* Sydney, Australia, pp. 103-108.

[6] Hansmann, U. et al., 2001. *Pervasive Computing Handbook*, Springer, Berlin, Germany.

[7] Jegers, K.; Wiberg, M., 2006, Pervasive Gaming in the Everyday World. In: *Pervasive Computing*, Vol. 5, No. 1, pp. 78-85.

[8] Levy, M, 2006, Developing Network Connected Mobile Games for J2ME Handsets Using SNAP Mobile. In: *Proceedings of Game Developers Conference (GDC) 2006*, San Jose, USA.

[9] Lonthoff, J.; Leiber, T., 2005, Mobile Location Based Gaming als Wegbereiter für Location Based Services. In: *LNI-Proceedings of the 19. DFN-Arbeitstagung über Kommunikationsnetze*, Volume P-73. Düsseldorf, Germany, pp. 343-360.

[10] Lonthoff, J.; Ortner, E.; Wolf, M., 2006, Implementierungsbericht Mobile Hunters. In: Roth, J.; Schiller, J.; Voisard, A. (Eds): *3rd GI/ITG KuVS Fachgespräch Ortsbezogene Anwendungen und Dienste*, Technical Report, Institut für Informatik, Freie Universität Berlin, 07.-08.09.06, Berlin, pp. 26-31.

[11] Magerkurth, C. et al. (eds), 2004, *Proceedings of International Workshop on Gaming Applications in Pervasive Computing Environments (PerGames) 2005*. Vienna, Austria.

[12] Magerkurth, C. et al. (eds), 2005, *Proceedings of 2nd International Workshop on Gaming Applications in Pervasive Computing Environments (PerGames) 2005*. München, Germany.

[13] Magerkurth, C. et al. (eds), 2006, *Proceedings of 3rd International Workshop on Gaming Applications in Pervasive Computing Environments (PerGames) 2006*. Dublin, Ireland.

[14] Mikoishi, 2004, *gunslingers*. In http://www.gunslingers.mikoishi.com.

[15] Nicklas, D. et al., 2001, Towards Location-based Games. In: *Proceedings of the International Conference on Applications and Development of Computer Games in the 21st Century: ADCOG 21*. Hongkong Special Administrative Region, China, pp. 61-67.

[16] Ortner, E., 2005. *Sprachbasierte Informatk – Wie man mit Wörtern die Cyber-Welt bewegt.* EAGLE-Verlag, Leipzig, Germany.

[17] Rashid, O.; Coulton, P.; Edwards, R., 2005, Implementing Location Based Information/Advertising for Existing Mobile Phone Users in Indoor/Urban Environments. In: *IEEE-Proceedings of the 4th International Conference on Mobile Business (ICMB'05)*, 2005, Sydney, Australia, pp. 377-383.

[18] Rashid, O. et al., 2006, Extending Cyberspace: Location Based Games Using Cellular Phones. In: *ACM Computers in Entertainment*, Vol. 4, No. 1, 2006, pp. 1-16.

[19] Ravensburger, 1983. *Scotland Yard*. Ravensburg, Germany.

[20] Richter, U. et al., 2004, Location-based Services: Konkurrenz durch lizenzfreie Alternativen. In: *VDE Kongress 2004*, Berlin, Germany, pp. 65-70.

[21] Röttger-Gerigk, S., 2002. Lokalisierungsmethoden. In: *Handbuch Mobile-Commerce*. Springer, Berlin, Germany, pp.419-426.

[22] Samsioe, J.; Samsioe, A., 2002, Competitor Analysis in the Location Based Service Industra. In: *IEEE-Proceedings of First International Conference on Mobile Business (ICMB'02)*, 2002, Athens, Greece.

[23] Schilit, B. et al., 1994, Context-Aware Computing Applications. In: *Workshop on Mobile Computing Systems and Applications.* Santa Cruz, USA, pp. 85-90.

[24] Schiller, J., 2003, *Mobilkommunikation*, 2nd edt, Pearson Studium, Munich, Germany, 2003.

[25] Schiller, J.; Voisard, A., 2004. *Location-based services*. Morgan Kaufmann Publishers, San Francisco, USA.

[26] Shivas, M., 2003, *J2ME Game Optimization Secrets*. In: http://www.developer.com/ws/j2me/article.php/10945_2234631_1.

[27] Tarumi, H.; Matsubara, K.; Yano, M., 2004, Implementations and Evaluations of Location-Based Virtual City System for Mobile Phones. In: *Proceedings of the IEEE Global Telecommunications Conference Workshops.* Dallas, USA, pp. 544-547.

[28] Unni, R; Harmon, R., 2003, Location-Based Services: Models for Strategy Development in M-Commerce. In: *IEEE-Proceedings of Portland International Conference on Management of Engineering and Technology 2003 (PICMET'03)*, Portland, USA, pp. 416-424.