Appendix A

Technological Enablers of Pervasive Games

Annika Waern, Markus Montola, and Jaakko Stenros

This appendix provides a rough overview on the current state of the art of positioning, proximity recognition, and wireless communication technologies useful in staging pervasive games. While a pervasive game can be staged with no technology at all, especially large-scale games and game-mastered games often utilize some of the following technologies.

Absolute Positioning

Much of the use of technology in pervasive games is about positioning the players as they move around in the world. Positioning technologies can be divided into those that provide an absolute position, globally or within a preset game area, or relative with respect to objects or people in the game.

Global Positioning System

The global positioning system is the dominant technology for positioning. Being a satellite navigation system, the GPS system works only when the device is under open sky. Under good circumstances, the technology can pinpoint you with the accuracy of a few meters. To provide limited positioning in areas outside GPS coverage, the system can be combined with different types of *dead reckoning,* the measurement of velocity, direction, and time in order to determine relative changes in position. In addition, GPS is free to use once the user has access to a GPS device. Map services, however, are usually subscription based; there are also subscription-based GPS services that provide higher precision through *differential GPS*. Differential GPS uses the known location of a fixed GPS receiver to calculate the position with higher precision.

GPS is designed to position people who want to be positioned, and as such it is not a very good technology for tracing players who are trying to hide or do not care. Physical obstacles and bad weather can stop GPS from working. Narrow streets and high buildings are especially problematic, but even a singular small wall can be a hazard if the player is standing right next to it. The further you go from the equator, the harder it is to position efficiently, as the satellites fly closer to the horizon. GPS is a global standard, but the systems are run by the United States government, and using GPS creates a dependency on U.S. foreign policy. Finally, GPS can become a power sink, draining the batteries fairly quickly.

If the players use cars or other vehicles in order to move during the game, it is a good idea to place the receivers on them. Cars tend to stay away from shadows cast by buildings, and they can also provide power for the receivers. However, an increasing number of high-end mobile phones feature built-in GPS receivers, making those a viable platform as well.

The European Union is building another satellite system, *Galileo*, which is a serious candidate for becoming a positioning system for pervasive gamers in Europe. It will be similar to GPS in that it will require special hardware to use, but it is intended to be more precise. Galileo will be regulated by a pan-European policy. The system is under construction at the time of writing and is planned to be fully operational in 2013.

Cell Positioning

Cell positioning is a form of global positioning that relies on the fact that the mobile phone operator knows exactly where the base stations for the mobile phone system are located. The phone operator always knows which base station a phone is connected to and can either relay that information directly or use lower level information (about the direction and distance of the phone to the base station) to approximate a more precise position of the phone.

Cell positioning is typically made available as an Internet-based *server-side* service. This means that a game server can contact the positioning server and request the position of specific phones based on their phone numbers. Because privacy protection is an issue for such services, the user must acquire different types of permissions from the phone operator to allow the game service to use positioning.

The quality of positioning is dependent on both the position of the player and the technology the operator is using for calculating positions. It can range from just giving the position of the base station to a very precise position of the phone within meters.

Server-side cell positioning can be very expensive and is typically charged per request. If you want to position a player once per minute, you have to be prepared to pay the bill 1440 times every day. Also, some operators do not provide this service at all.

The major advantages of server-side cell positioning are that when the operator supplies it, it is always available and works indoors as well as outdoors. In addition, it does not require any special hardware or even software running on the phone.

An interesting fact is that the cell information is actually generated in the phone. A mobile phone always knows its own cell ID, and some phones are able to display this information. When accessible, this information is free of charge. The problem with using the raw information of this *client-side* cell positioning is that mobile phones can switch base stations rapidly and unpredictably. Depending on the station, the base station radius can be anything from a few dozen meters to several kilometers, and players will experience random teleportation from time to time. This is especially problematic if the game features a static virtual world that should be overlapping with the physical world.

Wireless Local-Area Network Positioning

Wireless local-area network positioning works in a way that is very similar to cell-based positioning. It relies on knowing where a WLAN base station is located. Again, using triangulation algorithms and the signal strength of the station, a player's position can be calculated quite precisely. Both commercial and open source software is available for WLAN positioning.

WLAN positioning is a clear alternative for games where the game area is well known and not too large. It is possible to map out such a game area by putting up WLAN stations and positioning them. The advantage of this approach is that while the area is being mapped, you can provide Internet access over the same area.

As a global positioning technique, WLAN positioning is much less reliable. There are online Web services that aim to provide WLAN connectivity and positioning as a community service; anyone who sets up a WLAN station is encouraged to report it to the service to pool resources. The reliability and coverage of such services should not be trusted.

Examples of games utilizing WLAN positioning include *Epidemic Menace* (Case H), *Feeding Yoshi* (Bell et al., 2006), *Rider Spoke*, and *Plundr*. Of these examples, only *Epidemic Menace* knows the absolute location of a player, while the others use WLAN stations as ungrounded beacons—even though the positioning can be used globally, the game system does not correspond virtual locations with physical ones.

Self-Reported Positioning

Self-reported positioning is based on asking players to report their current position. This can be automated by, for example, having the players mark their location by clicking on a map on the device they are carrying. It is also possible to track the position of a player through monitoring how she chooses to view an online map. *Uncle Roy All Around You* was based on clicking on a map (Benford et al., 2008), *PacManhattan* players communicated with the game headquarters via phones (Case G), and *REXplorer* players select the closest building from a list (Ballagas et al., 2008). All these positioning methods have proved quite reliable—indeed, some (Ballagas et al., 2008) report that self-reported positioning works much better than satellite positioning in the urban canyons of Old Regensburg.

At its crudest, self-reporting can be set up with mobile phones (in the 1980s, some players used to carry rolls of quarters to be able to check in from pay phones). Either the players call in to tell where they are or a spy can follow the players and report on their whereabouts.

Proximity Recognition

In many cases, games do not need to know exactly where a player is. It is sufficient to know that she is close to something, is picking up a particular object, or meeting another player. A number of technologies can be used for this purpose. All of these technologies have limited uses also for absolute positioning, as long as the player is close enough to be positioned.

Radio Frequency Identification

Radio frequency identification is becoming the most widespread technology for proximity detection. Because there are several competing standards, we will only describe the major ones, divided into *active* and *passive* RFID.

All RFID technologies are based on a large number of small and fairly inexpensive *tags* that can be put on objects or hidden in the real world and a smaller number of electricity-powered *readers*, which are larger and more expensive. The reader must be held in the vicinity of a tag to read or change its content. Line of sight is not necessary; on many occasions a reader can read a tag through a paper or even a table surface. Tags can take different forms, and the smallest ones can be inserted under the skin or even eaten. The determining factor is the size of the antenna; with a small antenna, a tag can only be read at the range of centimeters, whereas large antennas allow a reading distance of several meters. Locating and reading a tag are very fast. Because the antennas must be roughly lined up, the relative orientation of the tag and the reader is important for a successful reading.

The smallest tags are typically *read-only passive* RFID tags, which do not need a power source. Instead, they are powered by the energy field generated by the reader. A read-only tag only contains one single piece of information that cannot be changed: a unique ID that is not shared with any other tag. There are also passive RFID tags that can store information written with a reader.

An active RFID system has an energy source (typically a battery) connected to the tag itself. This means that the tags can do things even when not read or written on by a reader. Such tags are sometimes packaged together with sensors so that they can track some information about their surroundings. The active RFID standards have been developed primarily by the transportation industry. For instance, they are used to ensure that a chilled cargo has not been subjected to heat during transportation. Active RFID typically supports larger reading distances than passive RFID.

The main hindrance of using RFID tags is the need for a reader device. There are affordable readers that you can plug directly into a mobile phone, but chances are none of your players have ever seen such a device before the game. Because passive tags are very inexpensive to buy, with prices ranging from a few cents to one Euro each, you can basically flood your game with tags if needed. The readers are more expensive, especially if they should be able to write as well as read or to communicate their data wirelessly.

Bluetooth

Bluetooth is a close-range communication protocol designed to support ad-hoc data transfer between devices. It also has use as a proximity technology. A device with Bluetooth can scan for others in its range. As in RFID, each Bluetooth device has a *unique* ID, which is immediately available from such a scan. Bluetooth scanning can be used for proximity detection without invoking any kind of communication between the two devices. Hence, the approval protocol for connecting the two devices does not come into play.

The good thing about Bluetooth is that most mobile phones and a large range of portable devices support the protocol, making it a technology that is readily at hand. The drawback is that scans are slow, unreliable, and drain quite a lot of battery power.

The Bluetooth protocol supports two kinds of scans: open scans and scans for devices that are already known. The latter is faster, slightly more reliable, and uses less power.

The Bluetooth standard is undergoing rapid development, and the transfer range is increasing. Recent devices are said to have a proximity range of up to 100 meters, which actually renders the technology less suitable for proximity detection. If you decide to use it in your game, you should check the scan range of your game devices first.

Infrared Communication

Infrared communication relies on invisible light signals sent between objects in line of sight. The requirement of line of sight makes it a useful proximity technology, and because it also requires a straight line between the communicating sensors, it is direction dependent. Laser games use infrared communication to establish who has taken a shot by whom, a usage that transfers readily to pervasive games. There is no specific communication standard used in infrared systems.

Wireless Communication

As discussed in Chapter Eight, the most central function of technology in pervasive games is to support communication between players or between players and game masters. This section goes through the most common technologies for supporting communication for mobile devices.

Wireless Local-Area Networks

Wireless local-area networks are a mobile version of a standard Internet access point. They only work in the vicinity of a base station. The advantages are that they are inexpensive and easy to set up. Access to the base station does not automatically mean that you have Internet access.

In urban areas, there are typically many WLAN base stations available from any position, but many of these are not open for connection to the Internet or require a paid account. The scarcity of WLAN base stations with Internet access makes WLAN more of a hot spot connectivity space than a continuous connectivity space.

General Packet Radio Service

General Packet Radio Service and 3G mobile phone standards are access technologies used in mobile telephone networks. Unlike WLAN, telecom operators deliberately seek to achieve continuous coverage. There are two modes of data communication on mobile phones: GPRS runs over the GSM network, whereas 3G is an integrated standard for mobile phone and data communication. With the right subscription, they always provide Internet access, but it is typically still expensive to use (often charged by communicated bit), although recently reasonably priced monthly subscriptions have been introduced in some regions. GPRS offers low bandwidth, which means slow downloads, and has a built-in delay in response times, which can sometimes be in the range of 20–30 seconds.

Although phone companies aim to provide continuous access, it is common to get disconnected from the network at times or to have very large variations in response times. Another problem is that not all operators handle data communication in the same way—some of them always prioritize voice communication.

A particular problem with GPRS and 3G is that you must use mobile phones almost exclusively in order to access them. It is difficult to develop a mobile phone application that runs on a wide variety of phones due to the differences in interfaces and ways of integrating third-party programs with main phone functionalities. Recently, many phone operators have begun to offer 3G modems that can be used with a laptop computer, making small laptops attractive candidates for mobile devices.

Bluetooth

Bluetooth is a close-range communication protocol designed to support ad-hoc data transfer between devices. It is used in mobile phones to support, for example, wireless earphones and on laptops to allow wireless connections to devices such as printers. Nowadays Bluetooth is available on most portable PCs and mobile phones, whereas game consoles support WLAN more often. The Bluetooth range is typically around 7 meters, but in future phones this is expected to increase to up to 100 meters.

Establishing a connection requires identification. The protocol in the Bluetooth standard requires that one of the devices asks to connect to another by setting a secret password and then the other accepts by entering the same password. Typically, this only needs to be done once for any pair of devices. In the future, the two devices know about each other and can connect automatically.

The communication protocol prioritizes data transfer, which is pretty high bandwidth—illustrated by the fact that you can use wireless earphones to listen to music. The look-up process (finding other Bluetooth devices) is, in contrast, rather slow and somewhat erratic. This means that games that use look-up as a game mechanic need to allow this search to take some time (up to 20 seconds).

Infrared Communication

Infrared communication also allows close-range (maximum 10 meters apart) connections, where the two devices are in direct line of sight of each other. IR is rarely used for communication in pervasive games due to line-of-sight limitations.

Virtual Content

In Chapter Four, we discussed that one of the most well-known approaches to spatial expansion is to use positioning technology to place virtual content at specific locations in the real world. Several techniques can be used to realize such overlays.

Triggered Content

Many pervasive games rely on location-based triggered content, such as video, audio, or text files. Sound is often the preferred type of output, as this allows players to look at the real world and experience the sound as part of it. In order for the superimposed content to pop us, the location of a player must be identified through some (arbitrary) positioning or proximity technique.

Visual content can be used as well, but it needs to be displayed on a screen. Small screens of mobile devices are unable to display very detailed content. One option is to display content publicly through fixed screen installations in the players' physical environment.

Content can be streamed to the device when it is time to display it or stored locally on the device and triggered under the right circumstances. Streaming allows game masters to change or add content while the game is ongoing, and it also prevents players from cheating by hacking the client and looking at the prestored files in advance. However, streaming is costly and can take time, leading to serious delays between the player action and its effect.

The more precise the positioning is, the more precise the connection between the physical landscape and the virtual content can be. For example, a sound can be played when the player actually points at a particular object or reads its RFID tag.

Augmented Reality

The most extreme version of superimposing virtual content is augmented reality, a range of technologies that strive for a strict, three-dimensional overlay between physical space and virtual content. In its most advanced versions, the augmented reality device is a head-up display complete with 3D sound, which superimposes 3D images and sounds onto the real world. Players are located using both absolute positioning and gyroscopes so that the system can know in which direction they are looking.

Full augmented reality technology is still in its infancy, and the technology needed is expensive. It is also very expensive to develop content for full-blown augmented reality. A particular issue is that the system needs an extremely detailed model of the real world where the virtual content is placed, for example, to allow a nearby real-world object to occlude a virtual model partly behind it.

Mobile Augmented Reality

Mobile augmented reality is a much simpler solution in comparison to full augmented reality, and such solutions are entering the market rapidly. Mobile augmented reality typically uses glyphs, black and white-patterned squares, which are placed in physical space. Players use a handheld computer with a digital video camera mounted on it. When players point the camera toward the glyph, the program is able to recognize both the particular pattern of the glyph and the camera's direction and distance from the glyph. Based on this, the program can pick out the right 3D model to display and position it in a specified place in relation to the glyph. If all of this is done in real time, the result is that the 3D model appears as if floating in space and the players can (to some extent) look at it from different angles through moving the device.

Mobile augmented reality is already available for some mobile phones, albeit the quality is still poor. Nonreal-time solutions are based on taking a photo of the pattern, sending it for analysis, and displaying the result. Games that use nonreal-time augmented reality can do server-side analysis and be based on normal camera phones with Multimedia Messaging Service (MMS) capabilities. Be aware, however, that many people have never sent an MMS from their own phone and that it can be costly to do so.