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MASTER'S THESIS

Lair of Beowulf

A Study of 3D Positional Sound in an Audio Mostly Game

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Abstract

Multimedia capabilities of mobile phones increases all the time, today it is possible to develop games with advanced sounds and graphics. Games with 3D graphics are developing fast. But sounds are seldom used to enhance the experience. The sounds in mobile phone games are often one short midi music piece, under a minute long and only a few short samples are used. The sounds often become repetitive; it is common that people disable the music and sounds when playing on mobile phones.

This Master of Science thesis in Media technology describes the development of a prototype and the experimental study that was conducted on it. The prototype is developed together with *Interactive Institute, Sonic studio*. The prototype is called *The lair of Beowulf*, Beowulf was a hero in a story which is the oldest written story in old-English. The game starts were Beowulf enters a cave, in the cave there are several unknown sounds to the gamer. The player of the game how no other cues of the game world than the sounds, which are played through a sound engine, called OpenAL.

The game was then used in an experimental study. The study was conducted on 11 participants. This study had two parts; in the first part the participant was asked how they experienced the sound on seven given points. Experienced sound in this case was how they thought each location looked and the feeling they got from it. In the second part of the test questions about the whole game were asked. How easy it was to navigate, if it was fun to play and similar questions.

The conclusion of the study was that it is very important to carefully select sounds. The illusion of the game world is more fragile when only sounds are used. It is more important to the context the sounds make the user experience in a sound mostly game, than in a game with where graphic describes the world.

Acknowledgments

The work of this thesis has been performed at Interactive Institute, Sonic Studio in Piteå. This thesis concludes my Master of Science in Media technology at Luleå University of Technology. First I would like to express thanks Katarina Delsing, for the opportunity to do my thesis at Studio Sonic, Interactive Institute.
This project was a part of the Audio mostly games project, I would like to thank the Audio mostly project team, Mats, Nigel and Stefan.
The game development team at Sonic studio has been:

- Supervisor at Sonic studio, and software designer – Mats Liljedahl
- Game play – Nigel Papworth
- Sound designer – Stefan Lindberg
- Programming – Mats Liljedahl, Martin Nordlinder

Game play, how things shall behave in the game world and which events that shall occur. All sound samples in the game are found in sample libraries by Stefan or sampled by him.

I would also like to thank my supervisor Josef Hallberg at Luleå University of Technology, and all test participants of the prototype.

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Martin Nordlinder

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1 Introduction

This chapter will describe the origin of this thesis and a briefly describe the key issues, the project background, purpose, limitations and goal.

1.1 Project background

Most games today are based on graphics both on PC's and mobile phones. Games in the horror genre often relay on graphics. Game often shows the entire in-game world with graphics. With only small cues graphically and some sounds and including some unknown elements, the game can become scarier. The hardware in mobile phones has been an obstacle when it comes to playing sounds and music, therefore mobile phone games have simple sounds and music. The technique used in mobile phones is progressing fast, but the display still is small. The possibility to get fast downloads with 3G, makes games with a vast library of sampled sounds possible. Hence it is achievable to make a game for mobile phones where sounds are used to deliver the experience.

Project Beowulf started with an aim to develop a game where sound is the corner stone of the game. The intention of having sound as the strongest information carrier brings new dimensions to the game. In an audio mostly game there still is space for the imagination. The user creates the story as the sounds are played.

1.1.1 Beowulf Legend

Beowulf is a poem from 700 – 1000 A.D. It is one of the lengthier Old-English poems with 3182 lines [12]. From the early 19th century it is referred to as Beowulf, earlier it was untitled. The heroic epic poem now called Beowulf is about a Swedish hero named Beowulf who travelled to Denmark to help to defeat a monster named Grendel. The events described in the poem take place during the 5th and 6th century. The first page of the original Beowulf poem in Old-English can be seen in Figure 1.

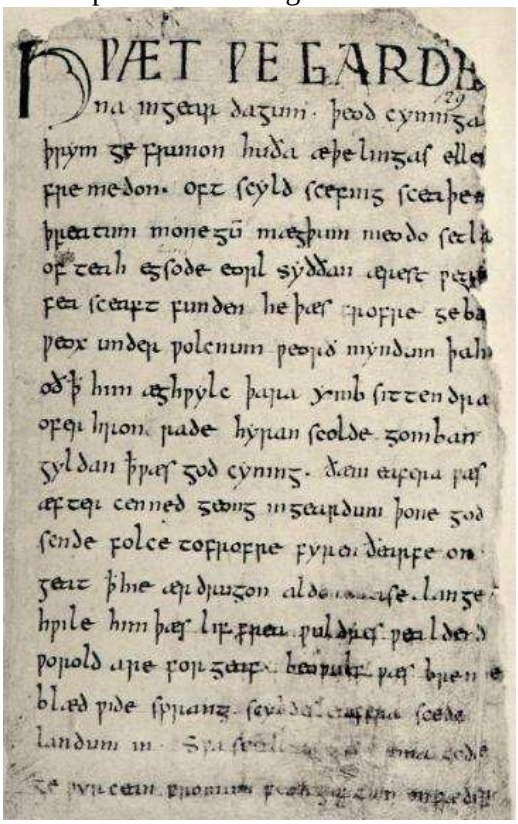

Figure 1 The first page of Beowulf

1.2 The Audio mostly games project

The lair of Beowulf, a mobile phone game where only sound is used to describes the game environment, is one of the Audio mostly games projects at the Interactive Institute, Sonic studio in Piteå. Interactive Institute is an experimental IT-research institute, creating results through combining art, design and technology. Interactive Institute consists of nine studios. Sonic studio focuses on the communicative aspects of sound and music in digital media, in the fields of Sound and music design for games and Sound design for industrial purposes.

1.3 Project purpose and goal

The purpose of this project is to investigate how a game were only sounds describes the surroundings, is experienced. Both the emotional and the spatializational experience will be studied.

Three questions will be studied:

- is it possible to navigate in the game world only from the sound information, how people experience the game
- is it fun to play
- how much of the total experience the person playing is filling in due to the lack of graphics.

These questions will answer if it is possible to pre-render sounds and retain the experienced world as the producers of the game intended.
The first goal of this project is to create an operational prototype. The second goal is validate the prototype and then test the experienced spatialization. In this case experienced spatialization is how people experience the game world with only sounds as cues.

1.3.1 Conceptual outline of the Lair of Beowulf prototype

In the prototype of the Lair of Beowulf game the user should be able to navigate in a sound mostly world. The prototype is based on one of the oldest Old-English poems, the poem is described in chapter 1.1.1. The Lair of Beowulf game world contains a number of caves, every cave has a theme. For example the theme of a cave could be bats, water or bubbling lava. The prototype shall be programmed in an object-oriented way.

1.4 Delimitations

Only Wav[1] files are used, one file for each room type. Only positions and time is used to render sounds. The reverb of different room types is rendered before the implementation, to have better control of what is tested and to make it easier for porting to mobile phones. Because of the future mobile phone implementation, we have limited the test to headphones. OpenAL does not have the ability to synthesize reverb.
The prototype of the game shall only have basic functionality, to test how easy/hard it is to navigate and to test how people experience a game without graphics. Only sounds are cues to the game world. The map does not show any in-game properties, it is only for navigational help, the sound do not have any graphical representation. The prototype is a part of Audio mostly project, and possibility of further development of the game shall be an aim.

1.5 Technical challenges

Because of the limited computational power in mobile phones, we have chosen a sound renderer without the ability to ray trace sounds, this could have enhanced to experience and the give better spatializational cues. Front-back faults are 4 times more common when using headphones than free field listening [1].

[1] Short form of wave audio format, a Microsoft standard for storing sound.

2 Theoretical background

This chapter describes briefly, how people experience stereo sound through headphones and speakers. A short description of Java and OpenAL The first part will describe what is needed when recreating a virtual soundscape, and it describes some common techniques used. The second part describes how sounds are interpreted as symbols and the last part will describe sound engines in Java.

2.1 Spatializational cues

There are eight cues to help locate sounds in space:

Interaural time difference (ITD)

The ITD is the time difference it takes for a sound to arrive at two sensors; in most cases the sensors are ears. An approximation of the ITD for an infinitely distant object can be computed by this formula [2]:

Equation 1 Interaural time difference ITD

$$ITD = \frac{a}{c}(\theta + \sin\theta)$$

Where head is approximated to a sphere with the radius *a*, Θ is the azimuth angle[2] and *c* is the speed of sound. To get a more accurate ITD you can approximate the head to a ellipsoid and still have low computational cost.

Head shadow

The head blocks sounds and creates an acoustical shadow behind the head, this creates a variation in sound pressure between the ears, this is sometimes called Interaural Intensity Difference (IID). But not all sounds are reflected by the head. Only sounds with a wavelength larger then the diameter of a head are reflected. For a human head frequencies above 1.3 kHz are reflected, producing a head shadow. And for frequencies above 3 kHz the intensity difference gives the best localisation. The difference in sound intensity can be very large between the two ears, especially if the sound source is coming from the left or right of the head. Difference in sound pressure can be up to 1000 times larger in such cases.

Pinna response

Describes the effect the external ear has on the sound. Figure 2 illustrates the pinna. Physical phenomena's that are affecting the acoustical effects of the pinna are reflection, shadowing dispersion, diffraction, interference, and resonance.

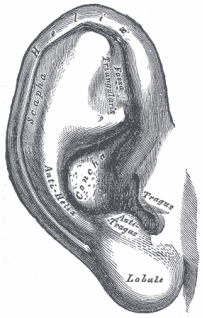

Figure 2 The pinna

[2] The elevation of a sound source.

Shoulder echo

Sound with frequencies between 1 and 3 kHz are reflected on the shoulders. This auditory cue can be a helpful to know the elevation of the sound. This cue has a minor impact on determining the sound location.

Head motion

Small movements by the head can improve to determine the sound location, especially for sound with high frequencies. This is a key factor when determining the sound location.

Early echo response

Early echoes are the original sound plus their reflections on objects, like floor, walls and tables. Early echoes occur 50-100 ms after the sound was created.

Reverberation

Other reflections are considered as reverberation. Early echoes response and reverberation can be a cue in determining distance and direction of the sound.

Vision

To confirm the direction of a sound, vision is used and automatically binds a sound to an object.

2.2 Recreating sounds

When recreating sounds intended to sound that they are coming from a particular direction, the following technologies are the most used.

2.2.1 Binaural sound

Sound that is intended for human ears, and therefore contains sound cues about the position of the sound. Sound recorded with a replica of a human torso, are called binaural recordings.

2.2.2 Head Related Transfer Functions (HRTF)

ITD and IID give a good localisation cue for sounds on the same level as the ears, but for sound with an azimuth angle they don't help. HRTF describes head, torso, and pinna, and they are used to approximate how sounds reflect on these body parts. Because of that these body parts are small, HRTF work best for sound that has a frequency above 4 kHz [1]. With help of HRTF it is possible to make a sound come from a particular direction through.

2.2.3 Open Audio Library (OpenAL)

A technique used mostly used in games. OpenAL is a cross-platform three dimensional API[3] developed by Creative [3]. It is free to use on almost every platform, on Nintendo GameCube and Sony Playstation 2 it is not free. Its primary purpose is to enable three dimensional positioning of sound around a listener. The rendering engine does all computation, such as Doppler Effect, attenuation etc. Because of the similarity to OpenGL in syntax and coding style, it is easy to implement this API in 3D games. It can be used with headphones, stereo or surround

[3] Application Programming Interface, allows different programs to exchange data between them.

sound amplifiers without any modifications. This spatialization technique works on most hardware today. OpenAL API consists of 4 libraries:

AL

OpenAL's main library contains functions to set position, velocity and volume of the listener and sound source.

ALU

This library contains mathematical function, mainly for manipulation of vectors and matrices.

ALC

Creates a rendering context and manages the resource usage of the OS

ALUT

Manages higher level functions, this makes it easier for the programmer to load a file and to do other I/O[4] operations.

2.2.4 Ambisonics

This technique requires 4 or more amplifiers. It is consists of two parts, encoding sound directions and amplitudes, and reproducing the recording on a manageable loudspeaker system.

2.3 Design and semiotics

According to Norman there are two perspectives when designing a product; the perspective of the designer and the perspective of the user [4]. The designer is constrained by a number of considerations; functionality, physical limitation, appearance and cost are examples of these. When considering the relation between design and emotion, functionality and appearance are the most relevant. The user's perspective

2.3.1 Sound semiotics

When designing auditory interfaces, it is common to use either an auditory icon or an earcon. An auditory icon is a sound that uses as recognisable sound as possible, a recording of a sound. An earcon is a short musical phrase, which must be associated with some kind of information, to make it possible for the user to understand the context. Sound in games can then be divided into avatar sounds, object sounds, character sounds, ornamental sounds and sounds instructions.

2.4 Java

In the beginning Java was Oak, the year is 1991. Oak was a programming language independent of the hardware it is running upon. Next year a demo of this system was shown on a device called star seven or *7. 1995 SUN changed the name to the current one Java and it was announced on SUN world. From now on Java technology was official. Next major step in the Java history is 1999 when Java 2 platform is introduced this platform remains until today. Minor enhancement has been released almost every year. The latest Java runtime released on the Java.com page when this thesis was written was version 1.5.0_06 [5].

Java which interprets the code as it is run, has been accused of slowness and big consumer of random access memory. This was true in the beginning, only simple application were programmed in Java before. Today, Java is almost as fast as C++.

[4] Input/output, a collection of interfaces to different units in a computer to communicate.

The syntax of the Java language is similar to C++ and C. But it has a big difference, the Java language has automatic garbage collection. The freeing of unused memory is done by the JIT compiler[5]. A similar language that is implemented on some Smartphones and PDA's with Windows Mobile is the mobile version of .NET called .NET Compact Framework (.NETCF).

2.5 Sound engines for Java

This chapter will describe the open source Java engines, which were candidates for use in this project.

2.5.1 Java Sound API

Standard classes for sound, included in J2SE 1.5 [6]. It has controllers for panning, reverb and volume. In versions newer than 1.5 "Direct audio device" is the default mixer, which does not support reverb. But only "Java sound audio engine" mixer supports reverb. "Direct audio device" has lower latency and than "Java sound audio engine".
These audio file formats are supported; AIFF-C, AIFF, AU, SND, WAVE and MIDI files. It is possible to play several files at the same time.

2.5.2 JOAL

The official OpenAL libraries supported by SUN [7]. At the moment, this release only contains instructions for building on Win32, MacOS X and Linux machines. OpenAL implementation in this package has quite good support for various sound effects and positioning of sound.

2.5.3 Lightweight Java Game Library (LWJGL)

Includes two sound engines binding, OpenAL and FMOD3 [8]. OpenAL implementation in this package has quite good support for various sound effects and positioning of sound. OpenAL bindings in LWJGL could support wav and ogg extension, ogg extension only works with early versions of OpenAL native files. LWJGL FMOD3 classes are free to use for non-commercial use. FMOD3 is for music streaming, with support for mp3, ogg, xm.

2.5.4 Audiere

Free to use, licensed under LGPL[9], and supports the most common audio formats. Streaming and buffered audio volume, pan, and pitch shift modification, flat tone, square wave, white noise, and pink noise generation. No sound rendering functions for positioning of sounds. Has binding for Windows and UNIX.

2.6 Mobile sound engines

2.6.1 JSR-000135 Mobile Media API

The standard API for mobile phones, this works on most of the phones out in the market. This API supports playing different sound formats supported by the model of the phone [10]. Limited to playing one sample file at a time, but possible to play a midi and a sample file in the same time. This API does only contain volume and mute controls.

[5] Just In Time, compiles code as it is run

2.6.2 JSR-000234 Advanced Multimedia Supplements

This specification includes 3D sounds, 3D graphics and other extensions to mobile phones. This supplement will be quite near the OpenAL and OpenGL specifications, some features are not implemented, the basic functionality is almost the same as for Mobile Media API [11]. Media control interface has extended functionality compared to Mobile Media API, it has pan, balance and effect controls. The effect control has reverb, chorus, virtualization and equalizer controls.

3 Implementation

3.1 Java

The game is implemented in Java on Windows XP, Java language was chosen because ability to port it to Mobile Phones and other OS. Java SDK[6] version used in Beowulf is 1.5.0_06. LWJGL version used is 1.0 beta 3.

3.1.1 Development tools used

Beowulf is developed in Eclipse 3.2 IDE[7] [13]. Eclipse has good CVS[8] support.

3.2 Game play description

3.2.1 The Map

The game takes place in caves connected with tunnels. Every cave has a distinct ambient sound. The ambient sound can be heard in the whole cave with the same volume and panning. Almost every cave has a point emitting a sound, these sound have distinct positions. They are played through the OpenAL API, which sets a pan and a volume that corresponds to relative direction and distance of the sound source.

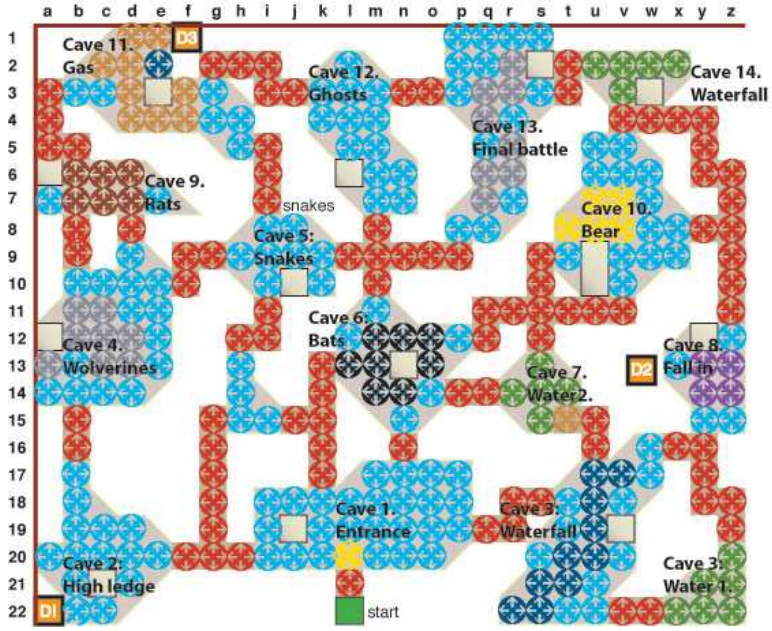

Figure 3 Map used in the prototype (Nigel Papworth)

In Figure 3 Map used in the prototype red correspond to tunnels, all other colours are in caves and match to different floor materials.

[6] Software Development Kit, also called devkit, allows the software engineer to create applications
[7] Integrated Development Editor, includes text editor, compiler and debugger.
[8] Concurrent Version System, used to have control on versions of uploaded files on a server.

3.2.2 Sound locations

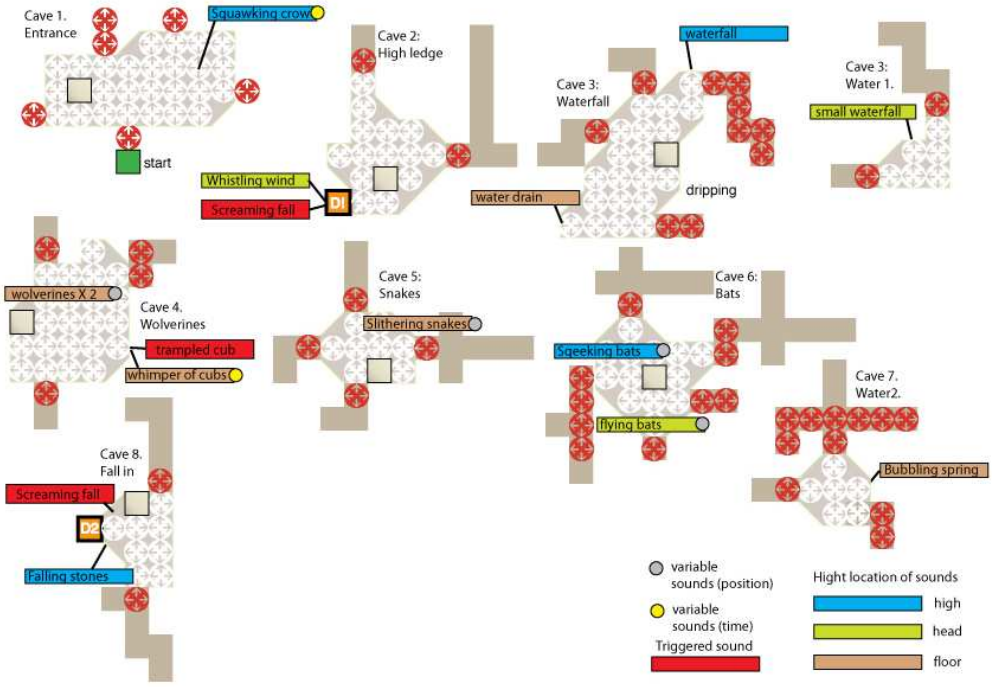

Figure 4 One of the sound location maps (Nigel Papworth)

Figure 4 illustrates where some of the sounds are located, the height of the sounds, if it is a triggered sound, on which point it is triggered.

3.3 Navigation

The player navigates with the forward, right and left key. When left and right are pressed the avatar rotates. Another implementation could have been to navigate through absolute direction. We choose the rotation implementation to avoid front-back faults [2], if it is possible to rotate it is a bit easier to know if the sound is in the front are back.

3.4 Sound engine

The Beowulf project needed a sound engine with basic positioning capabilities, OpenAL was chosen as sound engine for this project, because of the similarity to Advanced Supplement for mobile phones specification. There were two common choices of OpenAL bindings in Java; JOAL and LWJGL. LWJGL was implemented in this project, because of the good portability and stability. When a stereo file is played, it is not positioned.

In Beowulf there are 4 different types of sound implemented, footstep sounds, ambient sounds, positioned sounds and action sounds. Ambient sounds are background sounds with a lower volume and not tied to an action or position, like blowing wind. Positioned sounds are sounds from animals or things that are tied to an position. Action sounds are sounds that are triggered when the avatar performs an action, like rotating or hitting with sword. The ambient sound played in caves are stereo files, and do not need to be positioned.

3.5 Java Classes

The prototype of the game consists of two main folders, beowulf folder and beoTimer folder. The Beowulf folder has functions for; playing the sounds, create the map, updating the visual map, updating the position of the monster and Beowulf. The beoTimer folder has functions to schedule events in the game, see chapter Timer functions.

3.5.1 Main class

GameRun is the main class of this game and initiates all other classes and which is running the whole time. GameRun almost immediately starts a thread which is running when the game is on.

3.5.2 Map class

This class contains the whole map, and all sounds that the map contains, besides the avatar and monster sounds. The map UML[9] of the MapClass with Caves class is in Figure 7. The mapclass hold cave objects, which are Vectors. When the game start InilitazeMap() and initializeMapSounds() are called. The first function loads the Caves and the second one load all sounds.

Cave

Every cave vector consists of all the MapPoint that is in the cave. There are 17 caves in the prototype of the game. Every cave has two ambient sounds, a mono sound and a stereo sound. The mono sound is played in tunnels, from that direction the cave is relative to the avatar. The stereo sound is played when the avatar is in the cave. The functions of the Cave class are used to add mappoint, set ambient sound add moving sound get mapoint and leaving and entering the cave.

MapPoint

Every mappoint has a point object, which is subclass of java.awt, the type of the room and an integer which hold a number of how many times the point have been walked. The mappoint has functions for entering and leaving, increasing and getting how many times a point have been walked etc. In chapter 7.2 there is an UML of MapPoint class with all functions and objects.

3.5.3 Sound engine

Soundobject class

Every sound in the game is a soundobject, this class contains were the files with sounds is located, if the soundobject is currently playing a sound, the speed and direction of the sound, a Boolean which indicates if the sound has a position and some other attributes which can be seen in the UML figure of the SoundObject class. Functions in this class are used to play/stop sound, get the state of the sound, load the sounds and schedule the sounds. If the soundobject has several soundfiles loaded then you can randomly play any of them with playVariation function. The scheduler of the sound uses classes that are described in chapter Timer functions. The soundobject class calls functions in SoundScape class.

[9] Unified Modeling Language, a standardized general purpose modeling language to create an abstract model of a system.

SoundScape class

The soundscape class have help functions for rendering the sound to a position relative to the listener. With setListenerPosition(float x, float y, float z), the position of the avatar is set, the soundscape then calls lwjgl bindings for OpenAL in the lwjgl.jar file.
The first The same procedure is used for all sounds, but the setSoundPosition(float x, float y, float z) function is called. Every sound gets a soundID with makeSoundSource(int SoundID), for OpenAL engine then plays the sound relative to the listener when the play(int soundID).

LWJGL

To use LWJGL[8] bindings Beowulf's sound engine needs native files, lwjgl.dll and OpenAL32.dll on Windows XP, and liblwjgl.jnilib and openal.dylib on Mac OS X. The prototype has been tested and works on these two systems. The bindings in java to native files are in lwjgl.jar and lwjgl_util.jar.

3.5.4 Timer functions

For the ability to play sound randomly and to schedule events depending on time the game needs a function some kind of timer function. In Beowulf a timer is implemented through three classes, Beotimer, BeoTimeConsumer and BeoTimerTask. To schedule a sound or another event you extend the BeoTimeConsumer class with the code that shall be run on the scheduled time.
Example, this code will play a sound at scheduled time:

```
public void doTimerTask(BeoTimerTask){
        PlaySound();
}
```

The main class of the application that uses BeoTimer must contain an initiation of the BeoTimer, this is done through the setTimer function in BeoTimeConsumer. All tasks are saved in a vector with tasks, called mTimerTaskList in BeoTimer. SeeFigure 10 in Appendix 0 for an UML of the classes.

3.6 Beowulf client

When the prototype starts a black window with blue triangle on a blue square appears see Figure 5. In the tests the position of the avatar, blue triangle is shown instead of the Lair of Beowulf text. The directional keys are used to navigate in the prototype. Forward key moves the avatar in the direction the triangle points, left and right key rotates the avatar. When the avatars moves a new red square lights up and stays light up until the prototype is restarted.

Figure 5 Game window

4 Tests

The first part describes the test form used, and the second part contains the results from the test.

4.1 Method

The tests were performed on 11 subject, 7 men and 4 women. The age ranged from 13 to 45 years. The test began with a short presentation of the project, then the game prototype was started and the user got the first part of the test form. The average time for the user to describe the points was 30 minutes. The tests were conducted on both Windows XP and MacOS X. With Senheizer HD 570 and Sony MDR-V300 headphones.

4.1.1 The test form

The test form consists of two parts, in the first part the test subject was asked to write how he/she experienced the sound at 7 different points in the game. Every point was in a cave. Each point had an exclusive ambient sound belonging to the cave, and one or more sound sources which were positioned. The time used for each test subject to evaluate these points was measured, and a picture of the screen was taken at the end of the test.
Figure 6 Locations of evaluated points illustrate which points that were evaluated on the test form:

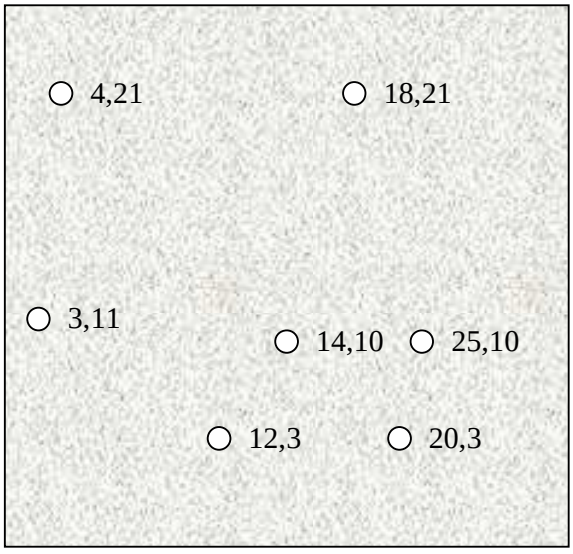

Figure 6 Locations of evaluated points

The second part of the test had question concerning the whole game. In Appendix 7.1, you can see the whole test form in Swedish.

4.2 Results

4.2.1 Perceived sound

Every point that was evaluated is presented with a collection of all answers from the test subject and a small description of the sound from developer's perspective. To compare the intended experience, with the how the test subject experienced the

sounds in the prototype. The sounds used and the origin of the them is included in the description of developer's intention.

All positions

Developer's intention
The ambient sound is a mixture of wind sound and sounds from a synthesizer. Ambient sounds are made with same procedure for every cave. The variation between the ambient sounds lies in the balance between the inputs. All positions tested are in different caves, reverb is pre rendered, and intended to sound like larger room.

Position 12,3

Developer's intention
The entrance cave with a positioned crow sound. The footsteps sound intended to sound like walking on solid stone ground in a cave. Sound from dripping water. Footsteps and crow sound are from a sound library.

Compiled data from test form

Perceived physical environment
Big cave, stone walls. Stonewalls round about, stone cave medium big. Humid cave. Cave, stone, water. Big room in a hard material, porous and nasty floor. Cave entrance, walking on twigs. In the centre of an entrance, walking on twigs.
Perceived characteristics and content of the environment
Crow cawing, feeling creepy, wet. Unpleasant big place with humid stones and moss, noiseless bats. Horrible crow and unstable ground. Humid, dark. Cold and windy. Something horrible, a bird is heard from nearby. Horrible. Bare and cold, water drips, some crow is heard from the right side.

Position 14,10

Developer's intention
A cave with insects and bats flying around. Footstep sound intended to sound like crushing insects when walking. At one position the bats are squeaking and at the other position there is a bat flying sound. Bat sounds are from a sound library. Reverb pre-rendered on sounds.

Compiled data from test form

Perceived physical environment
Forest, crunching twigs, really big cavity in the rock, above is a small hole that lets daylight in. Marsh. A little bit smaller room, corridor. Also here it is a horrible, porous ground. Cave, more space. Further in the cave, narrow, stony. Half big room.
Perceived characteristics and content of the environment
Crows, dripping water, buzzing bees, rats, mud. Insects, birds. A dark feeling appears. Wasps, bats. Here there are more bats, you can hear both their wing beats and peeps. Still very deserted. Buzzing mosquitoes, feels like I am on the way out, an opening Dried moss on the floor. (Poo) with flies, flying around, it stinks! The muffled noise does hurt my stomach, it smells musty, old filthy.

Position 4,21

Developer's intention

Cave with a waterfall, paddling in water sound when moving. The waterfall has a drain sound and a waterfall sound. The footsteps are made of a mix between a library sound and a recording of splashing water in a bathtub. The bubble sound from a FX-sound library which is slightly altered.

Compiled data from test form

Perceived physical environment
A bit smaller cave type. Low water, bubbling from down below. Under the water, no large surfaces around. Big cave. Small stone, cave. Marsh water. Wind cave, medium large cave in hard material, stone floor. Still bare stone walls.
Perceived characteristics and content of the environment
Creepy, with the soughing wind. Boiling sources of heat, humid, stinking. High water, bubbling pots, someone is breathing heavily. It seems that a door or exit is nearby considering the howling wind. My feet's get stuck in the ground, it bubbles, it is some dark slush. It is no animals here, if it is not a lion I hear mutter, but maybe it is not. Blowing a musty smell. Wet, bubbling, tight. Splashing in ca 3 cm deep water, somewhere the water is bubbling, this room is somewhat warmer than before, and very humid.

Position 3,11

Developer's intention
The wolverine cave, two wolverines at one position. Footstep sound intended to sound like crushed bones. The footstep is made from a recording of spaghetti and hard bread being cracked. Animal sounds are from a sound library.

Compiled data from test form

Perceived physical environment
Tunnel. Deep in the cave, like a room, 5*10 m. Wild dogs gnawing bones. Larger space. Big. Porous floor, maybe twigs or something similar. Smaller room. Crunching. Large room. The floor is made of thin stone plates.
Perceived characteristics and content of the environment
Stone floor, dogs. Wet twigs, dog. Angry dogs. Dog(puppy). It seems that a pair of dogs (more than 2) are nearby. Very heavy wind sound. A dog seems to be dangerous. Sweet and playful dog, but a little bit angry, I hope that it gnaws on a bone, but not mine. I surprised them. Dry, horrible. Some monster and a smaller dog can be heard. Wind that is blowing. En small dog barks, a bigger dog snarls. Otherwise it is calm, less desolated than before.

Position 20,3

Developer's intention
Gas cave, walking in mud sound. Three bubbling lava sounds, played from different positions. The sounds that are played when moving are recorded from moves in a bathtub. Waterfall is from a sound library.

Compiled data from test form

Perceived physical environment
Cave, but with a hole in the roof. At running water, feels like outside but a water drip now and then gives a feeling of that I still am in the cave. Waterhole with a water

wheel, maybe some kind of a machine. Wet ca 20 cm water on the floor. River or brook, big. Water very large brook behind a waterfall. Lake, dam. Stone walls, a hole in the roof.

Perceived characteristics and content of the environment

Motor boat? Running water, streaming. Wet, running water, maybe a waterfall or rain. Sounds like a 4 horse power motor boat! A little bit more space. Not as creepy here, only very wet but some cave feeling is still left. Some kind of machine can be heard, you get curios of what it can be. Murmuring water. Waterfall. Due to a hole in the roof daylight stream in, furthermore there is a waterfall that purls and where there is some vegetation.

Position 18,21

Developer's intention

Final battle cave, footsteps are intended to sound like walking on bones crushing the bones. A monster attack sound. Battle sounds are mixed from a sound library and recorded sound which are slightly altered.

Compiled data from test form

Perceived physical environment

More room like. The cave monster is luring in a hole. Big cave. In the mountain, narrow path, a little bit humid. Nasty floor, smaller room, feels like you are walking on glass or something similar. Tight. Small cave of stone, or some surrounded place. Dry environment, cave. Stone walls, open holes in walls, which makes a cold air streaming in.

Perceived characteristics and content of the environment

Snarling sound, walking on twigs. Crunching branch, spooky. Cruel big monster with reptile eyes, teeth. Creepy. Sound of a bear or a wolf. Walking on glass. Draughty, approaching the monster. Deserted, lonely, I feel lonely with the snoring of the monster, very creepy! Some kind of monster seems to lies down and sleeps. Twigs on the ground. Monster which is snoring, a little bit windy, creepy atmosphere. Some kind of animal. In the dark there is something that grunts, or alternative some person that sleeps and is snores deep

Position 25,10

Developer's intention

Cave with a positioned falling stones sound. The footstep sound should sound like walking on small stones. The footsteps and falling stone sounds are from sound library.

Compiled data from test form

Perceived physical environment

Big desolated, brook, river. Steps on old straws (sleeping place?). Cave, stones falling from the roof. Still in the mountain, large exit to a plain. Big space, maybe an abyss. Outside the cave. Twigs on the floor, relatively big room, stone feeling. Stone wall, with loose stones, which fall sometimes.

Perceived characteristics and content of the environment

A great amount of water, stones falling toward stone. Wind from right side, falling stones from right side. I am rolling the stones away. Windy. Falling stones, cracking under the feet's when I came in. Loose stones, draughty, open. It sticks in my feet, I am freezing, it is awfully windy unpleasant… I hear strange sounds, it sounds like stones hitting stones, feels like an exit is nearby, dry leaves on the ground. Above the cave there is some form of a way where vehicles are traveling, i feels like a opening somewhere where light come through.

4.3 Prototype functionality

All of the test participants could navigate in the game world and found all test points.

5 Discussion and conclusion

The purpose of this thesis was to develop and test a prototype of an audio mostly game. OpenAL was chosen for the ability to port the game to mobile phones, because it is quite similar to JSR-234[11]. OpenAL through LWJGL have been tested on both Windows and Mac OS, it worked flawlessly on both systems.

The experimental study confirmed that in game with almost only sounds it is more important to carefully choose the sounds than in a game with sound and graphics. The sounds do not always need to be realistic; sometimes it is better to have exaggerated sounds or semi-realistic sounds. In a game with almost only sounds it is more important to carefully choose the sounds than in a game with sound and graphics. When using sound and graphics the sound is often only a complement to the graphics and does not need to be descriptive, in contradiction to when using only sounds then it is important to have a descriptive sound if the intention is to make the sound fit to the game context.

It is almost crucial to test all the sounds in an audio mostly game to see if they fit into the context of the game. In the Beowulf prototype sounds with pre-rendered reverb were used, to maintain the illusion of a cave it is important to use the similar reverb on similar object in a cave. The use of bird and wind sound in Beowulf prototype lead to that many participants experienced an opening in the cave. This underlines the importance of choosing the sounds thoughtfully; the context of the game can be dramatically changed with one sound.

Audio only or audio mostly games opens the possibilities for people with visual impairments to play games. The audio mostly games enables to play games on places and situations where you must have visual feedback, like travelling with buss or train. Instead of listening to music on your mobile phone, you could play a game.

5.1 Future work

Some participants would prefer that the sound could change gradually when rotating to get a more intuitive navigation. In the prototype the sounds change in steps of 90 degrees directly. To see if it is the OpenAL implementation is adequate it could be interesting to test the game with reverb based on ray traced sounds with real time sound reflections on the walls. Testing the program on participants with visual impairments could lead to better sound interface and new possibilities and ideas.
For easier map creation a XML[10]-based map could be used.

[10] Extensible Markup Language, primary purpose is enable sharing of data between different information systems.

6 References

1. Jon Hansson, *Utvärdering av ljudkvalitet i fordon, 2006*, http://epubl.ltu.se/1402-1617/2006/039/LTU-EX-06039-SE.pdf

2. Richard O. Duda, Carlos Avendano, V. R. Algazi, *An adaptable ellipsoidal head model for the interaural time difference*, http://interface.cipic.ucdavis.edu/PAPERS/Icassp99.pdf#search=%22interaural%20time%20difference%22

3. Creative, *OpenAL*, http://www.openal.org

4. Donald A. Norman, Andrew Ortony, *Designers and users: Two perspectives on emotion and design*, http://projectsfinal.interaction-ivrea.it/2004-2005/SYMPOSIUM%202005/communication%20material/DESIGNERS%20AND%20USERS_Norman.pdf

5. Sun, *Java*, http://www.java.com

6. Java Sound API: http://java.sun.com/products/java-media/sound/

7. Joal: https://joal.dev.java.net/

8. Lightweight Java Game Library (LWJGL): http://lwjgl.org/

9. Audiere: http://audiere.sourceforge.net/

10. *JSR-000135 Mobile Media API*: http://jcp.org/aboutJava/communityprocess/final/jsr234/index.html

11. *JSR-000234 Advanced Multimedia Supplements*: http://jcp.org/aboutJava/communityprocess/final/jsr234/index.html

12. Wikipedia, *Beowulf*, http://en.wikipedia.org/wiki/Beowulf

13. IBM, *Eclipse*, http://www.eclipse.org

Johnny Friberg, Dan Gärdenfors, *Audio Games: New perspectives on game audio*: http://extrafancy.net/idia612/research/audioGames.pdf

7 Appendix

7.1 Test form

Ålder _____ Yrke_____
Kön_____ Utbildning_____

Position	Fysisk miljö (storlek, material)	Beskriv miljöns innehåll och karaktär

12,3

14,10

4,21

3,11

20,3

18,21

25,10

Hur lätt var det att navigera till punkterna ovan? (kryssa på skalan)
1 2 3 4 5 6 7 8 9 10
lätt---------- svårt

Beskriv din bild av spelets miljö som helhet.

Om du jämför detta spel med film, vilken typ av film tycker du ligger närmast?

- Skräck
- Science Fiction
- Äventyr
- Thriller
- Drama
- Komedi
- Annan genre_____

Hur kul var det att spela spelet? (kryssa på skalan)
1 2 3 4 5 6 7 8 9 10
tråkigt----------kul

Vilken position i kartan tyckte du hade den bästa/mest intressanta upplevelsen?

Var / i vilka situationer skulle du kunna tänka dig att spela detta?

- I bilen
- I TV-soffan
- På bussen
- På promenad
- Annat, var?_____

Hur mycket skulle du vara beredd att betala för ett sådant här ljudbaserat mobil spel?

10:- 20:- 30:- 40:-

50:- 60:- 70:- Annat belopp:_____

Räcker 30 minuter för att skapa sig en fullständig bild av miljön?

Ja nej hur lång tid tror du behövs?_____

Är det något som saknas i spelet? Kan du beskriva detta?

Vad tror du skulle få folk att stanna kvar i miljön efter det att hela kartan är avtäckt?

Spelar spel på mobiltelefon?

Ja Nej Om nej, varför?_____

Kan tänka sig att spela mobilspel i framtiden?

Ja Nej Om nej, varför?_____

Spelvana PC/tv-spel, totalt antal speltimmar/vecka

- Mindre än 1 timme
- 1-5 timmar
- 5-10 timmar
- Över 10 timmar

Spelvana mobiltelefon, totalt antal speltimmar/vecka

- Mindre än 1 timme
- 1-5 timmar
- 5-10 timmar
- Över 10 timmar

Övriga synpunkter

7.2 MapClass UML

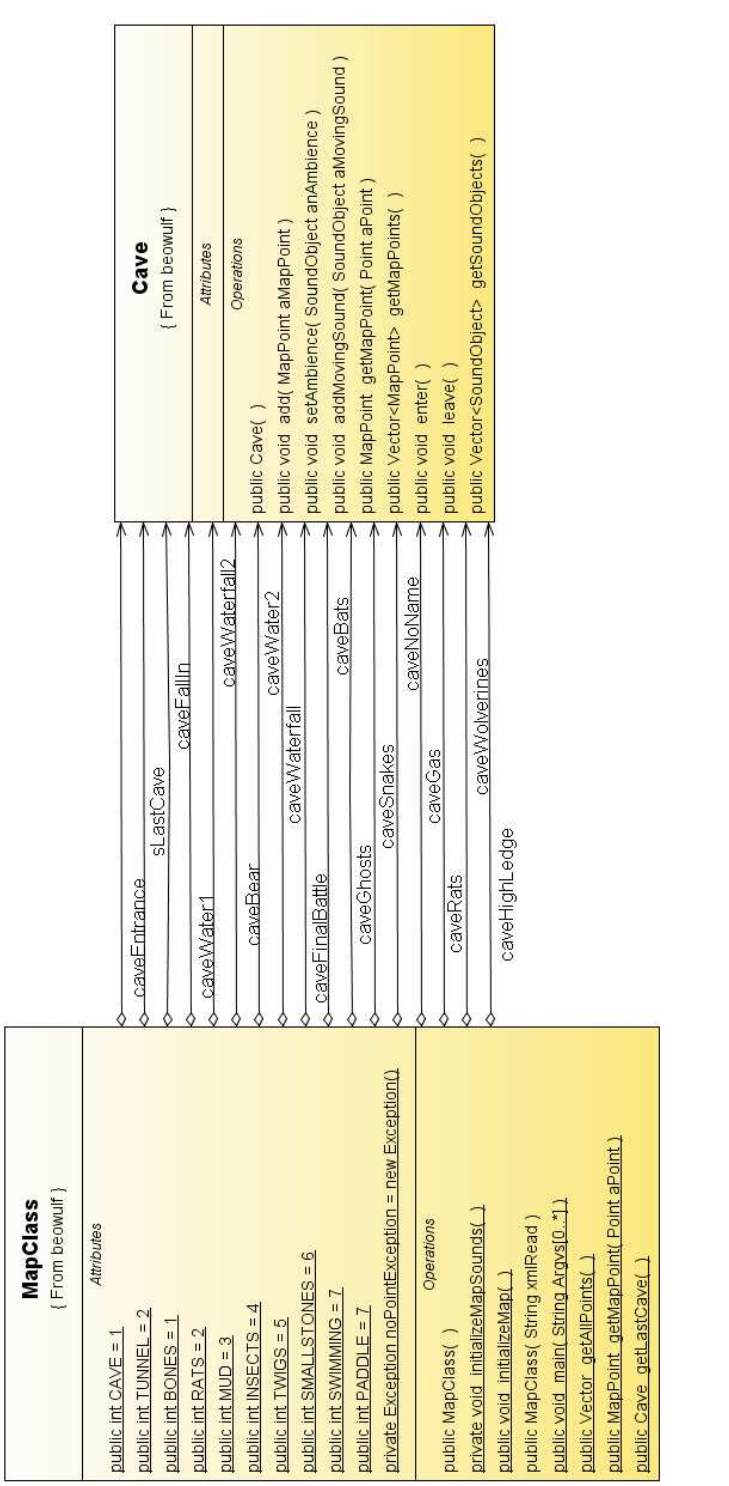

Figure 7 Map class and Cave class UML

7.3 MapPoint UML

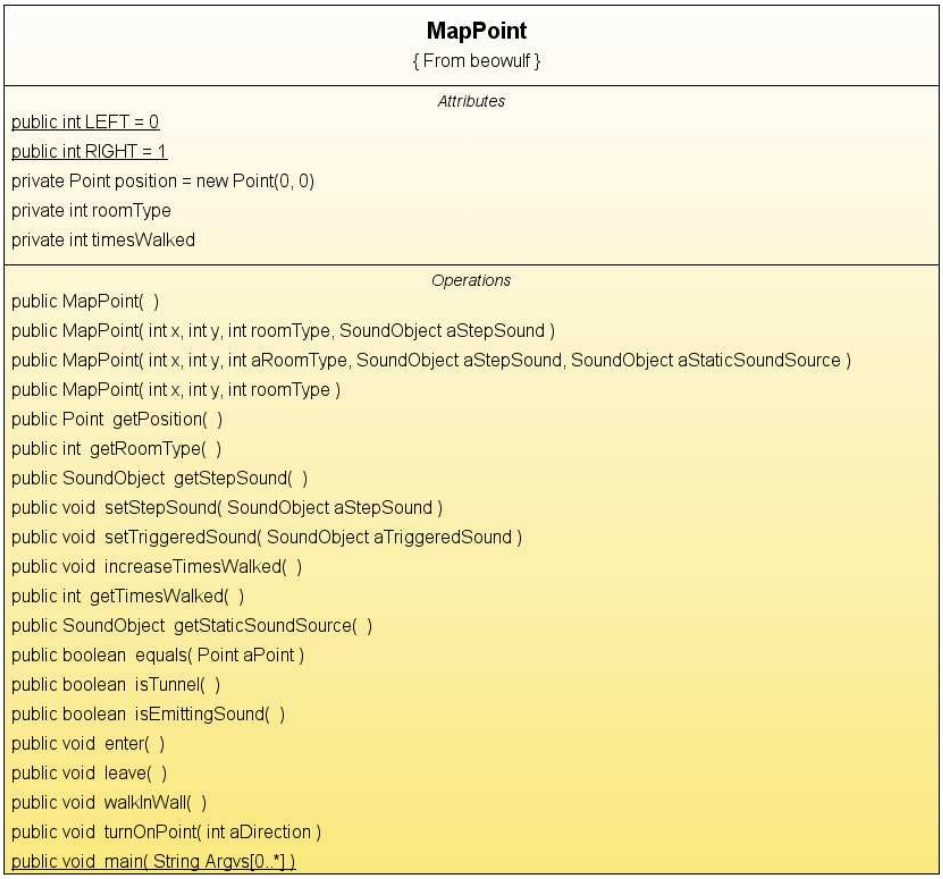

Figure 8 MapPoint class UML

7.4 SoundObject UML

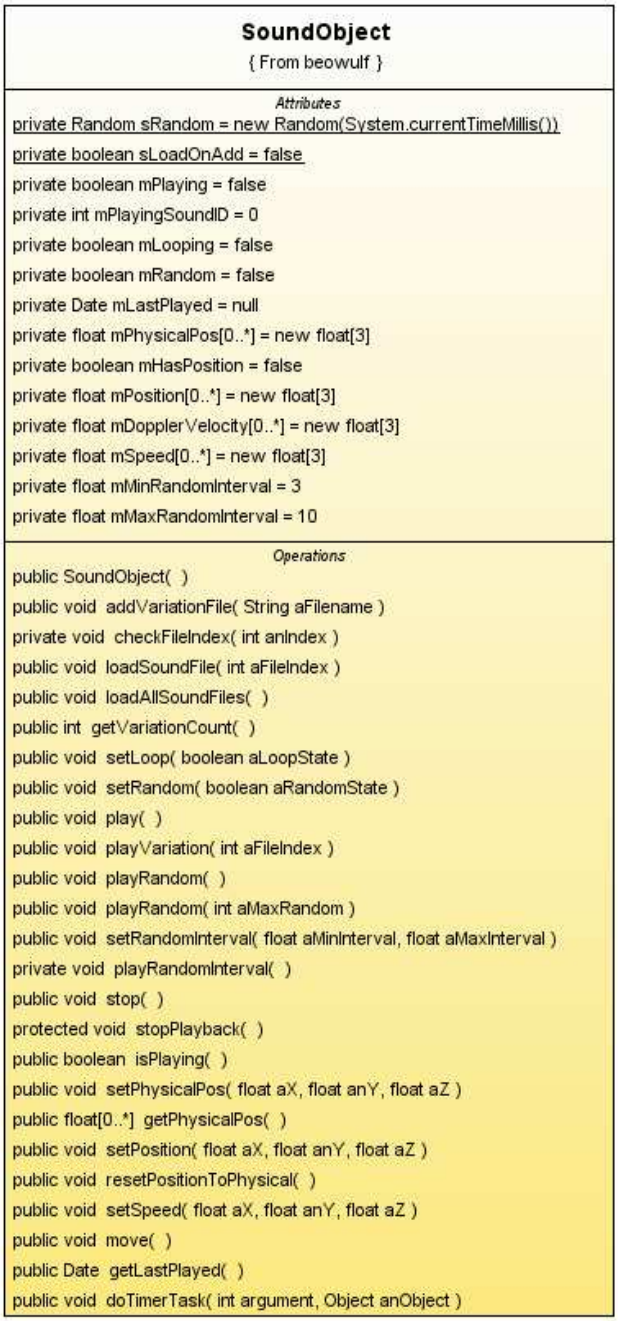

Figure 9 SoundObject UML

7.5 Timer function UML

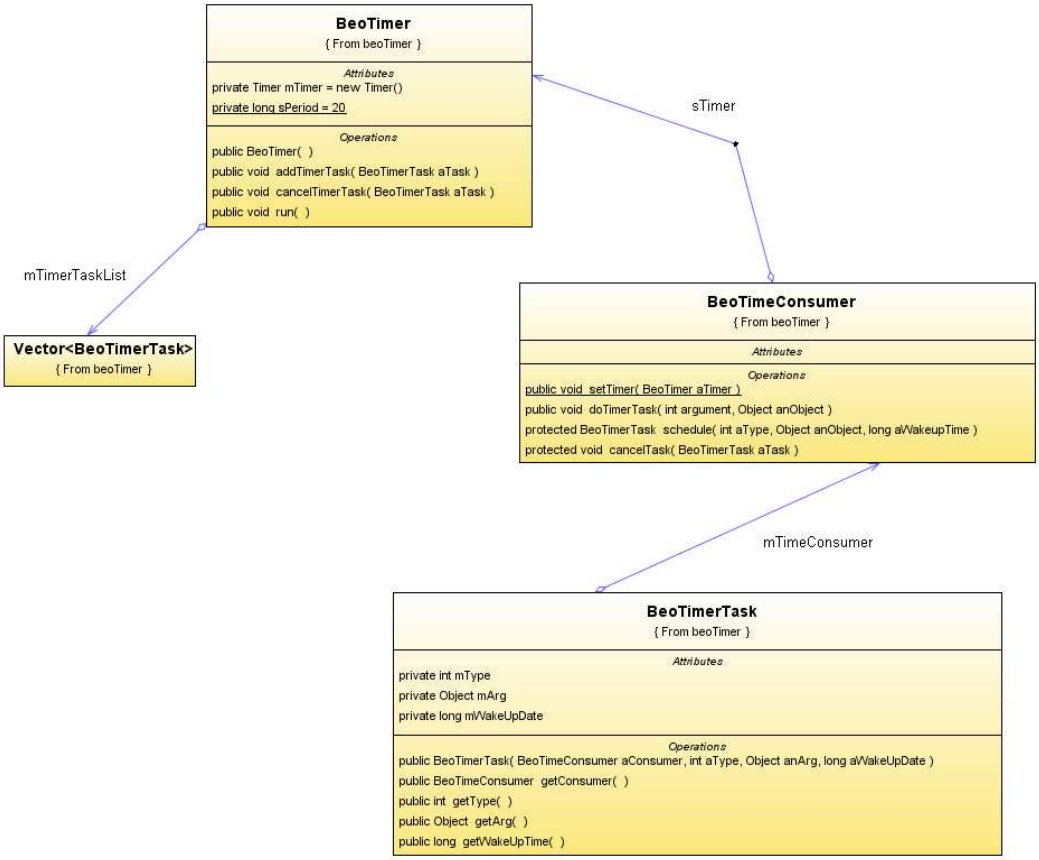

Figure 10 BeoTimer, BeoTimeConsumer and BeoTimerTask class UMLs

7.6 Test results from second part of test form

Table 1 Compilation of result from test form, continues on Table 2

	Subject 1	**Subject 2**	**Subject 3**	**Subject 4**
Age	20	22	20	25
Male/female	Male	Male	Female	Male
How easy was it to navigate?	4	4	8	7
How fun was the game?	7	3	6	5
How much could you pay for a sound based game? in SEK	10	10	30	20
	Subject 5	**Subject 6**	**Subject 7**	**Subject 8**
Age	45	13	28	27
Male/female	Female	Female	Male	Male
How easy was it to navigate?	5	6	6	6
How fun was the game?	6	6	4	4
How much could you pay for a sound based game? in SEK	40	30	30	30
	Subject 9	**Subject 10**	**Subject 11**	
Age	26	34	24	
Male/female	Male	Female	Male	
How easy was it to navigate?	6	7	7	
How fun was the game?	7	4	7	
How much could you pay for a sound based game? in SEK	20	30	30	

	Mean value	**Standard deviation**
Age	25,818182	8,316468
How easy was it to navigate?	6	1,264911
How fun was the game?	5,3636364	1,433369
How much could you pay for a sound based game?	25,454545	9,341987

Table 2 Compilation of data from test form, first part of this compilation on Table 1

If you compare this game to a movie…?	Number	
Horror	5	
Science fiction	1	
Adventure	8	
Thriller	2	
Drama, Comedy, Other genre	0	
Where would you want to play the game?		
Car	5	
TV-sofa	4	
Bus	6	
When walking	1	
Other, train	1	
Other, WC	1	
Do you play games on your mobile phone?		
Yes	7	I rather play on a console, pc or handheld
No	4	
If no, why?		
dull games, no fun games	3	
old phone	1	
not a game enthusiast	1	
Do you want to play games on your mobile in the future?		
Yes	9	
No	3	
If no, why?		
not a game enthusiast	1	
I rather play on my console	1	

7.7 Test results from points, Swedish

Sammanställning av svar från testformulär:
Position:
12,3
Fysisk miljö (storlek, material)
Stor grotta, stenväggar. Stenmurar runt om, sten grotta mellanstor. Fuktig grotta. Grotta, sten, vatten. Stort rum i hårt material, poröst och otäck golv. Grott öppning, trampar på kvistar. Mitt i grottöppning, trampar på kvistar.
Beskriv miljöns innehåll och karaktär
Kråka som kraxar, känns kusligt, blött. Obehaglig stort ställe med fuktiga stenar och mossa, ljudlösa fladdermöss. Läskiga kråkor och ostabilt underlag. Fuktigt, mörkt. Kallt och blåsigt. Något otäck, en fågel hörs en bit bort. Läskigt. Kalt och kallt, vatten droppar, någon kråka hörs från höger.
14,10
Fysisk miljö (storlek, material)
Skog, knastrande kvistar, riktigt stort hålrum i berget, rakt upp finns ett litet hål som släpper in dagsljus. Träsk. Något mindre rum, korridor. Även här ett otäck, poröst underlag. Grotta större utrymme. Längre in i grotta, smalt, stenigt. Halvstort rum.
Beskriv miljöns innehåll och karaktär
Kråkor, droppande vatten, surrande bin, råttor, gyttja. Insekter, fåglar. En mörk känsla infinner sig. Getingar, fladdermöss. Här finns fler fladdermöss, man hör både vingslag och deras pip. Fortfarande mycket ödsligt. Myggsurr, känns som man är på vägg ut, en öppning. Torkad mossa på marken. (bajs) med flugor flygandes runtom, det stinker! Det dova mullret gör så att jag får ont I magen, det luktar unket, gammalt, snuskigt.
4,21
Fysisk miljö (storlek, material)
Mindre grotta typ. Lågt vatten, bubblar upp underifrån. Under vatten, inga stora ytor runtomkring. Större grotta. Liten sten, grotta. Träskvatten. Vind grotta. mellanstort rum i hårt material, stengolv. Fortfarande kala stenväggar.
Beskriv miljöns innehåll och karaktär
Kusligt med vinden som susar. Kokande källor, fuktigt, stinker. Högt vatten, bubblande grytor, någon som andas tungt. Det verkar finnas en dörr eller utgång i närheten med tanke på vindens vinande. Mina fötter fastnar i det jag går i, det bubblar, det är någon mörk sörja. Här finns inga djur, om det inte är nåt lejon som muttrar typ. Fast det behöver det inte vara. Blåser lukt unket. Blött, bubbligt, trångt. Plaskar runt i ca 3 cm djupt vatten, någonstans ifrån bubblar vattnet upp, detta rum är något varmare än tidigare, och väldigt fuktigt.
3,11
Fysisk miljö (storlek, material)
Tunnel. Tunnel. Djupt inne i grottan, som ett rum 5*10 m. Vilda hundar som gnager på ben. Mer rum. Stort. Poröst golv, kanske kvistar eller liknande. Mindre rum. Knastrande. Storrum. Golvet består av tunna stenskivor.
Beskriv miljöns innehåll och karaktär
Stengolv, hundar. Blöta kvistar, hund. Ilskna hundar. Hund(valp). Verkar finnas ett par (minst 2) hundar i närheten. Mycket tungt vindljud. En hund verkar farlig. Söt och lekfull hund, fast lite småarg, hoppas att den biter på ett ben, fast inte mitt. Man överraskar dem. Torrt, otäckt. Något monster samt en mindre hund som hörs. Vind

som blåser. En liten hund käller, en större hund morrar. Annars är allt lugnt, mindre ödsligt än innan.

20,3

Fysisk miljö (storlek, material)

Grotta, men med hål i taket. Vid ett rinnande vatten, känns som utomhus men ett dropp då och då gör att jag nog är kvar i grottan. Vattenhål med vattenhjul, kanske nånslag maskin. Blött ca 20 cm vatten på golvet. Flod eller bäck, stort. Vatten mycket stor bäck bakom ett vattenfall. Sjö, damm.

Beskriv miljöns innehåll och karaktär

Motorbåt? Vatten som rinner, strömmar. Blött, vatten som rinner, kanske ett vattenfall eller regn. Låter som 4 hästars motorbåt? Lite större rymd. Inte lika läskigt här, bara väldigt blött men ändå någon slags grottkänsla finns kvar. Någon form av maskin hörs. Man blir nyfiken på vad det kan vara. Porlande vatten. Vattenfall.

18,21

Fysisk miljö (storlek, material)

Mer rumaktig. Monstret i grottan lurar i en håla. Stor grotta. Inne i berget, smal gång, små fuktigt. Äckligt golv, mindre rum, verkar som om man går på glas eller nåt sånt. Trångt. Liten grotta i sten, eller på nått inringat ställe. Torr miljö, grott. Stenväggar, hål i taket. Stenväggar, öppna hål i väggarna, som gör att kall luft strömmar in.

Beskriv miljöns innehåll och karaktär

Morrande ljud, går på kvistar. Knastrande gren, spökligt. Grymt stort monster med reptilögon, tänder. Kusligt. Björn eller varg som låter. Trampar på glas. Dragigt, närmar mig monstret. Ödsligt, ensligt, jag känner mig himla ensam med odjurs snarkningar, jätteläskigt! Ett monster av något slag verkar ligga och sova. Kvistar på marken. Monster som snarkar, lite blåsigt, kuslig stämning. Någon form av djur. Pga. hål i taket strömmar dagsljus in, dessutom finns ett vattenfall som porlar och där en del växtlighet finns. I mörkret finns något som grymtar, alternativt någon person som somnat och snarkar djupt.

25,10

Fysisk miljö (storlek, material)

Stort öde, bäck, flod. Trampar på gammal halm (sov platser?) Grotta, stenar som faller från taket. Fortfarande i berget, men en stor öppning mot en slätt. Stor rymd, kanske en avgrund. Utanför grottan. Kvistar på golvet, ganska stort rum, stenkänsla. Stenvägg, med lösa stenar, som faller ibland.

Beskriv miljöns innehåll och karaktär

Mycket vatten, stenar som faller mot sten. Blåst från höger, stenar rasar ner från höger. Rullar undan stenar. Blåsigt. Faller stenar, det krasade under fötterna när jag kom in. Lösa stenar, dragigt, öppet. Det sticker i fötterna, jag fryser för det är himla blåsigt obehagligt… Konstiga ljud hörs, låter som stenar som slår i varandra, känns lite som om man är nära en utgång. Blåsigt, torra löv på marken. Ovanför grottan finns någon typ av väg där fordon far fram, det känns som om det finns en öppning någonstans, som släpper in ljus.