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Fluid interaction in audio-guided museum visit: Authoring tool and visitor device

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Abstract

This paper presents an integrated system for location aware museum audio guide supporting sound spatialization. This system consists of a multi-modal visitor device composed of a head position, an orientation tracker and an audio headset. It aims at providing the visitor with a feeling of immersion within sounds virtually emanating from the artifacts exposed in the museum. The system is associated with a graphical authoring tool specifically designed for audio augmented reality in the context of museums. The proposed authoring tool enables to build the 3D representation of the museum, to add sound sources at different positions and altitudes, to build the virtual soundscape, and to create visitor scenarios describing how the visitor interacts with the soundscape while navigating through the museum artifacts. Experiments were conducted at the ' Musée des Arts et Métiers' in Paris, with the objective of reviving the machineries exposed at that museum by bringing to them the sound dimension from which they were deprived. The obtained results are very promising.

1. Introduction

Fluid interaction seeks to minimize the amount of attention requested from the user to interact with his environment and to reduce interruptions due to the mechanisms of interface [GSW01]. In the context of audio-guided museum visit, fluid interaction can be achieved by continuously capturing the visitor's localization, and then sending to him the right audio content depending on this parameter. Furthermore, instead of sending to visitors raw audio descriptions of the museum artifacts, immersing visitors in an audio augmented space enriches the museum visit and contributes to fluidify the visitor interaction with the museum environment. This audio augmented space can be created through sound spatialization.

Sound spatialization consists of the creation of a virtual sound scene, giving to the user the perception of being immersed in that scene by making use of its position and orientation on the space. The created sound scene, called soundscape, contains several sound sources placed in specific locations and has particular acoustic properties [FH08, NT06]. In the context of museum, those sound sources can be associated with the exposed artifacts.

In this paper, we present the results of an ongoing project aiming to develop an integrated system for location aware audio guide supporting sound spatialization for museum visit. It is different from previous approaches in a number of ways. The proposed prototype is a free handed device, since it is able to capture the visitor's head orientation and calculate his visual vector, without any action from the visitor except his displacement. The system is also fully distributed, which means that it provides an autonomous device for each user, and that the management of the system is achieved locally. As a consequence, the system can be simultaneously used by a large number of visitors. The former effort in our project [KLPDC09] was to experiment the coupling of sound spatialization and user's orientation tracking in a laboratory context using a wired localization sensor *(Polhemus Patriot)*. The present work is conducted with an objective of validating the orientation tracking in the museum context using a wireless orientation sensor *(SparkfunIMU)*, but also to provide the system with an authoring tool enabling the designer to conceive the soundscape, and finally to choose the visitor scenario fulfilling the sound spatialization.

The paper is organized as follows. First, we give a review on some related works in Section 2. We then describe the architecture and the usage of the proposed authoring tool in Section 3. The next section(section 4) presents the visitor device composed of the headset and the wireless sensor and the algorithms for exploiting them. In Section 5, the visit sce-

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nario and experiments for achieving the location aware audio guided in the context of the ' Musée des Arts et Métiers' museum are presented. Finally, we expose our conclusion and perspectives.

2. Related Works

This section starts by making an overview on some research efforts performed with the purpose of enriching the real environment with spatialized sound. Then, it presents important sound spatialization systems that have made use of the user's head tracking. Finally, it describes those head tracking based spatialization systems developed for museum environment.

2.1. Sound spatialization in Augmented Reality environments

Teleconferencing and remote collaboration using Augmented Reality (AR) is a potential application area for sound spatialization. CAR/PE videoconferencing system, comprises live video streams of the participants arranged around a virtual table [RLK*04]. It simulates a traditional face-to-face meeting by allowing three participants from different locations to communicate over a network in an environment simulating a traditional face-to-face meeting. Spatialized sound driven by headphones or 2.0 to 7.1 audio hardware was used to indicate different user positions.

In video games [SN01, EER08], sound spatialization not only enables to enrich visual information by helping players to determine locations of non-visible events and objects, but also to estimate the distance of visible objects. In [SJ05], Sodnik explored the user's capability to localize a spatialized sound (registered with a virtual object) in an Augmented Reality (AR) environment under different spatial configurations of the virtual scene. In order to achieve the experiment, an *AR* scene was created and observed through a Head Mounted Device (HMD) attached to a video camera. The user wears a stereo headphones to hear the spatialized sounds. Software support was provided using the *ARToolKit* computer vision tracking library.

2.2. Head tracking based sound spatialization systems

Besides sound spatialization systems where the user's position is manually specified, some research efforts have combined the sound spatialization systems with position and orientation head tracking tools enabling to update automatically the user's position inside the soundscape.

In Bristol CyberJacket project [CMM*06], a set of virtual sounds are projected into a physical space. The user experiments the produced soundscapes through a set of headphones attached to a wearable computer. A compass is fixed on the user's headphones which provides information on head orientation. The wearable computer is also aware of the user's location. It uses GPS for outdoor locations and an ultrasonic positioning system for indoor installations. With these two sources of information the wearable device can determine where a sound should be positioned with regards to the user.

Launched in 2008, the 'Sound Delta' project (http://remu.fr/wordpress/) has developed a device for real time interaction and simultaneous exploration. The user holds a computer used as an audio receiver. The position of the user is determined in real time using cameras for indoor and GPS for outdoor environment while his head's orientation is determined using an electronic compass. In order to experiment the device, the user is invited to a listening experience by moving through a physical space. The user gets the illusion of moving through musical sound sources that changes their settings depending on his position and orientation.

2.3. Location aware audio guide for museum visit

Experimenting audio guides in museum tours is not a novel idea. Most major museums over the world provide visitors with devices enabling them to listen to audio content that describes the artifacts exhibited in the museum. However, the majority of them require the visitor to select manually the artifact he is interested in so that the appropriate audio contents would be sent to him through the audio guide. Recently, some research efforts have begun to experiment automatic detection of the location of the visitor inside the museum building so that audio content can be sent to him in a transparent way.

Bederson [Bed95]was among the first to develop an electronic museum guide prototype supporting visitor-driven interaction enabling visitors to automatically get the appropriate audio content depending on their individual positions.

In addition to the automatic tracking of the visitor's location inside the museum, improving the settings of the played audio content with regards to the visitor's position and orientation could make the museum tour more interactive and amazing. A novel idea in this sense is the spatialization of the sound sent to the museum visitor. An example of such application is the interactive audio museum guide $ec(h)o$ [HW05]. In this project, the visitor position within the museum is tracked using RFID technology and cameras. In addition to the movement, the visitor's interaction with the system also includes object manipulation-based gestures. The visitor holds an asymmetrically shaped wooden cube to specify the direction he is directed to. Despite its reliability, the efficiency of the approach is discussed since the user is intended to specify manually his orientation. Also, only limited spatilization functionalities are provided since only the stereo effect (left, right) is provided and not the binaural effect (behind, above,...).

In LISTEN project [ZL08], the goal was to explore immersion in audio augmented environments by overlaying a virtual soundscape to the real environment. This system has been installed at the *Kunstmuseum Bonn* in the context of an exhibition comprising artworks of the painter *August Macke*. Visitor's head Tracking is performed based on Radio frequency (RF) burst signals and infrared cameras. A central unit collects each visitor's data corresponding to his absolute position and orientation. Then, appropriate auditory contents are selected, spatialized in real time and sent to the user headphones as a binaural data.The main drawback of the approach is the server-based processing which can be source of errors or latency in a peak time usage. In addition, the orientation of the visitor is restricted to the *Azimuth* angle without taking into account the *Elevation* and *Roll* angles.

2.4. Authoring tool in museum experience

We intend by authoring tool the graphical interface enabling the designer to compose virtual scenes and specify the interaction between the user and the real world. Designing an authoring tool is more frequent in the context of games and virtual reality, but it is less frequent in augmented reality, and much less in the context of museum experience.

Few softwares that allow to create scenes and soundscapes and attach them to an audio augmented reality were proposed in the last few years. *Spatialisateur (Spat)* developed by IRCAM Institut (www.ircam.fr) is a software framework dedicated to process real time sound spatialization in musical creation, post-production and concert contexts. It allows to specify spatialization parameters independently from the electro-acoustic restitution mode, but also to identify intuitively room effect parameters. However this software is designed for general situations and presents less capabilities for visualization and experiment of the created scene. It then requires to be extended by modules specifically designed to the final application and providing more facilities than sound spatialization control.

Based on this remark, *ListenSpace* [DW06, LP07] has been developed as a top level of *Spat*. It was designed as an authoring tool specifically adapted to the *LISTEN* project described above. *ListenSpace* enables describing the geometrical properties of all the objects composing *LISTEN* scene, and combining physical and perceptual acoustic parameters for defining the sound sources in the scene. However, the description of the scene in *ListenSpace* is limited to a 2-dimensional representation. This limitation deprives the designer of crucial information especially the height (altitude) of the sound sources.

3. Authoring tool

In our work, we present a domain-specific graphical authoring tool designed for audio augmented reality in the context of museum. The proposed authoring tool enables to build the soundscape related to any particular surface. The user is able to draw the museum's map, to add sound sources, to specify the perception and the private zones corresponding to each sound source, and to choose room effects. The objects are localized using a 3D coordinate system so that the user can add sound sources with different altitudes. Our authoring tool is provided with 2D and 3D interfaces that give a clearer view of the scene and virtually reproduces the visitor's field of view.

3.1. Edition and Visualization Interfaces

As the authoring tool application is launched, the visitor is considered to be at the origin of the 3D coordinate system. His position is shown using two interfaces:

- A 2D rendering interface that gives the 2D projection of the virtual scene seen from above. The main function of this interface is the edition of the virtual scene. The visitor is represented with a disk reflecting his position and an arrow representing his orientation.
- A 3D rendering interface that can mainly give two kind of views: objective view reproducing the upper view of the virtual scene, and subjective view reproducing the visitor's field of view. In addition to auditive immersion provided by the binaural rendering, this interface provides a visual immersion in the virtual scene. This will help the designer to take spatial dimension into consideration while designing the virtual sound scene.

The user is able to change the position and orientation of the visitor, and thus the rendering of the 2D and 3D interfaces, using a pointing device such as mouse or keyboard. (figure 1).

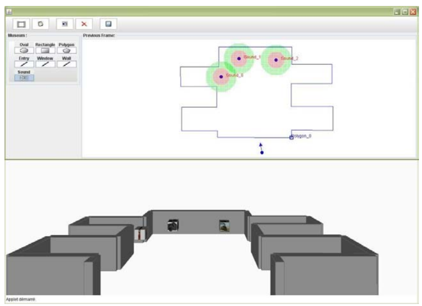

Figure 1: *Authoring tool.*

3.2. Drawing the museum map

The authoring tool enables the user to choose the correct shape that represents the museum's interior area, or the part of museum that will contain the soundscape. Using a 2D drawing interface, the user is able to use polygons, circles and other forms to draw the museum surface's shape. The 3D rendering of the museum is built as well as the user is drawing the shape. The user is able to add entries or windows but also to change the wallpapers by choosing the appropriate image or texture.

3.3. Adding sound sources

Using the object interface, the user is able to add sound sources to the scene. This is done by specifying the appropriate 3D coordinates of the corresponding artifacts. This would enable to place sound sources at different altitudes. When introducing a sound source, the user is invited to specify two sounds that relates to that object.

Ambient sound: that represents the sound coming naturally from the object when it is activated. For example, when that object is a car, the ambient sound would be the sound of the engine of that car when it is running.
Description sound: that represent the sound of a description of the object. It is destinate to be used, by default, when the visitor is in the private zone of the object (see Section 5).

When adding a sound source to the scene, the user has to specify two types of zones (figure 2).

The perception zone: it is the area where the sound coming from the sound source is perceived. Perception zones of several sound sources can intersect.
The private zone: it is a limited area containing the object. Only the sound coming from that sound source should be perceived in that zone.

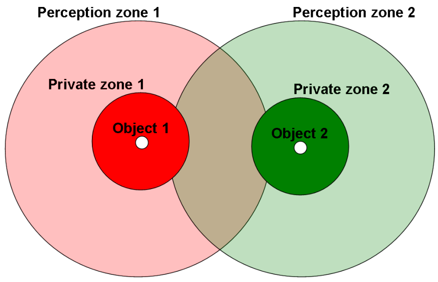

Figure 2: *Perception and private zones of two different sound sources.*

3.4. Room effects

in oder to embellish the audio rendering, and have a good binaural one, the user can specify and modify the parameters of room effects, and HRTF filters. Regarding the room effect several properties can be parametrized, we list here some of room effect parameters that can be modified:

Reverb_name : the name of the reverberation.
Diffusion : Reverberation diffusion(echo density).
Room : Room effect level at low frequencies.
Decay_Time :Reverberation Delay time at low frequencies.
Reflection : early reflection level relative to room effect.
Reflection_Delay Delay time of first reflection.
Reverb : late reverberation level relative to room effects.
Reverb_Delay : late reverberation delay time relative to first reflection.

This interface is still in design phase. We can add other parameters to improve the rendering sound quality.

4. Visitor device

The visitor has to wear a particular device. This device is composed of three main components: an orientation tracking tool collecting the orientation of the head of the visitor, a laptop where runs the sound spatialization software, and a stereo headset that bring specialized audio content to the visitor (figures 3 , 4).

Figure 3: *Experimental visitor device.*

Figure 4: *Orientation sensor fixed on headset.*

4.1. Audio display

The software used to ensure binaural cues was developed using NativeFmodex (FMOD's native version), a programming library and toolkit for the creation and playback of interactive audio. It was used because it is freely distributed with multi-platform support. NativeFmodex was used to create accurate 3D positioning of the virtual sound source. Filtering with a Head Related Transfer Function (HRTF) was used to perform binaural sound spatialization using a stereo headset. HRTF is defined as a mathematical function representing the acoustic characteristics of the head of an individual used to calculate the treatment applied to simulate 3D spaces from two channels.

4.2. Orientation tracking

Inertial tracking is relatively a newcomer to the motion tracking area. It begins to be used to determine head orientation in virtual and augmented reality application. Practical inertial tracking is made possible by advances in miniaturized and micromachined sensor technologies, particularly in silicon accelerometers and rate sensors [RLV03] . The inertial system that we have used in our experiment is the $6DOF-IMU-V4$ from Sparkfun. Unfortunatly, this sensor is not supplied with software for inertial navigation and we are not aware of any open-source software suitable for our research. We have chosen that sensor since it provides 3 axes of acceleration data, 3 axes of gyroscopic data, and 3 axes of magnetic data. In addition to wired connection, it supports also wireless Bluetooth linking. We are using this sensor in the aim of getting accurate measurements for the visitor's head orientation angles, especially **heading**, **elevation** and **roll**. **Heading** is defined as the angle in the local horizontal plane measured clockwise from a true North (earth's polar axis) direction. **Elevation** is defined as the angle formed between the X *axis* and the horizon/ground, and **roll** is defined as the angle formed between the Y *axis* and the horizon/ground.

Elevation and roll :
We can get a reliable measurements of elevation and roll by using accelerometer data provided by the $6DOF-IMU-V4$. In practice, the accelerometer coordinates are not correct when the sensor is laid flat. Therefore, we have to perform a calibration. The procedure we have followed for this end, consists of the following: we put the sensor in order to have successively the axes X, Y and Z in a vertical position. Then at each position we collect the returned accelerometer data: x_1,y_1,z_1 when X axis is vertical, x_2,y_2, z_2 when Y axis is vertical and x_3,y_3, z_3 when Z axis is vertical.
We first calculate the coordinates of the accelerometer's origin:
$x_0 = (x_1+x_2)/2$
$y_0 = (y_1+y_3)/2$
$z_0 = (z_2+z_3)/2$
Those coordinates are then used to correct the coordinates of the vector Force at each measurement:
$a_x = (x_{raw}-x_0)/(x_3-x_0)$
$a_y = (y_{raw}-y_0)/(y_2-y_0)$
$a_z = (z_{raw}-z_0)/(z_1-z_0)$
where x_{raw}, y_{raw}, z_{raw} are the accelerometer data.
If the sensor is not moving fast, the measurement of coordinates of the gravity vector allows to obtain the spatial orientation of the device in *elevation* and *roll*:
$Elevation = arctan(a_x/sqrt(a_y \times a_y + a_z \times a_z))$
$Roll = arctan(a_y/sqrt(a_x \times a_x + a_z \times a_z))$

Heading :
A naive approach to calculate *Heading* would involve a single integration of the *Azimuth* angular rate data gotten from gyroscope. It can also be calculated based on the magnetometer data. However, such measurement is not accurate. In fact, while magnetic sensor suffers from unpredictable disturbances, gyroscopic sensor is in itself prone to drift over time due to the buildup of small bias and drift errors. In order to avoid gyroscope drift and magnetic disturbance, our approach is to couple the data of magnetometer, accelerometer and gyroscope embedded to the *IMU* used to have an optimal heading tracking. Our sensor coupling approach consists on calculating the **Heading** provided by the magnetometer and the **Heading** provided by the gyroscope and then combining them to obtain an optimal heading tracking.

Magnetometer Heading : We start by calculating the heading using only the magnetometer data. The first step is to calibrate the compass. For this aim, we calculate the minimum and the maximum values from the magnetometer measurement through the 3 axis (x_{min}, y_{min}, z_{min}, x_{max}, y_{max}, z_{max}). The aim is to include ferrous content correction factors from the last user calibration routine. Nearby ferrous materials may create distortions in the earth's magnetic field at the sensor bridges, the new values of compass are:

$y_c = 2 \times (y_i - y_{min})/(y_{max} - y_{min}) - 1$
$x_c = 2 \times (x_i - x_{min})/(x_{max} - x_{min}) - 1$
$z_c = 2 \times (z_i - z_{min})/(z_{max} - z_{min}) - 1$

Because magnetometer sensitivity decreases as **Elevation** and **Roll** increase, we introduce them in the calculation of the **Heading**:
$X_h = x_c \times cos(-elevation) + y_c \times sin(-roll) \times sin(-elevation) - z_c \times cos(-roll) \times sin(-elevation);$

$Y_h = y_c \times cos(-roll) + z_c \times sin(-roll);$

Hence, the formula to calculate **Heading** from magnetometer and accelerometer is:
$Heading_m = arctan(Y_h/X_h)$

Gyroscope Heading : The **Heading** can be calculated from the gyroscope data as the following. Since, the gyroscope data representes the speed with which the three angles (**Heading**, **Elevation** and **Roll**) are changing, all we have to do is to integrate the gyroscope data corresponding to the **Heading** angle (heading_gyro):
$Heading_g = \int heading\_gyro.dt$
Finally, we need to multiply the result by a *scale factor* calculated experimentally (4/3 in our case), so that the **Heading** will be calculated in degrees.
Gyroscope data is returned with a *Bias* that means that $real\_heading\_gyro = measured\_heading\_gyro + BIAS$. The value of the *BIAS* can be estimated at the beginning of the experiment as the sensor is static. However, gyroscope is suffering from a drift. Which means that the *BIAS* changes over the time indepen-

dently from the measures. This makes the angular rate inaccurate after few seconds. In order to overcome this drawback, we propose to use variance of the angular rate in order to determine whether or not the sensor is moving. When the variance is close to zero, we assume that there is no motion, and then we update the BIAS with the gyroscope data. Actually, the variance can approach zero also in case of motion with a constant speed, however this is rarely the case when visiting the museum since the visitor turns his head quickly for a short time and stop his head to see the artifacts.

Combined Heading After getting two separate measurements of the **Heading** ($Heading_m$ by magnetometer and $Heading_g$ by gyroscope), we combine the two values to get the best heading measurement ($Heading_c$) and overcome the drawbacks of each sensor. We assume that there is magnetic disturbance when there is important difference between the variance of the gyroscope angular rate and the variance of the magnetic angular rate. So when there is no disturbance we put $Heading_c = Heading_m$. However, when disturbance is detected, $Heading_c = Heading_c + \Delta(Heading_g)$ where $\Delta(Heading_g)$ is the difference between $Heading_g$ and the latest non disturbed $Heading_c$.
The algorithms cited above enables us to minimize the effect of magnetic disturbances and gyroscope drift, and then get a reliable calculation of the heading angle. Such algorithms are cited as a first draft of a complete open source library for position and orientation tracking using IMU sensors.

5. Visitor's scenario

Connected to a motion and orientation sensor embedded in headphones, the proposed prototype creates a map of sound sources. It constantly analyzes the visitor 's visual vector, with the aim of delivering to him the appropriate composed sounds according to the objects he is surrounded with. The number of distinguished sounds to play, their types, their volumes, and the orientation (left, right, top, ...) from which they should be played regarding the visitor, are defined following a *visitor scenario*. The visitor scenario comprises a set of rules that fixe the previous criteria depending on the position and the orientation of the visitor. An unlimited number of visitor scenarios can be defined depending on the application the designer wishes to execute, and depending on the context.

5.1. The Museum context

Technical museums and especially the '*Musée des Arts et Métiers*' contains several machineries from different ages exposed in different ways. Some rooms contain few big machines, while others contain several small machines arranged in display cases, other objects are hanged from the ceiling (e.g. small aircraft,...), whereas others are put on the floor (e.g. piano, bicycle,...). Machines can produce rich, complex and intense sounds characterizing their functions. Unfortunately, many practical reasons prevent from running those machines to visitors, which deprive them of a rich information about there functioning. Placing loudspeaker near each machine is also inappropriate for practical issues but also since it prevent the visitor form an individual experience when dealing with museum artifacts. In fact, all the visitor would get the same audio content (either ambient sound or description sound) wherever they are. The museum would also turn into a noisy space if the visitor begins to hear sounds about all the machines in the museum without taking into account his position.

5.2. Immersion description combined scenario

The visitor scenario we propose here is a scenario that combines audio immersion in ambient sound and artifacts description. When the visitor enters the soundscape, his position and his head orientation are automatically sent to the sound spatialization system. This later retrieves the appropriate audio content according to the user position and orientation, and then sends it to the user headset as binaural data. The following actions can be considered:

Action 1: As the visitor enters the room, he begins to hear via his headset a predefined sound corresponding to the room topic, so he gets an initial idea about what the room contains.

Action 2: When the visitor enters the perception zone of a specified object (see figure 2), he begins to hear the ambient sound corresponding to that object. The sound is sent as a binaural spatialized sound. The volume and the orientation of the sound (left, right, top, ...) depends on how far the visitor is from the artifact and on which side the visitor is situated regarding that artifact.

Action 3: when the visitor reaches the intersection of perception zones of two or several sound sources, he simultaneously hears the ambient sounds of all these sound sources, where each sound is sent to the visitor headset depending on his position and his head's orientation. The visitor should be able to localize the artifacts surrounding him and estimate their distance, as different sounds come from different directions and positions.

Action 4: If the visitor enters the private zone of a sound source, after a number of seconds (specified by the designer using the authoring tool) he begins to hear exclusively the description sound corresponding to that object. This sound is also delivered as binaural spatialized sound.

All the changes in the audio content that the visitor hears are done in a fluent and progressive way so that the visitor does not feel cuts in the soundscape. When going from a use-case/action to another, the volume of the last audio content is decreased progressively as the volume of the new audio content increases.

5.3. Experiment

Experiments of our system are conducted in the 'Musée des Arts et Métiers'. In the following experiment, we were especially interested in testing the capabilities of our system only based on the orientation of the visitor. The position of the visitor (listener) was fixed by the authoring tool for the purpose of that experiment. Indications on how to get automatically the position of the user using wired or unwired devices can be found in our previous work [KLPDC09].

For this aim, we have chosen two rooms to experiment our device, a machineries room that contains few big machines, and an automatons room that contains several small machines. The objective was to be deal with different ambient sound types (recorded sound, composed sound, synthetic sound), but also to be confronted to different configurations of artifacts into the museum rooms.

First experiment (machineries room)

This square room contains a large electrostatic machine of the 18th century (figure 5), and an impressive ship engine from the 19th century (figure 6). The two artifacts are put one in front the other at east and west sides. The room has, at north side, an entry to a second large room dedicated to media technologies. Three ambient sounds should be heard in the room: two sounds coming from the two machines and a composed sound coming from the media room. None of those artifacts can be run since they are very old, so no real ambient sound corresponding to them could be recorded. Artificial sounds were then composed by a sound engineer. The ship engine sound was created by over-sampling, slowing-down, and then low-pass filtering a sound of a contemporary small boat. The electrostatic machine sound was created by mixing a sound illustrating the mechanical friction of the glass discs and the crank, along with the sound of some electric lightning. The sound coming from the media room was created by mixing sounds of some known media technologies such as printers and telegraphs. Although simple, this soundscape has been costly to produce. This should be taken into account for the future of the project.

Figure 5: *Experiment in the machine room: the visitor in front of the electrostatic machine.*

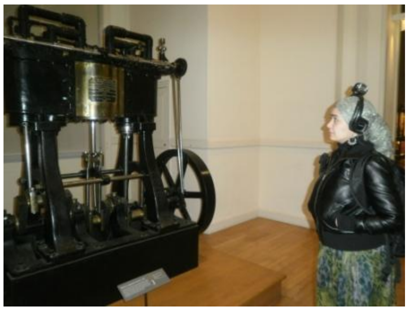

Figure 6: *Experiment in the machine room: the visitor in front of the ship engine.*

Figure 7: *Experiment in the Automatons room.*

Second Experiment (Automatons room)

This room contains several automatons that produce music such as the *"Joueuse de Tympanon"* (figures 7,8). Most automatons in that room are still functional. It was then possible to record the real sound reproduced by those machines while they are running. The main challenge in that room was that it contains several small automatons placed close to each others. The capability to distinguish the sounds coming from those artifacts strongly depends on the size of the perception zone (ambient sound zone) associated to each artifact. In fact, when the perception zone of an artifact is big, it

Figure 8: *Experiment in the Automatons room.*

will intersect with many perception zones related to the other artifacts. As mentioned in [KLPDC09], humans are able to distinguish up to six sounds. However, when more than six perception zones are intersecting, distinguishing the source of each ambient sound become very hard, especially when these sounds are similar. The other crucial parameter is the error of the sensor used to acquire the head's orientation of the visitor. In our case, this error was estimated to 10 degrees. These two observations were taken into consideration in order to fix the size of perception zone as small as possible so that more that 5 perception zones could not intersect.

6. Conclusion and Future Work

In this paper, we have presented an integrated framework combining sound spatialization, position/orientation tracking and authoring interface. According to such an architecture, a system for designing and achieving location aware audio guide for museum visit was developed. The objective was to enrich the museum visit with ambient sounds associated to the exposed artifacts, making the museum a vivid and animated environment while taking into account the intimacy and the individual experience of each visitor. Producing such a system requires federating software and hardware technologies from several fields. We have used *Fmod* library for realizing sound spatialization, *Sparkfun IMU* for performing orientation tracking, *OpenGL* library for producing the 3D virtual scene, *Java* and *Processing* for developing the authoring tool and connecting the different components of the system.

We follow an incremental approach for developing and evaluating the several components of the system. The work presented here was concerned with the authoring tool, sound spatialization and orientation tracking. Future work will focus on four major issues, that will need to be evaluated by pilot studies :

- performing experimental evaluation to validate the scenario and the authoring tool through real use-cases.
- developing new scenarios for visiting museum depending on the disposition of the exposed artifacts,
- position tracking for indoor spaces using additional devices (particularly steps-based systems),
- developing a control interface installed in small mobile devices (ipad, iphones, ...) enabling the visitor to interact with the soundscape by stopping or playing some sounds, changing the types of played sound (ambient/description), or changing perception and private zones of the surrounding artifacts.
- improving the authoring tool's 3D rendering.

7. Acknowledgment

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