PERIPHERAL NOTIFICATION WITH CUSTOMIZED EMBEDDED AUDIO CUES

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ABSTRACT

Peripheral notification services allow users to monitor information with less distraction of attendees in their surrounding. In the majority of cases, the information is provided by visual displays that often have several disadvantages, e.g. the lack of privacy or the user is locally bounded to the surrounding of the display.

In this paper, we introduce an approach for a discreet notification of persons in multi-user environments. In particular, we use the current user position to provide a personalized and location-aware notification service with non-speech audio cues embedded in aesthetic background music. Thereby we enriched the music, and especially the notification audio cues, with functionality to influence the perception and to control the attention of the listeners. These functional pieces of music should stay in the peripheral background to avoid too much attention.

The used ambient soundscapes and the set of corresponding notification instruments were composed and recorded by ourselves. The development process including compositional constraints with respect to auditive perception and emotional effects raised by music will also be introduced in this paper as well as the nomadic event notification service which includes our indoor positioning system for mobile devices.

[Keywords: Soundscapes, Non-Speech Audio Cues, Positioning]

1. INTRODUCTION

The proceeding enrichment of our everyday life with computational power and assistance applications can be a mixed blessing. On the one hand we benefit from user adaptive and easy to use systems that provide us with information. But at the same time we are exposed to the danger of a "cognitive overload". The necessary filtering of information should depend on the users preferences and result in an appropriate presentation that decreases distractions of the user and other attendees [1, 2]. How users should be provided with information depends on the complexity of data. For elementary data, the use of audio notification often makes more sense than overloading the human visual sense with additional information. Earcons are often used to provide users with information about the system status or ongoing computational processes [3]. They are short non-speech rhythmic sequences of pitch, so called motives, that can be combined to provide more complex information. Above all, notification with audio cues containing information can be done in a more peripheral way that can also be used for monitoring continuous changing data e.g. stock market progression [4].

The type and the variety of the available information still depends on the location of the computer system. Similar to the change from the wired analog phone to the cordless mobile phone, people want to receive important information location-independently. In our work, we use location awareness to notify users via peripheral audio patterns if a personal event occurs (e.g. receiving an email that matches a user predefined keyword or the notification of a forthcoming appointment). The localization is done by an indoor positioning system that runs on the users personal PDA in combination with IR and RFID tag arrays. The notification system automatically starts a preselected ambient soundscape on the audio surround system in the background if the user enters the room with his registered PDA and the service will periodically check whether an event occurs regarding the user. For example, as long as the user stays in the room his email account will be monitored and the subject line of arriving new messages will be compared with optional keywords. If an appropriate email arrives the current position of the user in the room will be figured out and the loudspeaker next to him will play his notification signal that is mixed into the soundscape. Unlike using the PDA loudspeakers for playing the notification signal, the use of the room speakers avoid the source detection of the notification signal. Not only the distraction can be avoided but also the privacy will be increased, because only the target person knows his personal notification instrument that he selected. Since the instrument fits into the composition other people will perceive the notification as part of the composition and not as a notification cue.

2. RELATED WORK

The Nomadic Radio [5] uses contextual audio cues on a wearable hands-free SoundBeam neckset for providing information. The scalable audio interface remotes services and messages e.g. for email, news broadcasts and calendar events with wireless LAN and a telephony infrastructure. The interaction device is mounted on the shoulder of the user and is connected with a mini-portable PC that is also worn by the user. Messages are announced depending on the current user conversation context via speech and rendered spatial audio cues. Wearing such an additional special device that has only the function to receive auditive notifications could be hindering and reduce the acceptance. We decided to use standard PDAs for our notification system because the spread and popularity of PDAs increased in the last years and hence these devices became an everyday life object with multiple functionality.

Hudson and Smith designed a non-speech audio system that provides a preview of incoming emails by combining sound samples [6]. The "audio glance" gives an overview of four important properties of a received message by coding information into the notification sound. First, the optional preamble sound is used for announcing messages that are classified as important. The sound of the main audio icon gives information about the message category, e.g. sender information in which the sample length represents the size of the mail body. For whom the mail is appointed to (single or group of users) is coded in the recipients icon and the finishing optional content flags announced mails where a keyword matching test for header or body is positive. The playback of the resulting sound could distract other people that are in the same room in which the notification takes place. Users can also receive their audio glance while they are away from their desk by holding up a color coded card in front of a camera that are mounted in other rooms. For multi-user environments, concurrently played samples could produce a confusing sound.

Brewster did research into the areas of application of non-speech audio in human-computer interfaces. In several experiments he investigated the effectiveness of earcons as navigation cues [7]. Among other things, he found out that earcons can be used to represent hierarchical structures after a short training phase. The results could even be improved by using compound earcons. A detailed introduction to non-speech audio cues for human-computer interfaces and the mentioned earcon experiments can found in Brewster‘s PhD thesis [8].

Areni and Kim observed how customers in a wine store can be influenced by background music. They compared the influence of two music genres (classical music and Top-forty music) on the buying behavior [9]. One of the findings was that customers stayed longer in the store with background music than without and the people were more interested in expensive wine when classical music was played.

3. AUDITIVE PERCEPTION

In our everyday life, probably the auditory sense is besides the visual sense the most important channel to find out what is going on around us. If we take a look on the evolution, the human being has the important abilities to receive noises, to locate sound sources and has access to an auditive memory database to interpret and categorize the sonic phenomenon. The process of auditive perception can be distinguished between the physiological phenomenon of hearing and the semantical sound processing which leads to the personal interpretation of the signal influenced by the experience of the listener.

The intensity and complexity of environmental noises influence whether we perceive a single sound or whether it is masked. That depends on multiple factors like loudness and the frequency of the noises. Traditional audio notification signals are mostly “stand-alone” cues that attract the attention of everybody in a room because they are not integrated in the natural sound environment. That works fine for high-priority notifications (e.g. fire alarm), but often a more personal and discreet notification is desirable. That fact is important for the design of our notification signals. On the one hand we want to seamlessly integrate the notification signal into the background music without arousing the attention of other people, but on the other hand the target person must become aware of the signal.

The auditory experiences will be permanently extended and can be trained. We use this fact to make the listener more sensible for his specific auditory signals that we use for attracting his attention. These audio cues are used to provide the listener with information that he links with the specific auditory signal. The user should choose by himself which sound he wants to link with the information, so we get an individual and personalized notification. Since only the user knows which sound he selected for which information, this type of notification also slightly fulfills the privacy aspect. For people with a less trained sense of hearing, a short training how the selected audio cue sounds like would make sense to ease the recognition.

Name of Function	Processing
Analysis	Identification of acoustic structure
Orientation	Sound source localization
Distinction	Separation of similar sounds
Completion	Intuitive completion of missing sounds
Structuring	Classification and segmentation of signals
Selection	Splitting into benefiting- and disturbing signals
Synthesis	Grouping of single sounds into complex structures
Storage	Ultra-short-term-, short-term- and long-term memory

Table 1: *Functions of auditive perception.*

Another important point is the fact that the perception is highly associated with the attention of a person. That fact is well-known from cognitive psychology and also the fact that the attention has a limited capacity. The allocation of the resource attention depends on the stimuli that act on the person. Already in the year 1952, Colin Cherry found out in his famous “cocktail party” experiment that the effect of the auditive stimulus is depending on the one hand on physical parameters like frequency and sound intensity and on the other hand on the current mental and social condition of the person. In the experiment, the participants had the ability to switch their focus of attention between different stimuli. The splitting of the attention describes the ability to perceive several stimuli at once. We use this subconscious perception for our unobtrusive soundscapes that will fade in the background of awareness after a while of playing. As soon as the intensity of a stimulus increases (e.g. loudness) or its character changes (e.g. pitch), the person will be aware of the alteration and will lead his focus on that stimulus (see also [10]). We use that fact to make the target person aware of an important event by leading his focus of attention on the notification signal.

We derived melodious and harmonious constraints from the *Gestalt laws*[1] that are well-known from visual cognition. These auditive laws describe the phenomenon that humans tend to combine perceived musical impressions into figures with certain properties. That process of grouping is done in the synthesis function which stands at the end of a row of perception functions that is listed in Table 1.

The Gestalt theory sees objects with specific attributes as a whole. Based on the Gestalt laws we defined some compositional constraints to increase the effectiveness of our soundscapes and notification signals. In the following, we give a brief overview of the six most important laws and why they influenced our compositional process.

- The *Law of Proximity* describes the phenomenon that notes in the proximate neighborhood will be grouped together. That effect creates a melody line and/or bass line. Another example is the grouping of repeating rhythmical figures to structures called rhythmic patterns. The fusion of single musical notes makes it easier to process the signal and enhances our musical experience database.
- We use the *Law of Similarity* to vary melody lines that we use for notification without destroying the recognition of the signal. In doing so, the basic structure of the melody

[1] Theory of Christian von Ehrenfels (1890) and Max Wertheimer (1912)

stays unchanged but the lines will be played by another instrument. This kind of variation is also used in the accompaniment of the core song in which repeating chords are slightly alternated to leave a more vivid mark.

- The *Law of Closure* assumes that the human brain adds missing elements to uncompleted structures. For example, if a person heard a melody several times he will not recognize when a few notes at non critical positions would be removed. The missing notes were perceived as good as they would have been played. The Law of Closure could implicate the risk that an often heard notification signal could attract the attention of the target person even if it is not played. To avoid that effect a slight modification of the melody or the rhythm could be useful without a new training phase because of the Law of Similarity.
- *Law of Continuity*. The attention continues following a melody line even if the line crosses another melody. Thus, if the attention of the listener follows a melody we can lead him to new musical sections. To get a seamless transition between sections (for example verse to chorus) we use so called interludes which leads the listener to the new section.
- The *Law of Symmetry* allows the listener to group similar patterns regardless how far they are away from each other, so he will recognize if he already heard parts of the compositions. Most of the time, the listener will also remember which instruments played in which section.
- The *Law of Common Fate* describes the grouping of notes with similar changes. That means two melody lines with a fixed interval between them will be perceived as one line (for example a parallel melody with a tonal distance of a third). We avoid this phenomenon because we would have a strong auditive stimulation caused by this strange sound.

4. COMPOSITIONAL REQUIREMENTS

At the beginning of the compositional process of functional music stands the analysis of the area of application and the effect, which we want to achieve with the help of the composition. In Section 3 we took a brief look at auditive perception and especially on the auditive Gestalt laws and why we took them into consideration for our functional compositions. Generally, such a piece of music should be able to influence the mood of the listeners and/or to attract their attention. The efficiency of this approach is well-known from movies in which the mood of the spectators is manipulated by variations and changes of musical elements like rhythm, interval or chord. These elements can be improved and analyzed by their acoustic structure described by duration, energy, pitch, timbre and harmonic structure [11]. The influence on the affective states, triggered by modifying acoustic structure values, can be manifold and is the goal of functional compositions (see also [12]).

In our everyday life, such functional music can also be found in public places like waiting halls, elevators and in shopping malls where ambient music is used to provide a more friendly and comfortable environment for customers. In 1978, Brian Eno was one of the first musicians who designed ambient music (Ambient 1: Music for Airports) which can be heard actively or used for background music depending on the listener who chooses whether he wants to pay attention or not. Among other things, typical features that were used: the beats per minute (bpm) of the music lies between 60 and 70 bpm (the resting pulse rate) and the volume is should be slightly above the environmental noise level.

Category	Parameter	Range	Emotional Impact
Time	Speed	fast - slow	pleasant - calm
	Phrasing	staccato - legato	lively - gently
	Rhythm	firm - smooth	serious - dreamy
	Dynamic	cresc. - decresc.	animated - relax
	Meter	even - odd	dignified - restless
Pitch	Mode	major - minor	bright - plaintive
	Frequency	high - low	exciting - sad
	Melody	ascending - descending	dignified - serene
	Note Range	$\geq$octave - $\leq$octave	brilliant - mournful
	Harmony	consonant - dissonant	serene - ominous
Texture	Volume	forte - piano	animated - delicate
	Orchestration	instrumentation	majestic - grotesque

Table 2: *Categorization of musical parameters, including range and emotional impact.*

This type of music is also known as "Muzak[2]" in which the complexity of the non-speech compositions is reduced to avoid the listener‘s attraction. These necessary compositional restrictions can be found in the musical components which can be described by their time, pitch and texture. The parameters of these three categories are used to influence how ambient a song will be.

The overall emotional effect induced by a composition can be described as the fusion of the parameter effects summarized in Table 2, which are the constraints for our compositions. But the act of composing functional music is more than mixing the favored elements because of the mutual influences that should be considered. Furthermore, the choice of the instruments in a composition (orchestration) is an important factor to influence the character of a composition. The melody can sound triumphant or serious if it is played by brass instruments whereas woodwinds express more awkward and whimsical feelings. Melody lines played on a piano have a brilliant effect and strings can create versatile moods. A detailed survey of musical characteristics and emotional expressions can be found in [13].

5. AMBIENT SOUNDSCAPES AND NOTIFICATION CUES

Our ambition to provide an ambient notification with audio cues came from the displeasedness with monotonously disturbing notification sounds. The main problem of traditional "stand alone" notification signals is the distraction of all present persons especially in multi-user environments. To introduce more privacy and confidentiality, we decided to integrate the notification signals with respect to the musical composition seamlessly into background music, the *ambient soundscape*, which serves as the musical envelope (see also [14]) . That core song should not have a special effect on the user in the sense of attracting his attention. The willingness and ability to relax also affect how effective the ambient soundscape can change the mood of the listener. One of the three self-composed ambient soundscapes can be heard on the author‘s website.

In the second phase we add auditory cues in the form of notification instruments to the ambient basic soundscape and direct them to the position of the person by using a spatial audio framework. In that way, users can be effectively notified without disturbing colleagues that are working in the same room. To get this

[2] labeled by the US company Muzak Holdings LLC

auditive notification system in a multi user room started, the participating persons have to learn their notification instruments that provides them with the audio cues. A selection of composed notification instruments for the ambient soundscape mentioned above can be heard on the author‘s website. An overview of the provided sound samples is listed in section 9.

Since the notification instruments can be seamlessly integrated in the ambient background song, the system works on the edge of human perception. That has the effect that an occurring notification should be perceived after a while. To prevent the effect of ignoring a notification, we also provide a hierarchy of notification signals that are grouped by their “level of intrusiveness”. The level can depend on the importance of the occurring event.

1. High-Priority. Signals: arousing noises (e.g. beep, siren and bell)
2. Medium-Priority. Signals: ambient noises (e.g. birds, rain, water- and wind noises)
3. Low-Priority. Signals: notification instruments (musical instruments integrated in background sound)

The notification cues can be mixed into the corresponding soundscape at certain points in time with respect to the composition to avoid disharmony. We are obliged to this restriction to guarantee a fluent integration. Because of the fact that each user can select his personal instrument, other attendees will not be able to associate an instrument to a specific user even if they recognize the new cue. The personal instrument will seamlessly leave the soundscape if the user informs the system by pressing a button on his PDA or desktop GUI that he perceived the notification.

The two musical components, namely the soundscapes and the notification instruments, were composed and recorded by ourselves. The compositions fulfill some perceptional constraints such as the auditive Gestalt laws [15, 16] that we introduced above and the consideration of the volume of the instruments that are well-known in musicology to influence the perception process. The user has the possibility to choose a soundscape that matches his personal preferred music style and an instrument or ambient noise (natural sounds e.g. sea gull voices or flowing water) that he can easily recognize. On the one hand we composed three musical core songs, whose information content is to be kept as small as possible. On the other side we arouse the attention of the target person with the help of inserted instruments and audio cues. Now, music is no longer a pure emotion mediator, but contains a unit of emotion and intellect, whereby the sum of these two factors results in the information content of the music.

The effectiveness of the peripheral perception with our acoustical notification system was successfully tested in a user study with 25 persons where we especially checked whether the users percept the notification instruments and how long they need to recognize the notification (delay time). The study was subdivided into a computational test and a questionnaire to get a subjective and personal feedback of the participant‘s opinion about the soundscapes and this type of notification. The laboratory test was done at a desktop PC where the participants had to concentrate on a primary task to direct their attention to a problem. Notification signals consisting of preselected notification instruments and a control signal were randomly mixed into the soundscape with respect to the build-up of the compositions. The time of the appearance of the signals, their duration and the time when the test person perceived the signal were logged and evaluated. One of the key findings was that some notification instruments, especially the drums and the piano, had been noticed almost as fast as the arousing beep signal. The overall notification efficiency (78%) which describes how many notification signals were perceived by the listeners was almost as high as the number of perceived beep signals (79%). The complete user study can be seen in [17].

6. EMOTIONAL EFFECTS

Both the core song and the optional notification sounds have to fulfill a variety of requirements to be able to influence the listener and to attract the attention of the target person without distracting other people in the surrounding. These effects that we introduce in the following make the compositions to functional pieces of music.

1. The *carrier effect* describes the basic phenomenon of music to contain and transfer information.
2. With the help of the *magnet effect* the person‘s focus of attention will be lead to the auditory phenomenon and in the direction of the source of sound (the basic effect of alarm signals).
3. The *dubbing effect* gives us the possibility to ignore environmental noises that are under a specific intensity threshold. That threshold highly depends on the frequency of the noise and the current activity of the person in other words his level of distraction.
4. *Mood manipulation*. The creation of a comfortable and ambient auditory atmosphere can create a mood-lifting feeling, that is often used in movie soundtracks to put the spectators in the right mood.
5. *Impact on behavior*. The behavior of the listener can be influenced by music. The musical genre and the individual music taste play an important role. For example a fast and loud rock song can increase the courage of a car driver whereas a smooth and slow classical piece of music will rather have the opposite effect (see also [18]). That is the intended effect for music in shopping malls.
6. *Effect of association*. Persons automatically link experiences with impressions from their senses to increase the effectiveness of their long-term memory. In doing so, a lot of people link a specific song for example with the remembrance of a dance with a former girlfriend.

Besides these general effects of music we also have to mention other attributes that influence the experienced emotion (see also [11]). First, the musical *preferences of the listener* (sociocultural factor) and his current (psychological and physical) state is important. The *context*, especially the location in which the person listens to the music influences his experienced emotion too. Including the impact of other stimuli from the environment on his other senses (e.g. visual and odor). Besides the already introduced *compositional features*, we also have to mention the *performance feature*, which reflects the technical and interpretative skills of the artist.

7. APPLICATION DESIGN OF THE NOMADIC EVENT NOTIFICATION SERVICE

In this section we introduce an implemented concrete application for the ambient notification. More precisely, we present an event notification service for mobile persons in multi-user environments. To give an example for an event notification, we implemented a service to unobtrusively inform registered persons about incoming emails that passed a keyword matching filter. We will also give a more detailed overview of the implemented *Indoor Positioning for Location Awareness* system.

Our claim to build a user centered notification service made a variety of demands on the architecture. Figure 1 gives a rough design overview of the four additional elements: *Positioning System*, *email Server*, *Sound Repository* and *SAFIR* (Spatial Audio Framework for Instrumented Rooms) that are used for the Ambient Email Notification service (*AEMN*). The service has been integrated into our test environment. Among other things, the room is augmented with eight loudspeakers that are mounted at the ceiling and a hidden surround hi-fi system which is connected to a audio server (see Figure 2). In the configuration phase, the graphical administration interface can be used to choose whether the user wants to use the stationary or the mobile notification mode. The first one makes sense if the user stays at his desk most of the time. He can authenticate himself with his name and his password. The location of his personal desk and email account login information are internally stored in an xml file on the AEMN server. The alternative is the mobile version where the users PDA is already registered and used for finding out his current position. We assume that each user has his own PDA, so we don‘t need a manual authentication. In both cases the user has the possibility to enter a personal keyword for filtering incoming messages by their subject line. Incoming messages of registered users are periodically checked by email agents that run on the AEMN server. After authentication, the user can select an ambient soundscape that ought to be played as the background sound. The system checks the sound repository for appropriate notification signals that can be integrated into the background soundscape as notification audio cues. After selecting his personal notification instrument, e.g. guitar or drums, the appropriate wav sound file will be retrieved from the sound repository and audio objects will be generated in the spatial audio system SAFIR [19]. AEMN recognizes when one or more registered users enter the room and automatically starts the selected background soundscape and the login process for checking the user accounts on the email server. The selected audio notification cues will be loaded. If a user receives a new email that passed the filter successfully, the coordinates of the current user position that is computed by his PDA will be matched to the spatial audio system coordinates (listener position) and the notification cue will be seamlessly integrated into the soundscape. The loudspeaker that is nearest to the target person plays the notification cue with slightly increased volume to ease the perception. The notification can be stopped by pressing a button at a small user interface that is running on the PDA or at the administration interface on the desktop computer. In the following section, we will give a more detailed overview of the structure and functionality of the positioning system.

7.1. Indoor Positioning for Location Awareness

Indoor-localization is currently an interesting research topic, since many ideas in the field of ubiquitous or pervasive computing need knowledge about the current user position. The Global Positioning System (GPS) is well known for such tasks in outdoor environments, but due to physical constraints the use of GPS inside of buildings is highly restricted, in most cases even impossible. There are several indoor-localization systems under research or even commercially available that mainly differ in costs, precision and the used sensors and senders. Another important distinction between localization systems is on which device the user positions are determined: On a centralized service or on a device that is

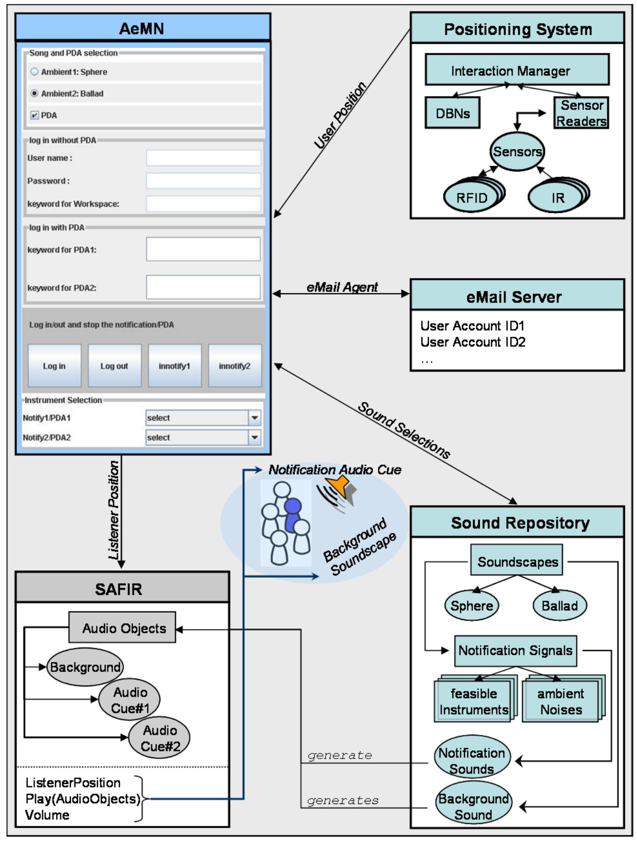

Figure 1: *Audio email notification design overview.*

worn by the user. In the former case, the so called exocentric localization, the environment is equipped with sensors. The users wear senders that are constantly emitting data to these sensors. A centralized server then uses the collected data to calculate the positions of the users. This approach seems to be perfect for location based systems, since the derived positions can easily be distributed to other services. The disadvantage of such a system is the violation of the user's privacy, since he is being tracked and he has no control over the use of his positioning data. Another drawback is that in case the user wants to know about his own position (e.g. for navigational purposes) the centralized position server has to send this data back to the user.

The latter case, the so called egocentric localization, is perfect for navigational tasks. Such a system uses the opposite approach, which means that the senders are installed in the environment and the users wear the corresponding sensors. In this approach the environment is sending data to the user which can then be used by his personal computing device (e.g. PDA or mobile phone) to determine his own position. Since there is no data-flow from the user back to the environment the privacy of the user, in terms of giving away his position, is protected. GPS can be seen as such an egocentric localization system, because the GPS-satellites are sending data to the users but they do not receive any data from the users. However, in the case of location aware services that do not run on the user's personal device (like our email notification), the egocentric system needs a way to provide the positioning data to these services. Although this seems to be a disadvantage and a violation of the user's privacy, it enables the user not only to

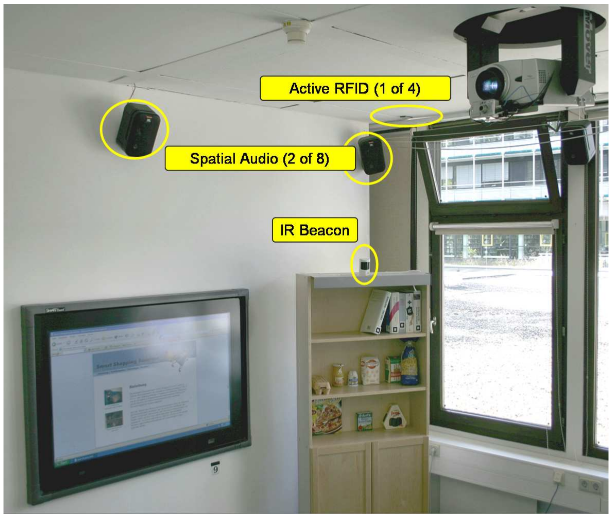

Figure 2: *Test environment with loudspeakers, RFID tags and IR beacon.*

choose whether he wants to give away his positioning data but also to which service he wants to give it.

The decision whether to use an ego- or exocentric localization often depends on the task or service that one wants to realize. For tracking patients in a hospital, with the purpose of not leaving anybody without medical attention, the exocentric approach would be preferable because the positioning data is more important for the medical personnel than for the patients themselves and the benefit of not being forgotten is much higher than the forfeited privacy (which is limited in a hospital anyways). As stated above, egocentric systems are perfect for navigation applications and they can be extended so that the user can choose to only give away his position to trusted services or services where his gain is higher than his loss of privacy.

7.2. LORIOT

For the ambient notification system, we use our own egocentric positioning system named LORIOT (Location and ORientation in Indoor and Outdoor environmenTs). LORIOT is based on infrared beacons and active RFID tags as senders. The corresponding sensors are the built-in infrared port of the user's PDA and an active RFID reader card that is attached to this PDA. Figure 3 shows an iPAQ with the installed active RFID reader card, an RIFD tag and an infrared beacon. Because the system is an egocentric one, the senders (infrared beacons and RFID tags) are installed in the environment and the PDA with the sensors is worn by the user. The active RFID tags have an internal 64 byte memory, of which 56 bytes are freely accessible. We use this memory to store the geo-coordinates of each tag (each tag "knows" its own coordinates). The infrared beacons send out a 16 bit wide identification code. The relation between such an identification code and the coordinates of its IR beacon is also stored in the RFID tags. This way all the external data that is needed to calculate the user's position is stored in the environment.

The position calculation is done with the help of a small dynamic Bayesian Network (DBN), which represents the accuracy of the infrared beacons and RFID tags in general. The idea behind this is that detecting an infrared beacon gives a high probability

Figure 3: *iPAQ with active RFID reader installed, an RFID tag and an infrared beacon.*

that the user is standing in the vicinity of that particular beacon and thus his coordinates are near to the beacon's coordinates. Receiving an RFID tag gives comparable little evidence that the user is near that tag, due to reflections and damping of the radio signals of the RFID tags. These characteristics are coded into the conditional probability table (CPT) of the DBN. During the runtime of the system, an instance of this DBN is generated for every sender that is received and each instance of the DBN is associated with the geo-coordinates of the corresponded sender. We call these instantiations of the DBN geo-referenced dynamic Bayesian Networks or geoDBNs. Each geoDBN calculates the probability that the user is standing at its coordinates and the actual user position is estimated by calculating the weighted sum of all geoDBNs. More details about geo-referenced Dynamic Bayesian Networks, the accomplished sensor fusion and the positioning system itself can be read in [20], [21]. If the user wants to use special location aware applications, like the ambient notification service, he can choose to give away his position to this application. With this mechanism the user can make a trade-off between privacy, benefit of an application and trust in an application.

8. CONCLUSIONS AND FUTURE WORK

We have introduced a system for acoustic notification through peripherally perceived soundscapes that also works in multi-user environments. While target subjects can be efficiently notified with our approach, other persons in the same environment will not be distracted, since the notification sounds are part of the composition of the background music and will only be recognized as notifications by their target person. Thereby, the type of notification can be selected and associated to events. The unobtrusive notification gives us the chance to follow a low level privacy approach. We could imagine application of our method in the following areas:

- *Shopping Mall*
  Employees can be provided with information (e.g. a cashier is needed in the point of sale area) without arousing the customers attention. At the same time the background soundscape has a comfortable effect on the customers.

- *Working Area*
  With the core song a comfortable atmosphere can be created. At the same time a seamless user notification can be triggered by arriving mail or upcoming appointments.

- *Medical Practice*
  Calming ambient soundscapes could be used in examination rooms with unobtrusive notification directed to the staff which are unnoticed by patients.

We already implemented an ambient notification service that works with personalized audio cues and that adapts to the position of the user with the help of his PDA. Occurring events can be announced by enhancing a background soundscape with a personal audio cue that is played near the user‘s current position with increased volume. In the following, we give a brief overview of our future work.

1. Connection to a user model ontology.
   The integration of *GUMO* (General User Model Ontology) [22] will result in a more adaptive and expandable notification service for instrumented rooms (see Figure 4). The enhanced personalization features include the position of the user, his personal music style, his favored instruments and his physical state that we will try to find out with bio sensors connected to the user [23]. The individual settings can then be accessed via http requests when the user enters a room.
2. Sound database extension.
   The extension of the sound repository to an efficient audio database server with a variety of new soundscapes will be continued. Including the integration of musical pieces from the *RWC Music Database* [24] that will be enriched with self-composed notification melodies with respect to the compositional requirements that we introduced above.
3. Audio notification cues with priority.
   Some audio cues and instruments are more qualified for peripheral notification than others. We will try to identify these distinctive specific constraints to group signals by their level of intrusiveness. This can be done with physiological experiments (bio sensors) and user studies. With that information we will hopefully be able to scale the impact of notification cues.

9. AMBIENT SOUND SAMPLES

Here you can find a short description of a few selected sound samples which can be found on the authors *website* or directly by following the web links.

- *Ambient Sound Sample No.1*
  Description: Ambient Soundscape AS01 (Background Song). Artificial sound without any notification instruments.

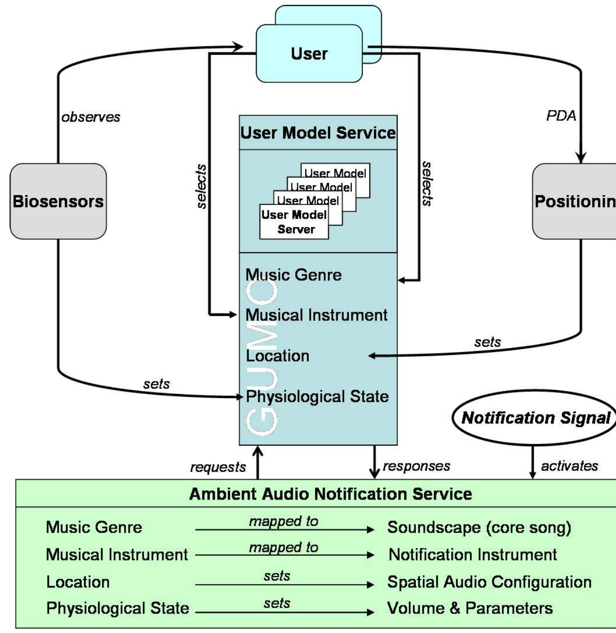

Figure 4: *User model integration for ambient audio notification.*

- *Ambient Sound Sample No.2*
  Description: Audio Cue played by notification instrument hi-hat.
- *Ambient Sound Sample No.3*
  Description: Audio Cue played by notification instrument piano.
- *Ambient Sound Sample No.4*
  Description: Ambient Soundscape enriched with notification instruments hi-hat, piano, strings and guitar.

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