The Computerization of Digital Audio Broadcasting Receivers and the Demand for Empathic Interface Solutions

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ABSTRACT

The aim of this paper is twofold: This paper presents a summary of our recent efforts for the enhancement of a computer-assisted Digital Audio Broadcasting Receiver with several alterations such as a personalization, service scanning, integration of podcasting into broadcasting, and a speech-based interfaces with an information retrieval system. The prototype is based on the mandatory features of WorldDMB's Digital Radio Receiver Profile 3 and is based on a flexible Java framework as well. From these new features and recently introduced standards it follows that new paradigms of interface design are necessary which are discussed subsequently.

INTRODUCTION

We observe worldwide a clear trend to enjoy audio contents independent from temporal and geographical constraints. Now, the audience expects those properties from all media devices or they turn away from an outdated radio. However, the digital radio is still in a growing state of penetration and has yet a huge potential for various and still unknown applications [1].

The Digital Audio Broadcasting (DAB) system possesses a well-standardized and powerful system layout for several media formats and applications. Based on the general DAB standard additional specifications are given to define the basics of the implementation of digital audio receivers. Both audio and data services can be received using the same equipment. In addition to the given standards, more detailed rules and guidelines were developed fortunately. In recent years much effort has gone into the advancement of standards for innovative applications.

Under the roof of the European Telecommunication Standards Institute (ETSI) were created specifications for well-structured and partially machine-readable text formats for electronic program guides (EPG), for an informing running text simultaneously broadcast with an audio signal (dynamic label plus, DL [9]), and news formats such as Intellitext and Journaline. Furthermore there are provisions for speech-based applications and proposals for a middleware architecture, presumably based on [2]. Recent initiatives are the Internet Media Device Alliance [3] and the RadioDNS [4].

These new capabilities can be used now to provide a better and more complete user experience. The DAB system is likely to turn from a classic only-audio receiver into a more enhanced multimedia platform as a part in symbiotic embedded systems such as multifunctional cell phones and sophisticated car entertainment systems as well. By doing so, radio can overcome its restrictions in content, presentation format and time and will be able to offer more comprehensive and contemporary choices. However, preconditions are among other things: forward-looking computer-based specifications of metadata, an adequate processor performance, a huge storage volume, a powerful screen etc. Further improvements in hardware can be expected for many years to come.

Further, we think, a new set of applications could be introduced to provide increased usability and user friendliness towards an universal audio manager. Hence, it is necessary to look beyond the delivery of improved quality of audio content and to use primarily datacasting applications [5].

The initial point of our developments is an advanced DAB multimedia receiver architecture, as mentioned in [1] supporting WorldDMB's profiles 1 … 3, see Figure 1.

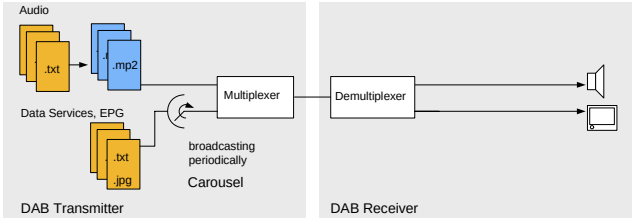


Figure 1: Basic DAB receiver

Our prototypes are extended receivers with own memory, computer assistance, additional WLAN access, podcast support, and a speech-based interface, see Figure 2.

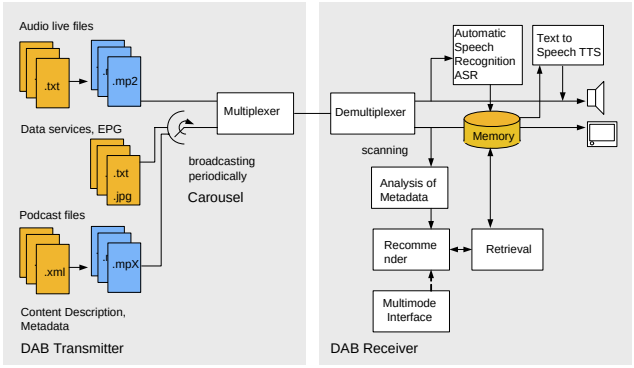


Figure 2: Enhanced DAB receiver

This report is a survey of selected own and other activities and contributions concerning the advancements of an enhanced processor-based digital radio. The presented system consists among other things of:

- a personal recommender/recorder for audio content,
- a solution for broadcasting of podcast content.
- a voice control of the device,
- a speech-enabled information retrieval system.

The following is a review of recent developments of a PC-based DAB receiver and the focus here is on interactivity, usability, cross-linkage, and on-demand qualities. Afterwards we discuss related problems of an appropriate interface design.

PERSONAL RECOMMENDER AND RECORDER

Traditional radio consumption was based on a passive and strict time-dependent paradigm of usage. The availability of audio contents was pre-defined by a rigid scheduling. User's role was only to choose among limited alternatives. A potential for active radio experience is now available: users should be allowed to access contents that fit their needs and attitudes at any time, while being encouraged to discover new domains of interest. Broadcast systems offer a limited control only: users select stations, not really content. Recommender and storage systems help to find out the content of interest.

There are at least two main paths to solve the problem of a higher temporal degree of freedom for content access. Firstly, it is possible to store all the broadcast audio content with an appropriate content description. The current standard of dynamic label plus provides a structured description of content similar to ID3 tags.

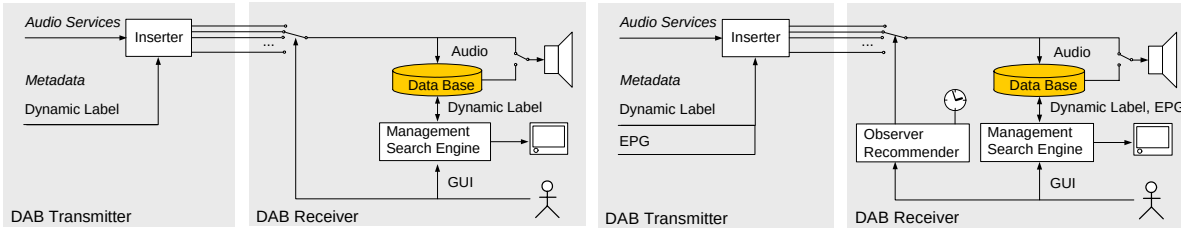
Secondly, it is possible to use a filter/recommender connected with an EPG and an extensive description based on the TV-Anytime standard (TVA) for future content. The additional application of DL plus for current content is possible as well [6], see Table 1.

A simpler concept in between the two above-mentioned concepts compared only keywords in the former dynamic label for starting recordings. This method was in the past very troublesome because the dynamic label was not formally structured [7] [8].

The monitoring resp. mailbox radio records usually a service completely. The receiver is "always on", which is a disadvantage because there is a permanent power consumption. The description of the program items is transmitted simultaneously. Since 2008 the dynamic label plus application is a well-structured description scheme (max. 128 bytes) [9]. However, the normalization of the descriptors (tags or labels) remains poor. The temporal dividing of the audio items is not completely supported by the standard. Therefore arise some practical problems of separation of the audio stream. Sometimes there are legal problems as well [10]. After recording numerous items the display shows a graphical representation of the content similar as a MP3 media player does. The content can be assorted or filtered by usual tools of the application or by the operating system.

On the other hand, the personalized or adaptive DAB receiver obtains user preferences explicitly as well as by autonomous recognition from condensed usage scenarios. The receiver automatically monitors a multiplicity of programs to recommend, store and offer interesting contents [11]. In order to transmit information on planned programs radio stations use the EPG.

Table 1: Comparison of personalization principles for radio receivers

Principle	Mailbox Radio [12], Monitoring Radio [6]	Adaptive Radio [8]
Schema		
Concept	system records everything, user chooses afterwards	setup of profile, system records selectively, adaptive
Content description	current: Dynamic Label plus, similar to ID3v2 [9]	current: dynamic label plus prospective: EPG
Advantages	uncomplicated, lucid	pre-selection, personalised, self-controlled, taxonomy is normalised and extensible, for multiple channels/services
Disad-vantages	no forward-looking behaviour for several channels/services, taxonomy is not normalised, not adaptive, selection is time consuming,	complex description and algorithms, quite inert

This overview is based on a standardized XML format. The program guides are consistently structured and therefore can be processed by computers. It is essential to note that EPGs use the classifications schemes of TVA. The program is described by program elements that can be recursively structured. Numerous descriptors are available for the title, the point in time and the duration, short, middle and long descriptions of the program, the genre, references to other information resources, relations to other program elements etc. The aim was the development of a personalized receiver including the following features:

- explicit definition and automatic recognition of user preferences,
- permanent analysis of entire program ensembles,
- creation of lists containing recommended programs,
- recording of programs relevant for the user.

There are two fundamental concepts to capture and analyse the preferences of users: The user explicitly enters preferences via an interface directly, or the system deduces preferences implicitly by continuous analysis of the user's behaviour.

The user's preferences in combination with the metadata constitute the fundamental information units for the recommendation of program elements. Figure 3 illustrates the mentioned elements and outlines the necessary connections to provide the functionality of the application.

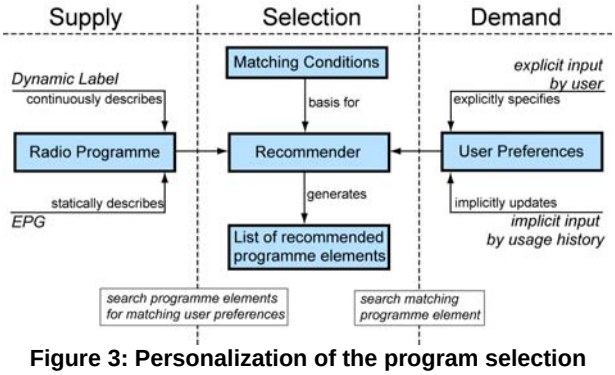


Figure 3: Personalization of the program selection

A specific problem is the granularity and depth of provided classifications to choose in the Interest Manager. Intentional our system provides only a small choice of content classification. The TV-Anytime standard allows more than 1000 different classification statements in several categories, what is difficult to provide without overstraining the user. On the other side the offered descriptors are often not suitable enough for a sophisticated audio classification.

The application extends the radio with the capability to clearly increase this density of information without necessarily demanding any additional efforts from the user. Radio may develop from a largely passively perceived medium to an individual media manager. Particularly the functionality of implicit preference definition by continuous analysis of the user's behaviour seems promising to the authors. By this means the recommendation of program elements is possible without any additional efforts by the user. For the enhancements of the DAB metadata system the following suggestions are proposed:

- Main radio stations must send DL and EPG in a proper and reliable manner,
- The time synchronization of the DL with audio has to be defined,
- The DAB variable program type PTy shall be dynamically used,
- TVA is to be defined radio- and country-specific.

The appliance of the personal audio recorder attracted interest and is generally considered as easy and convenient. Most people show interest in a solution providing audio- and metadata simultaneously and believe that the system is encouraging to listen more attentive, for longer and at different times.

SPEECH BASED INTERFACES AND SERVICES

The benefits of an speech-conversation system have for instance visual impaired persons, people who possess a miniaturized device without a display, and drivers. The obvious advantages of high topicality and mostly free of charge reception of the volatile medium radio are related to the lack of a search and memory function as we know it from the seemingly endless resources of the Internet.

For these two reasons our aim was to develop the concept of an entirely speech-based user interface for a digital radio in combination with the possibility to specifically search for stored audio and data content in a DAB receiver [13]. The structure of the entire system is shown in Figure 4.

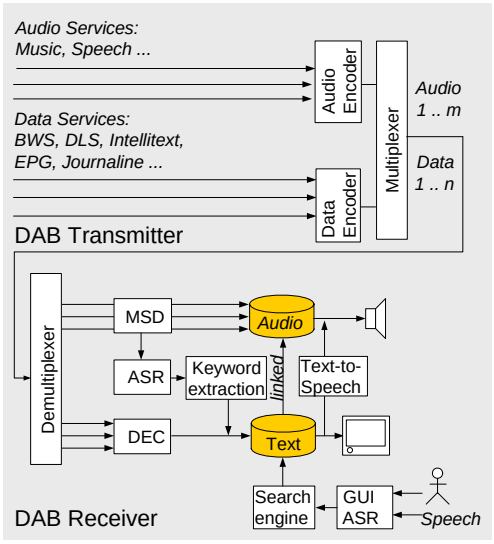


Figure 4: Overview of the system (DEC: Decoder)

The system utilizes a multichannel receiver with the possibility of simultaneously monitoring a variety of information sources with the purpose to generate spoken replies to verbal user requests. Furthermore, the system embraces an audio repository storing speech-based content elements to diminish the volatile property of broadcast content and to enable a memory function.

Broadcast websites may contain multifaceted news, press reviews etc. Because a lot of information is transmitted simultaneously as text messages in a DAB receiver environment, it is obvious to apply text-to-speech (TTS) and automatic speech recognition solutions (ASR) for a communication by speech assistance, because displays are often not appropriate.

The main result is a holistic approach and a operating system to store speech-based audio content and – for the first time – the entire range of functionalities contained in DAB services. All these information units are combined with the capability to search for specific content on the base of an efficient music-speech discriminator and a speech retrieval system for spoken content as well. The extension of a Digital Radio with the possibility of speech-based interaction in combination with multichannel monitoring, music-to-speech discrimination (MSD) and a memory function significantly adds value to a regular radio by promoting the evolution towards an embedded device providing the following functionalities:

- interactive search for content from audio and data information sources,
- speech-based output of content,
- completely controllable by spoken commands,
- basic personification and personalization.

The current limitations of the introduced system have to be handled by more efficient speech recogniser, sophisticated semantic retrieval algorithms, and a higher degree of parallel processing. The stability of voice services is to improve. The results for verbalizing data services such as general and traffic news, weather reports, press reviews are quite reasonable and hopeful. A speech-based data base for mobile devices is possible but not yet reasonable in every aspect.

PODCASTING CONTENT VIA BROADCASTING

Podcasting is relative a new example of the large number of possible use cases of transportation technologies beyond the Internet: traditional linear broadcasting, time shifted delivery, content on demand, and various cellular links such as point-to-point resp. point-to-multipoint. Due to the availability of push and pull technology on one device and the possibility of shifted media consumption user habits changed remarkable.

The emerging trend of podcasting has shown the request for highly personalized and on-demand media on PCs and mobile media players. Podcasting augments the importance of niche entertainment as well thematic special content with a strong and unique style. According to this, podcasting is well-suited for content that is offered on a regular basis. An alternative solution for time shifted media consumption are additional devices: personal or digital video recorders (PVR, DVR) on the base of EPG.

Our approach develops a technology how the podcasting concept can be expanded for non-web-based applications making them available to broadcast media with the tendency to generalizing the approach [14]. The two main objectives are: At first general methods of linking and distributing podcast content in broadcast and cellular systems are discussed. Secondly, the embedding of podcasting in broadcast systems is demonstrated in order to increase the comfort of media consumption, to lower the costs of networking, and to avoid load peaks while delivering podcast content on the Internet.

They describe fundamental characteristics of the subsequently by MOT transferred podcast files, see Figure 5. The costs of the XML description is significant compared with simple ID3 tags. However, the schemes are machine-readable without difficulty, expandable, and possess a fine-grained hierarchical description. The prototype software shows, that integration of podcast content into digital broadcast environments such as DVB or DAB/DMB is possible on the base of available standards and techniques.

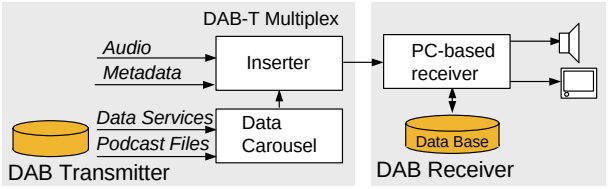


Figure 5: DAB podcasting setup

The integration of podcast content into broadcast and cellular systems is very promising, because the metadata and media content is already produced and available. With a minimum amount of editorial work a broadcaster can enrich linear TV and radio content with on-demand media and adapt to changing consumer habits. Podcasts are also appropriate for using collaborative filtering methods to find unknown but interesting and well-rated content in an ad-hoc environment as well. It can be promising to apply methods and tools of ubiquitous computing, computer supported cooperative work and other branches to improve the social character of podcasting in public places supported by broadcast and cellular systems.

INTERMEDIATE SUMMARY

The prototypes were implemented on the basis of a DAB receiver (DR Box 1, Terratec) connected via USB with a standard laptop configuration (Core2Duo; 1.8 GHz; 4GB DDR3-RAM; 500 GB HDD). The System uses Java JDK 6/MySQL 5.1 and is operating portable or mobile. No major obstacles exist to apply other communication channels such as satellite and HD Radios™ or Digital Radio Mondiale.

The Digital Radio was extended with new capabilities:

- An individual recommendation system on the basis of implicit preference definition without any additional efforts by the user,
- The user is able to personalize the selection of contents,
- Interactive search for content from audio and data information sources,
- Speech-based output of multifaceted content,
- Conversion of highly accepted internet search functions into the broadcast environment,
- Voice control of radio functionalities,
- The integration of podcast content into digital broadcast environments will provide new use habits of access with more freedom and lower costs.

The enhancements of a digital audio receiver significantly adds value by promoting the evolution towards an embedded device providing innovative functionalities. No major obstacles exist to extend the principles also on HD Radio™, internet services, and podcasts etc. Hence, the development of radio usage from passive listening towards an interactive and individual dialog is strongly supported and the improved functionalities render the radio to be an appropriate device to satisfy much more multifarious necessities for information than before. As a result users are capable of selecting desired audio contents more systematically, with higher concentration and with higher density of information from prospective, current and past programs.

At the end, the cost-benefit-ratio of the new functionalities is frankly to discuss after an detailed evaluation. Concerning metadata, generally spoken, there is too little support from broadcasters to enable qualified applications. Furthermore, there are several requests for the near future, among others:

- Broadcasters should send reliable and proper meta data, and EPG as well,
- DAB must becoming a reality in mobile phones,
- Receivers should be equipped with color graphic displays.

At the present time, a speech-based data base for mobile devices is possible but makes not good economic sense in every aspect.

DEMAND FOR NEW INTERFACE SOLUTIONS

The demand for enhanced, improved, and innovative interface solutions is the result of the above-mentioned and other new application properties of audio content managers such as:

- A growing multitude of available information channels by using multi-standard receivers, web access via WLAN, podcast files etc.,
- Multifunction devices with embedded concepts of hybridization such as cell phones, car entertainment devices including navigation, comfort control etc.,
- A large stock of stored audible content and increasing integration of media players, confusing data bases and navigation problems,
- Integration of new operation modes such as time shift, conditional access, tagging etc.,
- More visual indication such as text, imagery, slide shows, traffic maps etc.,
- Multimodal interfaces including speech-based interfaces and applications etc.,
- Problems of handover and service following between different platforms, in the future tag and store information for purchase/commercial use etc.

Currently, there exists only little research which broadens the diversity of interface solutions for the digital radio. Marks has seen early many new opportunities of DAB receivers and the need to rethink the requirements of them. The HuMIDAB project would research and evaluate an »easy-to-use« receiver with many enhanced features keeping the simplicity of the simple audio world [15]. DAB radios should be characterized by abstraction from technical details and service access should be content based, so that users can »forget« the technical delivery mechanism. However, the functionalities at that time were limited: no metadata, no stored audio files, no speech-based interfaces etc. One decade later there are new applications, opportunities and challenges.

Up to now, the radio was an easy medium: switch-on, choose a station and listen. This simplicity should not be sacrificed to annoying input procedures. The number of interaction dialogs must be adapted well considered. A strict balance between disturbing the user and a pleasant personalization of the system must be found. Another challenge is the adaptation to portable devices. Therefore the design of appropriate interfaces and principles of user interaction is required.

Freeman et al. studied the specific questions of usability of digital radio for blind people [16]. Consumer digital radio equipment is able to provide listeners with a range of additional features and functions over analog radio, including an increased choice of content through more stations, and the possibility of pausing live programs as well as recording and playing back digital radio broadcasts. This research report shows that equipment

design can be improved considerably, and that some significant changes are relatively easy to implement for the simple receivers.

Mason et al. show that there are advantages in using the kinds of multisensory signal processing graphical means to assist in navigation [17]. The application »Music Marker« is useful to navigate in audio material. They think, that further research into synaesthetic techniques offers an exciting approach to the problem of data analysis for radio as well [18].

We think, that after the liberation of the user from temporal and spatial constraints, the requirements for better emotional service and immediate wish fulfillments are growing massively. With the increasing amount of available features and functions it is necessary to improve the interface design towards elements of empathy.

Gerhäuser et al. presented in an advanced study constraints and first ideas in an introductory paper based on models and approaches of affective computing, of mood and emotion theory, and especially of sensor technology [19]. The authors pose the important question: which automatic solutions of content choice will be useful and accepted by users.

The development of new interfaces can use experiences from different research approaches such as affective computing, psychology, music information retrieval, new interfaces for musical expression etc. Hereinafter we present some solutions of modified interface designs.

EXAMPLES OF DIGITAL RADIO INTERFACES

Currently, most of the digital radios have only a tiny alphanumeric display with two lines. For the future full-color touch screens are announced [20]. For a *recommender of an adaptive radio* each program is shown as a table entry with title, start time and description on a colour screen, see Figure 6.

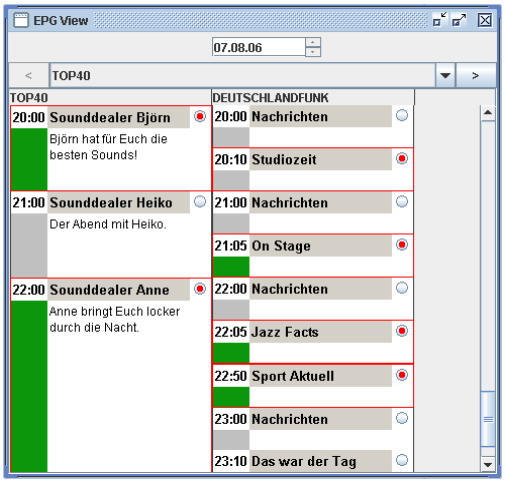


Figure 6: View of EPG (2006) [21]

It can be flagged for recording by using the radio button top right. The dark green bar at the bottom left indicates a recommended event which is automatically set for recording if the user specified it. The marked radio button indicates a program which is flagged for recording.

Figure 7 shows a graphical display with a combination of a *radio schedule (EPG) and buttons of a media player*. The entries can be marked for recording and in other menu the representation of program associated data resp. images is shown.

Figure 7: Prototype of a GUI for Digital Radio (2006)

The above-discussed *speech-based radio* is equipped with a multimodal interface. It enables the user to interact in two ways, via a speech-based user interface or a graphical user interface. It is important to note that both interfaces could be utilized for either case. They offer much more flexibility to the user in terms of navigation and information access, content can be presented with the visual and the audible interfaces concurrently. The user is able to specify a query by voice or over via an interface which is similar to a web based query field of a browser. Subsequently the system parses resp. interprets the input of the user and searches for corresponding data in the database. The results are listed into the GUI as shown in Figure 8 and the user is able to select a content element and to listen to the associated audio file.

Figure 8: GUI and results for a query in the speech repository (2008) [13]

Although our prototype utilizes underlying textual representation and employs text-based information retrieval techniques, this mechanism is hidden to a great extent from the user, only snippets are displayed. The results could be presented either as spoken response utilising text-to-speech technologies.

Furthermore, the development of a speech-based user interface enables users to operate the functional scope of a digital radio solely by vocal commands. Most importantly, this development was focused on a dialog system that conforms to the concepts of human-centered dialogues in an user-oriented manner, see Figure 8. In this way a sophisticated radio may offer with modest ambition similar favorable characteristics referred to multimodal content like internet services do for text.

For podcasting applications a new problem arises: There is to design and implement a suitable user interface for activating the stored podcasts because most of the receivers are not equipped with large display and the familiar mouse/pointer/icon paradigm. The user interface of the prototypical software is a first draft and offers a lot of room for improvements regarding design and user interaction, see Figure9.

Figure 9: GUI of Podcast Player with remote control (2008) [14]

For regular use there is the need for a subscription and on-demand media management that can be integrated with other features of modern digital broadcast receivers like personal video recording, web TV, and online radio streams as well. The Podcast Player displays the title and description text of the latest episode on the news feed below the logo and title of the podcast itself. In this example the radio archive of the current TV show is provided to the user. Again the colored function keys are offering further options with partially implemented features.

Sonification is the use of non-speech audio to deliver information or data. It forms an interesting alternative to visualization techniques in cases of miniaturized devices, in situations that require a constant awareness (traffic) or for blind or visually impaired people.

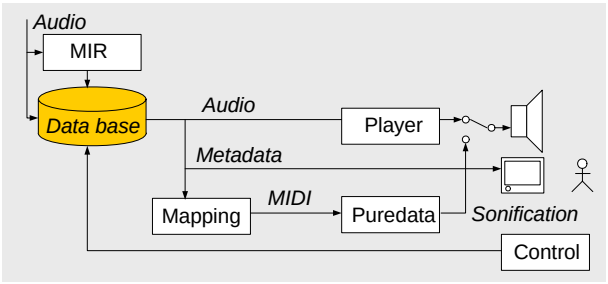


Figure 10: Sonification of radio content (2009)

Our approach uses a data base with audio recordings and metadata. These metadata are the result of several music information retrieval (MIR) processes describing genre, mood, tempo and other characteristics of the huge amount of data gained from radio or other sources. Those metadata are mapped to get attributes. Those data are the input for the graphical programming language Pure Data. As a result there are audible information as an orientation aid. By this means a navigation through data collections will be possible by synthetic sounds, see Figure 10.

CONCLUSIONS AND OUTLOOK

The combination of the far above-named elements and functionalities represents a fundamental modernization of conventional usage patterns with radio devices. Hence, the development of radio usage from passive listening towards an interactive and individual dialog is strongly supported and the improved functionalities render the radio to be an appropriate device to satisfy much more multifarious necessities for information than before. As a result users are capable of selecting desired audio contents more systematically, with higher concentration and with higher density of information from future, current, and even past programs. These presented functionalities and listener focused benefits were perceived very positively by test users and became generally accepted under the condition that the usage of the radio would be a fairly simple task. Radio should not lose its role in this magic audio world, at where you can have your own privacy, at where you can listen with simple devices to useful and entertaining information everywhere. However, one should always bear in mind that the value added messages or images should always be supplementary to the content and the audio effect of a radio program [22].

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REFERENCES

[1] Howard, Q.: One Digital Radio across Europe. EBU Technical Review. 2009-Q1. http://www.ebu.ch/en/technical/trev/trev_2009-Q1_DAB-Rx.pdf [acc. 5.8.09]

[2] Lee, G.; Yang, K.; Kwang, K.; Hahm, Y.; Ahn, C.; Lee, S.: Design of Middleware for Interactive Data Services in the Terrestrial DMB. ETRI Journal 28 (2006) No. 5, October, pp. 652-655.

[3] Internet Media Device Alliance. http://www.imdalliance.org/ [acc. 5.8.09]

[4] RadioDNS. http://radiodns.org/ [acc. 5.8.09]

[5] Kozamernik, F.: DAB – from Digital Radio towards Mobile Multimedia. EBU Technical Review January 2004.

[6] Schatter, G.; Rotzoll, C.: Subscription of Digital Broadcast Content Utilizing Syndication Feeds Mechanism. IEEE Transactions on Consumer Electronics. 54 (2008) No. 4, November, pp. 2015-2022.

[7] Nathan, D.; Sputh, B.; Faust, O.; Chua Beng Koon: Design and features of an intelligent PC-based DAB receiver. IEEE Transactions on Consumer Electronics 48 (2002) no. 2, May, pp. 322 – 328.

[8] Schatter, G.; Zeller, B.: Personalisation and Cross-Linkage of the Digital Radio DAB on the Basis of TV-Anytime, MPEG-7, EPG, and Dynamic Label. 8. Workshop Digitaler Rundfunk. Fraunhofer IDMT, TU Ilmenau, 13.-14. September 2007.

[9] ETSI TS 102 980 V1.1.1 (2008-09). Digital Audio Broadcasting (DAB); Dynamic Label Plus (DL Plus); Application specification

[10] Pizzi, S.: IBOC: The Next Copyright Battlefield. Radio World 02.01.2006. http://www.nab.radioworld.com/article/4030 [acc. 5.8.09]

[11] Schatter, G.; Bräutigam, C.; Neumann, M.: Personal Digital Audio Recording via DAB. Enhanced Radio as Interface. 7th Workshop Digital Broadcasting. Fraunhofer IIS Erlangen/Germany, September 14-15, 2006, pp. 146-153.

[12] Twietmeyer, H.: Mailbox-Radio. In: Jahresbericht Institut für Rundfunktechnik München, 2008. pp. 20-21. (in German). http://www.irt.de/fileadmin/media/downloads/publikationen/Jahresbericht_2008.pdf [acc. 5.8.09]

[13] Schatter, G.; Zeller, B.; Eiselt, A.s: Navigating Spoken Broadcast Content of a Digital Radio DAB by Music-Speech Discrimination and Information Retrieval. 9th Workshop Digital Broadcasting. Fraunhofer IIS Erlangen, September 18-19, 2008. pp. 159-167.

[14] Rotzoll, C.; Schatter, G.: Towards an Unified Approach of Podcast Distribution via Broadcast and Cellular Systems. 9th Workshop Digital Broadcasting. Fraunhofer IIS Erlangen, September 18-19, 2008. pp. 147-153.

[15] Marks, B.: HuMIDAB: A user interface for digital broadcasting. EBU Technical Review Winter 1998.

[16] Freeman, J.; Lessiter, J.; Ferrari, E.: Are you really listening? The equipment needs of blind and partially sighted consumers for accessible and usable digital radio. Research report i2 media research Goldsmiths University of London, 2009.

[17] Mason, A.; Evans, M.; Sheikh, A.: Music Information Retrieval in Broadcasting: Some Visual Applications. BBC Research White Paper WHP 166. BBC London, 2008.

[18] Schatter, G.; Züger, E.; Nitschke, C.: A Synaesthetic Approach for a Synthesizer Interface Based on Genetic Algorithms and Fuzzy Sets. International Computer Music Conference ICMC05. Barcelona, September 2005. pp. 664-667.

[19] Gerhäuser, H.; Dudek, L.; Kirsch, K.: Die "einfühlsame" Benutzerschnittstelle - Visionen einer zukünftigen Radionutzung (in German). 8. Workshop Digitaler Rundfunk. Ilmenau, 13.-14.09.2007.

[20] Frontier Silicon: Technology pioneer applies multimedia functions to DAB systems. Press release Frontier Silicon. London, 26 January 2009. http://www.frontier-silicon.com/media/releases/09/0126_touchscreen.htm [acc. 11.08.2009]

[21] Schatter, G.; Bräutigam, C.; Neumann, M.: Personal Digital Audio Recording via DAB. Enhanced Radio as Interface. 7th Workshop Digital Broadcasting. Fraunhofer IIS Erlangen, September 14-15, 2006. pp. 146-153.

[22] Han, Y: Possibilities of Value-added Digital Radio Broadcasting. Asia Pacific Broadcasting Union Conferences 2007.