7. A. Lugmayr, T. Saarinen, and J. P. Tournut, "The Digital Aura: Ambient Mobile Computer Systems," in 14th Euromicro International Conference on Parallel, Distributed, and Network-Based Processing (PDP 2006), 2006, p. 348

The Digital Aura - Ambient Mobile Computer Systems

Artur Lugmayr, Teemu Saarinen, and Jean-Philippe Tournut
Tampere University of Technology, Institute for Signal Processing,
New AMbient MUltimedia (NAMU) Research Group
lartur@acm.org, teemu.saarinen@tut.fi, and jp_tournut@hotmail.com

Abstract

Media evolved from media that can be described as integrated presentation in one form (multimedia), towards embedding the consumer into a computer graphic generated synthetic world (virtual reality), to the consumers' directly exposed to the media in their natural environment, rather than to computer interfaces (ambient intelligence), and will be evolving towards a fully real/synthetic world undistinguishable pure media (biomedia or bio-multimedia). This paper presents a solution for merging ambient intelligence with a mobile environment. Only a distributed intelligent network of interconnected mobile devices and sensor networks can enable the data acquisition, processing, and communication of information essential to perform the highly demanding tasks of an ambient system. This paper introduces the work of the newly established "New Ambient MUltimedia (NAMU)" research group. The key-idea is the development of the "Digital Aura", a consumer surrounding intelligent digital environment of ubiquitous and pervasive mobile facilities.

1. Introduction

The New AMbient MUltimedia (NAMU) research group at the Tampere University of Technology / Institute of Signal Processing conducts research on the converging home and mobile platform for home entertainment as well as the nomadic consumer. The team originally focused on digital television (see [1]), from where the research group evolved towards the research of more high-level solutions for smart distributed entertainment environments (see [2]). This publication shall introduce the vision of the research group to develop the 'Digital Aura', which is a mobile ambient system that has as underlying research question "what can be done with signalling information obtained from sensor networks around the mobile user in his natural environment to his benefit?".

On general level, the vision of the first author for the future of media systems is:

Media evolved from media that can be described as integrated presentation in one form (MULTIMEDIA),

towards embedding the consumer into a synthetic computer graphics world (VIRTUAL REALITY),

to the consumers' directly exposed to the media in their natural environment, rather than to computer interfaces (AMBIENT INTELLIGENCE),

and will be evolving towards a fully real/synthetic world undistinguishable pure media (BIOMEDIA).

The EC Information Society Technologies Advisory Group [3] defined the vision of ambient intelligence as goal for scientific work until the year 2010 for project initiatives in their final report "ISTAG Scenarios for Ambient Intelligence" in 2001 [4]. The key-idea of ambient intelligence is to surround users with smart and natural interaction interfaces (e.g. voice and gesture based input methods) and intelligent hardware (e.g. smart mobile phones) embedded in the natural environment of the user. To develop ambient systems, methods for ubiquitous computation, ubiquitous communication and intelligent user interfaces have to be explored and developed.

Ambient multimedia unifies methods and algorithms for three computational paradigms: *ubiquitous computation, ubiquitous communication* and *pervasive networking*.

Def. 1: *ubiquitous computation* seeks to "enhance computer use by making many computers available throughout the physical environment, but making them effectively invisible to the user [and impacts signal processing methods and algorithms networks in computational paradigms]" [5].

Def. 2: *ubiquitous communication* deals with the interconnection and communication between objects

embedded into the user surrounding environment for ex-changing data [6].

Def. 3: *pervasive networking* adds "computers and sensors 'everywhere' in [the user's environment and daily objects and enables] a "high degree of communication among devices and sensors through a ubiquitous and secure network infrastructure with a wired core and wireless adjuncts that communicate with the core..." [6].

However, scientific research on ambient intelligence or ambient multimedia is very fragmented and poorly integrated, due to the early development stage of this research field.

2. Analysis of existing projects

One of the key-projects while discussing ambient multimedia is MIT's *Oxygen* project [7]. However, the Oxygen project can be only seen as reference project and lacks on a top-level-vision as ISTAG's AmI vision does. The IST project *Amigo* [8] aiming at interoperability within the multimedia home. The IST project *AceMedia* focuses on the integration of knowledge, semantics, and content for human centered intelligent media. Systems shall be self-organizing, self-annotating, self-associating, and self-reformatting [9]. Of interest is the three mechanism of Autonomous Content Entities (ACE), consisting of a content layer, metadata layer, and intelligence layer enabling self-instantiation and distribution. More related scenarios and projects can be found in 'Ambient Intelligence to Go' [10], S. Holmlid and A. Bjorklind, where many projects have been collected. A compilation of the scenarios Holmlid and Bjorklind collected can be found in Table 1.

Table 1. Example projects (compiled in [10], where also Ref. to projects can be also found).

Project	Key-features
Home care	Smart monitoring of body parameters and interaction with health care personnel
Wall-screen display	Interaction between humans via wall-screen displays over wireless channels
Virtual museum guide	Location based intelligent museum guide leading the consumer through a museum
The Rover	Digital assistant keeping track of the visit of a tourist in another place by creating a digital visit album
Maria Road Warrior	Personalized communication device acting as substitute for PC, laptop, PDA and other electronic devices during travels as well as environment personalization and identifier device
Dimitrios and the digital me	Digital-Me as device performing communication between the consumer and other consumers via a virtual avatar
Carmen	Automatic Debiting System (ADS)
Smart space	Triggered emergency messages by a emergency management agency
Selective availability	Freedom for being unavailable for some sort of communication
Oxygen	Pervasive, embedded, nomadic, adaptable, efficient, intentional, and eternal human-centered computer system
AceMedia	Integration of knowledge, semantics and content for human centered media by a three layered approach (content, metadata, and intelligence)
Amigo	Device interoperability in a home-entertainment centre

3. Components of AmI for the digital aura

ISTAG's vision of AmI addresses various components. Within this section the most relevant components for the development of the *Digital Aura* are presented. Fig. 1 gives an overview of the overall ISTAG foreseen components of AmI.

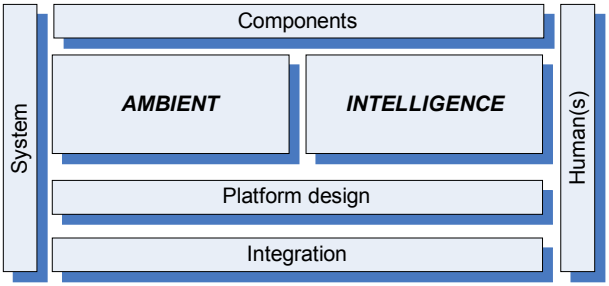

Figure 1. Components of Ambient Intelligence (AmI)

The components of ambient multimedia relevant for the development of the *Digital Aura* are (citied from [3]):

- **ambience:** "a system/environment/background view", including sensor technology obtaining data about the physical world, real-time embedded systems, ubiquitous communication ranging from pico-networks to mobile broadband access, I/O devices supporting touch-less control, and adaptive software;
- **intelligence:** "user/person/foreground view", that is including media management and handling, natural interaction, computational intelligence, contextual awareness, and emotional computation;

Leaving sociological aspects aside, a good qualitative measurement of mobile ambient systems can be the '*time-span till first contact with a human to successfully perform the human desired service*'. This time-span measures the time needed until a human comes the first time in contact with an actual human which is needed for fulfilling the human desired service. A consumer could enter a restaurant and order food at a table via a digital menu. The digital menu transmits wirelessly the data to the kitchen. The consumer would come first time in contact with a human when the waiter comes and brings his ordered food.

3.1. Ambience

The ambience is the natural environment of the consumer including several technical facilities such as devices, sensors, and I/O technology. Sensor networks are relevant to obtain any measurable actual world data. Creative application designer can build their services on top of this sensor data as e.g. GPS data for location based services or RFID tags for exchanging data.

The main component for the ambience of a mobile system is ubiquitous communication as well as ubiquitous computation. Both provide user-hidden and smart computer systems available anywhere and implicate intelligent (mostly) wireless narrowband (e.g. Bluetooth) or even broadband communication (e.g. UMTS) between them. We can speak of *ambient nodes*, being ubiquitous and pervasive those are interconnected via ubiquitous communication systems. The communication characteristics of ambient nodes are more of peer-to-peer and ad-hoc characteristics. This implies service layer protocols for negotiating services, identifying devices and users, and automated information exchange.

Each of these nodes can be classified according the *degree-of-sharing* and *computational visibility* as defined for appliance computing in [11]. The degree-of-sharing describes how 'private' a device is to the user (mobile, environmental, and community) with an increasing degree of sharing. Computational visibility defines the degree of ubiquitousness of a system (general purpose, special purpose, and embedded system) with decreasing degree of visibility [11].

I/O devices shall support the consumer in a minimal degree of essential visibility needed to perform the goals of the provided service (e.g. speech input or touch-less input).

Of importance are adaptable services to maintenance ambient nodes with minimal consumer interaction and automated system configuration. Automated adaptation of available capabilities to available resources as standardized within MPEG-21 is one example [12].

3.2. Intelligence

Where the ambience component of AmI describes more the consumer surrounding facilities, *intelligence* defines the methods, soft-components and functionality applied on top of the ambience component. A human foreground view is essential.

In the *Digital Aura* smart media are the entity exchanged between ambient nodes. Smart media require data-structures for representation, presentation, and semantics. Currently MPEG-21's *Digital Item (DI)* seems to be most suitable, as it allows the binding of resource (the media) to its descriptors (metadata) [13]. Metadata description can be arbitrary ranging from information about content, adaptation possibilities, among others. However, the DI structure is already standardized and an extension might be required to adopt it to an *Ambient Digital Item*.

DIs or ambient digital items require media management. There are many possibilities available as well as researched. A special focus has to be given on semantic annotation and media databases with content and metadata management capabilities (e.g. [14, 15]).

Natural interaction models emphasizing multimodal 'interaction with content' are part of intelligent computational models for the consumer to access ambience worlds. Technology performing natural interaction shall rely on speech, voice, gestures or human expressions and interfaces shall be transparent and invisible to extend of necessity.

Technology needs to adapt to humans – their behavior, interaction capabilities and way of thinking. Intuitive usage of technology shall be predominant. Not essentially only adaptation to humans is required. Also of importance is guaranteeing a certain degree of context awareness, addressing systems that are aware of the environment they are used. Especially mobile ambient systems require continuous context awareness, depended where the consumer is currently situated (e.g. shopping).

One very old research field is how computer system can express emotions and become more personal. Home robots are one example. Technology becomes more to an integrated system that recognizes human emotions and replies within suitable emotional context.

To enable several components mentioned above, a certain kind of computational intelligence – thus a set of algorithms and methods for mobile ambient systems – needs to be developed. These methods and algorithms shall adapt to humans, their behavior, preferences, emotions, and other necessities. These

other necessities relate more to technological factors such as media management or context awareness. One simple example are personalization tasks, where via a mobile phone personal profiles are exchanged with a mobile service provider (e.g. user identification).

3.3. Key-Technologies for the Digital Aura

A few of the expected key-technologies for the digital aura are enlisted here:

- peer-to-peer computation
- metadata
- agent technology
- service layer network protocols
- sensors between physical/cyber-world
- embedded system software
- tiny operating systems
- mobile technology
- RFID tagging
- …

There are many more key-technologies that will be enabling the *Digital Aura*. At this stage the previous ones shall be sufficient. The following sensor data shall be available for the *Digital Aura:*

- *location sensing data*: geographical (e.g. GPS), local (e.g. RFID), semantic location data (e.g. room), geometric location,…
- *context awareness data*: service data, …
- *consumer data*: behavior data (e.g. use-preferences), physiological data (e.g. heart rate), identification data (e.g. ID number), …
- *service space data*: available services, service space, digital communities, …
- *digital service provision data:* networking parameters, device capabilities, …

4. The Digital Aura

4.1.Objectives of the "Digital Aura"

The goal is to elaborate on the question, "what can be done with signalling information obtained from sensor networks around the mobile user in his natural environment to his benefit?" The overall objective of the research is the creation of a set of methods, algorithms and the technology for the design of an ambient system platform, Figure 2.

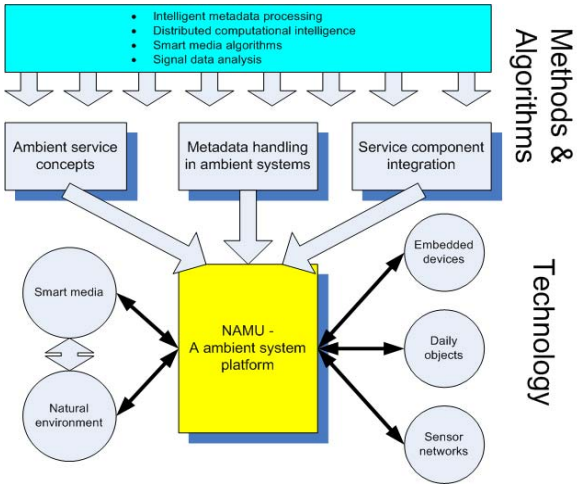

Figure 2. Digital Aura, the ambient system platform

Since such work is rather scarce in the literature, this research aims to develop a novel ambient system platform with related methods and algorithms to the scientific society. Multimedia is much more than compressed video, picture quality or human-computer user interface design. One potential future pathway of multimedia is to support users in their natural environment rather than teaching the user how to adapt to computer systems. Smart wireless devices knowing the situation the user is in, as well as intelligent media embed the user into services. The surrounding environment and distributed tiny computer systems shall enable natural and 'normal' interaction. The technological 'glue' for designing such ambient smart environments is middleware technology, metadata and adaptive software/services.

4.2. Basic Requirements of the "Digital Aura"

R1. *non-intrusive body parameter monitoring* - the *Digital Aura* shall include a monitoring of human behavior and service relevant body parameters;

R2. *natural interaction models* - interaction between humans, between devices, and between device and human shall be intelligent & ubiquitous and also support communities interacting via common displays;

R3. *mobile technology* - mobile phone technology as well as smart intelligent objects communicating over IP peer-to-peer act as target platform;

R4. *freedom of unavailability* - the freedom for being unavailable for some sort of communication except emergency communication shall guarantee privacy;

R5. *abstract reference* architecture - there is a need to develop an abstract reference architecture for ambient systems including intelligent middleware

technology, metadata, server architecture, and adaptive software/services;

R6. *metadata driven approach* - metadata shall act as catalyst for integration, adaptation, media management, media tagging,

R7. *ambient methods* - a set of methods and techniques needed to develop ambient system software are needed and shall cover algorithms, distributed intelligence, context awareness, location awareness, and analysis methods;

R8. *smart media* - new media types suitable for deployment on ambient systems need to be developed with a four layered approach: networking, content, metadata, semantics,

R9. *smart signal analysis* - smart signal data analysis and the development of methods suitable to build services on top are needed to get meaning into extracted sensor data;

R10. *distribution of ambient nodes* - computational demanding tasks shall be divided on the available resources also as they have to be divided between computational capabilities;

R11. *service development* – a set of services and service scenarios with the characteristics of ubiquitousness, pervasiveness, nomadic, adaptable, and consumer centered need to be developed.

4.3. Approach

The scientific aim is the development of a set of methods and techniques for the development of an ambient system. The key-problems tackled are:

- intelligent middleware and metadata processing (in specific MPEG-21 related technology);
- development of methods and techniques for the design of an ambient system platform;
- creation of new media types suitable for deployment on ambient systems;
- development of algorithms for distributed intelligent systems increasing context awareness;
- signal data analysis and development of methods what can be done based on extracted sensor data.

4.4. Research Steps

The scientific work will be performed in the following five steps:

1. definition of an abstract system reference architecture for ambient systems including hardware, software and network aspects;
2. implementation of an ambient system reference architecture for extracting signalling information from the natural environment and media;
3. specification of smart media and their representation and presentation as well as metadata structures suitable for ambient systems;
4. development and research of service concepts and related methods for service deployment on the ambient system reference architecture.

5. Development of the Digital Aura

Ambient systems are currently under very basic development and still require a more generalized methodology to integrate systems and its components. An integrated system shall provide a common infrastructure for easy ambient service deployment. These components include hardware platforms (e.g. embedded systems), sensor networks (e.g. obeying sensor data), ubiquitous-wireless networks (e.g. 3rd generation wireless networks), adaptive software (e.g. MPEG-21 adaptation mechanisms) and distributed intelligent processing of sensor data (e.g. agent based algorithms). The research plan for the first three years includes four components: (1) methods and algorithms for ambient-wireless multimedia system design; (2) methods and algorithms for metadata handling in ambient systems; and (3) methods for the development of the "*Digital Aura*" as one ambient service.

5.1. Methods and algorithms for new ambient-wireless multimedia system design.

A more system-analytic approach is required to design ambient-wireless multimedia platforms to integrate hardware, software, media and networks. Hardware components are highly distributed embedded devices empowered by smart system software. A high degree of distribution requires interoperability and an intelligent network protocol model to allow optimized communication under a certain *Quality of Services (QoS)*. Research focuses on smart embedded systems (e.g. based on Java platforms, see for instance Mobile MUVIS), ubiquitous communication, sensor based I/O device technology and adaptive software components are major part of the research. Under investigation are:

- development of an abstract system reference architecture including a set of methods, algorithms and functionality acting as reference platform for the scientific exploration of ambient systems;
- set of methods and algorithms for distributed computational intelligence (e.g. client-server architectures or grid computation);
- development of smart media concepts new ambient media content formats towards a personalized and more narrative user friendly form;

- methods for intelligent signal data analysis based on distributed sensor networks (e.g. for personalization and the creation of intelligent digital environments);

5.2. Methods and algorithms for metadata handling in ambient systems.

Metadata, commonly referred to as 'data about data' is one current method to deal with the integration of smart media systems. Existing appliances of metadata are MPEG-7 and MPEG-21. MPEG-7 is dealing with the extraction of metadata for database and retrieval purposes. MPEG-21 as metadata standard focuses on the delivery of media across heterogeneous networks and terminals [1, 2]. There is still a huge development needed to apply metadata in the context of ambient smart media in terms of: algorithms for metadata handling; media adaptation to context, semantic and perceptive user preferences, thin-light-weight metadata for embedded devices (e.g. smart phones or wrist watches); collection of data obtained by sensor networks into metadata structures; or processing of metadata for indexing, browsing and retrieval. Within the scope of this proposal fields of investigation are:

- development of a new ambient metadata structures suitable for ubiquitous exchange between embedded devices in ambient environments as e.g. based on the MPEG-12 or MPEG-7;
- algorithms for processing, managing, distributing and storing metadata in ambient systems including the development of an MPEG-21 based ambient "digital item";
- provision of a set of algorithms and methods for metadata processing based on sensor data retrieved about the natural environment and the user.

5.3. Methods for the development of the "DIGITAL AURA" as one ambient service

Where the above two topics focus especially on laying the foundations and theories to build ambient systems, this part of the research attempts to build methods and algorithms to create specific services for ambient systems. *Digital Aura* is the metaphor for a service concept contributing to ambient multimedia where data about the environment and the user is exchanged ubiquitously in specific service contexts. Each user has a "digital aura" on his mobile device containing his preferences and usage history. This information is exchanged automatically with other users and their natural environment to provide a sensible media experience in specific service contexts. The development of a set of methods and techniques for ambient system is not sufficient to benefit the user. The problem to be solved is which methods and algorithms based on signalling information from sensor networks are needed to build smart service contexts for the user (e.g. for travelling, dating, ambient societies, event management, shopping). The focus is on what is done with data obtained about user emotions, his natural environment, personalization information, etc. rather than obtaining and extracting the actual data. The goal of this part of the research work is:

- development of signal processing methods for digital aura related services (e.g. travelling, dating, ambient societies, event management, shopping);
- creation of sensible media, where media shall be sensed by humans rather than only perceived audio-visually as in existing multimedia systems;
- contribution to the scientific society with a world-wide first reference book dealing with the methods and algorithms for ambient media in specific service contexts.

6. Example Services and Applications

6.1. Location Depended Visitor Guide

Within the research group currently a location dependent visitor guide has been developed. The guide based on PDA and GPS technology leads visitors to our institution (see Fig. 3).

6.2. Mobile Digital Rights Management (DRM) System

The DRM system is designed to create means for normal people to act as private content providers. It is designed to comply the needs of MPEG-21 standards. For normal users it is secure to distribute their multimedia content, e.g. audio, video, pictures, etc. to desired groups of users or a single user.

The system is being developed with Java programming language and all the necessary license files are created by using the MPEG-21 standardized *Rights Expression Language (XrML)*.

First some multimedia content is uploaded to the server by the content provider. After this the content provider creates a license file in which all the necessary rights are granted for those persons to whom the content is targeted. In this case the content provider can also be a private person. The next step is that all the persons who try to download the content are authenticated and those persons to whom the required rights have been granted, may access the content. This DRM system is targeted for mobile platforms, which means that the user who is accessing the content will be using i.e. mobile phone (see Fig. 4).

6.3. Personalized Services

Many emphasize has been focusing on personalization for digital television (see [1, 16]) in previous years.

6.4. Future Applications

Our future scenarios shall be focusing on RFID tagging and potential services.

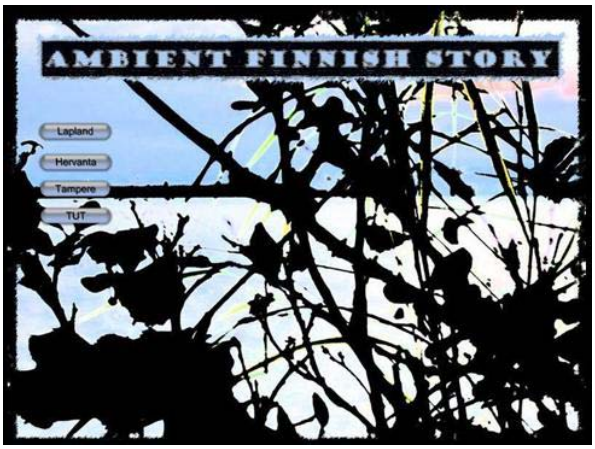

Figure 3: Mobile ambient system to guide visitors to our research institute (developed by Jean-Philipe Tournut)

Figure 4: Teemu Saarinen's mobile digital rights management system to download licenses.

7. Acknowledgements

The authors would like to thank the fruitful environment at the *Digital Media Institute (DMI)* at the *Tampere University of Technology (TUT)*.

References

[1] A. Lugmayr, S. Niiranen, and S. Kalli, *Digital Interactive TV and Metadata - Future Broadcast Multimedia*: Springer New York, 2004, http://www.springeronline.com/sgw/cda/frontpage/0,10735,5-175-72-26593988-0,00.html.

[2] A. Lugmayr, "From Ambient Multimedia to Bio-Multimedia (BiMu)," presented at EUROPRIX SCHOLARS CONFERENCE, Tampere, Finland, 2003, http://www.acten.net/cgi-bin/WebGUI/www/index.pl/newsletter11?wid=509&func=viewSubmission&sid=792, www.lugy.org.

[3] ISTAG, "Ambient Intelligence: From Vision to Reality," European Union: IST Advisory Group, draft report 2003.

[4] ISTAG, "Scenarios for Ambient Intelligence in 2010 - Final Report (Feb. 2001)," 2001, http://www.cordis.lu/ist/istag.htm.

[5] M. Weiser, "Hot topics-ubiquitous computing," *Computer*, vol. 26, pp. 71-72, 1993.

[6] NIST, "Pervasive Computation, Definition," http://www.itl.nist.gov/pervasivecomputing.html, http://www.itl.nist.gov/pervasivecomputing.html.

[7] MIT, "Oxygen," http://oxygen.lcs.mit.edu/.

[8] Philips, "Amigo," http://www.hitech-projects.com/euprojects/amigo/.

[9] Motorola, "AceMedia," http://www.acemedia.org/aceMedia.

[10] S. Holmlid and A. Bjorklind, "Ambient Intelligence to Go - AmIGo White Paper on mobile intelligent ambience," Linkopings Universitet, Santa Anna IT Research Institute, Prevas AB, Technology Nexus AB, and Ericsson 2003, www.santaanna.se/projectbriefs/AmIGo_WhitePaper.pdf.

[11] A. C. Huang, B. C. Ling, and A. Fox, "What is Appliance Computing?" presented at Workshop on Application Models and Programming Tools for ubiquitous Computing (UbiTools'01), 2001.

[12] J. Bormans, J. Gelissen, and A. Perkis, "MPEG-21: The 21st century multimedia framework," *IEEE Signal Processing Magazine*, vol. 20, pp. 53-62, March 2003.

[13] I. I. 21000-2, "Information Technology-Multimedia Framework--part 2: Digital Item Declaration," 2003.

[14] T. Kleinberger, L. Schrepfer, A. Holzinger, and P. M\"uller, "A Multimedia Repository for Online Educational Content," in *World Conference on Educational Multimedia: Hypermedia and Telecommunications*, vol. 2001, 2001, pp. 975-980.

[15] A. Lugmayr, A. Mailaparampil, F. Tico, S. Kalli, and R. Creutzburg, "A Digital Broadcast Item (DBI) enabling metadata repository for digital interactive television (digiTV) feedback channel networks," in *SPIE-EI 2003*. Washington, USA, 2003.

[16] A. Lugmayr and X. Duanbo, "MPEG-21 for the exchange of personal profiles between embedded devices," ISO/IEC JTC1/SC29/WG11 M10564, 2004.