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Taxonomy of XML based metadata in a real-time digiTV deployment environment: Digital Broadcast Item Taxonomy

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ABSTRACT

XML based metadata schemes and Interactive Digital Television (digiTV) are two new paradigms in the world of multimedia. Both paradigms shall be converged and provide an integrated solution for several participants in a digital, interactive television broadcast. The local digiTV equipment and software requirements for a metadata based service provision move more to an integrated multimedia experience. To be able to present a heterogeneous solution to the participants, certain preliminary assignments and structures have to be introduced. One integral requirement is the conceptualization of a XML based real-time metadata architecture in the world of digiTV to be able to apply advanced interactive narrative patterns (e.g. parallel stories), content descriptions (based on MPEG-7), and the description of items that are exchanged between users and the broadcast- and interaction service provider (e.g. MPEG-21). Within the scope of this research work we focus on the appliance of basic metadata concepts, real-time constrains, description schemes design for interactive broadcasts, cover conceptual design issues, metadata life-cycle, and synchronization mechanisms. We consider Digital Video Broadcasts (DVB) compliant design as entire requirement and show how metadata can be useful applied in accordance with this standard.

Keywords: MPEG-7, MPEG-21, TV-Anytime, digital TV, interactive TV, MXF, AAF, GXF

1. INTRODUCTION

Europe's emerging *digital, interactive TV (digiTV)* standards are specified by the *Digital Video Broadcast (DVB)*[1] consortium, where the *Multimedia Home Platform (MHP)*[3] defines end-consumer device application programming interfaces. TV in general is a highly narrative environment, therefore requires adequate structures to create, distribute, and compile different multimedia assets to a unified entity presented to the audience. Multimedia assets refer to any type of multimedia content-, and metadata. Metadata commonly referred to as "data about data" is a new paradigm in the world of multimedia, and describes content and assists in the distribution of digiTV related materials. Converging paradigms, digiTV and metadata based services, requires the introduction of a structured solution for packaging digital television materials together. MPEG-21, as defined by the *Motion Experts Group (MPEG)* is a standard for packaging-, protecting-, and exchanging digital content assets throughout its live-cycle. Therefore the introduction of MPEG-21 into the world of broadcasting as harmonization standard for different metadata-, and digiTV content standards is obsolete. Currently the authors work on the development of an MPEG-21 based *Digital Broadcast Item Model (DBIM)*, acting as umbrella over different metadata standards, and relying on an MPEG-21 defined *Digital Item (DI)* as entity of exchange throughout the life-cycle of digiTV content. The approach is comparable with a simple web-page. A web-page structures its digital multimedia content by the help of the *Hypermedia Tag Markup Language (HTML)*, where objects (e.g. images, text, sound, videos) are combined to one entity of presentation. Thus, unified representation, distribution, and presentation to the audience are enabled. In digiTV currently no such structuring element or description language exists, of how additional content to a broadcast stream can be aligned as one object thought its life-cycle. The *Digital Broadcast Item (DBI)* as developed by the authors of the paper fulfil this requirement and represent data structures for the delivery of digiTV content in any arbitrary form to the consumer, over a DVB compliant deployment environment.

Each DVB compliant environment consists of five participating parties: a *Service Provider (SP)* provides content in form of e.g. applications; a *Broadcast Service Provider (BSP)* is responsible for the deployment of broadcast services over IP-, terrestrial-, cable-, or satellite channels; the consumer might be connected to a *Multimedia Consumer Network (MCN)*, interconnecting several home network facilities; and a *Interaction Service Provider (ISP)* establishing the connection from the home-digi-TV equipment to the Internet. The exchange of media assets between different partners in the value chain is based on multiple different protocols and exchange channels, such as wireless, and wired protocol types.

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1.1. Metadata Standards And their life-cycle

A very general life-cycle model for metadata deployment has been developed within MPEG's MPEG-7 and MPEG-21 standardization efforts and is shown in Fig. 1. The overall life-cycle is divided in different phases, having common data interchange levels. *Pre-Production* starts with a concrete project idea that requires continuous refinement. *Production* relates to concrete development of the digital, interactive broadcast show including video, audio, and applications. Final preparation of materials is done in the *Post-Production* phase, where several entities are prepared for the delivery to the consumer. *Delivery* focuses on the final packaging of digiTV multimedia assets, including local resolution and authorization. *Consumption* is more consumers related and addresses usage and exchange, and continuous interaction and transaction management. The central entity in an abstract metadata life-cycle model is the *multimedia content repository*, which devotes to metadata storage. The overall process of metadata playout has to be controlled and monitored for more transparent delivery.

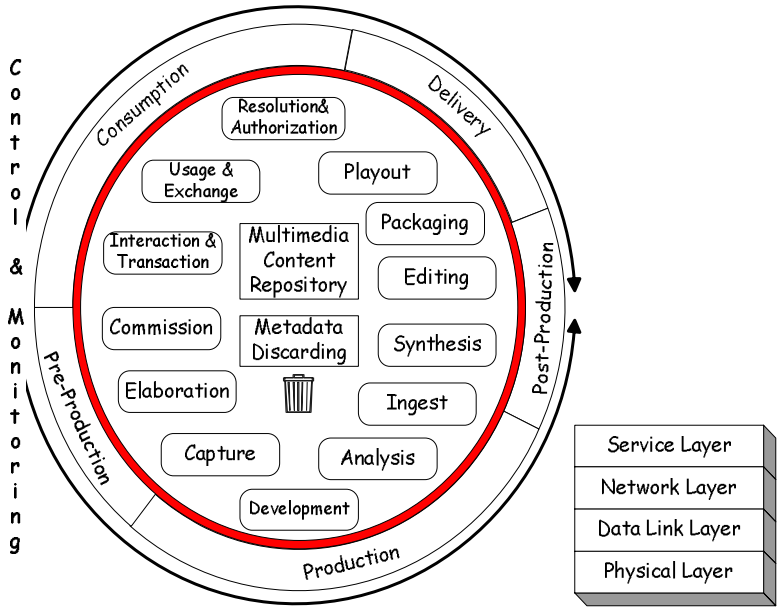

Fig. 1. Metadata life-cycle model for abstract metadata deployment. [1, and 8]

Each life-cycle phase has its own metadata standards for different purposes, as shown in Table 1. Almost all current standards are based on XML, and XML-Schema definitions, as defined by the W3C. Tab. 1 shows the entire set of metadata definitions considered during the development of the DBIM.

Tab. 1. Relevant metadata standards and their purpose.

Organization	Standard	Purpose	Life-cycle phase	Sample use-scenario
W3C	XML, XML-Schema, SGML	Metadata, and metadata schema language	Every	"mother of metadata definitions"
	SOAP, WDSL	Transmission, and service location	Delivery	eBusiness services
	RDF		Post-Production, Consumption	Muliple-Choice movie
AAF Association[18]	Advanced Authoring	Multimedia file format for metadata exchange	Production-, and Post-	File exchange in an

[1]This figure appeared in various different presentation, publications, etc. without any citation information. Together with ANDREAS MAUTHE it could be traced back to OLIVER MORGAN, which developed it for MPEG related standards.

	Format (AAF)	between systems, platforms, and applications	Production	editing environment
Pro-MPEG Forum[19]	Material eXchange Format (MXF)	Metadata interchange file format for production, streaming, and interoperability of multimedia assets	Production, and Post-Production	Acquisition and editing of movie material during production
GXF[20]	General eXchange Format (GXF)	Exchange of compressed video on a local area network based on FTP	Production, and Post-Production	Real-time editing of digiTV materials
MPEG[17]	MPEG-7 MPEG-7 BiM	Multimedia Content Description Interface Binary transmission of metadata	Production, Post-Production, Delivery, Consumption Delivery	Subtitles Compression during delivery
	MPEG-21	Digital content packaging, and rights management format	Post-Production, Delivery, and Consumption	Encapsulation and broadcasting of a whole movie including its subtitles, and applications as digital content package.
TV-Anytime[2]	TV-Anytime	Personal Data Recorder (PDR)	Post-Production, Delivery, Consumption	Personalized recording of movies during each day

1.2. Related research works

Unified metadata based service models start to get wide-spread acceptance in the research-, and commercial community. The *Dublin Core Metadata Initiative (DCMI)* is an organization for opened metadata standards promotion, in various applicable fields, such as e.g. in fields of digital libraries[11]. Metadata models related to e-Learning, management of virtual universities, and multimedia learning has been standardized by IEEE Learning Technology Standards Committee (LTSC) working group within the scope of the *Learning Object Model (LOM)*.[13] Other related research works within broadcasting relate various DVB standards[1], or works performed by the authors.[8, 14, 15, and 16]

1.3. Goals of this research work

The goals within the scope of this research work are:

- Brief introduction of the *Digital Broadcast Item Model (DBIM)*: The DBIM is a model for the distribution of digital, interactive TV content to multiple consumers, where MPEG-21's *Digital Item (DI)* declarations are the atomic unit of distributing content.
- Development of a DBIM metadata taxonomy: Categorization and alignment of different metadata standards for the DBIM according application scenarios.
- Synchronization, real-time constrains, and transmission modes of advanced metadata structures are dealt within the last part of the research work.

2. DIGITAL BROADCAST ITEM MODEL (DBIM)

The DBIM bases on a set of metadata definition for the purpose of unifying broadcast life-cycle management of multimedia assets. Multiple metadata standards are emerging, and their instantiated objects accessible throughout different content distribution channels (e.g. push, pull&push, pull). An abstract representation of broadcast content shall be composed as basis of a layer model, atomic units processed on this layer, and metadata definitions. The goal is the compilation of multimedia assets to a *Digital Broadcast Object (DBO)*, representing an instantiated DBI, based on MPEG-21 standards.

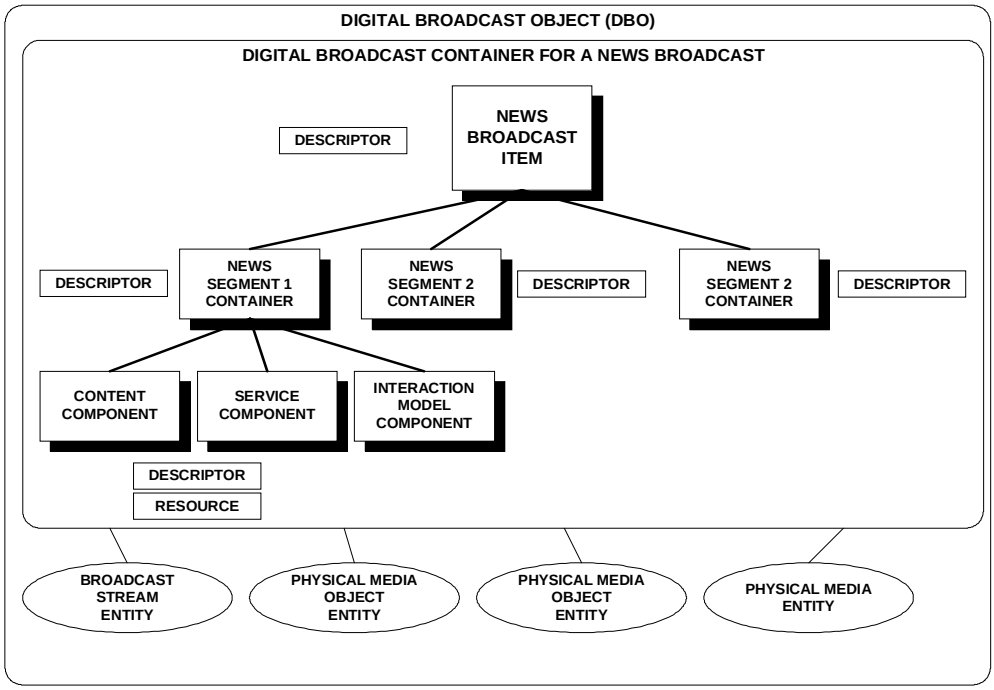

Fig. 2: Example for an instantiated DBI. A news broadcast encapsulated in MPEG-21 metadata structures.[8]

The context of applying a DBIM is related to digital television related multimedia home services. Several entities of an interactive broadcast show shall be enabled. The following features are covered:

- Consumer centred appliance especially in post-production, delivery and consumption
- Life-cycle management of digital broadcast content during pre-production, production, and storage on high level
- Unified delivery of digital, interactive broadcast content by applying MPEG-21's DI approach
- Linkage metadata definitions for service and application deployment
- Unified abstract service architecture, including protocol stack, feedback architecture, and broadcast architecture
- Abstract local facilities for deploying consumer platform independent, and adaptable content
- Opened framework

The applications of a DBIM are arbitrary and cover:

- Utilization of digiTV on-screen display technology (e.g. subtitles, content manipulation)
- Adaptable service types to different local resources (e.g. deployment of services over different network bandwidths)
- Introduction of semantic and narrative models as feature for deploying broadcast shows
- Content manipulation for customization of video- and audio content (e.g. exchange of actors)

DBIM's metadata definitions are based on a multilayer model of metadata with different purposes. Each layer has its atomic unit for processing, and consists of blocks relevant defining metadata structures for the deployment of advanced service types. Later sections within the scope of this research work explain their purpose and goals in further detail.

3. DBIM METADATA TAXONOMY

3.1. Life-cycle based taxonomy

Tab. 2. Metadata goals in various life-cycle phases.[6, and 23]

Life-cycle phase	Metadata to be captured	Metadata set described by	Metadata coding
Pre-Production	Commission Document	Commission data model	XML, requirements document
	Scripts, resource plan	Text, script data model	Document storage system, XML
	Plan of program composition (e.g. actors, location)	Program plan, data model of a composition	XML, Document storage system
Production	Metadata either captured or generated by the camera	MPEG-7 Content Management, and -Content Description	XML, MPEG-7
	Metadata captured by other devices than the camera (e.g. camera movement)	Camera Movement Trajectory (MPEG-7)	XML, MPEG-7
	Metadata directly associated at the time of capture	Program shooting metadata	MPEG-7
	Material segmentation	Association of timeline events, multimedia assets, and segmented objects	XML, MPEG-7
	Metadata ingesting	Manually edited metadata structures	MPEG-7, TV-Anytime
Post-Production	Review of material (editing and synthesis)	Logging data model	XML, MPEG-7, and TV-Anytime
Delivery	Packaging of multimedia assets	MPEG-21 Digital Item declaration	MPEG-21 DI, TV-Anytime
	Playout	Broadcast playout configuration metadata	XML, DVB Service Information, MPEG-7 BiM
	Adaptation to playout facilities	MPEG-21 Digital Item Adaptation, MPEG-21 Event Reporting	MPEG-21
Consumption	Resolution and Authorization	Local Metadata Asset references, MPEG-21 IPRM	TV-Anytime, URL, XML, MPEG-21
	Usage and exchange of digital multimedia assets in a multimedia home environment	MPEG-21 Digital Item Adaptation	MPEG-21 SOAP
	Interaction and Transaction	MPEG-21 event reporting	SOAP, MPEG-21, MPEG-7, TV-Anytime
Multimedia Content Repository	Content management, local resolution, interaction enabler	Several metadata descriptors	MPEG-21, XML, MPEG-7, TV-Anytime

3.2. DBIM taxonomy

The DBIM taxonomy is based on a multilayer model, where each layer is self-containing, has a different purpose, and metadata definitions. The physical media object, and as equivalence metadata structures convolve the lowest layer of the model, referred to as *Basic Tools*. Basic entities, and definitions, standards are part of this layer (e.g. MPEG-7, MPEG-2, image standards, XML). To obtain a self-containing layer, with predefined interfaces to higher layers, metadata and asset wrapper shall provide the opportunity of unified building blocks to higher layers in the taxonomy. *Multimedia Asset Tools*, building the second layer of the reference model, cover system architectural, and physical multimedia asset representation. This might be a multimedia content repository, or a shot movie with its spatial and temporal aspects. This layer deals with assets as a whole, thus complete multimedia objects (e.g. complete movie, digiTV broadcast show).

Elements and sub-elements of complete multimedia objects are covered on higher layer, by the *Object Tools*. Each element of a whole piece of multimedia object are addressed by this layer (e.g. shots, persons, sound effects) in temporal, as spacial and temporal alignment to the major contribution line. Especially add-on services, such as applications synchronized with a digiTV broadcast show are major part of this layer. The purpose of metadata definitions is more related for perceptive-, and representative purposes. *Service Tools* contain of metadata definitions for the development of services and applications (e.g. service description). Structure and semantic is introduced by the highest layer of the reference model, as convolved by *Narrative Tools*. They are relating different multimedia assets with each other and bring a certain meaning and relevancy into their temporal evolvement.

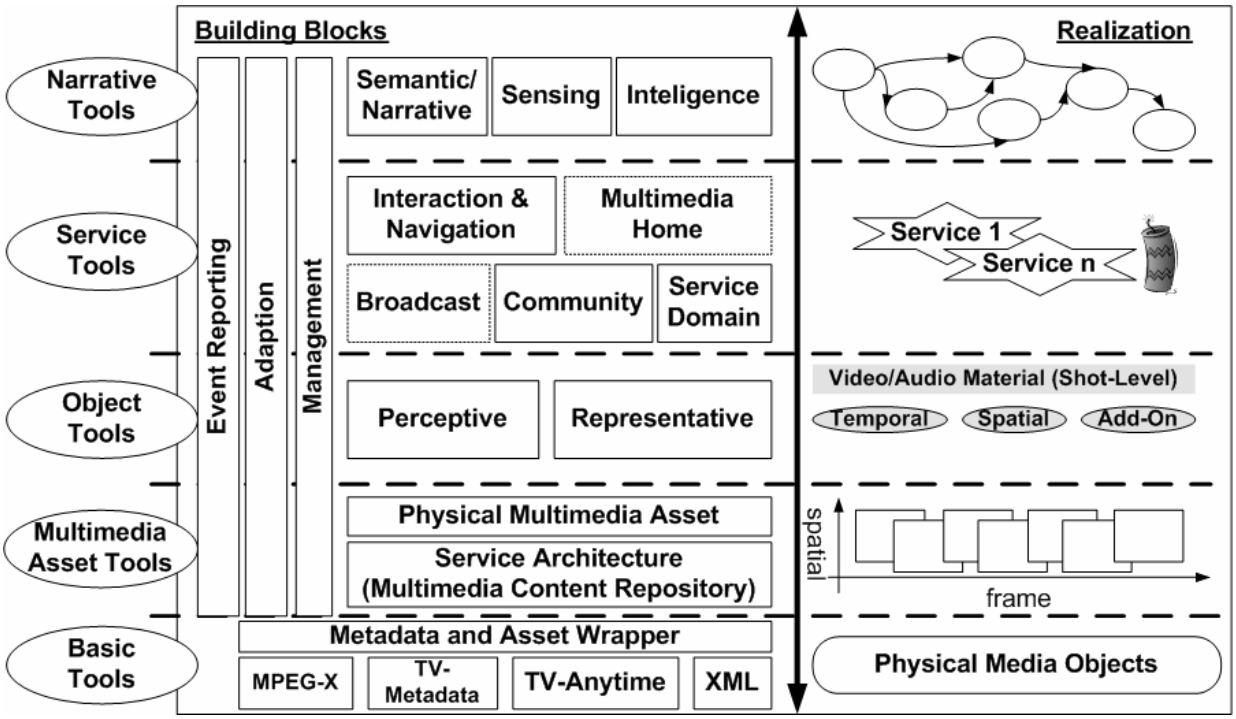

Fig. 3. Digital Broadcast Item Model Taxonomy.[8]

Relevant definitions throughout the multilayer model are *event reporting*, *adaptation*, and *management* metadata structures. Event reporting guarantees continuous updates, and the asynchronous/synchronous update of metadata trees on distributor-, and consumer side. The big field of adaptation addresses content adaptation to different local facilities, such as bandwidth requirements, display facilities, input devices, etc. From importance is management metadata, dealing with local resolution, life-cycle management, unified delivery, and content identification.

In the following a brief overview of different metadata categories and their relation to existing standards is given. A more general overview can be found in Tab. 3.

- **Basic Tools:** As metadata is defined in multiple sources, their convergence and sub-setting to obey new advanced metadata definitions is obsolete. XML and XML-Schema acts as "mother for several" other metadata definitions included in the basic tools: MPEG-7, MPEG-21, TV-Anytime, etc. The strength of TV-Anytime is their focus on digiTV related issues. MPEG-7 is relevant for the description of audiovisual content types. An extension of MPEG-21, as already presented as DBIM, results into metadata- and asset wrapper, as general structure for compiling several multimedia assets to a useful digital item. The atomic unit dealt with at this layer of the DBIM taxonomy is a multimedia asset in form of metadata or an physical media object.
- **Multimedia Asset Tools:** The atomic unit at this layer is a DBI, and its reference to concrete multimedia content assets. The multimedia metadata asset definitions relate to service architectural-, physical-, content management-, and content packaging assets aspects. The multimedia content asset relates to concrete entities of multimedia content, such as video frames, audio slices, images, etc. Temporal-, and spatial aspects have to be involved on this layer. Event reporting, adaptation, and management relate only to those aspects of multimedia assets (e.g. adaptation of bitrate to the related available network bandwidth. In conventional systems, the best description of this layer is given by commercially available multimedia content repositories. This layer is relevant for delivery, physical asset management, segmentation, linkage, and local resolution.
- **Object Tools:** The atomic unit are sub-elements of concrete multimedia assets, as defined in multimedia asset tools as atomic units. (e.g. a video is defined as atomic unit on multimedia asset tool level, its frames, and shots are atomic unit on object tool level.). Metadata definitions relate to sub-elements of concrete multimedia content assets.
- **Service Tools:** Atomic units that are processed on this layer are services, and several elements relevant for their deployment, multiple interaction devices, conservative interaction and navigation facilities, and a complete digitized home. Special focus is given to concrete services, requiring new metadata type definitions.
- **Narrative Tools:** The most sophisticating and intelligence is defined by this level of operation, where the atomic unit are story-, or narrative pieces as build on lower layers resulting into an intelligent, and semantic multimedia presentation. The goal of this layer is the introduction of semantic/narrative structures, sensing metadata, and definitions for the introduction of certain intelligence. Sample applications are e.g. the intelligent compilation of a news broadcast, in a personalized manner. To structure the "narrative", JON SAMSEL defined in Ref.[9] relevant geometric design patters, convolving the basis for designing interactive media. The ten different patterns are shown in Fig. 4.

Tab. 3. Overview of the DBIM tools, their atomic processing units, shown with examples. [8]

Toolset	Atomic Processing Unit	Example
Basic Tools	Physical multimedia metadata assets Physical multimedia content assets	MPEG-21 DIDL definition Image, video, audio-track
Multimedia Asset Tools	Digital Broadcast Item (DBI)	News broadcast encapsulated within a DBI including subtitles, applications, etc. Concrete reference to the physical content
Object Tools	Sub-elements of atomic units of multimedia asset tools	Video strips, audio-subtracks, etc.
Service Tools	Services, and applications	Topic constrained chatting synchronized to a news broadcast
Narrative Tools	Intelligent and semantic multimedia presentation	Video strips compiled together for a multimedia presentation

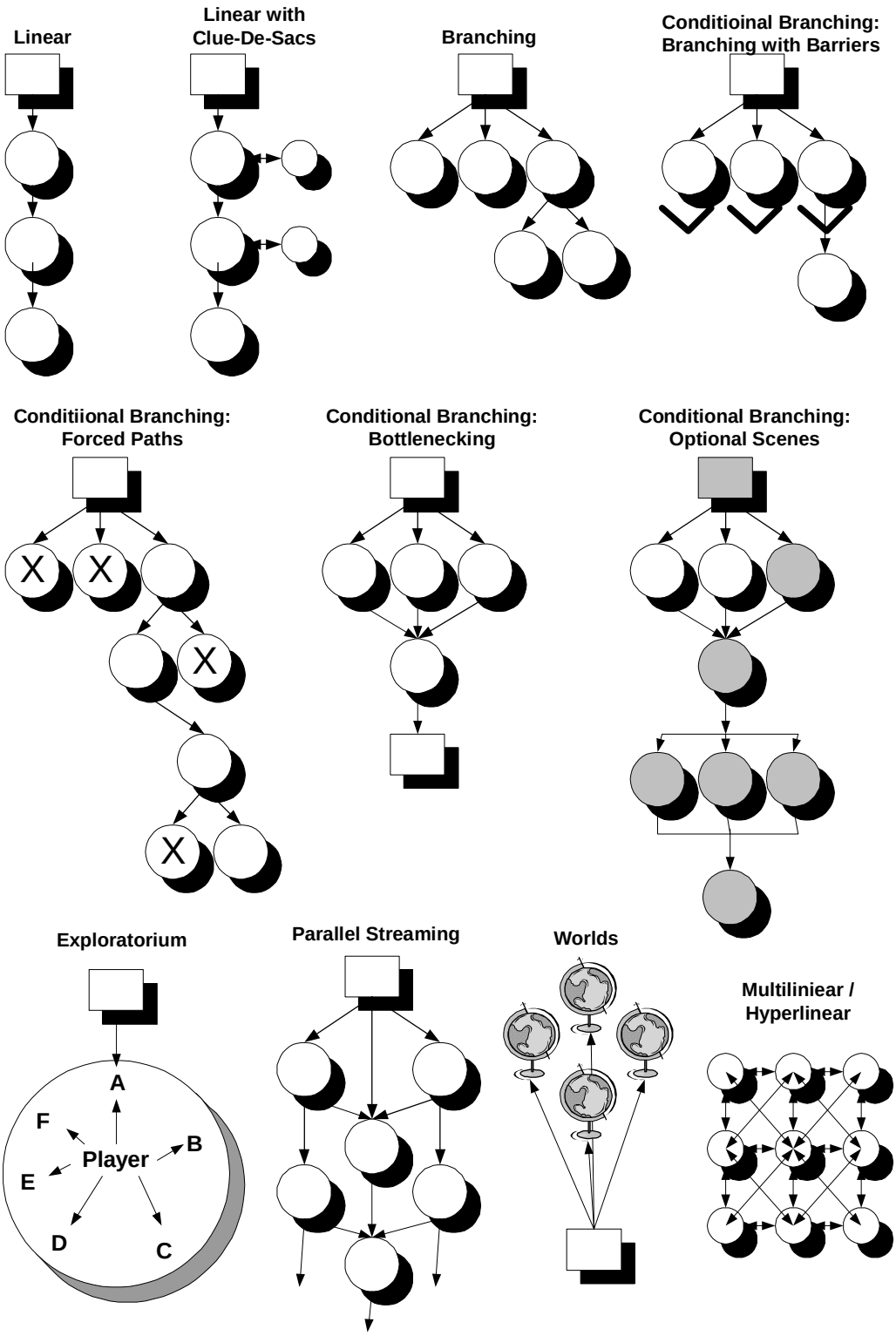

Fig. 4. Structuring Interactive Narratives by applying JON SAMSEL'S ten geometric design structures.[9]

4. SPECIAL DEPLOYMENT ISSUES

4.1. Synchronization

Tab. 2 shows different synchronization levels, as introduced in Ref.[10, 22.]

Table 2. Temporal synchronization models.[10, 22]

	Entity of Operation	Example	Characteristics
Media Layer	Single continuous metadata stream	PES BiM Application Stream	Device independent interface of operations en-/decapsulation processes
Stream Layer	Group of media streams Single Media Stream	MPEG-2 DVB stream A whole program inc. applications and content	Interstream synchronization Intrastream synchronization
Object Layer	Temporal synchron. Specification as input	Multimedia presentation Hyperlinked TV including object information	Intra-/Inter stream synchronisation based on lower layer calls
Transaction Layer	Higher layer Internet protocols (HTTP, etc.)	XML based eBusiness	Asynchronous / Synchronous
Human Layer	Human interactions	Activation of Hyperlinked TV	Asynchronous
Material Preparation Layer	Preoperational entities	Extraction of metadata	Soft deadlines

4.2. Transmission modes

Different transmission modes over different protocol types and distribution networks imply a certain abstraction and categorization to successfully provide an abstract framework for digiTV content. Simple categories as presented as follows are sufficient: temporal aspects. This layer deals with assets as a whole, thus complete multimedia objects (e.g. complete movie, digiTV broadcast show). Fig. 4 reviews structures for advanced digiTV experiences. They can be categorized according the required information channels:

- **Push Model Structures:** Most of current television shows are passive and provide only sequential or linear arranged story evolvement. There might be parallel stories within a movie, but the participant experiences a strictly predefined path through the story. He cannot influence its development during the narrative. Weak interactivity is the only possibility of participant involvement (e.g. customer polls, telephone feedback). Sequential with Clue-De-Sacs schemes are a linear sequence of nodes that can diverge into isolated nonlinear deviations. This offers the user the choice to step off the procedural path into areas that in no way fulfil the critical objective of the piece[21] (e.g. little applications that are synchronized with the content, entertainment shows with commercial breaks, shows where telephone calls of consumers are inserted).

  First forking facilities are provided by providing the user with branching points enabling forks in the story flow

(e.g. the user can choose either he prefers a love story like movie ending or a dramatic roundup by applying personalized filtering methods). Limiting the degree-of-choices is an entire requirement in a broadcast environment, due to lacks of resources. Therefore bottlenecking where multiple branches converge into a story spine allows keeping the structure of a major broadcast stream, with multiple minor or additional stream peaces (e.g. movie where for a certain period of time two different viewpoints of two actors are broadcasted).

Exploratoriums are worlds within worlds, where the current program flow can be paused and current scenes explored (e.g. during a scientific broadcast the participant can perform additional physical experiments in form of multimedia applications). Parallel streaming structures require multiple states and the interconnections in form of story paths between them (e.g. different scenes in different locations are streamed and the participant chooses himself which paths he would like to follow).

- **Feedback Model Structures:** A Feedback communication network allows advanced structures in a broadcast network, especially the invocation of advanced conditional branching methods. The methods mentioned in previous sections are also the basis for this communication model, but require feedback from either one consumer or multiple participant groups. Branching with barriers introduces puzzles or obstacles that are presented during the program flow and have to be solved before any continuation is possible (e.g. the whole participants have to solve a problem by sending solutions to the broadcaster before the show continues).

  Limiting the number of choices means to provide branching with forced paths. Especially for a broadcasting environment this seems to be an adequate solution to provide a broadcast stream as definite path, along which to seamless ends can be branched (e.g. only one solution solves the story puzzle of an interactive broadcast game). Branching with optional scenes enables the user with the ability to choose between alternatives – whether that spine is a story (as in an interactive narrative) or an objective (as in an informational multimedia application such as a training title).[9] Several structures from push model applications are extendable to feedback capability where multiple users can communicate with each other and/or with the broadcaster.

- **Distributed Model Structures**: Distributed content models require advanced scenarios and schemes for compiling story pieces to a useful entity. A structuring to Worlds, where specific environments are loosely interconnected and predefined events and forms of interactivity lead the user through the story, enables distributed technologies. Multiple users form their own story environment to achieve a predefined goal (e.g. broadcast computer games, where users create their own game parts and sub-stories).

  An extension to world structures is multimedia or hypermedia. The content author only limits and bounds very loosely participant and interactivity. The user itself creates the story (e.g. city simulation with multiple players, where the service provider announces the current state of the city in form of a news broadcast).Our implementation significantly varies from introduced methodologies, as our local MHP compliant hardware did not support all features required to support all transport facilities. In the following facilities for the carriage of our DBI are presented:

4.3. Real-time constraints

	Synchronization Model(s)	**Deadline(s) to be meet**
Narrative Tools	Human Layer	Soft d. for user interactions Hard d. for content synchron.
Service Tools	Transaction Layer, Human Layer	Soft d. for transactions; hard d. for human interactions
Object Tools	Object Layer, Stream Layer	Hard deadlines
Multimedia Asset Tools	Media Layer, material preparation layer	Hard deadlines for content synchronization, soft deadlines for access

		and resolutions
Basic Tools	-	supportive

5. CONCLUSIONS AND FUTURE WORK

The work regarding the DBIM is still in process and requires more detailed research. It shall lead to an abstract framework for the deployment of digiTV content. We would like to pinpoint to Ref.[8] as further reading, as this work will compile all information required for the development of a DBIM, ranging form systems, metadata definitions, theoretical aspects, etc.

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REFERENCES

1. Digital Video Broadcasting (DVB), *Digital Video Broadcasting (DVB)*, http://www.dvb.org.
2. TV-Anytime Forum, *TV-anytime forum*, http://www.tv-anytime.org, 1999.
3. European Telecommunications Standards Institute, *Digital Video Broadcasting (DVB): Multimedia Home Plattform (MHP)*, October 2001.
4. Jos´e M. Mart´ınez, *Overview of the MPEG-7 Standard*, ISO/IEC JTC1/SC29/WG 11 N4031, http://mpeg.telecomitalialab.com/standards/mpeg-7/mpeg-7.htm, March 2001.
5. David Bordwell and Kirstin Thompson, *Film Art: An Introduction*, McGraw-Hill Companies, Inc., 5th edition edition, 1997.
6. SOAP, *Simple Object Access Protocol (SOAP 1.1)*, World WideWeb Consortium (W3C), May 2000.
7. H. S. Thompson, D. Beech, M. Maloney, and N. Mendelsohn (Eds). “XML Schema Part 1: Structures”. W3C Recommendation, May 2001. http://www.w3.org/TR/xmlschema-1/.
8. A. Lugmayr, *The Digital Broadcast Item Model (DBIM)*, Licenciate Thesis, 2003, in process.
9. Samsel, J., and Wimberley, D., *Writing for Interactive Media – The Complete Guide*, Allworth Press (1998).
10. A. Lugmayr, S. Kalli, R. Creutzburg, *Synchronization of MPEG-7 metadata with a broadband MPEG-2 digiTV stream by utilizing a digital broadcast item approach*, Real Time Imaging and System Components, SPIE, Seattle,2002, to be published.
11. Dublin Core Metadata Initiative (DCMI). www.dublincore.org.
12. Muller, H.; Tan, E, *Movie maps*, Information Visualization, 1999. Proceedings. 1999 IEEE International Conference on, Vol., Iss., 1999. pp. 348-353
13. IEEE Learning Technology Standards Committee (LTSC), ltsc.ieee.org.
14. A. Lugmayr, S. Niiranen, A. Mailaparampil, P. Rautavirta, M. Oksanen, F. Tico, and S. Kalli, *Applying mpeg-21 in digital television - example use scenarios: epostcard, egame, and eticket*, 2002 IEEE International Conference on Multimedia and Expo, August 26-29, 2002, Lausanne, Switzerland. 4 s, 2002.
15. A. Lugmayr, J. Lyytinen, A. Mailaparampil, F. Tico, S. Maijala, S. Tuominen, T. Pihlajamäki, P. Rautavirta, M. Oksanen, J. Spieker, S. Niiranen, and S. Kalli, The future interaction tv project developing diet - digital interaction environment for tv. Proceedings of the 5th Nordic Signal Processing Symposium, NORSIG 2002, October 4-7, 2002, on board Hurtigruten, Norway. 6 s., 2002
16. C. Peng, A. Lugmayr, and P. Vuorimaa, *A digital television navigator*, Multimedia Tools and Applications nl. Kluwer Academic Publishers. 17, s. 121-141, 2002.
17. Motion Pictures Expert Group (MPEG). MPEG-7 and MPEG-21 standard families. www.mpeg.org.
18. AAF Association. Advanced Authoring Format (AAF). www.aafassociation.org.
19. Pro-MPEG-Forum. Material Exchange Format (MXF). www.pro-mpeg.org.
20. SMPTE, General eXchange Format Definitions.
21. .A. Lugmayr, R. Creutzburg,, S. Kalli., and A. Tsoumanis: Face Customization in a Real-Time digiTV Stream. In: SPIE Proceedings of Electronic Imaging (2002)

22. E. Bertino, and E. Ferrari, “Temporal Synchronization Models for Multimedia Data,” IEEE Transactions on knowledge and data engineering, Vol. 10, No. 4, July/August, 1998.
23. IBC 2002. Conference Proceedings. Amsterdam. 2002