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A business-driven framework for automatic information extraction in professional media production

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Abstract

Purpose – This paper aims to propose a service-oriented framework for performing content annotation and search, adapted to the task context. Media production workflows are becoming increasingly distributed and heterogeneous.The tasks of professionals in media production can be supported by automatic content analysis and search and retrieval services.

Design/methodology/approach – The processes of the framework are derived top-down, starting from business goals and scenarios in audiovisual media production. Formal models of tasks in the production workflow are defined, and business processes are derived from the task models. A software framework enabling the orchestrated execution of these models is developed.

Findings – This paper presents a framework that implements the proposed approach called Metadata Production Management Framework (MPMF). The authors show how a media production workflow for a real-world scenario is implemented using the MPMF.

Research limitations/implications – The authors have demonstrated the feasibility of a model-based approach for media processing. In the reification step, there is still information that needs to be provided in addition to the task models to obtain executable processes. Future research should target the further automation of this process.

Practical implications – By means of this approach, the implementation of the business process defines the workflow, whereas the services that are actually used are defined by the configuration. Thus, the processes are stable and, at the same time, the services can be managed very flexibly. If necessary, service implementations can also be completely replaced by others without changing the business process implementation.

Originality/value – The authors introduce a model-based approach to media processing and define a reification process from business-driven task models to executable workflows. This enables a more task-oriented design of media processing workflows and adaptive use of automatic information extraction tools.

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Paper type Research paper

1. Introduction

The work presented in this paper focuses on professional audiovisual media production and archiving workflows, in particular on workflows deployed at broadcasters and in media production houses. The tasks of media professionals in such workflows include searching for and accessing audiovisual content, such as finding appropriate clips from recent material to be included in a production, locating relevant archive material or reviewing relevant sections of other media's coverage on the same event or topic. Many of these tasks can be supported by automatic metadata extraction tools, such as analysis of speech or visual information in the content.

The transition from traditional linear tape-based production to entirely file-based and increasingly distributed workflows is now a reality that needs to be managed efficiently. The result of this paradigm shift will not be a new set of fixed workflows; rather the new workflows will be dynamic and constantly changing as novel IT-based production and distribution technologies emerge. The tools supporting tomorrow's media production and archiving workflows must thus be able to adapt to the users' tasks, content types and production context. This adaptation can be enabled by task models, means of implicit and explicit user feedback and integration of benchmarking capabilities. Such workflow principles can efficiently be applied in combination with open service-oriented architectures (SOAs), which allow customising systems on the basis of standardised component interfaces.

In this paper, we propose a service-oriented framework for performing content annotation and search in media production tasks. The processes are derived top-down, starting from business goals and scenarios in audiovisual media production. Formal models of tasks in the production workflow are defined, and business processes are derived from the task models and implemented by means of the framework.

The rest of this paper is organised as follows. Section 2 presents the method for identifying the business goals and scenarios to be supported by automatic processes. In Section 3, we discuss the formalisation of tasks and the conversion into executable business processes. Section 4 describes the implementation of a framework executing these processes and Section 5 presents results. Section 6 concludes the paper.

2. Identifying business goals and scenarios

A set of high-level goals and usage scenarios has been selected as guiding elements for the requirement analysis, inspired by emerging philosophies in software development life cycle, which recommend the use of top-down and scenario-based approaches for complex software systems (Koehler *et al.*, 2006; Liu, 2008; Rosson and Carroll, 2009; Kaindl, 2011).

Several approaches are available in software engineering literature for solving the problem of scenario-driven design. Among those, we chose a methodology inspired by the S-Cube approach (Di Nitto and Plebani, 2010; Jackson, 1995). This method distinguishes between high-level goals (named business goals), i.e. target conditions which are to be met by the system from a mainly business process-oriented perspective, and more detailed scenarios, which are more practical settings in which actors and systems interact to achieve a specific result. Both business goals and usage scenarios are represented with textual descriptions and some additional features. Usage scenarios are always accompanied by a unified modeling language use case diagram. Tables I and II report the respective template tables for these descriptions, as specified by S-Cube.

An extensive analysis was conducted to capture a wide range of meaningful usage environments and an importance ranking was assigned. Based on this ranking information, a selection of the business goals and corresponding scenarios was performed, and the selected ones were further analyzed and broken down into requirements and functionalities. Table III reports the basic descriptions of the four top-ranked business goals.

For each of the scenarios, we collected descriptions of the tasks performed, e.g. gathering content for use in a documentation and selecting content from incoming feeds for use in a news broadcast. We asked professionals to specify the actors, input/output data, frequency, time budget and success criteria of these tasks in a structured

Field	Description
Unique ID	Give a unique ID for this goal/assumption
Short name	Give a short name for this goal/assumption
Type	One of the following: Business goal Domain Assumption
Description	Specify the intention of the goal/assumption
Rationale	Give a justification of the goal/assumption
Involved stakeholder	Stakeholders involved in the business goal/assumption
Supporting materials	Give a pointer to documents that illustrates and explain this goal/assumption (in particular those of domain analysis)
Priority of accomplishment	One of the following: *Must have*: The system must implement this goal/assumption to be accepted *Should have*: The system should implement this goal/assumption: some deviation from the goal/assumption as stated may be acceptable *Could have*: The system should implement this goal/assumption, but may be accepted without it
Tentative scheduling	Tentative scheduling of accomplishment. To be used only if the case study has to be implemented

Table I. Business goal description template

Field	Description
Unique ID	Give a unique ID for this scenario
Short name	Give a short name for this scenario
Related to	Specify the goal/assumption ID to which the scenario is related
Involved actors	Specify the actors involved in the current scenario
Detailed operational description	Give a textual description of the scenario
Problems and challenges	Describe the specific problems that each scenario addresses or that consumers and providers face
Additional materials	UML diagrams supporting the understanding of the scenario

Table II. Scenario description template questionnaire. This information served as the basis for the formalised description and modelling of relevant tasks.

3. Formalising tasks and processes

We propose the introduction of a task-based approach in the domain of multimedia content analysis and processing to orchestrate media processing services based on a task context. Using formalised machine-readable task models, multimedia analysis tools can be connected to support a real media production workflow. In user interface (UI) design, it was proposed already more than 25 years ago to follow a task-based approach (Green, 1985). Thus, a large share of the literature on formal task models

Business goal	Description	Scenarios
Fast retrieval of very recent material	This business goal states that very recent material should be immediately retrievable. To accomplish this immediate disclosure of newly ingested material, indexing it for search immediately is necessary	Fast content disclosure for news production
Efficient retrieval of historical archive material	This business goal states that archive material should be efficiently retrievable and that very specific questions could be asked to the retrieval system (e.g. a very specific quote of a politician, appearance of specific objects, time constraints, [. . .])	Searching archived material, including deep archive
Access to international feeds and their use in news production	This business goal addresses the need to have seamless and efficient access to the content of international feeds (e.g. the Eurovision Network) through a rich metadata query interface and subsequent utilisation of selected material in subsequent phases of news production	Distributed semantic search and retrieval of multilingual content Dynamic configuration of features for content enrichment Machine-supported subtitle generation
Distributed repository for all steps in metadata production and usage chain	The business goal addresses the need in modern distributed media production facilities to accumulate content files and all types of related metadata in one central repository for the overall production and usage chain. All steps in such a distributed chain can produce new metadata, can use the information of already available metadata or can combine or aggregate metadata. The distributed repository application has the intention to collect different locally separated repositories to one global accessible system and provide common global interfaces specialised for content production, post-production and search, and browsing and recommendation steps	Distributed content metadata production and post-production

Table III.
Top ranked business goals and scenarios

comes from the area of model-based UIs (for a historical overview see Meixner *et al.*, 2011).

The term task is used here to denote a sequence of actions performed by one or more users to achieve a defined goal in the production process, usually using a set of tools. A task has a defined set of input items and produces a set of output items. For example, "Content Search" could be defined as "The action performed by the employee of a broadcaster to find an audiovisual content item (the output item) with a specified topic (the input item)". We denote the language to define and describe task models as a task metamodel. A task model is an abstract representation of a task, i.e. an orchestrated set of actions performed by actors to reach a specific objective. The objective is expressed in terms of conditions that have to be satisfied by the reference domain. Pre- and post-conditions may pertain to single objects or sets of objects or to the entire domain. The task model is formalised using a task metamodel. The example mentioned above, which is classifiable as a task model, is stated using the task metamodel "English language".

We have reviewed various candidate representations for task metamodels. In addition to the surveys available in literature (e.g. Guerrero Garcia *et al.*, 2012), we have considered machine readable definition, the availability of tools and documentation, serialization options (preferably Extensible Markup Language [XML]), adoption (e.g. in the W3C MBUI work) and existing work in relation with business process modelling. Metamodels that are specific to UI design have been excluded. ConcurTaskTrees (CTT) (Paternò *et al.*, 1997) has been proposed as a graphical model for tasks. The model has been extended over time and is probably the most widely used of all task metamodels. A process for developing task models from informal scenarios has been proposed in (Paternò and Mancini, 1999) and a Java-based graphical editing environment exists (CTT Environment). (ANSI CEA, 2018, 2008) is a consumer electronics standard for representing models of user tasks. A differentiation between task classes and instances is made, introducing two levels of abstraction. The standard defines a serialization in XML (using RelaxNG) and ECMAscript (for custom data types and scripts checking conditions). A Java reference implementation is available but does not provide tools for modelling. The authors of (Zuehlke and Thiels, 2008) present the Useware engineering process, which tries to apply software design processes to designing tools in manufacturing. useML has been defined to model such a user-centred design process, and the useML XML notation is introduced in (Reuther, 2003). An editor for useML called Udit is proposed in (Meixner *et al.*, 2009). In a comparison of different task model notations (Guerrero Garcia *et al.*, 2012), the authors compare features of different models, and propose a metamodel integrating the concepts from the different task model notations. The W3C Model Based User Interfaces (W3C MBUI, 2011) has recently compared the temporal operators supported by different types of task metamodels.

From our analysis, it was concluded that CTT is the metamodel supporting the largest set of temporal operators needed for connecting tasks. As a result, we chose to adopt CTT. We use an extension called collaborative CTT (Mori *et al.*, 2002), which allows modelling the cooperative execution of a task by multiple actors (users and systems).

The basic structure of the CTT model is a tree representing the breakdown of tasks into subtasks. On each level, temporal dependencies between subtasks (e.g. serial or parallel) can be modelled. We defined a task model covering the role of each actor, and described cross-links (e.g. information exchange and interactions) between tasks from different roles. An example of a task model is shown in Figure 1. The bidirectional

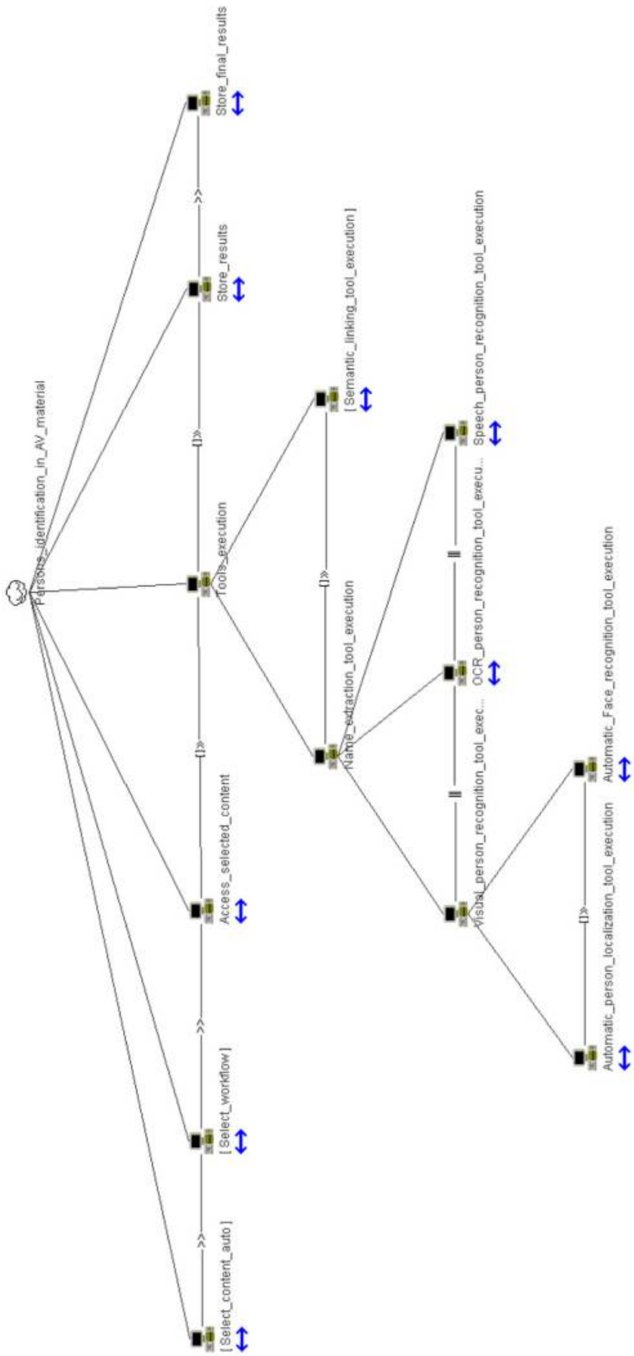

Figure 1.
Task model for multimodal person recognition in video

arrows below the task symbols indicate interaction with other roles, such as automatic systems or users.

3.1 Reification

To derive a business process from a task model and finally arrive at an executable analysis job, we propose a reification process in analogy to that used in model-based UI design (Calvary *et al.*, 2002). This reification process is shown in Figure 2. It starts from the task model, from which a business process is derived, which turns the hierarchical task structure in a (possibly branched and nested) chain of services. This step is discussed in the remainder of this section. Then, specific service implementations and further parameters of the workflow are defined, and finally, a job is executed for a specific media item (or set of items). The latter two steps are covered by the implementation described in Section 4.

It is apparent that there is an overlap between task models and business process models. Formal and machine-processable representations exist for each of them. However, we started with the task models rather than business processes for the following reasons. Task models provide a more user centric and holistic view of the system. While complex process modelling frameworks, such as Business Process Model and Notation (BPMN, 2011), also include higher levels of abstraction and non-system tasks, these models tend to be more complex and more difficult to understand than task models, which are more familiar to end users. Task models provide support for UI design and there are existing frameworks for building UIs based on task models.

3.2 Transforming task models into business processes

The first step of the reification is to automatically create executable process representations from the task models. The authors of (Sousa *et al.*, 2008) were the first to describe relations between entities in task models and entities in business processes. UsiXML (User interface extended Markup Language) was used to model the UI aspects of the business process model, and the Cameleon reference framework (Calvary *et al.*, 2002) was applied to derive the final UI. In (Pintus *et al.*, 2010), it is observed that the notion of a task in CTT and BPMN is not equivalent, and it is thus proposed to augment BPMN models with a CTT model for each interactive service. In a recent work (Kolb

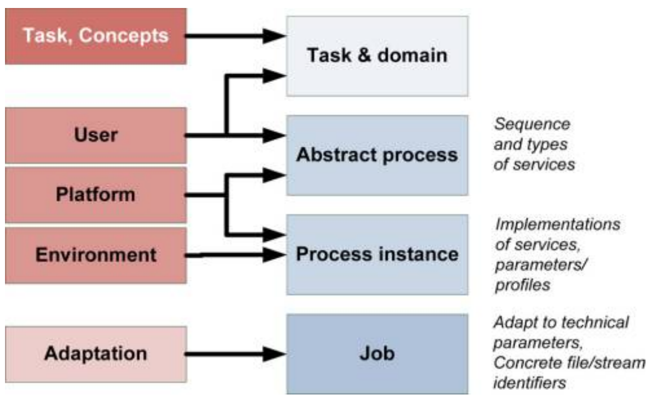

Figure 2. Reification process for service orchestration

et al., 2012), modelling of CTT elements when transforming a task model to BPMN is discussed.

The authors of (Kolb *et al.*, 2012) make use of the (optional) distinction of activity types introduced in BPMN 2.0. Business rule activities are not used but might be interesting as specializations of service activities in some cases. Figure 3 shows the mapping of the temporal operators of CTT: their mappings are defined to result in BPMN models that are behaviourally equivalent to the CTT models, i.e. they share the same set of producible execution traces (in terms of order of events). To resolve ambiguities between sets of 2+ tasks with temporal relations, the authors propose to rather add additional tree levels than to rely on the precedence of temporal operators.

Most of the mappings proposed by the different authors are consistent or at least very similar. Some differences are caused by the different mapping directions in the different papers, in cases where different BPMN constructs map to the same CTT construct. Similar cases have start, end and intermediate events, which do not exist in task models but can be easily introduced during mapping (possibly with the task precondition). Differences exist concerning the modelling of choices. The mapping of a deterministic (explicit) choice is consistent; however, that of the non-deterministic choice is not. First, the mapping proposed by (Kolb *et al.*, 2012) (two event-based gateways) does not conform to the BPMN standard, as event-based gateways must have intermediate events or receive tasks connected to their outgoing flows. Also, there is no reason to make the converging gateway event-based, it can simply be exclusive. It is also not clear how an inclusive gateway as proposed by (Sousa *et al.*, 2008) would provide the option to include the choice being made.

In our task models, parts of the process are performed by different roles. CTT provides cooperative task models for this purpose. Similar constructs are supported in BPMN, but to the best of our knowledge, mapping of cooperative task models to BPMN has not yet been discussed in literature. We use the following associations between cooperative CTT and BPMN elements. The cooperative task model and the models for each of the roles are modelled as lanes in BPMN, and there is a separate start and end event for the part of each role. Cooperation tasks are used in CTT to add support for multiple roles, which not only might indicate a user activity but also could include systems/services with different roles. Thus, they are not necessarily mapped to a user activity as proposed by (Kolb *et al.*, 2012). For interaction tasks, there exists an ambiguity whether an automatic process needs to call a service that presents information to the user and takes user input or the initiative starts from the user who has the option to use an application and provide input. Connections between tasks need to be defined in the CTT model, which are modelled as message flows in the business process

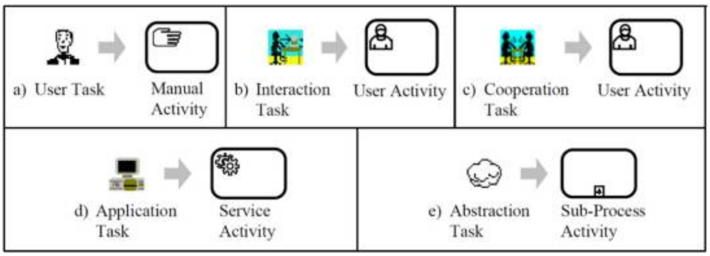

Figure 3.
CTT task types and their mappings to BPMN activities (from 0)

notation. In contrast to the mapping proposed by (Kolb *et al.*, 2012), any non-leaf task (i.e. any task that has subtasks) is mapped to a subprocess in our approach, independent of its type. Optionally, subprocesses can have their start/end events or not (this is mainly an interoperability issue with specific BPMN implementations).

Technically, this mapping is implemented as follows. The task models created in CTTE can be exported in an XML representation of CTT. We have developed an automatic conversion from of task models from this XML representation to business processes represented in the BPMN 2.0 format. The conversion has been implemented as an Extensible Stylesheet Language Transformations (XSLT) [*URL omitted for review*].

4. Implementation

This section describes the implementation of the framework for service orchestration and execution of media analysis processes, called Metadata Production Management Framework (MPMF) within the overall system. The framework takes the business process represented in BPMN 2.0 format as input, and – with the help of additional configuration information – completes the reification process to execute a media analysis process and monitor its progress.

4.1 Requirements

The proposed approach for the implementation of the MPMF is based on SOA principles to match the current developments in broadcasters' production environments, where SOA solutions are increasingly adopted for the integration of IT systems. The MPMF should meet the following requirements:

- Integration of a large number (>40) of heterogeneous, distributed services (specifically for automatic content annotation) through REST- or SOAP-based web service interfaces;
- Integration of a distributed repository for storage and retrieval of essence and metadata;
- Ability to import externally prepared business processes represented in the BPMN 2.0 format (as resulting from the reification as described in Section 3);
- Implementation of additional process logic on top of BPMN 2.0;
- Flexible service configuration; and
- Ability to configure and control the framework through an external control and configuration user interface.

Finally, the implementation should be compatible with the Framework for Interoperable Media Services (FIMS, 2015). FIMS is a joint initiative of the Advanced Media Workflow Association (AMWA) and the European Broadcasting Union (EBU), defining standards to enable flexible, efficient and scalable SOA-based media processing systems.

4.2 Components in the MPMF framework

Within a distributed media processing system, the MPMF fulfils the role of a mediator, interconnecting and controlling all other components via web service interfaces and supporting the communication and exchange of essence and/or metadata between them. Figure 4 shows the system overview, focusing on the MPMF.

For the realization of the MPMF, the Red Hat JBoss ® Enterprise SOA Platform (version 5.3) was chosen as a basis. JBoss provides a modular architecture with much functionality rendering it very flexible. The platform is available as open source software and is Java based, allowing for efficient combination and extension with the specific software components which were developed to realize the MPMF. The JBoss Enterprise SOA Platform provides a generic process engine (jBPM) which can be accessed for process control and monitoring through an on-board web service interface. The core of jBPM is a light-weight, extensible workflow engine written in Java that allows execution of business processes conforming to the BPMN 2.0 specification.

The integration layer in the MPMF consists of all components that were developed to extend the JBoss Enterprise SOA Platform environment with the specific functionality for the MPMF, which are:

- client components for each analysis service and for each distributed repository service;
- generic service handler component;
- process logic components; and
- error handling components.

In addition, the MPMF contains a workflow configuration component for which an own web service interface was implemented. As each analysis service provides a dedicated web service interface, it was required to implement corresponding client components separately for each service in the MPMF to be able to execute the service by its specific API.

To support the correct execution of a BPMN 2.0 process loaded onto the JBoss Enterprise SOA Platform, a generic service handler was implemented. For each activity in the BPMN 2.0 process, this handler takes care of the more detailed steps to be taken within an activity in the following sequence:

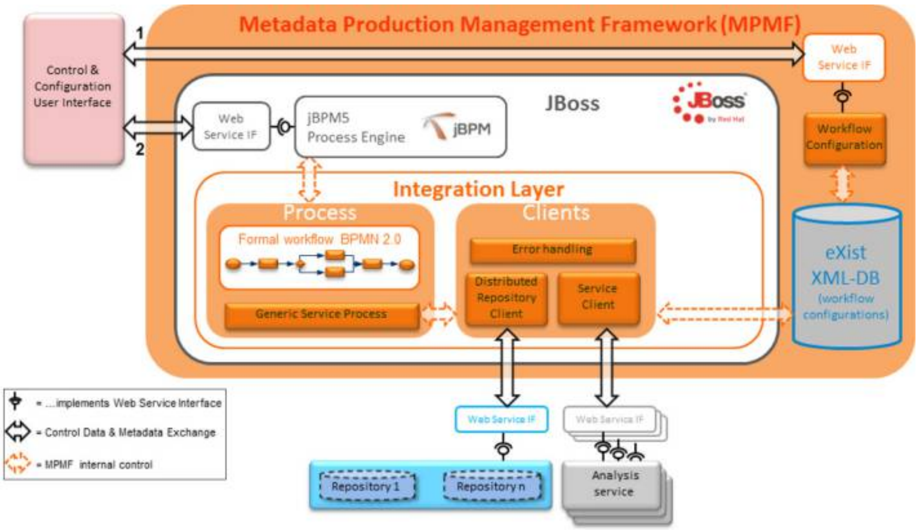

Figure 4.
System overview

- reading the parameters from the appropriate workflow configuration;
- initialising the content/metadata repository;
- calling the respective analysis service by using the dedicated client component and monitoring its execution; and
- updating the content/metadata repository.

In each of these steps, the generic service handler accesses the appropriate software modules provided as Java classes to perform the following actions:

- the communication with the content/metadata repository using the appropriate web service interface;
- the communication with analysis services through the respective web service interface; and
- handling of execution errors, either at the process level or internally in the MPMF for those errors that are raised during the communication with the analysis and repository services.

The BPMN 2.0 processes generated from the task models form a solid base for the concrete implementation of the scenarios (as listed in Table III) to executable workflows. Nevertheless, some adaptations were required to meet technical requirements of the JBoss Enterprise SOA Platform. Custom adaptations had to be implemented to realize process logic to, for example, handle branching within the process dependent on the output of an activity. In addition to that, the components for error handling were not considered from the perspective of task models, but these routines are indispensable for the technical implementation as they are required to guarantee an error-robust operation of the MPMF.

In addition to the JBoss extensions in the integration layer, the MPMF was equipped with an XML database (eXist 2.0) which provides the possibility to store different workflow configurations for a business process. For each single activity which is included in a business process, the configuration specifies all parameters which are to be used for the correct service execution. A service was developed to support the workflow configuration functionality in the MPMF, providing a web-service interface for external access (see Figure 4). Through this web-service interface, the external control and configuration UI can read, optionally modify and store workflow configurations before starting a business process. The corresponding workflow configuration model is shown in Figure 5.

5. Results

5.1 Implemented services

Based on the usage scenarios, an appropriate set of analysis services has been identified. These are required to realize the processes and can be divided into three main categories:

1. video and audio analysis (e.g. key frame extraction, near duplicate detection, automatic speech recognition and genre detection);
2. text analysis (e.g. machine translation, named, entity recognition); and
3. human interaction (result verification and manual annotation).

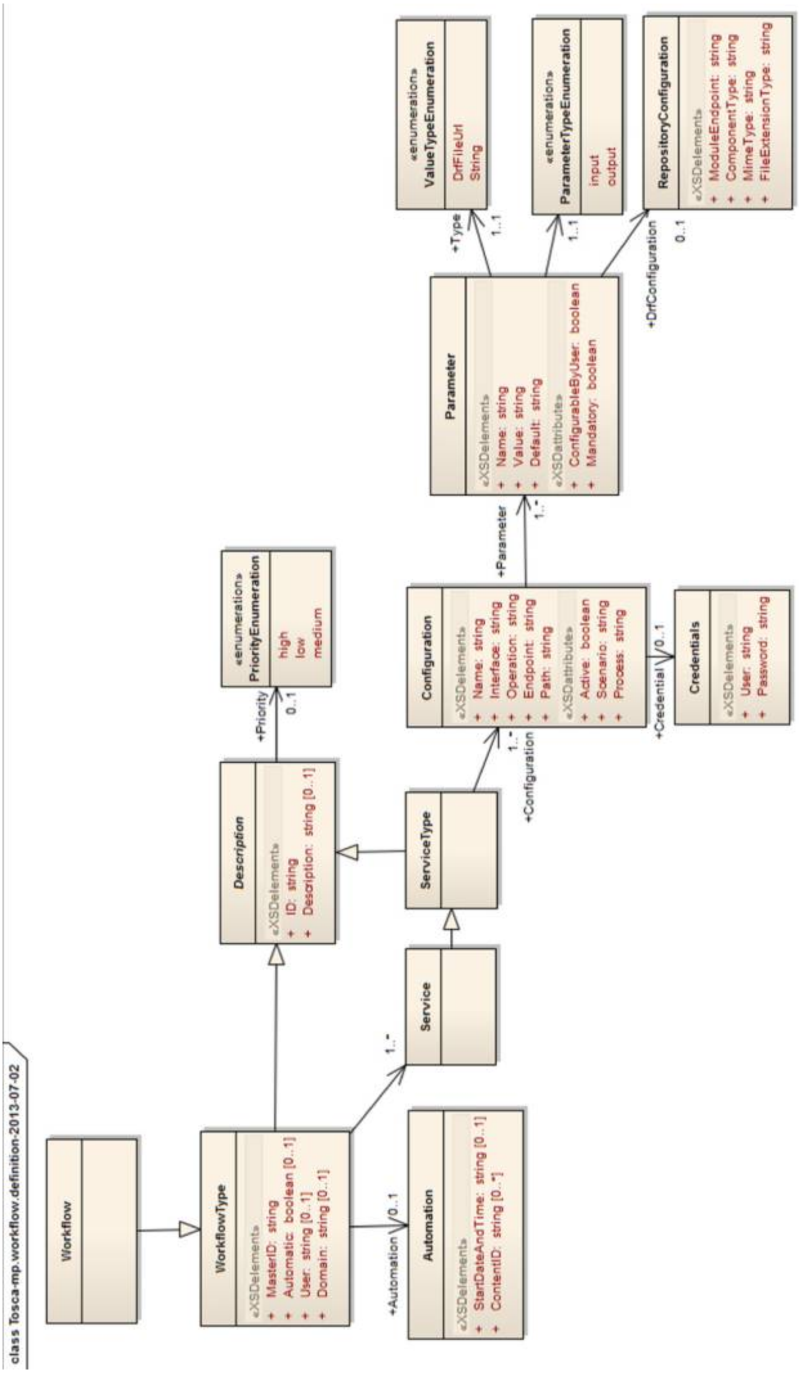

Figure 5.
XML schema for workflow configuration

It was found that different usage scenarios independent of each other use the same task in a different context. To avoid unnecessary duplication of tasks a common workflow – the so-called Configurable Analysis Task Model (CATM) – has been defined. The CATM combines all individual tasks of several usage scenarios into one single workflow. This ensures that an activity is performed only once. A corresponding configuration allows controlling the workflow according to the usage scenarios.

The simplified representation of the CATM in Figure 6 shows various feature extraction and analysis subprocesses that consist of multiple activities (in blue), a human interaction activity (red) and subprocesses that are covered by a single activity in the MPMF (yellow). Within the CATM, some activities depend on others; for example, the CATM includes a genre-dependent branching in which one of three analysis subprocesses in the business process is executed based on the results of the genre classification. These subprocesses contain activities that specifically support the further processing of essence having the respective genre (e.g. sports or news, see Figure 6).

To keep the workflow flexible enough, an additional independent configuration solution was developed which can be used independently of the process engine. It allows the user to readjust individual activities or services to some extent. The user should be able to change the relevant settings for an activity or service at any time without having to change the business process implementation. For example, he should be able to set the target language for an automatic translation service.

The workflow configuration is managed separately and only loaded at runtime of the business process. Before the user starts the business process, he can make the relevant settings for each corresponding activity. When starting the business process, the relevant configuration must be referenced. In addition to the user modifiable settings in the configuration, it is also possible to define which service is executed for a specific activity in the given business process. This way, it is possible to (de-) activate relevant activities within a business process to flexibly support multiple usage scenarios.

5.2 Example scenario

The following is a description of an example scenario for the system. This scenario was one task used as part of user trials for validation of the developed system:

> It is late 2004, and the Tsunami in the Indian Ocean hit the coast of several countries in this region. You are working on a story for a news broadcast on this topic and there is an item coming in from a German source on a video feed. You want to assess whether this item is relevant and part of that material could be included in your story. Automatic information extraction tools can help you in this assessment, to understand what the item is about (even if you do not understand German) and to get an overview of the content. You do not have the

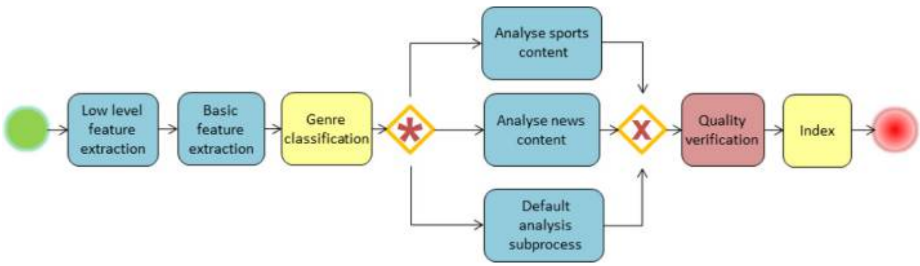

Figure 6. CATM process model – simplified representation

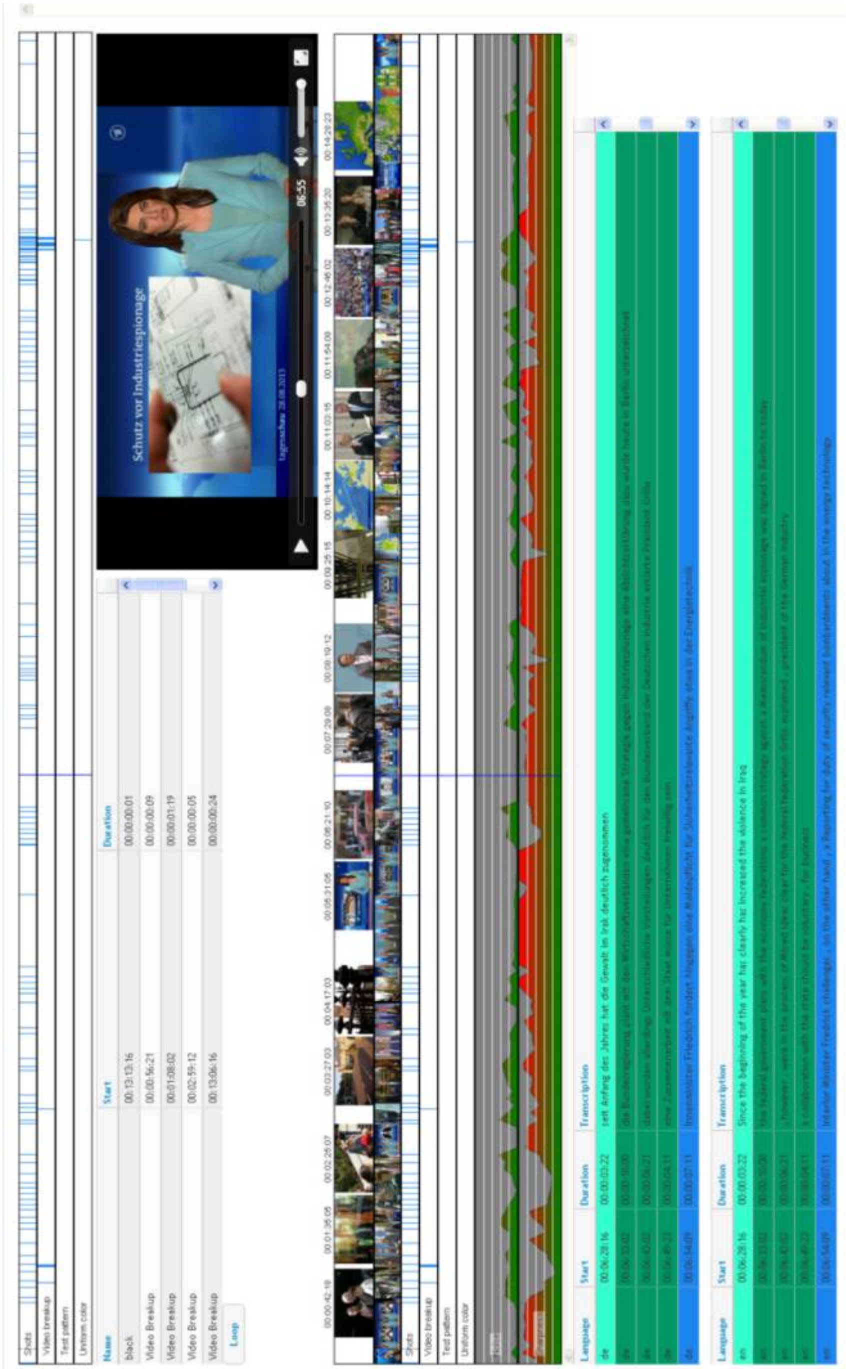

Figure 7.
User interface of the AVDP viewer

necessary information extraction tools at your local site but only a computer with a web browser. You upload the item from the feed to a distributed repository. You can trigger automatic analysis for this item and monitor the completion of this process. Then you can view the different analysis results to assess the relevance of the item. You can modify/add some of the annotations for later use, e.g. to use part of the item in a longer news magazine. To use the item later, you can use a search tool to find it again based on the annotations.

The user accesses a web-based UI to add the clip from the feed to a distributed content repository. Then the control and configuration web UI is used to invoke automatic content analysis. This creates a job instance of the CATM, using a configuration selected by the user. In this scenario, the user probably will select a configuration that is optimised for speed. Genre classification identifies the clip as a news item, and language identification determines that the speech is in German. The news analysis branch is executed, activating (amongst others) the automatic speech recognition modules and the machine translation tools with the appropriate configurations. In addition, visual content analysis (e.g. face detection, near duplicate detection) is executed.

At the output of the automatic content analysis, a metadata document conforming to the MPEG-7 Audiovisual Description Profile (AVDP, ISO/IEC 15938-9:2005/Amd 1:2012) is created. The results of the analysis process can be reviewed by the web-based AVDP viewer, shown in Figure 7.

6. Conclusion

We have proposed a novel approach to defining business processes and orchestrating services for supporting media production processes with automatic metadata extraction. Starting from a high-level view of the business goals supported, we derive scenarios and descriptions of tasks. We have introduced a model-based approach (known from user interface design) to media processing, and have proposed a reification process that turns a formal task model (represented in CTT) to a business process (represented in BPMN 2.0) and with the help of a workflow configuration into an executable job. A framework called MPMF has been implemented for the flexible and adaptive orchestration and execution of automatic metadata extraction.

By means of this approach, the implementation of the business process defines the workflow, whereas the services that are actually used are defined by the configuration. Thus, the processes are stable and, at the same time, the services can be managed very flexibly. If necessary, service implementations can also be completely replaced by others without changing the business process implementation.

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