# Towards Context-aware Multimedia Processing through Semantic Web Services

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## ABSTRACT
The increasing availability of distributed digital TV and multimedia (MM) resources - content and Web services - on the Web, raises the need to automatically retrieve and process resources to satisfy a given context. In order to fulfill a particular content need, usually a set of operations, realised through Web services, have to be orchestrated to retrieve and process, e.g. scale or transcode, MM content out of distributed repositories. However, the heterogeneities between concurrent MM metadata schemas and vocabularies raise issues with respect to interoperability. To overcome these issues, we propose the derivation of so-called Situation-driven Processes (SDP) for the digital TV domain. SDP are supported through a dedicated ontology, being aligned to the SWS reference ontology WSMO, and provide a means to semantically describe context-driven Web service orchestrations as being required for context-aware MM resource retrieval. Providing a specific SDP derivation for MM consumption contexts – being aligned to concurrent MM and TV metadata schemas and vocabularies – supports the automatic discovery of MM and TV resources while supporting interoperability across distinct MM and TV content repositories.

## Categories and Subject Descriptors
H.1.2 [**Models and Principles**]: User/Machine Systems - *Human information processing*; H.3.5 [**Information Storage and Retrieval**]: Online Information Services – Web-based Services; H.4 [**Information Systems Applications**]: Miscellaneous.

## General Terms
Design, Experimentation.

## Keywords
Semantic Web Services, TV, Multimedia, Provisioning, Context.

## 1. INTRODUCTION
A continuously increasing amount of *digital TV content* and *multimedia (MM) resources* is available on the Web, ranging from user-generated video content, commercial Video on Demand (VoD) portfolios to a broad range of streaming and IPTV resources and corresponding metadata records [16]. Please note that in the following the term MM refers to all sorts of MM and TV content. Besides, a widespread availability of open and web accessible software interfaces – for instance based on standard Web service technology such as SOAP [19], UDDI [20] and WSDL [21] – provides access to software functionalities able to process MM resources, i.e. to retrieve, transcode or scale content [16][17]. In line with the increasing usage of the term Web service in a broader sense, in the following we will use it synonymous with any kind of software functionality which is accessible through HTTP or any other IP-based layer.

The widespread availability of MM-related Web services raises the need to automatically discover, compose and process appropriate content for a given need within a certain context. Whereas the *context* is defined as the entire set of surrounding situation characteristics, each individual *situation* represents a specific state of the world, and more precisely, a particular state of the actual context [18]. Particularly, a *situation description* defines the context of a specific situation, and it is described by a combination of *situation parameters*, each representing a particular situation characteristic. Following this definition, *context-adaptation* can be defined as the ability to adapt to distinct possible situations.

Particularly in the field of MM provisioning, context parameters are manifold and have a strong impact on the potential appropriateness of resources. Parameters comprise, for instance, the constraints raised by the device, e.g. resolution, or performance, the ones indicated by the connection, e.g. the available bandwidth and reliability or the user-related ones, such as personal preferences and background knowledge. Therefore, the challenge is to provide the appropriate MM content to suit a given context, what usually involves the dynamic discovery, composition and orchestration of sets of software operations, to retrieve and process content appropriately.

With respect to this goal, several issues are apparent:

I1. **Concurrent metadata schemes and vocabularies.** Distinct approaches to metadata capturing exist, ranging from light-weight tagging approaches as deployed within user-driven websites such as youtube[1] or general-purpose metadata standards such as Dublin Core [6] to fully-fledged domain-specific metadata standards such as MPEG-7 [9] or TV-Anytime[2]. Besides, concurrent vocabularies – differing in terminology, syntax or language - are widely used to describe metadata leading to heterogeneities and ambiguities [10][16].


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[1] http://www.youtube.com
[2] ftp://tva:tva@ftp.bbc.co.uk/pub/Specifications/0-Specifications.html

I2. **Lack of metadata comprehensibility and semantic meaningfulness.** Web service as well as MM content metadata lacks expressivity due to merely syntactic annotations – usually based on XML schemas – not exploiting semantics of the used terminology [1][8][14]. This issue applies to both, available content and accessible software functionalities such as Web services, and hence, hinders the automatic composition and processing of both. Moreover, current MM metadata schemas usually focus on the low-level parameters describing the actual format and audio-visual characteristics of MM assets, although a combined representation of both the actual content semantics as well as its audio-visual format is required [13].

I3. **Lack of unified MM resource vocabulary.** Particularly, the annotation of all sorts of MM resources and their specific characteristics requires a formal semantic vocabulary dedicated for this purpose [11][15]. Whereas certain vocabularies for annotation of MM content do exist – some even exploiting formal semantic representation languages – these are widely heterogeneous and no common alignment does exist. Moreover, existing vocabularies do not facilitate representation of both MM services as well as content and are not aligned to existing MM-specific and domain-independent representation approaches.

Semantic Web Services [7] aim at the automatic discovery and orchestration of resources, Web services and data, based on comprehensive semantic representations. In order to enable the automatic provisioning of MM resources while overcoming the issues introduced above, we propose a SWS-based framework which abstracts from both (a) annotation schemes and vocabularies and (b) available software interfaces, such as Web services. By deriving *Situation-driven Processes (SDP)* [4] – which are aligned to the SWS reference model WSMO [22] – for the needs of MM consumption and provisioning contexts, we enable the representation of comprehensive context-adaptive service orchestrations in terms of domain-specific parameters. SDP, supported through a dedicated ontology, allow the representation of comprehensive, context-adaptive service orchestrations. Representing MM resources and the contexts in which they are consumed through a coherent formal vocabulary enables the automatic composition and orchestration of Web services which finally retrieve and process the appropriate content to suit a given set of MM context parameters. The alignment of existing MM vocabularies and metadata schemes further facilitates interoperability with existing MM technologies.

# 2. SEMANTIC WEB SERVICES

SWS technology aims at the automatic discovery, orchestration and invocation of distributed services for a given user goal on the basis of comprehensive semantic descriptions. SWS are supported through representation standards such as WSMO [7][22] and OWL-S [12]. We particularly refer to the *Web Service Modelling Ontology* (WSMO), a well established SWS reference ontology and framework. The conceptual model of WSMO defines the following four main entities:

- *Domain Ontologies* provide the foundation for describing domains semantically and are used by the three other WSMO elements.
- *Goals* define the tasks that a service requester expects a Web service to fulfill.
- *Web service* descriptions represent the functional behavior of an existing deployed Web service. The description also outlines how Web services communicate (*choreography*) and how they are composed (*orchestration*).
- *Mediators* handle data and process interoperability issues that arise when handling heterogeneous systems.

SWS reference models are usually supported through dedicated reasoners, such as the Internet Reasoning Service IRS-III [2] and WSMX [23], which act as broker environments for SWS following one of the established reference models. In that, a SWS broker mediates between a service requester and one or more service providers. Based on a client request, the reasoner proceeds through the following steps:

(i) Discovery of potentially relevant Web services.
(ii) Selection of set of Web services which best fit the request.
(iii) Invocation of selected Web services whilst adhering to any data, control flow and Web service invocation constraints defined in the SWS capabilities.
(iv) Mediation of mismatches.

However, the domain-independent nature of SWS reference models requires their derivation to facilitate the representation of certain domain-specific contexts.

# 3. CONTEXT-AWARE MM PROCESSING

Following our vision, MM provisioning applications follow a SWS-based approach based on abstract semantic representations of contexts and resources. In that, given a certain context representation, resources are dynamically composed and processed by means of automatic service orchestrations.

In the area of digital MM provisioning, usually a particular user need is satisfied through a combination of services [17]. For instance, to provide a user with a certain video asset, functionalities such as retrieval of the appropriate content together with its processing – e.g. transcoding or compressing – according to the actual user context are required. Such functionalities are becoming increasingly available in terms of Web services and web-accessible APIs. Both, the actual user need and the nature of the required software services are strongly dependent on the actual user context, i.e. the apparent situation parameters. To cater for this aspect, we introduced the notion of SDP in previous work [3][4]. Here, we propose their domain-specific derivation for the needs of MM provisioning.

## 3.1 Situation-driven Service Orchestrations for Context-aware Multimedia Processing

Following our vision, a SDP consists of *Situations (S)* and *Goals (G)*, where a Goal represents a particular activity within a process from a user perspective and links two situations leading from an initial situation to a desired situation (Figure 1). Each Goal is supported by a set of *Brokered Goals (BG)* which are achievable and brokered via a SWS broker. Since we refer to WSMO as SWS reference implementation, BG are derived from WSMO Goals. BG and SWS support the system perspective of a process, since they are linked (via mediators) to semantic descriptions of available Web services that, once discovered and selected, will provide the appropriate resources needed to progress a situation. For instance, one BG could be aimed at retrieving required video content out of specific repositories whereas another aims at transcoding the asset according to constraints posed by the user environment. Note that the achievement of BG subsequently modifies the actual situation until the desired situation is reached.

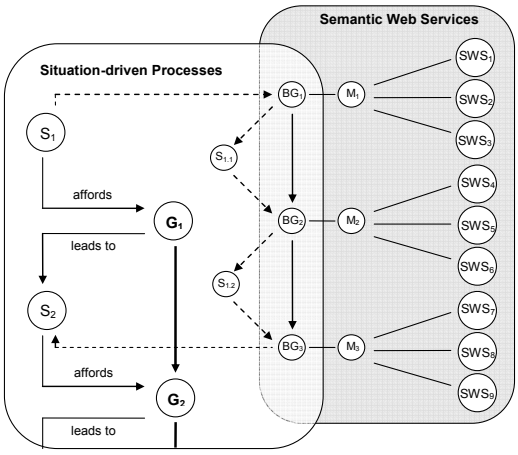


**Figure 1. Situation-driven Processes for SWS.**

In previous work, we provided a general-purpose and domain independent formalisation of the SDP approach by means of a dedicated ontology (SDPO) which is aligned to WSMO as well as other well-known foundational ontologies [3][4]. Please note that process situations are highly dependent on the domain and nature of a process, since each domain emphasizes different situation parameters. Therefore, we foresee multiple domain-specific derivations of the introduced SDP-model. Particularly in the field of MM provisioning, context parameters are rather diverse and manifold. Hence, we propose the domain-specific derivation of SDPO to appropriately represent MM provisioning contexts.

## 3.2 Conceptual Framework

Based on previous research [3], we foresee a conceptual approach aiming at overcoming the issues introduced in Section 1 and consisting of two key principles:

P1. Abstracting from heterogeneous MM vocabularies and schemas,
P2. Abstracting from MM content and services.

While P1 aims at providing a common semantic basis to align concurrent MM metadata formats, schemas and vocabularies from the domain of digital MM provisioning, P2 targets the abstraction from distributed MM content and Web services. Figure 2 depicts the conceptual framework adopted to realise principles P1 and P2 in the domain of digital MM content. We introduce a semantic representation layer stack, derived from [3] and adopted for the MM domain, consisting of 3 layers. The *Semantic Web Service Layer* abstracts from available distributed Web services – which operate on top of distributed MM content – by means of SWS technology to enable the automatic discovery and orchestration of available services. The *Semantic SDP Layer* realizes the SDP vision by providing a domain-independent vocabulary for SDP by means of a dedicated ontology (SDPO) [3][4]. To abstract from distinct metadata vocabularies and schemes which are widely utilized to annotate MM resources, the *Semantic MM Processing Layer* provides a common vocabulary to represent MM resources – content as well as services – by means of a shared ontology (*MM Processing Ontology, MMPO*). The latter is aligned to the Semantic SDP Layer and derives its concepts for the specific needs of MM processing.

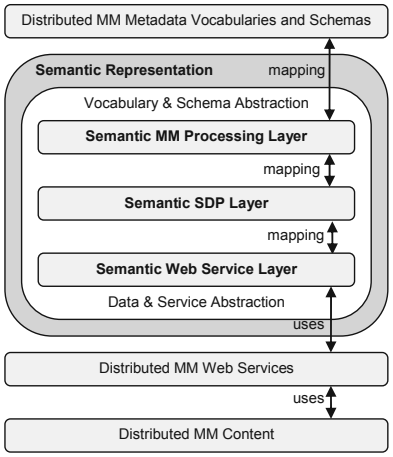


**Figure 2. Conceptual Framework.**

MMPO particularly considers the representation of (a) low-level descriptions of the (audio-visual) format of the MM asset and (b) annotations of the actual content. In that, MMPO provides the basis to align distinct external vocabularies - such as domain ontologies to support (b) as well as MM specific metadata schemas and vocabularies to support (a) - and to express domain-specific SDP which describe context-sensitive MM processing sequences.

A SWS broker and reasoning environment, such as IRS-III, is capable of hosting and reasoning on the proposed semantic layers. Given a particular request which defines the actual context by means of a situation description (Section 3.1), reasoning on the provided ontologies – as part of the proposed semantic layers – allows to automatically compose a SDP which considers all processing activities required to satisfy the actual context. This SDP is executed in terms of SWS goal achievements what leads to the automatic orchestration of Web services which retrieve, process and adapt the actual MM content which is then delivered to the users device. A first prototypical application deploying parts of the conceptual framework above has been developed. The application utilizes SDPO to support automated selection between a number of MM-related Web services which deliver MM content and make use of the youtube-API[3] as well as the data feeds provided by BBC-Backstage[4] and Open Video[5].

# 4. CONCLUSIONS

In order to enable automated discovery and composition of all sorts of digital MM resources – MM content assets and streams as well as Web services that process these – we proposed a conceptual framework based on SWS. By introducing a set of semantic layers, we aim at the semantic abstraction from both distributed MM content and services as well as concurrent metadata schemas and vocabularies. Following up on previous work of the authors, we adopted the notion of SDP – allowing for the semantic representation of context-adaptive Web service orchestrations – and foresee a domain-specific derivation for the field of MM processing. The inherent alignment of our framework with established SWS technologies in terms of WSMO enables the automatic execution of SDP by means of SWS discovery and orchestration. Hence, we

[3] http://code.google.com/intl/en/apis/youtube/
[4] http://backstage.bbc.co.uk/
[5] http://www.open-video.org/

address the context-adaptive composition and orchestration of MM services and content at runtime, i.e. when the actual content need occurs, as opposed to the common predefinition of Web service orchestrations at design-time. By also aligning the provided semantic layers, namely the Semantic MM Processing Layer facilitated through MMPO, to concurrent external MM vocabularies and metadata schemas, we particularly foresee the ability to transform between different MM metadata approaches to facilitate interoperability.

The authors would like to highlight that following the conceptual framework proposed here requires an additional effort, which needs to be investigated within future work. However, through alignment of the proposed layers with well-established standards and upper-level ontologies – as discussed in [4][5] – a high level of interoperability and applicability of the resulting annotations can be ensured. Future work is dealing with improving the ontologies needed to fully realise the proposed layers as well as the SWS-based application framework.

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