Model Operations for Quality-Driven Multimedia Delivery

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Abstract. With the recent advances in distributed systems and wireless technology, users can access any information, from anywhere with any device. Multimedia delivery services are currently under development to operate in such environments. In this context, it appears essential to offer and support different levels of service according to users requirements and expectations and to work towards quality-driven delivery (QDD). Implementing QDD mechanisms leads us to consider different issues such as system components interoperability, quality information management, distributed execution of QDD activities and multi-criteria optimization. In this paper, we focus on quality information management to support QDD. We propose a model management approach to the problem and we introduce metamodel and model operations for that purpose. We use conceptual graphs formalism to develop our QDD metamodel and we show how the conceptual graph derivation mechanism can be applied to implement some fundamental model operations.

1 Introduction

In the last two decades, we have been faced with tremendous evolution of distributed multimedia systems in order to support emerging applications such as electronic commerce, health-care applications, digital publishing or infotainment. These applications integrate large amounts of voluminous data, located on several sites interconnected through various communication networks and potentially accessed by a large number of users. Such complex environments require the integration of system management mechanisms providing system scalability, application adaptation and quality of service (QoS) support [14]. Scalability refers to the capacity of the system to evolve according to the charge it faces. Application adaptation refers to the ability of the application to change its behavior according to the changes occurring in the processing environment. QoS is a more general concept referring to the capacity of the system to offer and support different levels of service according to users requirements and expectations. Scalability and application adaptation can be considered as some of the possible mechanisms used to provide QoS support.

QoS support was initially introduced in the field of telecommunication networks and multimedia systems [13] and led to proposals for management strategies aimed at deciding whether and controlling how multimedia streams can be delivered to the user with some constraints. These constraints are expressed during a specification step where the user specifies his requirements, generally concerning system performance relative to media delivery and synchronization. The system then works to deliver the specified level of service and for that purpose transforms the users' requirements into various constraints mainly targeted to the transport system [7].

If we consider the notion of QoS from a broader perspective, we have to position the user at the center of the process and allow him to express non-functional requirements. We can then talk about quality-driven delivery (QDD) where the user's quality requirements are taken into account in the different steps of the delivery. With this perspective in mind, implementing QDD mechanisms leads us to consider different issues such as system components interoperability, quality information management, distributed execution of QDD activities, and multi-criteria optimization. In this paper, we focus on quality information management to support QDD. We propose a model management approach to the problem and we introduce metamodel and model operations for that purpose. We use conceptual graphs formalism to develop our QDD metamodel and we show how the conceptual graph derivation mechanism can be applied to implement some fundamental model operations. The rest of the paper is organized as follows. Section 2 presents the principles of QDD and motivates the use of an approach based on model management. We present our modeling formalism and our architecture in Section 3. In section 4 we propose and explain our metamodel. Section 5 presents some operations we need to process on models in order to support QDD. Section 6 concludes and presents some future work.

2 Quality-driven Delivery

Quality-driven delivery refers to the capacity of services to deliver objects, while considering the users expectations in terms of non-functional requirements. For example, an adaptive video delivery service must consider user expectations in terms of the perceived quality of video sequences to be delivered, as well as the characteristics of the equipment used for delivery (cellular phone, PDA or other). In this case, the video delivery service has to choose among possible variants of the video sequence, the one satisfying the user expectations and the equipment constraints.

Some approaches have been proposed for multimedia application adaptation, more specifically for adaptation to the technical infrastructure used for accessing multimedia objects [8][6][15]. Most of them are more oriented towards resource allocation than user-perceived quality. We believe that it is time to consider maximizing the user-perceived quality as a main objective.

These considerations may be placed in the more general context of the Web Accessibility Initiative (WAI) initiated by the World Wide Web Consortium. The accessibility to the World Wide Web is important and there are barriers on the Web for many types of disabilities. A QDD approach based on the user requirements considers all personal (physical, cognitive and affective) parameters.

In this section we first introduce the general principles and activities involved in a QDD process and we illustrate them with the help of a simple adaptive video delivery application. We then motivate the use of a model management based approach.

2.1 Principles and Activities

QDD can be viewed as a generalization of QoS management, and some of the traditional QoS activities can be transposed for QDD. More specifically, when studying quality information management, we are mainly interested in the three following QoS activities: specification, monitoring and mapping.

Specification consists in identifying the quality dimensions to express user's requirements such as time, cost or data quality and of defining the expected level of quality. Monitoring consists in collecting information on the quality level that can be provided by the different components of the distributed multimedia system, such as the video server, the communication server, the database server or the client device. Mapping consists in converting qualitative and subjective quality levels into quantitative and measurable quality levels, as well as to convert these quantitative quality levels to constraints corresponding to resource requirements for the object delivery. A QDD system then requires the description and management of this quality information. Based on this information, the system takes decisions that are transmitted to the different components supporting QDD.

To illustrate the principles of QDD, we take the example of a simple adaptive video delivery service where the users specify their quality preference according to three dimensions: the language of the audio sequence and the size and the frame rate of the video. The adaptation process leads to take decisions in order to deliver a variant of the initial high quality video sequence compatible with the available resources.

2.2 Quality Information Management

The focus of the work presented in this paper is the management of quality information or quality metadata related to the user requirements, the objects to be delivered and the resources used for delivery. Quality information comes from different sources and can be heterogeneous. For example, quality information associated to video objects can differ depending on the encoding format and the standard used to describe associated metadata. The monitoring tools used to collect quality information about the service level of the system components can also produce heterogeneous information. We see that there is a need for homogenization and integration of quality information. Different factors can influence user-perceived quality, and any metadata associated to multimedia object should be considered as a potential candidate for being a quality factor. Thus, there is a need for extension and adaptation of quality information models as well as for tools allowing description, integration and translation of quality information sets coming from different sources and represented using different formalisms or standards.

This problem is similar to the problem of data migration or schema translation in the field of metadata management for data warehouses and web portals. For QDD, we are interested in a subset of metadata, metadata describing the quality of objects, data sources or resources. To solve the problem of data migration and schema translation, database researchers have recently proposed an approach based on model management [1] [2]. These authors propose to address the problem from a higher level of abstraction and to work on models rather than working on data. This approach would lead to the development of a generic infrastructure for managing models and to the introduction of model operations for integration and translation of data.

At the same time, in the field of software engineering and more specifically for software production, the Object Management Group (OMG) recently launched the Model Driven Architecture (MDA) to move from code-oriented software production techniques to model-oriented production techniques [10][3]. The objective is to allow abstraction, refinement and different viewpoints of models representing the function, structure or behavior of a system. The other important objective is to be able to design models independent of platform and implementation environments. The concept of platform-independent model (PIM) and platform-specific model (PSM) have been introduced for that purpose.

We believe that quality information management for QDD is a good candidate for model management, because not only are we concerned by integration and translation of quality metadata but also because QDD is provided in a distributed and heterogeneous environment where monitoring tools are fully platform-dependant.

3 Modeling Formalism

When looking at modeling techniques to deal with model management in the context of QDD, we have chosen conceptual graphs formalism for two reasons: (i) type definitions are made at instance levels, and (ii) there exists a very powerful mechanism called conceptual graph derivation, that can be used for fundamental model operations.

In this section, we first introduce our overall modeling architecture and identify where our work takes place, and then we give a brief introduction to conceptual graphs for those who are not familiar with this formalism.

3.1 Modeling Levels

Our overall modeling architecture is a four layers architecture, based on the notions of model, metamodel and meta-metamodel.

In our context we define a model as an abstract representation of something that happens in the real world. A model is a simplification of a situation that takes place in the real world. The way and the vocabulary we use to build models are called the metamodel. The metamodel is a precise definition of the constructs and rules that are used in models. At the highest level, the meta-metamodel defines the language used in metamodels. In this paper we use the conceptual graph formalism to represent these models and their relationships.

Conceptual graphs are graphs made of concepts (a box with a type label and a referent) and conceptual relations (a circle with a type label). The type label identifies the type of the referent or of the relationship. Conceptual graphs will be presented in more details in the next section.

Figure 1 illustrates the four layers architecture where:

- M0 is the real world where the situation we want to represent takes place. The M0 level is described at level M1.
- M1 is the model level. It represents a particular situation of the real world. It defines types and instances that represent the real world, M0. Models at level M1 are expressed using a language that is defined at level M2.
- M2 is the metamodel level: our meta-model for QDD. It contains all the vocabulary used at level M1.
- M3 is the meta-metamodel: the formalism of conceptual graphs. We show only constructs of the formalism that are involved in the example. A complete description can be found in [5]

In Figure 1, at level M0 Mary is specifying her requirements. She wants her video in French. This is represented at level M1 by Req. This requirement contains a qualitative dimension Language which is characterized by the value 'French'. At level M2 we find the vocabulary needed to describe M1. In the example, for clarity purpose we show only concept types QualitativeRequirement, QualitativeDim, Value and relation type chrc (characterizes). At level M3 is the meta-metamodel with Concept Type and Relation Type. The meta-metamodel is defined using itself and thus is the highest level.

The conceptual relation meta links two constructs from two adjacent levels or two constructs from level M3. In Figure 1 conceptual relations meta has been added to better understand the different modeling levels and their relationships. They are implicitly defined in the type of concepts.

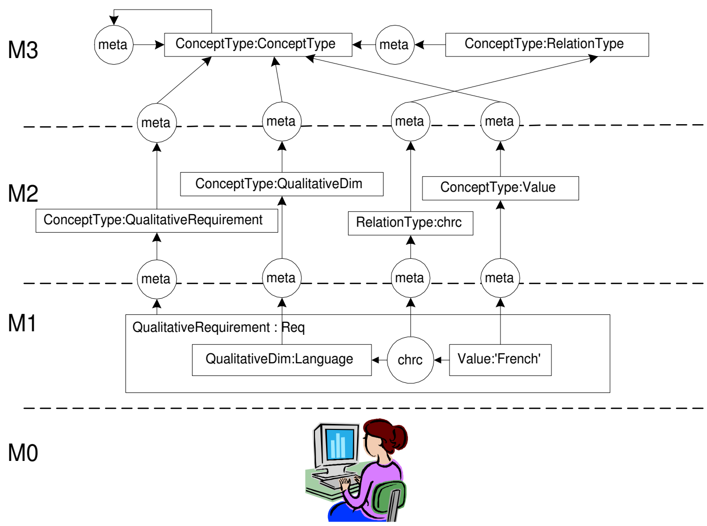

Fig. 1. Four Layers Architecture.

3.2 Conceptual Graphs

This section presents a brief introduction to the formalism of conceptual graphs introduced by John Sowa in 1984 [11]. Only a minimum explanation is provided as required to understand the rest of the paper. More information on conceptual graphs can be found [12] and [4].

Conceptual graphs are a formalism whereby the universe of discourse is modeled by concepts and conceptual relations. Concepts may be categorized based on the type of conceptual relations they have with other concepts. Concept types define these categories. A concept type is defined by a definition graph any instance of that concept type must comply with. Figure 2 presents the definition graph of EMPLOYEE that means that an employee is a person that works for some organization.

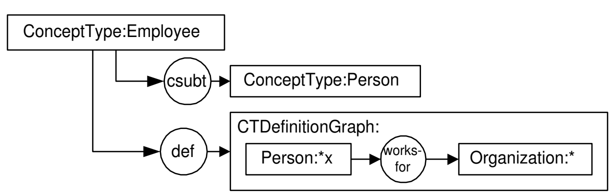

Fig. 2. Conceptual Graphs: Type Definition.

We now present two theorems from [11] that specify how conceptual graphs can be structured.

Theorem 1. *Generalization, denoted $\leq$, defines a partial ordering of conceptual graphs, called the generalization hierarchy. For any conceptual graphs u, v and w three conceptual graphs, the following properties are true:*

– Reflexive. $u \leq u$;
– Transitive. *If* $u \leq v$ *and* $v \leq w$*, then* $u \leq w$;
– Antisymmetric. *If* $u \leq v$ *and* $v \leq u$*, then* $u = v$;
– Subgraph. *If* v *is a subgraph of* u *then* $u \leq v$;
– Subtypes. *If* u *is identical to* v *except that one or more type labels of* v *are restricted to subtypes in* u*, then* $u \leq v$;
– Individuals. *If* u *is identical to* v *except that one or more generic concepts of* v *are restricted to individual concepts of the same type, then* $u \leq v$.

Last we present the fundamental operation on conceptual graph that calculate the specialization relationship.

Theorem 2. *For any conceptual graph* u *and* v *where* $u \leq v$*, there exists a mapping* $\pi : v \rightarrow u$*, where* πv *is a subgraph of* u *called a projection of* v *in* u*. The projection operator* π *has the following properties :*

– *For each concept* c *in* v*,* πc *is a concept in* πv *and* $type(\pi c) \leq type(c)$*. If* c *is individual, then* $referent(c) = referent(\pi c)$*.*
– *For each conceptual relation* r *in* v*,* πr *is a conceptual relation in* πv *and* $type \pi r = type(r)$*. If the ith arc of* r *is linked to a concept* c *in* v*, the ith arc of* πr *must be linked to* πc *in* πv*.*

We will use these theorems for model management operations. The reader interested in their demonstrations will find them in [11].

We can now understand why conceptual graphs are well adapted for model management. Types definitions are made at instance levels that, means that types are defined by graphs made of instances and part of these instances may be generic or individuals. Types and instances are represented with the same elements: concepts and conceptual relations. Therefore we define models (types) and requirements (instances) as graphs and we use generalization and derivation operations to manipulate them. Using Object oriented technology like UML is more problematic because classes (types) and objects (objects) are different in nature and cannot be mixed or manipulated by the same tools.

4 Metamodel for QDD

In this section, we present the metamodel we propose for QDD. This metamodel specifies the vocabulary and grammar we will use to describe quality information for users, media objects and system components.

4.1 Dimension

Quality information is built with the concept of dimension. Dimensions are used to describe objective or subjective characteristics relative to the quality of a delivery service or the quality of an object to be delivered. Subjective characteristics refer to the quality level perceived by the user while objective characteristics refer to a measurable quality level. An example of a dimension is network-throughput. This dimension is objective and can be measured using monitoring tools for communication networks. We call such a dimension a quantitative dimension. An example of a subjective dimension can be response-time with the values: (unacceptable, bad, good, excellent). This dimension a qualitative dimension since the possible values depends on the perception or the interpretation of the user. Figure 3 presents the concept type definition graph for Dimension. A Dimension is defined on a domain of possible values.

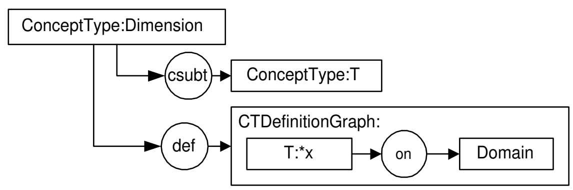

Fig. 3. QDD Metamodel : Dimension element.

We define two types of dimensions: qualitative dimensions and quantitative dimensions.

4.2 Quality Information Models

The quality information, built with the concept of dimension, is modeled in quality information (QI) models. QI models describe the structure of quality information and allow the reuse, transformation and extension of existing models. A Model is represented by a graph that contains Dimension elements. Figure 4 shows the concept type definition graph for Model.

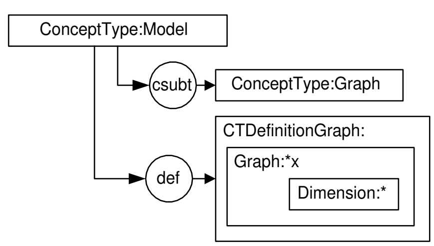

Fig. 4. QDD Metamodel : Model element.

QI models can be User Quality Model or Actor Quality Model. The model elements of a User Quality Model describe the dimensions used to specify the expected quality level. We make a distinction between Qualitative Quality Model where the dimensions included in the model are qualitative dimensions, and Quantitative Quality Model where the dimensions are quantitative dimensions. Figure 5 presents the type hierarchy for Model.

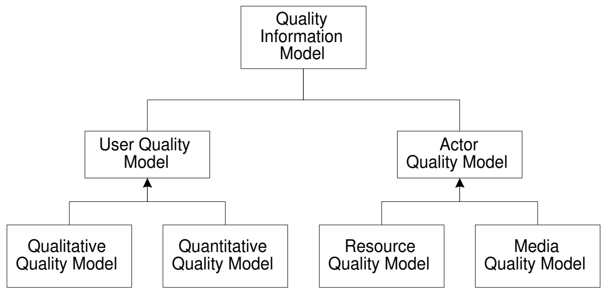

Fig. 5. Quality Information Models.

The model elements of an Actor Quality Model integrate the quantitative quality dimensions along which is described a quality level. We make a distinction between a Media Quality Model built with the dimensions used to describe the quality level of an object to be delivered, and a Resource Quality Model describing the quality level offered by a system component (communication network, database system, video server, user's device etc.).

We give in Figure 6 an example of a Quantitative Quality model. The model has been simplified in order to understand the relationship between the metamodel at level M2 and models at level M1. The VideoDeliveryModel is a graph that contains three dimensions Language, Frame Rate and Size.

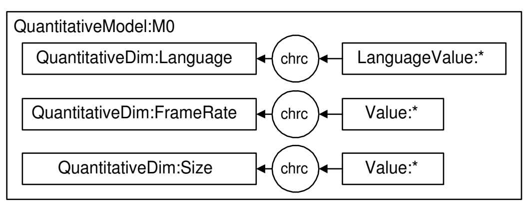

Fig. 6. QDD Models : an example.

4.3 Derived Models

In our approach, we consider that there exists a predefined Quality Information Model: the Core Model. The Core Model is unique and contains the predefined set of dimensions relevant for all types of QDD services. From this Core Model, we can derive other models. The Core Model can be built on the basis on existing standard such MPEG-7[6]

Derived models are models that are built from other models. A derived model is a graph that is a generalization of another model. Explanation of derivation mechanism will be detailled in Section 5

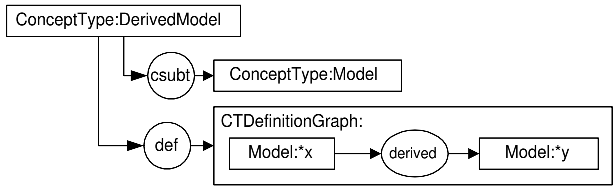

Fig. 7. QDD Metamodel : Derived Model element.

4.4 Instances of Models

From Quality Information Models we instantiate Quality Information. We distinguish : Qualitative Requirement, Quantitative Requirement, and Quality Level. From a Qualitative Quality Model we instantiate a Qualitative Requirement which is the user's specification of the expected quality level. From an Actor Quality Model we instantiate a Quality Level for a given actor (media or resource) and from a Quantitative Quality Model we instantiate a Quantitative Requirement

In Figure 8 is the concept type definition of Quantitative Requirement. Quantitative Requirements are built from Quantitative Quality models. A quantitative requirement is a graph that has a relationship instOf with a quantitative quality model. Explanation of instantiation mechanism will be detailed in Section 5

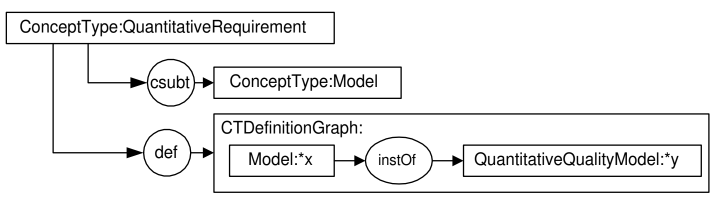

Fig. 8. QDD Metamodel : Quantitative Requirement element.

5 Model Operations

While considering model management for QDD, we have to consider the different operations to be performed on models during the different steps of a QDD process. The first operation occurring is the definition of the different QI models supporting the process. In order to avoid repetitive tasks in model definition and creation and to favor reuse of predefined or existing models, we introduce the derivation operation. The second operation we consider in this paper is the model instantiation, where a container for quality information is created in associating values or constraints to the dimensions that constitute the QI model.

Another important operation is the model transformation, where semantic or implementation rules are expressed to transform instances of a source model to instances of a target model. The transformation operation is not discussed in this paper and is part of our future work.

In this section, we focus on model derivation and model instantiation and we show how the conceptual graph derivation mechanism can be applied for these two operations on QI models. We illustrate these operations with a given model.

5.1 A Quality Information Model

Let $\mathcal{M}0$ be a Quantitative Quality model, Figure 9 presents $\mathcal{M}0$, an example of generic quality model. The graph $\mathcal{M}0$ groups three quantitative dimensions describing the quality of a video Language, FrameRate and Size. Each dimension is characterized by a Value. In the case of Language, a specialized value LanguageValue has been defined as a subtype of Value.

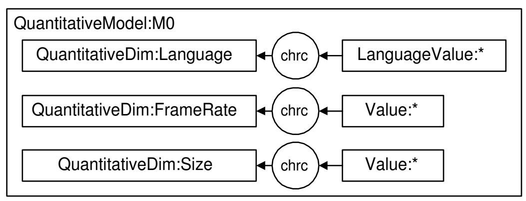

Fig. 9. A Quantitative Quality Model for video delivery..

5.2 Model Derivation

In our approach, derivation is defined as a model specialization. A generic model is specialized into a more specific model where each element of the specialized model is a specialization of an element of the more generic model. In object oriented modeling and in object oriented programming, specialization is well defined [9]. The specialization is implemented through the inheritance mechanism in UML which is based on segment descriptors and full descriptors. A full descriptor is the specification of characteristics of instances. A full descriptor is produced from a set of segment descriptors connected by generalization relationships. Segment descriptors are the elements defined in UML models.

Using conceptual graphs, the model derivation mechanism we defined for QI model management consists in a generalization. From a generic model, a generalization is done by the user selecting the dimensions which he or she is interested in. In this step, the user suppresses the dimensions that are not relevant for him. The result is a subgraph of the original one so the result model is a generalization of the generic model.

From a generic model, $\mathcal{M}0$ we want to derive two QI models for two specific video delivery applications where the users are only concerned by the language quality dimension in the first application and by Frame-rate and Size in the second one. The selection of the pertinent dimensions for the application is made.

The first one is only concerned by the dimension Language. The resulting graph $\mathcal{M}1$ is presented in Figure 10. It is reduced to one dimension. The second one is only concerned by the dimensions FrameRate and Size. The resulting graph $\mathcal{M}2a$ is presented in Figure 10. It is reduced to two dimensions.

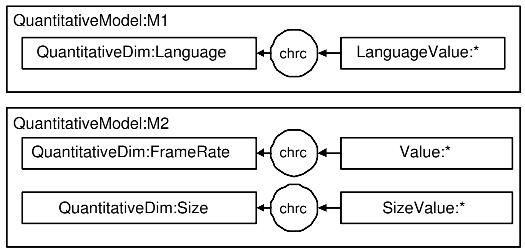

Fig. 10. Model Derivation : example 1 and 2.

In both cases we have a subgraph of the original graph $\mathcal{M}0$. According to Theorem 1 (Section 3.2) $\mathcal{M}1$ and $\mathcal{M}2$ are subgraphs of $\mathcal{M}0$ then we have $\mathcal{M}0 \leq \mathcal{M}1$ and $\mathcal{M}0 \leq \mathcal{M}2$. In the context of conceptual graphs, we use generalization to define the model derivation operation as follows :

Definition 1. *A model $\mathcal{M}x$ is said a* derived model *from the model $\mathcal{M}y$ if there exists a projection $\pi : \mathcal{M}x \rightarrow \mathcal{M}y$. There are the following properties :*

– *$\pi(\mathcal{M}x)$ is a subgraph of $\mathcal{M}y$.*
– *$\mathcal{M}y \leq \mathcal{M}x$.*

5.3 Model Instantiation

Model instantiation corresponds to the creation of a container for Quality Information and the creation of expressions (values or constraints) on the dimensions that are part of a given Quality Information Model. Instantiation of a Quality Information Model produces a Quality Information. Instantiation of a Qualitative (Quantitative) Quality Model produces a Qualitative (Quantitative) Requirement, corresponding to a constraint specifying the quality requirements and expectations for a given user. Instantiation of an Actor Quality Model produces a Quality Level corresponding to the description of the quality level of a system component or of an object to be delivered.

This operation corresponds to the conceptual graph specialization. In the example 1 the requirement is on the language of the video. The language must be French. The concept that represents the value of the language is replaced by an individual concept that refers to the language French. Figure 11 presents the resulting graph $\mathcal{R}eq1$ which is an instance of model $\mathcal{M}1$.

In the second example we assume a new type has been defined. This new type SizeValue is a subtype of Value. Its domain is for example 320x240, 640x480, 720x480. In order to restrict the possible values of size to this set of values we

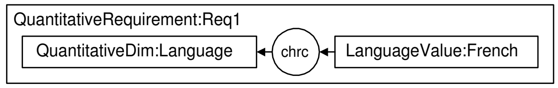

Fig. 11. Model Instantiation : example 1.

replaced Value by sizeValue. The concept remains generic, so it is one of the three possible values. As in the first example, the user wants a specific value for the frame rate, 30 images per second in this case. The generic concept `[Value:*]` is replaced by the individual concept `[Value:30]` . Figure 12 presents the resulting graph $\mathcal{R}eq2$ which is an instance of model $\mathcal{M}2$.

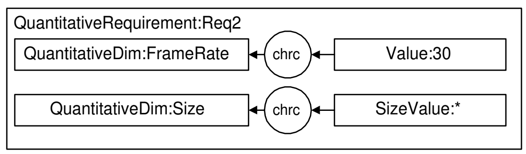

Fig. 12. Model Instantiation : example 2.

In both cases, we use the model instantiation operation which corresponds to the specialization mechanism of conceptual graphs. According to Theorem 1 (Section 3.2) every concept of $\mathcal{R}eq1$ and $\mathcal{R}eq2$ have the same type or a subtype and the referent is the same or a generic referent has been replaced by an individual one in respectively $\mathcal{M}1$ and $\mathcal{M}2$ then we have $\mathcal{R}eq1 \leq \mathcal{M}1$ and $\mathcal{R}eq2 \leq \mathcal{M}2$. The instantiation operation is a specialization in the context of conceptual graphs and we can define it as follows.

Definition 2. *A Quality Information $\mathcal{QI}x$ is an* instantiation *of a model $\mathcal{M}x$ if there exists a projection $\pi : \mathcal{M}x \rightarrow \mathcal{QI}x$.*

6 Conclusion and Future Work

In this paper we have presented a metamodel for quality-driven delivery using conceptual graphs as a modeling formalism. With this metamodel, we have specified the vocabulary and grammar we use to describe quality information for users, media objects and system components.

We have also showed how two model management operations: derivation and instantiation may be implemented in a very simple way through the derivation mechanism of the conceptual graphs. Using the conceptual graphs formalism helped us to clarify the concepts of our metamodel and the corresponding operations. Conceptual graphs appear to be a neutral and powerful modeling formalism for defining model management mechanisms.

In the future, we will work on another important operation for QDD: the mapping operation. Mapping allows the expression of semantic relationships between the concepts of different quality information models. These semantic relationships are defined on the quality dimensions and will be used to transform instances of a source model to instances of a target model. We believe that conceptual graphs with its inference capabilities and agents are certainly a good candidate to formally define mapping operations.

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