Functional Requirements for a Generic Distributed Multimedia Presentational Application [1]

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Abstract

Recent advances in multimedia technology lead to the development of multimedia information systems where services for multimedia objects creation, storage, access, tranfer and presentation are integrated. This integration requires to address issues in different fields such as database systems, communication networks, operating systems or signal processing and needs a thorough understanding of the possible target applications and their requirements. In this paper, we examine in details a generic multimedia presentational application. We propose a functional architecture composed of three different levels : the user interface level, the function level, and the database system level. For each level of this architecture, we describe the functionalities and list the set of corresponding requirements.

Keywords : multimedia applications, functional architecture, functional requirements

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1. Introduction

With the recent advances in computer technology it is now possible to develop multimedia information systems integrating several types of information such as alphanumerical data from traditional applications or images, sounds, graphics and video from more sophisticated applications [Fox, 1991; Narasimhalu, 1991]. Potential applications of this technology are numerous, and generally grouped into presentational applications providing remote access to multimedia documents [Miller, 1993] or into conversational applications involving multi-directional, real-time communications[Rangan, 1993a].

The development of multimedia information systems requires the integration of services for multimedia objects creation, storage, access, tranfer and presentation [Berra, 1993] and leads to join research efforts from different fields such as database systems, communication networks, operating systems or signal processing. In this framework, the Canadian Institute for Telecommunication Research has initiated a research project on Broadband Services. The goal of this Major Project is "to develop a thorough understanding of the hardware, software, networking and database issues related to the development of efficient and flexible multimedia presentational applications" [Wong, 1993]. Influenced by the MultiNews project, presently under definition at the Center for Information Technologies Innovation (CITI) of the Canadian Ministry of Industry and Science [Dupont, 1993], a multimedia news-on-demand service has been identified as the target application and provides the functional and architectural requirements for the different components of the project. The objectives of this paper are to examine in details the target application in order a draw the functional architecture and to specify the corresponding requirements.

The paper is organized as follows. Section 2 gives a general presentation and the classes of users. Section 3 proposes a functional architecture for the news-on-demand system and discusses the three levels of this architecture: the user interface level, the function level, and the database system level. For each level of this architecture, we describe the functionalities and list the set of corresponding requirements. In Section 4 we present our conclusions and examine directions for future work.

2. A Generic Multimedia Presentational Application

The purpose of the news-on-demand system is to offer an integrated, computerized multimedia news service to various customers. The contents is extracted from existing news sources such as radio, TV, wire services, print, and recomposed as (possibly personalized) multimedia objects the clients will access. The documents contain images, text, audio and video. Potential users are government institutions, decision makers in companies, journalists, business services, etc. The

system runs in a fully distributed architecture where multimedia data are stored on different sites, and users can access them from different places through the network. More specifically, the goals of the news-on-demand system are the following:

1. To offer services to efficiently store, access and analyze multimedia news.
2. To offer tools for the construction, presentation and reproduction of multimedia news.
3. To consider the user's environment and preferences.

In this section we discuss the potential users of the news-on-demand System and their particularities.

Persons involved in the process of production and consumption of multimedia news can be classified into four categories: news publishers, news analysts, news producers and news consumers. For each category, we give a simple example scenario of their use of the news-on-demand system.

News publishers

News publishers are responsible for delivering the news materials over different media. For example, CBC provides the daily TV and radio journals, a press agency provides photographs and the written press provides full texts of newspapers. These users manipulate mostly monomedia objects: radio, TV, pictures, graphics or texts. Descriptive and indexing information associated to these objects are also provided: such as date, hour, subject of the photograph as well as information concerning the representation of the object: format, size, etc. We name all this information *registration information.*

Scenario : News publishers daily produce a large amount of data from different source types: audio, video, written press. Some of these data is digitized with specific equipment and stored in the system.

News analysts

The information provided by the news publishers are unusable if they are not well described. The role of news analysts is to associate semantic information to the different monomedia objects: texts, audio, images or video. This semantic information can be key words or specific interpretation of the object and we call it *description information*. The analysts first manipulate a monomedia object and build a one-level composite object composed of a monomedia object and its description information.

This analysis process requires specific tools for description, classification and indexing. The analysts will use existing standards or recommendations for the description and classification.

For some data types such as texts, this process can be automatic. For other types, such as still images and video, some elements of automatic analysis are being developed, but at the present they are not yet suitable for large scale commercial application.

Scenario: A video sequence is viewed by the analyst, decomposed into shorter segments, each of which is annotated by a few keywords.

Multimedia news producers

The work the news analysts have done, results in annotated monomedia objects. These objects are used by the news producers to generate multimedia or hypermedia objects to be consulted by the clients.

News producers build multimedia objects by linking monomedia elements and by producing control information such as presentation formats (templates) and synchronization scenarios to define the temporal order of display. Document formatting standards such as ODA [Dengel, 1992], SGML, MHEG [Price, 1993] or HyTime [Newcomb, 1991] should be used in this process.

Scenario: A multimedia news producer creates a multimedia object concerning the candidature of Quebec City for the 2002 Winter Olympic Games. He first browses the monomedia objects associated to that event: radio and TV news, newspaper articles and then constituted a new object composed of some video sequences, audio sequences and a set of selected news clips and commentaries. He then specifies the layout and the synchronization of the different components and enters the object in the multimedia news database.

Multimedia news consumers

The multimedia news consumer inspects the database in order to find multimedia news of interest to him. He can consult the multimedia news database in different ways: browsing, specifying an identifier or by conditional queries. These consultation modes will offer a wide range of possibilities to explore the database.

While consulting the multimedia news database, the consumer can reproduce the documents he found. The system provides reproduction facilities and manages the copyright fees.

Scenario: A multimedia news consumer searches multimedia news describing the candidature of Quebec City for the 2002 Winter Olympic Games. He wants to get a copy of the different articles describing this event as well as a copy of corresponding news clips. He wants these clips on video tape for further projection.

3. Functional Architecture

The following figure shows the functional architecture for the news-on-demand System. This architecture is composed of three autonomous levels: the user interface level, the function level and the database system level. Each of these functional components will be later mapped onto physical components (machines), since the environment of the news-on-demand system is fully distributed. A first proposition for the mapping of the functional architecture to a computational architecture can be found in [Kerhervé, 1994].

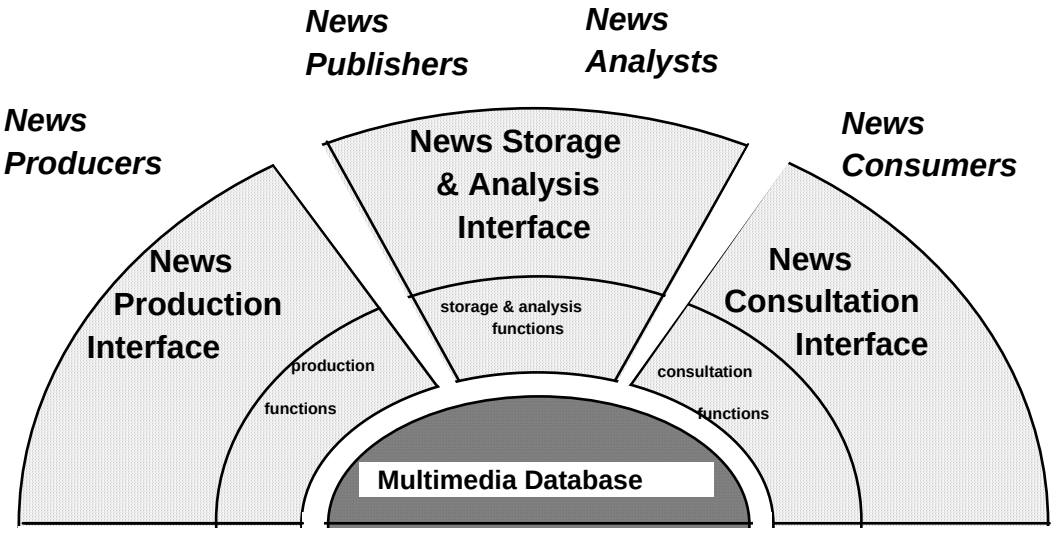

Figure 1: Functional architecture for the news-on-demand System

The user interface level is in charge of managing the different user interfaces and the user environment. The interfaces answer the specific user's needs: production, consultation, storage and analysis of multimedia news. Since one of the goals of the news-on-demand System is to offer flexible user profile environments, this component offers services to set, modify or delete a specific user profile. The user profile also takes into account the parameters of the quality of service. At this level, the system also controls that the user has authorizations to access the documents.

The function level is responsible of the transformation of a user's specific demand to the target operations required from the database system. For instance, when a news producer creates a multimedia news document, he first searches existing documents in the database and then composes a new document. This process has to be decomposed into two different parts: the search and the construction. Thus, the production function will use services from the consultation function and from the database management system. In that case, the production function determines and synchronizes the different operations processed by those two components.

The database system level provides reliable and coherent storage of multimedia documents as well as concurrent access to these documents and to their components. The database system offers data definition and data manipulation languages to the application level. The data definition language allows the definition of the structure, the content and the behavior of multimedia documents. The data manipulation language is used to retrieve, modify, delete and insert documents in the multimedia database. This data manipulation language is also used to process specific operations on multimedia documents such as zoom on images or transcription of texts. Due to performance constraints for storage and access to multimedia data, especially for continuous data (sound and video), the database management system can use services from specific components such as continuous media servers. Nevertheless, all the access to the data stored in specific servers will be controlled by the database system.

In the following sections, we describe the different levels of the above architecture in more detail.

3.1. The User Interface Level

Different interfaces are defined to answer specific needs of various user groups, considering the environment associated to these groups. The news-on-demand users define their favorite environment such as the word processor, the communication environment as well as the tools for document annotations. This environment can be dynamically modified.

In this section we focus on the three different interfaces: production, consultation and storage and analysis.

3.1.2. Multimedia News Production Interface

The multimedia news production interface is dedicated to the generation of multimedia news documents. This interface is concerned with the creation of documents as well as with their modification.

Creation

The creation of a multimedia news document needs the specification of the three components of such a document: the structure, the content and the presentation [Christodoulakis, 1986; Meghini, 1991]. The structure defines the objects that are part of the document and their organization, the content contains these objects (a set of monomedia objects from different types) and the presentation gives information for the layout of the document.

A multimedia news document can be viewed as a composition hierarchy of different objects. This hierarchy describes the structure and the content of the multimedia document. Object

composition can be defined according to specific constructors. For instance a document can be defined as the composition of:

- a name
- an ordered list of pictures
- a set of audio sequences
- a text description

This composition hierarchy is enriched with constraints defined on the different components of the multimedia document. These constraints can be semantic, spatial or temporal; the last two categories belong to the presentation part of the document. For example, while creating a new document, a user can specify semantic constraints giving the maximum size, or the maximum number of levels in the composition hierarchy. The system will be responsible to check that these constraints are satisfied during the creation. The structure of the document is defined by the user and specific tools must be offered to help the user in this task.

While defining the content of the multimedia document, the user might choose to reuse existing documents or to capture new objects. The reuse of existing documents needs a preliminary step to retrieve them, while capturing new objects such as audio or video needs the connection to specific equipment. The production interface will then use the same services as the consultation interface and the monomedia storage and analysis interface.

The presentation part of the document specifies how the components of the multimedia news document will be presented to the final user. This specification is made through temporal and spatial relationships between objects. The temporal relationships describe the synchronization points while spatial relationships describe the organization of the components on the screen.

Much effort is being spent on the standardization of multimedia and hypermedia documents. An open question is to decide whether a specific multimedia document model (MDM) has to be proposed or whether an emerging standard such as MHEG [Price, 1993] or extensions of ODA [Hunter, 1989] will be chosen.

Modifications

The construction of multimedia news documents is a long and difficult task which can be progressively refined. Thus, the system must offer facilities permitting to modify a document. The modifications can appear on the structure, the content or the presentation part of the document.

Modifying the structure is necessary when a new object is, for example, added to the original document. This modification has impact on the structure but also on the content of the document since this object must be considered as part of the content.

The modification of content must be provided on basic monomedia objects such as texts, graphics and still images. The multimedia news production interface will be in charge of the connection with editing tools for these objects. Such editing tools could also be offered for audio or video object modifications.

The presentation of documents can evolve and the creator can also need to prototype a presentation before adopting a specific one. Thus, tools must be provided at this level to help the creator in the specification and evolution of the temporal and spatial constraints of the document presentation.

The following paragraph lists the requirements for the multimedia news production interface.

Requirements

. definition and storage of multimedia objects according to predefined conceptual structures;

. use of existing documents for the creation of new documents;

. specification of different relationships between the components of the multimedia document (spatial and temporal relationships);

. dynamic modification of the structure and content of a multimedia document.

3.1.3. Multimedia News Consultation Interface

The final users of the news-on-demand service search multimedia documents in the system and can reproduce these documents. The system provides reproduction facilities and manages the copyright fees.

The consultation of multimedia news documents can be separated in two different and complementary steps: the search process, which we call the access and retrieval process, and the manipulation process which follows, and offers the user the possibility to process specific actions on the retrieved object.

In order to search multimedia documents, the users can use several retrieval techniques [Berra, 1993]: retrieval by keywords, browsing, guided tour, full text retrieval, similarity retrieval. Several techniques such as retrieval by keywords, browsing or guided tours are general for all the media while others, such as similarity retrieval or full text retrieval, are specific for still images or texts. The consultation interface offers these different possibilities and their combination to the user.

We group the different consultation modes in two different categories. The first concerns the access to a single document while the second provides for the retrieval in a set of documents.

Access to documents is specific in the sense that it doesn't need the evaluation of a query expression, since the identifiers of the accessed objets are given by the user, or generated by the browsing system. In this category we group: access by identifier, browsing and guided tour.

access by identifier

Generally the access to a document is preceded by a retrieval step where the user (or the system) keeps the identifiers of the object. The user is then able to specify the identifier of the document and the system just accesses it and proceeds to its presentation.

browsing

Here, the user wants to navigate in the composition hierarchy of the multimedia documents. The system must offer specific tools to facilitate this navigation, such as description of the different nodes, representation of the hierarchy, etc. In this consultation mode the system uses the different links defined between objects (composition or hypermedia links).

guided tour

The guided tour is a predefined way to inspect the multimedia document database. In such an interface, the system has to identify the guided tour and just play it.

The second category of consultation mode is concerned with the expression of conditions that the documents must satisfy. In this category, we distinguish four different types of condition expression: conditional statements, full text retrieval, similarity retrieval and retrieval by content.

retrieval by conditional statements

The user specifies different conditional statements that the documents have to satisfy. These statements are expressed with predicates and can be of the form of boolean requests. The predicates are expressed on semantic information that has been previously defined in the database.

Example: retrieval by keywords
Retrieve all the multimedia documents produced by CBC in January 1993
The following boolean request can be used for that example:
Publisher = “CBC” and Date = “January 1993”

The conditional statements can include spatial as well as temporal predicates. The temporal predicates specify the synchronization of the components of the multimedia document. They can also be used to examine the evolution of objects (medical images). The following temporal predicates should be offered: after, before, during, between, in, overlaps, meets, equivalent, adjacent, follows, proceeds.

Example: by temporal predicates

Retrieve all documents where an audio sequence is played before the video sequence.

The spatial predicates specify the composition of the objects in the multimedia documents. They can also be used when spatial information is stored in the database (geographical information systems for example). The following predicates should be offered: right of, left of, in front of, behind, intersects, contains, above, below... Other spatial predicates can be defined.

Example: by spatial predicates

Retrieve all the documents where a map of the 2002 Winter Olympic Games installations is superposed on a map of Quebec City.

The two following types of consultation are also concerned with the expression of predicates on the documents, but these predicates may need specific processing steps (retrieval by content) or specific tools to express the conditions (similarity retrieval).

retrieval by content

In this type of consultation, the user specifies predicates on the content of the document and specifically on the content of basic monomedia objects such as texts or images. This kind of consultation needs the generation of different steps to analyze the text or the image. This analysis step can be very complex, especially in the case of image analysis.

Example: full text retrieval

Retrieve all the documents that contain the string: "broadband services".

Example: retrieval by image content

Retrieve all the images of Québec City containing the Frontenac Castle.

similarity retrieval

Similarity retrieval enables the expression of conditions not by words but with the help of an example. In that case, the consultation interface offers tools to draw or show the example or the frame the user wants to find in a multimedia document.

Example

manipulation

At the end of the searching process, the user can execute some operations on the document. These operations are independent and not linked to the search process. The consultation interface must offer tools to facilitate this kind of manipulation.

Example

Enlarge the window for the video sequence.

The following paragraph lists the requirements for the multimedia news consultation interface.

Requirements

. reproduction of documents on specific supports according to their type;

. access to the multimedia documents according to different modes;

. dynamic manipulation of the document and its different components.

3.1.1. Monomedia News Storage and Analysis Interface

The monomedia storage and analysis interface is dedicated to the news publishers who load the database with basic monomedia objects (texts, still images, graphics, maps, audio and video). This interface offers connections to specific equipment (video camera, sound recorder, digitizers...) to capture these objects. After being captured and digitized, the objects are described and analyzed by monomedia analysts. The analysts associate registration information to the objects as well as description information describing their contents. Each medium has a predefined schema for the description of registration and description information. Generally these schemata contain keywords and a brief description.

As far as continuous data (audio and video) is concerned, the description of monomedia objects is specific since the analysts can decompose an object into smaller pieces such as decomposing a video sequence into different scenes. In this decomposition process, the analyst specifies time units linked to the monomedia object. These time units are part of the description of the object and can be used in the storage process, as for example to encode the video sequence or index a set of video sequences.

The following paragraph lists the requirements for the monomedia news storage and analysis interface.

Requirements

. capture and digitization of monomedia objects;

. definition and efficient storage of monomedia objects;

. definition and storage of registration and description information.

3.1.4. User Profile

The news-on-demand users create, consult or analyse multimedia documents and use specific tools to perform these different tasks. These tools must be adapted to the user's preferences and habits. Thus, the system must keep the description of these preferences in a user's profile. These preferences include his favorite authoring tools as well as the part of the multimedia database he generally accesses and the quality of services he wants to get in his different tasks. The specification of these preferences is done by the user and can be modified each time the user needs it.

The specification of the user's preferences concerning the quality of services is done according to the task he performs. Actually, when a user is producing a new multimedia document, he first searches in the database for the documents he will include in the new one. While performing this task, the user will certainly visualize some documents, but the quality he requires for them is certainly less high than in a consultation and reproduction task. In the different tasks, the user can also negotiate the quality of services.

The following paragraph lists the requirements for the user profile management level.

Requirements

. definition and modification of the user's favorite tools for creation, consultation and analysis of multimedia documents;

. definition of the user's quality of service parameters.

In this section we examined the different interfaces offered to the users and we gave the functionalities regarding to the creation and consultation of multimedia news documents as well as the storage and analysis of monomedia documents.

3.2. The Functions Level

The previous section concentrated on the interface level of the news-on-demand system and the production interface has shown the importance of a multimedia document model to specify the different components of these complex objects. At the interface level, the system uses the

multimedia document model (MDM), this model is considered as a logical model, which helps the user in the description and the utilization of the multimedia documents. This logical model has to be mapped onto a physical model in order to efficiently store and access the documents in the database. This transformation from the logical model to the physical model is done by the function level. The functions level is also responsible of the transformation of a user's specific demand to the target operations required from the database system [Berra, 1990].

The three components of this level are: the production function, the consultation function and the storage and analysis function. They offer services to the user interfaces as well as to each other. In the following sections we examine the three components in more detail.

3.2.1. Production Function

In Section 3.1.1, we presented the different possibilities the users are provided with, while building a multimedia news document and we specified the different components of this document: the structure, the content and the presentation. These three components can be defined by the user or extracted from existing documents with the help of the multimedia news production interface.

In the first case, when the user defines the components, the multimedia news production interface captures all the information, whether with specific equipment for images, sound or video, or with specific tools such as word processors. All the elements are defined according to an external multimedia document model, captured, and then transmitted to the production function for database storage. The production function is then responsible for transforming the external structure to the internal structure supported by the database system. As for example, if an object oriented database is used, the production function will identify the different classes, which are concerned with this document and will generate the corresponding requests to be submitted to the database system. This transformation step will be different if the database system is an extended relational database system.

In the second case, when a user builds a multimedia news document from an existing one, the production interface connects him to a subset of the consultation interface in order to select the pertinent documents. The production function must keep the references to those documents in a workspace in order to use them in the production process. Since the system must allow object sharing, those references will be incorporated in the new document using a composition mechanism. The production function is in charge of this document composition mechanism. It is also responsible for transforming the structure of already existing documents into other structures if they are offered at the external level.

For example, in order to create a new document, the user can choose the MHEG standard as the multimedia document model. Since the documents that he wants to reuse are multimedia

documents defined with an extended ODA standard, the production function has to transform an extended ODA document into a MHEG document before submitting the storage request to the database system.

The following paragraph lists the specific requirements for the production function.

Requirements

. efficient management of the workspace for the production process;

. mechanisms for external to internal structure transformation;

. efficient management of the interaction with the database system in the production process;

. mechanisms for the integration of an existing structure into a new one.

3.2.2. Consultation Function

Both the monomedia news production interface and the multimedia news consultation interfaces interact with the consultation function. Four different tasks can be identified for this function: access to the database system for consultation functions, consultation workspace management, internal to external model transformation and temporal and spatial relationships enforcement.

While using the multimedia news consultation interface or the multimedia news production interface, the user accesses to the database according to the different modes presented in Section 3.1.2. The interface level provides the user with graphical user interfaces, adapted to each access mode. All the information concerning the database access is transmitted to the consultation function, which generates the corresponding request formulated in the database manipulation language. At this step, the consultation function may enrich the user's requests with his profile. The requests are then submitted to the database system and the consultation function waits for the results.

The results of the requests are transmitted to the interface level, and the consultation function may keep some parts of the result for further use. As for example, if the user wants to access to multimedia news through hypermedia links, the consultation function keeps in the workspace references that will be used to access other documents. The efficient management of this workspace is an important task to be performed by the consultation function.

When the consultation function transmits the results to the interface level, some transformation may be required to change from the internal model supported by the database system

to the external model required by the interface level. This task is symmetric to the one performed by the production function.

The last task performed by the consultation function is the enforcement of spatial integration and temporal synchronization of the different components of the multimedia news document. Actually, spatial and temporal relationships between the components are an important characteristic of the multimedia news document. These relationships are stored in the database as part of the presentation component of the multimedia news document. The consultation function is in charge of extracting these relationships from the document and to enforce them while interacting with the interface level.

The following paragraph lists the specific requirements for the consultation function.

Requirements

. efficient management of the interaction with the database system in the consultation process;

. efficient management of the workspace for the consultation process;

. mechanisms for internal to external structure transformation;.

. mechanisms for the enforcement of temporal and spatial relationships.

3.2.3. Storage and analysis function

The monomedia news storage and analysis interface provides the user with tools for capture and description of monomedia objets. This interface interacts with storage and analysis function, which performs three different tasks: monomedia objects storage, monomedia objects description and monomedia objects indexing.

As does the production function, the storage and analysis function identifies the internal structures that are required for the database storage of the monomedia objects. This task also requires the transformation of the external structure into the internal structure supported by the database system. The storage and analysis function therefore generates the database manipulation language requests for the insertion of those objects. The storage and analysis function is also responsible of the efficient storage of the monomedia objects, that means that this component of the system decides whether specific compression techniques can be used.

In order to be efficiently retrieved by the consultation function, the monomedia objects have to be described. This description is done according to specific description schemata that are stored in the database. The storage and analysis function uses these schemata to provide the interface level with the description information that can be used in the description process. Thus, in order to

retrieve the pertinent information, the storage and analysis function generates some requests for the database system.

The description of the monomedia objects can be done according to terms (keywords) associated to the objects, but can also be done according to the contents of the monomedia objects. In this second case, the storage and analysis function must provide mechanisms for content indexing, especially for spatial data as well as for video objects.

The following paragraph lists the specific requirements for the storage and storage and analysis function.

Requirements

. efficient management of the interaction with the database system in the monomedia objects storage process;

. mechanisms for external to internal structure transformation;

. efficient storage and access to description and registration information

. mechanisms for monomedia objects content indexing .

In the different components of this level, the system must integrate the user's environment, specifically the quality of service he is requiring. The quality of service parameters are added in the formulation of the request for the lower components.

3.3. Database Management System Level

The database management system (DBMS) provides reliable and coherent storage and concurrent access to the multimedia documents. The system must support the definition, storage and retrieval of multimedia documents according to the requirements resulting from the previous sections. In this section we decompose the database requirements in four categories: the data definition language, the data manipulation language, the data storage and the support for the database coherence.

3.3.1. Data Definition Language

In Section 3.1, we presented the interfaces for monomedia storage and analysis as well as for multimedia news production. For these interfaces, we pointed out the following requirements regarding to the definition of different objects that will be stored in the multimedia database and are:

. the monomedia objects;

. the registration and description information.
. the multimedia objects defined according to predefined conceptual structures
. the spatial and temporal relationships between the components of the multimedia document

To meet these requirements, the database system must support a powerful conceptual data model providing concepts for basic objects, composite objects and relationships [Woelk, 1987b]. These concepts are generally present in different object models [Bertino, 1991] supported by existing object oriented database management systems [Cattell, 1991]. Nevertheless, these object data models have to be enhanced in order to meet the specific characteristics of multimedia objects. The data definition language offered by a database system enables the user to define the structure and behavior of objects according to the concepts supported by the conceptual data model. In this section, we point out the characteristics of multimedia objects through the study of basic objects, composite objects and relationships. We then formulate the requirements for the data definition language.

Objects model real-world entities, and basic objects model an atomic entity such as an image, a text or a video as well as an integer, a real or a string. Basic objects are defined according to predefined data types provided by the data definition language. The basic data types offered by traditional database systems generally answer only the needs of traditional applications and are limited to types such as integer, real, string or date. In the framework of OO database systems, some efforts have been dedicated to extend the set of predefined data types to support texts, graphics, still images or audio [Woelk, 1987a]. However, much efforts must be dedicated to the integration of predefined data types for video, as well as to the integration of a wide range of formats for the basic monomedia objects.

Different predefined data types, corresponding to formats or standards, must be provided by the data definition language for texts such as postscript, RTF or RTE; for audio such as ADPCM; for images such as TIFF, VIFF, PICT or JPEG, as well as for video such as CIF or MPEG [LeGall, 1991]. These different formats have to be clearly identified according to those used by the publishers who will be involved in the target application. The use of specific formats will also be conditioned by space and performance requirements and the choice will certainly retain the formats or standards that are less space consuming. Associated to these types, that specify the structure of basic objects, the behavior of these objects should be described through a set of primitives enabling the manipulation of these objects [Woelk, 1987a].

A composite object can be defined in terms of other objects. All the basic objects may be combined using constructors such as lists or sets in order to build new objects. That means that the data definition language should offer the possibility to use these constructors in the definition of

new data types in order to provide extensibility to the types system. On the other hand, the data definition language should also provide a set of predefined composite data types that correspond to formats or standards the target application could use. In this category we find specific logical structures for multimedia documents such as ODA [Hunter, 1989], SGML or MHEG[Price, 1993] or a specific structure defined specifically for the target application.

In Section 3.1.1, we pointed out that, in the definition of the document structure, the presentation part specifies the spatial and temporal constraints existing between the components of the document. These constraints are included in the set of relationships that link the components together. Some of these relationships are inherent to the conceptual model, as for instance in the object data model, the aggregation relationship is present in the composition hierarchy and the generalization/specialization relationship is present in the inheritance hierarchy. Nevertheless, object-oriented models do not support temporal and spatial relationships, thus the conceptual model should be enriched to include this kind of relationships [Little, 1991; Little, 1992]. The database definition language must provide data types for the description of these relationships as well as primitives for their manipulation.

The following paragraph lists the requirements for the data definition language.

Requirements

. support for a powerful conceptual data model for multimedia objects;

. existence of predefined types for monomedia objects (texts, graphics, images, sound and video);

. definition of composite objects

. definition of relationships between objects: semantic, temporal and spatial;

3.3.2. Data Manipulation Language

In the previous section, we defined the requirements for the data definition language provided by the database system. This language enables the definition of the structure of the database, that is its schema, while the data manipulation language enables the user to insert, retrieve, modify and delete objects in the database. In this section we examine the functionalities that the database manipulation language should provide in order to meet the requirements of the different interfaces described in Section 3.1. These functionalities are divided into two different categories and concern the retrieval sub-language and the update sub-language.

The retrieval sub-language offered by the database management system must be powerful enough to allow the expression of the different types of queries, which were presented in Section 3.1.3 as follows:

. access by identifier
. browsing
. guided tour
. retrieval by conditional statement (keywords, spatial and temporal predicates)
. similarity retrieval
. retrieval by content

In these different types of queries we can distinguish set-oriented queries and navigation queries. Set-oriented queries are concerned with the selection of a set of multimedia documents satisfying some criteria. These criteria are generally expressed through predicates. In Section 3.1.2 we pointed out the need to express temporal or spatial predicates on multimedia documents. We also gave some examples of queries where specific processing is required for the query evaluation : content retrieval in image database is a good example since image processing is a preliminary step to searching. Artificial intelligence brings an important contribution to these problems and deductive database systems could be considered for content retrieval queries.

Navigation queries are concerned with object access through the composition hierarchy of a multimedia documents. Acces by identifier as well as browsing are such queries. Their processing need a first step to identify the reference of the object and the second step is the real access to the object. Combination of the two query modes should be provided in order to isolate a set of documents in which the browsing process can be executed.

The data manipulation language should provide a multimedia document modification sub-language. This language should enable the modifictation of the structure (schema evolution) as well as the content of the multimedia document.

Recent efforts have been dedicated to query languages for multimedia databases. Some projects are especially concerned with medical applications [Cardenas, 1993], [Chang, 1980], [Chu, 1992], [Joseph, 1988] others with office information systems [Ishikawa, 1993], [Christodoulakis, 1986]. Each of them offers specific predicates for multimedia document retrieval adapted to images, texts or graphics. Other propositions have been presented for querying multimedia databases [Golshani, 1992], or video databases [Oomoto, 1993]. All these works should be considered as well as those from standardization groups for object-oriented database languages [Atwood, 1994] and for the SQL database query language evolutions [Melton, 1993].

The following paragraph lists the requirements for the data manipulation language.

Requirements

. query language for set-oriented retrieval and navigational access

. language for multimedia documentt modification

3.3.3. Data Storage

The database management is in charge of the data storage. All the information accessible to the users is described in the database and accessed through the database management system. The data storage functionality is provided by a storage sub-system which is in charge of deciding how and where the data will be stored. How the data will be stored concerns the internal model used for the storage, while the question where the data will be stored concerns the architectural components of the global system that are used for the storage.

The internal storage model is used to map the conceptual structures defined in the previous sections onto internal or physical structures supported by the storage sub-system. This transformation step should be processed with severe performance and occupation constraints. For instance, an image defined as a VIFF image at the conceptual level, can be transformed as a JPEG image before being stored, in order to reduce the occupation space. Thus, specific compression techniques should be used to respect the space constraints. These compression techniques must be provided for the different types of monomedia objects: text, graphics, images, sound and video, as well as for combination of monomedia object such as sound and video. In that case the temporal relationships between those two monomedia objects are an important element in the compression process. The performance constraints concern the time required for accessing the different objects and are especially important while accessing continuous media such as sound or video [Rangan, 1993b]. Thus, specific indexing and clustering techniques must be provided for the different types of media.

The computational architecture of the news-on-demand system proposed in [Kerhervé, 1994] is fully distributed and follows a client-server approach. Several distribution levels are provided: the first one between the client and the server and the second one between the server and the different components used for the storage of multimedia data. It clearly appears that data such as images, voice and video require specific sub-storage systems, dedicated to the efficient storage and access. Thus the database system and especially the storage sub-system should manage the distribution of

the data on different machines. It must store the description of the objects localization and keep the distribution transparent to the applications. The distribution information should also be used by the database system to optimize query processing as well as to estimate the time required to access the remote data. Thus a distribution model should be provided in order to describe the localization of the objects as well as mechanisms for object migration.

The following paragraph lists the requirements for the data storage sub-system.

Requirements

. efficient storage techniques for continuous media objects (sound and video) as well as for multimedia objects;

. clustering and indexing techniques for multimedia objects;

. support for a distribution model;

. transparent access to specific storage components.

3.3.4. Data Consistency

Database systems provide transaction management to ensure the global database consistency, even when users concurrently access the database or when failures occur. The database consistency is defined according to a set of integrity constraints that the data must satisfy. In order to efficiently manage the database consistency, a multimedia database system must provide mechanisms to define and check integrity constraints, to control concurrent access to the database and to be resilient to different types of failures. These mechanisms must be provided for multimedia objects, which are large and have complex structure. In this section we examine the functionalities the database system should provide regarding to database consistency and give the corresponding requirements.

The database consistency is defined according to a set of integrity constraints. The database system must provide a language allowing the definition of integrity constraints on multimedia objects. Those constraints should be structural : a multimedia object hierarchy must be limited to eight levels; behavioral : a Hytime multimedia document cannot be transformed to a MHEG multimedia document; or semantic : the cost of multimedia documents provided by CBC must be lower then 200$. Other constraints can derive from the localizatuion definition : all the JPEG images should be stored on this site. The integrity constraint definition language should be powerful enough to enable the definition of these different types of constraint. Corresponding mechanisms for efficient integrity checking should also be provided.

Multimedia documents are accessed by various users according to different modes : creation, consultation or modifications. Generally, transactions on multimedia documents are long duration

transactions and the concurrency control mechanisms should be adapted to these transactions characteristics. Thus, providing versions of multimedia objects should help the efficient access to multimedia documents for consultation.

Different types of failure may occur and the database system should offer mechanisms to be resilient to transaction failures, system crashes as well as secondary storage crashes. Thus the database should be saved at regular intervals and some replicated copies mechanisms should be offered to ensure data availability.

In the framework of object-oriented database systems, many recent efforts have been dedicated to integrity constraints definition and checking [Formica, 1992], concurrency control and recovery; these results should be considered in our context. Since the system architecture supports distribution, all these strategies should be provided in a distributed environment [Ozsu, 1994].

The following paragraph lists the requirements for data coherence enforcement.

Requirements

. mechanisms for integrity constraint definition and checking;

. mechanisms for concurrency control with the help of object versions;

. mechanisms for database recovery.

. mechanisms for distribution management.

4. Conclusion

This paper defined the requirements for a generic multimedia news-on-demand service that has been identified as the target application for the Broadband Services project from the Canadian Institute for Telecommunication Research. We first gave a general presentation of the application and drew the functional architecture of the system. The proposed architecture is composed of three different levels : the interface level, the function level and the database level. For each level of this architecture, we described the functionalities and gave a set of requirements.

The mapping of this functional architecture onto a computational architecture has been proposed in [Kerhervé, 1994] and an implementation of a prototype of the multimedia news-on-demand system is in progress. This prototype also implements a QoS demonstrator where the user can specify the parameters for quality of service. Our future work is concerned with the design and implementation of a negotiation protocol between the application processes, the database servers and the transport service allowing the dynamic renegotiation of quality of service parameters.

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