Conceptual Title Abstractions: Modeling and Querying Very Large Interactive Multimedia Repositories.

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CONCEPTUAL TITLE ABSTRACTIONS: MODELING AND QUERYING VERY LARGE INTERACTIVE MULTIMEDIA REPOSITORIES*

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Abstract

Organised units of interactive multimedia material, called "titles", are becoming rapidly available beyond their original format, namely Compact Disks, and they appear in Digital Libraries and on the Web. For large collections of such titles, browsers and query mechanisms addressing the multimedia assets alone while reasonably well developed are inadequate: we lack techniques for efficient generic retrieval of structured multimedia information. In this paper we present the notion of *conceptual title abstractions*, a representation of one or more titles that captures and abstracts at a variable level of detail the structure, interactivity and generic content of the represented titles. We develop an algebra for title abstractions -which form a partial order- and present a language which can be used for specifying and abstracting titles. A straightforward extension of the language can be used to query databases of title abstractions, and indirectly very large repositories of organised interactive multimedia material. Examples taken from applied projects illustrate the approach, as the language was originally developed for the specification and production of multimedia titles in series.

1. Introduction

Interactive multimedia titles, or simply titles -a term carried over from paper to electronic publishing- are units of organised multimedia information which, until recently, resided mainly on compact discs. The advent of the Web, however, and the appearance of the first digital libraries enlarge the habitat of titles which can now reside anywhere on the Internet, be distributed across local or global networks, or even have a transient and virtual existence: a net-surfing session on the Web is a title of sorts. In this way we already have millions of titles, the full information content of which is huge by any standard. Although such collections of titles are not organised as proper databases, they are very large repositories of organised interactive multimedia information -an extremely valuable resource.

Available means of accessing such information are either browsers or query mechanisms addressed to the multimedia assets alone. Direct presentation to a human viewer is considered to be the prime purpose and the main means of relaying information and communicating via these titles [7]. Search engines on the Web,

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quite efficient and effective in what they do, focus exclusively on text. To really tap the information resource we need a different approach for querying and navigating in these repositories, one that would resemble our own way of recalling information from our minds, human remembering.

The specification of any title to be developed addresses two domains at the same time: the -part of the- real world represented (that cars have engines, for instance) and the computational system developed (that cars have video clips associated which are triggered by clicking at the car ignition, an one-square inch hot spot on the screen, for instance). Viewed from another angle, the specification of a title regards its structure, interactivity and content. It is exactly with respect to these characteristics that we would like to be able to query and navigate through a title repository. One way to do this is a title meta-database, i.e. a database with title attributes, or descriptions; this would be quite a reasonable approach for content-related querying ("look for titles on Corfu with recent hotel information including pictures"). But it would be rather cumbersome and extremely restrictive if not impossible to put structure and interactivity as normal title attributes in such a meta-database. To deal with this problem we introduce the notion of title abstractions (Section 2).

A title abstraction is a generic representation of the title's presentational structure, its interactivity and its content. The level of abstraction is variable, from the title itself (zero abstraction) to the all-encompassing (infinite abstraction). Naturally, what is practically relevant are the in-betweens. A title can have (better: can fall under) a large number of different abstractions, differing not only in terms of detail (in which sense each abstraction is a generalisation of the other) but also differing with respect to what is being abstracted (for example content or interactivity). Thus given a set of titles, the set of all their possible abstractions form a partial order with respect to abstraction detail. The concept of title abstraction originated from modeling and specification of title series, called "Model Title Specification" in [5, 24], where it proved quite valuable as the key concept for a methodology to reduce time and cost in developing similarly structured titles. In this paper we propose that the same concept is applicable to querying and navigation of large repositories of titles, through a database of title abstractions, indirectly pointing to the titles themselves.

In Section 4.1 we introduce the basics of an algebra of abstraction transformations, as the basis of query evaluation for title abstraction databases (section 4.2). Throughout the paper, the level of representation, or modeling or abstraction is the semantic one. This is proper because it is too early in the development to fix models at the logical and even more at the physical level. However, as shown in [15] the transition from our representations to any well defined model, is straightforward.

Section 3 motivates, defines, and shows the usage of the Title Abstraction Definition and Query Language, a semantic level specification and query language, based on and extending OMT [15]. As pointed out in [9] there is a natural one-to-one correspondence among queries, object class definitions and constraints. So, it is a straightforward extension of the language proposed in [15] and used in [5, 24], to specify titles (by defining the necessary classes) that are used for querying title abstraction databases (by "selecting" the corresponding classes). The detailed syntax of the language is given in Section 5, as a language for modeling interactive multimedia information, specifying titles in series and querying title abstraction databases.

The papers cited in the following paragraphs clearly show the origins of this work: research on multimedia object modeling such as [8,11,12,22,25], on query languages such as [8,14,20] as well as some classic work on temporal and spatial relationships [1,3,13] form the basis of the present work.

Related work includes research on using meta-data for capturing the structure and the content of multimedia documents [16] or the features of multimedia objects for efficient queries [4] and intelligent browsing through collections of media objects [6], explanation-based generalization techniques for formulating general concepts from specific examples [19], similarity-based queries for approximate pattern matching and information filtering based on abstraction transformations for query evaluation [10] and structural queries on the Web [4,7,17].

2. Multimedia Title Abstractions Database

A *multimedia title abstractions database* is a repository for *structural and presentational abstractions* of interactive multimedia titles. The content of such a database is title abstractions with respect to title semantic structure, title presentation and title control flow and interactivity.

A title abstraction can be seen as a *generic specification* of a multimedia title in terms of content, spatio-temporal synchronization and interactivity aspects as opposed to its *full detailed specification* e.g. if the detailed specification of a title includes the exact timing of an image sequence during presentation, for its generic specification the *sequential* temporal relation would suffice. A title can have many generic specifications in various abstraction levels and many titles may fall under the same generic specification.

A limited analogy with the concept of multimedia title abstractions databases is databases containing abstracts of text documents, derived -automatically or by hand- from text documents stored in textual databases.

From a database theory view, we can think of a title abstraction to be the *title database schema* of a *title database*. A title database contains the multimedia titles that conform to this schema. This view assumes that the title database schema captures not only the real world aspects (e.g. a hotel has rooms) but also the presentational (layout and temporal synchronization e.g. the hotel is presented via a scene containing two non-overlapped photos) and the control flow aspects of a multimedia title. The semantic design of a title database, which results in this title database schema, would be based on data models that can capture these aspects [8,11,12,15,22].

The term *title database schema* may be misleading, as the schema of a title database may represent just a set of structurally similar titles [5] which may result in a database schema of only one title and limited usefulness. However, the term does give a good idea of the concept of title abstraction. Under this light, a multimedia title abstractions database is a repository for title database schemata.

In the rest of this paper we will refer to this database as the *Multimedia Title Abstractions Database.*

So, as shown in Figure 1, we have two different types of repositories: The existing *Multimedia Title Repositories*, which contain multimedia titles too loosely organised to be called a database, and the proposed *Multimedia Title Abstractions Database* whose instances are title abstractions representing -and possibly pointing to- a multitude of multimedia titles each.

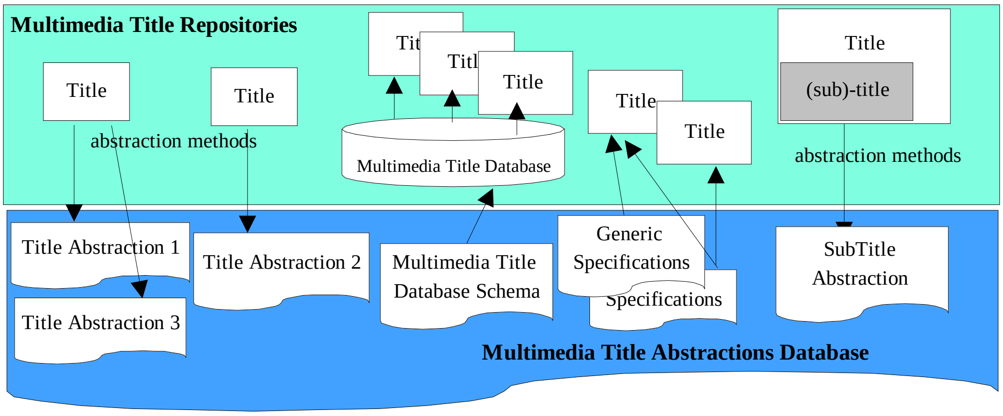


Figure 1: Multimedia Title Repositories Vs Multimedia Title Abstractions Database

Let us now focus on the contents of the Multimedia Title Abstractions Database. In the following subsections we give an example of what a title abstraction could be, how these title abstractions can be represented in the title abstractions database and how we can obtain such title abstractions.

2.1 An example of a multimedia title abstraction

An example of a multimedia title abstraction is shown in Figure 2. It represents part of the multimedia tourist title database schema for a series of tourist titles, developed in the context of a project [5] and modeled using the extended OMT object model proposed in [15].

In this project a methodology was proposed and applied for the production of whole series of similar multimedia titles with the purpose of reducing the cost and development time. The basic idea behind the methodology is the *generic specification* of the title's content, presentation, interactivity and control flow. There, this was achieved by narrative specifications and specially designed forms, from which a *multimedia title database schema* was developed based on the OMT [21] object model. In [15] we took the methodology one step further and formalized it. We used, in as much as possible, the same models and techniques used in standard applications for conceptual modeling of the outside world, based on concepts which have proven to be understandable and usable: entities, relationships, attributes, isa hierarchies, aggregation and grouping, augmented with minimal concepts for spatio-temporal synchronization and interactivity. The extensions proposed, are defined briefly here[†] and are exemplified via the OMT data model in the legent of Figure 2 (extended-OMT data model).

The extended data model of the tourist title series captures the following:

- *the abstraction of the real world* e.g. each tourist title refers to one geographic area which may consist of a number of referencing places, such as a village.

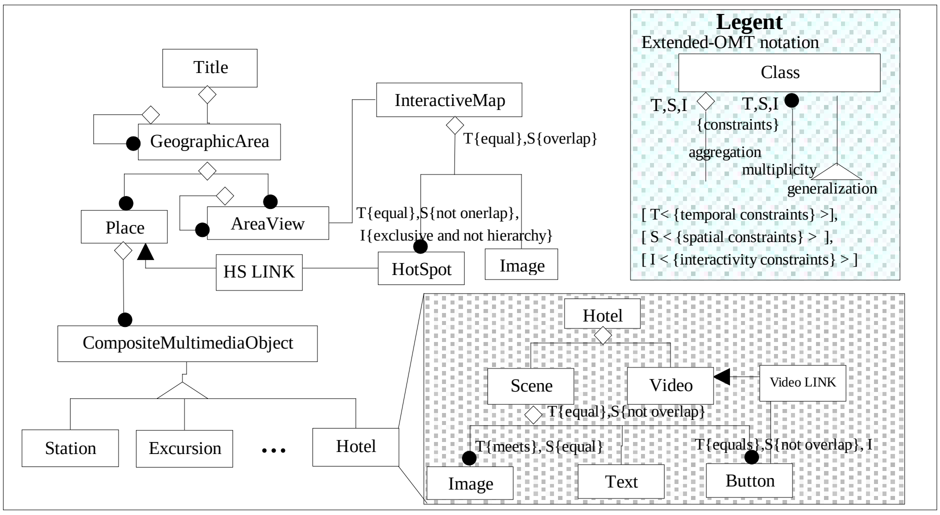
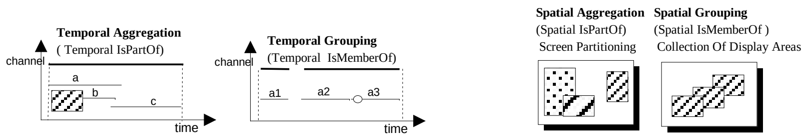


Figure 2: A title abstraction for a series of tourist titles using the extended-OMT object model

- *the abstraction of the presentational structure* e.g. presentations are possible from several points of view such as historic, accommodation or transportation.

[†] ***Temporal Relationships**:* Multimedia objects have a special attribute called "playout duration", whose domain is the set of temporal intervals. Temporal-aggregation is an aggregation in which the playout duration of the composite object is determined by the playout durations of the constituents. Temporal grouping is the grouping where the playout duration of the composite object has value equal to the union of the temporal intervals of the playout durations of the constituent objects.



***Spatial Relationships**:* Visual objects are spatial objects whose *presentational position* models the screen portion they occupy. Spatial-aggregation [9,23] is an aggregation in which the presentational position of the composite object is determined by the presentational positions of the constituents (denotes "screen partitioning"). Spatial grouping is the grouping where the presentational position of the composite object is the union of the presentational positions of the constituent objects and "collection of display areas".

Interactivity : Interaction facilities are objects, usually visual ones, with a special attribute, *interactivity*. The domain of the attribute is subsets of triplets (e_i, c_j, a_k), where e_i is an *event*, c_j is *condition*, and a_k is an *action*. *Interactivity-aggregation* is the aggregation in which the interactivity of the composite object is determined by the interactivity of the constituents and denotes "partitioning of interaction possibilities". *Interactivity grouping* is the grouping where the interactivity of the composite object is the union of the interactivity of the constituent objects and denotes "collection of interaction possibilities".

Geographic areas are presented by a map corresponding to views (e.g. historic map). Places are presented by a composite multimedia object (e.g. slide show).

- *the abstraction of the spatio-temporal synchronization and interactivity of composite multimedia objects* (screen layout and temporal relations among multimedia objects). e.g. Hotels are presented by a composite scene, consisting of a temporal sequence of photos, a piece of text and a number of spatially arranged buttons. Pressing the video button, the video for the hotel plays.

2.2 Where are abstractions derived from?

The example given in section 2.1 refers to one source of multimedia title abstractions: sets of multimedia titles with similar logical, presentational and interactivity structure. Each set is stored in one title database whose schema is the title abstraction for all the titles in the set. However interesting this case, it is not representative. By and large most multimedia titles have their own specific logical, presentational and interactivity structure and a generic representation of this structure is not readily available. The important issue here is how to abstract the generic structure of a title from the title itself or, in general, from a more specific title abstraction. Figure 3 depicts two title abstractions from the same concrete title, each one in a different abstraction level. Examples of titles that fall under these title abstractions are also shown.

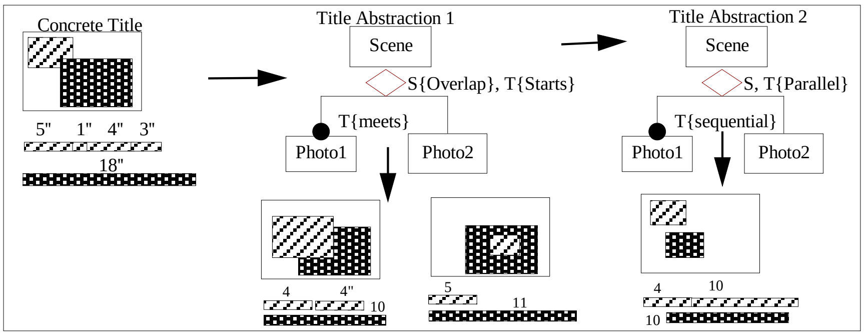


Figure 3: Title Abstractions from a concrete Title

Generalizing from specific representations has long been a major focus of AI research [16], where instance-based generalizations are attempted for various application fields. Abstracting the spatio-temporal synchronization, control flow and interactivity of multimedia titles from concrete titles should possibly utilize a common representational platform. The MHEG standard [18] -currently under development- provides a standard means for representing multimedia content, conditional links and spatio-temporal relationships. Title abstractions can be captured from MHEG-encoded multimedia titles. In [15] we discuss an initial approach on how MHEG is related to semantic models used for the conceptual modeling of interactive multimedia applications.

Notice that, depending on the abstraction level and to what is being abstracted, a title can fall under many title abstractions and many titles may conform to the same title abstraction. In fact, the possible abstractions of a title form a partially ordered set with respect to abstraction detail (discussed in section 4.1)

A portion of the Web explored during a browsing session can be considered also a multimedia title. Obtaining these title abstractions could be based on works like [7]. There, a system (Hy+ visualization system [2] supporting visualization of the database schema together with the database instances) is used for displaying graphically the history of the navigation of such portions of the Web. Queries for filtering out interesting sub-graphs of the browsed Web are also described.

2.3 How can multimedia title abstractions be represented?

A number of data definition and query languages for multimedia databases have been proposed [8, 20] as well as declarative ways with special focus on the definition of spatio-temporal composition of multimedia applications [9,25]. [14] is a survey of data definition and query languages for multimedia database systems.

However, representing and querying multimedia title abstractions calls for languages that satisfy some particular requirements (analyzed in section 3.1). We define a data definition and query language, called *Title Abstraction Definition and Query Language (TADQL)*, the formal syntax of which is given in section 5. Interactive multimedia titles modeled using the extended-OMT can be represented with the TADQL. The particular characteristics of TADQL are:

- it is a declarative *title abstraction* definition and *title abstraction* query language at the semantic level.
- it captures both the real world aspects and the presentational and interactivity aspects of multimedia titles.
- it provides a way for defining title abstractions in different abstraction levels, in terms of the structural properties of titles abstractions (spatio-temporal and interactivity constraints, class types and modeling constructs), through abstraction hierarchies of these constructs (e.g. INPUT is more abstract than BUTTON, PICKER etc., sequential is more abstract than meets, met-by, before and after (discussed in detail in section 4).
- it provides as standard class-types some common structures of multimedia titles such as SLIDESHOW and INTERACTIVE IMAGE (meta-classes defined in [15]).

An example of how (part of) the title abstraction of Figure 1 is defined in TADQL is given below:

```
CREATE CLASS Title
TYPE AGGREGATION_OF (GeographicArea)
CREATE CLASS GeographicArea
TYPE AGGREGATION_OF ( GROUP_OF (GeographicArea), GROUP_OF (Place),
GROUP_OF (AreaView) )
…………..
CREATE CLASS Hotel
TYPE AGGREGATION_OF (Scene, VIDEO)
SubType Of CompositeMultimediaObject
CREATE CLASS Scene
   TYPE AGGREGATION_OF (
         GROUP_OF (IMAGE) : TEMPORAL {meets}, SPATIAL {equal},
```

TEXT,
GROUP_OF (Button): TEMPORAL{equal}, SPATIAL{not overlap},
INTERACTIVITY
) : TEMPORAL {equal}, SPATIAL {not overlap}

3. Querying the Multimedia Title Abstraction Database

The WWW is the largest information resource available today. There are millions of HTML documents and very soon there will be millions of organized multimedia applications that a user can potentially browse. It has been realized that due to the rapid growth in data volume, Internet-accessible information is difficult to use effectively; text or context filtering retrieval methods are developed to address this need. *Filtering* in the retrieval of multimedia applications however can have one more approach which is not limited to content, but extended to spatio-temporal structure and the interactivity involved.

Consider the following query: find all the multimedia titles containing an object (e.g. a hotel) presented via a screen consisting of a slideshow and an image with several active hotspots on it. The content of these items is of no concern to the query while the structural and presentational aspects of the titles and possibly the semantics of the composite object (e.g. it refers to a hotel) are.

This query is a description of a *multimedia (sub-)title abstraction* and corresponds to the *key value* at the searching process. The output of the query would be all the multimedia title abstractions that "match" this *key title abstraction.* The multimedia title abstractions contain links to the concrete titles.

"Matching" the *key title abstraction* has the semantics of "can be abstracted to the key title abstraction". The retrieved title abstractions contain a (sub-)title abstraction that *can be abstracted to the key title abstraction* if abstraction transformations apply on it (section 4).

The *Multimedia Title Abstractions Database* which contains all the title abstractions is the database queried. A query can be defined either through TADQL or visually, through an extended semantic model (each title described in the extended-OMT model can be defined via the TADQL).

In the next section we analyze the requirements of a query language for multimedia title abstractions, exemplified by title abstraction queries.

3.1 Multimedia Title Abstractions Query Language: Requirements

The basic requirement of a title abstractions query language is to be able to retrieve all the multimedia title abstractions that contain a (sub)-title abstraction (fragment) which "matches" the title abstraction given. So, the query language should be able to describe these title abstractions and consequently must at least have the expressive power of the title abstraction definition language. Further, queries can be formed by combinations of title abstractions utilizing the logical operators *and* and *or* (e.g. If a_1, a_2, a_3 are title abstractions, query can be: (a_1 *or* a_2) *and* a_3 etc.). Given that the structure of the Multimedia Title Abstraction Database queried is unknown to the user, the query language should provide mechanisms for efficient retrieval of multimedia titles by fuzzy and imprecise queries and support partial matching in query evaluation and relaxation of queries. Finally, searching by title abstractions may result in a large number of titles, so incremental (nested) queries should also be supported. What follows is an analysis of such requirements along with title abstraction query examples.

3.1.1 Query language requirements concerning title abstraction properties

As described in Section 2 a title abstraction contains generic information about the title's semantic structure, presentation, control flow and interactivity, so a title abstraction query language should support:

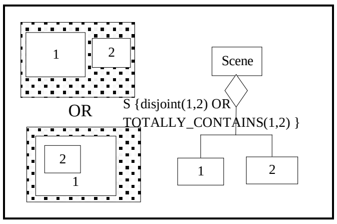
i. *Queries on the semantics of multimedia title abstractions*, including queries on these parts of title abstractions which capture the real world aspects and queries on the types of basic information units of the title, such as image, audio etc.

Example query1 : get all title abstractions containing a hotel abstraction presented by an IMAGE and a VIDEO. In TADQL:

```
SELECT TitleAbstractions
MATCH ( SELECT HotelAbstraction
            WHERE TYPE = AGGREGATION_OF(IMAGE, VIDEO)
          )
```

ii. *Queries on title abstractions presentational structure.* This includes:

- queries on *screen layout* of multimedia title abstractions, referring mainly to relative positioning of visual information units on screen surface and to spatial integrity constraints at various abstraction levels (any of the topological relationships between two spatial objects [3, 9, 25] and combination thereof) .

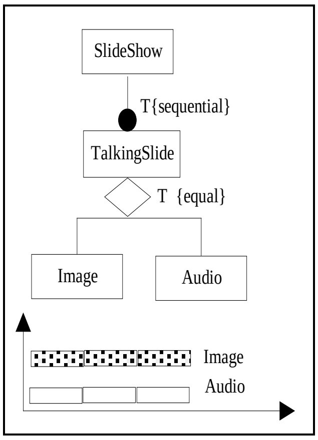


Example query2: get all title abstractions containing a screen with two photos, either disjoint or the one totally contains the other.

- queries on *temporal synchronization* of objects in multimedia title abstractions. The query language should support queries on temporal structures such as temporal aggregation or temporal grouping and on temporal integrity constraints at various abstraction levels (parallel, sequential or any of the 13 temporal relations [1] and combination thereof)

Example query3 : get all the title abstractions that contain a sequence of slides synchronized with pieces of audio. Query In TADQL:

```
SELECT TitleAbstractions
MATCH ( SELECT SlideShowAbstraction
        WHERE TYPE = GROUP_OF(
        SELECT TalkingSlideAbstraction
             WHERE TYPE = AGGREGATION_OF
                 (IMAGE,VIDEO):TEMPORAL{equals})
          :TEMPORAL{meets} )
```



iii. Queries on the *control logic and interactivity* of title abstractions including:

• the *interaction possibilities* offered e.g. get all title abstractions that have a number of BUTTONS and many HOTSPOTS spatially arranged all over the screen.

• the *interactivity structures* (aggregation and grouping) and *interactivity integrity constraints* e.g. get all title abstractions containing a scene whose interactivity is determined by the interactivity of its non-overlapped hotspots.

• the *behavior* of the multimedia objects under certain *conditions/events* e.g. get all title abstractions that contain a three-step loop. Queries on behavioral aspects of multimedia titles are the most complicated ones, as they require well-defined underlying models that capture this behavior (dynamic models or object-oriented models through methods)

Example query5: Get all title abstractions which contain a set of active non-overlapped hotspots and when a user clicks on any of them, a video clip plays.

Query In TADQL:

```
SELECT TitlesWithLinksFromHotSpotsToVideo
MATCH ( SELECT LinkClassAbstraction
        WHERE TYPE = LINK (GROUP_OF(HOTSPOT): SPATIAL{not overlap}:
                          CLICK),  (VIDEO: play)
      )
```

iv. Queries on any *combination* of temporal, spatial and interactivity aspects of multimedia title abstractions.

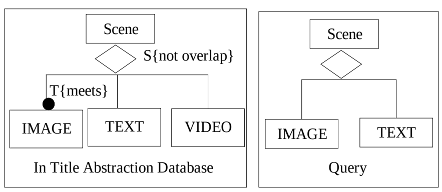
Example query6: Get all title abstractions containing a book metaphor with pages of hyperlinked text, possibility of changing pages interactively via index buttons which are spatially disjoint with the book.

3.1.2 Generic Requirements of a Title Abstraction Query language

A title abstraction query language should also support:

i. Fuzzy queries. Fuzziness refers to non-well-defined constraints or structural properties e.g. slide shows where photos change *very quickly* or screens having *many* photos, where the temporal relation and the multiplicity of the grouping association are not well defined.

ii. Queries with incomplete information in terms of structural properties of title abstractions e.g. asking for aggregation constructs by specifying a subset of their potential parts.



iii. Query relaxation. An overly restrictive query (e.g. temporal constraint “meets” in a slide show) may result in an empty set of titles while the title abstractions database may contain similar title abstractions (e.g. slide shows with “before” constraint) that the user would like to retrieve. Relaxing the query by performing abstraction transformations on it might have as output many titles -quite likely the intended answer.

iv. Incremental queries. A title abstraction query performs a filtering of title abstractions based on human remembering and may result in a large number of title abstractions. Incremental reformulation of queries or nested queries (on the result of the previous query) are useful either for getting more specific results or for further querying on the content of multimedia titles (e.g. retrieving titles with images that contain cars).

v. Composite queries. e.g. get all title abstractions that include a page with a video and a set of buttons *or* include a full screen slide show.

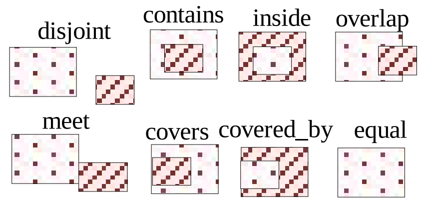
4. On Title Abstractions Transformations and Query Evaluation

In this section we introduce the basics of an algebra of abstraction transformations, as the basis of query evaluation for title abstraction databases. The approach of applying transformation rules for query evaluation has been followed also in [11] for the purpose of answering queries in terms of similarity of objects (objects that match a pattern approximately).

4.1 Title Abstraction Transformations

Let C be a set of object-oriented modeling constructs for the semantic modeling of interactive multimedia title abstractions e.g. C is a subset of the modeling constructs of the extended-OMT. C= TC ∪ SC ∪ CT ∪ AC where:

- TC is the set of temporal constraints between two time intervals [1] in various abstraction levels. TC = {meets, met-by, before, after, during, contains, overlaps, overlapped-by, starts, started-by, finishes, finished-by, equal, sequential, parallel}
- SC is the set of binary topological relationships between spatial regions in 2-D [3] in various abstraction levels. SC = {disjoint, meets, overlap, covered_by, covers, equals, inside, contains, GENERAL_OVERLAP, TOTALLY_CONTAINS, TOTALLY_INSIDE, LINES_TOUCH }



Basic binary topological relationhips

- CT is the set of multimedia class types [18]. CT = { CONTENT, MULTIPLEXED_CONTENT, INPUT, OUTPUT, VISUAL OBJECT, IMAGE, VIDEO, AUDIO, ANIMATION, TEXT, GRAPHICS, PICKER , HOTSPOT , SELECTABLE_CONTENT , STRING , VALUATOR , SELECTOR , MENU , EVENTER , BUTTON, ANIMATION, SLIDESHOW}
- AC is the set of abstraction modeling constructs.
  AC = {Aggregation association construct, multiplicity association construct}

I. We define the relation $_{a}\geq$ *"more or equally abstract than"* on the set C :

<u>On Temporal Constraints</u>

1. sequential ${}_a\geq$ {meets, met-by, before, after }
2. parallel ${}_a\geq$ {during, contains, overlaps, overlapped-by, starts, started-by, finishes, finished- by, equal}
3. $\forall c \in TC$, “not c” ${}_a\geq$ TC - $\{ x \mid c \; {}_a\geq x \}$

On Spatial Constraint

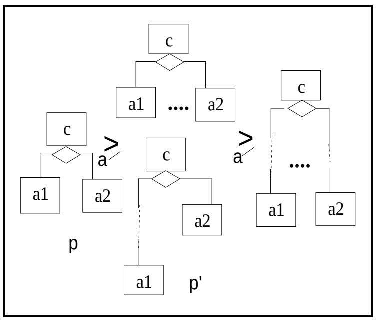
1. TOTALLY_CONTAINS ${}_a\geq$ {contains, covers, equal}
2. TOTALLY_INSIDE ${}_a\geq$ {inside, covered_by, equal}
3. LINES_TOUCH ${}_a\geq$ {meet, covers, covered_by, equal}
4. GENERAL_OVERLAP ${}_a\geq$ {overlap, covered_by, covers, equals, inside, contains, TOTALLY_CONTAINS, TOTALLY_INSIDE }
5. $\forall c \in SC$, “not c” ${}_a\geq$ SC - $\{ x \mid c \; {}_a\geq x \}$

On Class Types

1. CONTENT ${}_a\geq$ {VISUAL OBJECT, IMAGE, VIDEO, AUDIO, ANIMATION, TEXT, GRAPHICS }
2. MULTIPLEXED_CONTENT ${}_a\geq$ {VIDEO, ANIMATION, SLIDESHOW}
3. INPUT ${}_a\geq$ {PICKER , HOTSPOT , SELECTABLE_CONTENT , STRING , VALUATOR , SELECTOR , MENU , EVENTER , BUTTON}
4. OUTPUT ${}_a\geq$ {CONTENT, VISUAL OBJECT, IMAGE, VIDEO, AUDIO, ANIMATION, TEXT, GRAPHICS}
5. PICKER ${}_a\geq$ {HOTSPOT , SELECTABLE_CONTENT}
6. SELECTOR ${}_a\geq$ {MENU}
7. EVENTER ${}_a\geq$ {BUTTON}
8. $\forall c \in CT$, “not c” ${}_a\geq$ ST - $\{ x \mid c \; {}_a\geq x \}$

On Aggregation association constructs

Let AGGREGATION_OF(p) be an aggregation association construct on a set of classes p, where
$p = \{a_i \mid a_i \in CT \cup AC \}$.
If AGGREGATION_OF(p′) is an aggregation association construct on a set of classes p′ where
$p' \supseteq \{a_i \mid (a_i \in p) \text{ OR } (a_i \in q$, q set of classes and AGGREGATION_OF(q) $\in p)\}$
then, AGGREGATION_OF(p) ${}_a\geq$ AGGREGATION_OF(p′)



On multiplicity association constructs

Let c = GROUP_OF(A){mc} be a multiplicity association construct (structural, temporal, spatial or interactivity) on a set of objects of class A and mc the set of multiplicity constraints on c (e.g. {4}, {ordered}, {>5}).

If c′= GROUP_OF(A){mc′} and $mc' \subseteq mc$ then $c' \; {}_a\geq c$.

II. We define ${}_a\geq^*$ the transitive closure of the relation ${}_a\geq$.

III. We define the *abstraction transformation* $f_a: C \rightarrow C$:

$f_a(c) = c' \Leftrightarrow c' \;_a\!\geq^* c$ where $c, c' \in C$.

If $f_{a1}, f_{a2}, \ldots f_{a2}$ abstraction transformations, $f_a = f_{a1} \circ f_{a2} \ldots\ldots\ldots \circ f_{an}$ is an abstraction transformation (synthesis of abstraction transformations).

IV. Let TA be a set of *title abstractions* and $T \in TA$.

If $\exists\, c \in C$ in T, we denote $T \mid f_a(c)$ an *abstraction transformation on T* where c has been transformed to $f_a(c)$.

V. We define the relation $_a\!\geq$ "*more or equally abstract*" on the set TA as follows:
If $T_1, T_2 \in TA$, then $T_1 \;_a\!\geq T_2$ if $\exists c \in C$ in T_2 such as $T_1 \equiv T_2 \mid f_a(c)$.
The following hold for the relation $_a\!\geq$ on the set TA:

(1) For all $T \in TA$, $T \;_a\!\geq T$ (Each title abstraction matches itself)

(2) For any T1, T2, T3 $\in$ TA, if T1 $_a\!\geq$ T2 and T2 $_a\!\geq$ T3 then T1 $_a\!\geq$ T3.

(3) For any T1, T2 $\in$ TA, if T1 $_a\!\geq$ T2 and T2 $_a\!\geq$ T1 then T1 $\equiv$ T3.

The relation "more or equally abstract" ($_a\!\geq$) on the set TA is reflexive (1), transitive (2) and antisymmetric (3), so $_a\!\geq$ is a *partial ordering* on the set TA.

To define an abstraction transformation f_a on the set TA, we accept by convention that if an abstraction transformation f_a is not meaningful when applied to title abstraction T, then $T \mid f_a = T$.

If TA is a partially ordered set of title abstractions with respect to $_a\!\geq$, then an abstraction transformation f_a on TA defines a new partial ordered set TA′ with respect to the relation $_a\!\geq$. The new set TA′ is related with TA as follows:

Let $TA=\{T_1, T_2, \ldots T_n\}$ be a partially ordered set with respect to $_a\!\geq$ and f_a an abstraction transformation.

$T \mid f_a = \{T_1', T_2', \ldots T_n'\} = TA'$. TA′ is a partially ordered set of title abstractions with respect to $_a\!\geq$ and $T_1' \;_a\!\geq T_1$, $T_2' \;_a\!\geq T_2$, ….. $T_n' \;_a\!\geq T_n$.

4.2 On title abstraction query evaluation

A query is a title abstraction, the key title abstraction. A title abstraction T is considered answer to the query Q if there is an abstraction transformation f_a on T ($T \mid f_a$) such as $Q \equiv T \mid f_a$.

As null transformation is an abstraction transformation, so title abstractions which matches the query without any transformations are answers to the query.

Relaxation of queries: If there no f_a on T such as $Q \equiv T \mid f_a$, the query can be "relaxed" by applying abstraction transformations on it.

5. Title Abstraction Definition and Query Language (TADQL)

The following is BNF notation of the Title Abstraction Definition and Query Language syntax. Words in <*italics*> denote non-terminal elements of the language. Clauses in [ ] are optional arguments. **Bold** is used to denote reserved words.

<class definition> : **CREATE CLASS** *<new _class_name>*
TYPE <*class type* **>**
[*<hierarchy>*]
<class reference> : *< class_name>* | *<class type>* | *<select statement>*
< class_name> : identifier
<hierarchy> : **SuperType Of** *<sub_class_list>* | **SubType Of** *<super_class_list>*
<sub_class_list> : *<object_class_name>* | *<sub_class_list>, <object_class_name>*
<super_class_list> : *<object_class_name>* | *<super_class_list>, <object_class_name>*
<*class type***>** : *<Simple_class_type>* | *<Composite_class_type>*
<new_ class_name> : identifier
<Simple_class_type>[‡] : **CONTENT | MULTIPLEXED_CONTENT | COMPOSITE |**
VISUAL_OBJECT |
INPUT | OUTPUT
IMAGE | VIDEO | AUDIO | ANIMATION | TEXT | GRAPHICS |
PICKER | HOTSPOT | SELECTABLE_CONTENT |
STRING | VALUATOR |
SELECTOR | MENU |
EVENTER | BUTTON |
SLIDE_SHOW | INTERACTIVE_IMAGE
<Composite_class_type>:
GROUP_OF (*<member_class>)* [{*<constraints>*}] [: *<presentation_info>*]
| **AGGREGATION_OF** (*<part_class_list>*) [{*<constraints>*}] [: *< presentation_info>*]
| **LINK**[§] (*<source_ class_list>*) (*<target_class_list>*)
<member _class> : *<class reference>*
< part_class_list> : *<class reference>* | *< part_class_list>, <class reference>*
< source_class_list> : *<class reference>* [: *<condition>*]
| *< source_class_list>, <class reference>*[: *<condition>*]
< target_class_list> : *<class reference>* [: *<action>*]
| *< target_class_list>, <class reference>*[: *<action>*]
< constraints> : *<statement>* | **not** *< constraints>*
| *< constraints>* **and** *< constraints>*
| *< constraints>* **or** *< constraints>* | *(<constraints>)*
<statement> : string | function
<condition> : *<statement>* | **not** *< condition >*
| *< condition >* **and** *< condition >*
| *< condition >* **or** *< condition >* | *(<condition >)*
<action> : *<statement>*
< presentation_info>[**] : Any combination of *<temporal_info>*, *<spatial_info>* and *<interactivity_info>* separated by commas (“,”)
<temporal_info> : **TEMPORAL** [{*<temporal _constraints>*}]
<temporal constraints> : *<temporal relation>* | **not** *<temporal relation>*
| *<temporal constraints>* **and** *<temporal constraints>*
| *<temporal constraints>* **or** *<temporal constraints>*

[‡] A *<simple_class_type>* is a standard class type denoting primitive multimedia classes and composites thereof, which are very common in multimedia applications and can be used as reserved words

[§] **LINK** class type defines a class which specifies a set of relationships between one or more “sources” and one or more “targets”. Each relationship is composed of conditions associated with the sources and actions to be applied to the targets. The definition of Link class complies with the MHEG standard [18].

[**] *<presentation_info>* adds presentational information on the aggregation and grouping constructs (spatio-temporal composition and interactivity of multimedia titles during presentation).

| (<*temporal constraints*>)
<*temporal relation*> : **meets | met-by | before | after | during | contains | overlaps**
| cverlapped-by | starts | started-by | finishes | finished-by | equal
| sequential | parallel
<*spatial_info*> : **SPATIAL** [{<*spatial_constraints*>}]
< *spatial constraints*>: < *spatial relation*> | **not** < *spatial relation*>
| < *spatial constraints*> **and** < *spatial constraints*>
| < *spatial constraints*> **or** < *spatial constraints*>
| (<*spatial constraints*>)
< *spatial relation*> : **disjoint | meet | overlap | covered_by | covers | inside | contains | equal**
| GENERAL_OVERLAP | TOTALLY_CONTAINS | TOTALLY_INSIDE
| LINES_TOUCH
<*interactivity_info*> : **INTERACTIVITY** [{<*interactivity_constraints*>}]
< *interactivity constraints*> : < *interactivity relation*> | **not** < *interactivity relation*>
| < *interactivity constraints*> **and** < *interactivity constraints*>
| < *interactivity constraints*> **or** < *interactivity constraints*>
| (<*interactivity constraints*>)
< *interactivity relation*> *:* **hierachy | transparent | opaque | exclusive**
<*query definition*> : **SELECT** < *abstraction name*>
< *match statement*>
< *match statement*> *:* **MATCH** (<*select statement* **>)**
| < *match statement*> **and** < *match statement*>
| < *match statement*> **or** < *match statement*>
<*select statement*> : **SELECT** < *class name*>
WHERE TYPE = <*class reference* **>**
<*abstraction name*> : identifier

6. Conclusions

In this paper we dealt with an opportunity more than with a problem: the opportunity of effective and efficient extracting information from the vast repositories of organized multimedia units which reside not just on individual CD-ROM's but mainly and increasingly on the Internet, in distributed, transient and virtual forms. To extract such information we need querying and navigation mechanisms that go beyond simple browsing or exact querying of multimedia assets. We proposed and developed such a mechanism, based on the concept of title abstraction, a representation of the structural, presentational, interactivity and thematic aspects of the title. Abstractions are a flexible concept and the formal language in which abstractions are expressed, an extension of OMT, is suitable for title specification, constraint definition and query expression.

We presented this Title Abstraction Definition and Query Language as an object-oriented conceptual-level language, for two reasons: to help the reader understand and evaluate its usefulness without undue notational burden; and because little is accepted as standard for the logical and physical level in this area.

Of the several issues for continuation of our research, two stand out as more significant: First is to complete the formal aspects of the abstraction transformations algebra; and then to apply the concept on real title repositories. For this we intend to develop software tools which will extract abstractions from titles.

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