13 FUZZY LOGIC TECHNIQUES IN MULTIMEDIA DATABASES QUERYING: A PRELIMINARY INVESTIGATION OF THE POTENTIALS

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Abstract: Fuzzy logic is known for providing a convenient tool for interfacing linguistic categories with numerical data and for expressing user's preference in a gradual and qualitative way. Fuzzy set methods have been already applied to the representation of flexible queries and to the modelling of uncertain pieces of information in databases systems as well as in information retrieval. This methodology seems to be even more promising in multimedia databases which have a complex structure and from which documents have to be retrieved and selected not only from their contents but also from their appearance, as specified by the user. This paper provides a preliminary investigation of the potential applications of fuzzy logic in multimedia databases. Querying issues are more particularly emphasized. We distinguish two types of request, namely those which can be handled within some extended version of an SQL-like language, and those for which one has to elicitate user's preference through examples and which have an incremental nature. Moreover, the particular case of semi-structured documents is briefly discussed. Lastly, potentials of flexible constraint satisfaction problems in document production are pointed out.

13.1 INTRODUCTION

With the advent of the multimedia age, new functionalities and capabilities are needed for managing new kinds of data: images, sounds, texts, video data, and their combination into composite objects. The spatial, temporal, storage, retrieval, integration and presentation requirements of multimedia data differ significantly from those for traditional data. A multimedia DBMS (Adjeroh and Nwosu, 1997) must address many requirements such as:

- traditional DBMS capabilities,
- huge capacity storage management,
- information retrieval,
- media composition, integration and presentation,
- query support,
- interface and interactivity,
- performance and QoS (Quality of Service).

The full use of such information systems raises new issues, specially for the access and the manipulation of information in a more intuitive, less formalized and human-friendlier way. It poses new challenges from data indexing to querying and retrieval; due to the richness of multimedia data content, querying systems must have extended capabilities: providing high-level abstractions in order to model multimedia data and their presentation, querying them by the appearance rather than by their content, querying by example and allowing for flexible queries.

It is well-known that fuzzy logic provides a framework for modelling flexibility and vagueness in the interface between human conceptual categories and data. Such capabilities have been already developed in the database field, specially for handling flexible queries. There has been only a few very preliminary and very specialized papers on the use of fuzzy logic in multimedia databases systems (Bosc, Connan and Rocacher, 1998; Connan and Rocacher, 1997). In this paper, discussing some emerging but promising applications, we suggest that this methodology might be even more necessary and useful for multimedia applications, although no specific systems are surveyed.

In the next section, we explain multimedia databases specificities and features, versus "classical" (relational) databases requirements. Then, in Section 13.3, we restate and synthesize the contributions of fuzzy approaches to database and information retrieval systems. In the last section, we examine what functions, traditionnally allocated to DBMSs, still make sense in a multimedia environment, what new ones would be useful, and how fuzzy set-based techniques make it actually possible to improve multimedia systems capabilities. We specially investigate the querying step, by considering representative examples in the following.

13.2 MULTIMEDIA DATABASES

To meet the requirements we have mentioned, the multimedia DBMS must address a number of issues, including: data modelling, object storage, indexing, retrieval and browsing, query support, multimedia objects integration and presentation. A multimedia DBMS should provide tools for the efficient storage and manipulation of multimedia data in all its varied forms (Pazandak and Srivasta, 1997). We can view a multimedia database as a controlled collection of multimedia data items, such as text, images, graphic objects, sketches, video and audio. The multimedia DBMS should accommodate these special requirements by providing high-level abstractions in order to manage the different data types, along with a suitable interface for their presentation.

Some multimedia data types such as video, audio, and animation sequences also have temporal requirements, which have implications on their storage, manipulation and presentation. Images, graphics and video have spatial constraints in terms of their contents, and objects in an image present some spatial relationships between them. Representing multimedia information such as pictures or image sequences poses some problems for information retrieval due to the limitations of high level textual descriptions, and the massive information available according to the context, interpretation, user's profile, etc. The lack of standard structure of potential information means that it can be difficult to express precise queries from the beginning. The limitations of textual descriptions associated to a document imply the need for content-based access to multimedia information, referring for instance to shape, color, texture, etc.

On the whole, characteristic features of multimedia data are: lack of structured information, inadequacy of textual descriptions, multiplicity of data types, spatial and temporal characteristics, and huge volumes of data. Besides, the problems of heterogeneity of formats and of inconsistency between pieces of information, commonly encountered in multiple source databases, are still present in multimedia systems, but will not be addressed in the following since they are specific to them.

13.2.1 Indexing

Queries in relational systems are exact match queries: the system is able to return exactly those tuples a user is precisely asking for and nothing more. To specify the resulting relation, conditions concerning known attributes of known relations can be formulated.

From the Information Retrieval area, we know how difficult it is to characterize the contents of textual objects. Problems are encountered on the one hand in specifying the contents of the objects, and on the other hand, for describing the objects one is looking for. In multimedia databases, the question is thus how to characterize the 'contents' of image, audio or video data. Indeed, we must face the problem of giving an interpretation to a photo or a song, for which many interpretations exist in general, according to the context, the user's point of view (Apers et al., 1997).

Multimedia data must be preferably interpreted before they can be queried, in order to generate content descriptions (otherwise it might be more costly to make it on line). Multimedia information can be retrieved using identifiers, attributes, keywords,... Keywords are by far the predominant method used for indexing multimedia data. These keywords are metadata, since they are data about multimedia data. A user is supposed to select keywords from a set of words belonging to a prescribed vocabulary (specialized or not) or thesaurus. This method is simple and intuitive, but depends on the subjectivity of the person who makes the indexation or on the underlying hypotheses of an automatic indexation system, and obviously depends on the given vocabulary. Thus, indexing is context-dependent. Introducing abstractions allows the user to refer to the data in terms of high level features, which constitute his model of the application domain. For the retrieval and organization of the multimedia data, it should be possible to provide several layers of abstractions.

By contrast, low level representation of multimedia data encodes the physical reality. Automated indexing based on this representation uses features such as color, shape, texture, spatial information, symbolic strings, for indexing images; for instance (Flickner et al., 1995). For audio data (Wold et al., 1996), describing can involve analysis of the signal or speech recognition followed by keyword-based indexing; other perceptual and acoustic features are used for music data, such as note, tone, duration, or rhythm signature, chord and melody.

However, it is difficult to completely automate indexing: while the computer can easily analyze a picture containing works of art in terms of colors, textures, and shapes (Martinez, 1998), it is almost impossible to automatically determine interpretive or aesthetical features of an art object (e.g., is the red circle a rising sun on the landscape or the brim of a hat ?).

13.2.2 Querying and information retrieval: content-based query and retrieval

Roughly speaking, we can distinguish between queries aiming at retrieving one document from some distinctive pattern, and topically-oriented requests aiming at collecting a family of related documents. For instance, searching for data which contains specific audio samples or spoken parts, such as broadcasted news about a specific issue specified by some terms. In addition to single media based search, one may want to access data on the basis of a multiple media specification. In this case, a query usually involves different multimedia data types, various attributes, possibly keyword-based or content-oriented, or even contextual information. Retrieval algorithms must support content and context-based retrieval and multimedia DBMS should offer support for spatial and temporal queries.

Extensions of conventional concepts of query languages - all the retrieved objects exactly match to the query - will require that these characteristics be taken into account. It requires approaches that can deal with the temporal and spatial semantics of multimedia data, or query languages that can incorporate flexibility in the expression of requests. Indeed, queries are usually imprecise, so, relevance feedback and meaning similarity, rather than exact matching, and mechanisms for displaying ranked results are important. This is particularly important in combination with content-based access, where the specifications are often approximate and imprecise.

Besides, since information extracted from the data or from the queries might contain errors or might be inconsistent, query interpretation should accommodate uncertainties. Thus, facilities are needed in order to support incomplete information. Moreover, multimedia querying should offer support for new requirements such as querying by examples (from an existing image), querying spatial or temporal data, flexible querying using fuzzy predicates.

13.3 FUZZY DATA BASES

Research on "Fuzzy databases" (see Bosc and Kacprzyk, 1995; Petry, 1996) has been developed for about twenty years by a few small groups of scholars, with only marginal connections to the main trends of database research. If we except the more recent use of fuzzy techniques in data mining, these works have been mainly concentrating on three issues:

- flexible querying in classical languages (e.g., Kacprzyk and Ziolkowski, 1986 ; Bosc and Pivert, 1995), and in object-oriented languages (DeCaluwe, 1997);
- handling of imprecise, uncertain, or fuzzy data (e.g., Prade and Testemale, 1984; Dubois and Prade, 1997a);
- defining and using fuzzy dependencies (e.g., Raju and Majumdar, 1988; Bosc et al., 1998).

An introduction to these different issues may be found in a recent survey by Bosc and Prade (1997).

These tasks involve the three basic semantics which can be naturally attached to a fuzzy set (Dubois and Prade, 1997b), namely : preference, uncertainty and similarity. Indeed, the flexibility of a query reflects the preferences of the end-user. Using a fuzzy set representation, the extent to which an object described in the database satisfies a request then becomes a matter of degree. Besides, the information to be stored in a database may be pervaded with imprecision and uncertainty. Then ill-known attribute values can be represented by means of fuzzy sets viewed as possibility distributions. Moreover, a query may also allow for some similarity-based tolerance: close values are often perceived as similar, interchangeable (e.g., Buckles and Petry, 1982). Indeed, if for instance an attribute value v satisfies an elementary requirement, a value "close" to v should still somewhat satisfy the requirement. The idea of approximate equality, of similarity plays a key role also in the modelling of fuzzy dependencies. However, this last research trend will not be reviewed in the following, since this issue does not seem to be immediatly relevant for multimedia databases.

An advantage of fuzzy set-based modelling, is that it is mainly qualitative in nature. Indeed in many cases, it is enough to use an ordinal scale for the membership degrees (e.g., a finite linearly scale). This also facilitates the elicitation of (context-dependent) membership functions, for which it is enough in practice to identify the elements which totally belong and those which do not belong at all to the fuzzy set.

Fuzzy set-based techniques have been also raising interest in information retrieval for a long time (see Kraft and Buell, 1983; Miyamoto, 1990; Bordogna et al., 1995). In these approaches, degrees of relevance can be attached to each pair (key word, document). Besides, we may also think of fuzzy thesauri; but then we have to distinguish between a statistical degree which reflects the co-occurrence of non-interchangeable keywords in the description of documents belonging to the same corpus, and a degree of (approximate) synonymy between keywords (or a technical key word used for indexation and a user word). The analysis of relevance might be further refined by distinguishing, for a given vocabulary, between keywords which more or less certainly pertain to the document, and others which are relevant but somewhat optional (Prade and Testemale, 1987).

13.3.1 Advantages of flexible querying

Fuzzy set membership functions (Zadeh, 1965) are convenient tools for modelling user's preference profiles and the large panoply of fuzzy set connectives can capture the different user attitudes concerning the way the different criteria present in his/her query compensate or not; see (Bosc and Pivert, 1992) for a unified presentation in the fuzzy set framework of the existing proposals for handling flexible queries.

Thus, the interest of fuzzy queries for a user are twofold:

i) A better representation of his/her preferences. For instance, "he/she is looking for an apartment which is not too expensive and not too far from downtown". In such a case, there does not exist a definite threshold for which the price becomes suddenly too high, but rather we have to differentiate between prices which are perfectly acceptable for the user, and other prices, somewhat higher, which are still more or less acceptable (especially if the apartment is close to downtown). Obviously, the meaning of vague predicate expressions like "not too expensive" is context/user dependent, rather than universal. The large panoply of fuzzy set connectives can capture the different user's attitude concerning the way the different criteria present in his/her query compensate or not. Moreover in a given query, some part of the request may be less important to fulfil; this leads to the need for weighted connectives. Elicitation procedures for membership functions and connectives are thus very important for practical applications.

ii) Fuzzy queries, by expressing user's preferences, provide the necessary information in order to rank-order the answers contained in the database according to the degree to which they satisfy the query. It contributes to avoid empty sets of answers when the queries are too restrictive, as well as large sets of answers without any ordering when queries are too permissive.

13.3.2 Flexible queries and their evaluation

13.3.2.1 Enlarging a pattern by a tolerance relation

Two values u_1 and u_2 belonging to the same attribute domain U may be considered as approximately equal even if they are not identical. For instance if the pattern requires somebody who is 40 years old, an item corresponding to a person who is 39 may be considered in some cases as approximately matching the request. An approximate equality can be conveniently modelled by means of a fuzzy relation R which is reflexive (i.e. $\forall\, u \in U$, $\mu_R(u,u) = 1$) and symmetrical (i.e. $\forall\, u_1 \in U$, $\forall\, u_2 \in U$, $\mu_R(u_1,u_2) = \mu_R(u_2,u_1)$). The closer u_1 and u_2 are, the closer to 1 $\mu_R(u_1,u_2)$ must be. The quantity $\mu_R(u_1,u_2)$ can be viewed as a grade of approximate equality of u_1 with u_2. R is then called a proximity or a tolerance relation. When the query pattern is represented by a subset P of U (P may be fuzzy) but the retrieved item is a (precise) constant d, the tolerance R can be taken into account in the degree of matching by replacing P by the enlarged subset P ô R, defined by

$$\mu_{P\hat{o}R}(d) = \sup_{u \in U} \min(\mu_P(u), \mu_R(u,d)) \geq \mu_P(d). \quad (1)$$

Note that when P is fuzzy, $\mu_P(d) = 1$ still means total compatibility with P and $\mu_P(d) = 0$ means total incompatibility with P. Intermediary degrees of matching account for partial compatibility.

13.3.2.2 Weighted combination of matching degrees

In case of the *logical* conjunctive combination of several requirements P_i, which corresponds to an egalitarist view between the different requirements, the elementary degrees of matching are aggregated by the min operation which might be weighted for taking into account the importance of each requirement (min is the largest associative aggregation operation which extends ordinary conjunction; it is also the only idempotent one). Thus, for a piece of information $d = (d_1, \ldots, d_n)$, we obtain the global matching degree

$$\min_{i=1,\ldots,n} \max(1 - w_i, \mu_{P_i}(d)). \quad (2)$$

with $\mu_{P_i}(d) = \mu_{P_i}(d_i)$ where u_i is the precise value of the item d for the attribute pertaining to P_i, and where the following condition should be satisfied by the weights w_i:

$$\max_{i=1,n} w_i = 1, \qquad (3)$$

if there is at least one requirement that is imperative and thus can eliminate an item d when it is violated. Clearly when $w_i = 0$, the degree of matching $\mu_{P_i}(d)$ is ignored in the combination, then P_i has absolutely no importance; the larger w_i, the smaller the degrees of matching concerning P_i which are effectively taken into account in the aggregation. The normalization (3) expresses that the most important requirement has the maximal weight (i.e., 1) and is compulsory.

In the above model, each weight of importance is a constant and thus does not depend upon the value taken by the concerned attribute for the considered object d. This limitation may create some unnatural behaviour of the matching procedure. For instance, the price of an object you are looking for may be of a limited importance only within a certain range of values; when this price becomes very high, this criterion alone should cause the rejection of the considered object, in spite of the rather low importance weight. To cope with this limitation it has been proposed (Dubois et al., 1988) that the weight of importance become a function of the concerned attribute value.

Recently, Fagin and Wimmers (1997) have advocated the use of another weighted aggregation mode , namely

$$\Sigma_i (w_i - w_{i+1}) * i * f(x_1,\ldots, x_i)$$
$$\text{where } \Sigma_i w_i = 1 \text{ and } w_1 \geq \ldots \geq w_i \ldots \geq w_n,$$

and f is an aggregation function. The advantage of this scheme is its generality; moreover, it enjoys a restricted linearity property w.r.t. to the weights w_i which makes it similar to a Choquet integral (see, e.g., Grabisch et al., 1995). However this framework requires a *numerical* scaling, while (2) requires an *ordinal*, linearly ordered scale only (1- (·) being the order - reversing map of the scale). Indeed, since the numerical meaningfulness of degrees of relevance of documents, or of degrees of importance of keywords is debatable, qualitative aggregation schemes are more desirable.

We may think think that in some cases, min based aggregation leads to a ranking of retrieved items that is insufficiently discriminating because it relies on the comparison of the least satisfied properties. This can be greatly improved by the use of refinements of the min ordering (Dubois, Fargier, Prade, 1996b).

13.3.3.3 Hierarchical requirements

This framework also allows for conditional requirements. A conditional requirement is a constraint which applies only if another one is satisfied. This notion will be interpreted as follows: A requirement P_j conditioned by a hard requirement P_i is imperative if P_i is satisfied and can be dropped otherwise. More generally, the level of satisfaction $\mu_{P_i}(d)$ of a fuzzy conditioning requirement P_i for an instance d is viewed as the level of priority of the conditioned requirement P_j, i.e., the greater the level of satisfaction of P_i, the greater the priority of P_j is. A conditional constraint is then naturally represented by a fuzzy set $P_i \rightarrow P_j$ such that:

$$\mu_{P_i \rightarrow P_j}(d) = \max(\mu_{P_j}(d), 1 - \mu_{P_i}(d)) \quad (4)$$

where $P_i \rightarrow P_j$ is a prioritized constraint with a variable priority.

Nested requirements with preferences, of the form "P_1 should be satisfied, and among the solutions to P_1 (if any) the ones satisfying P_2 are preferred, and among those satisfying both P_1 and P_2, those satisfying P_3 are preferred, and so on", where P_1, P_2, P_3..., are hard constraints (Lacroix and Lavency, 1987), can be understood in the following way: satisfying P_2 if P_1 is not satisfied is of no interest; satisfying P_3 if P_2 is not satisfied is of no use even if P_1 is satisfied. Thus, there is a hierarchy between the constraints. One has to express that P_1 should hold (with priority 1), and that if P_1 holds, P_2 holds with priority α_2, and if P_1 and P_2 hold, P_3 holds with priority α_3 (with $\alpha_3 < \alpha_2 < 1$). Thus, this nested conditional requirement can be represented by means of the fuzzy set P*

$$\mu_{P*}(d) = \min(\mu_{P_1}(d), \max(\mu_{P_2}(d), 1 - \min(\mu_{P_1}(d), \alpha_2)),$$
$$\max(\mu_{P_3}(d), 1 - \min(\mu_{P_1}(d), \mu_{P_2}(d), \alpha_3)). \qquad (5)$$

Another type of sophisticated flexible queries which can be handled in the fuzzy set framework are those which call for an extended division, e.g., «find the items which satisfy at a sufficienly degree all the important requirements» (Bosc et al., 1997; Dubois et al., 1997).

13.3.3.4 Logical and compensatory ANDs

Queries are usually compound, and this raises the issue of finding the appropriate aggregation operation for combining the elementary degrees of matching. Even if the combination is linguistically expressed by the conjunction AND, it may correspond to very different aggregation attitudes ranging from logical to compensatory ANDs. Logical ANDs are modelled by weighted min operations as explained above. Many other (weighted) operations exist (for example, weighted averages correspond to an utilitarist view where compensation makes sense). Procedures for the practical elicitation of the right AND operator can be based on the ranking by the user of a few prototypical examples presented to him in order to identify what kind of aggregation he implicitly used (Dubois and Prade, 1988). More generally, examples can be used for identifying an operator in a parametered family.

13.3.3 Robust querying

As we already said, flexible queries are often motivated by the expression of preferences or tolerance, and of relative levels of importance. However, the use of queries involving fuzzily bounded categories may be also due to an interest for more robust evaluations. This is the case in a query like "find the average salary of the *young* people stored in the database", where the use of a predicate like "young" (whose meaning is clearly context-dependent) does not here refer to the expression of a preference; here, it is rather a matter of convenience since the user is not obliged to set the boundaries of the category of interest in a precise and thus rather arbitrary way. In such a case, a range of possible values for the average salary instead of a precise number will be returned to the user. This range can be viewed as bounded by the lower and the upper expected values of a fuzzy number; see (Dubois and Prade, 1990). It is a robust evaluation which provides the user with an idea of the variability of the evaluation according to the different possible meanings of 'young' (in a given context).

Another important class of flexible requests oriented toward robustness are those involving linguistic quantifiers such as 'most', e.g., «do most of the international trains leave on time?». In such a query, 'most' should be understood as a potential proviso for exceptions rather than as the approximate specification of a proportion to be checked (Bosc , Liétard and Prade, 1998).

13.3.4 Uncertain data

Viewing tuples as lists of attribute values, fuzzy data are associated with lists of fuzzy sets. Such lists contain possibly ill-known attribute values pertaining to the description of objects. Namely, a component in a list refers to only one (ill-located) element of the scale or domain of the concerned attribute; the corresponding fuzzy set which restricts the possible values of this attribute is called a possibility distribution.

The basic dissymmetry of the pattern-data matching is preserved by this modeling convention. Indeed, a fuzzy pattern represents an ill-bounded class of objects, while a fuzzy item represents an ill-known object whose precise description is not available. Namely let P and D be respectively a pattern atom and an item component pertaining to the same single-valued attribute, which are to be compared. P and D refer to the same scale U conveying their meanings. Let μ_P be the membership function associated to atom P and π_D

be the possibility distribution attached to D. Both are mappings from U to [0,1], but $\pi_D(u)$ is the grade of possibility that u is the (unique) value of the attribute describing the object modelled by the item. D is a fuzzy set of *possible* values (only one of which is the genuine value of the ill-known attribute), while P is a fuzzy set of *more or less* compatible values. For instance $\pi_D(u) = 1$ means that u is totally possible, while $\pi_D(u) = 0$ means that u is totally impossible as an attribute value of the object to which the item pertains. In the following μ_P and π_D are always supposed to be normalized, i.e., there is always a value which is totally compatible with P, and a value totally possible in the range D.

Two scalar measures are used in order to estimate the compatibility between a pattern atom P and its counterpart D in the item list, namely a degree of possibility of matching $\prod(P ; D)$ and a degree of necessity of matching $N(P ; D)$ which are respectively defined by (see Zadeh (1978), and Dubois and Prade (1988)):

$$\prod(P ; D) = \sup_{u \in U} \min(\mu_P(u), \pi_D(u)), \quad (6)$$

$$N(P ; D) = \inf_{u \in U} \max(\mu_P(u), 1 - \pi_D(u)). \quad (7)$$

The limiting cases where $\prod(P ; D)$ and $N(P ; D)$ take values 0 and 1 are useful to study in order to lay bare the semantics of these indices. For any fuzzy set, F on U, let $F^\circ = \{u \in U \mid \mu_F(u) = 1\}$ be the core of F, and $s(F) = \{u \in U, \mu_F(u) > 0\}$ its support. Then it can be checked that

(i) $\prod(P ; D) = 0$ if and only if $s(P) \cap s(D) = \emptyset$,
(ii) $\prod(P ; D) = 1$ if and only if $P^\circ \cap D^\circ \neq \emptyset$,
(iii) $N(P ; D) = 1$ if and only if $s(D) \subseteq P^\circ$,
(iv) $N(P ; D) > 0$ if and only if $D^\circ \subset s(P)$ (strict inclusion).

Note that $\prod(P ; \{d\}) = N(P ; \{d\}) = \mu_P(d)$ in case of a precise data ($\pi_D(d) = 1$ and $\pi_D(u) = 0$ if $u \neq d$).

Besides, fuzzy relations R on the real line can be used to grasp such usual notions as "much-before", "closely after", etc that can be applied to the comparison of (fuzzy or non-fuzzy) time-points and time-intervals. Thus, $\prod(D_1 \hat{o} R ; D_2)$ and $N(D_1 \hat{o} R ; D_2)$ evaluate respectively to what extent it is possible and certain that the fuzzy point D_1 be in relation R with the fuzzy point D_2. See (Dubois and Prade, 1989) for an extension of Allen(1983)'s temporal relations to the case of fuzzy data and/or fuzzy relations.

13.4 FUZZY SETS TECHNIQUES IN MULTIMEDIA SYSTEMS QUERYING

Making the most open form of querying possible addresses the need for a richer mixing of DB and IR in terms of predicates. New operators must be integrated into queries that often refer to the document appearance rather to its content. The notion of "content" already exists in classical IR through keywords, but not in classical DB.

As we already said, audio data, for example, can be indexed by signal analysis or speech recognition followed by keyword-based indexing. So, the fuzzy set techniques referred to in the previous section can be applied in multimedia data querying. We can also imagine audio records segmented and classified according to the speaker, or the musical atmosphere, with an assessment of level of similarity.

The previous section deals with "classical" flexible queries, that can also work on an abstract representation (metadata) of the objects, via indexes for instance. Indeed, the next sub-section deals with multimedia-oriented extensions of SQL/OQL. We will then consider queries implicitly specified through examples.

13.4.1 SQL/OQL like queries

It seems that one of the main differences between a multimedia database and an ordinary one from a querying point of view, is that in the first case the request may refer to a document[1] in terms of its appearance (e.g., in terms of features such as size, color, shape of pictures included in it) and not only in terms of its information contents. The lack of standardized structure of the document(s) to be retrieved calls for the use of flexible queries. e are going to illustrate these different points by several examples.

Q1. Retrieving an already seen document . The request refers to characteristic details in terms of appearance (spatial constraints).

"Find **THE** paper published in the *early 90's* which deals with 'x...' and 'y...', and *maybe* also with 'z...', with two pictures on the first page, of which the red one is *rather on the right*"

An extended OQL translation of this query could be (Ogle and Stonebraker, 1995):

```
select q
from q in doc_lib
where
q.creation_date in early_90() /*on-line process, expression of fuzzy set */
and q.description#'x....' and q.description#'y...'
and (maybe) q.description#'z...'
and count(meets_criteria(q.first_page(), picture))=2
and exists p1 in picture where meets_criteria(q,p1)
and meets_criteria(p1.histogram, «Red»)
and exists p2 in picture where meets_criteria(q,p2)
and meets_criteria(p1, (rather) right p2)
```

in which the features pertaining to the uncertainty of the description are highlighted.

[1] The notion of composite object is covered by the notion of "document".

early_90() is a fuzzy predicate expression which will be used for estimating the plausibility that a current document be the document we look for. **maybe** will be understood in the following way: the overall relevance of a document which does not deal with 'z...' will be discounted with respects to the ones which deal with 'x...', 'y...' and 'z...' (in other words, the latter documents are hierarchically preferred, see section 13.3.2 equation (5)). The evaluation of the fuzzy predicate expression '**rather** on the right' exploits the HTML description of the structure of the document.

Q2. Retrieving an already seen document (temporal constraints)
"Find **THE** video sequence which comes after a scene in which there's a man waiting *close to* a tree during *about 30 seconds* and where *a little after* we hear the sound of an engine"

```
select q
from q in video_lib
where
exists s where (
exists m where m.class#human and meets_criteria(s,m)
and exists o where o.class#.... and meets_criteria(m,(close_to) o)
and meets_criteria(s.length(), (about) 30 s))
and (exists sound where sound.class=engine
and meets-criteria(sound, (little_after) s))
and meets_criteria(q, after s)
```

about 30 s and **little_after** are temporal fuzzy predicates which can be evaluated from the story board.

The evaluation of **close_to** presupposes either a very precise indexation or an online evaluation of the image. If it is not possible (e.g., the indexation only mentions a man and a tree without distance information), the evaluation process should not reject the document even if it discounts it. This is a very general issue in such a problem where due to the lack of known structure of the document we cannot know if some feature is available or not. In such a case, the relevance of the current document will depend on the number of available features of the description (a document mentioning a man and a tree will be preferred to a document mentioning only a man or only a tree, etc).

Q3. Looking for a collection of never seen documents.

Visual display.

"find the documents dealing with 'x...' in which *most* pictures are from the 90's"

```
select q
from q in doc_lib
where
q.description#'x....'
and exists p in picture where meets_criteria(q,p)
and (most) p.creation_date in 90()            /* extended division */
```

This supposes that the detailed description of the picture includes its creation date.

This is an example where most is a proviso for exceptions (a document will be all the more preferred as it includes less photos before 1990 and more photos of the 90's).

"find the paintingS with *warm* colors"

```
select q
from q in photo_lib
where
q.class#art_object
and q in warm_colors()
```

By contrast with the previous example, here, warm_colors rather reflects user's preferences. warm_colors is a fuzzy set of colours whose definition may be context-dependent (see 4.2).

Auditory display

"find the pieceS where cellos *dominate*"

```
select q
from q in audio_lib
where
q.class#music
and cello.duration%q.duration in dominate()
```

The evaluation of a document supposes that it is known when cellos play and when they don't.

13.4.2 Incremental building of queries from examples

The user is not always able to easily express his request even in a flexible way. First, it may be more convenient for him to express what he is looking for from examples. Second, since he may have absolutely no a priori knowledge of the amount of retrievable documents (for a given request), it may be useful if the system is able to guide him about what exists.

Querying based on examples, for elicitating user's preferences, can provide the necessary information for building a query. Thus, the user may say to what extent a few examples of documents are similar to what he is looking for by using some (finite) similarity scale. Then, relevance of current documents is evaluated in terms of their similarity with respect to these examples. Issues are then close to fuzzy case-based reasoning (Dubois et al. 1998).

A first request, if it is too general, may retrieve too large a number of documents. Many techniques (fuzzy or not) exist for clustering such a set of documents. Then, these clusters have to be summarized in terms of prototypical elements (e.g. implicit keywords in an abstract) which are provided to the user. Once the user has chosen a cluster, he can refine his specification by means of a more accurate flexible query. This specification can be expressed in term of weighted keywords (and in term of similarities with other words).

13.4.3 Flexibility and semi-structured information

An important class of multimedia documents are semi-structured documents. The idea is here to allow for flexibility in exploiting semi-structured information (Abiteboul 1997), like HTML documents (Chrisment and Sedes, 1998). More precisely, we may like to refer to the structure in a flexible way.

Indeed, the request may refer to the description of a document structure (e.g. title, author(s), probably an abstract, maybe key-words, a body structured in sections and sub-sections, certainly followed by references, among which we preferably may find some author's name...).

Thus, a first level of querying, already exemplified in 4.1, is to retrieve an already seen document where the description refers to its structure (Djennane and Sedes 1996) in a flexible way.

Another example of this type of query is: 'find the paper including imperatively keywords 'x...', and preferably keywords 'y...', and which refers mostly to good papers in the domain'. The retrieving of relevant paper requires (i) to identify keywords and references in the document, (ii) to check if most of the authors belong to a set of 'good' authors on the domain associated with the present keywords.

Another type of query is to ask for "similar" documents, in terms of structure, from the previous sample structure.

13.5 OTHER RELATED ISSUES

Multimedia document editing environments mainly aim at enriching the representation of spatial placement and temporal layout (e.g., "the 2 sequences at the same time" in video). Modelling composition between objects and their synchronisation (intra/inter component) must express temporal relationships and spatial ones. One of the problems of multimedia document modelling is the specification of relationships and constraints: "this object finishes more or less at the same time as this other one". The display of multimedia objects must be coordinated so that the display meets prespecified and dynamic temporal and spatial constraints. For instance, Madeus (Jourdan et al., 1997) is a multimedia authoring and presentation tool that takes into consideration the four dimensions of multimedia documents: logical, spatial, temporal and hyperlinking. The temporal organisation of the document is called scenario. The temporal constraint networks formalism has been chosen to represent the set of temporal relations used to relate objects. Its advantage is to be easily interfaced with a declarative symbolic representation based on a set of quantified Allen operators together with a set of causal operators. In such a context, it may be useful to express flexibility in the adjustment constraints (e.g., beginning *nearly* at the same time) as well as in spatial ones (this object should *be rather on the right* of the other one). For that purpose, works on flexible constraint satisfaction problems (e.g., Dubois, Fargier and Prade, 1996a) are relevant.

It is worth pointing out that the handling of flexible queries may also require the evaluation of features at the signal level. For instance, in a remote image database, queries may for instance refer to the "average surface area of the large parcels". For such a query, the first step is a matter of image processing: detecting boundaries of parcels, computing their surface. The second one consists in entering, via the interface, what the user means by "large" (1 or 10 ha ?). The relative position of two objects in an image can be also computed at the pixel level using fuzzy set methods (Matsakis, 1998).

The intended purpose of this paper is to provide a preliminary investigation of the potential applications of fuzzy logic techniques in multimedia databases. Emphasis has been put on querying issues. However it is worth pointing out that these techniques could be also fruitful in other multimedia problems that we just briefly described above. Several different uses of fuzzy logic techniques in relation with multimedia systems have been surveyed. Among them, the application of these tools to semi-structured documents seems to be particularly promising and could be developed in a near future. Indeed, the current information systems technology is widely available and provide the support on which fuzzy specifications can be based. Some other applications clearly requires advanced indexation or on-line content analysis of the documents, which maybe still partially beyond the current available technology.

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