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An Integrated Approach to Digital Objects Storage and Retrieval

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Abstract: Image retrieval systems are becoming increasingly important in areas of research and commercial use. The storage of digital objects in the traditional databases is considered inadequate because of the extensive precise data required for successful retrieval. In addition, the retrieval process has been implemented using content-based image retrieval (CBIR) that relies on retrieving stored images from a collection by comparing low level features (binary form) that are automatically extracted from the images themselves. Data retrieval requires knowledge of attributes stored along with an adequate and flexible query language. For image repositories and retrieval, we noted that the integration of XML technology and case-based reasoning is more efficient and of great benefit in this area. This is mainly because users both in indexing and retrieval processes, tend to use old cases by associating images that reveal similar features. It is also because XML extends the original theory and offers a flexible approach with accurate data modelling and management tools. In this work, we also used fuzzy reasoning to convert the quantitative attributes into qualitative terms for indexing and retrieval.

Key words: XML, image retrieval, case-based reasoning, fuzzy logic

INTRODUCTION

No fewer than 170,000 items had, it was universally reported, been stolen or destroyed from Baghdad's Museum during the second Iraq war in 2003. These are representing a large proportion of Iraq's tangible culture. A large number of the famous artifacts in history and treasures including the best-known ancient Mesopotamian artefacts kept in the Baghdad Museum, are believed to have been looted in the disorder following the entry of US forces into the city. These objects include many of the most famous works of ancient Sumerian, Akkadian, Babylonian and Assyrian art, including the Uruk vase, dating from 3500BC and artefacts excavated from the ancient Sumerian city of Ur.

This study describes the design and prototype implementation of a novel architecture for integrated metadata and concept based indexing and retrieval of museum information. The system constitutes a virtual museum preserving some works that are lost and providing more versatile access to the images and information of lost treasures from Baghdad museum, in particular.

From prehistoric times, human communication has depended upon the creation and use of image-base information. This use has been increasing due to the growing use of digital technology such as scanners, digital cameras and mobile telephone. The rapid growth of the World Wide Web (WWW) has greatly motivated researchers and industry to develop tools in order to meet these increasing demands on image storage and retrieval[1].

One of the limitations of the current image analysis techniques necessitates that most image retrieval systems use some form of text description provided by the users as the basis to index and retrieve images. These techniques are rather primitive at present and they need further development and refinement. As the image retrieval system must be flexible to serve variety of users with different requirements, it not possible to index images based on pre-defined categories or on simple keyword matching techniques. For this reason, free text description is normally used. However, the quality of these descriptions is highly variable, given the inherent time costs and linguistic ambiguities associated with annotating images with text. Also, the performance of the retrieval process is highly dependent on a close match between the queries and the image descriptions. The queries may include vague or fuzzy terms that require special treatments.

In image systems, the data storage is only as useful as the retrieval methods. Therefore, another limitation of the current image retrieval systems is the use of sound knowledge representation paradigm. This is because the domains of these systems can be hardly represented by logical formalization. Therefore, we used case-based reasoning that has been proven more effective in such week-theory domains[2].

In order to maintain a close match between the user queries and the retrieved images, we therefore used an integrated technique based on similarity matching and fuzzy reasoning for indexing and retrieval of images.

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We also adopted XML case-representation to facilitate the image storage and retrieval process[3].

Image case-based reasoning: Case-based reasoning makes use of past experiences to derive the solution for a new problem. It has been widely implemented in practical applications[4,5]. To process past experiences (cases) efficiently, a common case-based reasoning technique is to select some characteristics that are representative of the cases and use them as indexes to store the cases. Later, to solve new problems, the system uses these characteristics as probe to retrieve the set of similar cases that are then adapted and modified to arrive at a targeted solution. Often, it is a common practice to narrow the set of retrieved cases by means of a similarity metric. Another problem encountered in case-based reasoning is the acquisition of past experiences when the reasoner is initially deployed. At that early stage, the reasoner may have to find a solution from scratch due to insufficient numbers of past cases to be used as model. Therefore, we used XML as case representation for making up structured knowledge-rich data. XML has been proven an effective knowledge representation technique for image database that is capable of XML is capable of representing sophisticated structures of a variety of types, well beyond the simple tables of delimited text commonly used to exchange information and comes with tools for describing those structures.

For dealing with image retrieval, we consider the query entered by the used as a new instance to be matched against existing cases that are previously collected and maintained in the case base (repository). An alternative source of expertise is an extensive memory of a case base CB= $\{C_1, C_2, C_k\}$. Faced with a new instance N, it may be possible to estimate a meaning for N by assuming that some suitable description of N relates to an equivalently phrased description of a case C_i of CB in the same way that the meaning of N relates to the meaning of C_i.

An image can be described by a set of (attribute, value) pairs. These pairs, which represent classification criteria, enable the users to select an image (a case) from already known images (case base) based on the degree of similarities between the description of a new image and of the selected images that may be described by qualitative and quantitative features. For case indexing and retrieval, there is a number of approaches deal with qualitative attributes[6]. We have, in particular, encouraged by the recent attempts at building systems that combine CBR and fuzzy set theory. In this work, we present an integrated approach that can deal with both qualitative and quantitative attributes. The approach converts the quantitative attributes into qualitative terms for indexing and retrieval. It applies fuzzy sets concepts to case indexing and retrieval to achieve that[7].

Using fuzzy indexing and retrieval allows attributes that are characterized by numerical values to be converted into fuzzy sets to simplify comparison. For example, the height of the artifact can be converted into categorical scale (e.g. tall/large, medium and short/small). Also, fuzzy sets allow multiple indexing of a case on a single value with different degrees of membership. For example, if the size is 60cm, this can be classified as tall with 0.4 and medium with 0.7, where 0.4 and 0.7 are the degrees that the height is classified as tall or medium respectively. This treatment increases the flexibility of case matching by allowing the case to be considered as a candidate when we are looking for an artifact with either large or medium size.

The key to satisfactory use of the case base is a simple and general scheme for the formation of reasoning. The present scheme depends on similarity matching of the properties of a given problem instant, a new case, to the properties of cases (objects) in a hierarchical structure. In contrast to other schemes, there is no context used in this scheme.

Image repository: The system database was designed to emphasize simplicity and portability. These criteria can be achieved by using XML file structure that also enables a smooth navigation and editing of the document. Therefore, the internal representation of the knowledge base is constructed using XML with multiple inheritances[8,9].

Every image added to the database is copied into the appropriate subfolder in the main directory of images and a resized small version of the file is copied into the thumbs directory. The XML directory contains the index files required to maintain the integrity of the directory structure and to manage the data extracted from the images. The design supports a simple access to data and ease of data distribution. When an image is added to the database, features are extracted from the image and stored in an index file in the xml directory of the database. The XML index file contributes to the design goals of simplicity and portability by allowing easy access to the underlying data.

The system is implemented using ASP.Net and DOM (Document Object Model). Using the DOM has several advantages over other available mechanisms for the generation of XML documents such as writing directly to a stream.

Since the DOM transforms the text into an abstract representation of a node tree, problems like unclosed tags and improperly nested tags can be completely avoided. When manipulating an XML document with a DOM, we need only to worry about parent-child relationships and associated information. The node tree created by the DOM is a logical representation of the content found in the XML file, it shows what information is present and how is it related without necessarily being bound to the XML grammar.

The way in which the DOM represents the relationship between data elements is very similar to the way that this information is represented in modern hierarchical and relational databases. This makes it very easy to move information between a database and an XML file using DOM.

Fuzzy sets and membership functions used in the system: In fuzzy sets an object may partially belong to a set, so the set must be represented by a continuous membership function that maps the domain of the set to an interval of [0, 1]. For example, the following functions (1-3) and Fig. 1 show the membership functions of high, moderate and low utilization as they are applied to the size and estimated price of an artifact in our application. Classical sets, which are subsets of fuzzy sets, represented by binary membership functions and therefore, they are subsets of fuzzy sets[7].

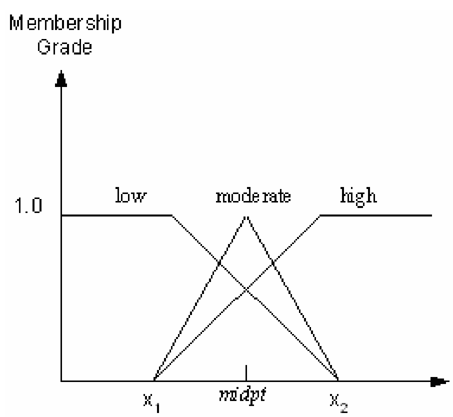

Fig. 1: The memebership function of high/tall, moderate/medium and low/small

1. $\mu_{high}(x) = (x-x_1)/d_o$ if $x_1 \leq x \leq x_2$, 0 if $x < x_1$, and 1 if $x > x_2$
2. $\mu_{moderate}(x) = (x-x_1)/0.5d_o$ if $x_1 \leq x \leq$ *midpoint*, $\mu_{moderate}(x) = (x_2-x)/0.5d_o$ if *midpoint* $\leq x \leq x_2$, $\mu_{moderate}(x) = 0$ otherwise
3. $\mu_{low}(x) = (x_2-x)/d_o$ if $x_1 \leq x \leq x_2$, 0 if $x > x_2$, and 1 if $x < x_1$

Where x_1, x_2, d_o and *midpoint* are as follows:

$$x_1 = \begin{cases} x_{CPU} = 30 \\ x_{I/O} = 20 \end{cases} \quad x_2 = \begin{cases} x_{CPU} = 70 \\ x_{I/O} = 40 \end{cases} \quad d_o = \begin{cases} d_{CPU} = 40 \\ d_{I/O} = 20 \end{cases}$$

$$midpt = \begin{cases} midpt_{CPU} = 50 \\ midpt_{I/O} = 30 \end{cases}$$

Since fuzzy sets use possibilities rather than binary membership values, a threshold value is often used to differentiate those considered highly likely to be a member of a set from those considered relatively unlikely. For example, when we are seeking for artifacts that have large size or tall, we may want to consider only those with membership grades of tall are above 5. This value is generally called α-cut. For example, if the membership function of tall, as defined in Fig. 2, is given and if the α-cut is set at 5 for tall, then artifacts with height greater than 55cm are considered tall, whereas artifacts that have their heights greater than 61 are considered very tall.

An additional set of extensions to the index structure allows queries to specify numeric ranges. Information retrieval systems normally treat numbers as keywords; a user searching for "2000 B.C." can find the exact value "2000 B.C.", but it is not possible to search for "between 2000 and 2200".

To enable numeric queries, when the system encounters a number it stores it as several keywords representing different time periods which contain the target number. For example, "1999 B.C." might be indexed under the keywords "Sumerians" and "Elamites".

When a user searches for a range, the keywords necessary to exactly cover the range are identified. Query results from each of these keywords are combined disjunctively. For example, a user specifying a numeric range of 1000-2200 might cause a query for the keywords "Sumerians" and "Elamites".

Image indexing and retrieval: Case attributes can be either quantitative or qualitative. Qualitative attributes accept nominal values. For example, the artifact type is a qualitative attribute whose value may be stone, bronze/copper, clay, gold, ivory, or shell. Quantitative attributes, on the other hand, allow values to be measured on a numerical scale.

Fuzzy indexing and retrieval are useful in domains where cases have quantitative attributes. For cases with qualitative attributes only, indexing can be performed on attributes directly. For example, artifacts can be classified as large, medium, or small (three classes according to their size); or can be classified according to their materials into six classes: stone, bronze/copper, clay, gold, ivory, or shell. We can easily index systems by their materials. If we also want to include the height or size, indexing becomes more complicated since the value of this attribute can be any positive real number. However, with a proper transformation into a few discrete classes based on practical requirements, indexing becomes easier to handle.

The process of fuzzy indexing is, therefore, of two stages. Quantitative attributes are first processed by the fuzzifier (called fuzzification) and then indexed on the resulting classes (indexing) before being stored in the CB. The following section describes these stages in more detail and illustrates how they can be applied to the lost treasures domain.

Fuzzification process: The fuzzification process includes the following steps:

1. When a case is encountered, qualitative attributes are identified.
2. For each quantitative attribute, proper classes are determined based on practical needs.
3. The membership function of each class and its associated α-cuts are determined.

4. Numerical values of each case are converted into proper classes for indexing.

To illustrate the fuzzification process, a running example is used. The context is a lost treasure domain that contains Artifacts, Figurines, Inlays, Jewelry, Metal Vessels, Musical Instruments, Pottery, Relief, Seals, Sculpture, Vessels and Terracotta. They are categorized into six different types: stone, bronze/copper, clay, gold, ivory, or shell. Figure 2 shows some of these objects in the XML database.


```
<?xml version="1.0"?>
<IMAGES>
  <IMAGE>
   <SERNO>1</SERNO>
  <MuesumNumber>IM19755</MuesumNumber>
  <CATEGORY> Limestone, Female </CATEGORY>
  <MATERIAL> Limestone              </MATERIAL>
  <KEYWORDS> Female, Standing, Limestone
                                          </KEYWORDS>
  <DESCRIPTION> Standing Female, Eyeballs of Shell
                                       </DESCRIPTION>
  <DIMENSION/HEIGHT/LENGTH> 54cm,
       tall/0.62, medium/0.25, small/0.0.13  </HEIGHT>
  <LOCATION> Tell Asmar </LOCATION>
  <PERIOD> Sumerian, Early Dynastic II 2600 B.C.
                                             </PERIOD>
  <STATUS> Stolen  </STATUS>
  <URL>http://MySite/ImageGallery/Images/
                                 standing_picl.jpg </URL>
  </IMAGE>
  <IMAGE>
   <SERNO>2</SERNO>
   <MuesumNumber> IM19653 </MuesumNumber>
   <CATEGORY>Female, Standing, Stone
                                      </CATEGORY>
    <MATERIAL> Stone </MATERIAL>
    <KEYWORDS> Female, Standing, Stone, South-Iraq
                                          </KEYWORDS>
   <DESCRIPTION> Statue of female wearing elaborate,
          flounced garment leaving one shoulder bare
                                       </DESCRIPTION>
    <DIMENSION/HEIGHT/LENGTH> 36cm,
           tall/0.54, medium/0.6, small/0.7 </HEIGHT>
     <LOCATION> Khafaji </LOCATION>
     <PERIOD> Sumerian, Early Dynastic II 2800 B.C.
                                             </PERIOD>
      <STATUS> Unknown  </STATUS>
      <URL>http://MySite/ImageGallery/Images/
                                 standing_pic2.jpg </URL>
  </IMAGE>
  <IMAGE>
    <SERNO>3</SERNO>
    <MuesumNumber>IM19759</MuesumNumber>
  <CATEGORY>Male, Stone, Standing </CATEGORY>
 <MATERIAL> Stone, Limestone </MATERIAL>
 <KEYWORDS> Male, Standing, Stone, South-Iraq
                                        </KEYWORDS>
 <DESCRIPTION>Statue of male bearded,
   long hair, bare-chested wearing flounced skirt,
   hands folded, standing on flat base </DESCRIPTION>
 <DIMENSION/HEIGHT/LENGTH> 54cm, tall/0.57
                 medium/0.46, small/0.42
                                        </DIMENSION>
  <LOCATION> Tell Asmar </LOCATION>
  <PERIOD> Sumerian, Early Dynastic, 2600 B.C.
                                      </PERIOD>
  <STATUS> Stolen  </STATUS>
  <URL> http://MySite/ImageGallery/Images/
                     standing_pic3.jpg</URL>
</IMAGE>
<IMAGE>
   <SERNO>4</SERNO>
   <MuesumNumber>IM9659</MuesumNumber>
   <CATEGORY>Female, Stone, Standing
                                      </CATEGORY>
   <MATERIAL> Stone, Limestone </MATERIAL>
   <KEYWORDS> Female, Standing, Stone
                                        </KEYWORDS>
   <DESCRIPTION>Statue of female
    wearing flounced garment leaving
     one shoulder bare, hands folded,
        standing on flat base     </DESCRIPTION>
<DIMENSION/HEIGHT/LENGTH>
   tall/0.059,  medium/0.8, small//0.4
   36cm </DIMENSION>
<LOCATION>  Khafaji  </LOCATION>                    <PERIOD>
Sumerian, Early Dynastic,
      2600 B.C.            </PERIOD>
 <STATUS> Stolen  </STATUS>
  <URL>
  <http://MySite/ImageGallery/Images/>
standing_pic4.jpg</URL>
  </IMAGE>
</IMAGES>
```


Fig. 2: Some cases in XML case-representation

Table 1: An image instance

Attrubute	Value
MuseumNumber	multicasts
CATEGORY	
MATERIAL	Limestone
KEYWORDS	Female Standing
DESCRIPTION	Standing female, eyeballs of shell
HEIGHT	65
LOCATION	Tell Asmar
PERIOD/YEAR	2600
STATUS	Stolen
URL	Standing_Pic1.jpg


```
<IMAGE>   <SERNO>4</SERNO>
<MuesumNumber>IM9659
        </MesumNumber>
<CATEGORY>Female, Stone,
  Standing </CATEGORY>
<MATERIAL> Stone,
  Limestone </MATERIAL>
<KEYWORDS> Female,
Standing, Stone
      </KEYWORDS>
<DESCRIPTION>Statue of
 female wearing flounced
  garment leaving one
  shoulder bare, hands
  folded,
standing on flat base
      </DESCRIPTION>
<DIMENSION> tall/0.059,
 medium/0.8, small//0.4
     36cm </DIMENSION>
<LOCATION> Khafaji
        </LOCATION>
<PERIOD> Sumerian, Early
  Dynastic, 2600 B.C.
        </PERIOD>
<STATUS> Stolen</STATUS>
<URL>
<http://MySite/>
ImageGallery/Images/
 standing_pic4.jpg</URL>
</IMAGE></IMAGES>
```


Fig. 3: A problem instance

In the transformation of the measurement data in Table 1, the fuzzifier handles the quantitative values that need to be converted into qualitative data. Usually, we classify the artifact height into three classes: tall, medium and small. Using the membership functions, given above, the fuzzifier converts the height value 0.65 into membership grades of the respective classes: 0.88 for tall, 0.25 for medium and 0.13 for small.

Table 2: Cases in sample base case (CB)

	Key Words	Descript.	Fuzzy Height	Fuzzy Price	Period/Year	Unusual Property	Status
1	Female	Standing	tall/0.62 medium/0.25 small/0.13	*	2600	*	Stolen
2	Female	Wearing garment, bare shoulder	tall/0.54 medium/0.54 small/0.45	*	2800	*	Unknown
3	Male	Bearded, long hair Wearing skirt	tall/0.3 medium/0.6 small/0.7	*	2600	*	Stolen
4	Female	Standing, wearing garment	medium/0.45	*	2600	*	Stolen
5	Male	Standing, wearing skirt, beardless	*	*	*	*	Unknown
6	Female	Wearing garment, one shoulder bare	heigh/0.57, medium/0.46 small/0.42	*	2600	*	Unknown
7	Female	Standing	heigh/0.92medium/0.15	*	*	*	Stolen
8	Male	Wearing short skirt	tall/0.45 medium/0.5 small/0.42	*	1800	*	Stolen
9	*	Standing figures	heigh/0.3 medium/0.4 small/0.7	*	1800	*	Stolen
10	Male	Standing, bearded	tall/0.9 medium/0.4	*	2800	*	Unknown

Table 3: An image instance

Attrubute	Value
MuseumNumber	
CATEGORY	Limestone
MATERIAL	Female
KEYWORDS	Standing female,
DESCRIPTION	eyeballs of shell
HEIGHT	54
LOCATION	
PERIOD/YEAR	2600
STATUS	Stolen
URL	

However, if the α-cut is set to 0.5, then the height, in this case, is classified as tall/0.88 only.

Image acquisition: Once a problem instance is indexed, four additional attributes are added before it becomes a case to be stored in the case base (CB). These additional attributes are: the case number, the *unusual* or the *interesting* property. Artifacts can be characterized of having unusual properties if their heights or sizes are too small or too large, i.e. out of the usual height or size ranges. Angles or animals that take human shape and vise versa are examples of artefacts with *interesting* property. At the final stage a case number is assigned and the case is added to the case base (CB).

The XML database is constructed after repeating the same procedures on other instances entered by the users. At the moment, the image database contains 600 cases that are divided into 20 categories.

Image acquisition can be done one at a time. However, the XML databases can be created if the user has some knowledge of XML technology.

Fig. 4: The main menu

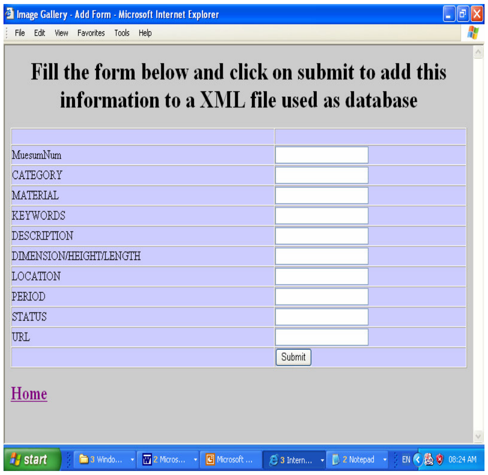

Fig. 5: Entry data form

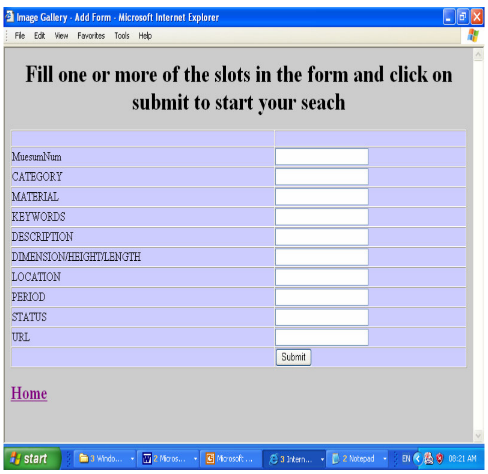

Fig. 6: The search form

Fig. 7: The results of searching for images when the data in Table 3 are entered

Table 2 shows some of the XML cases that are used in the discussion.

Image retrieval: Retrieval is an important process in case-based reasoning. Faced with a problem instance, the case based reasoning (CBR) first ranks cases in CB based on their degree of similarity with the problem instance. A similarity score that is computed by comparing each case with the problem instance quantifies this. Next, CBR retrieves the most similar cases.

For improving retrieval we used a fuzzy method that combines the fuzzy terms with known qualitative attributes and uses them as keys for retrieval of similar cases. The selection of past cases that best match the present problem depends on being able to identify and evaluate relevant attributes and being able to perform

Table 4: Distances between the problem instance of Fig. 3 and the candidate cases

Case	Fuzzy Height	Distance
1	tall/0.62, medium/0.25, small/0.13	0.85
2	tall/0.54, medium/0.9, small/0.45	0.2
6	tall/0.57, medium/0.85, small/0.42	0.09
7	tall/0.92, medium/0.15, small/0	1.38
Problem Instance	tall/0.59, medium/0.8, small/0.4	0

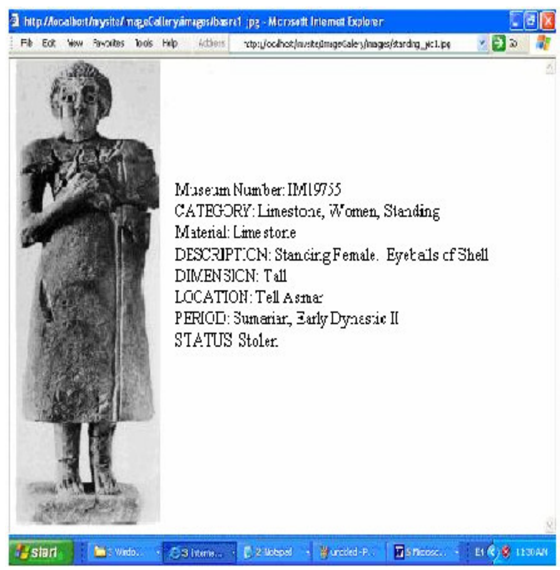

Fig. 8: Image along with its details

simple matching between cases. Given the cases in Table 2, suppose the goal is to retrieve an image similar to that described by Table 3. After transformation of data in Table 3, the following problem instance is produced and added to be a new entry in the XML database.

Based on the matching attributes of the problem instance, the case retrieval can easily select the cases 1, 2, 6 and 7 from the CB to be used as bases for performance evaluation of this new problem instance. Fuzzy retrieval often results in a set of candidate cases for reasoning. The issue following fuzzy retrieval is to find the most similar case among candidates. There are several ways of finding the most similar case. In this work, we use the following algorithm (similarity measure).

1. The similarity measure, dq, is calculated as follows:
2. dq = $\sum_{i=1}^{n} a_i$; where n is the number of the attributes.
3. The parameter, a_i, is set to -1 if the unusual-property for both the problem instance and the case has the same value; a_i is set to 0 if the attribute's value for the case is equal to the attribute of the problem instance; a_i is set to 0.5 if the attribute's value for the case is a wildcard (i.e. '*'). Otherwise the measure for the attribute is set to 1.
4. The similarity measure for fuzzy attributes is calculated as follows:

$$d_i = \sum_j abs(x_{ijk} - x_{ijn})$$

where x_{ijk} and x_{ijn} are the grades of attribute *i*, class *j*, for cases *k* and *n* respectively.

5. The similarity measure for the case is the sum of the results obtained from (1) and (2).
   $d_c = d_q + d_i$

Table 4 displays the results of applying this algorithm to the problem instance in Fig. 3 and the cases in Table 2. Case 6 is, therefore, the most similar case to the problem instance.

Experiment: Figure 4 provides the main menu of the image gallery. If we choose the option Fig. 5 will be displayed if the user has chosen the option "Add New Image Record" from the main menu, Fig. 5 will be displayed. If the option "Search the Database" is selected, then Fig. 6 will be displayed allowing the user to enter text to start searching the database for images that reveal similar features. Now, if the data presented in Table 3 are entered, then the system will display the results shown in Fig. 7. Clicking on any of the retrieved images, more information on that image along with its large size will be displayed. Figure 8 shows this action.

CONCLUSION

The results given above have been produced using XML file structure. This work aims to demonstrate the use of case-based reasoning for image storage and retrieval.

Cases may contain quantitative and qualitative attributes that are hard to index and manage in the case base; hence it is important to develop an effective method for handling them. In this work, we presented and used an integrated approach that uses fuzzy set concepts for indexing and retrieval of similar cases. The approach converts the quantitative attributes into qualitative terms. It applies fuzzy sets concepts to case indexing and retrieval in order to overcome the problem.

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