Smelling Objects for Multimedia Database Applications

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Abstract: The paper presents our view on the ways that olfactory information could be integrated into multimedia database applications by means of smelling objects. Until recently, multimedia applications have been mainly limited to the use of audio-visual information, stimulating only two of the five senses of human beings. The development of olfactory devices, along with significant progress in understanding the human olfactory system in the last years offers tremendous opportunities for building multimedia applications stimulating also the sense of smell. This could bring important advance in fields like education, medicine, military, and entertainment in the near future. We implemented five types of smelling objects that we used for storing and retrieving olfactory information together with audio-visual information in/from a multimedia database system.

Keywords: digital smell, multimedia objects, multimedia applications

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1. Introduction

In our previous works [1], [2], [3] we have already proposed a theoretical model of a multimedia database system integrating digital smell along with audio-visual information, called AViSS (*A*udio-*Vi*deo-*S*mell-*S*ystem). The prototype consists of three main components:

- *The Multimedia User Interface* (MUI) – the only component that is available to the user includes I/O multimedia devices and a Multimedia Software Interface (MSI);
- *The Processing Unit* (PU) – the component including a Multimedia Query Processor and a Synchronization Algorithm for the delivery of multimedia data;
- *The Multimedia Database* – includes a Hierarchical Storage Management System (HSM) for the efficient management of a hierarchy of magnetic and optical storage media and a collection of objects classes, which represents the foundation of the system.

The overall structure of AViSS has been presented in [1], where we also asserted the flow of information in the system and the main functionalities of each component. Then, important aspects of the Multimedia User Interface (MUI) have been discussed in [2]. These include various types of input/output devices (with emphasis on display technologies), as well as the structure and the functions of the Multimedia Software Interface (MSI). In [3] we evaluated the usefulness of the AViSS prototype in educational applications, based on the idea that using all of the three media – auditory, visual, and odor-based – in a carefully designed combination has the potential to provide a higher memory recall rate than in the case of using any combination of only two of them, as well as in the case of using each of them independently.

Improving the theoretical proposal described in the previous papers, the implementation phase of AViSS[1] introduced a hierarchy of object classes, focused on the integration of the olfactory information in the system. In comparison to other works, the novelty consists in the implementation of five new (olfactory) data types in the context of multimedia database systems, which establishes the foundation for the specification and processing of multimedia queries that also include olfactory features (see section 4).

The integration of digital smell into multimedia applications critically depends on the limitations imposed by the currently available olfactory output devices, also called *olfactory displays* (see [4], [5]) or *whiffers* (see [6]). During the implementation of AViSS we used the Scent Dome olfactory device and its additional software package (Senx-Ware Scent Design Studio - SDS) developed by Trisenx Holdings Inc. and already available on the market [7]. We will briefly describe the main functionalities of such a device in the next section of the paper. We will also refer to the limitations of the device whenever necessary in our explanation.

1 AVISS is an object-relational multimedia database system. The class hierarchy has been modeled in an object-oriented manner and implemented in MS C# .NET programming language. The multimedia objects have been mapped to the MS SQL 2000 Server relational database system.

2. Functionalities and Limitations of Olfactory Output Devices

The olfactory displays are electronic devices able to produce and release olfactory stimuli according to a digital fingerprint. Since the source of the olfactory stimuli is not a natural source (e.g. flower, tree, animal), but a digital fingerprint, the process is defined as a *virtual olfaction* and the system is called *virtual olfactory display*.

In [5] a virtual olfactory display (VOD) is defined as a system including a hardware device, a software package, and a set of chemical compounds that work together to produce olfactory stimuli and release them into the human operator's environment.

The hardware device that emits the smell is called a *whiffer* in [6]. Whatever its name, such a device works very similarly to an ink-jet printer. It has a number of different basic chemical compounds stored in a cartridge, which can be mixed in various concentrations, according to a digital fingerprint, in order to produce the desired smell. The mixture is then released into the user's environment.

Already at the end of 1990's several companies have announced their own devices producing computer-controlled smell. The first attempts of launching such equipment to the market failed (iSmell Personal Smell Synthesizer from DigiScent, SENX from Trisenx). Ruetz Technologies reported the use of their scent device called Sniffman in a multimedia 'niche' application for cinema (Duftkino2). At the beginning of 2004, Trisenx Holdings Inc. launched the Scent Dome device and the SDS software package for electronic commerce, interactive entertainment, training, and educational purposes. These technologies are already commercially available3.

The Scent Dome uses cartridges of 20 totally independent chambers, each of them containing a different basic aroma. Within the chambers, the fragrances and aromas are stored in small containers, the proprietary dispersion mechanism, which hold a volume capacity of 7 cc. The device is connected to a PC through a RS-232 serial port/USB adapter and receives commands from the SDS custom software. The user can select both the desired aroma and the duration of the release, and save them as a fragrance file (.frg). The setup can be re-used locally on the same machine, sent via e-mail, or even published on a website to remotely activate another Scent Dome device.

The SDS software package allows the user to create its own fragrances, using the basic aromas from the cartridge (Creating Fragrance). The user can select up to 4 aromas to be mixed in various concentrations to create a unique fragrance. Based on this information, the individual chambers containing the selected basic aromas open to create the new scent. After approximately 7 seconds a small fan inside the device is activated for 60 seconds to release the fragrance. Another option is to create an Aromatherapy setup. The user selects up to 4 fragrances and specifies the time on (the moment when the fragrance is released) and the time off (the moment when the fragrance chamber deactivates). The cycle is automatically repeated four times, at which time the device is reset and ready for a different selection (see [7]).

The delay between the moment of sending the digital fingerprint to the device and the moment of actually releasing the fragrance is crucial for the design of multimedia applications using a scent device and is reflected in our design of smelling objects. Another limitation resides in the fact that only one scent can be display at a time, while images can be displayed simultaneously on the same visual display. Moreover, the impurities in the user environment can influence the perception of the released mixture, which makes the device proper for use in closed and clean-air spaces. The odor-diffusion area is also very small, which makes it rather difficult to use the device for multi-user applications.

3. Smelling objects in AViSS

We have implemented two main categories of objects in AViSS:

- *mono-media objects* – objects of one of the following data types: Text, Image, Audio, Video, *Digismell*;
- *composite-media objects* – objects containing a combination of olfactory information with one of the audio-visual data types.

The novelty of AViSS in comparison with other multimedia database management systems described in the literature consists on the integration of the olfactory information. The system includes both the mono-media class *Digismell*, and four composite-media object classes integrating olfactory information along with the typical multimedia data (text, image, audio, and video). Let us briefly describe these new types of multimedia objects in the following subsections (see Figure 1 below).

2 See http://www.sniffman.de for details.
3 See http://www.trisenx.com for details.

3.1. The Digismell Class

The *Digismell* object class is a subclass of the generic class called *Object*, from which it directly inherits the following attributes:

ID = unique numerical identifier of each object in the system;

Name = textual identifier of each object in the system. It is more relevant and easier to use than the ID numerical identifier (the later is mainly used by the internal AViSS mechanisms, while the former is provided to users);

Size = numerical attribute that measures the necessary storage space (in kilobytes) for each object. This attribute is very important for the HSM, the hierarchical storage subsystem that should efficiently manage the storage media attached to the system;

Path = textual attribute that provides the correct path to the source file of each multimedia object. The path contains a directory hierarchy on the storage media of each multimedia object and the full name of the source file. In the case of a distributed system, the *Path* attribute also contains the IP of the node (machine) on which the object is stored;

Keywords = textual attribute containing a set of keywords extracted from the content of the multimedia object. This could be of very high importance for the efficient querying of multimedia data.

These attributes inherited by the *Digismell* class from the generic class *Object* are also directly inherited by the other mono-media object classes within AViSS: Text, Image, Audio, and Video.

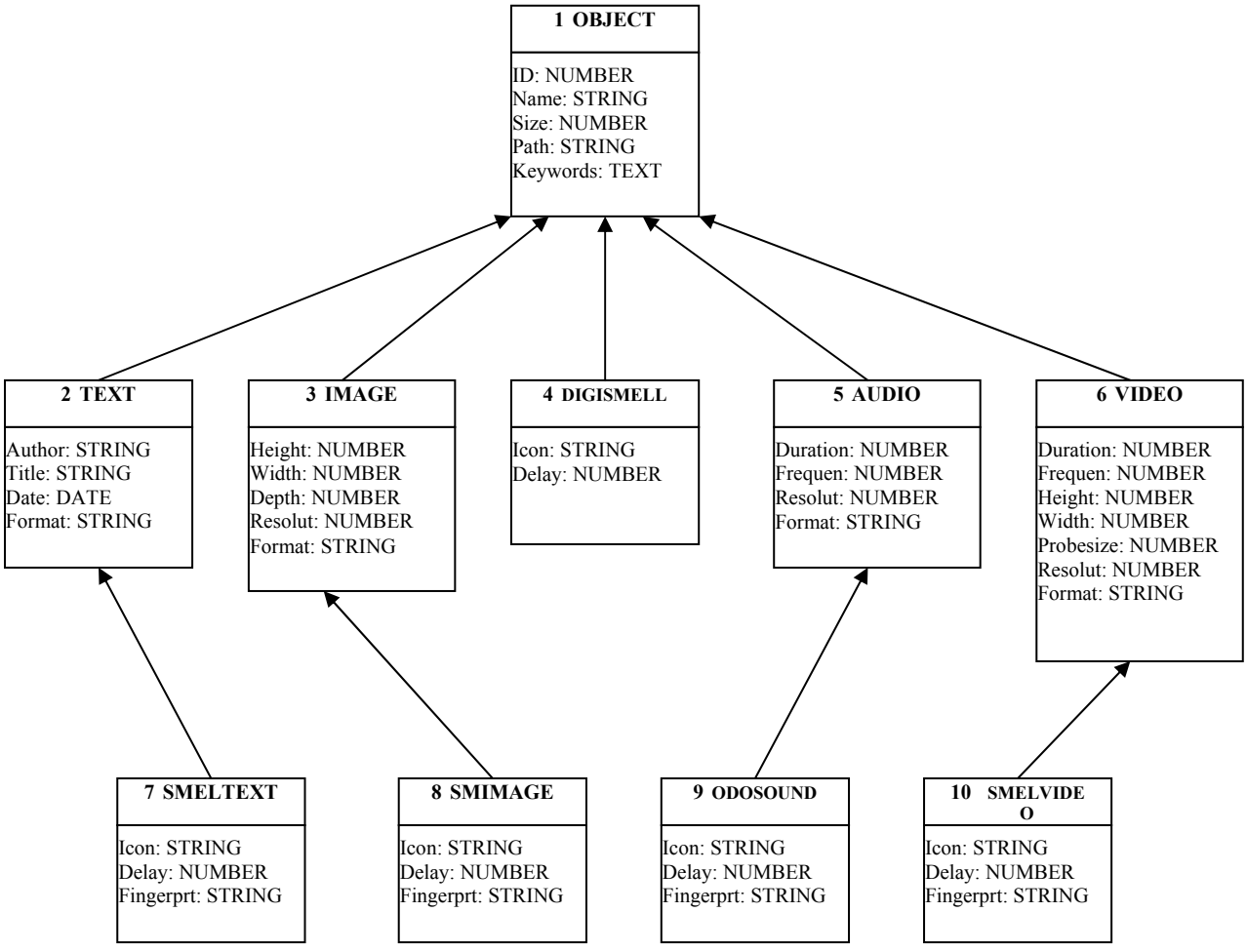

Figure 1: Proposed Class Hierarchy in AViSS

The source file indicated through the *Path* attribute contains the digital fingerprint of the *Digismell* object.

The structure of the source file mainly depends on the capacities of the olfactory output device integrated in the system. For example, using the olfactory output device Scent Dome (described in [7]) requires the occurrence of following parameters in the source file:

- *cartridge* – allows the user to choose the set of basic aromas to be used in order to create a new aroma (Scent Dome currently provides two different types of cartridges - *Fragrance* and *Food* – but other cartridges can be added without affecting the main functionalities of the device);
- *fragrance combination scheme* – there are 2 possibilities currently available: to combine up to 4 aromas in order to create a new one (*Creating Fragrance*) and to release it into the user's environment; to create an *Aromatherapy* setup that will be automatically repeated four times;
- *aroma composition* – specifies the basic aromas from the current cartridge used to create a new aroma and their concentrations in the final mixture;
- *release duration* – specifies the time interval (number of seconds) for the release of the mixture into the user's environment.

Here is an example of a possible general digital fingerprint for a new fragrance *S1* created by mixing *aroma1* (10%) and *aroma2* (90%) basic aromas from the *Cart1* cartridge in a *Creating Fragrance* setup.

```
[S1.frg]
Fragrance          // Creating fragrance setup
 2                 // Setup code
 1001              // Cartridge code
Aroma1             // Aroma name
 5                 // Delay for Aroma1
 10          // Concentration Aroma1
 6                 // Code Aroma1
 0
Aroma2             //Aroma name
 53          // Delay for Aroma2
 90          // Concentration Aroma2
 8                 // Code Aroma2
 0
```

Displaying the olfactory file actually means transmitting the above-mentioned parameters to the olfactory device, mixing the basic aromas, and releasing the new aroma into the user's environment.

The specific attributes of the *Digismell* object class are:

Icon = textual attribute similar to the *Path* attribute, indicates the path to the associated icon of the *Digismell* object. The icon plays an important role in suggesting the user the significance of the aroma. It is mainly used by the software multimedia interface;

Delay = numerical attribute measuring the period of time (in seconds) between the moment of sending the parameters to the olfactory device and the moment of releasing the aroma into the environment. This attribute is critical to the synchronization algorithm of AViSS and to building interactive multimedia applications.

The behavior of *Digismell* objects consists in releasing an aroma based on the digital fingerprint stored into the source file. It is also expressed by the value of the *Delay* attribute, which is calculated as the maximum of the delays of the basic aromas included into the digital fingerprint.

In order to facilitate object retrieval, the setup information (cartridge code and setup code), the composition (basic aromas and their concentrations), and the delay of *Digismell* objects are inserted into the database at the moment of object creation or indexing.

3.2 Composite-media Smelling Objects

For the multimedia applications that we want to build on the top of AViSS, the simple presence of *Digismell* objects is not completely justified. In most of the cases, the integration of olfactory information is relevant only in combination with the other multimedia data, more precisely to enrich text, image, audio, and video objects with olfactory stimuli. Therefore, we implemented the following composite-media data types within AViSS:

Smeltext – textual information enriched with olfactory information. This kind of objects could be used for the design of *smelling e-books*, *smelling e-cards*, or even *smelling e-mails*, in order to enhance the impact of a particular story or message with relevant olfactory stimuli;

Smimage – still image enriched with olfactory information. The semantic dimension of such an image increases by adding olfactory stimuli in accordance to its visual meaning. Among the multimedia applications that could use smelling images we include: botanical studies (smell plays an important role in the study of plants), electronic marketing and selling of aromatic products (coffee, tea, perfumes, aromatic candles, sticks and napkins, cosmetics);

Odosound – audio sequence enriched with olfactory information. Sound files (including music in a digital format) convey messages to the auditory. The message could be enriched with olfactory information in order to have a greater impact on the listeners. Many musical bands use odorant emissions during their concerts to stimulate crowd's involvement;

Smelvideo – video sequence enriched with olfactory information. This kind of video sequences can be successfully used in the entertainment industry, for instance in the case of smelling movies (we have already mentioned DuftKino – the olfactory cinema), or even for educational purpose.

Adding olfactory information to audio and video sequences, which are continuous data (i.e. dependant on a time scale) makes the process of segmentation even more difficult than it already is. Consequently, we define the *Odosound* and *Smelvideo* objects as being audio and video segments that have a distinctive background of olfactory information, which means that the smell emission doesn't change during the display of the entire object. More complex audio and video sequences (even short movies) can be built on the top of this kind of smelling objects by correctly treating the delays generated by the olfactory output device. The display of the auditory and visual data must be synchronized with the release of the additional olfactory information (this is the role of the synchronization algorithm of AViSS).

Each of the four composite-media object classes presented in Figure 1 directly inherits attributes and behavior only from the corresponding super-class, but not from the *Digismell* object class. For instance, a *Smimage* object is primarily an image, inheriting attributes and behavior from the *Image* class. The specific attributes of the *Digismell* class (*Icon* and *Delay*) are also taken into account to discriminate between a simple *Image* object and a *Smimage* object. Although tempted to use the multiple inheritance (inheritance from both super-classes *Image* and *Digismell*), this could induce many ambiguities during the implementation. Both super-classes inherit several attributes from the generic class *Object* and would create a „dreaded diamond".

All of the four composite-media object classes previously defined include the *Fingerprint* textual attribute, similar to the *Path* attribute of the *Digismell* object class. The *Fingerprint* attribute provides the path to the digital fingerprint of the olfactory information. This is required as far as the *Path* attribute inherited by the composite-media object class from the generic class *Object* via its mono-media super-class refers to the path to the source file of the audio-visual information (Text, Image, Audio, or Video).

The behavior of a composite-media object is more complex than the behavior of a mono-media object. For example, displaying a *Smimage* object involves the presentation of the corresponding *Image* object on a visual display, synchronized with the releasing of the corresponding scent on the virtual olfactory display. This is also valid for the behavior of the other three types of composite-media objects: *Smeltext*, *Odosound*, and *Smelvideo*.

The delay produced by the technological limitations of the currently available olfactory output devices in presenting the olfactory information to users, decisively influences the behavior of the composite-media smelling objects. Displaying smelling objects involves synchronization between audio-visual information (which can be almost instantly presented) and olfactory information (which requires a delay in the presentation). Otherwise, the significance of the presented smelling object is lost and a high degree of confusion is induced at the user's perception level.

4. Aroma-based Queries in AViSS

Alike most of the database systems, the query process in AViSS consists of three main phases: query specification, query execution, and displaying the results. In addition, the design of the five odor-based object classes in AViSS allows users to create and execute aroma-based queries against the multimedia database, which is to our knowledge the first implementation of this kind.

Aroma-based queries in AViSS are content-based queries that retrieve smelling objects from the multimedia database according to their olfactory composition. In the query specification phase, in addition to audio-visual attributes or content features, the user can select up to four basic aromas and set the concentration for each selected aroma, thus creating an olfactory predicate within the complex multimedia query.

When the query is executed, the *Multimedia Query Processor* initially identifies the object classes that could generate results. For example, if the user builds a multimedia query that requires objects with both auditory and olfactory attributes, it is obvious that *Image* or *Smimage* objects could not be retrieved. Therefore, objects of these types are not further taken into account, thus considerably reducing the object search space for large collections.

In the case of content-based multimedia queries that would retrieve objects on their audio-visual as well as olfactory content, another important optimization step is easily made by firstly selecting only those objects that include the specified basic aromas. This implies the execution of a simple SELECT query, as the olfactory composition of the smelling objects is mapped in a table of the relational database. Retrieving objects on their audio-visual content is usually more complicated and therefore applied to the reduced search space, in order to improve the response time.

The results of an aroma-based query in AViSS is a list of smelling objects ordered descending by their total relevance, which also includes the olfactory relevance. This is crucial in the case of all multimedia database systems, which are large collections of multimedia data that usually allow querying on fuzzy predicates (e.g. similar to, mostly blue). Thus, the list of results is normally very long, but only the first few retrieved objects are relevant to the user (similar to Internet search engines).

The olfactory relevance of a smelling object related to an aroma-based query reflects the similarity between the olfactory composition of the object (its basic aromas and their concentration) and the selection made by the user in the specification phase. It is calculated using the following formulas:
(olfactory relevance of object *O* related to query *Q*)

$$r_S^Q(O) = \frac{\prod_{i=1}^{n} r_S^Q(a_i)}{n} \quad (1)$$

(olfactory relevance of aroma a_i related to query *Q*)

$$r_S^Q(a_i) = \frac{1}{|c_{ai} - c_i|} \quad (2)$$

where:

O = the smelling object;
Q = the aroma-based query;
n = the number of basic aromas contained by *O*;
c_{ai} = the concentration of aroma *i* in the olfactory composition of object *O*;
c_i = the concentration set for aroma *i* in the query *Q*;

Exception for (2) is when c_{ai} equals c_i, in that case the relevance of aroma a_i related to query Q being 1.

5. Conclusions

The integration of olfactory information in multimedia applications has the potential of increasing the impact on user's perception and its degree of involvement, which can lead to a higher accomplishment of the application objectives. It can be presumed that it is more worthwhile to design and use smelling objects (audio-visual objects enriched with olfactory information) like those presented by us in this paper, than to simply release scents into the user environment. The smelling objects can be stored by means of a multimedia database and efficiently retrieved also by their olfactory content.

On the other hand, the presence of olfactory information considerably decreases the performance of the system, as a consequence of the delay induced by the technical limitations of the currently available scent output devices. Moreover, it requires efficient synchronization between audio-visual data and olfactory stimuli in the phase of presenting the smelling objects to users. Additional problems can reside in the high cost of the output device and its cartridge, which does not make it attractive for personal use. Therefore, we expect the first multimedia applications including smelling objects to be used in education and research, medicine, and military.

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