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Paper:

The User Interface and Content-Based Image Retrieval Systems

C.C. Venters, J.P. Eakins and R.J. Hartley

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The User Interface & Content-Based Image Retrieval Systems.

Colin C. Venters

Department of Information & Library Management, University of Northumbria at Newcastle, Lipman Building, Newcastle Upon Tyne, NE1 8ST. colin.venters@unn.ac.uk

Dr. John P. Eakins.

Department of Computing, University of Northumbria at Newcastle, Ellison Building, Newcastle Upon Tyne, NE1 8ST. john.eakins@unn.ac.uk

Richard J. Hartley

Department of Information & Library Management, University of Northumbria at Newcastle, Lipman Building, Newcastle Upon Tyne, NE1 8ST. richard.hartley@unn.ac.uk

Abstract.

User interface design for content-based image retrieval systems is proving to be a fruitful area of research. However, a number of design issues need to be addressed. The major problem lies in the need to provide users with high-quality interfaces for query formulation and display of results. This paper describes the background and intentions of a new Department of Education and Employment (DfEE) Information Science Research project. The project aims to investigate the design and development issues of a user interface for a content-based image retrieval system. The following areas are discussed: the background, the research problem, the aims and objectives, and the methodology.

1. Introduction.

New approaches to the problems of indexing visually oriented material have focused on the development of interactive systems that allow the automatic retrieval of images on the basis of image content. Despite the importance of designing usable interfaces, the current interfaces for a number of these systems suggest that the design of an effective user interface has not yet been achieved. The design and development of a user interface for these retrieval systems is proving to be particularly problematic. The major difficulty lies in the need to provide users with high-quality interfaces for query formulation and display of results.

This paper outlines a DfEE Information Science Research Studentship project at the University of Northumbria at Newcastle (UNN). The research seeks to address the problems of user interface design by investigating the design and development of a Graphical User Interface (GUI) for the ARTISAN (Automatic Retrieval of Trademark Images by Shape Analysis) system. The paper focuses on the following areas: the background, the research problem, the aims and objectives, and the methods by which we hope to achieve the overall aim.

2. Background.

2.1. Digital Images.

Developments in computing technology have resulted in a growing number of computer-based applications and systems which produce and utilise image data e.g. engineering and architectural systems. This technological development has resulted in an escalation in the number of digital images in the world. Digital images are defined as images that consist of a set of elements (pixels), defined on an n-dimensional regular grid that have the potential for display [1].

For example, NASA's Earth Observing satellite generates approximately 1 terabyte of image data per day [2]. This proliferation of digital images has created a need for efficient, economic storage and flexible retrieval and manipulation of vast amounts of image data [3]. However, information professionals have only focused their attention on the challenge of managing visually oriented material in the last decade [4]. Visually oriented material is defined as material that consists of non-textual data.

2.2. Image Retrieval.

From cave paintings to computer-generated graphics the visual image has existed in many forms throughout the development of the human race. From an information management perspective the ability to effectively manage visually oriented material has posed enormous problems. These difficulties have been addressed in some depth by Cawkell [5], Enser [6], Shatford [7] and Svenonius [8]. However, such is the recognition of the indexing problem, it is noticeable by its absence in a number of image collection projects [5].

Efforts to address the problems have resulted in attempts to develop effective indexing systems. A number of major indexing systems now exist e.g. Art & Architecture Thesaurus (AAT), ICONCLASS, and TELCLASS. However, these indexing systems have only provided a partial solution to the problem. The AAT system is designed only to handle Western art and architecture out of the totality of art and architecture. ICONCLASS covers the same subject area with a different emphasis. Cawkell also suggests that the verbal descriptors available to describe the visual content of an image are often inadequate to express meaning for non-subject specialists [5].

The main difficulty of indexing images arises from the intrinsic 'non-verbal symbolism' of images and the 'reading' process [9]. The ability to read visually oriented material is subject to the knowledge and subject expertise of the reader, and their ability to translate and interpret meaning. For example, the goddess Venus may be used to symbolise love. This example illustrates that in order to interpret the 'non-verbal symbolism' of a picture some degree of background knowledge and subject expertise is required on the reader's part. As Enser's research illustrates, description and meaning of a visual image is open to individual interpretation [10]. Sunderland also demonstrates that the ability to interpret visually oriented material is subject to a number of factors which compound the problem further e.g. age, gender, social grouping [11]. The phrase "one picture is worth a thousand words" [12] emphasises the difficulty faced by information professionals in developing effective indexing systems to manage such material.

The physical task of indexing images is a labour-intensive operation. For example, The Durham Record [13] was a major 2 year project undertaken by Durham County Council Arts, Libraries & Museums Department. It attempted to make available the Council's collections of pictorial images and other data relating to the history and industrial tradition of County Durham. The main element of the system was Durham County Council's photographic collection. This included all the photograph collections at Durham City Library and other smaller branches, together with selected photographs from the 15,000 held in the Darlington Local Studies Centre, The Durham Light Infantry Museum, the County Archaeological Service and some special collections at the County Record Office. One of the many problems the project faced was the time taken to index the volume of digital images. The indexing was undertaken by a small team, and initial estimates had envisaged indexing an average of 200+ images a day. In reality only a maximum of 60 images could be indexed in any one day.

So as more projects involving the electronic storage and retrieval of images have been developed, the problems of indexing digital images have become more acute [4]. The difficulties involved in finding appropriate solutions to the problems of indexing images, combined with the physical task of indexing the volume of images, make the task of human indexing almost beyond the bounds of possibility. It is evident from the problems outlined that there is now a growing requirement to develop alternative approaches and methods to manage, organise, navigate and retrieve an ever increasing number of visually oriented material. However, the issues involved in developing effective alternative approaches are complex.

Research and development in the field of image processing and recognition has grown from modest beginnings to a thriving area of research and development. There is now a growing number of world wide research projects which are investigating image processing and recognition [14-22]. One particular area under investigation focuses on the retrieval of images on the basis of a direct matching operation between a specified dataset of images and a visual query. This research has advanced significantly over recent years and has resulted in a number of working prototype content-based image retrieval (CBIR) systems. These CBIR systems allow users to query and retrieve images based on a specific criterion or combination of criteria e.g. colour, texture, shape, volume, spatial constraints, objective and subjective attributes [2]. This ability to store and retrieve images within a single application has created exciting and new opportunities for improved management and access to visually oriented material. A review [2] of CBIR systems outlined the numerous and diverse applications in which these systems have the potential to play a principal role e.g. art galleries and museums management; architectural and engineering design; interior design; remote sensing and management of earth resources; geographic information systems; scientific database management; weather forecasting; retailing, fabric and fashion design; trademark and copyright database management; law enforcement and criminal investigation; picture archiving and communication systems. Nevertheless, the difficulties involved in developing such systems are problematic e.g. image encoding, storage, compression, transmission, display, shape description and matching. The following sections briefly outline a number of prototype CBIR systems:

2.2.1. QBIC: Query By Image Content.

IBM have developed a system called QBIC (Query By Image Content) [14, 23]. The system allows users to perform a variety of searches based on the principles of visual properties. Images can be searched by percentages of properties such as colour, colour layout, shape, and textures occurring in the images e.g. 40% of a specific shade of green, 20% of a shade of white. The search will return hits arranged by rank output. For example, a query using a white house on a green background could produce a match with a white bird on a green background. QBIC also allows users to restrict the number of returned hits by using a combination of keywords such as the artist's name, and media with the visual image content query.

QBIC is currently being tested by a number of institutions e.g. the Art and Art History project at the University of California, Davis (UCD) [24], the Fine Art Museum of San Francisco [25], and the French Ministry of Culture [26]. The initial results of these test were variable. While the retrieval performance for some images is encouraging, specific images highlighted the limitations of the QBIC software. For example, the UCD database contained approximately 38 images of horses in various positions e.g. side, front, back three-quarter views. When a query was performed on any of these images, only 3-4 images containing horses were retrieved. This poor retrieval performance was the result of the software's inability to discern between horses if the views were significantly different [27].

2.2.2. VIRAGE.

VIRAGE [15] are developing similar image recognition technology to that of IBM. The technology lets users search and sort collections of photographs, graphics, and other images based on the visual attributes of the image data. The Visual Information Retrieval (VIR) technology developed by VIRAGE uses attributes of images, e.g. colour, texture, structure, and composition, to perform searches through collections of visual assets to find images that are visually similar. To allow for the different needs of each search, the weighting of search criteria, such as colour, texture or composition, can be adjusted to interactively refine the results. Similar to QBIC, the VIRAGE system also allows searching by keyword. The success of VIR technology is reflected in a number of commercial organisations incorporating the technology into their products e.g. Oracle [28], Kodak [29], PhotoDisc [30].

Work on image processing and recognition within UNN has focused on providing automatic retrieval of images containing specified shape-similarity [20, 31]. Initial research concentrated on the development and evaluation of a prototype system for a restricted class of images [32]. The resulting system, known as SAFARI (Shape Analysis For Automatic Retrieval of Images), supported a database of two-dimensional line drawings of simple machined parts, performed automatic shape analysis, and provided both example-based similarity retrieval and partial shape matching facilities. The encouraging retrieval performance of the initial prototype suggested that its principles of shape description and feature extraction were worth further development. The findings of this research have been developed a stage further with the ARTISAN project. ARTISAN assessed the feasibility of generalising the image retrieval approach developed in the earlier SAFARI system to a wider range of image types. The dataset used was a set of abstract geometric images from the UK Patent Office's Trade Marks Registry. A recent evaluation of the systems image retrieval performance produced encouraging retrieval results despite difficulties in retrieving a relatively small number of image classes. However, these problems suggest that the current system does not yet offer reliable enough performance to form the basis of an commercial image retrieval system [33].

3. Research Problem.

One of the primary elements of any computer-based system is the user interface [34], yet Chang [3] fails to stress the importance of the user interface as a major feature in his assessment of the requirements for pictorial information systems. In contrast, Eakins [35] in his review of the prospects and problems of pictorial information systems believes that the effectiveness of image-based retrieval systems is being hampered by a number of existing problems, one of which is the user interface. This disparity in opinion together with the apparent lack of literature focusing on user interface design for CBIR systems suggests that the problems of designing suitable user interfaces for such systems have not been addressed in any great depth. However, the design of a user interface is complex.

3.1. User Interface Design.

Most systems are well-defined in terms of the technical tasks that are to be performed, yet the user interfaces are generally the least understood and the most hastily designed components [36]. Poor interface design can result in a number of problems e.g. increased frequency of errors in system operation and data entry, poor systems performance, systems failure, and user frustration.

The design of any user interface requires some appreciation of human psychology in order to understand human-computer interaction, principally, perception and cognition, and needs to take these human cognitive abilities and limitations into account. However, systems and people are complex. Difficulties arise between the end-users ability to communicate their requirements, and the system developer's ability to assess and analyse user interaction, user requirements, and to evaluate users opinions to produce a flexible and usable interface design. For example, users may have identified specific requirements that could improve their ability to perform various tasks. However, although users may verbalise there requirements, they generally lack the technical jargon and knowledge to convey these requirements to system developers [37]. In comparison, system developers assume that users understand their technical jargon and overestimate the knowledge of the user [38].

This recognition of the complexities of designing user interfaces by the majority of system designers has resulted in a proliferation of approaches to the design of the user interface [39]. Several methodological approaches have been devised which have established a suitable criterion for designing user interfaces and providing the means for evaluating them [34, 40-43]. However, in our opinion this recognition does not appear to have been adopted by developers of CBIR systems. The major problem of designing a user interface for CBIR systems lies in the need to provide users with high-quality interfaces for query formulation and display of results.

The ability to formulate and communicate a query is a fundamental function of all information retrieval systems. The difficulty encountered with this approach to image retrieval lies with the formulation of a visual query. The more complex the shape and structure, the more difficult it is for the user to formulate and produce a usable visual example. Some appreciation of a specific dataset will help demonstrate the problem. The dataset used by ARTISAN was a set of images from the UK Patent Office's Trade Marks Registry. A sizeable number of the Trade Marks Registry dataset is made up of abstract geometric design which have little or no representational meaning. Typical images for this class are monochrome, multi-component, with few textured areas. The following images are examples from the UK Patent Office's Trade Marks Registry:

Figure. 1.

Figure. 2.

Figure. 3.

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The problems of indexing visually oriented material have been briefly outlined in Section 2.2. These examples demonstrate the difficulties involved in attempting to apply an indexing language to abstract geometric shapes. Simply, the same image can be described in a number of different ways. Figure 1. demonstrates the subjective nature of describing abstract geometric shapes. For example, the image could plausibly be described as twelve individual bars, four wedge-shaped blocks, three concentric arcs or one thick circular arc. The limitations and difficulties of applying an indexing language to an abstract geometric shape demonstrates the importance of developing alternative methods that allow query formulation and retrieval of such images. However, the problem lies in designing suitable tools and features that allow the formulation of such complex visual queries. The following section briefly outlines the current features of the QBIC, VIRAGE and ARTISAN user interfaces:

3.1.1. The QBIC & VIRAGE User Interface.

Currently QBIC [14] and VIRAGE [15] demonstrate their imaging technology through the Web. The Web interface to both systems allows the user to select an image from a randomly displayed group of thumbnail images by clicking on the chosen image. Features to refine the search criteria, such as colour, texture or composition, can be selected through a variety of buttons, drop-down menus, icons and dialogue boxes. Hits are again displayed as thumbnails in rank output in an expandable holding area which can display 12-48 images at a time. Remaining images can be viewed by scrolling through the holding window. However, one important feature missing from these Web interfaces is a facility that allows end-users to construct a visual query. The user interface for the QBIC experimental system at the Art and Art History project at UCD [24] differs slightly from that accessible over the Web. The GUI on the QBIC prototype system allows users to form a visual query by painting, sketching or selecting graphical elements [2, 27]. However, no formal evaluation has been conducted into the usability and functionality of such features.

3.1.2. The ARTISAN User Interface.

Since the main focus of the projects research to date has been the automatic retrieval of images containing specified shape-similarity and not the user interface, the current ARTISAN [20] system has neglected the overall design of the user interface. The ARTISAN [20] system runs on a PC under a Windows 3+ platform. The current interface has the look of a standard Windows environment e.g. buttons, dialogue boxes, check lists, scroll bars, menu bar, icons, drop-down menus, tiled windows. To run a query users can use a specified or randomly selected file number from the database. Users can select a criteria of run-time matching options by checking a number of retrieval preferences e.g.

symmetric and asymmetric spread, boundary shapes and positions, blackness, family characteristics. Retrieved images are displayed in rank output with the initial query image included in the search output for comparison. Images not currently visible on the screen can be viewed by using a scroll bar. Again no facility is currently provided by the system to allow end-users to interrogate the database by means of formulating a visual query.

The approach to image processing and recognition adopted by QBIC [14, 23], VIRAGE [15], and ARTISAN [20] suggest that searching for images visually, rather than by keywords or associated descriptors is worth pursuing. However, the current interfaces for QBIC, VIRAGE, and ARTISAN lead us to conclude that the design of an effective user interface has not been investigated in any depth. If CBIR systems are to be viable applications, the design of a suitable user interface for query formulation and the display of results is one of most fundamental aspects of developing the systems. The design of an appropriate user interface which allows the formulation of an accurate visual query still requires investigation.

4. Aims & Objectives.

The current interfaces for ARTISAN, QBIC, and VIRAGE demonstrate the need to produce flexible and usable interface designs for CBIR systems. This research project aims to design and evaluate a GUI for ARTISAN, and in so doing establish a framework for future developments and designs of user interfaces for CBIR systems. To achieve this aim there are various objectives that must be achieved:

- investigate user interface design with a particular emphasis on human-computer interaction.
- examine user needs and requirements for content-based image retrieval systems (CBIRS) in general, and the ARTISAN shape retrieval system in particular.
- develop and evaluate several interface test designs for the ARTISAN shape retrieval system.

To accomplish this, the following methods will be employed:

4.1. Assessing User Requirements.

It has been suggested in Section 3.1 that a user centred approach, focusing on the human-computer interaction (HCI), is required to produce a sound, flexible and usable interface design. Therefore, building on the areas identified in the review of the literature, e.g. user interface design, HCI approaches and methods, data collection and field work concerning users requirements will be a necessity prior to prototype interface development. It is important at this stage to gain in-depth knowledge and insight into end-user requirements in order to develop appropriate and possible interfaces. Potential volunteers will be identified based on suitability and willingness to participate e.g. patents and trademark agents. A criterion for selecting the sample will be developed as the project progresses, however, at the time of writing it is not possible to state what this will be. Combining the experience and knowledge of the selected volunteers and a demonstration of the current ARTISAN system, data concerning possible interface requirements will be collected using recorded, semi-structured interviews. The scale of the data collection will be constrained by both time and money but sufficient data will be collected to enable an interface specification to be developed for the design of possible prototype interfaces for ARTISAN.

4.2. Design and Development of the User Interface.

The results of the data collection, identification and application of interface design issues, and the specification developed in the previous stage will lead to the design and subsequent development of a possible number of prototype interfaces for ARTISAN. Whilst the design and features cannot be determined in advance of the user requirements, it is helpful to illustrate some possible approaches. For example, three types of user interfaces could be developed for the ARTISAN system.

- an example-based interface, in which a query can be scanned on the screen by placing the sketch under a scanner, or submitted to the system as a rough sketch using existing commercial drawing packages.

- a menu-based interface, allowing users to select and combine query features, represented as text descriptors or icons, perform Boolean searches on the database, examine results and amend queries where required.
- a browsing interface. Images could be computed and clustered according to similarity measurements with icons representing each cluster displayed on the screen. Selection of an icon would then allow the display of full information about the object and its drawing file.

However, our initial ideas lead us to hypothesise that specific features of the user interface will be more intuitive to particular types of users. This could be overcome by introducing a 'wizard' that offers a variety of methods for interrogating the database. For example, one 'wizard' feature could help the user build and formulate a visual query by selecting and combining various predetermined search preferences and shape features. This might be ideally suited to a novice user who has little experience of using image retrieval systems. While the concept of 'wizards' are not new they have not yet been applied to the problem of visual query formulation or CBIR systems.

4.3. Evaluation.

The effectiveness of interface designs should be measured in terms of usability, utility, control, efficiency and ultimately user satisfaction. Evaluation and analysis of users opinions of the design of a suitable interface for ARTISAN will be the cornerstone of the research. The user interface will be evaluated using a mixture of both naive and expert users. The precise mixture of techniques will be developed as the project develops but is likely to include questionnaires, observation and interviews. It is important to continually re-evaluate the prototype. If time and resources allow, a sample of users will be used for a follow up interview to gain more extensive and qualitative information. The interface will be refined further as a result of the information gained in the evaluation.

5. Summary.

User interfaces are critical to the success of any software system. Accepting the hypothesis that one of the major obstacles to effective content-based image retrieval systems design lies in the need to provide users with high-quality interfaces for query formulation and display of results, interface design is a fundamental element to the overall success of CBIR systems. A number of interfaces could be developed for these system e.g. example-based interface, menu-based interface, browsing interface that may provide a suitable interface for query formulation. However, what constitutes an appropriate interface for query formulation and display of results for CBIR systems still has to be investigated in greater depth. Whilst the investigation will concentrate on the specific case of the ARTISAN system, this research project will attempt to highlight the unique problems associated with human-computer interaction (HCI) and the design requirements for a user interface for CBIR systems in general. If successful it is hoped that the findings will contribute a framework of theoretical principles, guidelines and models for the development of more user centred interfaces for content-based image retrieval systems. In terms of research into CBIR systems it can be concluded that the user interface remains the least researched and developed element of the system.

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