What Happened to the User?

Perspectives on the Role of the User in Content Based Image Retrieval Research

1. Abstract

This paper discusses the role of the user in Content Based Image Retrieval Systems. The main goal of the paper is to discuss potential reason for why there is a seeming lack of focus on the human in a large part of current CBIR research and literature. Using computer science as a backdrop, we discuss the traditions and standards that have influenced CBIR research. Some potential explanations for the observed lack of user focus are discussed. Finally some possible benefits of an increased user focus are presented. The paper is written as a part of the Philosophy of Science Course at the faculty of Social Sciences, University of Bergen.

2. The User in Content Based Image Retrieval

2.1. Content Based Image Retrieval

Selection of relevant images from large, digital image databases is one of the more challenging areas in multimedia information processing. As the computational and storage capabilities of computers have increased, traditional, text-based techniques for image description and retrieval have proven inadequate (Huang and Rui 1999).

An alternative approach has emerged from the computer science fields of *computer vision*, *pattern recognition* and *signal processing*. Rather than relying on text, methods based on extracting and comparing structural features, such as colour, textures, shapes or spatial arrangements, from images have been developed (Faloutsos, Barber et al. 1994). These systems, commonly known as Content Based Image Retrieval (CBIR) systems, identify and retrieve images based on a structural similarity comparison between a seed image and the images in the collection.

CBIR systems and the CBIR approach received very much attention during the late 90s, primarily driven by the computer vision community (Huang and Rui 1999). Several prototype systems such as IBMs QBIC[1] (Faloutsos, Barber et al. 1994) and VIRAGE (Bach, Fuller et al. 1996) were developed, proving the viability of the concept. However, while there was some success, especially for collections of relatively homogeneous images, such as face and fingerprint recognition, it became apparent that the statistical and mathematical algorithms and tools for object recognition were inadequate for general image retrieval.

2.2. An Observation: Lack of User Focus

A brief look at the literature and research effort in the field during the last decade reveals that focus has mostly been directed towards improving the computational algorithms, tools and methods used for analyzing, comparing, retrieving and managing images[2]. The actual role and tasks of the end user have been given comparatively little attention in research

As an example, consider one area of CBIR which still is relatively unexplored; how users can articulate a visual query that represents their information need. A visual query is a query expressed using visual techniques and visual components rather than textual. Visual queries, expressed as images, are usually compared to the images in a digital image collection, and relevant images are retrieved based on structural similarities between the visual query and the images in the image collection.

The most widely used form of visual queries, is to accept user drawn sketches as the basis for a query, known as Query-By-Sketch (QBS). In QBS, users create visual queries by sketching their images by free hand or by building them from image components such as rectangles and circles. There are two main challenges facing QBS. Though the actual tools and methods used to draw sketches might be simple and easy to use[3], creating *good* drawings can be difficult. If the enquirer has limited artistic abilities, he might not be able to create a

[1] An actual implementation of QBIC CBIR search is available at the Russian Hermitage Museum. This is an excellent demonstration of CBIR principles, and is still available at the museum web page: http://www.hermitagemuseum.org/fcgi-bin/db2www/qbicSearch.mac/qbic?selLang=English
[2] Note that this observation is not based on a thorough literature study, but my own experiences with literature and presentations during several years of work within the discipline.
[3] Remember that most of us learned to draw before we could write.

freehand drawing structurally resembling anything like the images he wishes to retrieve. These problems are fundamental for a general CBIR system, and yet they are relatively unexplored. While there are examples of such research, an example being the usability study reported by van den Broek, Kister et al (2004), there is seemingly little interest in the CBIR community to understand and improve this part of CBIR systems.

2.3. Paper Motivation and Goals

The main motivation behind this theory of science paper is to discuss some potential reasons for why there is a seeming lack of focus on the human aspect in CBIR research and literature.

One of the main goals and motivations of CBIR research is to assist human users to manage, index and retrieve images more efficiently. Based on this, one might be lead to believe that the human element should be an important part of research in the field. And yet, this does not appear to be the case. Using computer science as a backdrop, we discuss some possible explanations for this observation and argue for why an increased user focus might be beneficial.

3. The Role of the Human Element in CBIR Research

Content Based Image Retrieval has its roots in different computer science fields, and is deeply set in the natural science research traditions. A discussion the research traditions and ruling norms in these disciplines might give some fundamental insights in the role of the user in CBIR research. So let us begin our discussion by taking a closer look on the origins and traditions of Computer Science. Where does it originate, what does it concern and what are the main research interests in this field?

3.1. Computer Science as a Backdrop

In 1967, Alan Newell, Alan Perlis and Herb Simon defined computer science as "the study of phenomena related to computers" (Newell, Perlis et al. 1967), while the Association for Computing Machinery, ACM, states that

> *[Computer Science is] the systematic study of algorithmic processes that describe and transform information, their theory, analysis, design, efficiency, implementation, and application. The fundamental question underlying all of computing is, 'What can be (efficiently) automated?'* (ACM 1989)

And, in his essay on the Methodology of Computer Science, Timothy Colburn (2004) states that the field contains

> *[..] theories for understanding computer systems and methods; design methodologies, algorithms and tools; methods for the testing of computer related concepts; methods of analysis and verification of such concepts, as well as tools and methods for knowledge representation and implementation.*

Together, these definitions of computer science emphasize three important areas of computer research:

- Computer science research is the construction of complex instruments
- Computer science is the study of algorithms
- Computer science research includes understanding the natural phenomena surrounding the existence of the machine in its environment.

Much of research in computer science has traditionally focused on the two first areas, while the latter area has largely been addressed by researchers with background in psychology, information science and the social sciences.

The field itself predates the modern digital computer, and the term *computer* historically referred to human individuals performing calculations. Early researchers in the field were predominately interested in *computability*; what can be computed by simply following a list of instructions, without any insight or ingenuity, thus reducing the need for manual calculations and automating tedious and error prone work. During the inter-war years, the term *computing machine* came to refer to a machine that performed the work of a human computer, especially those in accordance with the effective methods of the Church-Turing Thesis. This thesis states that a mathematical method is effective if it could be set out as a list of instructions able to be followed by a human clerk with paper and pencil, for as long as necessary, and without ingenuity or insight (Copeland 2004).

Computer Science came into its own as a discipline during the 1960s, with the development of basic formal languages and automata theory with applications to parsing and compiling, and development of theories of mathematical and mathematical semantics and language definition techniques.

Computer Science has its roots in mathematics, linguistics and formal logic. Historically, there are three main research paradigms which have governed the development of computer science and still characterize the field. It is in part a *scientific discipline* concerned with the empirical study of a class of phenomena, in part a *mathematical discipline* concerned with the formal properties of certain classes of abstract structures, and in part a *technological discipline* concerned with the cost-effective design and construction of commercially and socially valuable products (Wegner 1976).

Wegner (ibid) further classifies the first three phases of development of the discipline, respectively dominated by empirical, mathematical and engineering research paradigms:

1. A "data gathering" phase from about 1950-1960 in which the prime activity was the discovery and description of computational phenomena, with hardly any work on the development of models, abstractions or theories. The paradigm appropriate to this activity is the paradigm of the empirical science.

2. An "elaboration and abstraction" phase from about 1961-1969 concerned with the extension and elaboration of computers and languages discovered in the 50s and with the development of abstractions to account for the observed properties of the phenomena of computer science. The paradigm appropriate to this activity is the paradigm of mathematics.

3. A "technological" phase from 1970s onwards concerned with the management of the increasingly complex software-firmware-hardware systems required for the solution of system and applications programming problems. The paradigm appropriate to this activity is the paradigm of engineering.

These three research paradigms are more or less concerned with the two first areas defined above; the study of *computers as instruments* and the study of *algorithms*. In the years following the infancy of computer science, we have seen the development of new research fields focusing more on the surroundings phenomena of the computer, such as *Human Computer Interaction (HCI)*, *Computer Supported Cooperative Work (CSCW)* and *Information Retrieval (IR)*.

While Computer Science has its roots in the natural sciences, these other fields have evolved from the border between fields such as Cognitive Psychology, Cognitive Science, Social Psychology, Administration and Organization Theory and Cognitive Psychology; and Computer Science (Ess 2004). Today, these are core disciplines within the field of *Information Science*.

A particular trait of disciplines related to the study of computers and their role which differ them from traditional scientific fields, is the rapidity of their evolution. The 'traditional' Kuhnian view of a paradigm is described as a transition of a research discipline through revolutions; *normal science, crisis, revolution, new normal science*, where researchers of a new paradigm gradually take charge of a field (Gilje and Grimen 2001). Wegner (1976) describes the situation of the early years of Computer Science as one where several different paradigms coexisted:

> *Computer science is distinguished by the rapidity of this evolution so that research workers representing all three paradigms are active in the same generation. The current divergences of opinion in the academic community concerning the nature of research in computer science [..] are in part due to the rapidity of this evolution.*

While fields such as HCI and CSCW fall within the original definitions of Computer Science, they are based upon different research traditions and have other methodological approaches. And while it might be claimed that these fields are subfields of Computer Science, it is probably more correct to label them as new paradigms rather than direct continuations of computer science.

As for computer science today, it is still firmly rooted in the research traditions of the empiric sciences, or *logical empiricism*. This is a positivist approach to science, with its root in the Vienna School, and is primarily characterized by some key ideas (Hacking 1983; Mjøseth 2006)

- An emphasis upon verification; that significant proportions are those whose truth or falsehood can be settled in some way
- Pro-observation; what we can empirically observe provides the best foundation for our non-mathematical knowledge
- Anti-cause; that there is no causality in nature over and above the constancy with which events of one kind are followed by events of another kind
- Downplaying explanations; these may help in organizing phenomena, but does not provide any answer to "Why" questions.
- Anti-theoretical; reality is restricted to the observable
- Anti-metaphysics; Untestable proportions, unobservable entities, causes and deep explanations are deemed meaningless as we have no method of verifying them
- Emphasis on logic, meaning and the analysis of language.

Principles such as repeatability, reductionism and refutability are fundamental concepts in this tradition. In its strictest sense, such research excludes everything but the natural phenomena or properties of knowable things, together with their invariable relations of coexistence and succession, as occurring in time and space. It postulates that the observed phenomenon can be made objectively and rigorously.

However, computer science is also in some ways unique among the natural sciences with respect to types of models it is concerned with. In seeking explanations, science often constructs models to test hypotheses when explaining phenomena. These models, in the form of experimental apparatus, are often physical objects. However, the models built and manipulated in computer science are not physical at all. Computer science is concerned with the study of computational processes, which is distinguished from a chemical or electrical process in that it is studied in ways that ignore its physical nature (Colburn 2004). Colburn further states that

> *These processes can be tested by executing the program and observing its behaviour. It can also be reasoned about abstractly, so that questions can be answered about it, such as whether there are other processes which will have the same effect, but achieve it more efficiently. Building computational models and answering these kinds of questions form a large part of what computer scientists do (Ibid).*

This emphasizes that *physical computational devices*, as opposed to models or theories should be the central matter of computer science. It also emphasizes that the phenomena of computer science include both computers and phenomena related to computers such as algorithms, programs and programming languages. The study of such phenomena is concerned with the design and analysis of efficient algorithms for particular problems, and with the attempt to find optimal algorithms for performing a particular task (Wegner 1976).

This discussion implies that the human factor is not a research interest within the Computer Science discipline. One advantage of these traditions is that it is possible to identify the precise relationships between chosen variables. Using analytical techniques the aim is to make generalizable statements applicable to real-life situations. Through controlling the number of variables, complexity is reduced. Reduced complexity generates less noise, allowing for a closer study of the variables. Furthermore, the research objects in computer science being of a non-physical nature, the researcher can have a very high degree of control over the experiment. Introducing human factors increase the number of variables, thus increasing complexity and uncertainty.

3.2. CBIR as a Computer Science

Content Based Image Retrieval is a relatively new research discipline; the term CBIR seems to have originated in 1992, when it was used by T. Kato (1992) to describe experiments into automatic retrieval of images from a database, based on the colours and shapes present in the images.

In their summary paper Eakins and Graham (1999) state that CBIR is

> *The process of retrieving desired images from a large collection on the basis of features (such as colour, texture and shape) that can be automatically extracted from the images themselves.*

As illustrated by this, one of the major goals of CBIR is to automate the process of annotating and retrieving images, which puts it within ACMs definition of computer science. The techniques, tools and algorithms that are used originate from fields such as statistics, pattern recognition, signal processing, and computer vision. These fields are deeply rooted within both Computer Science and the natural sciences, and research in CBIR follows the governing research traditions and standards in this field. And while there are examples of CBIR research that approaches the field from different traditions, it is deemed likely that the general discussion about Computer Science above is also valid for the field of CBIR.

3.3. Where is the User in CBIR Research?

The above discussion of the research traditions and paradigms can give us some indications as to why there might be a lack of focus on the user. Other explanations could be:

- The user is not interesting to CBIR researchers
- Including the user in CBIR research is expensive and complicated
- The user can be simulated
- Technology is not advanced enough to include users in the experiments

In the following, these explanations will be discussed in light of the previous discussion of CBIR and Computer Science traditions. This is by no means an attempt to create an exhaustive list of possible explanations for the seeming lack of user focus, but rather to challenge some possible explanations that might arise from a biased view of computer science.

3.3.1. Lack of interest in the user

First of all, we have seen that computer science research includes "phenomena related to computers", and how humans interact with computers clearly falls under this definition. And yet, we have a situation where there is little focus on the user in CBIR literature. One might then ask if the researchers in general have a "lack of interest" in the human factor.

We have already stated that the main goal and motivation of a large part of CBIR research, is to enable people to manage, index and retrieve images more effectively. While the different research projects might not include the human factor, the underlying goal of most CBIR research is still to assist humans to overcome the challenging issues related to having direct access to very large collections of images. Clearly, this does not indicate a "lack of interest" in the user.

What at first might seem like a lack of interest in the user is more likely a lack of focus on the user as a research objective. Traditionally, computer scientists in general and CBIR researchers in particular are more concerned with the design and analysis of efficient algorithms for particular problems, and with the attempt to find optimal algorithms for performing a particular task rather than how these algorithm are used by end users.

While the above discussion illustrates that the user indeed is a relevant and important motivating factor behind CBIR research, this does not bring us any closer to an answer to the questions posed in this paper. We have mentioned that introducing a human factor in experiments leads to increased complexity and uncertainty. However, new fields such as Human Computer Interaction and Usability Studies have developed methodologies focused towards the evaluating how users use and interact with computers. Still, if we accept the seemingly lack of user-related research within the CBIR field, we need to question if there are any particular traits with some parts of Computer Science in general, and CBIR in particular, which complicates user involvement. This leads us to the next possible explanation; involving the user in CBIR research is expensive or complicated.

3.3.2. The Cost of User Involvement

Much research in CBIR, as well as Computer Science in general, is aimed at designing, analyzing and optimizing algorithms for different tasks. One of the main strengths of computers is their ability to perform vast amounts of calculation and computation iterations continuously and without errors. Given a certain hypothesis or model to be tested, it is relatively easy for the researcher to change variables, perform repeated experiments and measure the results of these changes. As long as the experimental components are algorithms and processes completely under the control of the researcher, it is relatively inexpensive to make small changes and evaluate effects.

Introducing a human factor to the experiment introduces a new layer of complexity and uncertainty. Individual humans are, by nature, not as predictable as computer models or algorithms. Even if we take the *principle of charity* approach, which states that we always should understanding a speaker's statements and actions by rendering the best, strongest possible interpretation (Gilje and Grimen 2001), we cannot expect completely rational, objective or consistent results from human individuals.

One particular trait which separate human beings from animals, natural phenomena and computational algorithms, is that we attribute meaning to both observed phenomena and our own actions (ibid). In the case of computational algorithms, one can expect consistent behaviour as long as one does not directly change its contents. When dealing with human entities, we have to take numerous other variables into consideration. First of all, the research has to relate to humans who have their own interpretation of a situation, which might change over time. Furthermore, variances in individual characteristics, such as mood, health and fatigue, as well as vast differences between individuals; personality, perception, interpretation and cultural context will influence the results obtained from human participants. This might be considered as in direct conflict with the objectivity and repeatability criteria of the natural science disciplines.

Next, subjective evaluation by humans is expensive and time consuming. For example, consider the case of perceptually prefiltered video reported by Steiger, Ebrahimi et al (2005) on the effects of perceptual prefiltering of video streams[4]. Perceptual prefiltering is the process of enhancing relevant portions of an image or of a video, and simplifying contextual information in order to improve the perceived quality or the compression ratio.

One of the goals of this project was to evaluate how the quality of different bit rate compressions had on the effect of perceptual prefiltering. 4 sets of video streams were subjected to different bit rate compressions, followed by a perceptual prefiltering of the stream. The researchers were interested in seeing how much the video streams could be compressed and prefiltered without reducing the quality to a point where the prefiltering had a detrimental effect on the viewer's experience of the video stream.

Ideally, this kind of research should be performed with human observers, as it tries to measure human perception, which is by nature subjective. However, in order to evaluate this, a human observer would have to compare the quality in the four different video streams exposed to several different bit rate compressions. Each compression technique requires the user to compare all 4 video streams to the original stream, and evaluate the perceived loss of quality. A subjective evaluation of the different streams is expensive, time consuming, and it is at best difficult to asses the video quality in real time for human observers. Furthermore, with what we know about human experiment subjects, unless there are a large number of people observing all the different video streams, it can be difficult to achieve objective and repeatable experimental results.

Steiger, Ebrahimi et al approached this problem by proposing an objective quality metric that mimics the behaviour of human observers. Their results from experimenting with the metric claimed that it was consistent with the subjective evaluation scores, indicating that it could act as a replacement for human subject. By using this metric, they claimed to be able to reduce the cost and complexity of having a human research element, while still retaining the validity of the experiment.

3.3.3. Simulating the User

The above example serves as a good illustration of the problem of cost and complexity connected with involving a human element. Although Steiger, Ebrahimi et al performed a subjective test with humans, it was done in a very small scale in order to test the objective quality metric. Since the metric apparently was successful in simulating human behaviour, it became possible to use this 'simulated human' as a metric for large scale experiments. By eliminating the human element, the researchers could perform several experiments, testing different variables without the added cost and complexity of human factors.

While there are obvious advantages to this reductionist approach, we need to question if anything important is lost when the role of the user is reduced to a simulated metric. Fjelland (1999) distinguishes between *methodological reductionism* and *ontological* reductionism. The former being an uncontroversial and useful scientific strategy, which assumes that the phenomenon is not completely described at the reduced level, while the latter assumes that the observed phenomenon can be completely described at the reduced level.

While I am careful in accusing either CBIR research in general or the research presented Steiger, Ebrahimi et al for ontological reductionism, I find it difficult to accept that it is possible to give a completely realistic simulation of human behaviour. While the strategy clearly is useful for reducing the cost and complexity connected with analyzing and creating algorithms in the field, it is both possible and necessary to evaluate the final findings from such experimentation on real life situations involving real users. Even though research such as reported by Steiger and Ebrahimi (2005) claims with some credibility that is indeed possible to create

[4] While this initially might seem irrelevant to the research discussed in this paper, this research is actually closely related to the CBIR discipline. Improvement in the processing power of computers has lead to similar research on both video and audio, and there is much overlap between the research communities.

objective metrics simulating human perception, at least in this particular case, I do not feel completely confident that the final results of such research is indeed useful for human purposes until it has been thoroughly tested with human participants. I will return to this discussion in the final part of this paper.

3.3.4. Technological Advancement of the Field

When the computational power of both software and hardware allowed for large scale digital image collections, the shortcomings of current indexing- and retrieval techniques became evident. CBIR emerged in the early 1990s as an answer to these challenges, and during the early years it was proved that it was indeed possible to use statistical and mathematical tools developed for areas such as pattern recognition, medical image analysis and computer vision to automatically index and retrieve images. This resulted in both research prototypes and a limited number of commercial applications. Some of the early research was indeed devoted to the role of the user (Faloutsos, Barber et al. 1994; Cruz and Lucas 1997; Hibino and Rundensteiner 1997; Jose, Furner et al. 1998; Eakins and Graham 1999). However, little research effort has been directed towards this in recent years.

After some time the initial optimism diminished with the realization that while the concept was indeed viable, the technology was lacking in respects to heterogeneous image collections. This is also noted in contemporary reviews, as summarized by Eakins and Graham (1999)

> *[The conclusions] are that, while there are serious limitations in current text-based techniques for subject access to image data, significant research advances will be needed before visually-based methods are adequate for this task. [..] The field is expanding rapidly, but [..] many major research challenges remain, including the difficulty of expressing semantic information in terms of primitive image features, and the need for significantly improved user interfaces.*

Today, there is still no significant breakthrough in important aspects such as complex shape recognition and object segmentation, and a large part of the effort seems to be directed at optimizing and developing tools and algorithms towards this end.

Since there has been little significant advancement in the fundamental tools and algorithms, it is understandable that this has been given more focus than the role of the user. Unless the fundamentals are improved, one might understandably argue that focus on the user aspect of CBIR systems are only marginally useful.

3.4. Should the User Be Included in CBIR Research?

Based on the above discussion, one might argue that working on issues related to the user is currently of limited value to the CBIR field. However, we should also ask ourselves if there are any potential benefits to an increase in user focus.

First of all, let us again return to the main motivation behind the development of the CBIR discipline; providing assistance to the indexing and retrieval of images. If the user is left out of the loop entirely, how can we be sure that the achieved results actually take us closer to this goal? Even if a certain algorithm or method has proven to be effective for a simulated human, can we be certain that it will be of any use to a real human? And if we build upon such results without ascertaining that it is indeed useful, how does this influence future results? Answering these questions clearly indicates that at least some focus on the user is important. While one should not underestimate the importance of improving the fundamental tools, one should always remember why the research is important.

From a completely different point of view, a unilateral focus on the underlying algorithms might lead to an imbalance between what is possible technically, and what the end users are able to use. One potential peril of not focusing on the user is that one might not realize the full potential of the available technology. While this has several implications, we will focus on one very important aspect here; *access to information*. While current technology might not be sufficient to fully realize the potential of Content Based Image Retrieval, it is quite possible to use the existing technology in new ways.

The development of the World Wide Web (and similar electronic media) has made tremendous amounts of information available at our fingertips. However, access to this information is almost exclusively based on textual proficiency. If one for some reason has problems expressing yourself verbally through text, this information is inaccessible for you. It might be possible that techniques based in CBIR research might be used to assist such individuals in gaining some access to this information.

Of course, I am not suggesting that researcher from CBIR and Computer Science should abandon their efforts to solve the fundamental issues. However, the above example shows us that it might be fruitful to approach an area from more than one angle. As far as I know, there have been few attempts at utilizing existing CBIR technology in such ventures.

4. Conclusion

The starting point for this paper was an observation of a general lack of user focus in Content Based Image Retrieval research. It is believed that while there are some characteristics of this field which complicates the inclusion of the user, such as the cost and complexity of a human factor, a lack of technological advancement in the field or the possibility of simulating the user, the main reason lie in the research traditions and standards that CBIR research is founded on. CBIR research is based in Computer Science and various disciplines of it, which firmly places it within the traditions of logical empiricism.

We have also seen that while keeping the human factor out of CBIR research in some cases indeed might be a viable and fruitful strategy, it believed that keeping a unilateral focus on the computational and technical aspect of the area might not realize the full potential of the field. It is also believed that an increased focus on the user might provide a fresh take on a field which has seen little significant advances during the last few years.

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