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Abstract

This paper gives an overview of the evaluation of the Informedia Digital Video Library system at the Open University. An introduction to the technology that Informedia uses is provided and the functionality of the system as applied at the Open University is described. We report on our user study, which involved participants from the University's library, academic and production units. Practical hands-on sessions, followed by group discussions were used to carry out the evaluation. Data was collected by way of pre-evaluation questionnaires, post-evaluation questionnaires and by audiotapes of the group discussions. Good points and problem areas of the system, as identified by the evaluation, are presented. The user feedback on the system was very positive and appeared to indicate a definite potential for the system at the OU.

1.   Background

1.1.   Informedia

The Informedia project[1] based at Carnegie Mellon University (CMU) was part of the first NSF/DARPA/NASA Digital Library Initiative (1994-1998) and was the only DLI project focusing on information extraction from video and audio content. The aim of the project was to build a digital video library system [1]. The Open University (OU) has contributed approximately 170 hours to the video library of educational material and was one of 4 evaluators of the delivered system.

In building the Informedia Digital Video Library System, Carnegie Mellon University has successfully integrated speech, image and language processing technologies in the development and deployment of the Informedia Digital Video Library. As well as an educational digital video library, the project has developed a News-on-Demand service and is working on an Experience-on-demand service, using the same technologies. Carnegie Mellon University pioneered the automatic creation of multimedia abstractions [2], demonstrated empirical proofs on the benefits of multimedia abstractions [3] and retrieval [4], and gathered usage data of

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[1] The Informedia project [online]. Available from http://informedia.cs.cmu.edu/ [Accessed January 1999].

different summarisations and abstractions [5]. The project has proved that the content of video can be unlocked, but also that further refinement in certain areas is necessary [6].

1.2   The Open University

The Informedia project is an important development and is central to the Open University's[2] present and future organisational needs. These are centred on the improvement of the organisational memory to facilitate re-use of its teaching materials collections. The Informedia system could potentially help to achieve this by providing online access to the content of OU TV programmes. It could facilitate re-use and assist with the commercial exploitation of these assets.

At present information about educational video material is available mainly at programme level. This information can be retrieved through a catalogue, which is available over the Internet. The documentation of the content is improved through the creation of shot-lists (sequences of footage and the timings) for a sample of materials. Access to the content itself can currently be obtained through viewing the programmes using VCR's.

The major potential benefits from the Informedia technology is the timesaving in creating the digital video library and the improved access to the material. Current working practices could be radically changed by the innovative technologies employed by the Informedia project.

1.3   Informedia evaluation project at the Open University

The role of the Open University is twofold: contributor and evaluator[3]. In this paper we report on our evaluation study which was led by the Library's Interactive Open Learning Centre and was conducted by staff from the Institute of Educational Technology of the Open University. The project started in February 1998 and reported in December 1998 [7]. Potential users of the system from various departments across the University have participated in our study. The evaluation assesses the usability of the system and the extent to which it could meet user requirements.

The results of this study have informed the Informedia project team at CMU and have provided us with an initial assessment of the potential usage of the system within the Open University. This paper describes the Informedia technology, the configuration of the Informedia system at the Open University, related research and products, and reports on the outcomes of the user study.

1.4   Library

The Open University Library[4] is undertaking a major change in direction, which is a result of the opportunities afforded by networking and the growth in electronic publishing. The Library's remit has been extended to develop a strategy for supporting students through networked access to information, which will also enrich services for the OU campus community [8]. Additionally, the Information Technology Support and Development Group has been established to promote, support and lead technological innovation and to undertake a programme of research into all relevant aspects of the electronic library.

The development of the Interactive Open Learning Centre and Media Archive is another component of the changing environment in the Library [9]. The Centre manages and promotes a hybrid collection of Open University teaching materials, including nearly 30 years of course production in a variety of media and formats (print, audio, video, software). More recently digital versions of course elements have been added to this. The Centre provides a showcase for staff, students and external visitors and aims to demonstrate best practice in externally produced materials.

1.5   Institute of Educational Technology

The Institute of Educational Technology (IET) has an international reputation as a centre of excellence in research into the application of new technologies in teaching and learning. Members of IET work in collaboration with Open University faculty and regional colleagues, advising on all aspects of educational technology and evaluating its effectiveness, or assisting colleagues in devising appropriate evaluation strategies. The Institute's PLUM programme (Programme on Learner Use of Media)[5] has developed a range of evaluation methods and procedures in collaboration with the University of Hull's TELL consortium (Technology Enhanced Language Learning).

[2] The Open University [online] Available from http://www.open.ac.uk/ [Accessed January 1999].
[3] The Informedia evaluation study was based on: Simpson E. Carnegie Mellon University Informedia Digital Video Library Project , Funding proposal, Open University Library 1997. (Internal document).
[4] The Open University Library [online] Available from http:/oulib1.open.ac.uk/lib/ [Accessed January 1999]
[5] PLUM [online] Available from http://www-iet.open.ac.uk/iet/PLUM/plum.html [Accessed January 1999]

There is currently a major focus on the formative and summative evaluation of multimedia applications. During the formative phase, usability data is collected that enables designers to improve the software, while the summative phase tests the success of the program in the context of a learning situation, investigating conditions that achieve best results for students, and providing information about cost-effectiveness. The Institute also plays an important role in developing and promoting organisational memory systems which can facilitate access to research papers, evaluation reports, course materials or experts in particular areas of educational technology.

2. Technology

2.1. Informedia

2.1.1 Introduction

The Informedia system uses a combination of speech recognition, image recognition and language understanding to segment and index the video library. A brief overview of the technology follows below [10]. As a first step video material is digitised and stored as MPEG-I video. The speech recognition creates a text transcript of the narrative with exact begin and end timings for each word. This enables the alignment of the words to the video in a later stage. During searches this allows for exact location of search terms in video segments. Natural language processing is used to initially segment the video. In a further phase this is combined with image recognition to enhance the segments (video paragraphs). Image recognition is used to identify for example the presence of faces; this information again is closely linked to the video. Natural language processing is also used to increase the search capabilities by employing word stemming and synonyms.

Meta-data is created and entered when the video is digitised and it includes for example the producer, the name of the programme (or series title) and copyright date. Additional meta-data includes the details of the digital video such as the frame rate, duration and encoding date.

2.1.2 Functionality of the system applied at the Open University

The Open University uses version 2.2.1 of the Informedia Digital Video Library System. Our application of the Informedia DVLS does not employ a database management system and the functionality therefore does not include skims (summarisations of video content), image matching facilities, extended searching facilities or the possibility of recording annotations by users. The application of speech recognition for retrieval purposes is not used, because the recognition engine used by CMU is not suitable for the recognition of the British-English accent. The system does include the visualisation tool mentioned before and the video re-use tool.

The user can select the browse option to retrieve information. The library consists of various collections; each populated by a number of programmes. Each of the programmes is split into video paragraphs. Browsing can take place at collection, programme or paragraph level. At each of these levels the user can choose to view the filmstrip – sequential selection of key frames - or play the full video.

The collection can also be searched. Within the current system searches can be performed on the text of the transcript or the titles of the programmes with an option to use Boolean operators. Search results are shown as key frames each representing a segment or video paragraph of about 2 minutes duration. Further information on the content of the paragraph can be obtained by looking at the individual frames. At this stage the exact location of the searchterm(s) is indicated by red pointers, which are attached to the frames.

The search results can be presented in a different way by using the visualisation tool. This feature has not been used extensively within this project and is likely to be more useful in a larger library of materials. The video paragraph can be viewed by clicking on the key frame or frames. The videos will then start at the point indicated by the key frame or frame selected by the user.

While the video is playing the transcript scrolls along with it, at the same time the system highlights the words in the transcript as the audio is played back. The user can jump to the next or previous paragraphs, the next location of the search term in the paragraph, or select any sequence within the video. This selection can then be copied and pasted into another application using the video re-use tool.

2.1.3 Technical infrastructure

The video library contains approximately 80 hours of Open University material: i.e. 160 programmes with an average length of 30 minutes. This represents approximately 1 year's worth of production of OU TV programmes and forms a small subset of the total collection, which we estimate to be 3000 hours. Another 90 hours of digital material is available but has not been used within the evaluation project due to the limited storage capacity on the server (60GB). This collection of material has been processed - i.e. digitised,

segmented and indexed - at Carnegie Mellon University using the original video material on tape and the programme transcripts.

The Informedia system can be used from 6 client machines in the Library, which are linked by a dedicated network connection to the server. This connection has a capacity of 100Mps and the connection from the hub to the actual client machines can transfer data at a rate of 10Mps. The clients are Pentium PC's with a standard specification (166 Mhz or higher, 32 MB Ram or more).

The network traffic that was generated during the evaluations sessions – when a maximum of 5 people was using the system at the same time - has been monitored. During a typical 40 minute session approximately 960 Mbytes in total was transferred and the maximum traffic per second was about 0.5 Mbytes. These are averages however and we were not able to measure the peaks. This data indicated that using the system over the main campus network would not be a problem, although a constant monitoring would be necessary.

The response time from initiating a search to receiving the search results on the screen is fairly constant around 5 seconds and the same applies to retrieving the full video. The system has occasionally been used over the main campus network and subjective observation does not show a decrease in performance. The performance may deteriorate when information is retrieved from a larger library or when significantly more people are accessing the materials but there is currently no data to support this assumption. So far, the performance and robustness of the system have impressed us.

2.2 Related research and products

Against the background of the launch of digital TV in Europe and the growth of the number of broadcast channels, asset management has become an important topic for the broadcasting industry. Technology incorporated in products such as Informedia could potentially play an important role in this development. Based on the following overview of current technical research and available products a number of trends can be identified:

- content-based/similarity/visual queries;
- real-time indexing with as little manual intervention required as possible (e.g. for broadcast news applications);
- speech recognition so that indexing and searching can be based on the audio transcript in addition to the extraction of closed caption text, metadata and manual annotations;
- searching, retrieval and playback across networks/World Wide Web.

Related research projects include Euromedia[6], a partnership between a group of mainly European broadcasters, consultants and technology providers. The emphasis is not so much on the development of new technologies, rather on the adaptation of existing technologies. VISION (Video Indexing for SearchIng Over Neworks)[7] is a project funded by the University of Kansas, which aimed to develop a system that digitises, processes, indexes and compresses video in real time on an inexpensive general-purpose computer.

There are currently three main commercial products: Virage Video Cataloger[8], Excalibur[9] and ISLIP[10]. Informedia's core technology is used by ISLIP, the project's commercial spin-off.

2.2.1 Evaluation Research

A number of evaluations of digital libraries have been reported in the last few years, indicating a growing awareness that user studies are an essential part of the successful development of digital libraries. Buttenfield describes the work of the User Evaluation Team for the Alexandria Digital Library Project [11]. The team has designed user evaluation test instruments to determine that specified user requirements are appropriate. They have conducted empirical tests involving interactive logging of user sessions, questionnaires, talk-aloud protocols and videotaping of sessions, asking users to talk-aloud as they view the videotape. It can be difficult to deal with the sheer volume of data collected through multiple instruments, but the results give a much richer picture than would be obtained through one instrument alone. They note the difficulties that first time users experience with navigating, and have designed tutorials as a result. However, patterns of motivated browsing and retrieval differ from patterns of use generated in the tutorials.

Buttenfield also notes that user requirements change in the course of using a system. User evaluation is therefore shooting at a moving target. To account for this, they have undertaken longitudinal experiments, returning a number of times to the same users. Marchionini, Plaisant and Komlodi take up a similar issue when

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[6] Euromedia [online] Available from http://www.foyer.de/euromedia/home.html [Accessed October 1998]

[7] VISION [online] Available from http://www.ittc.ukans.edu/~sgauch/DVLS.html [Accessed October 1998]

[8] Virage Video Cataloger [online] Available from http://www.virage.com/ [Accessed October 1998]

[9] Excalibur [online] Available from http://www.xrs.com/ [Accessed October 1998]

[10] ISLIP [online] Available from http://www.islip.com/ [Accessed October 1998]

they say that digital libraries are not static entities; they are constantly evolving with users and technology [12]. There ought to be alternative interfaces for different users and needs -- interfaces that users can select according to their experiences and immediate needs. The above authors stress the need for principles and guidelines for user-centered design of digital libraries. These must include regular user needs assessment, ongoing usability testing, and iterative design procedures. Greene, Marchionini, Plaisant and Shneiderman note that designers often fail to provide appropriate previews and overviews to give an overall sense of the structure and materials available [13]. The design of effective previews and overviews requires a thorough analysis of the application domain with respect to what information objects are available to users, how those objects are related and how users can manipulate them.

There is currently growing interest in the application of qualitative and ethnographic research methods to the evaluation of digital libraries. Researchers at the Interactive Multimedia Group (IMG) at Cornell University are using a concept mapping strategy in the context of investigating the cognitive, behavioural, and social implications of using such systems. Mead and Gay have come to the conclusion that "user acceptance and usability are major issues in the design of digital libraries" [14]. Their research has shown that students often do not make effective use of available database resources, and that to overcome this problem, user interfaces that accommodate diverse needs and search strategies need to be developed; users also need to be trained in communication and information seeking behaviours. The results of our evaluation at the Open University would tend to confirm this view. We need to bear in mind, however, that there may be resistance to training on the part of the user [15].

There is already a body of research looking at information searching behaviours and the assessment of information needs [16 - 18] and a growing number of publications which relate to searching in digital libraries [19, 20]. We hope that our work will contribute to the specification of user needs in an educational environment, in relation to producers of distance learning course materials and to adult learners.

3.   User study OU

3.1. Sample

8 user groups took part in the evaluation including a total of 29 participants. The size of the groups ranged from 3 to 5 people. Participants were:

- 8 people from library staff (for example, counter staff and subject specialists)
- 15 people from academic staff involved in course production including re-use of course materials.
- 6 people from multimedia production units and broadcasting services

3.2. Materials and Procedures

A pre-evaluation questionnaire was sent out to the participants by e-mail prior to the focus group sessions. The questionnaire was used to inform participants about the Informedia system and to gather information on expectations of Informedia (Figure 1), computer experience and involvement in video-usage. Focus group sessions consisted of two activities: an individual hands-on session and a group discussion.

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5. please say (briefly):

      (a)   WHY you think you might use a system such as Informedia in your work

      (b)   HOW you think you might use it

Figure 1. Example question from the pre-evaluation questionnaire

3.2   Practical Informedia sessions

The hands-on sessions allowed participants to use the Informedia software. Each participant worked individually through the software for approximately 1 hour, guided by task-lists. These lists offered information on the basic functionality and helped the participants work through the system in a structured fashion. They were designed to ensure that participants used all the basic functions and allowed them to record their actions and comments. Information recorded on these task-lists included information on keywords used in searches, preferences in search methods, ease of use, additional functionality required, and presentation of results (Figure 2).

Select a 10 second segment from the piece of footage you viewed and transfer it to a Word document. (Hint: use the buttons available when viewing the footage and in Word insert the footage as an object)

How easy/difficult was it to perform this task?

very easy	easy	fairly easy	fairly difficult	difficult	very difficult
O	O	O	O	O	O

Should there be additional help provided by the program to let you transfer the segment to a text document?

Yes	No
O	O

If so please give details of information/help required:
Comments about this task:

Figure 2. Example task in task-list

Following the individual practical session, participants were asked to fill in a short post-evaluation questionnaire. Information recorded included the participants' general opinion of the system, whether Informedia would be useful in their work and whether Informedia would be useful for the Open University.

3.3   Group discussions

After the individual practical sessions, participants were involved in a group discussion of approximately 30 to 40 minutes. The sessions were audiotaped and chaired by a researcher who wrote down the main points of discussion.

The aim was to start a discussion among the participants in order to find out about possible usage and required functionality. Discussions were steered to cover topics such as positive and negative points; difficulties encountered in using the system; its usefulness in the participants' work environment; and the changes needed in the system.

3.4   Findings

3.4.1   Characteristics of participants in the evaluation

The pre-evaluation questionnaire indicated that one third of the participants was involved with TV production and under a half was working with video material. Most indicated that they were experienced and confident in using computer systems and information retrieval systems. When asked why they might use a system such as Informedia in their work there were generally two classes of response. The library staff indicated that they saw such a system being used as an information resource in their contact with students, staff and the public. Production and Academic staff, however, saw Informedia being used more as a search and retrieval system for visual/video information for course materials. Production staff particularly noted the use of the system in this manner in the face of increasing financial restrictions and an existing comprehensive archive of video produced by the Open University.

3.4.2   Good points about the system

In the discussion sessions, it emerged that users particularly appreciated the following aspects of Informedia:

- visually pleasing interface
- quick response to search queries
- excellent picture and sound quality
- fast and smooth video playback
- ability to browse as well as search
- access to materials which one would not otherwise know about
- visual cues for keeping track of where you are
- availability of text transcript and sound

- ability to cut and past search results into a Word document

3.4.3 Problem areas

The problem areas can be summarised as follows:

- Very limited search facilities (search on transcripts only, no subject indexing for example, no advanced Boolean searching, no search on particular fields such as year of production, named contributors, no ability to narrow down searches)
- Limited feedback to users about search outcomes (difficult method of ranking of video clips, meaning of red thermometer bar unclear, unfamiliar terminology)
- Difficult identification of video clips (no OU course-codes or titles, more information needed on the video, i.e. names of presenters, contributors)
- User interface design issues (no bookmarking facility, insufficient labelling of buttons in video playback window, difficulties in customising video playback window, the use of the Find function to expand the Help index was unclear).
- Difficult use of the video copy facility.

3.4.4 Discussion

Results from the task-lists indicated that in using the system, the majority of users indicated that they preferred to search the system using individual search terms or combination of terms rather than using the facility to formulate queries in plain English. They described the system as generally easy to search and found the video viewing facility easy to work with. The browsing facility was also rated as generally easy to use. What was commented on by most users in the focus group discussions, was the fact that although searching was apparently easy the presentation of the retrieved results was somewhat problematic. Users commented that in some cases the retrieved results were not relevant to what they entered as search terms. The task list also indicated that very few users realised that when search results were presented, a vertical thermometer bar next to the key-frame indicated the relevancy of a segment in the video to the search terms.

The final task also prompted users to question the way in which searches were carried out, that is, what was searched was the text that accompanied the video. Production and academic staff commented that this method did not allow them the opportunity to search for particular pieces of footage, yet this would be their main reason for using the programme if it was made available.

In contrast to searching the system, users expressed difficulty in performing copying and pasting tasks where either segments of video or the accompanying text needed to be transferred to a word-processing package. Commonly, most users asked that the processes of copying and pasting, especially the latter, be made clearer. Suggestions included a step-by-step guide to carry out the procedures, or have the purpose of the video editing buttons represented more clearly, either with icons or by scrolling. Those with a production background also requested that timing information be provided.

In consolidating the findings based on the task-lists, it appears that the usability of the system in terms of searching is generally supported by the users. The system is regarded as somewhat limiting at the moment as it confines searches to the transcript of the video material and not the visual content. Where the system presents most problems in terms of usability is in the copying and pasting of information, text and video images, to other computing applications. This was highlighted because the system did not comply with copying and pasting conventions in the computing environments that users were familiar with.

The overall evaluation results show that the system initially comes across as being easy to use, or 'easy enough' to use. This could be partly because its functionality is very limited (in version 2.2.1). We do not know how easy it would be to use a system, which incorporated all the facilities that participants would like to have. Some of the problem areas, in particular "limited search facilities", appear to have been addressed to some extent by more recent versions of the software or in commercial products using similar technology. For example: the more recent version of Informedia makes it possible to do field searches, and to include user annotations, different textual information (e.g. about copyright), and bookmarks.

Potential application areas for the Open University include course production, re-versioning, multimedia production, broadening access to OU materials. For each area certain conditions would have to be met, ranging from improved searching facilities and cataloguing, to more complete and up-to-date video content and additional data to be made available (copyright information) within the system. Potential uses:

- locating re-usable video resources in a vast collection
- using compilations of video clips in course team discussions
- picture research for OU textbooks

- selection of visual images from TV programmes to use on air, providing a better information service about OU TV programmes to students and the general public
- broadening student access to OU materials and to "learning snippets"
- sale of videos or video clips
- identification of copyright
- archiving of video collections
- finding unexpected but useful resources, when searching for something else, being able to build up and save individualised collections of clips.

With respect to the potential use of the system in the OU few participants committed themselves to a definite 'yes'. However, the responses were generally very positive and appeared to indicate a definite potential for the system at the OU. The information given by the participants seems to show that there is a substantial demand for the Informedia technology at the OU.

5. Conclusions

The findings seem to indicate that there is definite potential for using this system, provided that certain modifications can be made. Our results also confirm the findings of the Informedia team at CMU that the content of video can be unlocked using the Informedia technology. Bearing in mind that we have been using a limited version of the Informedia system and that some of the issues raised are being addressed by the Informedia team and in similar products, further testing of Informedia in more practical working environments would be necessary to assess its full potential.

6. Acknowledgements

Reference List

1   Christel M. and Pendyala K. Informedia goes to School. Early findings from the Digital Video Library Project. D-lib Magazine, September 1996 [online] Available from http://dlib.org/dlib/september96/informedia/09christel.html [Accessed December 1998].

2   Wactlar, H.D., Kanade, T., Smith, M.A., and Stevens, S.M. Intelligent Access to Digital Video: Informedia Project. IEEE Computer, Volume 29, No.5, May 1996. pp. 46-52.

3   Christel, M., Winkler, D., and Taylor, C. Improving Access to a Digital Video Library, Human-Computer Interaction: INTERACT97, the 6th IFIP Conf. On Human-Computer Interaction, (Sydney, Australia, July 14-18, 1997), pp. 524-531.

4   Hauptmann, A.G. and Wactlar, H.D. Indexing and Search of Multimodal Information, International Conference on Acoustics, Speech and Signal Processing (ICASSP-97), Munich, Germany 1997.

5   Christel, M., Winkler, D., & Taylor, C. Multimedia Abstractions for a Digital Video Library, Proceedings of the 2nd ACM International Conference on Digital Libraries, (Philadelphia, PA, July, 1997), pp. 21-29.

6   Wactlar H, Christel M, Gong Y, Hauptman A G. Lessons learned from the creation and deployment of a terrabyte Digital Video Library. To appear in IEEE Computer, February 1999.

7   Van der Zwan R M and Kukulska-Hulme A M. Endreport Informedia evaluation study. Internal report The Open University, December 1998.

8   Carty J, Stark I, van der Zwan R M, Whitsed N. Towards a strategy for supporting distance learning students through networked access to information: issues and challenges in preparing to support the Doctorate in Education. Education for Information 1996, Volume 14, number 4, December pp. 305-317.

9   Van der Zwan R M and Whitsed N, Innovation in the Open University Library - the Interactive Open Learning Centre and Media Archive. Vine 1998 Issue 107 Digital Images in Libraries pp. 25-29.

10   Christel M and Martin D. Information Visualization within a Digital Video Library. Jounal of Intelligent Information Systems. To appear in Special Issue on Information Visualization. (November/December 1998) Volume 11 Number 3.

11   Buttenfield B. User Evaluation for The Alexandria Digital Library Project, 37th Allerton Institute Conference, University of Illinois at Urbana-Champaign 1995, discussion document, [online] Available from http://edfu.lis.uiuc.edu/allerton/95/s2/buttenfield.html [Accessed January 1999]

12   Marchionini, G, Plaisant C, Komlodi A. Interfaces and Tools for the Library of Congress National Digital Library Program. Information Processing & Management 1998, 34, 5, pp. 535-555.

13   Greene S, Marchionini G, Plaisant C, Shneiderman B. Previews and Overviews in Digital Libraries: Designing Surrogates to Support Visual Information-Seeking, CS-TR-3838, University of Maryland Technical Report 1997.

14   Mead J P, Gay G. Concept Mapping - An Innovative Approach to Digital Library Design and Evaluation 1998.[online] Available from http://edfu.lis.uiuc.edu/allerton/95/s2/mead/mead.html [Accessed October 1998]

15   Curtis K L, Weller AC, Hurd J M. Information-seeking Behavior of Health Science Faculty: The Impact of New Information Technologies. Bulletin of the Medical Library Association. 1997 Vol. 85 No 4, pp.402-410.

16   Nicholas D. An Assessment of the Online Searching Behaviour of Practitioner End Users. Journal of Documentation. 1996 Vol. 52 No 3. pp. 227-251.

17   Nicholas D and Martin H, Assessing Information Needs: A Case study of Journalists. ASLIB Proceedings 1997 Vol. 49 No 2. pp. 43-52.

18   Ellis D and Haugan M. Modelling the Information Seeking Patterns of Engineers and Research Scientists in an Industrial Environment. Journal of Documentation. 1997 Vol. 53 No 4. Pp. 384-403.

19   Srinivasan U, Gu L, Tsui K, Simpson-Young W G. A. Data Model Support Content-based Search in Digital Video. Australian Computer Journal. November 1997.

20   Christel M and Martin D. Information Visualization within a Digital Video Library. Jounal of Intelligent Information Systems. To appear in Special Issue on Information Visualization. (November/December 1998) Volume 11 Number 3.