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DVP

Distributed Video Production Distributed Musical Rehearsal and Distributed Video Editing and Retrieval

Central to the Distributed Video Production (DVP), an European ACTS project, are distributed pilot applications for professional digital video production over ATM broadband networks (LAN and WAN). This paper presents an overview of that project.

The DVP project investigated the Quality of Service (QoS) requirements of broadcasters for several forms of distributed video production and run a series of trials of distributed virtual studios (studio on demand), distributed virtual reality, distributed musical rehearsals and distributed video editing and retrieval. The CUI of the University of Geneva participated in the DVP project in the distributed musical rehearsal (DR) and distributed video editing and retrieval (DVER) applications.

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Overview of the DVP project

The global spread of computer networks is revolutionizing video production. Distributed production environments interlinked by local or wide area networks (LAN and WAN) are emerging these days allowing for real-time transferring and sharing digital media over peer-to-peer or client-server configurations. In the European ACTS project "Distributed Video Production (DVP)"[1][1], leading European broadcasters and technology providers are using the latest broadband network technology (Asynchronous Transfer Mode, ATM) to link multiple locations into a single production environment and to create an open architecture for distributed video production.

The basic technology for DVP is transferring studio-quality digital video over broadband ATM networks which guarantees dedicated channels of bandwidth for real-time digital media transfer and avoids the performance degradation in shared bandwidth networks. The distributed DVP architecture imposes stringent and complex requirements on the switching and transport architecture of a network. The different DVP applications face different problems with video coding and compression, transmission and processing delays, synchronization requirements, and quality of service (QoS) parameters ([2] [3] [4] for surveys). Each of these problems has to be solved for each application adequately. E. g. delay is a critical issue in the distributed musical rehearsal application. A musician cannot coordinate with the conductor if the video and audio signals are a few hundredths of milliseconds late. In order to solve this kind of problems under realistic conditions, pilot applications and trials of distributed virtual studios, distributed telepresence, distributed virtual reality, and distributed video archiving were substantial parts of the DVP project. The project identified requirements, developed prototypes, and performed trials for well defined, realistic scenarios in very narrow time frame.

The DVP consortium consists of five European broadcasters, computer and video equipment manufacturers, and video production companies. Project leader was GMD.

DVP Scenarios

The different DVP application scenarios comprise a rich set of real life video production situations. In a series of trials end users tested prototype systems and judged the potentials of the services provided. Integrated systems and field trials were important elements of DVP. The prototypes developed in the project are not simply for lab use but were used under actual working conditions. The four DVP pilot applications were:

- *Distributed Virtual Studio:* Bringing together real actors and objects (props) from different, separated, studios in a common real or virtual studio. The main point is the use of ATM to carry broadcast-quality video and camera tracking data between the functional components needed to realize a virtual studio system.

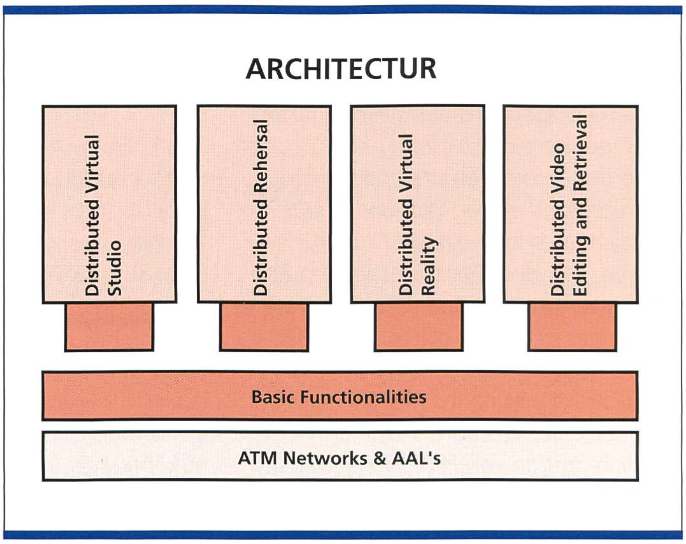

Fig. 1. DVP ATM architecture for distributed professional video production.

[1] This work was supported by the Swiss Federal Government with the OFES grand No. 95.0493 and the Commission of the EU under the project AC 089.

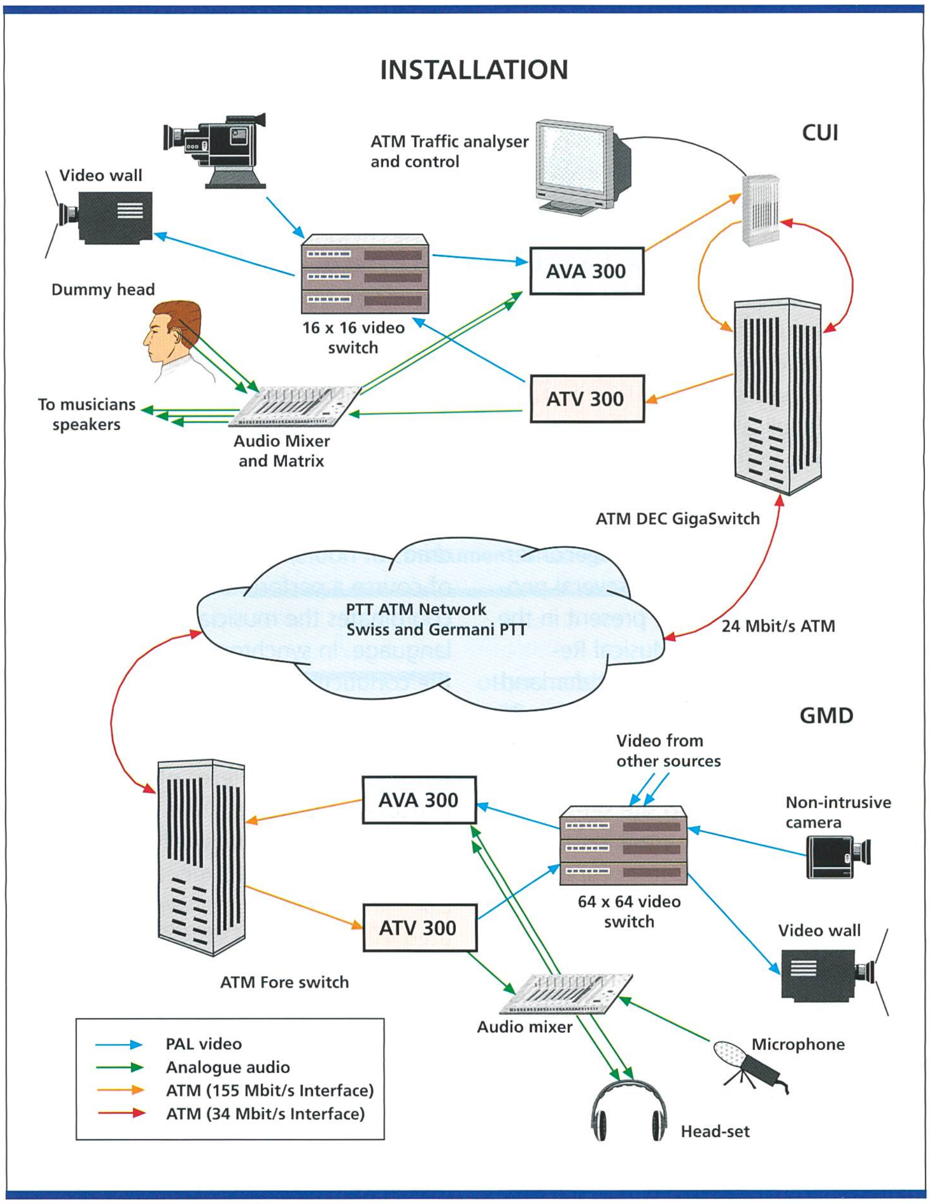

Fig. 2. Distributed Rehearsal studioinstallation.

– *Distributed Video Archiving, Indexing, and Retrieval:* Provide an integrated environment in which new technologies for video and audio post-production (digital Video archive, and non-linear editing) will be accessible via a uniform user interface, disregarding their physical location. The video editing functionalities are coupied with a powerful Information Retrieval system in order to access the distributed video archives in a transparent and effective way.

– *Distributed Rehearsal:* The aim of the distributed rehearsal application is to allow the organization of rehearsals without requiring the participants (actors, musicians, conductors etc.) to be physically in the same room, eliminating thus the need to travel from one City to another for participating in the rehearsal. In this application delay is utmost critical.

– *Distributed Virtual Reality Environments:* to establish an interactive, realtime ATM network connection between two Virtual Reality Visualization Systems across the North Atlantic and evaluate the capabilities, practicality, performance and cost of Distributed Virtual Reallty Technology for performing collaborative product or process design review on industrial show case applications.

In fig. 1 the overall DVP architecture is sketched schematically with ATM networks as central exchange medium. The basic DVP architecture allows for integrating the different complex video production functionalities as on demand services which can be ordered and used online over the network. For professional video an acceptable video quality is prerequisite. Therefore the underlying network has to offer enough bandwidth for transmitting professional video signals, which might be up to 270 Mbit/s for D1. Shared video servers allow for random access of video shots and takes across the network. Post production studios with non-linear editing devices can access videos directly from the video server without file transfer and time consuming copying procedures.

DVP Architecture

Distributed video production refers to situations where the cameras, recorders, switches, mixers and other equipment used in video production (or post-production) are located at several sites linked by high bandwidth network connections. In fig. 2 the DVP architecture is described as layers of basic functionalities and layers of more application specific services on top of ATM networks. In order to share and exchange video, audio and data between the different clients and servers on the DVP ATM network, common interfaces, common video, audio, and data formats, have to be chosen. Uniform easy to use intuitive user interfaces are of great advantage for operating such a variety of different applications. The distribution of functionality, processes, and computational power between server and clients highly depends on the application and therefore has to be flexible and scaleable enough in order to be adaptable to relevant application demands.

Fig. 3. Nov. 1996. Distributed Musical Rehearsal CUI set-up.

Distributed Musical Rehearsal

One of the four pilot applications of the EU ACTS Distributed Video Production (DVP) project is the Distributed Rehearsal (DR) [5], aiming in developing a studio-based teleconferencing service enabling small groups of geographically separated actors and musicians to conduct rehearsals as if face-to-face. The Object Systems Group of the CUT at the University of Geneva was the coordinator and responsible partner for the Distributed Rehearsal application. The other partners collaborating in the DR application were GMD (German) and GRAME (France).
The target of the DR applications was to produce a natural immersive teleconference environment allowing several people to work together as if present in the same (rehearsal) room. Musical Rehearsal, being one of the most demanding teleconference applications, was chosen as the pilot application for the development of the teleconferencing service. Toward this target a two site set-up was implemented. The first site is installed at the German Research Center for Information Technologies – GMD at Sankt Augustin, just outside Bonn, and the second site at the Centre Universitaire d'Informatique of the University of Geneva. A number of tests and rehearsal trials were performed [4] aiming in testing and fine tuning the equipment, and measuring the qualitative and quantitative performance of the system based on a methodology developed within the project.

Functional Specifications for a Distributed Musical Rehearsal

The target of a musical rehearsal is to prepare the musicians and the conductor for the final performance. The musical rehearsals of modem music leading from the first meeting of the musicians and conductor, to the public performance of the musical piece, are organized, in general, into three major phases:

- The protocol phase, where the musicians and the conductor get acquainted with each other and the musical piece.
- The rhythm phase, where the musical piece is played in successive fragments with the tempo slowed down in the delicate parts.
- The sound phase, where the sound level and quality is fine-tuned and possible problems are resolved.

The protocol phase is in general short (30 to 60 minutes), while the rhythm and sound phases are very long (hundreds of hours). During a rehearsal (and of course a performance) the conductor coordinates the musicians using body language. In synchronizing the musicians the conductor takes into consideration the layout (distance, position) of the musical instruments in the room as well as the speed of the reflexes of the musician. In a localized rehearsal the musicians and the conductor are physically in the same room. In a distributed rehearsal the musicians and the conductor will be distributed in two or more sites. Since the experiment for a distributed rehearsal using telepresence techniques is novel, we only considered the two-site case with the conductor at one site and the musicians at the other site.
In general the requirements for organizing a distributed musical rehearsal are these of a telepresence session. That means that the basic need is the existence of (at least) a video wall with minimal dimensions 2 × 3 m and high resolution video projection, and at least a hifi audio system. The goal is to give the impression to the rehearsal participants that they are physically in the same room. However a musical rehearsal needs not only a higher quality of audio but in addition it requires an accurate 3D restitution of the sound space and very low transmission latency. This is due to the fact that the conductor needs to be able to also identify the exact position of each musical instrument and synchronize as accurately as possible with the musicians.

Fig. 4. Nov. 1996. Distributed Musical Rehearsal Conductor's view/Dummy Head.

Overview of the installation

We installed two distributed rehearsal studios, one in the University of Geneva and one at GMD. Although the two studios are not identical, the basic technology used is the same.
For the video capture non-intrusive microcameras (Panasonic) as well as small consumer digital cameras (SONY DCR-VXIOOOE) were used. The projection was made using 2 tri-tube projectors low luminosity projectors (SONY-230 ANSI Lumen) at GMD and a high luminosity light-valve projector at CUI (BARCO 8100-800 ANSI lumen). The video walls used standard medium quality screens with a size 2 × 2,6 m.
To accurately reproduce the sound of the orchestra at the conductor's site, two different sound capture systems are installed and tested. A dummy head and a

Fig. 5. May 1997. Distributed Musical Rehearsal – Conductor at GMD.

Fig. 6. May 1997. Distributed Musical Rehearsal CUI set-up and Dummy Head.

dual microphone set up. The dual microphone was placed next to the video wall. For both systems a matrix was used for the correct three dimensional reproduction of the sound.
The video and audio were digitally encoded and transmitted using ATM lines. The codes used were the FORE AVA-300 and ATV-300. The video was encoded in an MJPEG stream and the audio was digitized in DAT quality. The bandwidth used for the transmission of the video (non-interlaced, PAL 25 fps) was between 12 and 14 Mbit/s (depending on the image complexity) and for the audio (DAT stereo) 1,5 Mbit/s. The video encoding-decoding delay was 46 ms while the transmission delay was 9 ms. The audio encoding-decoding delay on the other hand was 6 ms and we introduced a 20 ms buffering in order to eliminate buffer underflow producing an annoying clicking in the audio.

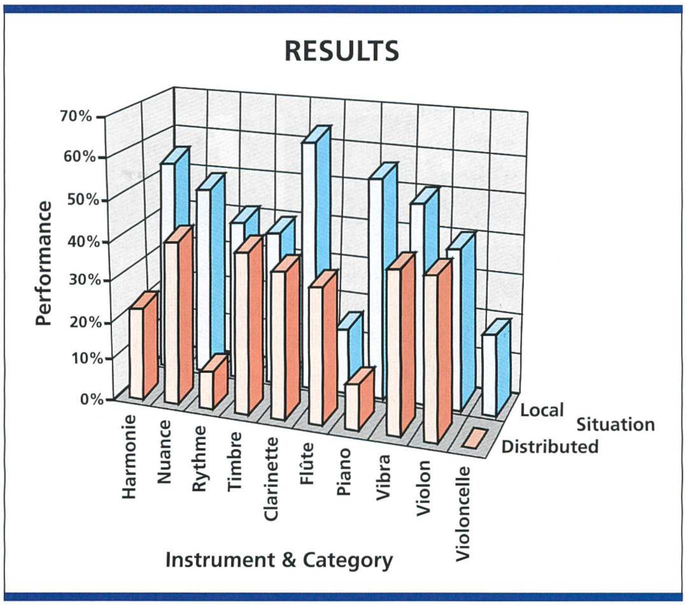

Fig. 7. Objective evaluation results.

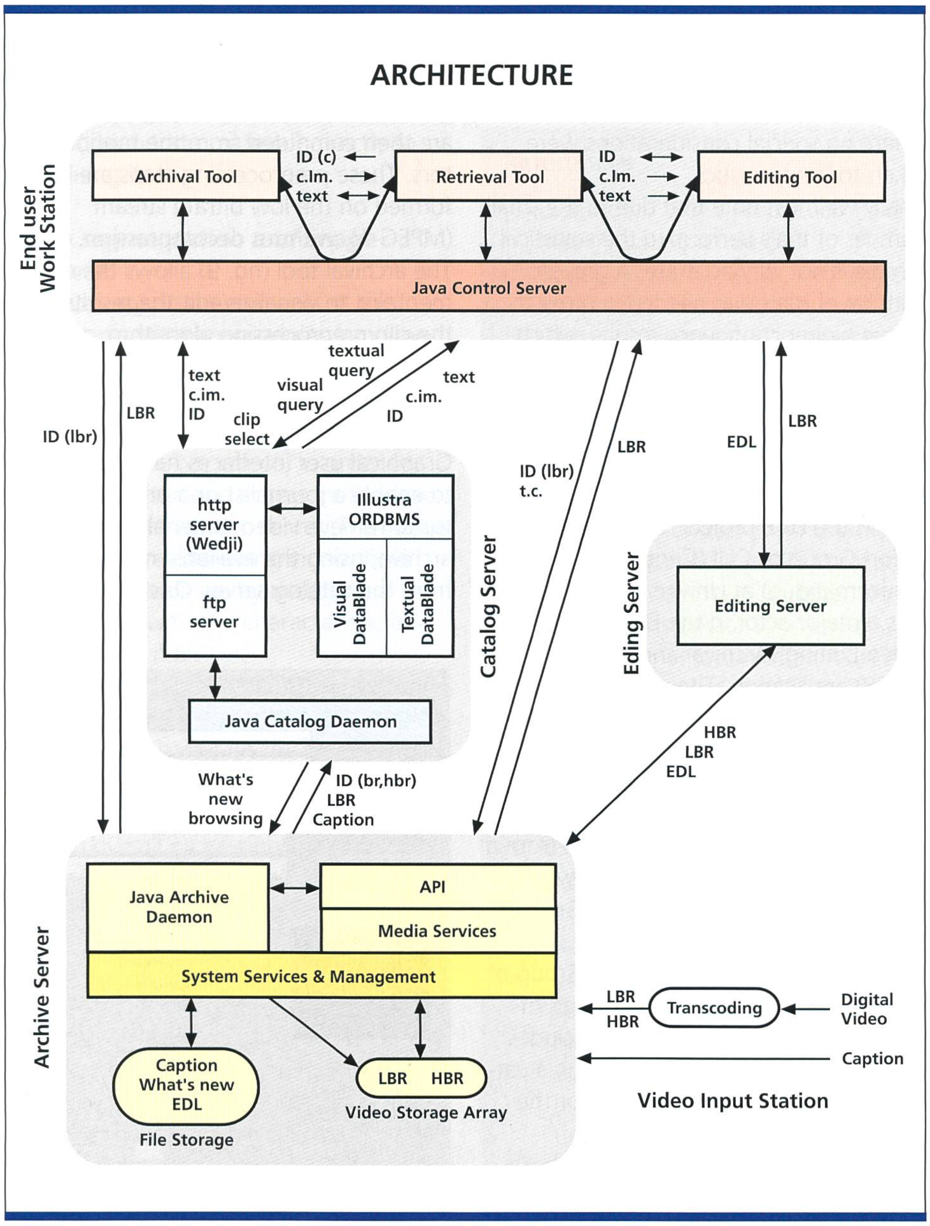

Fig. 8. DVER System Architecture.

Distributed Rehearsal Trials

From the several tests and trials performed the most characteristic ones were a distributed singing rehearsal and two distributed musical rehearsal [6] [7] [8]. While the singing rehearsal was an early trial and it did not make use of the video wall at CUI but a large television screen (117 cm), the musical rehearsals were full scale trials using the complete studio installations.
A first full scale distributed musical rehearsal trial was organized in November 15th 1996 between the University of Geneva and the GMD by the GRAME EOC. The total duration of the rehearsal was six hours. The piece retained for the distributed musical rehearsal trial was Pierre Bouiez's "Dérive", composed for six instruments: piano, vibraphone, violin, cello, flute and clarinet (fig. 3 and fig. 4). The musicians were installed in Geneva while the conductor was in Germany.
A second distributed musical rehearsal was organized in May 30th 1997 (fig. 5 and fig. 6). In this rehearsal the retained piece was H. P. Platz's "Pièce Noire", for 12 musicians. The total duration of the rehearsal was six hours.

Evaluation methodology

A very important issue for the distributed rehearsal system is the objective measurement of its quality and in consequence the limits of its usability. For this reason a

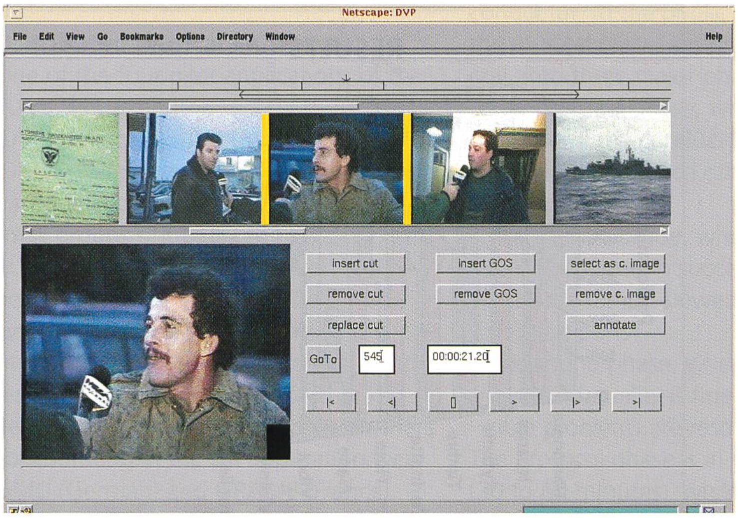

Fig. 9. Main panel of the Archival Tool.

methodology was developed for the objective measurement of the system quality [5]. The methodology is based on the fact that in a musical rehearsal the conductor must control, identify and possibly modify notes that are coming wrong in the musicians' scores. Specifically the scores given to the musicians contained various errors (like time errors, pitch errors, dynamic errors etc.) when compared to the score given to the conductor. The conductor was then asked to detect the errors in the musicians scores. By reproducing the same test in a local situation with different but equivalent test scores, and comparing the errors found in the distributed rehearsal and in the local rehearsal we were able to establish a concrete measurement of the System quality. The objective evaluation results (fig. 7) indicate that the overall quality of the DR system is about 40% of a normal localized rehearsal. However it is interesting to note that the performance differs drastically from instrument to instrument. For example the performance for the flute is superior in the distributed environment than in the local one, the performance of the violon is equal for both environments, while the performance of all other instruments is inferior in the distributed environment. In our opinion this is due to the fact that the audio capture system behaves differently for each musical instrument, depending on its frequency range and its harmonics. Due to the digitalization of the sound it is probable that some phase information and high frequency harmonics are lost. Another factor that might contribute in the performance degradation of the system are the differences in the clock rates between the analog-to-digital and digital-to-analog hardware.

In addition the acoustics of the local and remote rehearsal rooms contribute greatly in the rehearsal performance. While the local rehearsal was done in an acoustically tuned theater, the distributed rehearsal was performed in a room where no special considerations were taken for its acoustics.

Finally we must note that due to the small number of trials performed the statistical sample is not very accurate. A greater number of trials was needed in order to obtain higher confidence results, which however was not possible within the budget and time-frame of the project.

Distributed Video Editing, Archival and Retrieval

Within the DVP project, the Computer Vision Group of CUI (Centre Universitaire d'Informatique) at University of Geneva was a major actor in the Distributed Video Editing, Archival and Retrieval (DVER) application. The goal was to provide broadcasters with a complete solution for distributed video post-production, which integrates archival, retrieval, and editing functionalities. The DVER application of the DVP project stems from a collaboration with GMD (Germany), Intecs (Italy), RAI (Italy), Intracom (Greece), MegaChannel (Greece), and TSR (Geneva). The Computer Vision Group of the CUI has coordinated the design of the system architecture, which includes an archive server, an editing server, a catalog server, and a client station for the end user (fig. 8).

The archive server stores videos at both low and high bitrates, and offers video streaming and file transfer services. The catalog server hosts a database where the metadata of video clips are stored and indexed. The client station allows users to perform archival and retrieval operations, as well as video editing using existing material at low bitrate. The editing list created by the user is then processed by the editing server and applied to the corresponding high bitrate material, in order to produce the ready-to-broadcast final video.

Video Archival

The catalogue server automatically fetches the low bitrate version of each new clip in the video archive and preprocesses it, in order to extract metadata. First, a video clip is decomposed into smaller segments, by detecting the transition between shots and by analyzing motion properties. For each shot, still images (keyframes) are extracted for display purposes, and to enable automatic image indexing using a wavelet approach. Camera and camera lens motion (pan, tilt, zoom, stationary) properties are then computed from the motion vectors. These preprocessing steps are performed on the low bitrate stream (MPEG-1), without decompression.

The archival tool (fig. 9) allows the documentalist to visualize/edit the results of the clip preprocessing algorithm, and to enter additional textual annotation.

Video Retrieval

Graphical user interfaces have been built to enable a journalist or a program director to retrieve video material from the archive, using the available metadata from the catalog server. Once the desired

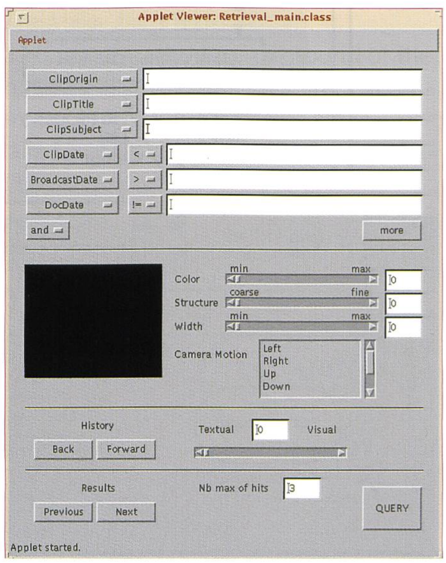

Fig.10. Main panel of the Retrieval Tool.

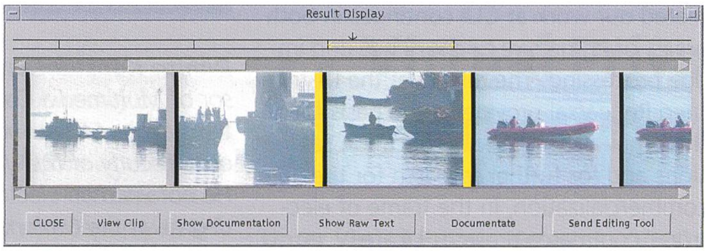

Fig. 11.
Query results.

items are selected, it is possible to export them to the editing tool. The retrieval tool (fig. 10) allows one to query the database using textual and visual information. Textual queries address specific fields entered during the archival process. Visual queries address metadata extracted during the preprocessing phase. The user specifies an example image, and defines the desired type of camera motion.
Query results are shown to the user within the result window (fig. 11). Once desired items are identified, it is possible to select a clip, or a part of it, and to export it (low bitrate material) directly to the Editing Tool.

Video segmentation and image retrieval

The most important elements of the DVER application are modules handling the automatic video segmentation and image retrieval. The aim of the video segmentation is to automatically extract visual indexes from videos, in order to provide sophisticated access methods to the contents of a video server. The image retrieval aims at retrieving video shots from a video archive, by matching a query image with the characteristic images of each shot.
For the video segmentation two pattern recognition techniques have been implemented, both based on the processing of MPEG-1 motion vectors, without need for video decompression [9] [11]. In this way, an overall processing speed of 56 frames/s could be achieved on a sun workstation. The first technique detects shots boundaries, i. e. transition frames between video segments with uniform visual and motion properties. In order to compute an approximation of the optical field, frame-to-frame motion vectors are derived for all frames, by combining forward and backward predictions of neighbouring P and B frames. For each frame, features describing the statistics of these vectors are extracted. A Bayesian approach is then employed in order to classify each frame either as a default, or as a boundary one. The underlying model is a multivariate Gaussian function, for which the mean vector and covariance matrix are learnt from a set of training data. This method has been tested on a total of approximately 9000 frames, yielding a classification performance of 0,2% false positives, and 2% false negatives.
The second technique aims at characterizing each shot by the type of camera motion, i. e. into the classes pan, tilt and default. Again, a Bayesian classification approach has been adopted, using features describing the statistics of the MPEG motion vectors over an interval of consecutive frames. Supervised learning was achieved by manually labelling each frame into a class and by estimating models of probability distributions in the feature space. Despite some difficulties in manual labelling, due to the object motion or camera oscillations, classification performance on new samples are 4% false positives for both pan and tilt, and 10% false negatives.
For the image retrieval a content-based image retrieval technique has been implemented, based on the wavelet transform [10] [12]. Haar wavelets are used to extract a number of coefficients, representing the image at various resolutions. In order to reduce the storage and search spaces, a compression scheme is proposed, achieving very high compression ratios. This technique is designed to

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select a small number of wavelet coefficients that statistically characterize the image, given the database population, while preserving perceptually-relevant information on its visual content. A parametric matching function, establishing the similarity between an image and a user-defined query, has been defined. Three options are provided to the user in order to formulate queries in a flexible way. The first one is the definition of regions of interest in the example image. The second one is the selection of a preferred spatial scale characterizing the desired object, which ranges from coarse (overall structure) to fine (texture properties). The third one is a relevance measure of the color composition in the query image. From each value of these parameters, mathematical expressions are given to characterize the matching function. Compared to other commercially available image retrieval systems, one major advantage of the proposed system could be observed, namely the possibility for a new user to explore the database more efficiently. This is mainly due to the unicity of the underlying feature representation (wavelet coefficients), and to the possibility to understand the relative importance of each parameter, thanks to the well-defined mapping of the matching function.

Assessment

The participation and contribution of CUI in the DVP project was recognized by the project management and partners as essential to the success of the project. The innovative application and the results obtained from the Distributed Rehearsal, provided the basis for the design of the DVP video codec and influenced the manufacturers of video codes in the design of their next generation systems. Furthermore in the DVER application the research and the implementation of the video segmentation and image retrieval algorithms proved invaluable in the completion and demonstration and use of the system by the partner television stations. Another result of the CUI participation in the DVP project was the testing of the ATM European infrastructure. From the numerous ATM based tests and trials we performed we were able to test the limits of the ATM technology in QoS and capabilities, as well as compare the differences of ATM policies and accessibility in different European countries.
Although the DVP project has been completed our work at CUI continues in both areas, of immersive telepresence and image processing. The results of the Distributed Rehearsal provide us the basis for the organization of tele-education sessions and for further research for the commercialization, in the frame of electronic commerce projects, of life audio/video material. The Distributed Video Editing and Retrieval research results are further expanded in combination with watermarking techniques targeting in the commercially secure distribution of video material. 7

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Dimitri Konstantas *is Assistant Professor of Multimedia Communication Systems at the Social and Economics Science Faculty of the University of Geneva. He obtained an electronic engineering degree at the National Technical University of Athens in Electrical Engineering in 1981, a MSc in Computer Science at the University of Toronto in 1983 and a Ph.D. in Computer Science at the University of Geneva in 1993. From 1985 until 1987 he was researcher at Institute of Computer Science, FORTH, at Heraklio, Crete; from 1987 to 1993 he was research assistant at the University of Geneva and since 1993 he is Assistant Professor at the University of Geneva. Dimitri Konstantas is author of many articles on Object Oriented Systems, Computer communications and Multimedia Systems, has participated in numerous European and Swiss research and industrial projects and he has been a consultant to several European companies. His present interests include electronic commerce (commercialization of intangible goods), multimedia applications and commmunication systems. He can be contacted at: Dimitri Konstantas, Centre Universitaire d'Informatique, 24, rue General Dufour, CH1211 Genève 4 or dimitri.konstantas@cui.unige.ch*

Zusammenfassung

DVP – Distributed Video Production, Distributed Musical Rehearsal sowie Distributed Video Editing and Retrieval

Dieser Beitrag vermittelt einen Überblick über das europäische ACTS-Projekt «Distributed Video Production» (dezentrale Videoproduktion, DVP). Das Kernstück des DVP-Projekts bilden dezentrale Pilotanwendungen für die professionelle digitale Videoproduktion via ATM-Breitbandnetze (LAN und WAN). Das DVP-Projekt untersuchte die Servicequalitätsanforderungen (QoS) von Fernsehstationen für verschiedene Arten von dezentralen Videoproduktionen und führte eine Reihe von Versuchen mit dezentralen virtuellen Studios (ad-hoc-Studios), dezentraler virtueller Realität, dezentralen Musikproben sowie dezentralem Videoschnitt und dezentraler Videobearbeitung durch. Das CUI der Universität Genf beschäftigte sich im Rahmen des DVP-Projekts mit den folgenden drei Anwendungen: dezentrale Musikproben (DR), dezentraler Videoschnitt und dezentrale Videobearbeitung (DVER).

Dr. Alain Jacot-Descombes *received his PhD in 1993 from the University of Geneva in the area of image processing. Between 1994 and 1995 he worked as invited researcher in the Electrotechnical Laboratory (ETL), Tsukuba, Japan where he was involved in research projects on representation and archiving of multimedia documents. From 1995 to 1997 he was project leader in the DVP project for the development of the content based search of video archives. From 1997 to 1999 he worked in STERIA as project leader. Since 1999 he is director of the Informatics Division of the University of Geneva. His e-mail address is: Alain.Jacot-Descombes@adm.unige.ch*

Thierry Pun *received his Ph.D. in image processing in 1982, at the Swiss Federal Institute of Technology in Lausanne (EPFL). He joined the University of Geneva, Switzerland in 1986, where he is currently full Professor at the Computer Science Department. Since 1979 he has been active in various domains of image processing, image analysis and computer vision. He has authored or co-authored over 140 journal and conference papers in these areas, and led or participated to a number of national and European research projects. His current research interest is focused on several aspects of the design of multimedia information systems: image and video content-based information retrieval systems, Web browser for blind users, and image and video watermarking. For more details see: http://cuiwww.unige.ch/~pun*

«Virtual Private Networks – verbesserungsbedürftig»

Unter Virtual Private Networks (VPN) versteht man die Anbindung von mehreren Netzwerken oder einzelnen Computern mittels öffentlicher Telefonleitungen oder Internet Protokoll. VPN-Anbieter bleiben jedoch hinter den Erwartungen zurück. Die Unternehmensberatung Frost & Sullivan sieht denn auch im Markt für Virtual Private Networks ein grosses Verbesserungspotenzial.

Eine Befragung von 500 europäischen Grossunternehmen – alles gegenwärtige oder zukünftige VPN-Nutzer – bescheinigte den Anbietern Mängel in wesentlichen Punkten: Bei der Produktanpassung, der Kundenbetreuung und bei Produktinnovationen. Somit bleiben die meisten Anbieter derzeit noch weit hinter den selbstgeweckten Erwartungen zurück.

Bei den VPN entfallen teure Standleitungen oder Frame-Relay-Anbindungen. Um die entsprechende Sicherheit beim Datentransport zu gewährleisten, werden die Datenpakete für den Versand verschlüsselt. Das Interesse an Virtual Private Networks ist dementsprechend gross.

Die Anwender setzen hohe Erwartungen in die von den VPN-Anbietern in Aussicht gestellte Revolutionierung des Kommunikationsmanagements. Der Markt bietet dank der möglichen Kosteneinsparungen ein enormes Expansionspotenzial. Als wichtigste Wachstumsmotoren nennt die Studie[1] die weiter zunehmende Globalisierung und die ständig wachsende Menge an zu übertragenden Daten.

Als wichtigste VPN-Anbieter nennt die Studie die Firmen AT&T Unisource, Cable & Wireless, Concert, Equant, Global One, IBM, Infonet und MCI Worldcom. Das Unternehmen mit der grössten Durchschlagskraft und den besten Wachstumschancen im VPN-Bereich sei MCI Worldcom. Der Konzern zeichne sich durch die aggressivste Preisstrategie und die höchste Absatzreichweite aus. Die Befragten bescheinigen dem Unternehmen eine hohe Leistung und Qualität seiner Dienste. Frost & Sullivan würdigt diese Leistung mit dem «Market Engineering Competitive Strategy Award», der damit zum ersten Mal einem europäischen VPN-Anbieter verliehen wird.

Dass sich der Markt immer noch in der Entwicklungsphase befindet, zeigt sich in den gegenwärtigen Bedürfnissen der Kunden. Nach Ansicht von Gareth Williams, Analyst bei Frost & Sullivan und Autor der Studie, stehen derzeit grundlegende Faktoren wie Preis, Verfügbarkeit des Dienstes, Zuverlässigkeit und Sicherheit im Vordergrund. Mehrwertfunktionen wie direkter PC-Zugang zu Telefonnetzen, abteilungsweise aufgeschlüsselte Abrechnung und Konvergenz von Daten und Sprache sowie von drahtloser und drahtgebundener Kommunikation spielen heute noch keine entscheidende Rolle für den Absatz von Virtual Private Networks. Dies soll sich jedoch innerhalb der nächsten zwei Jahren ändern.

Um sich zukünftig im Markt behaupten zu können, müssen VPN-Anbieter zudem kundenspezifische Lösungen auch für kleinere Anwender entwickeln. Zudem sollte die Öffentlichkeitsarbeit der Anbieter verstärkt und die Beziehungen zu den Medien ausgebaut werden, um eine steigende Akzeptanz und einen höheren Bekanntheitsgrad bei möglichen Anwendern zu erreichen. Dringenden Handlungsbedarf sehen die Autoren der Studie auf dem Gebiet der Kundenbetreuung. Die Anbieter stehen derzeit unter einem hohem Druck. Sie müssen nicht nur ihren Service verbessern, sondern auch Preisführerschaft beweisen, um sich Kundentreue zu erarbeiten.

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[1] Report 2660: «VPN End-User Perception Study», Preis: Euro 7000.–