



SMASH

Storage for
Multimedia
Applications
Systems in the
Home

FINAL REPORT

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1. EXECUTIVE SUMMARY

Three years ago --when SMASH started-- digital satellite broadcast just started, digital terrestrial broadcast was just a dream, hardware (MPEG decoders) were expensive and digital storage for consumers was not available. Now three years later, the situation in Europe has changed drastically.

At the start of the SMASH project we had the following vision and ideas: in the future (which happens to become true very fast now) most information will enter the home in a digital way and it will be required that the user at home can store and retrieve this information in an easy and cost effective way.

Therefore several new techniques had to be developed in the area of mass storage and retrieval technologies. We had the idea that the mass storage concept is best realized by the combination of a **digital tape drive (DTD)** and a **hard disk drive (HDD)**. This concept should exploit the advantages of both components and hide their drawbacks.

Our vision that much information will become available digitally has become true in two areas: the massive use of MPEG-2 for digital satellite services and the internet for the WEB information. On the storage technology front, both affordable HDD's and consumer DTD's are becoming available and therefore the project has been well timed.

To remain focussed on the applications and user benefits we have selected early on three application areas, each one quite different from the other but all three characterized by their need for a HDD-DTD combination. The first and most interesting one has been the recording and retrieval of MPEG-2 video received by a satellite dish. We call this application the DVB-VCR.

The second one is a new concept of personal education where the student has (almost) all material which is relevant for a course on one tape.

The last one is a storage application for Internet services. At this moment internet storage is not such an issue because most people are connected with low speed modems. This will change very much in the future with the arrival of cable modems.

For all three applications a working prototype has been realized with very attractive user features. More details on those can be found in chapter 4.3.

But to be able to realize all this, several new technologies had to be developed. First of all we had to realize a system which is able to receive MPEG streams in real time from a Set Top Box, buffer those temporarily on the HDD and transfer them to the tape drive. Real time performance proved to be very challenging. Moreover we had to use a tape drive which was not really designed for this purpose.

Secondly we had to develop new techniques for fast search and retrieval because this becomes far more difficult when using MPEG. This has been achieved by storing program abstracts on the HDD so that retrieval can be done very fast.

Thirdly we have developed techniques for watermarking the MPEG streams as an aid for copy protection.

A last issue we had to tackle was an agreed and common interface between the SMASH storage unit, consisting of the HDD and DTD, and the three application units. All those achievements are described in more detail in chapter 4.2.

For the reader of this report to obtain a fast insight in the total system we have written chapter 4.1 in which we explain also the main new features which are possible with a HDD-DTD combination.

The project has reached its final goal, which was to demonstrate the concept for the three applications. The technologies we have developed can now be used for real product implementations. Also the prototypes we have can and will be used for further user evaluation. Many new insights have been obtained and especially the total system knowledge we have built up is of large importance. It is foreseen that the partners in the future will either continue to further develop the technologies or to start product development based on the current results obtained.

2. PROJECT OBJECTIVES

The amount of digital information entering the home will increase significantly in the future. The consumer at home will want to store some of this information. Especially the storage of digital video will require tens of Gigabytes of storage capacity (a library of 200 movies will require one Terabyte of storage). The only storage technology available in the near future to handle this will be magnetic tape. However tape drives have some disadvantages such as long wind times. Also a tape drive can only perform one operation at a time: either recording a program or playing back another one.

The aim of the SMASH project is to investigate the possibilities to eliminate the disadvantages of tape drives and to extend even their possibilities. One of the goals is to realize a storage system that can at the same time record a program and playback another program using only one tape drive. Such a system should be connectable to digital satellite receivers and be able to record in a transparent way the digital broadcasts, including all the extra information which is transmitted along with the broadcast.

To support such services and new features more demands will be put on the storage system at home. To realize this **several objectives** have been defined.

The first one is to integrate the tape drive with a hard disk. In this integrated unit the tape drive will be for mass storage and the disk will serve to store information which needs to be accessed interactively. The user should not be bothered with where information is stored and therefore a management system is necessary that allocates the information automatically. Moreover it should be investigated how the hard disk in the system can realize much faster search than what is possible with a tape drive only.

The second objective is to study and realize the downloading and storage of all the new services that will enter the home. By downloading often used information ahead of time, the user can avoid network peak-charges but also improve the access time. Therefore optimally an interactive application makes use both of the storage in the information server and of the information available on his local storage. The challenge is to develop an integrated approach for various applications that use both storage systems efficiently.

The third objective is that we have to solve the problem of the bit rates of the services which enter the home. The bit rates are not fixed and may vary even within one service. The current tape drives support only one or a few discrete data rates. It is therefore necessary to investigate how the hard disk can function as a buffer between the service and the tape drive. Moreover the access time of the tape drives needs to be improved as well as the storage capacity such that the user has a vast amount of information available on one cassette. Information capacities of more than 100 Gigabytes are foreseen on one cassette.

The overall objective of the project is therefore *"to develop and show the technical feasibility of an integrated storage unit that is connected to the network and other consumer equipment and that enables to download, store and retrieve at home all future multimedia applications."*

In the future this storage unit at home may even function as the local storage server inside the home being able to deliver information to the entertainment equipment as well as to the PC's in the home. This makes it necessary to develop a cost effective interconnection system for the home.

The end result of the project will be the demonstration of an integrated storage system, based upon state-of-the-art advanced key components, that will contain a disk and a tape drive. One or more important applications will be developed on this system in order to show the possibilities of the SMASH system.

Besides showing the technical feasibility the aim is also to actively work on the standardization of such a system. For the tape system this means the standardization on how the information is written onto the tape.

3. RELATIONSHIP TO ACTS PROGRAMME OBJECTIVES

The SMASH project is embedded in ACTS DOMAIN-1 (Multimedia Services). In this domain we participated in Sub-domain 3 which is called "Server-Based Multimedia Services". The contribution of the SMASH project in this domain was focused on the role of local storage in the Home and how it can be combined with storage functions present in the network.

SMASH has also actively participated in chains. The most important chain is the SII-chain which is on "Interactive Multimedia Services". Contributions has also been given to the DAVIC chain activities.

The participation in European standardisation bodies has been a focus point. On the one hand we actively contributed in the ongoing DVB activities and on the other hand we were involved in the CENELEC Technical Committees which are responsible for the definition of future digital interconnect systems in the home. Towards the end of the project we have also made an important contribution to DAVIC.

Furthermore, in 1997 partner Philips hosted two young scientists from University of Ljubljana under the Visiting Scientists Programme. They contributed to the SMASH work.

4. MAIN ACHIEVEMENTS OF THE PROJECT

In this chapter we will give a short introduction to SMASH, followed by a description of the embedded Storage System Technologies. We finish with a description of the realized applications.

4.1 Introduction
4.2 Storage System Technologies
4.2.1 External Interface
4.2.2 Prototype
4.2.3 Visual Navigation
4.2.4 Copy Protection
4.3 Applications
4.3.1 DVB-VCR
4.3.2 WEB-VCR
4.3.3 REA-application

4.1 Introduction

The overall objective of the SMASH project is to develop and to demonstrate the technical feasibility of an integrated storage unit for multimedia applications in a domestic environment, called the "SMASH Storage System" or "SMASH Combo Server". This section outlines the system concept, the selected applications and supporting technologies, so that the subsequent sections, which discuss the storage system and applications in more detail, can be understood in the proper context.

After an initial orientation study in the first year of the project, in the second year the SMASH project selected three application fields in which crucial performance and usability tests for the SMASH storage unit are undertaken. Specifically the selected applications concentrate on evaluating the new functionality that can be achieved with the integrated disk/tape storage unit. These applications have been worked out in great detail and user tests have been completed on a laboratory scale in the last year of the project.

The three applications are:

- The DVB-VCR: A recorder and player for satellite and cable DVB services, especially digital MPEG video with contained service information, which will use the storage unit for additional functionality (break button, simultaneous recording and playback) and increased user friendliness (browsing and selection of services using the program guides and visual contents of the services, content management of tape collections),
- The WEB-VCR: A recorder and player for a wide variety of internet services, concentrating on creating a personalised local archive for web pages and supporting audio-visual streams, and logging of interactive audio-visual sessions,
- The remote education package (REA): An application study that concentrates on how previously stored educational material on the SMASH combo server can be maintained, efficiently accessed and controlled both locally by the student as well as remotely, if needed, by the teacher. Three target courses are under development: Digital Signal Processing, 3-D Computer Graphics, and Virtual Reality.

In addition to these applications, two important technologies were identified and developed, especially in support of the DVB-VCR:

- A cryptographic approach was developed to prevent unauthorised copying of recorded material. In digital video recorders that make perfect copies of the original, this is of great importance.
- Methods for extracting still images from MPEG video streams were developed, and the use of these images for navigation through the video content was studied.

In the domestic environment the SMASH storage system serves as a remote server for multimedia applications.

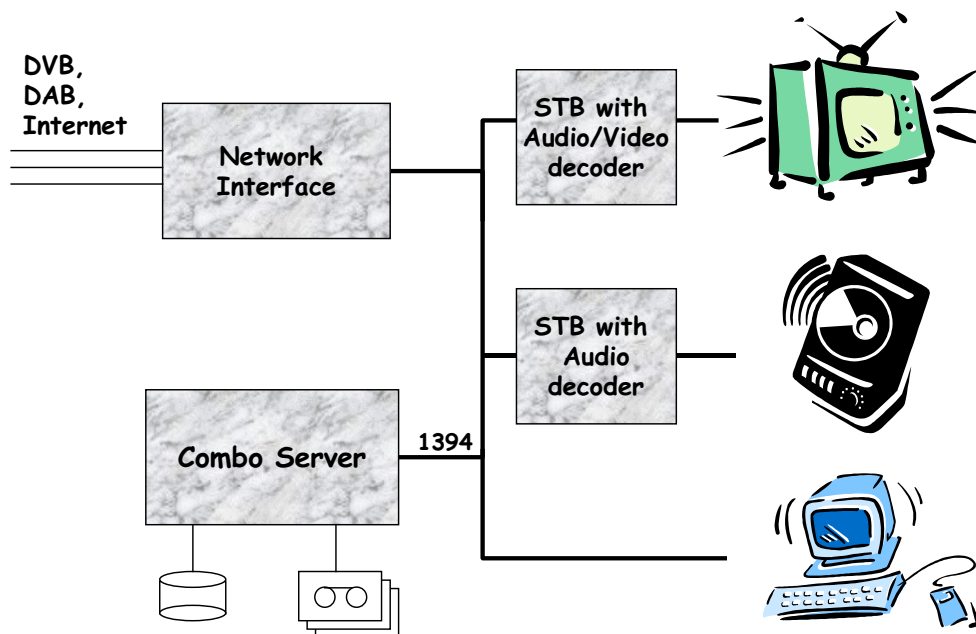


Figure 1: SMASH Combo server in a home network environment

Figure 1 shows the project's conceptual view on the place that the SMASH combo server has in the consumer's home. The server is externally connected to the network through a set top box (DVB input) and / or through a PC (internet connection). These two external connections have established themselves as the dominant digital information providing pipes for many multimedia applications in the near future.

The combo unit itself does not have a user interface, but is accessed through either the PC application with Internet/Java interface or through the set top box (STB) application running for instance an MHEG engine.

The architecture of the storage unit is currently built around two tightly coupled but technologically different storage media (hence the name "Combo"), namely a linear tape drive (LTD) and a hard disk drive (HDD). The linear tape drive is a cheap (in terms of Ecu/Mbyte) high capacity storage medium (30 Gbyte or more) with relatively slow access, while the hard disk drive provides a relatively expensive, smaller capacity storage (e.g. 2 Gbyte) with fast random access. The two components of the SMASH server are managed by the operating system of the unit itself, while PC/STB applications can access the data residing on LTD or HDD through the Application Programming Interface (API). The multimedia data used in

applications will be dynamically stored in a distributed way, depending on the character of the multimedia data and on the application. The main distinction in storage will be between (audio-visual) stream data (to be stored on the LTD) and random access data files (to be stored on the HDD). To the user, however, the server system will be transparent, i.e. the user is not aware of how the data is distributed over the LTD and HDD. The combo server has specific software/hardware functionality for managing the stored data, including copy protection and a multimedia database (MMDB) for efficient retrieval of stored information.

The chosen architecture of the combo server combines the advantages of hard disk technology (fast and random access) with those of linear tape technology (huge storage capacity). This means that besides the typical application of disk and tape storage, also new functional primitives emerge, such as:

- huge storage capacity for multimedia stream data (e.g. MPEG streams) on the LTD while simultaneously providing possibilities for efficient management, browsing, and reduction of playing delay because of the random access possibilities provided by the HDD for selected data,
- simultaneous storage and/or playback of multiple streams using the HDD as intermediate buffer,
- pre-caching of stream data from LTD to HDD to improve response times to user or application requests,
- masking of interruptions during recording or playback of streams from the LTD due to for instance end-of-tape or tape change, by using the HDD as temporary buffer,
- recording of streams with variable bit rate. Since the linear tape drive is essentially a constant bit rate device, the hard disk can be used as a large capacity buffer to carry out the conversion from variable to constant bit rate,
- super real-time downloading of audio-visual services,
- break button to temporarily interrupt viewing of real-time services by using the combo server as a "very long delay line".

In the following chapter 4.2 we will present the different technologies which are needed to build a SMASH Storage system. In Chapter 4.3 we present details on the three main applications we have worked on.

4.2 Storage System Technologies

4.2.1 External Interface

The Interconnect System is the gateway for applications running on clients like DVB Set Top Boxes or PCs towards the SMASH Storage Device working as a remote server.

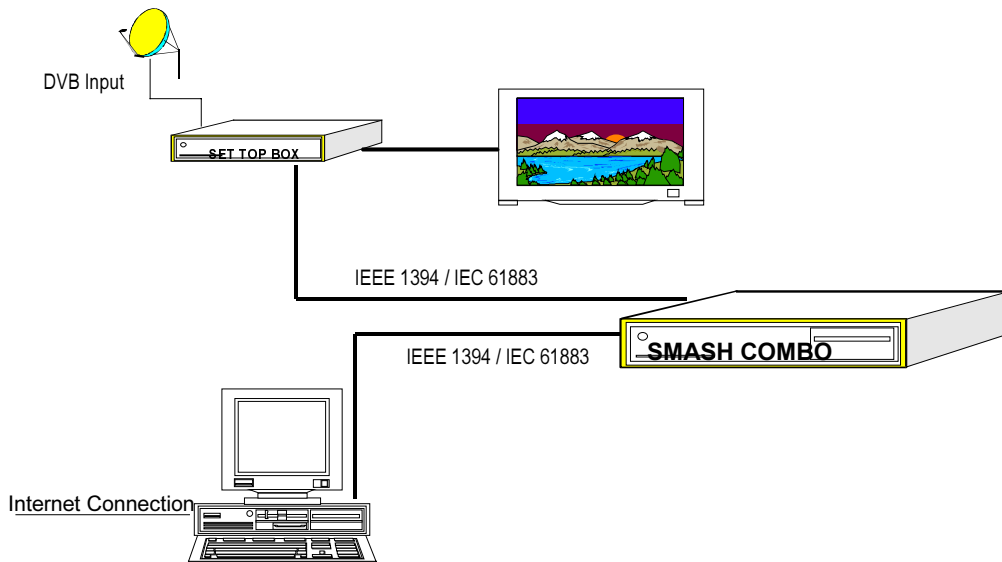


Figure 2: The SMASH Storage Device as a Remote Server for Applications

The Serial Bus **IEEE 1394**, which fulfils all the requirements for the SMASH storage device and its applications, has been chosen as the interconnect system for the combo. Very few devices, designed for just a single application, were on the market with 1394 interfaces at the beginning of the project. Meanwhile more and more devices with an IEEE1394 interface have been announced or launched, so that from today's point of view the choice made at the beginning of the project has been proven to be the right one.

The 1394 digital bus as specified by IEEE only provides the basic layers for data transport. It specifies the "physical"-, the "link"- and the "transaction" layer. No provisions were available for the needs of real-time data streams like DVB (MPEG2 TS) or DVC. An extension to meet the "streaming" requirements has meanwhile been standardized as IEC 61883. This format adds another layer on top of IEEE1394, the "Common Interface Packet", which provides mechanisms to adapt various data formats to 1394. To apply these mechanisms to applications and its real-time stream formats was one of the basic tasks of the project. As a result one important building block of an "open interface" has been developed and proven by a reference implementation.

For verification a demonstrator based on a commercial DVB Set Top Box and a PC based storage device has been set up (see Fig. 3). In the course of this project the real-time interface based on 1394 has been designed for the demonstrator to support MPEG 2 transport stream for the DVB recorder application.



Figure 3: Demonstrator for IEEE 1394 based DVB/MPEG transmission

The second building block, required for an “open interface” is the control module. Basic commands for remotely controlling the SMASH storage have been specified and implemented as the first step. By experiments with the demonstrator, the feasibility of the concept using the IEEE 1394 Digital Interface as the Interconnect System for the SMASH combo has successfully been proven.

This has led to the deliverable “**Specification of the Interconnect System**”, which defines the Application Programmable Interfaces (API) of the “open interface” as used for the SMASH Combo. The API allows application programmers to make use of the features of the SMASH device without being bothered by details of the technical implementation of the instrument.

To support the project applications (see section 4.1) the SMASH server should be able to handle the following types of information or files: text, graphics, animation, digital audio and video.

To access these file types the application programmer can use function calls of the API. To cope with the different types of files followings the API consist of the following main groups:

- Low level API
- File system API
- Streams API
- Operational Management API

The **low level API** can handle complete tapes, partitions of a tape and a hard disk as a cache for tape partitions. In addition to basic (hard-)disk commands, e.g. *open* and *close* files, *read* and *write* files, commands for accessing information from tape are provided, e.g.: *lookup*, *restore*, *archive* and *archive(FileList)*

The **files system API** is provided by classes in the `java.io` package. This enables to handle also new files defined in future for new applications.

The **streams API** can handle real time AV data like MPEG1, AVI, Quicktime, or MPEG2 partial transport stream. Following commands have been implemented: *Play*, *Pause*, *Resume*, *Stop*, *Record* and *Status*

The **operational management API** has been introduced to deal with application specific implementations of the generic commands, e.g. *OpenSession*, *CloseSession*, *List*, *Free*, *Mount*, *Unmount*, *Initialize*.

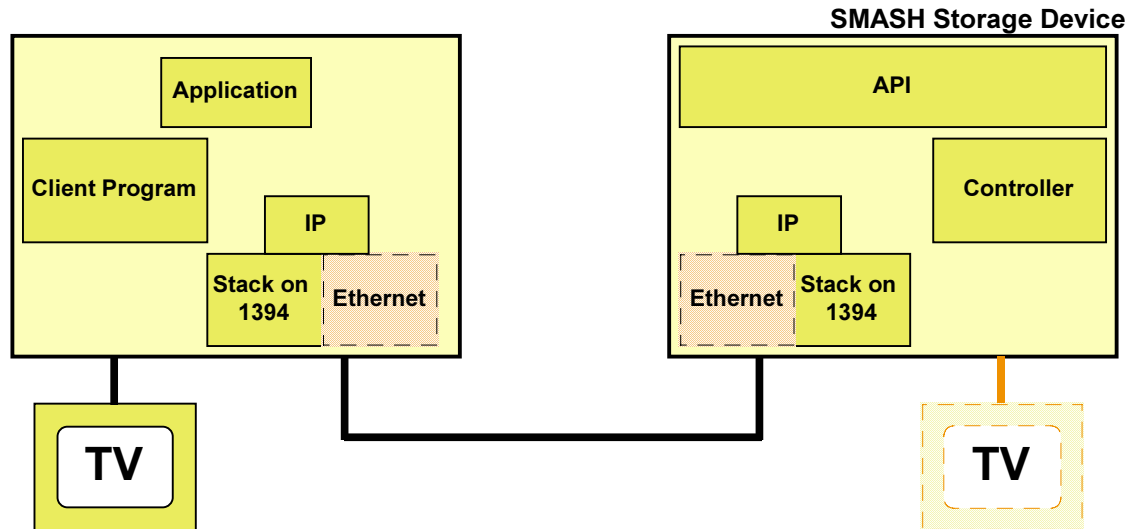


Figure 4: Present (hatched blocks) and proposed interconnect for the final SMASH storage device

4.2.2 Prototype

An important part of the SMASH project has been the realisation of a realistic experimental set-up. The experimental SMASH system serves the DVB-VCR, Web-VCR and Remote Education applications, that are described in section 4.3. The technical concept of this storage server is described below.

In a SMASH application, a multimedia client presents the user with an intuitive interface for high-level control over his data including video, audio, hypertext documents and more. In our current system the SMASH client software runs either on set top boxes or on PC's. This client communicates with the data server, or Combo, which does the actual data handling. A single SMASH Combo can serve several clients. In a SMASH system the tasks of the Combo server include:

- **Handling all storage-related requests from the clients:** e.g. recording a video stream. The Combo is responsible for the distribution of data over the tape and disk, the client only sees one storage system.
- **Maintaining a table of contents:** different (multimedia) databases are used for the different applications
- **Sending data to the clients for use:** e.g. playback of video data, general use of plain files that together constitute a course.

The client's main tasks are

- **Handling all user interactions** through an intuitive graphical user interface (GUI) and input controls (remote control, mouse, keyboard).
- **Ordering required data** and meta data from the Combo and proper handling of this data (e.g. displaying graphics, playing back video).

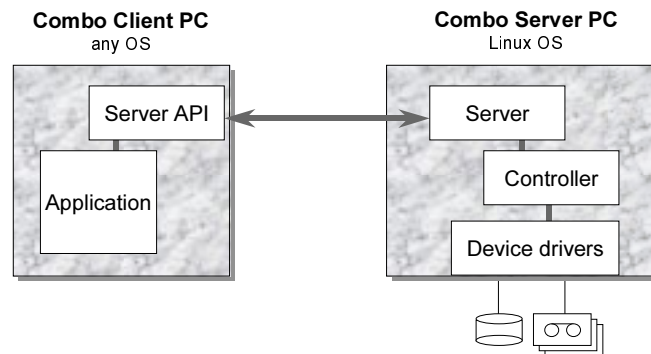


Figure 5: Client – Server approach in general Combo software architecture, used in both DVB-VCR and Remote Education applications .

The basic software architecture of our client / server SMASH applications is graphically presented in figure 5. The client is running an application that uses the Combo remotely through its API. On the Combo, the server software handles the communication with the clients, and passes commands on to a controller, that does the actual work: scheduling data transport, managing device I/O. etc.

In the beginning of the project we have spend sufficient time analysing the requirements and defining the type of experiments we wanted to carry out with the prototype. We opted for a flexible system, which allowed us the following possibilities: easy experimenting with the system, be able to support user trials, to suggest improvements to the concept, easy and flexible hardware interfacing of several special functions and an easy software development environment. Hence a PC platform is the obvious choice for our SMASH prototype.

Figure 6 shows the basic hardware architecture of the system. The server PC is running the Linux operating system, a choice based on its multi-tasking capabilities and its relatively easy hardware control. It has the hard disk and a Tandberg MLR-3 tape drive, as well as set-top boxes and dedicated hardware to deal with DVB video streams coming in and going out. The process of keyframe extractions is handled on a dedicated TriMedia™ board. This board should also be part of the server, but unfortunately Linux support was not available in time, and we decided to connect the board to the client PC instead, as a temporary solution.

The client PC runs Windows 95, because only for this OS a TriMedia™ driver is available. The TriMedia™ board is used for extracting Electronic Program Guide (EPG) information and keyframes from a DVB transport stream in the DVB-VCR application. The client sends this extracted meta data to the MMDB at the server. For communication between the two PC's we use an ethernet link, which will be replaced by IEEE 1394 when boards and drivers become available.

The requirements for the Combo server differ in the DVB-VCR, Web-VCR and RE applications. Both the Web-VCR and RE applications require just a hard disk and tape drive, but no DVB video streams or keyframe extraction are required. The hard disk file system is exported to a client using Samba or NFS.

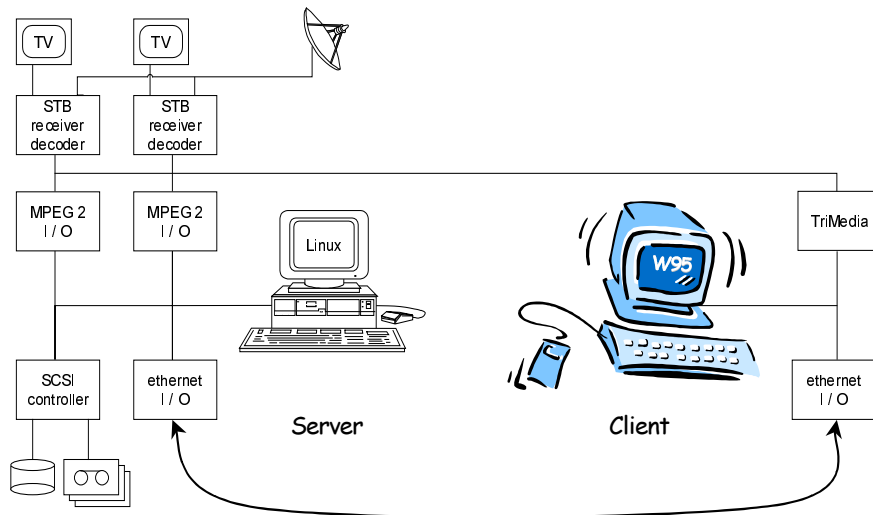


Figure 6: Hardware architecture of the Combo system; the TriMedia™ will be moved from the client PC to the server PC in the near future. TriMedia™, MPEG-2 I/O and STB's are not required for Remote Education.



Figure 7: SMASH Combo server with settop boxes, tape and disk drives and a simple graphical user interface of the DVB-VCR demonstrator: The key-frames represent the contents of the tape.

In the DVB-VCR application, DVB streams are received from satellite by a dish antenna connected to a set top box (STB) from which the MPEG 2 data is collected by a custom-made PCI board for recording and playback. During playback, the stored MPEG 2 data is passed back to a STB for decoding and displaying on a conventional TV. For processing multiple streams (such as simultaneous recording and playback), a second TV/STB/-MPEG I/O chain is present. In figure 7 a photograph is shown of the DVB-VCR system.

4.2.3 Visual Navigation

The SMASH storage device allows the recording of huge amounts of information. In particular, in the DVB-VCR application, large volumes of MPEG compressed video will be stored. The retrieval of specific pieces of video material or the browsing of the available stored video therefore becomes time consuming, if not inefficient. In the DVB-VCR application enhanced user interfaces give textual and visual cues on the contents and structure of the recorded programs so that browsing and navigation in stored programs becomes more efficient and user friendly [15]. An impression of such a user interface is given in Figure 8.



Figure 8: Impression of User Interface for the Video Browsing and Navigation.

Since the *large amounts* of stored *MPEG compressed* video programs are not easily accessible for browsing and navigation, the user interfaces should rely not on the actually recorded video streams, but on an abstracted version thereof [2, 7, 8, 12]. The solution chosen was to extract upon recording time already relevant meta-information and store this information separately in a multimedia data base for later usage. This multimedia data base itself is stored on the hard disk of the Combo system so that random and quick access to the abstracted information is possible [11, 26].

The meta-information that has been studied in most detail are *key frames*. Other meta-information currently being retrieved and stored on-line are DVB-SI and subtitles. Key frames are those frames in a television program that represent certain relevant actions. The steps that are taken to obtain the key frames on-line are (see Figure 9): MPEG-TS demultiplexing, partial decoding of I-frames, shot change detection using these partially decoded I-frames, and finally selection of key-frame(s) from a shot [4, 6, 17]. The selected frames are stored in a multimedia database, together with proper references to the stored MPEG streams and any additional meta-information. Though the detection and extraction of key frames is a process not as computationally intensive as full decoding of MPEG video, the initially developed (mainly for design and testing purposes) software-only implementation ran in significantly less than real-time. Real-time key frame detection and extraction on live DVB broadcasts has been realized in the project by using the Philips' video signal processor TriMedia. This hardware implementation also allowed for large scale performance evaluation of the selected detection and extraction algorithms. In Table 1 a summary is given of one of the crucial steps, namely the real-time shot change detector, on various types of programs.

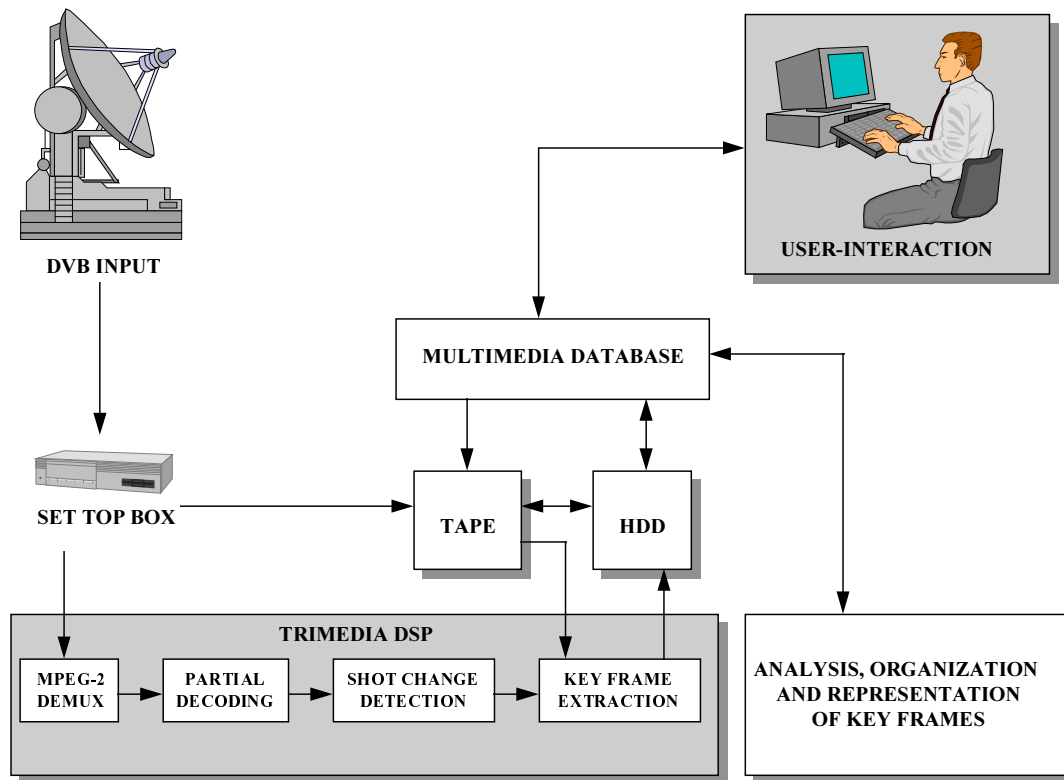


Figure 9: System view on key information (key frames) extraction and organization

Table 1: Evaluation results of real-time shot change detection.

Sequence name	Jurassic Park	Monty Python	Dutch News	Commercials	Football
Genre	Movie	Comedy series	News	Commercials	Sport
Duration (minutes)	116	23	16	2	5
KF dimensions	90x72	66x72	66x72	66x72	66x72
GOP	12	12	12	12	12
I-frames	14503	2891	1990	247	631
Key Frames	1084	179	181	43	39
% of KF	7.47	6.19	9.1	17.42	6.18
Average, KF every	6.42 s	7.75 s	5.27 s	2.75 s	7.76 s
Missed KF	57	8	1	-	0
False alarms	24	12	12	-	3
% of missed KF	5.26	4.47	0.55	-	0.00
% of false alarms	2.21	6.70	6.63	-	7.69

After abstracting the recorded program, postprocessing steps can be carried out on the key frames in order to organize them logically. It is necessary to impose such a meta-structure on the key-frames in order to reduce the number of key frames to be used in the user interface (see entry "Key Frames" in Table 1), and in order to break container-like programs (broadcast news, sports programs, etc.) into self-contained items. Two types of programs have been considered in this respects, namely movies – in which case the key frames are hierarchically organized to obtain an episode-like structure – and broadcast news – in which case the key frames are used to delineate the news items.

The method for organizing key frames in episodes (or logical story units – LSU's) works as follows [18, 33]. Within a single movie episode there is a high temporal consistency of the visual content of key frames. It can therefore be expected that within an episode every now and then similar *visual content elements* (scenery, background, people, faces, dresses, specific patterns, etc.) appear and some of them most likely repeat. Clearly the matching of the content may not happen immediately in successive video shots, but most likely there will be a match within a certain time interval. Based on this observation, an LSU can be defined as a series of temporally contiguous video shots, characterized by overlapping links that connect shots with similar visual content elements. Figure 10 illustrates the application of this definition in a detection algorithm. Figure 11 shows a hierarchical structure in which the key frames are organized under the LSU structure.

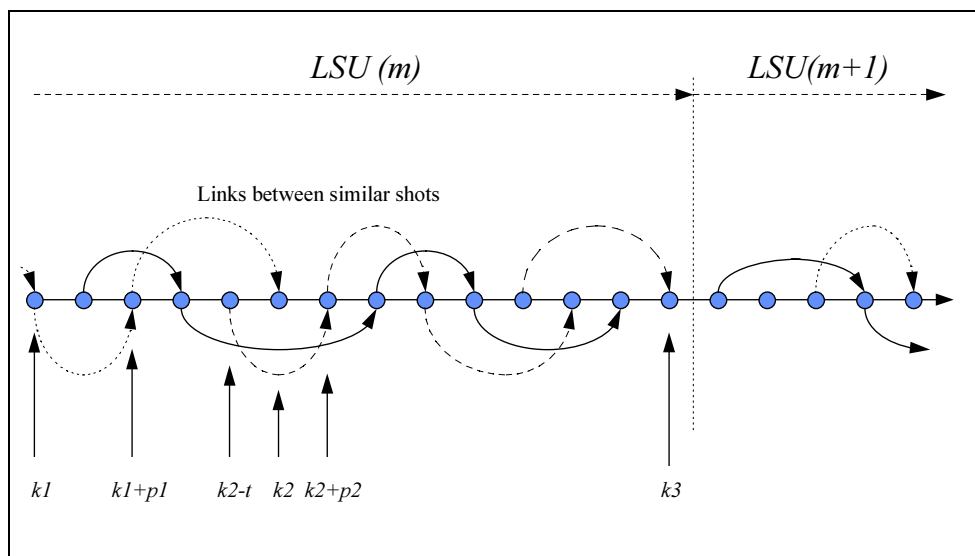


Figure 10: LSU characterized by overlapping links connecting similar video shots.

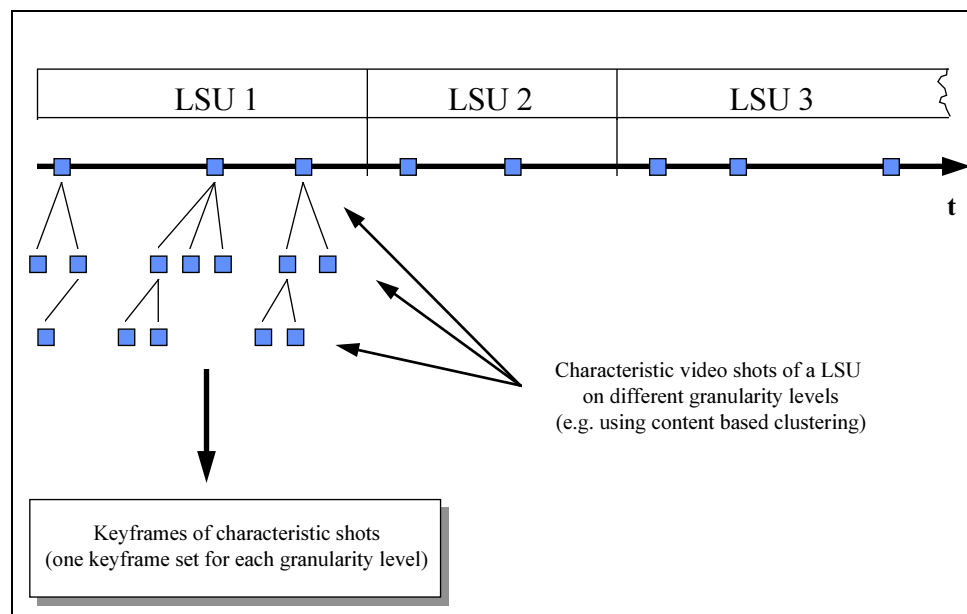


Figure 11: Key frames from a movie represented using LSUs.

For broadcast news we have used the following approach [36, 37]. News items are often encapsulated between (and sometimes mixed with) shots of the news reader or anchor person. The anchor person shots are visually characterized by studio background and by one or two news readers appearing separately or together, also with some possible variations of

a camera angle and changes in news icons appearing in a screen corner (see figure 12). These shots can be static or dynamic (containing some camera operations like zooming or panning) and contain certain percentage of same or similar visual features. After detecting shot boundaries the presence of a news reader can be detected in the key frames, from which the structure of the news program –including the news topic boundaries– can be detected.

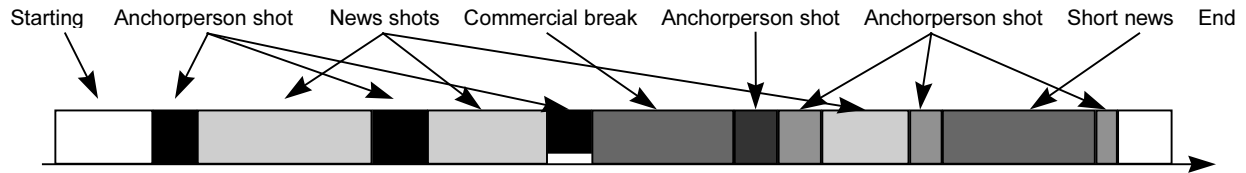


Figure 12: Structure of a news program. Different colors of blocks belonging to anchorperson shots indicate their different types

4.2.4 Copy Protection

Though there are many advantages to the domestic availability of large capacity storage devices such as the SMASH Combo server, one major disadvantage is that illegal copying of high-quality broadcasted materials becomes very easy. It is therefore necessary to not only develop technical solutions to the storage problems, but at the same time to investigate and develop ways of avoiding illegal copying, i.e., copy protection methods [3, 13, 24]. The importance of copy protection systems is stressed by representatives of the consumer electronics and motion picture industries who have agreed to seek legislation concerning digital video recorders that would protect both intellectual property and consumers' rights. A recommendation is submitted to the US Congress, which allows copyright proprietors to prohibit copying from pay-per-view, video-on-demand programming and pre-recorded media. In European context, DAVIC is looking for standardization of copy protection mechanisms.

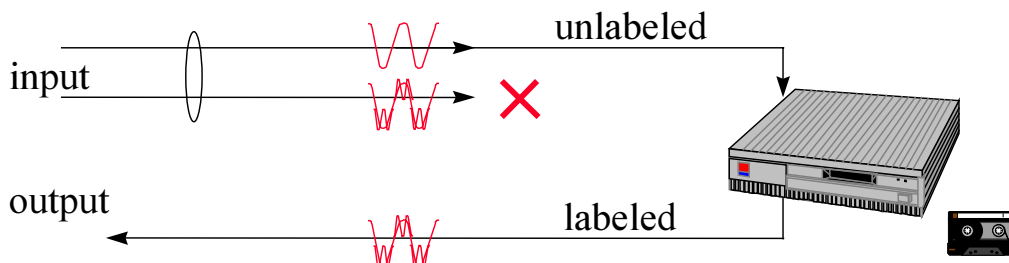


Figure 13: Concept for copy protection in a SMASH.

For the SMASH Combo server a copy protection system for MPEG compressed video has been developed [16, 29]. The copy protection method is based on labeling techniques and allows only one copy of digital multimedia (video) data (Figure 13). Labeling or watermarking of visual information is based on embedding hidden signals (labels) in the pictorial information, such that it cannot easily be removed without seriously affecting the quality of the labeled information. Upon recording time, the MPEG streams to be recorded are checked for the presence of a watermark. If the watermark is present, the Combo device refuses to record that particular MPEG stream. If the watermark is not present, the Combo device will record the MPEG stream, but only after embedding the watermark. This prevents further copying of that information by other Combo systems.

There are several requirements which the labeling technique should satisfy. The labeling technique should not be too complex and operate in real-time on compressed data. Its presence should not affect the size and the quality of the multimedia data. The strength of the copy protection scheme relies on the robustness of the labeling technique. In other words: it

should be impossible to remove the label without affecting the quality of the multimedia data significantly.

Two new watermarking algorithms have been developed, specifically intended for MPEG video copy protection, together with a model that allows for the optimal tuning of the method's parameters. At the same time exploratory investigations have been carried out on the likely attacks that "hackers" could carry out on watermarked information as so to remove the watermark and break the copy protection, and of the strength of existing watermarking techniques against these attacks [31, 34].

The most promising watermarking technique that we have developed is based on discarding parts of the (quantized) block-DCT coefficients in the (compressed MPEG I-frames) video stream [32]. Depending on whether a "0" or "1" bit needs to be embedded, the high frequency components of the top-half or bottom-half of an N by N set of (8x8) DCT-blocks are discarded. This difference in "energy" between top and bottom half of the blocks can be detected by the watermark extractor. In order to avoid unnecessary visual artefacts, the DCT blocks in an MPEG I-frame are pseudo-randomly shuffled (Figure 14). The pseudo random generator seed is the "key" to the decoding of the watermark. In case the process is carried out on compressed streams, only partial decoding is needed for the labeling and no re-encoding is required (except for table lookups and re-multiplexing).

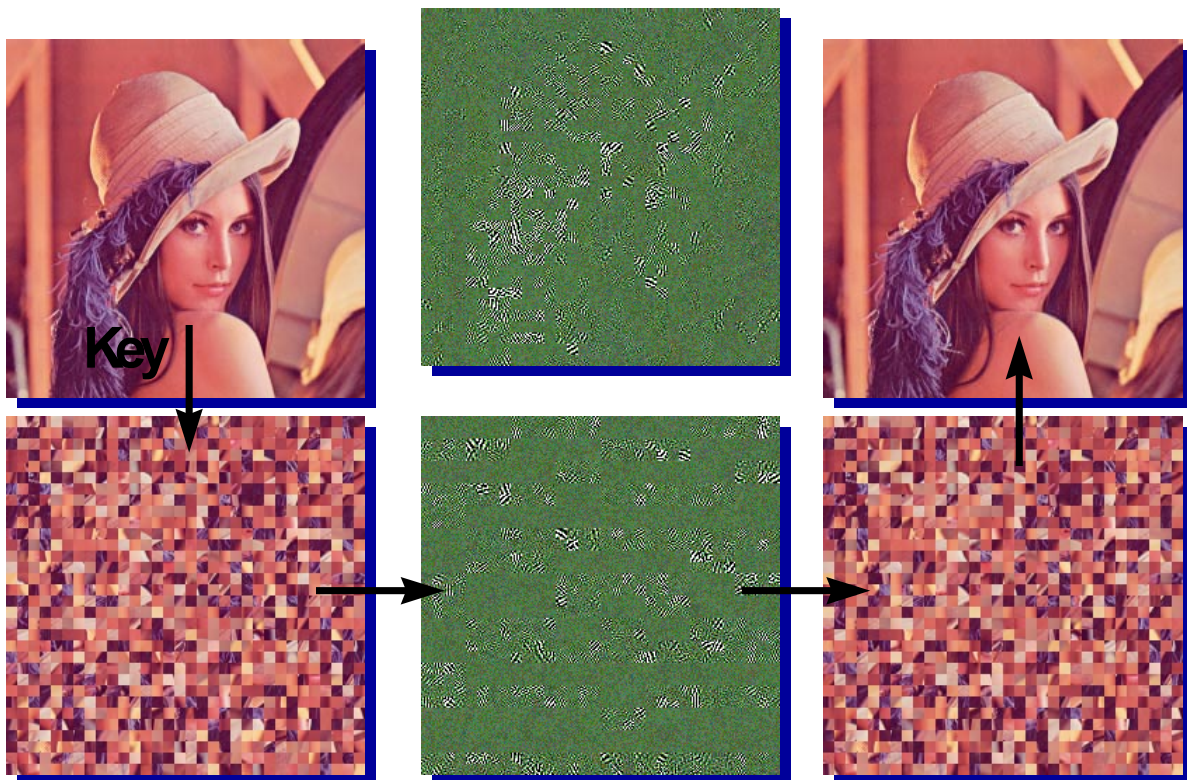


Figure 14: Illustration of the pseudo-random block shuffling and the result of embedding a label string: Left: original images, Right: labeled images, Middle: difference images

4.3 Applications

4.3.1 DVB-VCR

4.3.1.1 Functionality Innovation

The DVB-VCR demonstrator is a prototype digital video recorder for digital video broadcasts. It uses the SMASH Combo as a storage device in a client-server concept. The DVB-VCR differs from existing VCR's in many ways, including:

- New technology: the DVB-VCR stores and reproduces broadcast signals in the digital domain (DVB).
- Mass storage: the storage capacity of the tape used in the demonstrator is 10-14 hours of video. Next generations of the tape unit will increase the capacity to several tens of hours on a single tape volume.
- Fast access storage: the presence of a hard disk gives many possibilities. Not only does it allow fast retrieval of all kinds of data (table of contents, electronic program guide, images), but by smart buffering it allows simultaneous recording and playback on a single tape volume.

The application translates all these technological differences to new functionality, such as:

- The ability to record and play back simultaneously. This can be recording a movie while watching another previous recording, or watching a movie with delay, *while it is still being recorded*.
- Easy programming and retrieval. The user can always get an overview of what is on his tape (TOC: table of contents) and what is on TV (EPG: electronic program guide). Operations like programming for recording and selecting for playback are all done in simple point & click style.
- Content management. The systems keeps track of 'what is where' on the tape, the consumer is not aware of the details. In fact, a program can be scattered over a tape in order to use space efficiently. The user only creates (by recording) and deletes programs, much like in a file system on a PC.
- Graphical navigation. The use of key-frames enables easy navigation through a program. It also gives the consumer a quick visual impression of a recording.

4.3.1.2 User interface

After studies on the possible user interaction with the DVB-VCR application, a interaction design was chosen. All screens are displayed on a TV set, and can be controlled via the buttons of a remote control. Below, the main screens of the application are described.

The combined TOC - EPG screen

The screen in figure 15 gives an overview of programs which are available now or in the near future. Hence, it combines an electronic program guide (EPG) with the table of contents (TOC) of the tape. The blue columns on the right show the TV schedule for today, or several days ahead. Using the cursor, the consumer can easily navigate through the channels and programs. Once the user selected a program, he can mark it for recording, notification, or additional information supplied by web sites and teletext. The green columns on the left contain the recorded programs. A recorded program automatically appears in the column labelled 'Recent', from which the user can decide to drag it to the 'Keep' column, or to delete it. Recording a program for viewing is a simple matter of pointing to it and hitting the button, regardless of the column.



Figure 15: User interface screen displaying a combined table of contents and electronic program guide.

The information and key-frame screen

The information and key-frame screen shows the collected textual information on a particular program, at present limited to title, time and date, and a short description. In addition, a series of key-frames, acquired during recording, are available to the user. The user can choose to animate them, which gives him a quick impression of the program. The user may also browse through them, and choose to start playback from a particular key-frame.



Figure 16: User interface screen displaying information on a selected recorded program, including a textual description from the EPG, and key-frames for quick browsing or navigation.

The pause button function

An interesting feature that is enabled by the ability to record and playback simultaneously, is the pause button function. When watching a live broadcast, the user can 'pause' the program, e.g. to answer the phone. Later he may resume the program, i.e. resume watching it with a time delay with respect to the live transmission. What actually happens is that upon activation the function starts recording. Resuming simply means to start playing back from the beginning of the recording, while the recording still continues. The user may catch up the live broadcast by playing fast forward, or by skipping parts.

If the tape and hard disk are both used for this buffering, the buffer will practically never be full. In case of a hard disk only system, or when the tape is full, the buffer capacity of a 1 GByte disk enables roughly a 30 minute buffer.



Figure 17: User interface screen displaying the pause button function. The video is frozen during a pause, and the buffer state is displayed.

4.3.1.3 User responses

The system described above is fully operational, and works perfectly well with live DVB transmissions. Large-scale user test could not be performed within the framework of this project. However, the system has frequently been demonstrated, in total to several hundreds of people.

The reactions of the people who have seen and tested the demonstration so far are almost unanimously positive. The main conclusions are:

- Everyone recognises the need for content management on a VCR. The what-is-where problem is universally acknowledged, and our approach is welcomed as the long-sought solution.
- The point & click operation is seen a major step forward with respect to the customary showview functionality in programming for recording.
- The key-frames are generally seen as a big advantage, both for getting a quick impression and for selective viewing.
- Simultaneous recording and playback is not generally seen as a great feature, until we explain that it enables you to come home half an hour late for a movie, and watch it anyway (instead of waiting for the recording to finish and watch it the next day).
- The pause button function is very attractive, but some people find the link with a VCR illogical, the function would be more at home in a TV.
- Quite some people wonder why a tape is still used when optical discs (DVD) is available. (the answer being that it is a matter of storage capacity, tape is a factor of 10 ahead and much cheaper).

In summary, the reactions are very positive and encourage us to continue this work.

4.3.2 WEB-VCR

4.3.2.1 Features and functionality innovation

The WEB-VCR demonstrator is an application prototype for remote accessing and locally storing video streams from the Internet. It exploits the SMASH Combo System as a storage device in a client server architecture. The application presents the following features and functionality:

- an integrated and easy to use environment for accessing WEB pages with related video streams from the Internet and for storing and thereafter accessing them from the local Combo System
- a familiar VCR like Interface during the interaction of the user both with the Internet and the Combo System
- a dynamically downloadable application into an appropriate WEB Browser such as the Netscape one, enhancing the Browser with VCR-like capabilities
- to play MPEG-1 video streams coming from either the network or the Combo System
- to record them and to record full WEB pages along with their user selected first level video links in the Combo System
- to play and record video streams in parallel
- the capability to deal equally well with a large number of small pieces of information such as the Internet pages and the huge sized MPEG-1 video streams

The system architecture:

The application runs in a Windows PC with an MPEG-1 decoder board allowing to decompress MPEG-1 files and play them in video overlay on the PC screen. The "Real Magic" MPEG-1 decoder from SIGMA Design has been chosen as it matches more strictly the application requirements such as the possibility to handle a buffered flow of data from the digital video file to the decoder board and the availability of a low-level API to interface the playback functionality of the board from a Windows (either 16 or 32 bit) application environment. The application has been designed with a layered architecture using the JAVA paradigm as shown in the following figure:

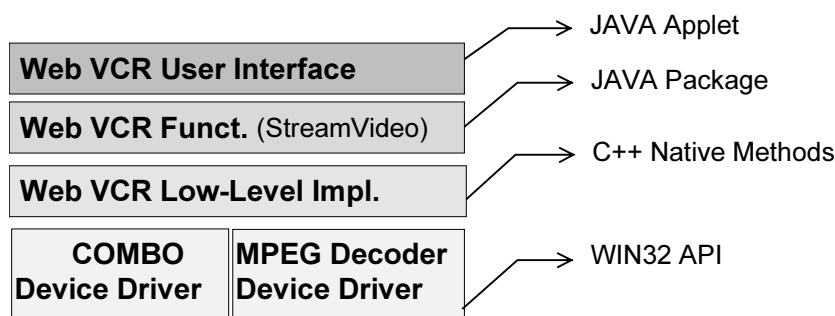


Figure 18: The WEB-VCR software architecture

The graphical User Interface of the application is implemented through a JAVA applet while the software functionality has been implemented in a JAVA "Package" called *StreamVideo*. The Stream Video package holds the class hierarchy of the objects that map the data model of the WEB-VCR application (see Deliverable #9 for Stream Video package description). The interaction of the application with the decoder board has been realized through the methods of the *StreamVideo* package that deal with video files as "JAVA native methods", i.e. as methods whose code is written in a different language from JAVA (such as C or C++). Moreover, in order to improve the performance of the application, the native methods have been implemented as "Netscape Plug-in" using the Netscape *LiveConnect* technology pro-

viding high performance improvement and allowing to interface Java applets with local plug-ins.

The LiveConnect JAVA RunTime extends the standard JAVA RunTime adding a new Package to the JAVA Class hierarchy. This new package contains the "Plugin" class whose methods are implemented as Native Netscape Plugin.

4.3.2.2 User interface

The WEB-VCR application has been designed to allow the following types of interaction with the user:

- *Internet Interaction*: when the user refers a video stream stored on a remote Internet site
- *Combo Interaction*: when the user refers a video stream stored on the Combo System.

Internet Interaction

The user interacts with the application trough a VCR-like interface which provides the following buttons with the following commands:



During the so called '*Internet Interaction*' the user can select a video link thus enabling the activation of the JAVA applet which features a VCR user-interface.

When a video link is selected the command PLAY, RECORD and PAGE RECORD are enabled and the user can push one of them to start the selected functionality.



Figure 19: The User Interface of WEB-VCR 'remote side'

The PLAY functionality starts a connection between the local PC and the remote server where the video stream is stored. The MPEG frames coming from the server are passed to the MPEG decoder board, which decodes them and play them in a video-overlay window on the PC screen.

The RECORD functionality acts in a similar way as the PLAY function except for the buffer data that are played and simultaneously stored in a file in the COMBO System. The user assigns a name to the recording video stream using the text box located near to the buttons of the VCR interface. When the recording phase comes to an end, an HTML page referring to the recorded MPEG-1 video stream and to the VCR applet is automatically generated. Moreover, an index, the local ComboIndex HTML page, is updated with the reference to the new-recorded stream. The ComboIndex HTML page contains the entry points to all the video streams and the Internet HTML pages recorded in the Combo Tape.

The PAGE RECORD functionality allows to store an HTML page and acts like the RECORD functionality for the selected video streams linked by the page.



Figure 20: WEB-VCR demonstrator featuring the VCR like Interface playing a video stream from the Internet while a tape is being inserted in the Combo System for storing

Combo Interaction

The user interacts with the video streams stored in the COMBO system from a WEB browser through a VCR-like Interface providing the following commands:



PLAY PAUSE STOP DELETE

The PLAY functionality, in particular, starts a connection between the local PC and the Combo device to enable the buffered data flow from the Combo towards the MPEG-1 decoder board.



Figure 21: The User Interface of the WEB-VCR side Combo

The DELETE function allows cancelling a video stream from the COMBO together with all the references to it. As regards to the "Internet Interaction", the RECORD function is not available because it is not meaningful in a Combo context.



Figure 22: WEB-VCR demonstrator featuring the VCR like Interface and playing a video stream being retrieved from the Combo System

4.3.3.3 User responses

The WEB-VCR application prototype has been tested internally on an Intranet Subsystem using a 100 Mbit connection which simulates a broadband network of a digital city. The interface has been perceived familiar and easy to use. A critical aspect of the application could be the response time of the network which has to allow a continuous data flow to enable a video stream playing. However the internally performed tests based on the Intranet Subsystem have presented acceptable results.

4.3.3 REA-application: Interactive Remote-Education Demonstration Package

4.3.3.1 Functionality Innovation

The remote-education application (REA) is a multimedia-supported WWW educational tool, which uses the SMASH Combo as a mass storage device. The REA differs from existing educational tools in many ways, including new technology and new functionality:

- Usage of a mass storage device to locally store a large collection of lecturing material (in the form of interactive experiments, high quality pictures, and movies) on the tape. In particular, high quality pictures and movies are stored in large data files which are not suitable for repeated downloads to local personal computers at home.
- Interoperability between the mass storage device and the Internet in an automated way. The user doesn't need to care where the lecturing material is. He / she can study a course from the tape and at the same time browse over the Internet for similar material or send an e-mail to the teacher. He / she can also retrieve homework from the remote computer at the school.
- Elimination of the low-speed-transmission restricting factor for the on-line multimedia-supported remote education. Using the mass storage device, the low speed transmission caused by narrow-bandwidth lines and modems doesn't restrict usage of remote education because only a small amount of data is transferred on-line over the Internet.
- Optimization of the sequence of files in which they are stored on the tape to minimize the average access time for files on the tape. Using the knowledge about the course structure and the size of files, the optimized sequence of files on the tape is established. Additional reduction of access time is obtained by using the hard disk in the mass storage device for caching.
- Graphical navigation based on mind maps. The graphic user interface is built using Java applets and supports browsing of lessons in a graphic way using mind maps as well as browsing through a usual Windows tree structure.

4.3.3.2 Remote-education application

The remote-education application (REA) is based on the WWW and it is implemented in the Java programming language. It consists of different programs (a Web browser, a simple WWW server, and a tape controller) combined together into one program application. A graphic user interface is built under the WWW browser like Netscape or Microsoft Internet Explorer. The idea is to keep the application as general as possible. This means that the same concept of the educational tool can be used with or without a local mass storage device [22]. To achieve such a goal, an interface between the application level and the storage device is used to hide the storage from the application. As the interface is used a simple WWW server. It accepts an HTTP request for a file on the local storage device from the WWW browser and it sends back the required files as an HTTP response. If the required file is not on a hard disk, it sends an API command to the tape-device controller running on the server to copy the file from the tape to the hard disk [19].

The remote-education application is based on the client – server architecture. The client is a PC with Windows 95 or Windows NT operating system, which has installed the WWW browser (Netscape or Microsoft Explorer) with multimedia and Java 1.1 support. A PC with a tape drive for 13 GB linear tapes under the Linux operating system is used as a server called Combo. The Combo and the client PC are connected with the Ethernet. Usage of the REA in a computer classroom is shown in Figure 23.

In general, the teacher's system is the same as the student's system but this is really a minimum requirement. Usually, the teacher should have a more powerful computer with addi-

tional software for editing different types of multimedia files. An additional program is required for copying the prepared courses on the tape.



Figure 23: The Remote-Education Application (REA) used by students in a computer classroom.

The REA uses a large number of mostly small files, while other SMASH applications deal with only a few very large files (movies). The problem is how to write all these small files on the tape to avoid long delays when the selected file should be copied from the tape to the disk. Because the structure of the course is known in advance, an optimization of the sequence of files on the tape is performed using a genetic algorithm.

4.3.3.3 User interface

The remote-education application itself is written in Java and JavaScript programming languages and runs in both popular WWW browsers (Netscape and Microsoft Internet Explorer). The user interface is developed on the idea of mind maps to give a better insight into the course materials and the relations between the topics [25]. A view of the user interface can be seen in Figure 24. The interface is divided into three sections:

1. The upper smaller part of the window contains the toolbar with various buttons for additional interaction with the application. Besides navigation buttons (arrows), the toolbar also contains three network-related buttons ("*new browser window*", "*send e-mail*", and "*get homework*"), an option button (to mark chapters as learned / not learned, or to close all of the expanded chapters in the course) and a help button for online help.
2. The main part of the window (*main view*) contains a mind map of the selected chapter or the courseware document describing the chapter. A mind map is a visual representation of a concept and its related sub-concepts. The presented concept is displayed as the central item of the mind map, with its related sub-concepts arranged around it.



Figure 24: Application's user interface.

3. On the left side of the window the students see the chapter-based linear structure of the course they are studying (*course view*). A structure similar to the well-known Windows 95 tree structure (representing files and directories) is used for this purpose.

Students have several possibilities for navigation within REA:

- Display the contents of individual chapters by clicking on the chapter titles in the course view,
- Browse the courseware materials by clicking on the three arrow buttons on the toolbar,
- Move through the courseware by clicking on mind maps in the main view, and
- Navigate by clicking on hypertext links within the materials (As when exploring non-required topics through mind maps, a new window opens up with the contents of hyper-link. When students finish with browsing, they close the window and return to the topic, they last studied.)

The first two possibilities were designed to follow the lecture material defined by the lecturer. The third one was added to browse the material in an arbitrary way and to explore the material which is not included in the lecture. The results of the questionnaire show that despite the different purposes of the ways the material can be reached, usually, a particular user prefers only one way, but different users have chosen different possibilities as preferable.

4.3.3.4 Evaluation of the system

The remote education application has been tested on demo lessons of computer graphics, virtual reality and digital signal processing. User trials have been performed to evaluate the concept of the application. The system was tested by 15 users who were mainly researchers and students that are involved in various aspects of the SMASH project in Ljubljana. The results of the evaluation of the user trials are summarized in the following table:

User satisfaction	☺	☹	☹
Design of GU interface	80%	20%	0%
Concept of mind patterns	80%	13%	7%
Lecture flow & material exploration	80%	20%	0%
Interactivity	87%	13%	0%
System capabilities (e.g., response time)	7%	80%	13%

Users' impressions about using this learning system were positive. The users like the design of graphical interface, the concept of the mind patterns and the possible interactions. The only concern goes to system response time in the cases when the system has to reach the material stored on the tape. For this purpose it should be added special warnings to inform the user about the expected time in which the required services can be completed and allow the user to cancel the required service.

5. MAIN CONCLUSIONS REACHED

In this chapter we will not repeat the many technical results we have obtained in this project. Rather we will present our main conclusions on how all the partners have gained knowledge through this project, on the total system knowledge we have reached and how we should continue in the future.

At the start of the project, we realized that the hard disk had to play an important role. Since the HDD's should be used in a Consumer Electronics (CE) environment rather than in a PC environment and also because the HDD in the SMASH project should perform other tasks than in a PC application, we had a major issue here to solve. Moreover we had very little knowledge on IDE/SCSI like interfacing. Through a lot of work and experimentation we could build an experimental system which, to our opinion, is the first system where CE and PC technologies have been merged into one system.

From the PC area we used the HDD and also a Tandberg SCSI tape drive. We used the SCSI interface as the basic interface to realize the system.

From the CE area we used digital set top boxes for the reception of digital satellite MPEG-2 programs as well as for the display of the MPEG streams when they are retrieved from the SMASH system.

As a result of this experimental work, we have merged not only CE and PC technologies but we also solved some new problems such as the real time processing and communication of several simultaneous MPEG-2 streams.

This has resulted not only in a storage system with very new features but also in a good insight in a total storage system chain in the home environment where we start from digital satellite reception up to the display of MPEG streams on consumer displays.

Besides the MPEG storage at home we worked also on a totally separate application. This was mainly done by our University partner in Ljubljana and it focussed on the need to have course information on line available based on local storage. This opened up the possibility of new ways to structure and use course material. The prototype we developed in the project is demonstrated at many places and we expect that this way of working will be used in the future by other institutes. Also this proved to be a successful cooperation between a university and an industry partner where both profited from the cooperation.

The prototypes we have developed have user interfaces which are suitable for usage by non experts. We have used this to show and experiment with the different possibilities the system offers such as fast search using visual abstracts on the HDD, instant replay of tape programs using buffers on the HDD and many more. The user tests have learned us what are the most important aspects and also the shortcomings the system still has.

So an important conclusion is that, although the current SMASH system already provides many new features, some important aspects are still missing and need further work. We will finish this chapter by explaining what are those areas for future work.

There is still work to be done on several aspects of the system but we will focus in this chapter on only the two main areas.

The first area is the lack of performance from the existing key components which are needed in the system. One example are the rather long access times of the used tape drive in our system. The tape drive we used is however designed as a back up streamer for file servers or high end works stations. So additional work is needed to develop this technology more for consumer SMASH applications.

Another very different area is the lack of information for automatic programming of the system. It would be desirable that in the future, the consumer at home can program his recorder in a very different way from the methods used now such as Showview. Preferably he can see on his TV screen an overview of the programs which are going to be broadcast and select a program on his remote control and give a command to record it. After that the recorder can take care when exactly the program should be recorded and from which channel. However at this moment such information is not available from the broadcasters and moreover there is no agreed standard on this in Europe. Work has to be done to improve this situation.

6. INPUT TO STANDARDS AND ACTS GUIDELINES

It is the aim to transfer important results from the SMASH project into Standardisation Committees. Since the start of the project some contributions based on obtained results have been prepared for standardisation committees. The partners of the SMASH project are involved in ongoing standardisation efforts and are discussing issues which are relevant for the SMASH project.

The first group to mention is the SMI group inside the DVB organisation. The SMI group stands for Storage Media Interoperability and addresses many issues related to the interface between the DVB set top box and the storage modules.

The second group is the IHDN group inside the DVB organisation. The IHDN group stands for In Home Digital Network and addresses the issues of connecting set-top boxes and storage devices via a home network.

The third group to mention is the QIC standardisation committee in which standards for tape storage are discussed. We have submitted proposals to define standards for tape storage products with a capacity of up to 25 Gbytes per tape.

The fourth group is the DAVIC group in which the SMASH partners are also active. Issues which are relevant for local storage are being discussed.

The last group is the MPEG-7 standardization effort. From early on, the SMASH project has been given presentations [15, 26] on the relation between MPEG-7 and local storage at home.

7. OVERALL IMPACT, EXPLOITATION AND DISSEMINATION

Introduction

In this report you find contributions of several partners from the SMASH project. The impact, exploitation and dissemination is very specific for each partner and depends also on the kind of partners. Much effort has been spent to disseminate the results of the project via papers which have been presented at important conferences or have been submitted to journals. A list of all publications can be found in section 9. The separate contributions of the partners explain in sufficient detail their view on the SMASH project and its exploitation possibilities.

Philips

The impact of the project has been on several aspects. The most important one has been achieved with the final demonstrator of an integrated system which is controllable with a conventional remote control, using an advanced user interface which brings all the SMASH features to life. This demonstration to several people has resulted in the belief that a SMASH system is both very interesting for the consumer but also that it is realizable with current day technology.

The exploitation of the project will be along different ways. SMASH has developed many new technologies and aspects of a storage system and it will be possible to take some of the developed ideas and try to realize them in a product. In some cases the tape drive will not be necessary and a product may be developed with a hard disk only. On the other end, when developing new tape products, not always a hard disk is needed to implement some SMASH ideas. Several exploitation possibilities exist and will be pursued.

The dissemination of information has been achieved internally in the company by organizing special workshops and many demonstrations. We have realized also a mobile version of SMASH with a mobile satellite dish and we are able to now give demonstrations everywhere. The only infrastructure we need is a power supply plug of 220 volts. With this demonstrator we plan to give some demonstrations at conferences.

TU-Delft

The results that have been achieved with the detection, extraction and organization of key frames, especially for movies and broadcast news, have been widely disseminated through contributions to and (invited) presentations at technical conferences in the field of image/video processing and multimedia, and have led to submitted journal papers (see "List of Published Papers"). These results will be exploited by the University partners in the following ways:

- implementation and usage of the developed technology in future projects with broadcasters, multimedia companies and consumer electronics R&D laboratories,
- inclusion in university education programs in the field of Information and Communication Technology.

The overall impact of the results in detection, extraction and organization of key frames is twofold. Internally they have led to a much better understanding of the possibilities and limitations of using key frames, and have initiated a wealth of new research questions, both technically (e.g., "how to go from key frames to key objects") and cognitively (e.g., "what are

representative key frames from a user point of view"). Externally, the concepts of logical story units in movies and topic delineation in container-like programs are novel results that could influence the standardization of "content descriptors" (MPEG-7, DAVIC) in the near future.

The results that have been achieved with watermarking of MPEG compressed video have been widely disseminated through contributions to and (invited) presentations at technical conferences in the field of signal/image/video processing and cryptography, and have led to submitted journal papers (see "List of Published Papers"). These results will be exploited by the University partners in the following ways:

- implementation and usage of the developed technology in future projects with broadcasters, multimedia companies and consumer electronics R&D laboratories,
- inclusion in university education programs in the field of Information and Communication Technology.

The impact of this work is twofold. In the first place, as a University a better understanding has been obtained of the possibilities and limitations of securing digital video information in general. It has become clear that among the spectrum of potential applications for watermarking, really only copy protection and finger printing of digital video information will have a future. Secondly, we have contributed an entirely new and very efficient watermarking technique for MPEG compressed video streams. The approach set forth in this technique will have an impact on further work in this field by third parties.

Deutsche Thomson-Brandt

Impact:

The structure of the Digital Interface IEEE1394 is constructed within several layers: The specification of the Physical Layer and the specifications and protocols of the Link-, Transaction- and the Bus Management Layer has successfully been verified. It has been shown, that the protocols for the real time transmission of MPEG2 Transport Stream in accordance to the rules described in the international standard IEC61883 are suitable to connect DVB Set Top Boxes with Storage Devices. An Application Programming Interface and the mapping of the commands on the structures of the interface has been specified.

Exploitation & Dissemination:

The knowledge achieved on the digital interface in the course of the project is the basis for future interconnects between different CE instruments as well as PC products. The reference implementation of the interconnect also enabled the company to demonstrate the functional blocks of a full chain for the some key applications

The verification and testing of the Digital Interface will be continued in co-operation with Philips within the Eureka Commend project

It is intended to integrate a Digital Interface in accordance to IEEE1394 into future CE products. The expected time frame for ramp up in the market is in the magnitude of 2 to 3 years.

Olivetti

The project has offered through the WEB-VCR prototyping activity the opportunity to the Olivetti team the opportunity to acquire/deepen the knowledge and master a set of innovative tools dealing with Java, Netscape environment and development tools, MPEG and storing COMBO subsystems integrated in the application prototype. This experience has set up the base for the information gathering in Internet for collecting Internet pages with all its first level links and it has been a first step in the direction of internal development of information gathering agents in an important information domain such as "the news domain". This experience has been exploited internally and will be exploited further in the continuation phase of

SMASH project, i.e. STORit project where a service (based on AMICO: <http://amico.arianna.it/>) will be set up for providing to the students and professors an information environment focused on a specific educational domain offering in particular information gathering, filtering and profiling capabilities. In the information gathering and in particular in the preprocessing phase a number of agents, running in background, visit a list of sites selected from an educational domain collecting Internet pages and storing them together with all their first level links in the COMBO subsystems. Later on in the post-processing phase the gathered information are retrieved from the COMBO subsystems for elaboration, indexing and categorization and made available to the user for retrieving according to his own profile.

Tandberg Data

Tape Storage in Multimedia Applications

Tandberg Data (TD) is traditionally focused on Tape BackUp and Tape archive applications. In SMASH Tandberg has worked together with companies with an entirely different focus and this has been very educating.

The SMASH project has shown that in Multimedia applications the focus is shifted away from the traditional requirements as capacity and transfer rate towards another set of important requirements.

It seems that the most important requirement is reduced Data Access Time. A tape drive can never compete with a hard disk, but it is still necessary to minimise the access time. To reduce the access time one has to work with several functionalities of the tape drive:

- Random Access: The tape drive is in nature a sequential access device, but by using intelligent partitioning of data and smart intercommunication between the drive and system the typical access time may be significantly reduced. This topic has been thoroughly discussed in SMASH and TD will most likely implement new functionality to address this in future tape drives.
- How to find data : By keeping track of where the different data is located data the drive will be able to shorten the time used for searching back and forth.

Host Interface

Most of today's tape drives supports the SCSI interface. In future Multimedia applications an IEEE1394 interface would be more suitable.

Standardisation

During the SMASH project Tandberg Data has been an active member of the QIC committee, focusing on the MLR standards. As the QIC committee now is less active we still have the MLR standards and the Travan standards that succeeds QIC.

Particularly important for Tandberg Data are the MLR standards (MLR1 and MLR3) since they have formed a base for future MLR standards such as MLR5 and MLR7.

University of Ljubljana

The results that have been achieved with the remote-education application (REA) have been disseminated through contributions at the technical conferences in the field of multimedia and education, and through local presentations at the University as well as at the Infos '98 exhibition in Slovenia. These results will be exploited by the University and its partners in the following ways:

- Implementation and usage of the developed technology in future multimedia-based distance learning projects.

- Usage of the developed remote-education application and courses in the educational process at the University of Ljubljana, first at the Faculty of Electrical Engineering and at the Faculty of Computer and Information Science.
- Probably usage of the further enhanced REA with additional tools like the whiteboard and videoconference for educational and self-educational purposes at some companies and / or schools.

The impact of the work is manifold. In the first place, we have participated in a large European R&D project with partners from the industry and from universities. The results of such co-operation are new contacts with European partners and important experiences about the work in such projects. Secondly, we have had possibilities to use the latest technology as well as technology which is developing and will be available in the near future. And finally, the remote-education application, which has been developed as a demo application, combines a mass storage device and Internet in an efficient way and enables the usage of multimedia-enhanced remote education at home regardless of low speed transmission caused by narrow-bandwidth lines and modems. Possibilities to study at home, use multimedia courses without any limitations and have on-line connection to the teacher and colleagues open new directions in the educational process and will influence on improved and better education in the future.

8. LIST OF DELIVERABLES

ID	Title	year/ month	nature*	type*
1	Analysis of interrelations to other projects	y1/m07 Sep95	R	Public
2	Report on first analysis of important applications	y1/m12 Feb96	R	Restricted
3	Report on the future needs for and the technical possibilities of a SMASH	y2/m06 Aug96	R	Internal
4	Specification of an integrated linear/HDD storage unit	y2/m06 Aug96	S	Internal
5	Report on technical possibilities and methods for security of SMASH and for fast visual search on compressed/encrypted data	y2/m09 Nov96	R	Public
6	Report of the interconnect system architecture	y2/m12 Feb97	R	Restricted
7	Report on the system specification of an advanced linear system	y3/m03 May97	R	Public
8	First system concept	y3/m06 Aug97	R	Internal
9	Application prototype	y3/m06 Aug97	P	Restricted
10	Submission of a multimedia file format for linear recording	y3/m06 Aug97	S	Internal
11	Functional prototype of the linear/HDD storage unit	y3/m09 Nov97	P	Internal
12	Specification of the interconnect system	y3/m12 Feb98	S	Public
13	Specification of hardware and software architecture for security and intelligent search facilities	y3/m12 Feb98	S	Internal
14	Final report of the system architecture	y4/m06 Aug98	R	Restricted
15	Report on ongoing standardisation efforts	y4/m06 Aug98	R	Public
16	Demonstrator concept of a Multimedia Recording system	y4/m06 Aug98	O	Restricted
17	Remote education application	y4/m06 Aug98	P	Restricted

*Legend: **Nature** R= Report, S= Specification, P= Prototype, O= Other

All public Deliverables can be retrieved via the SMASH Homepage:
<http://www.extra.research.philips.com/euprojects/smash>

9. LIST OF PUBLISHED PAPERS

ref	Date	Author	Title	Journal/conference
1	May '96	E. Persoon et al	The future needs for digital storage at home: how the SMASH-project will solve them	ECMAST 96, Louvain (submitted)
2	May '96	A. Hanjalic et al	Achievements and Challenges in Visual Search of Video	17th Symposium on Information Theory in the Benelux, Enschede, May '96
3	May '96	G. Langelaar et al	Copy Protection for Multimedia Data based on Labelling Technique	17th Symposium on Information Theory in the Benelux, Enschede, May '96
4	Aug '96	A. Hanjalic et al	A New Key-Frame Allocation Method for Representing Stored Video Streams	First International Workshop on Image Databases and Multimedia Search, Aug 96, Amsterdam
5	Aug '96	V. Braun	Impulse Response Measurement of a Magnetic Recording Channel Using Golay Sequences	6th Benelux-Japan Workshop on Coding and Information Theory, Essen
6	Sep '96	R. Lagendijk et al	Visual Search in a SMASH system	ICIP'96, International Conference on Image Processing, Lausanne (CH), September 1996
7	Sep '96	M. Ceccarelli et al	A Sequence Analysis System for Video Databases	5th Workshop on Time-Varying Image Processing and Moving Object Recognition, Florence (IT), Sep '96
8	Oct '96	R. Lagendijk et al	Methods for Browsing and Copy Protection in Multimedia Storage Systems	ICOMT'96: International Conference On Multimedia Technology and Digital Telecommunication Services, Budapest (H), 28-30 Oct. 1996
9	Nov '96	V. Braun	On Impulse Response Measurement Techniques for Linear Tape Recording Channels	1996 IEEE Global Communications Conference (Globecom'96), 18-22 November 1996, London
10	Dec '96	E. Persoon	Set Top Unit with (SMASH) Storage	invited presentation on UNITEL meeting, 4 December 1996
11	97	Ceccarelli et al	A Sequence Analysis System for Video Databases	Contribution to Book: Time-Varying Image Processing and Moving Object Recognition 4
12	Feb '97	A. Hanjalic et al	Automation of Systems Enabling Search on Stored Video Data	SPIE/IS&T ELECTRONIC IMAGING '97, Storage and Retrieval for Image and Video Databases V, San Jose, February 1997
13	Feb '97	G. Langelaar et al	Robust Labeling Methods for Copy Protection of Images	SPIE/IS&T ELECTRONIC IMAGING '97, Multimedia Data Security, San Jose, February 1997
14	Feb '97	V. Braun	On Modulation, Coding and Signal Processing for Optical and Magnetic Recording Systems	Thesis, Essen, Fortschritt Berichte VDI Reihe 10, Informatik Kommunikationstechnik, nr. 504 (VDI Verlag GmbH, Düsseldorf)
15	Apr '97	R. Lagendijk et al	(The SMASH project's) Perspective on Browsing of Consumer Video Archives	MPEG-7 Bristol Seminar Presentation
16	May '97	G. Langelaar et al	Real-time Labelling Methods for Compressed Video	18th Symposium on Information Theory in the Benelux, Veldhoven, 15-16 May 97
17	Jun '97	A. Hanjalic et al	A Novel Video Parsing Method with Improved Thresholding	3rd Annual Conference of the Advanced School for Computing & Imaging, Heijen (NL), 1997
18	Jun '97	A. Hanjalic et al	Detection of Global Story Units in Full-length Movies	IEEE Workshop on Content-based Access of Image and Video Libraries, Puerto Rico, June 1997

ref	Date	Author	Title	Journal/conference
19	Sep '97	M. Leban et al	Structure of a remote education application using a local mass storage device	ERK'97, Sep 97, Portoroz, Slovenia
20	Sep '97	E. Persoon	Information Delivery to the Home	ERK'97, 26 Sept 97, Portoroz, Slovenia
21	Oct '97	M. Leban et al	Multimedia distance education using a local mass storage device	ICOMT'97, Budapest, Hungary
22	Oct '97	J. Tasic et al	The multimedia supported remote education application	Workshop on IDL Systems, Split, Croatia
23	Oct '97	V. Braun	Golay Complementary Sequences for Identification of Linear Systems with Weak Nonlinear Distorsion	IEE Proc. Science, Measurement and Technology
24	Oct '97	G. Langelaar	Overview of Protection Methods in Existing TV and Storage Devices	submitted for: Journal Publication: Wireless Communication, The Interactive Multimedia CD-ROM
25	Nov '97	M. Marolt et al	A distance learning application based on a digital library of courseware	IFIP 97, The virtual Campus, 27-29 Nov 97, Madrid
26	Feb '98	M. Ceccarelli	Meta-data for Broadcasting	MPEG7 Workshop, 16 February 1998, Brussels
27	Mar '98	E. Persoon	SMASH: a concept for advanced use of storage in the home	IMAGINA'98, March 4-6, 1998, Monaco
28	Mar '98	A. Kosir et al	Software Architecture of Mass Local Storage Supported Remote Education Application	submitted for: ECMAST'98, May 98, Berlin
29	Mar '98	R. Lagendijk et al	Watermark signal processing techniques for video copy protection	IEEE signal processing symposium in the Benelux (SPS98), March 98, Leuven, Belgium
30	May '98	M. Marolt et al	Distance education using a local mass storage device	Melecon '98, May '98, Tel Aviv, Israel
31	Jun '98	C. Langelaar et al	Watermark removal on non-linear filtering	ASCI, June 98, Lommel, Belgium
32	Aug '98	G. Langelaar et al	Real-time Labeling of MPEG-2 Compressed Video	Journal publication: Journal of Visual Communication and Image Representation. Special Issue on "Image Technology for World-Wide-Web Applications"
33	Sep '98	A. Hanjalic et al	Automated Segmentation of Movies into Logical Story Units	Journal publication: accepted for publication in IEEE Transactions on Circuits and Systems for Video Technology
34	Sep '98	G. Langelaar et al	Removing Spatial Spread Spectrum Watermarks by Non-linear Filtering	European Signal Processing Conference (EUSIPCO'98), special session on "Watermarking Copyright Protection and Access Control for Multimedia Services, 8-11 Sept 1998, Rhodes, Greece
35	Sep '98	M. Pogacnik et al	Kontroler multimedijske pomnilniške enote	ERK'98, Sep98, Portoroz, Slovenia
36	Oct '98	A. Hanjalic et al	Template-based Detection of Anchorperson Shots in News Programs	ICIP'98, 5th IEEE International Conference on Image Processing, Chicago (IL, USA), 4-7 Oct '98
37	1999	A. Hanjalic et al	Semi-automatic news analysis, classification and indexing system based on topics pre-selection	accepted for publication: SPIE/IS&T Electronic Imaging 1999, Storage and Retrieval for Image and Video Databases, San Jose Ca.

10. HOW TO CONTACT THE PROJECT

SMASH maintains a public Homepage at the following URL:

<http://www.extra.research.philips.com/euprojects/smash>

This Homepage contains further details on the project, an up-to-date contact list, links to the public SMASH Deliverables and links to public SMASH papers.

You can also directly contact the following SMASH contact persons:

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