

Multimedia catalogue – the RAI experience

R. Del Pero, G. Dimino and M. Stroppiana

RAI Research Centre

At the beginning of 1997, RAI launched an internal project with the goal of digitizing and redocumenting all the audio-visual materials produced and owned by RAI. The project has been subdivided into several sub-projects, according to the parallel developments taking place in multimedia catalogues, radio and TV libraries, etc.

After a brief description of the system architecture, the article describes the RAI Multimedia Catalogue in some detail.

1. Introduction

The RAI television and radio archives contain several hundred-thousand hours of programmes, stored on various media formats, most of which are obsolescent. The present yearly growth is estimated at about 60 000 new supports for TV production, and about 40 000 new supports for Radio.

A traditional method of organizing this bulk of archive data does not allow for an efficient exploitation of programme content in the production environment, where the retrieval and delivery times play a crucial role. In particular, the manual handling of traditional storage media is incompatible with today's requirements and expectations.

In 1994, RAI started a project for the migration of endangered material from the old and obsolete supports to new ones, performing at the same time a new and complete re-classification of this material. Moreover, at the beginning of 1997, an interdepartmental project was launched whose goal was the digitization and redocumentation of all the material owned and produced by RAI. The project, managed by the Director of the *Audiovideoteche* department, has been subdivided into several sub-projects that relate respectively to the development of:

- ⇒ a multimedia catalogue;
- ⇒ a compressed TV library;
- ⇒ an uncompressed TV library;
- ⇒ compressed and uncompressed radio libraries;
- ⇒ a security system.



Access to the present archive requires many steps, several of which are manually managed. The overall procedure – from consultation of the programme catalogue, to delivery of a copy of the material – can sometimes take several days.

The new system that RAI is developing will drastically reduce this time, through the development of a *Multimedia Catalogue* and the automation of the library management functions. Such a system will be available to internal users (such as producers, directors, journalists) and, in general, to other people working in the production environment, as well as to external users such as researchers in social sciences.

The role of the new catalogue is that of a comprehensive search tool that will allow users to locate the required footage among the bulk of archived material. The catalogue will contain not only textual information, but also still pictures that relate to TV programmes, and the associated audio. From the catalogue, it will be possible to address not only programmes, but also segments and shots (i.e. it will offer shot “granularity”). The description given in this article will usually refer to documentation about TV material, as this represents the most general case, but it applies equally to radio and photo material with minor modifications.

2. General description of the new archive architecture

The archive can be subdivided logically into three main subsystems: the catalogue, the video libraries and the audio library, as indicated in *Fig. 1*.

The catalogue includes the documentation that relates to the Radio and TV materials, consisting of text and multimedia objects, audio and key-frames. The functions supported are: searching, navigation and previewing of the programme, and segment documentation – where a *segment* is a temporal part of the programme, having a close semantic meaning.

The libraries store the physical copies of the content (radio and TV materials) and their role is the preservation and handling of the media.

The catalogue and the libraries must be kept aligned so that the user, after querying the catalogue and locating the programme segments of interest, can send the relevant identification information to the appropriate library and receive a copy of the selected material without requiring any further viewing operations.

The alignment between the catalogue and the libraries can easily be obtained when the catalogue is populated by means of documenting the materials previously stored in the libraries, because the correct material identification and temporal references can immediately be determined. In the case of a parallel feeding of the catalogue and libraries with pre-recorded mate-

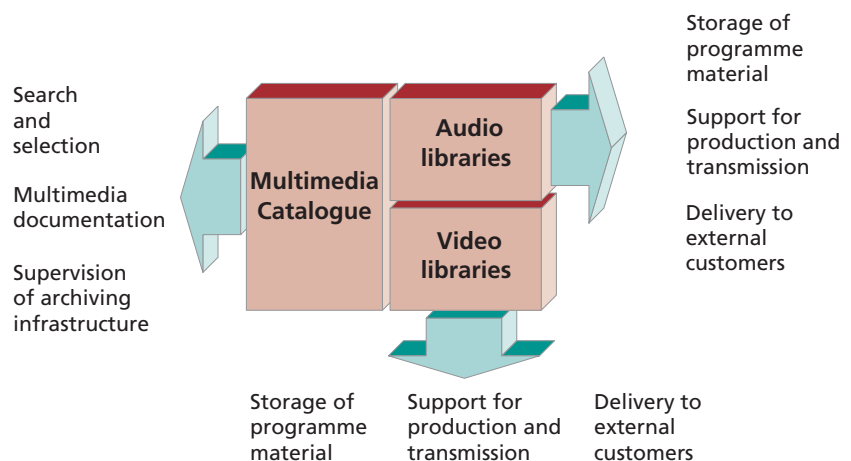


Figure 1
Functional block diagram of the RAI archive.



rial or from on-air feeds, the alignment between the catalogue and libraries is more delicate and must be considered attentively. However, this second case offers more freedom in the organization of the archive workflow, as there is no need for tight coupling between the two subsystem input operations.

The catalogue can be accessed on the RAI intranet by a vast number of concurrent users, via a web browser. Access to the libraries is restricted to a limited number of people in the production environment, both for copyright reasons and for keeping the network loading under control. The selected material can be delivered to the requester in several formats according to the connection available: as a file (used mainly in the Radio environment), as a TV video stream (TV *fast library*) or as a tape (TV *master library*).

3. Archive population strategy

The strategy followed in order to populate the new system with TV material is twofold:

- ⇒ documentation and digitization of all the programmes daily broadcast by the three RAI national channels;
- ⇒ digitization and redocumentation of endangered legacy materials from the archive.

The first activity is done using a pipeline originated at play-out, where live programmes are recorded for archiving. At the same time, all the materials are digitized and compressed (using MPEG-2), and the multimedia information to be included in the catalogue is extracted. The advantages with this strategy are that no additional tapes are moved to and from the archive for documentation and digitization purposes, and there is no need to generate and deliver copies of the programmes to the *documentalists* (these are contracted people, working outside the RAI facilities, who can record the programmes themselves at home on VHS-format equipment). The link between the various versions of a programme is then represented by the transmission time, which is the same at any acquisition station.

The migration to digital formats and the redocumentation of the legacy materials is done selectively using an urgency policy, i.e. the most endangered materials are processed first.

4. The video libraries

Information technology (IT) offers a versatile and future-proof way of storing and managing audio-visual materials as files, with features such as format independence which is hardly achievable with dedicated audio-video equipment. Unfortunately, storing the whole RAI TV archive at full CCIR 601 quality would require several tens of petabytes (10^{15}) of mass storage – a real challenge even for the most advanced systems in use today. Therefore, the adopted solution for the time being is that of maintaining a full-quality video library, named the *master library*, which is mirrored by a low-quality IT-based library, named the *fast library*. The latter contains MPEG-2 compressed video that can be used for viewing, disaster recovery, TV production not requiring very high quality, etc.

The master library contains analogue and digital video, stored on conventional video supports. At present, the master library is not managed in a completely automatic way. The sup-



ports are stocked on pallet boards contained in a warehouse. The locations of the supports and pallets are available on a computer system, and the movement of pallets is performed by robots.

In the fast library, the material is organized in files and stored on two different memory levels. The first level consists of on-line hard disk memory, while the second level is constituted by robotized tape memory. A caching process manages the transfer of materials between the first and second memory levels. The use of two memory levels enables an analysis of costs and performance to be made. In fact, due to the large amount of video material we have at RAI, a memory system based only on disks would be extremely expensive. On the other hand, the access time of material stored on tapes is not satisfactory, particularly if the number of concurrent accesses is high. A compromise is obtained using both tape and disk memories, where the latter acts as a cache for the former. The material is transferred from tapes to disks when required (and not already existing on disks), and is transferred from disks to tapes when not in use and when disk capacity is required.

5. The audio library

The application of computer technologies has enabled RAI to develop an Audio Master Library (a system called *Audioteca*) that holds – in digital form and in very high quality – the contents of all the radio programmes and the vinyl records and CDs

This system is composed of three main parts, connected via flexible high-speed networks.

The “**Trascrizioni**” subsystem (already finished and working) is responsible for the digitization of the existing archived materials (mainly on ¼-inch tapes). The audio signal is converted to digital linear PCM in stereo, at 48 kHz sampling rate, with 24 bits per sample. The system implements several features that allow for a drastic reduction in the digitization costs:

- ⇒ Automatic check of some significant features of the digitized sound (silences, saturation, abnormal spectrum, etc.). These parameters can reveal certain errors that can be proposed to the operators for acceptance.
- ⇒ Automatic control of the media players (tapes, records, etc.);
- ⇒ Systematic quality verification made by the operators on the most important parts of every document. This will include the critical points revealed by the computer.
- ⇒ Statistical checks on the complete documents.

The “**Grande Archivio del Suono**” (GAdS) subsystem is the master audio library that is responsible for the conservation and handling of the digitized material, based on a robotic archive (tape library) with a capacity of 350 Tbyte in DLT tape format. The audio files are formatted according to the AES/EBU BWF standard [EBU document Tech. 3285].

The “**Isole di Produzione**” are clusters of interlinked workstations that are used with specific kinds of production (news production, entertainment production, regional sites, etc.). These workstations are also linked to the *Grande Archivio del Suono*.

From these workstations, it will be possible to control the process with high-quality standards, and without having to move around either the people or the media.



6. The multimedia catalogue

6.1. Basic architecture

The multimedia catalogue must serve two roles. In its first role, the system should act as a repository for the multimedia objects and information that is gathered and generated during the various phases of the documentation process; in this role, the system interacts with the documentalists. Its second role is the publication of the final product to the user; it should support searching, navigation and pre-viewing of the documentation, and managing the links with the content libraries.

As a consequence of the different constraints relating to these two roles, an architecture based on two coupled subsystems has been selected, as illustrated in Fig. 2. The first subsystem, called the *Documentation Catalogue*, acquires the multimedia objects, and supports the documentation and validation phases. The second subsystem, called the *Publication Catalogue*, receives the validated programmes, and supports the services aimed at the users, i.e. searching, navigation, previewing and links to the libraries in order to request the downloading of the content.

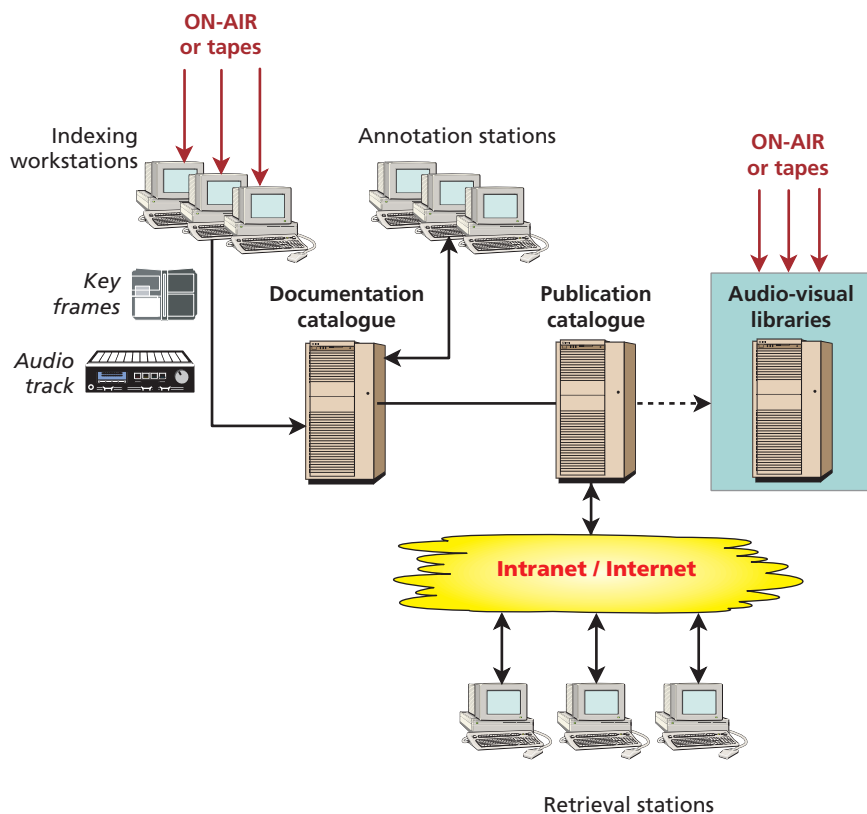


Figure 2
Basic architecture of the Multimedia Catalogue.

As shown in Fig. 3, the functions relating to the multimedia Documentation Catalogue are:

6.1.1. Documentation Catalogue

As shown in Fig. 3, the functions relating to the multimedia Documentation Catalogue are:

- ⇒ acquisition of multimedia objects (audio, keyframes and temporal references);
- ⇒ merging of multimedia objects into programme items;
- ⇒ indexing and documentation of the programmes;
- ⇒ programme validation;
- ⇒ transferring of the validated programmes to the Searching Catalogue.

a) Multimedia object acquisition

The acquisition station is based on a custom bi-processor workstation which receives at its



input a composite video signal and a temporal reference, and which performs in real-time the following activities:

- ⇒ digitization and compression of the audio;
- ⇒ detection of shot changes;
- ⇒ extraction of a keyframe for each shot;
- ⇒ association of the starting time and duration of the shot with each keyframe.

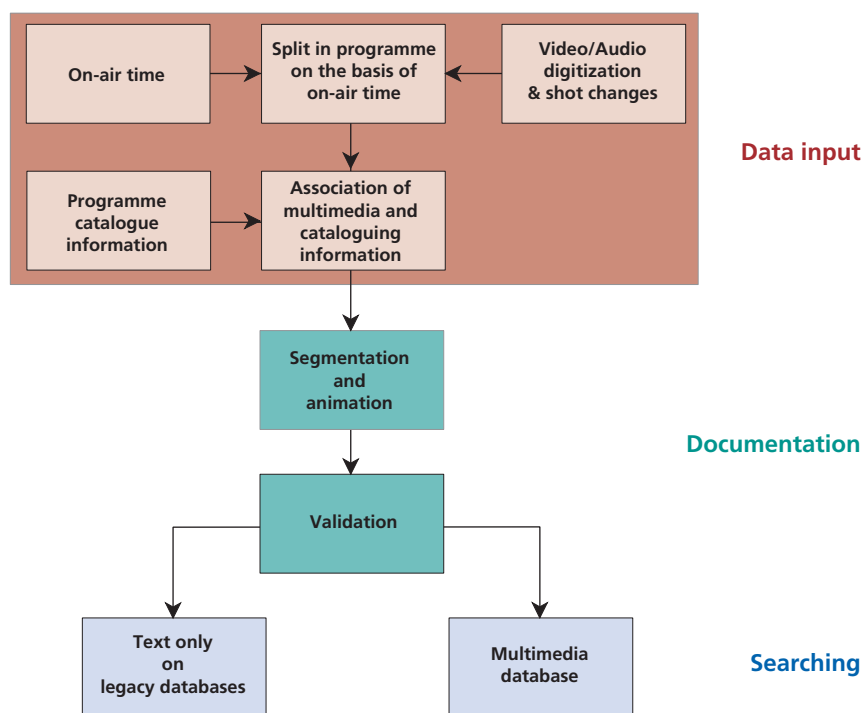


Figure 3
Functional block diagram of the Documentation Catalogue.

The output stream is sent to the Documentation Catalogue server.

b) Subdivision of multimedia objects into programme items

In the Documentation Catalogue, the continuous flow of multimedia objects is processed in order to create programme items in the database. At present, this operation is performed manually, supported by information about the transmission start and end time of each programme, automatically loaded from an administrative database. The available precision – sufficient for administrative operations – is not adequate for a completely automatic segmentation of programmes; therefore, an operator is required to refine the cut points. This step is simplified in the digitization chain for the legacy materials as there is very often a one-to-one correspondence between tapes and programmes.

In this phase, a programme entity is created in the database, binding the multimedia information with some basic classification information, such as the name of the programme, the credits, identification codes of the programme, corresponding tape(s) in the master library, etc.

c) Indexing, documentation and validation

The documentation of programmes is performed by outsourcing this work to a number of contracted companies. A general architecture has been individualized to include independent documentation islands that are connected to the Documentation Catalogue via a dedicated network. In this way, the multimedia objects are transferred from the Documentation Catalogue to a server located in each documentation company, and then connected via a LAN to

the individual documentation stations. The produced documentation is sent back to the Documentation Catalogue and added to the corresponding programme item in the database. The documentation must be validated subsequently by the archive department, before its publication.

d) *Transferring of programme items to the Publication Catalogue*

The validated, documented, programmes are transferred to the Publication Catalogue and then made available to the users by means of search, navigation and previewing functions.

6.1.2. Publication Catalogue

The Multimedia Catalogue must be able to manage the documentation relating to TV, radio, papers and photos stored in the various RAI libraries. Considering that RAI owns a huge amount of material that is increasing very rapidly, the Multimedia Catalogue (including the documentation) would also have to be very large. A single database supporting the whole catalogue would consist of a very large number of records and would have a predictably poor performance. Consequently, it has been decided to partition the database according to the type of material, while maintaining the capability of searching in parallel across all the partitions. The expected advantages are a large reduction in the size of each database, and a corresponding reduction in the number of concurrent users on each partition. This will lead to an increase in performance, a higher flexibility and a better scalability of the system. An additional cost to be sustained will arise from the need to maintain a distributed database which is, by its very nature, more complex than a centralized one.

The user stations can be linked to the Catalogue by means of local or geographical networks, using web interfaces and standard browsers. The coding of the multimedia information has been carefully chosen in such a way that it uses minimal network resources while maintaining sufficient quality for the services provided.

6.1.3. Selected technology

The documentation structure is modelled using an object-oriented approach. This structure has been mapped onto an Object-Relational Database (ORDB) that extends the entity-relation concepts with some features borrowed from the object-oriented technology.

It is then possible to have tables of data addressed by means of the traditional SQL language, which allows for easy and efficient design & development of the searching functions, in combination with features such as user-defined data types and functions, and class inheritance. It is expected that this approach has the flexibility needed to support future releases of the system which include new requirements and new technologies. When compared with a traditional relational database, ORDB technology has proven to be very effective in the implementation of navigation functions in the media objects that make up the documentation of the programmes.



6.2. Data model

The material is logically structured according to a data model that considers a *programme* belonging to a *series* which, in turns, belongs to a *product*. The programme can be divided up into *segments* which are composed of *shots*. These different levels are defined as follows:

- ⇒ **Product:** a collection of collections, constituting a complete television programme or “title”. It can also be defined as “all the programmes with the same title”;
- ⇒ **Series:** a set of programmes (collection) related to the same product;
- ⇒ **Programme:** a media object with a unique timeline (where a *media object* is an entity in the multimedia database). It can be part of one or more collections, and can be sub-divided into one or more segments. A programme can also be defined as “an episode of a product”;
- ⇒ **Segment:** part of a programme with a closed semantic meaning;
- ⇒ **Shot:** a shot of video extracted from a programme, usually using automatic segmentation tools, according to some technical criteria, e.g. a scene change, a dissolve, a wipe.

Annotations are associated with the first four levels of data, i.e. the product, series, programme and segment levels.

This structure is very general and can support recursive documentation that includes re-uses of the material. A typical case is shown in Fig. 4 which depicts segments included within segments.

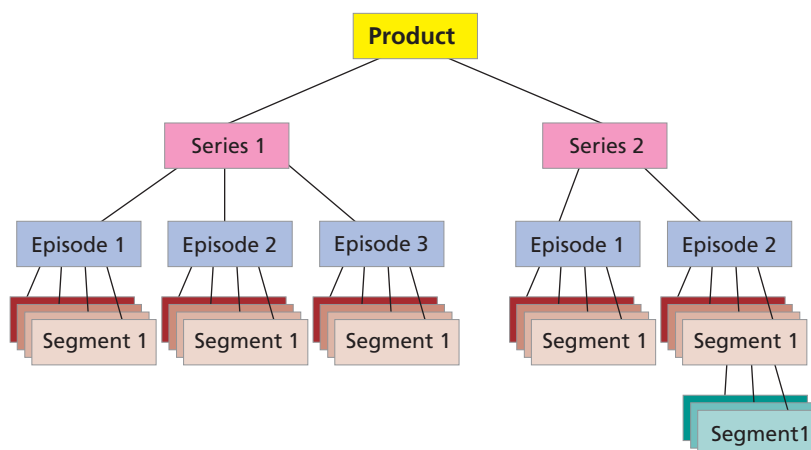


Figure 4
Data model of TV programmes.

Each programme item comprises still pictures, compressed audio, formatted fields and free text. The still pictures consist of keyframes extracted from the TV programme, scaled to $\frac{1}{4}$ size and JPEG compressed. The audio is derived from the programme soundtrack, compressed using MPEG layer-3 (now called MP3) at 8 kbit/s. The formatted fields and free text include: the classification information, automatically downloaded from legacy databases; a minimal documentation generated in the production phase (e.g. title and credits), and the annotation typed in by the documentalist during the documentation phase.

6.3. User functionalities

6.3.1. Search

To determine which tools the search interface for the Catalogue must offer to its users, an analysis of user types must be performed.



At least two user classes must be considered:

- 1) a generic user who accesses the Catalogue mainly for documentation purposes, without specialized information on its organization;
- 2) an expert user who is able to exploit every feature of the system, using complex queries.

Users belonging to the first class require a very friendly interface and the possibility of extending the search to many or all of the different types of material.

On the other hand, users in the second class are, in the most part, professional researchers looking for specific materials to be included in new productions and therefore they need to locate the items in the shortest time, by means of comprehensive user interfaces.

Furthermore, as different documentation fields are required for different kinds of materials, a query on the whole Catalogue must be based on the subset of documentation fields that is common to all the documentation typologies.

Based on the above considerations, three searching levels have been considered:

- 1) on the documentation of all the material, i.e. TV, radio, paper and photos;
- 2) on the documentation of a single type of material, i.e. TV, radio, paper or photos;
- 3) on the documentation of specific genres, e.g. TV fiction, dramas, magazine programmes, news, Radio news, etc.

The search at the third level is performed on all of the documentation fields, the formatted data and the free text. However, the search at the first two levels is performed only on free text and a limited subset of the formatted data. This subset contains the documentation fields available on all the material that is taken into account at that level. Clearly, this subset is more limited at level 1 than at level 2.

The search can be composed using logical operators and by looking for either the exact word, a similar word or a synonym. The searching mode is set up by the user before starting the searching operation.

The result of a search query consists of the number and list (titles) of the occurrences found. By clicking on such an occurrence, the navigation interface opens and the user is able to navigate within the selected programme.

6.3.2. Navigation

The results of a query can be any type of documented object, i.e. a product, series, programme, segment or shot. These are all entry points to a graph of related objects, interconnected either:

- ⇒ through a structural link (hierarchical or temporal) such as from a programme to its included segments (hierarchical);
- ⇒ from one segment to the next one of the same programme (temporal), or;
- ⇒ through an association established by the documentalist, e.g. a set of news items on the same topic, or a programme and its script.



Therefore, after browsing the objects resulting from a query, the user can navigate across the graph of related objects.

The user interface for navigation is illustrated in Fig. 5. On the left of the window is displayed a list of the segments included in the programme: it consists of the most representative keyframes (according to the documentalist's judgement), the title of the segment, and its duration.

At the top of the window, the Product, Collection and Programme titles are shown. The duration of the episode, as well as the production and on-air dates, are also indicated.

By clicking on the buttons in the centre of the window, a documentation area is displayed (description, credits, themes, technical information, content index, etc.). The picture at the bottom of the window shows the index of the programme segments, organized by content. The round buttons at the bottom of the window are used for navigation.

Using this interface, it is possible to display information relating to a selected segment, as shown in Fig. 6.



Figure 5
Navigation interface at the programme level.



Figure 6
Navigation interface at the segment level.

The page structure and the basic information relating to the Product, Collection and Programme at the navigation level are the same as for the Programme level. The keyframes in the left panel refer now to the most significant segment shots. A selection of the most important shots is carried out by the documentalist in order to limit the number of displayed pictures and to reduce the downloading time. In any case, if required by the user, the complete list of shots can be displayed.

The documentation areas associated with the segment object contain information that is spe-



cific to the segment, including segment description, video content description, participants list, location, environment, etc.

In the top right corner of the programme and segment interfaces, there is a traffic light icon. It indicates the presence (red) or absence (green) of legal constraints on the use of the material. Normally, the materials in the Catalogue are owned by RAI and are available for internal re-use but, occasionally, the allowed use may be constrained according to specific contracts. In the case of a yellow traffic light, the situation has to be cleared with the legal department.

At the segment level, a previewing function is available. To limit the database size and keep the network occupancy as low as possible, the preview – called *animation preview* – is obtained by displaying the keyframes for the duration of the relative shots, in synchronization with the soundtrack (MP3, compressed at 8 kbit/s).

6.3.3. “Palinsesto” interface to browse undocumented programmes

The complete documentation process, from the capturing of key frames to the uploading of the validated documentation to the Publication Catalogue, requires several days. For some genres such as news, the multimedia objects associated with the classification and broadcast date of the corresponding programme already constitute a valuable information source to some types of users.

Therefore, undocumented material is uploaded to the Multimedia Catalogue on the day following the transmission, without waiting for the completion of the documentation process.

These materials can be accessed through knowing the relevant broadcast time or title. The enabled functions are: display of key frames; animation preview and display of the broadcast and classification date.

The interface to navigate programmes by transmission schedule is called *Interfaccia di Palinsesto* and is shown in *Fig. 7a*. All the programmes transmitted in a specified day are listed, together with their respective transmission starting and ending times, and the titles. The icons at the right of the title indicate (from left to right) the availability of the classification information, the presence of multimedia objects (key frames and audio) and the availability of the documentation. By clicking on one of these icons, the corresponding information is displayed as shown in *Fig. 7b* (in this case, after clicking on a multimedia objects icon).

Abbreviations

AES	Audio Engineering Society	JPEG	(ISO/IEC) Joint Photographic Experts Group
BWF	(EBU) broadcast wave format	LAN	Local area network
DLT	Digital library/linear tape	MPEG	(ISO/IEC) Moving Picture Experts Group
IEC	International Electrotechnical Commission	PCM	Pulse code modulation
ISO	International Organization for Standardization	RAI	<i>Radiotelevisione Italiana</i>

In the upper half of this window is displayed the programme title and some keyframes in a temporal order. By moving the slider that is located below the keyframes, it is possible to scroll through all the keyframes linked to the selected part of the programme. When you select a particular keyframe in this sequence, it will be copied to the frame in the lower half of the window. By using the buttons under this frame, it is possible to start and stop the animation preview, and also to return to the start point.

The icon depicting an open book informs the user that the programme has been documented. By clicking on this icon, the navigation interface shown in *Fig. 5* will show up and the user can then start navigating through the programme documentation and the associated documents.

7. Links between the catalogue and the libraries

The Multimedia Catalogue also contains an identifier of the files or supports which store the video and audio, as well as the initial timecode and the duration of every shot. Therefore, when accessing the Catalogue it is possible to select a part of a programme on the basis of the documentation. The selected part is associated with the file or support identifier, and with the initial and final timecode.

If the requested content is stored in a robotized library, the addressing parameters are transferred automatically to the library server which will (i) locate the file, (ii) extract the requested portion of the programme and (iii) will make it available on the network. It is possible to request each portion of a programme contained between two selected shots.

If the requested content is stored in a traditional video library, a form will automatically be filled in with the parameters that refer to the material, and will then be transferred to the desk of the archivist responsible for the library, who will retrieve the requested content and send it on to the user.

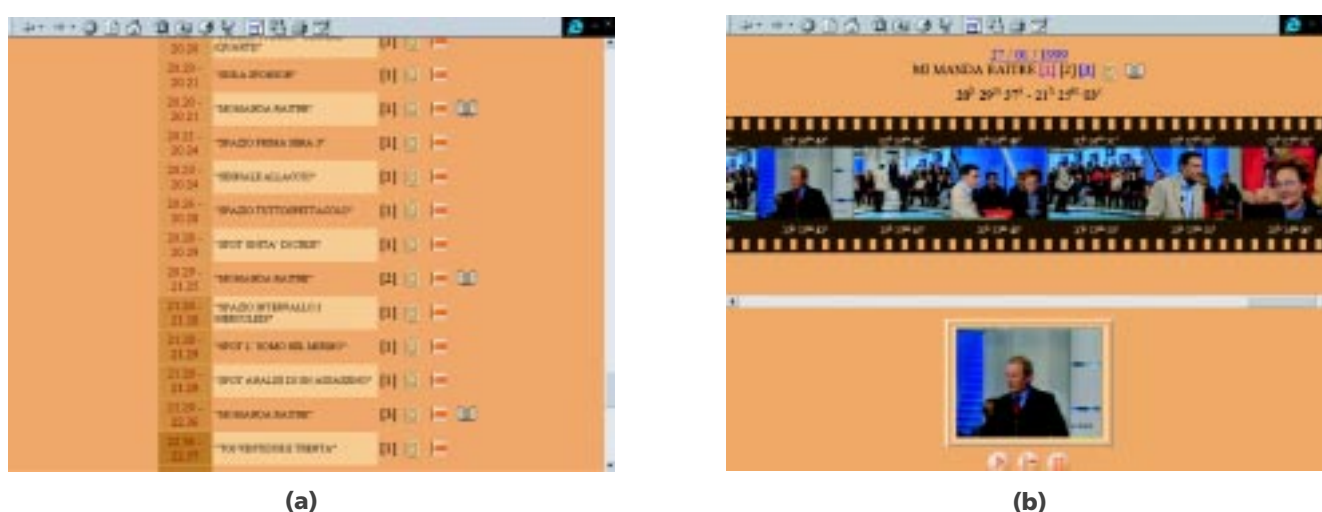


Figure 7: "Palinsesto interface"
(a) list of the transmitted programmes in a specific day;
(b) Interface for the key-frame presentation.





Roberto Del Pero obtained a degree in electrical engineering from the Polytechnic of Turin in 1983. In 1985 he joined the RAI Research Centre in Turin, working on digital video signal processing and compression.

Mr Del Pero is currently involved in the RAI archive project for the analysis and development of the Multimedia Catalogue.

include the design of automated digital archives and the application of information technology in television production.

Giorgio Dimino received a degree in electrical engineering from the Polytechnic of Turin in 1987. In 1988 he joined the RAI Research Centre in Turin, working in the field of digital audio and video compression, and archiving. His current interests



Mario Stroppiana received a degree in Mathematics from the University of Turin in 1970. Since 1968, he has been working at RAI Research Centre and has been involved for many years with modelling and computer simulations of analogue broadcasting channels. Since 1985, his interests have moved towards digital signal processing, coding and quality evaluation.



Mr Stroppiana is currently responsible for the Research Centre department which is involved in the innovation of production systems, and in video/audio quality evaluation methodologies.

8. Conclusions

This article has described the features and architecture of the RAI Multimedia Catalogue and the new tools developed for querying and browsing through the RAI archives. It has focused on the acquisition of multimedia objects, the segmentation and documentation of programmes, the search and navigation facilities, and the link to the libraries which automatically extracts the requested content.

It is expected that new technologies will become available in the next few years, to substantially reduce the costs of producing the documentation. In particular, automatic tools for the indexing and segmentation of audiovisual sequences – currently being studied in the framework of MPEG-7 and in several European projects – could operate as automatic pre-documentation tools. Content-based retrieval tools could also play an important role if applied to still images and audio, allowing for queries based on the content similarity. This effort could achieve positive results if supported by international standards.

Another important issue that arises from this article is that a reliable link between the catalogue and the libraries is only possible if there is an unequivocal relationship between the materials and the corresponding documentation. If tools such as the RAI Multimedia Catalogue are to be used to support the automatic exchange of programmes between companies, or for electronic commerce of content using worldwide networks, the content identifier must be globally unique. At this moment in time, standard proposals for a Unique Material Identifier (UMID) and a Unique Programme Identifier (UPID) are under study by the Standards bodies.

