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Implementation and Analysis of Several Keyframe-Based Browsing Interfaces to Digital Video

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Abstract. In this paper we present a variety of browsing interfaces for digital video information. The six interfaces are implemented on top of Físchlár, an operational recording, indexing, browsing and playback system for broadcast TV programmes. In developing the six browsing interfaces, we have been informed by the various dimensions which can be used to distinguish one interface from another. For this we include layeredness (the number of "layers" of abstraction which can be used in browsing a programme), the provision or omission of temporal information (varying from full timestamp information to nothing at all on time) and visualisation of spatial vs. temporal aspects of the video. After introducing and defining these dimensions we then locate some common browsing interfaces from the literature in this 3-dimensional "space" and then we locate our own six interfaces in this same space. We then present an outline of the interfaces and include some user feedback.

1 Introduction

The technologies used to capture, compress, store and transmit TV-quality digital video are now so far advanced that the development of digital libraries of video information is now an achievable target for many organisations. In our research group we are developing Físchlár[1], a system which currently captures, stores, indexes and allows browsing of broadcast TV material to users within our organisation [1]. Using a dedicated video server we can store almost 4 weeks of continuous content which we can stream to over a hundred users, concurrently. Our work is currently based around indexing and browsing broadcast TV materials with a view to developing a digital library of such materials where users will be able to access this stored archive, not just to select programs to stream and play, but to do other, content-based manipulations.

In coming years, people's home video watching habits and styles will become quite different from now, as new digital video content management systems and interactive TV are developed and start appearing on the marketplace. Because the material is in digital format, this will allow easy searching and browsing of video content information such as movies, TV broadcasts and personal archives.

In the domain of non-temporal media, quite a few innovative and creative interface development efforts for browsing can be found including interfaces such as text

[1] The word Físchlár comes from fís (video) and chlár (programme) in the Irish language.

browsing/visualisation [2] [3] and the interfaces developed for browsing different types of data spaces [4] [5], but only very limited efforts and studies have been made on browsing interfaces to time-based media such as video, examples being [6], [7], [8] and [9].

Current efforts in digital video research are usually centred on automatic video indexing techniques while user-interface aspects are often demoted to the last stages of a project where some test users approve the acceptance of the system's interface, rather than the nature of video data and its possible end user interface and content visualisation being a separate subject of study on its own. It is indeed important to develop effective and efficient techniques to automatically index video materials, but unless we also consider how the output of these techniques can be properly used for providing good front end user interaction we may find that such technically-driven innovations will not be of any use in practice. What is needed is a more focused and systematic study that considers the characteristics of the video to be handled and to connect this to the development of a front-end information visualisation and user interface, with user-oriented, iterative evaluations and refinement.

In this paper we present our current work on keyframe-based video browsing user interfaces and user interaction by categorising and characterising different possible ways for users to browse video data. We use this idea to design innovative video browsing interfaces and conduct a focused study by adapting a parallel, iterative method with actively involving real users into everyday usage of a digital video system. In the following section we describe a digital video demonstration system called Físchlár which we use as our user interface testbed, then in section 3 we consider the nature of video data we are handling and identify three important dimensions in providing user interfaces using that data and some of the possible values for these dimensions. In section 4 we introduce Físchlár system's six distinctive video browsing interfaces and present a 3-dimensional space where we locate each of the six interfaces. Section 5 describes briefly each of the six interfaces with initial test users' comments and briefly what other possible interfaces could be implemented, and section 6 concludes with our plans for further interface development and evaluation.

2 The Físchlár System

The technologies needed to support manipulation of digital video information by computer have now developed enough to allow simple capture and playback of digital video on desktop machines. Beyond that, however, we are now at the point where video *content-based* browsing has become possible as new video indexing techniques have been studied and developed during the last few years. A fundamental primitive operation which is needed in order to allow any content-based operations on video is 'shot boundary detection' which automatically segments video material into individual camera shots by analysing differences of video content frame-by-frame, and then from each shot automatically select one or several frames ('keyframes') that represent the content of the shot. This generally results in a large set of pertinent keyframes as an output and this set of images is used by end users for browsing video content.

In the work of the Centre for Digital Video Processing at Dublin City University, we have been developing and evaluating effective shot boundary detection techniques [10] [11] [12] as a foundation for our fully working demonstration system, Físchlár.

Físchlár is a web-based system for capturing, storing, indexing and browsing broadcast TV material. It allows a user to set the recording of broadcast TV programmes by providing an easy-to-browse online TV schedule. Once the user sets the recording of a particular programme, Físchlár records and digitises the program when the TV broadcast time comes, using MPEG-1 format. The encoded programme is then fed into our shot boundary detection module and the resultant set of well-chosen keyframes are passed back to Físchlár to be used as part of a user's browsing interface. The user can then browse the keyframes with a web browser and can start playback at any point of the video by clicking on a keyframe.

The system allows users access to an archive or digital library of recorded TV programmes and has been running since July 1999. Through person-to-person introduction and active promotion within our department we now have our user base ranging from dedicated regular users to infrequent casual users, mostly postgraduate students and staff. The Físchlár system is described in more detail in [1].

While initially serving as a demonstrator for our shot boundary detection work, we are also using Físchlár as an underlying support system for further work in summarisation, personalisation and searching of video from an archive or library of stored programmes. For now, Físchlár has also become a testbed for various keyframe browsing user interfaces, although we plan to work on other video browsing methods such as skim [8] and others in near future. In keyframe-based browsing, once a basic set of keyframes are extracted from a video programme and stored in the system as metadata for that programme, it becomes simply a matter of how to present those keyframes onto the user's screen. Using the dimension framework that is described in following sections, we have been designing, implementing and testing several distinctive keyframe browsing interfaces all running on top of Físchlár. Although these distinctive interfaces are running independently, they use exactly the same set of keyframes from the video, which makes them more directly comparable.

3 Dealing with a Large Amount of Temporal Data

A set of keyframes extracted from video can be displayed in many different ways and styles. There have been numerous experimental and commercial digital video systems each with different visualisation and user interfaces, but a system having a single interface for video browsing would be too much of a simplification considering the many other possible ways that could have been useful, and would also lead to poor usage and frustrated users. In practice, a single all-encompassing interface would be impossible and several variations are needed, each of which has to tackle a well-defined specification which can be obtained from many sources such as potential exploitation of the video data itself and prospective future users' requirements. Acknowledging the various factors that could be considered, we focused on the exploitation of the video data itself, by analysing the characteristics of video data we have to handle. We identified different underlying *dimensions* the video data has and different *values* that each dimension can take. In other words, the video data we want to provide an interface to can be modelled in a multiple-dimensional space where each dimension contains a certain number of values. "Designing an interface" in this context becomes a matter of making a choice of different values for each dimension, different sets of choices resulting in different interfaces.

The data we manage is sets of large numbers of keyframes in temporal order. Dealing with a large number of keyframes, the first dimension we identify is what we call "layeredness" - a matter on whether to display all available keyframes directly to users or to allow a way for more selectively presenting them. The temporal nature of the data leads us to think of two more dimensions - "Provision of temporal orientation," or how to make time information of video visible to the user, and visualisation style we call "Spatial vs. Temporal visualisation."
These three dimensions and their possible values will be considered now.

3.1 Layeredness

A set of keyframes selected from shot boundary detection more often than not means a very large number of keyframes. For example, in our experience a 30 minute soap opera might generate more than 400 keyframes, and a large number of keyframes can be impractical for browsing. The method of reducing the number of keyframes ("keyframe filtering") may vary from simply selecting an arbitrary keyframe by grouping all keyframes in a regular interval, or more complex ways of content-based and semantic-level keyframe grouping.

Whatever the method of reducing the number of selected keyframes may be, this implies a layered presentation where several different granularity levels can be chosen as an option.

At one end of the layeredness of keyframe-based presentation there will be a single keyframe that represents the whole video clip, as is frequently done for displaying search results for a video clip in experimental systems such as [13] [14] [8]. One cannot expect this single keyframe to be able to convey the content of the whole video, but still it works as a kind of icon for the video and locates clips within the whole video. At the other end of the layeredness scale there will be the most detailed, full listing of keyframes with each representing a camera shot in the video, as most of current semi-automatic video cataloguing systems do [15] [16] [17]. Whereas this full keyframes listing shows the most detailed view of the video content, it loses some of its purpose for browsing because it takes so long to look at all the keyframes.

Between these two extreme layers, we can think of intermediate layers with different levels of detailed. It will not be possible to say which level of granularity is best for every situation as one user in a situation will have different needs from another user in the same or a different situation - a busy user might want to look at what the video content is on one screenful of small keyframes, while a user looking for a particular scene might want to browse in as detailed a way as possible and may be willing to spend more time, and so on. It might also be the case that different types of user groups prefer browsing at different levels of granularity, leading us to consider a browsing interface with the level of granularity customisable for users. In general a user might want to have an overview look of the content and if s/he finds it interesting then may want to see a more detailed view. This idea of "overview first, zoom and filter, then details on demand" [18] has been amply emphasised in the field of information visualisation, and should be desirable to apply in keyframe-based interfaces as well.
The important values we identified in providing layered keyframe presentations are:

- The number of different layers available
- The navigational link between different layers (and visualisation to show which layer the user is currently in)

The above ideas can be summarised as the following figure:

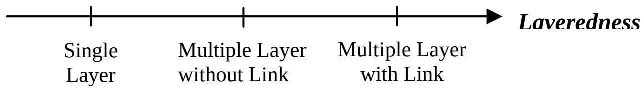

Fig. 1. Layeredness dimension and some values

3.2 The Provision of Temporal Orientation

With the video medium having a temporal nature as one of its fundamental characteristics, it is important to provide a cue for the sense of time in user browsing. A set of keyframes usually provides no proper time sense or temporal orientation, other than a rough progression from one keyframe to the next. Looking at the keyframes selected based on camera shots can even distort and mislead the time orientation, as the number of shots and thus keyframes from one time segment can be very different from those in another segment of the video but of the same length, depending upon the frequency of camera shot cuts in the video content. A familiar time orientation used in many interfaces is known as the 'timeline bar' (either as an indicator or controller) and is usually found in most video player software such as Microsoft’s Media Player or RealNetworks RealPlayer. In keyframe browsing, it is easy for the user to lose the sense of time and at what point s/he is currently looking at in the video, and in our work we considered some way of indicating the time sense as an important dimension in browsing. Several existing examples of this implementation are found such as simply time-stamping the numeric time in each keyframe as in [19] [16] [15], displaying quantifiable objects to visualise shot length [20] or a timeline bar indicating current position of user's keyframe browsing such as in [17]. We can identify some of the possible values for this dimension, as:

- The indication of absolute time in the currently viewed keyframe or set of keyframes (exactly how much into the video the current keyframe is)
- An indication of the current browsing point in relation to the whole video

The above ideas can be summarised by the following figure:

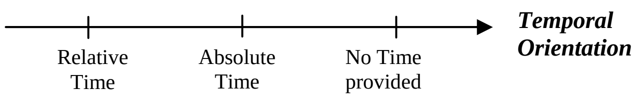

Fig. 2. Temporal Orientation dimension and some values

3.3 Spatial vs. Temporal Visualisation

The conventional keyframe browsing idea would be to miniaturise each keyframe into a small thumbnail size image and present many of them on one screen - much the same as the digital image retrieval user interfaces used in art gallery booths or CD-ROM picture collections where the user's query result is displayed as a set of thumbnail images so that s/he can quickly browse and identify the images s/he wants. But it is also possible to present keyframes on a user's screen one by one, the system automatically flipping through the keyframes. Considering the fact that the original video is time-based and sequential, it seems to make sense to present keyframes in an identical time-based and sequential manner, and this might even provide the feeling of watching the video. Current digital video systems' user interfaces based on keyframes mostly feature showing thumbnail size keyframes spatially such as MediaArchive [19], FRANK [21], MediaSite Publisher [17], Excalibur Screening Room [16], VICAR [22], Virage VideoLogger [15] AT&TV [23], and infrequently found are the systems presenting keyframes temporally such as DVB-VCR [24], WebSEEk [25] and movie browser tool [26]. Such an unusual video browsing study as comparing spatial presentation with temporal presentation in terms of different user tasks is also found [27] and our study in a sense extends this work by including more variety of visualisation styles. Then again, this can be summarised as the following figure:

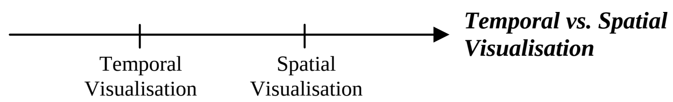

Fig. 3. Temporal vs. Spatial Visualisation dimension and its two values

3.4 Using the 3-D Representation of Video Data to Specify Browsing Interfaces

Assembling these analyses of video data into one leads to a 3-dimensional space where each axis represents each dimension drawn above. In this space we can locate positions of several existing video browsing interfaces, for example SWIM hierarchical browser [28], DVB-VCR [24] and AT&TV [23]. (see Figure 4 below).

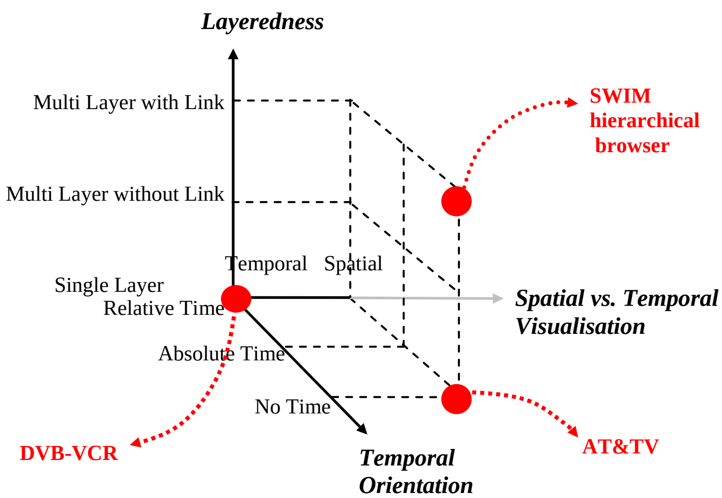

Fig. 4. Dimension Space and three example interfaces' positions

This way we can see different browsing interfaces more globally in their relative positions in terms of three dimensions. All three example interfaces located in this space are in fact choices among alternative ways of designing interfaces. Our approach is to propose several further well-specified browsing interfaces in this space, by locating a particular point in the space. Each of our proposed interfaces aims to fulfill the identified values from each dimension. As the next section will illustrate, we designed and implemented six distinct browsing interfaces for the Físchlár system, which provide good coverage of the dimension space.

4 Dimension Space and Six Físchlár Video Browsers

The Físchlár system is currently running with six distinctive keyframe browsing interfaces. Our users are free to use any of these interfaces to browse and play TV programmes they, or others, have recorded. This section will address the six interfaces' individual specifications in the dimension space, and the next section will describe each of the six interfaces. As the following figures will show, our objective is to cover as well as possible the previously defined dimension space in order to propose alternative browsing possibilities for the Físchlár system. The six Físchlár video browsing interfaces are listed below and are attached to a specific colour which will be used consistently in the following figures throughout this paper.

Table 1. Físchlár Video Browsers and assigned colours

Scroll Bar Browser (SB)	Overview/Detail Browser (OD)
Slide Show Browser (SS)	Dynamic Overview Browser (DO)
Timeline Bar Browser (TB)	Hierarchical Browser (H)

4.1 Layeredness and Físchlár Interfaces

The idea of layeredness can also be found in text indexing in information retrieval systems. In those systems, there exist alternatives from the classical list of keywords to complex indexing languages. Choosing an alternative is mostly a problem of properly identifying the users of the information retrieval system: the more knowledgeable the user is about the domain, the more complex the indexing language has to be to satisfy him/her. The layeredness in our dimension space can be viewed in the same way: from a simple, single layer keyframe list to a more complex, multiple layer list. The more knowledgeable the user is about the video content, the more layers and complex arrangements of data s/he will want to use.

Our choice here is to design three single layer interfaces and another three multiple layer ones (for the latter, two that provide point-to-point navigational link among layers, and one without any navigational link).

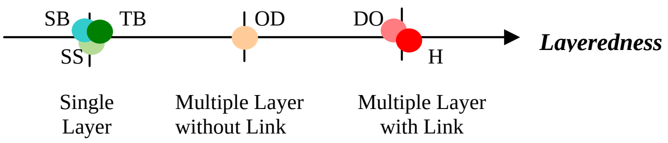

Fig. 5. Six Físchlár interfaces on Layeredness dimension

4.2 The Provision of Temporal Orientation and Físchlár Interfaces

Providing time information (either absolute time into the video or displaying the current point of video in relation to the whole length) or not are possibilities that must exist as alternatives to each interface. Therefore we decided to widespread our six interfaces in all the values. Of the six Físchlár interfaces,

- two interfaces do not provide time at all;
- two interfaces show the current point relative to the whole video;
- two interfaces show both the current point relatively as well as absolute time

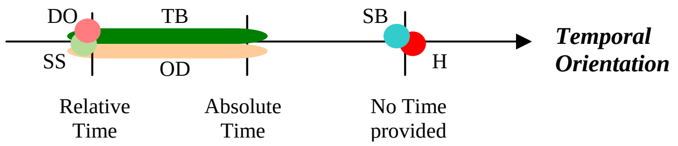

Fig. 6. Six Físchlár interfaces on Temporal Orientation dimension

As can be seen, the distribution of the six interfaces in terms of this dimension has been made so that different interfaces provide properly covered combinations with the layeredness dimension - single layer with time, multiple layer with time, and so on.

4.3 Spatial vs. Temporal Visualisation and Físchlár Interfaces

The choice between spatial and temporal visualisation of keyframes might be largely a matter of the available time of the user. We observed that often the initial test users preferred spatial visualisation unless the video is quite short. This may explain why we have mostly implemented spatially displayed interfaces instead of temporal ones. From this idea we introduced another interface that mixes both spatial and temporal visualisations, which covers both values in the following figure (Dynamic Overview Browser).

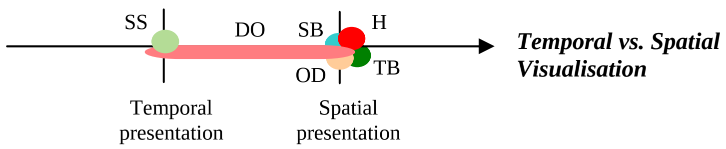

Fig. 7. Six Físchlár interfaces on Temporal vs. Spatial Visualisation dimension

4.4 The Six Físchlár Interfaces in Dimension Space

The above three figures can be combined into one 3 dimensional space with one axis representing each dimension. This combined figure shows all essential dimension value choices of the six Físchlár browsing interfaces at one glance.

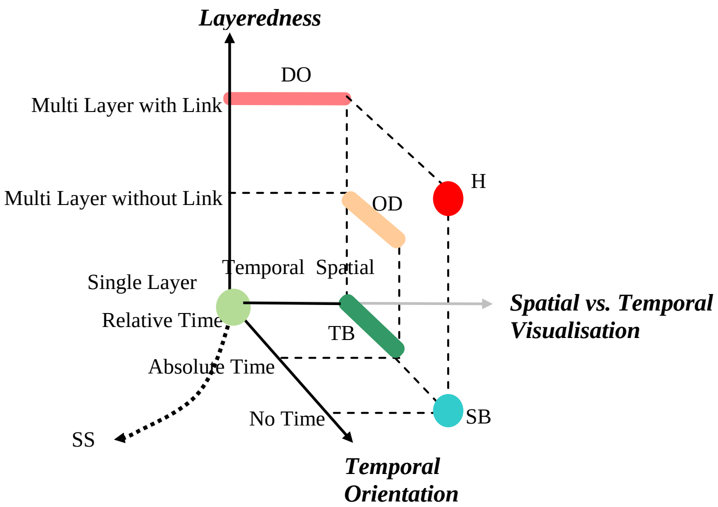

Fig. 8. Dimension space and current six Físchlár interfaces

Following this positioning of our six browsing interfaces in the dimension space presented, we now go into details of each interface.

5 Físchlár Video Browsing Interfaces and Characteristics

This section describes each of the six Físchlár interfaces which were introduced and viewed in the dimension space above. Presented below are screen shots, short descriptions and some selective and indicative comments from our users. Beginning with the Timeline Bar front end, interaction and dialogue with our users brought up new ideas and critiques, which then led to further ideas and then into additional front end interfaces. Added interfaces were again tested with users and, over time, some obvious usability problems were identified and removed as we then started to stabilise the features of each user interface.

The user interfaces presented below are a snapshot of the on-going refinement and discussion with our users within the Lab so far and will be further refined, although we note that these six user interfaces are fairly stabilised and fixed at this point.

5.1 Six Físchlár Browsing Interfaces

Single Layer	Without Time		**Scroll Bar Browser:** The user scrolls up and down using the scroll bar to the right to browse all the keyframes for the video arranged next to each other. Familiarity with normal scroll bar, easy control and immediate response are strong points. Some user comments: Simple to use; I feel pictures are more accessible; too much information; doesn't look organised.
	With Temporal Orientation		**Slide Show Browser:** Keyframes are automatically flipped through one by one, and at the bottom scroll bar the timeline indicator shows the current point in the video. Easy to lose the context as the user can only look at one keyframe at a time. Some user comments: It takes too long to see all the keyframes; it would be better to be able to control the speed of flipping.
			**Timeline Bar Browser:** Presents fixed number of keyframes (24) on one screen, and as the user moves the mouse cursor over the timeline bar at the top, the screen of keyframes flips through to the next set of keyframes. The timeline bar provides temporal orientation, windows are proportional to the time covered by the set of 24 keyframes, and the ToolTip shows the exact time of the current screen. Some user comments: Browsing screen is very inviting; easy and simple.
Multiple Layer	Without navigational Link		**Overview/Detail Browser:** Initial screen displays a small number of “significant” keyframes selected from throughout the video, thus providing an overview. When the user wants more detailed keyframes, s/he clicks a button at the top and then the browser changes to the Timeline Bar Browser. Some user comments: Not sure if overview screen is necessary at all.
	With Navigational Link		**Dynamic Overview Browser:** Initial screen displays one small set of keyframes (as an overview), then when the user brings the mouse to any of the keyframes, the pointed keyframe slot starts flipping through the detailed keyframes within that slot. Small timeline bar appears under each keyframe, indicating current point. There is no sudden major screen change that can disorient a user, and overview and detail are linked to support navigation. Combined spatial and temporal browsing. Some user comments: Very novel; It takes too long to see each slot's keyframes.

Hierarchical Browser:
Initial screen displays 6 keyframes at the top level, then as the user brings mouse cursor over one of the keyframes, another 6 keyframes(lower level) within selected keyframe are immediately displayed. Thus by using the mouse the user can browse the hierarchically broken down keyframe structure in a highly interactive way. This idea has been developed and implemented earlier [6] [28].
Some user comments:
I'd expect the structure precisely broken down by topic.

5.2 Further Improvements and New UI Additions

The dimension space is useful for us to come up with new browsing interfaces. For example, in the space we can think of a new interface by dragging the "Scroll Bar Browser" inward along the *Temporal Orientation* axis to provide time information - this will be a Scroll Bar Browser variation with stronger time orientation for the user.

Also, we want to drag all the bottom user interfaces up to the top on the *Layeredness* axis by implementing additional layers to Scroll Bar Browser, Slide Show Browser, Timeline Bar Browser and Overview/Detail Browser.

Figure 9 below shows some possible interesting browsers in the dimension space.

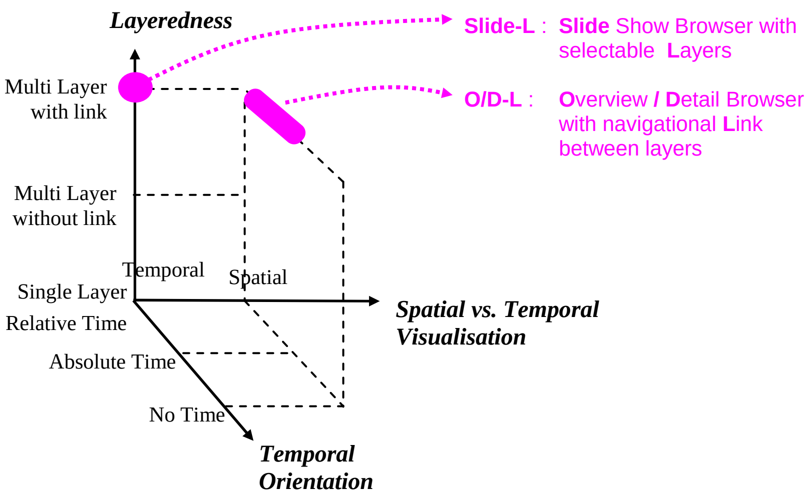

Fig. 9. Dimension space and some possible interfaces

A final note is that care has to be taken when shaping a new browser idea and implementing it. When a new browser is designed and implemented, it might be the case that the general usability problems hinder the browser and make it a bad browser when the novel idea behind it might be a very good one and worth consideration. One should not hurriedly abandon the new implementation and bury a novel browsing idea just because some artefacts make it a poor browser overall. The designer has to carefully and creatively rearrange the interface in such a way that the usability problems can be avoided or minimised while still keeping the original browsing idea.

6 Conclusion

In this paper we described our work in developing video content browsing interfaces based on keyframes. We identified three important dimensions in video data browsing, then used them to implement some of the representative interfaces. While we continue to test these interfaces with users to improve them, we also add completely new interfaces by identifying what the current interfaces are lacking in the dimension space and again getting users to try them. This user-oriented, parallel and iterative design method we find very suitable for developing novel interfaces such as video content browsing, and Físchlár system has been serving this purpose very well.

We also find a need to more specifically categorise users' browsing tasks depending on a person's cognitive direction in browsing, rather than covering it all as simply 'browsing'. A user might be browsing to get the overall gist of the whole programme as quickly as possible, or to find a certain scene s/he had already seen in order to watch that particular moment again, or even to find out why's or who's by browsing here and there to gather related information in the video. For certain kinds of tasks we plan to record all episodes of a TV programme (for example a popular soap) and use this as a testbed for the users who have already seen the series before and want to find out particular scene or scenes in the recording, so that we can see a particular browser being better utilised for content-knowledgeable users, and so on.

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