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How to Make Audio/Video as Easy to Use and Share as Text.

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Digital media content is growing exponentially, but audio and video are difficult to search and share. This paper describes *Souvenir*, a system which offers a flexible and comprehensive way for people to use their handwritten or text notes to retrieve and share specific media moments. Souvenir enables users to take notes on a variety of devices, such as the paper-based CrossPad, the Palm Pilot and standard keyboard devices. Souvenir can segment unstructured handwriting into an effective media index without the need for handwriting recognition. Using Souvenir, people can easily use their notes to create hyperlinks to random-access media stored in a digital library. Souvenir also has web publishing and email capabilities to enable anyone to access or email media moments directly from a web page. Souvenir annotations capture additional and complementary information that can not be easily inferred by automatic media indexing techniques. This paper presents an overview of Souvenir's functionality, offering a brief description of its handwriting segmentation and media synchronization algorithms. It also discusses the design rationale guiding the development of Souvenir and provides an informal evaluation and discussion of Souvenir's effectiveness.

1. INTRODUCTION

Digital media content is growing exponentially and represents the next wave of the Internet. The capture, storage and distribution of digital audio and video are becoming easy and inexpensive. Corporations are adopting streaming media to save time, reduce costs and enrich their communications. Consumers are acquiring digital media recording equipment and starting to create personal digital media collections. However, audio and video are difficult to search and share in a personal way (Adowd et al., 1998; Moran & al., 1997; Stifelman, 1996; Weber, & Poon, 1994; Wactlar et al., 1996; Whitaker et al. 1994).

This paper describes *Souvenir* which enables anyone to use what comes easy to them, creating handwritten notes, as an access and annotation mechanism to do something that is difficult for most, retrieving and sharing specific moments in a digital media library. The goal of Souvenir is to offer a flexible and comprehensive way for anyone to share and integrate digital media moments into their workflow.

People are increasingly using handheld computers to record information in mobile settings. Tablets and devices combining paper and digitizing technology, such as the CrossPad or SmartPad, can be used to create handwritten notes that are captured as digital ink. Souvenir leverages the increasing adoption of digital media and handheld computers to enable people to use their notes to playback or share specific moments in digital media libraries.

1.1 User Need

Digital libraries aim to make media-rich information accessible to "anyone, anywhere, anytime." However, users need to find it easy to access and use this media-rich content. Knowledge workers have to be able to integrate specific media moments into their workflow. Consumers want to personalize digital media and share specific moments with friends. But, general users do not possess the media editing skills and tools that are currently needed to pinpoint and organize specific media moments. What if people could use existing skills, such as taking notes and editing text, to pinpoint specific media moments and create personalized media presentations?

Souvenir has been designed to give users ease-of-use and flexibility in how they can interact with digital media: 1) Users don't have to learn a specific query language. Instead, they can use familiar skills and "loosely structured" interaction modes to access digital media, which can be stored in highly structured repositories. 2) Users can personalize digital audio/video by creating annotations that can be used as an access index. They can use diverse access and annotation devices, such as palmtop, laptop or desktop computers. 3) Users can use their annotations to create hyperlinks to random-access and integrate specific media moments into their workflow without being held captive by how and where the digital media is stored.

This paper is organized as follows: First, previous work is briefly reviewed. Second, Souvenir's functionality is described. Different scenarios are discussed of how users can take media-enabled notes on a variety of devices. We address the strengths and weaknesses of the different note-taking devices supported by Souvenir. A flowchart shows how Souvenir can convert unstructured handwritten notes into media-enabled web pages. A visual overview captures how the Souvenir Desktop application offers users a seamless way to use their notes to create hyperlinks to random-access media stored in a digital library. A "segment-oriented" framework is introduced to support both handwritten and text notes as well as the playback of different media recordings in the same Souvenir document. Third, we discuss the special issues that arise when handwritten notes captured as digital ink are to be used to index digital media. An algorithm for segmenting digital ink is briefly described that exploits spatial and temporal characteristics of how people write without having to recognize their handwriting. We also discuss the need for multiple and complementary ways to index digital media. Fourth, a flexible mechanism for synchronizing notes and media is described. Finally, we provide an informal evaluation of Souvenir and discuss its effectiveness.

2. PREVIOUS WORK

Previous research has investigated how to provide easy access to digital media collections (Adowd et al., 1998; Cruz & Hill, 1994; Moran & al., 1997; Weber & Poon, 1994; Wactlar et al., 1996; Whitaker et al.). Xerox PARC has developed Tivoli (Moran et al., 1997) for a note-taker to summarize captured meetings. Classroom 2000 (Adowd et al., 1998) automatically captures classes and integrates them with annotations created during class. Marquee (Weber, & Poon, 1994), Filochat (Whitaker et al., 1994), Dynomite (Wilcox et al., 1997) and Audio Notebook (Stifelman, 1996) have clearly demonstrated how personal note-taking can make audio/video retrieval easier.

The use of digital ink to access digital media has been studied by several research groups (Adowd et al., 1998; Chiu & Wilcox,1998; Moran et al., 1997; Stifelman, 1996; Weber, & Poon, 1994; Whitaker et al., 1994, Wilcox et al., 1997). The Classroom 2000 system (Botherton et al., 1998; Truong & Abowd, 1999) employs a simple temporal and spatial heuristic to link handwritten notes with audio recorded at the same time. Chiu and Wilcox (1998) present a way to generalize simple heuristics into a more general algorithm using hierarchical clustering.

In terms of automatic methods for indexing digital media, there is the major Informedia initiative that combines advanced speech, language and image understanding technology to transcribe, segment and index large video media repositories (Wactlar et al., 1999).

Souvenir is innovative in that it offers a comprehensive and flexible solution for anyone to easily personalize and retrieve audio/video and create hyperlinks to random-access media to share specific moments with others. Souvenir offers users a seamless way to structure their handwritten notes, combine them with text and to publish both digital ink and text as media-enabled web pages.

3. SOUVENIR

Souvenir is a digital media annotation tool with web publishing and email capabilities. It enables people to use their handwritten or text notes as a personal audio/video index. Souvenir time stamps the user's note-taking activity and uses these time stamps to synchronize the notes with the timeline of a media recording. Palmtop, laptop or desktop computers can be used to take handwritten or text notes while digital media is being recorded or played back. Users can take notes during (the playback of) a lecture, interview, meeting or movie. Users can be there in person or remotely via phone, teleconferencing or the Internet. At the same time, the audio/video recording or playback can occur on their palmtop, laptop, and desktop computer or remotely on an Internet server. Souvenir enables users to link their notes to the related media file wherever it is stored. Once linked, users can double click any digital ink or text to play the media at the time the note was taken.

Figure 1 provides a flowchart of how Souvenir can convert "unstructured" handwritten notes into structured data that (a) can be used to query and access a digital media library, and (b) can be published as media-enabled web pages.

Figure 2 shows an overview of Souvenir's functionality: 1) Users can take media-enabled notes in multiple ways: (a) the media is recorded or stored on the same device used for taking notes; thus making it easy to synchronize media and notes internally; (b) media and notes are stored on different devices, but they can be synchronized locally; (c) the notes can be synchronized with media hosted on a remote Internet server. 2) The referenced media can be uploaded to or stored in a digital media library. 3) The Souvenir Desktop application offers users a flexible and seamless way to link and synchronize their handwritten or text notes via the network with the appropriate media file in a digital library. The Souvenir Desktop enables users to store, synchronize, annotate, edit and publish their notes created by a palmtop, laptop or desktop computer: (a) handwritten notes can be segmented and annotated with text; (b) only the text components of the segments can be displayed and shared with others. 4) Users can publish their Souvenir documents as a set of web pages. 5) Users can email hyperlinks to specific media moments directly from a web page or using the Souvenir Desktop application.

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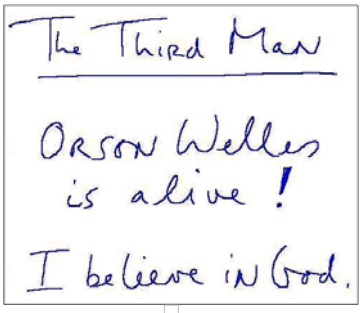


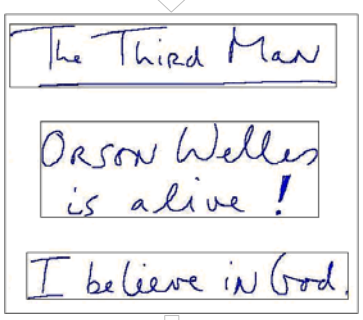
Unstructured Handwritten Notes

Handwriting is ideal for taking quick notes to capture one's thoughts. However, handwritten notes are "unstructured" and text notes are highly structured. Hence, handwritten notes need to be grouped and structured to enable both digital ink and text in the same Souvenir document and to be an effective query index for digital media/*.

Media-enabled Notes

Souvenir time stamps the user's note-taking activity so that these time stamps can be used to synchronize the notes with the timeline of a media recording to enable pinpoint media playback.

2



Segmentation of Handwritten Notes

Souvenir can organize digital ink into segments without having to recognize handwriting. Souvenir employs a "segment-oriented" framework to support: (a) both handwritten and text notes as well as (b) the playback of multiple media recordings in the same document, (c) to enable users to interact with digital ink at a higher-level of organization instead of having to manage a large number of individual strokes, and (d) to create hyperlinks to random-access media wherever it is stored.

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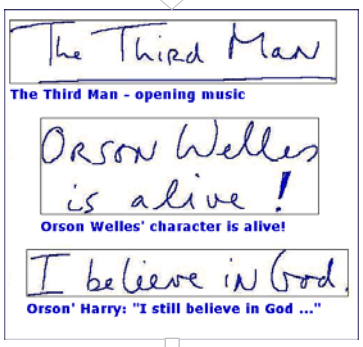

Text Annotation of Digital Ink

Handwritten notes are often hard to read and therefore difficult to share with others. In Souvenir, users can easily annotate an ink segment, where the associated text is displayed directly below it.

Media Synchronization

Souvenir can automatically synchronize notes and media if (a) the audio/video is recorded on the same device used for taking notes, or (b) the media playback occurs in the Souvenir Media Player. In all other cases, users simply need to identify a specific media moment to be linked with a specific note. After that, Souvenir does the rest. Double clicking on the digital ink or text will play the associated media.

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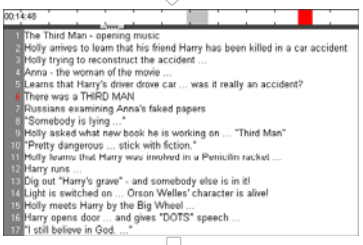

Text View of Notes

Users can use the "text only" view to expand their initial, quick notes to create a full report to be shared with others. They can edit and rearrange their text notes as well as "copy & paste" notes from other Souvenir documents that reference different media files. A media timeline on top of the text notes enables users to fine-tune the relationship between their notes and the associated media.

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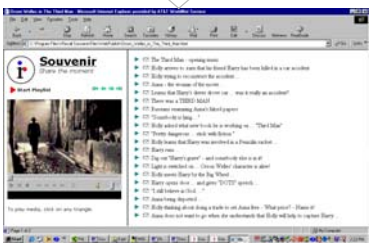


Web Publishing & Email Sharing

Users can publish their Souvenir documents as a set of web pages so that others can access or share via email specific media moments directly from a web page. The media owners do not lose control over their content, because users are only creating and sharing pointers to specific media moments instead of actually copying the content.

Figure 1: shows how Souvenir can be used to convert "unstructured" handwritten notes into structured data that (a) can be used to query and access a digital media library, and (b) can be published as media-enabled web pages.

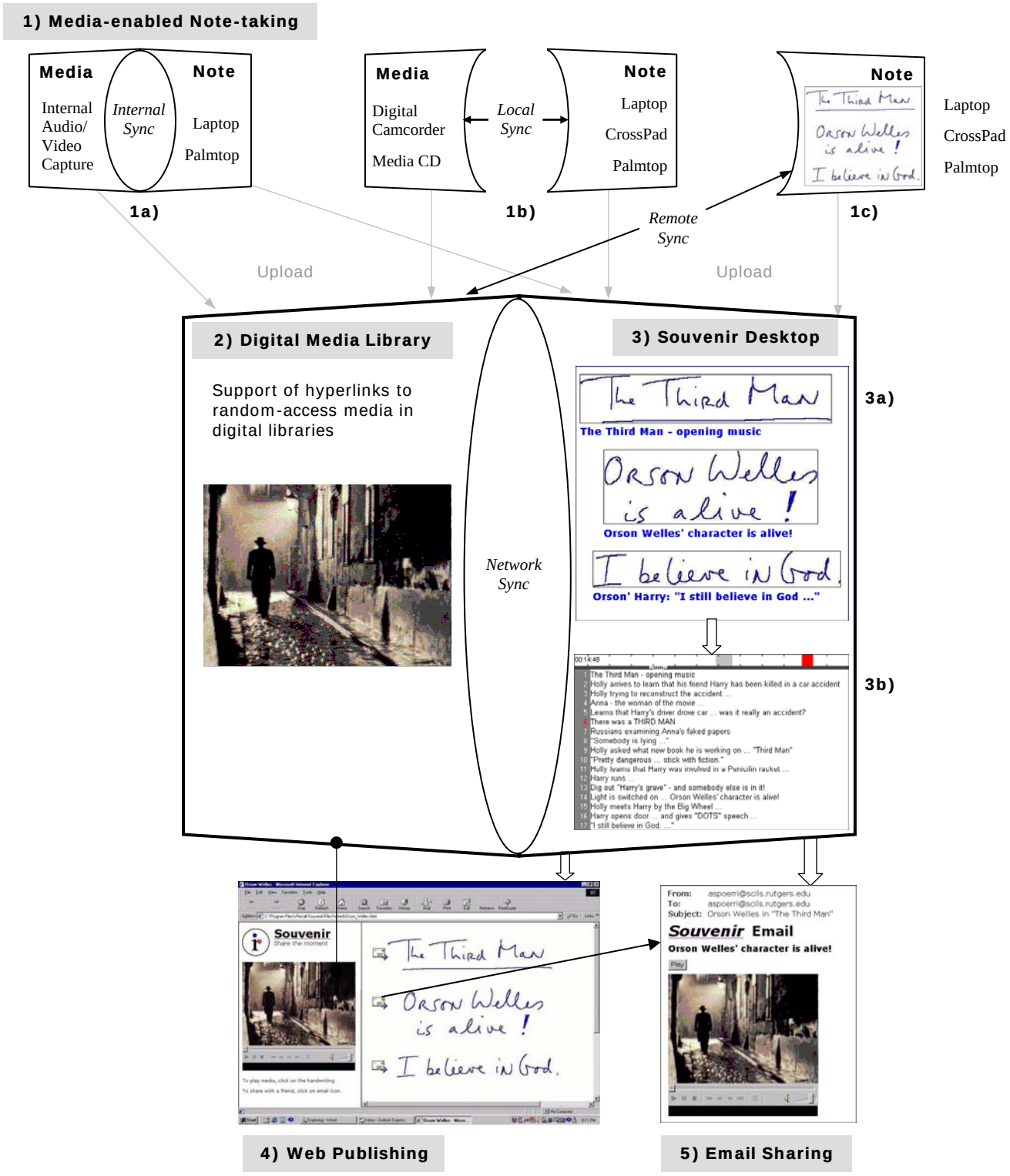


Figure 2: shows an overview of Souvenir's functionality: 1) Users can take media-enabled notes in multiple ways (see text for more info). 2) The referenced media can be uploaded to or stored in a digital media library. 3) The Souvenir Desktop application offers users a seamless way to synchronize their notes via the network with the appropriate media in a digital library. The Souvenir Desktop enables users to edit their notes: (a) digital ink can be segmented and annotated with text; (b) only the text components of the segments can be displayed. 4) Users can publish their Souvenir documents as a set of web pages. 5) Users can email hyperlinks to specific media moments directly from a web page or using the Souvenir Desktop.

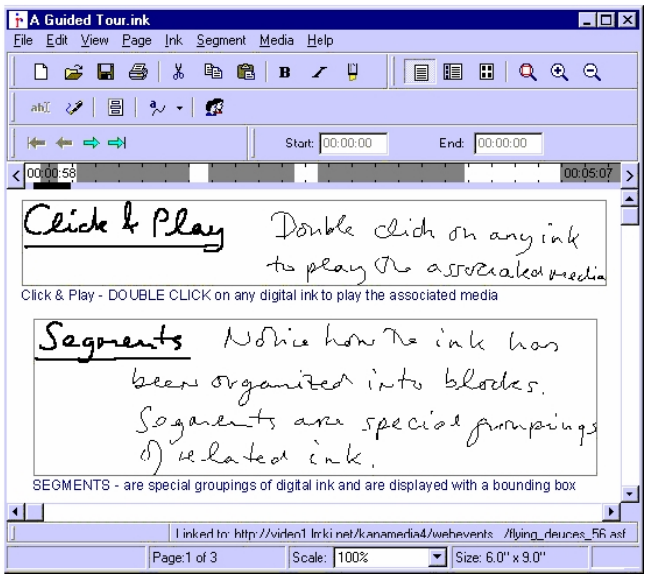


Figure 3: The *Souvenir Document* window consists of a *media timeline* and a *document display*, which shows digital ink segments surrounded by a bounding box and the associated text directly below. Double-clicking on the digital ink or text plays the associated media. The media timeline shows how the segments, displayed in dark gray, are related to the media.

3.1 Souvenir Desktop

The Souvenir Desktop application enables users to store, synchronize, annotate, edit and share their media-enabled notes that were created using a palmtop, laptop or desktop computer. The Souvenir Desktop offers users a seamless way to synchronize their notes via the network with the appropriate media wherever it is stored. The Souvenir document window, which makes pinpoint media playback possible, consists of a media timeline and a document display (see Figure 3). The media timeline enables user to fine-tune the relationship between their notes and the associated media. The document display supports three display modes (ink only, text only, and ink & text), thumbnails and different magnifications views.

3.2 Supported Annotation Devices

Souvenir is flexible in terms of the devices that can be used to create media-enabled annotations. Souvenir currently has companion applications for the *Palm Pilot* and the *CrossPad*, a portable digital notepad that digitizes notes written on paper, to enable the capture of handwritten notes as time-coded digital ink. Notes taken with a Palm Pilot or CrossPad need to be uploaded to a PC.

The Souvenir Palm Application enables users to create time-stamped notes, where each note has three components: 1) “Digital Ink” – handwritten notes created by writing with a stylus on the Palm screen. 2) “Text” – created using Graffiti or a keyboard. 3) “Keywords” – up to six keywords can be assigned to a note.

Users can think of a Souvenir Palm note as a “post-it” note on which they can scribble short handwritten notes, add text notes on the backside and categorize it using up to six keywords at the same time. The notes created with the Souvenir Palm application are uploaded to a PC each time the user performs a HotSync and are automatically transferred to the Souvenir Desktop application.

The note-taking devices supported by Souvenir have different strengths and weaknesses in terms of creating media-enabled notes: (a) The CrossPad enables note-taking on paper, which is the preferred way for most people to take notes, and its writing area is large enough to take extensive handwritten notes. But, the CrossPad can not record or playback digital audio or video. CrossPad notes have to be uploaded to the Souvenir Desktop to be linked to the related media recording. Stifelman (1996) has developed a digital notepad prototype that can record digital audio, but it could not be successfully commercialized. Further, the CrossPad and digital notepads like it have only been adopted by a small user population so far. (b) The Palm Pilot has been widely adopted because of its effective interface and small size, which in turn makes it difficult to take extensive digital ink notes. This is why the Souvenir Palm application also supports text notes. The Palm Pilot is ideal for taking short handwritten or text notes in a way that is non-intrusive during a meeting or class. (c) Keyboard-based devices are universally used. However, most people can not type as fast as they can write by hand. Users need to be skilled typists to take notes that do not "lag behind" the media moments they wish to pinpoint. (d) Tablet computers can be used to take media-enabled notes, but their current costs are prohibitive.

As the above discussion shows, there does not currently exist an "ideal device" for taking extensive media-enabled notes easily, quickly and affordably. This is why the Souvenir Desktop application has been designed to support notes created by a variety of devices, which are currently affordable and could be adopted or are being used by a large user population.

3.3 Segment-Oriented Framework

A Souvenir document is composed of *segments*, whose data structure stores: (a) digital ink and/or text; (b) the associated media file and its playback start and end times. Souvenir employs a "segment-oriented" framework to support: (a) both handwritten and text notes as well as (b) the playback of multiple media recordings in the same document, (c) to enable users to interact with digital ink at a higher-level of organization instead of having to manage a large number of individual strokes, and (d) to create hyperlinks to random-access media wherever it is stored. These hyperlinks make it easy for anyone to share specific media moments without the need to transfer large media files. The media owners do not lose control over their content, because users are only sharing pointers to specific media moments instead of copying the content.

Souvenir is built on the premise that users' initial notes are "imperfect" or "noisy" in terms of how precisely they pinpoint the intended media moment and how completely they describe or annotate it. Souvenir aims to make it easy for users to "edit and polish" their initial Souvenir notes to create a report that can be published and shared with others via the Internet. Souvenir has been designed so that users can use their text editing skills to organize and refine their initial media-enabled notes. In particular, Souvenir organizes handwritten notes into segments so that users can interact with digital ink at a level of organization that is familiar and makes it easy to edit and refine their hand-written notes. Users can easily annotate digital ink segments with text or add new text and link it to a specific moment in a media recording. Users can edit and rearrange their notes as well as "copy & paste" notes from other Souvenir documents that reference different media files. Users can then publish their report as set of web pages so that others can access or share via email specific media moments directly from these pages (see Figures 1 and 2).

3.4 Media Editing

The notes taken by general users have a tendency to lag behind the moment in the media recording they wish to pinpoint. Souvenir has been designed to make it easy for users to correct for this "lag problem." On the one hand, users can specify a general "playback offset" that is added or subtracted from the “start” and “end” times of all segments in a Souvenir document. On the other hand, users can fine-tune the relationship between a specific segment and its associated media. Users can edit and change the “start” and “end” media times of a segment via edit controls in the document window or by interacting with the media timeline. The media timeline shows how the ink and text segments are related to the timeline of the associated media recording(s). The segments are displayed in dark gray on the media timeline (see Figure 3). Users can change the start and/or end time of a segment by changing its spatial area in the media timeline.

4. STRUCTURING HANDWRITING

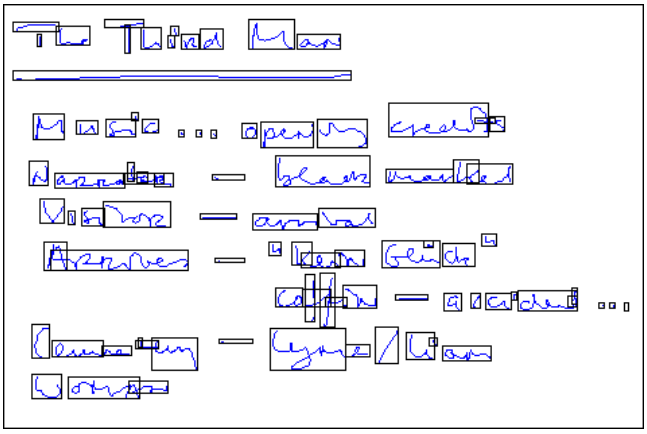
Handwriting is ideal for taking quick notes. However, handwritten notes are "loosely structured" whereas text notes are highly structured. Hence, handwritten notes need to be structured to enable both digital ink and text in the same Souvenir document and to be an effective index for digital media. Furthermore, people need to be able to interact with digital ink at a level of organization that is easy and familiar. People most commonly interact with text at the word, sentence or paragraph level, where the latter two units of organization are used for attaching annotations in text documents.

At the lowest level of organization, handwritten notes are a collection of strokes, where each stoke represents the pixels touched between successive "pen-down" and "pen-up" events. Figure 4(a) shows a collection of strokes that are surrounded by rectangular bounding boxes. Human handwriting is structured and governed by constraints. People (in the West) have a tendency: (a) to write consecutive or related words spatially close together; and (b) to create straight lines of text. Further, people have a tendency to write a few (lines of) words describing their current thought, to pause for a while and then to start a new thought or to add more to the current or to a previous thought. These constraints can be used to create a simple, yet robust digital ink segmentation algorithm, which assumes that users create lines of text and write top to bottom. However, the algorithm makes no assumptions about the direction, orientation or line height of the hand-written text and can adapt to the user's current writing style. The algorithm segments digital inks into units of organization that are equivalent to text paragraphs (see Figure 4(b), (c)). Users can now interact with their handwritten notes in a familiar way and organized in such a way that makes it easier to annotate, edit or refine them .

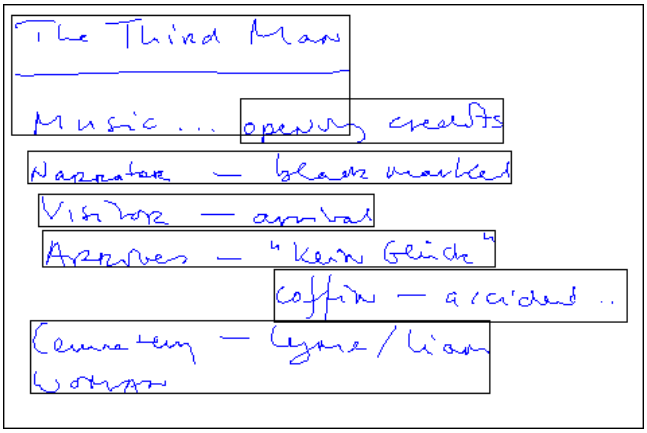
The Souvenir segmentation algorithm groups digital ink into segments by exploiting spatial and temporal character-istics of how people write without having to recognize their handwriting. Figure 4 shows how Souvenir can segment and structure handwritten notes that initially consist of a collection of strokes: (a) shows the individual strokes, which represent the pixels touched between successive "pen-down" and "pen-up" events, surrounded by bounding boxes; (b) shows the segments detected by the Souvenir algorithm and displays them with rectangular bounding boxes - "opening credits" is detected as a separate segment because of a significant time gap in note-taking activity; (c) demonstrates that Souvenir can segment text written at different angles in the same document. The detected segments are displayed with minimal area bounding boxes, which make it easier to see the individual segments.

Once Souvenir has segmented the digital ink, users can easily change or edit the detected ink segments by merging, splitting, ungrouping, regrouping or annotating them. For example, users can split a segment by selecting it and moving the cursor inside of it - the segment is then split in two based on the cursor position in an interactive way. The goal of the Souvenir segmentation algorithm is not to "perfectly" segment the digital ink, but instead to organize it so that users can more easily edit their handwritten notes.

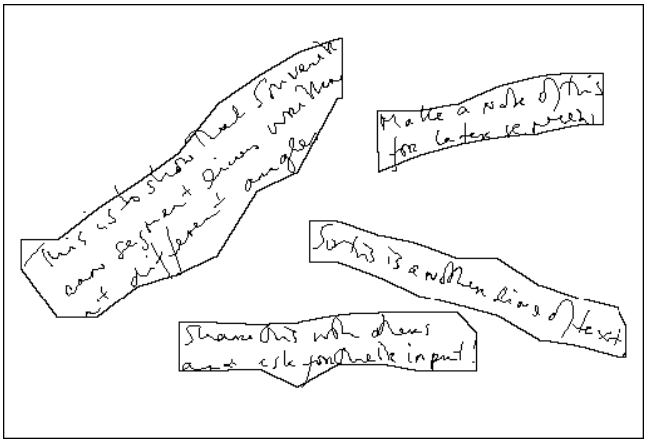
As Figure 4(b) shows, digital ink in close spatial proximity is not always created close in time. This fact matters because Souvenir wants to use the temporal properties of handwritten notes to index audio/video. Without access to the creation times of the digital ink, it is difficult to detect that notes spatially close have not been created close in time. Souvenir uses note-taking devices, such as the Cross-Pad or Palm Pilot, that time-stamp digital ink. One of the goals of Souvenir is to make visible when digital ink was added later in time in the vicinity of already existing ink.



(a) Individual strokes, which represent the pixels touched between successive "pen-down" and "pen-up" events, surrounded by bounding boxes.



(b) Detected segments by Souvenir shown with bounding boxes. "Opening credits" is detected as a separate segment because of a significant time gap in note-taking activity.



(c) Demonstrates that Souvenir can segment text written at different angles in the same document. The detected segments are displayed with minimal area bounding boxes, which make it easier to see the individual segments.

Figure 4: shows how Souvenir can segment and structure digital ink that initially consists of a collection of strokes.

Next, we need to discuss the different ways in which users may intend to relate a note with digital media. The "intention" or function of a note in relation to a media file can be: (a) to just comment on a specific moment in time; (b) to describe a limited time period in a media recording; (c) to fully capture the spoken content in a one-to-one relationship with the written notes, as is the case in closed captioning, but which can only be created by a specialist; or (d) to be an addition to an existing note that pinpoints a media moment other than the current media time. Now, it takes a certain amount of time to create a note and the note-taking timeline is linear and monotonic increasing. Additional information is needed to determine the specific purpose of a note in relation to the media timeline. For example, if the state of the media recording or playback device is in "pause" or "stop," then the written words are most likely to describe or comment on the current media time. Souvenir takes into account the relationship between media playback and note-taking timelines when linking notes and media (see Figure 5).

As the above discussion shows, structuring digital ink as well as synchronizing it to the appropriate media moments can be difficult. Souvenir offers users a seamless and flexible way to structure and synchronize their handwritten notes with digital media wherever it is stored.

4.1 Multiple & Complementary Indexes

Audio and video content can be described at multiple levels of organizations to facilitate the creation of a retrieval index. There are major research efforts to automatically identify the content of individual image frames or movie sequences (Wactlar et al., 1996). The media index created by user annotations represents an additional and complementary way to index digital media. On the one hand, human media annotations are time consuming to create and have required so far specialized software tools to produce. On the other hand, the user annotations represent "value-added" information that can not be easily inferred by automatic techniques. Souvenir aims to "liberate" the creation of user media annotations: (a) a variety of inexpensive devices and tools can be used to create them; (b) the media-enabled annotations can be leveraged without being held captive by where and how the digital media is stored; (c) users can use their time more productively, because they get a personalized media index "for free" when they take Souvenir notes while experiencing digital media.

5. Note & Media Synchronization

Souvenir time stamps the user's note-taking activity. It uses these time stamps to link and synchronize the notes with the timeline of a media recording. This way the notes can be used to access and playback specific moments in a media recording. The synchronization of the notes and media timelines is conceptually straightforward: identify a specific media moment to be linked with a specific note and the resulting relationship between their respective time-

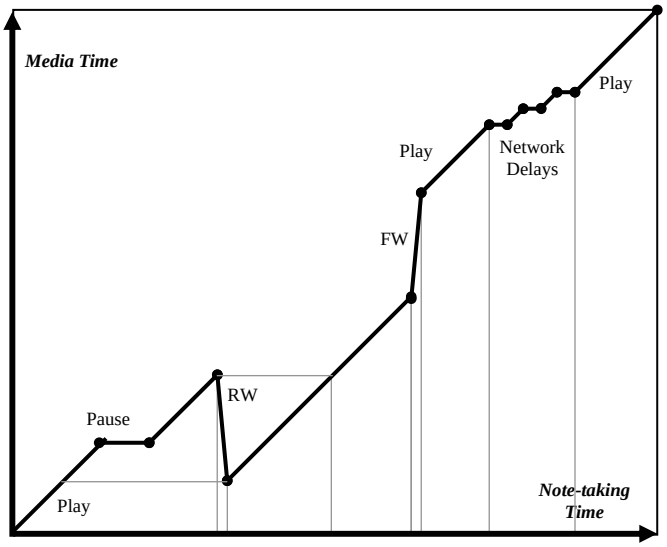


Figure 5: shows the piecewise linear relationship between media playback activity and simultaneous note-taking activity that needs to be taken into consideration when synchronizing Souvenir notes and media.

codes can be used to compute the media playback offsets for all the other notes. This presupposes that the recording or playback of the media is a strictly monotonic, linear event. However, users can pause, play, rewind or fast forward the media while taking notes. If the media is delivered via a network, playback delays can also occur. The Souvenir Media Player keeps track of when a user plays, pauses, rewinds or fast-forwards a media recording. This player, which can play local as well as Microsoft or RealNetworks streaming media, also monitors the network performance if the media is streamed. Souvenir can use this database of media playback activity to link the user's note-taking activity with the appropriate media moments.

Souvenir automatically performs the synchronization of notes and media if (a) the audio/video is recorded or played back on the same device used for taking notes, or (b) the media playback occurs in the Souvenir Media Player. In all other cases, a wizard will guide users through a simple process where they need to identify a specific media moment to be linked with a specific note. After that, Souvenir completes the synchronization of notes and media, taking into account the piecewise linear relationship between media playback activity, network performance and simultaneous note-taking activity (see Figure 5).

Souvenir is build on the premise that users want the flexibility to use different devices to capture and playback digital media. However, users will want to be able to share their media-enabled notes with others. Hence, they will want to upload or store the referenced media in a digital library that accessible to others via the Internet. Souvenir makes it easy for users to update or change the location information of the media recordings referenced in a Souvenir document.

6. EVALUATION & DISCUSSION

Souvenir has been downloaded by quite a few people. Informal tests of Souvenir's digital ink segmentation algorithm are encouraging (see Figures 1, 3 and 4). The algorithm can segment notes created by different note-takers without the need for any training or special instructions. However, a formal evaluation is needed and planned to test the effectiveness of the segmentation algorithm more rigorously. Considering the high variability of human handwriting, the algorithm tracks simple properties that are robust enough to detect segments that are useful and match how the note-takers would visually parse their notes. As mentioned, handwritten words in spatial proximity can be assigned to different segments when they were not all created at the same time. This can be "visually counter-intuitive" until the user remembers that the timeline of how the notes were created is not always easy to see.

Souvenir offers users a flexible mechanism for linking notes and related media. In the "worst case," users have to identify a specific media moment to be linked with a specific note and then Souvenir does the rest. However, general users will adopt Souvenir only if the synchronization is automatic and transparent.

So far users have had to use specialized tools to pinpoint and share specific media moments. Using Souvenir, users can create a media "edit list," which stores the start and end times of a series of media clips, without having to learn new skills. Souvenir has been designed to enable users to use their note-taking and text editing skills to manipulate digital media without having to be concerned about where and how the referenced media has been stored.

Souvenir makes it easy for anybody to bookmark specific moments in streaming media hosted on the Internet. However, some media sites make it difficult to identify the URLs of their media content to prevent "deep linking." Having access to the URL makes it possible to play the streaming media in the Souvenir Media Player, which in turn makes it easy for Souvenir to automatically link the notes with the related media. The reluctance of media sites to make the media URLs easily available is a pity, because Souvenir encourages its users to only create and share pointers to specific media moments instead of actually copying the content and media owners losing control over their content. Actually, the Souvenir media annotations could be used for community building and data mining purposes. The Souvenir notes make it possible to access and share specific media moments without the need to view the entire recording, resulting in a more efficient use of server resources. Content providers can use the personal media annotations and the resulting targeted access of their content to visualize frequently accessed moments.

7. CONCLUSION

Souvenir is a versatile note-taking tool to pinpoint, share and publish audio/video highlights. Souvenir is innovative in that it offers a comprehensive solution for users to use their handwritten or text notes to create an effective audio/video index. Souvenir annotations capture additional and complementary information that can not be easily inferred by automatic media indexing methods. Souvenir gives users flexibility in how they can access and integrate digital media moments into their workflow. Users can take media-enabled notes on a variety of devices, such as the paper-based CrossPad, the Palm Pilot and standard keyboard devices. Souvenir can organize digital ink into segments, which are detected using a segmentation algorithm that exploits spatial and temporal characteristics of how people write without having to recognize their handwriting. Souvenir employs a "segment-oriented" framework to support: (a) both handwritten and text notes as well as (b) the playback of multiple media recordings in the same document, (c) to enable users to interact with digital ink at a higher-level of organization instead of having to manage a large number of individual strokes, and (d) to create hyperlinks to random-access media wherever it is stored. Souvenir is flexible in terms of how to synchronize notes and media, taking into account the piecewise linear relationship between media playback and note-taking timelines. Souvenir also has web publishing and email capabilities to enable anyone to access or share specific media moments directly from a web page.

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