Time Quilt: Scaling up Zoomable Photo Browsers

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ABSTRACT

As automatic image indexing technologies have yet to mature [19], large digital photo collections still require a correspondingly large manual organization effort. Without such an effort, only the camera-recorded metadata, specifically the creation date, and the photos' visual contents are available. Current zoomable photo browsers (e.g., PhotoMesa [7]) are designed to support visual searches but, in trying to maximize screenspace usage, they cannot effectively convey temporal order. Conversely, a linear timeline layout makes poor use of screenspace and requires excessive panning. We propose *time quilt*, a novel layout that conveys temporal order while making better use of space than a linear timeline.

In an experimental comparison of space-filling, timeline, and time quilt layouts, 10 participants carried out the task of finding photos from their personal photo collections averaging 4,000 items. They performed 45% faster on time quilt.

Furthermore, while current zoomable photo browsers are designed for visual searches, this support does not scale to thousands of photos: individual thumbnails become less informative as they grow smaller. We introduced and found a subjective preference for the use of representative photos to provide an overview for visual searches in place of the diminishing thumbnails.

Categories & Subject Descriptors: H5.2 [Information interfaces and presentation]: User Interfaces. - Graphical user interfaces.

General Terms: Human Factors, Design.

Keywords: Photography, timeline, space filling, time ordering, representative photo, zoomable user interface.

INTRODUCTION

Compared to film photography, digital photography has a lower cost for taking and storing pictures. As a consequence, digital photos tend to accumulate much more quickly than film photos. From IDC's 2003 U.S. Consumer Digital Imaging Survey, 17% of the respondents took 50–100 photos per month, yielding collections of up to 6,000 images over a 5 year period. 8.9% of the respondents took more than 100 photos per month.

As a photo collection grows, it becomes harder to manage. Particularly, it takes time and effort to create structures that will facilitate browsing and searching that collection (e.g., tagging the photos with keywords, filing them into a hierarchy of file folders, annotating them with comments). But the very aspect of the collection that demands organization—its size—also defies manual organization: Frohlich et. al. [11] reported that very few families participating in their user study systematically organized their digital photo collections.

There are means for automatically index photo collections by visual content analysis, but Kuchinsky et. al. [15] expressed concern that such content-based indexing and retrieval approaches focused on directed search but neglected users' information seeking behaviors. As if confirming this concern, Rodden and Wood [19] reported that the content-based image retrieval feature offered in their user study's test system was rarely used and its perceived utility was low.

While most photo browsers rely on the presence of user-provided metadata to support effective searching and browsing, users cannot always be counted on to invest time and effort to create complete, coherent structures. However, the metadata recorded by cameras, specifically the creation date, and the photos' visual contents are always guaranteed to be present. Not only is creation date recorded automatically, it is also an essential factor by which people browse their photos [12]. With only creation date and visual content, people can perform two complementary tasks:

- reminisce over a past period of time, to answer such questions like, 'what pictures do we have from the last five years?'; and

- find photos associated with some memorable events (e.g., 'that photo of you hanging from a cliff that I took on our trip to the Grand Canyon two years ago').

Zoomable photo browsers (e.g., PhotoMesa [7]) are designed for the second task by maximizing screenspace usage (with a space-filling layout such as quantum treemap [7]) for faster visual searches. Their space-filling layouts, however, are not designed to convey temporal order. Although they can cluster photos by creation date, the clusters are not laid out in such a way that communicates their order in time. Changing the layouts of existing zoomable photo browsers to convey time will sacrifice screenspace. A linear timeline trades all space optimization for a straightforward presentation of temporal order. We propose a layout called *time quilt* that wraps photo clusters in columns to make a compromise between space-filling and time-ordering (Figure 1).

Not only do existing zoomable photo browsers need to convey temporal order, their support for visual searches must also scale to the order of thousands of photos. These browsers currently do not implement any form of semantic zooming to compensate for the loss of visual information when thumbnails become too small to be recognizable and distinguishable from one another. Figure 1 shows how representative photos can be used to provide a more informative overview than a rendition of scaled down thumbnails.

CONTRIBUTIONS

In this paper, we propose *time quilt*, a novel layout for zoomable photo browsers designed to convey temporal order while making better use of space than a linear timeline. It is a compromise between space-filling layouts and the linear timeline layout. We also propose using representative photos to implement semantic zooming as the number of photos grows and the thumbnails become too small to support visual searches in these browsers.

In an experimental comparison of space-filling, timeline, and time quilt layouts, 10 participants carried out the task of finding photos from their personal photo collections averaging 4,000 items. They performed 45% faster on time quilt (Bonferroni $p < 0.05$) and indicated a subjective preference for the use of representative photos (5.70 on a Likert scale of 7, $p < .01$).

PRIOR WORK

Personal digital photography started to attract the attention of researchers in 1999 as Kuchinsky et. al. [15] introduced FotoFile, a consumer-oriented multimedia organization and retrieval system. This work recognized consumers' lack of economic incentives for up-front time and effort devoted to annotating their own photo collections for the purpose of directed, keyword-based searches later. Kuchinsky et. al. also noted that automatic content-based indexing and retrieval

Figure 1. Time quilt – a layout designed to convey temporal order while making better use of screenspace than a timeline, showing approximately 5,500 photos with representative photo overview

were not the complete solution, either, as they did not map to consumers' information-seeking behaviors. In light of these observations, FotoFile was designed to support both directed searches and exploratory browsing.

In the same year, Combs and Bederson [8] built the first zoomable image browser and found that such a zoomable UI performed as well as a conventional 2D image browser, but better than a 3D browser for collections of up to 225 images. However, they did not test their browser on larger, *personal* photo collections. Bederson followed up in 2001 with PhotoMesa [7], a second zoomable photo browser that used space-filling layouts as discussed above. PhotoMesa was implemented in the Pad++ UI framework [6] but it did not at the time make use of the semantic zooming support that the framework already offered.

Kang and Shneiderman [14] introduced PhotoFinder in 2000, equipped with a set of visual Boolean and dynamic query interfaces. Users can search for photos based on multiple criteria, including date, people, event, location, color, keyword, rating, etc. In essence, PhotoFinder attempted to address searching more than browsing.

In 2002, Platt et. al. [17] performed on of the first formal user studies of personal photo collections (averaging 850 images). Their photo browser, PhotoTOC, introduced representative photos to create an overview, table-of-content summary of photos clustered by date and time. Their contributions included the user of representative photos, new algorithms for clustering similar photos by date other attributes, and methods for selecting representative photographs. Their browser rendered the representative photos in a separate overview pane; while in our work, we render representative photos *in the place of* their clusters—that is, we implement semantic zooming. At the time, the study found that choosing an inappropriate thumbnail to represent a collection caused great difficulty with the users for finding a photo, though we did not find this to be a problem in our time quilt-based test browser.

As the domain of personal digital photography got the spotlight, in 2003, Rodden and Wood [19] took a step back and asked, "How do people manage their digital photographs?" Their six month-long user study on 13 participants concluded that two of the most important features to support in photo browsers were (1) automatically sorting photos in chronological order and (2) displaying a large number of thumbnails at once. Their participants most commonly wanted to browse their personal photos by event rather than by querying them based on more specific properties. This finding motivates our investigation of a time-ordering layout that visualizes a large number of images all at once.

Finally, in 2004 Drucker et. al. [9] presented a careful selection of many previous research concepts integrated into a single browser, the MediaBrowser. By integrating temporal clustering with rapid selection, they were able to make it easier for users to annotate their collection. Like the makers of the previously discussed photo browsers, they too found it hard to conduct a formal study on their prototype. Nevertheless, an informal study directed their attention to the scalability of their browser: loading MediaBrowser with more than 500 or 600 objects renders individual thumbnails hard to distinguish by eye. This is a motivation for our use of representative photos.

With regards to presenting temporal information, there is also much prior work. In particular, Plaisant et. al. [16] presented LifeLines in 1996 as a simple and tailorable visualization environment for showing personal histories in multiple facets. Also in 1996, Fertig et. al. [10] presented the system Lifestreams for showing a user's personal file system in a timeline format. However, it is not clear how either LifeLines or Lifestreams can be customized to show thousands of photos effectively.

Ringel et. al. [18] also investigated a timeline layout to present search results from personal information corpora. They used photo thumbnails as landmarks on their timeline visualization although the main information being visualized is not photographs but e-mail messages, appointments, and other documents.

The software industry has also introduced time-based browsing of personal photo collections. For example, Adobe Photoshop Album [2], Microsoft Digital Image Library [3] and Picasa [5] provide a linear timeline while ACDSee [1] and iPhoto [4] support a monthly calendar view.

The scalability of thumbnails has also been investigated. As the number of thumbnails increases, the thumbnail size decreases. To address the problem of shrinking thumbnails, Suh et. al. [20] proposed a method of automatically cropping a photo to keep only its most salient region such that a more recognizable thumbnail can be generated from it. This solution works to some relatively small size, but beyond this, no recognizable thumbnail can be generated regardless of the original image's saliency. This is why we chose to investigate the use of representative photo overview to replace the shrinking thumbnails.

DESIGN RATIONALES FOR TIME QUILT LAYOUT

Space-filling versus Time-ordering Layouts

The essence of the time quilt layout was derived from two observations:

- Space-filling layouts do not convey chronological order effectively. Figure 2 shows a space-filling layout (quantum treemap) of a sample collection of 5,500 photos clustered by dates and times. While May 8th, 2004 and May 15th, 2004 are closer dates than May 8th, 2004 and June 3rd, 2003, they map to clusters that are further apart.

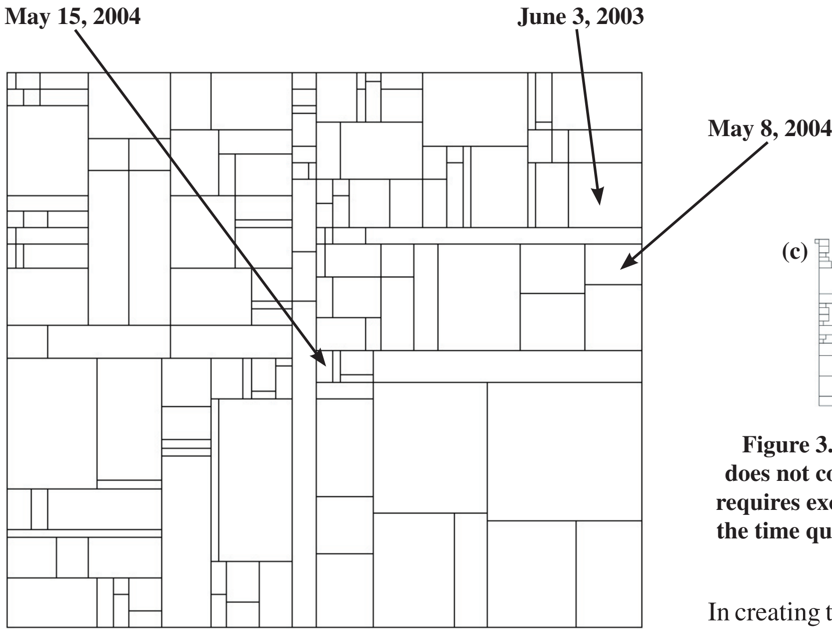
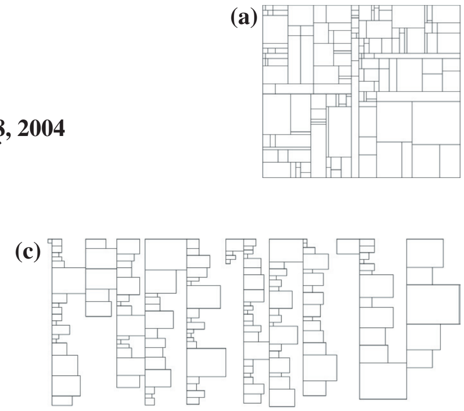


Figure 2. Space-filling layouts do not convey chronological order: closer dates might map to far-apart clusters

Although, the hierarchical nature of the space-filling layout in Figure 2 might be understandable at the overview level, it makes the task of finding the next cluster in time difficult when the visualization is zoomed in. For a large photo collection, the user does need to zoom into a smaller section of the whole visualization before s/he can perform a visual scan.

- While space-filling layouts fail to convey chronological order, the traditional, linear timeline yields a severe aspect ratio for a large collection (Figure 3). It makes poor use of screenspace and requires excessive panning to visually scan over several consecutive clusters.



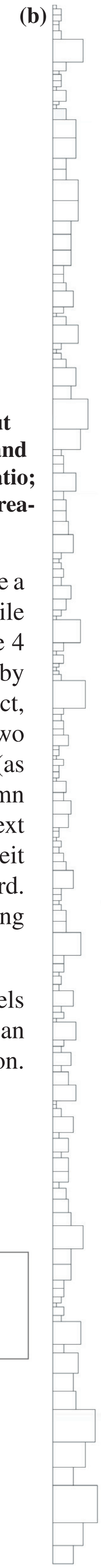


Figure 3. A space-filling layout (a) saves space but does not convey time; a timeline (b) wastes space and requires excessive panning due to adverse aspect ratio; the time quilt layout (c) conveys time and achieves reasonable aspect ratio

In creating the time quilt layout, we wished to make a compromise in conveying chronological order while avoiding severe aspect ratios. Figure 3 and Figure 4 illustrate how time quilt satisfies this requirement by wrapping the clusters in vertical columns. In effect, it is a compressed horizontal timeline. Although two clusters consecutive in time might be far apart (as might be in a space-filling layout) due to a column break, there is a simple strategy to go to the next cluster even if the visualization is zoomed in, albeit the strategy might involve a lot of panning upward. Compared to a timeline, time quilt requires panning less frequently.

The maximum column height is measured in pixels at the 100% zoom level where thumbnail images can be rendered as is without any scaling transformation.

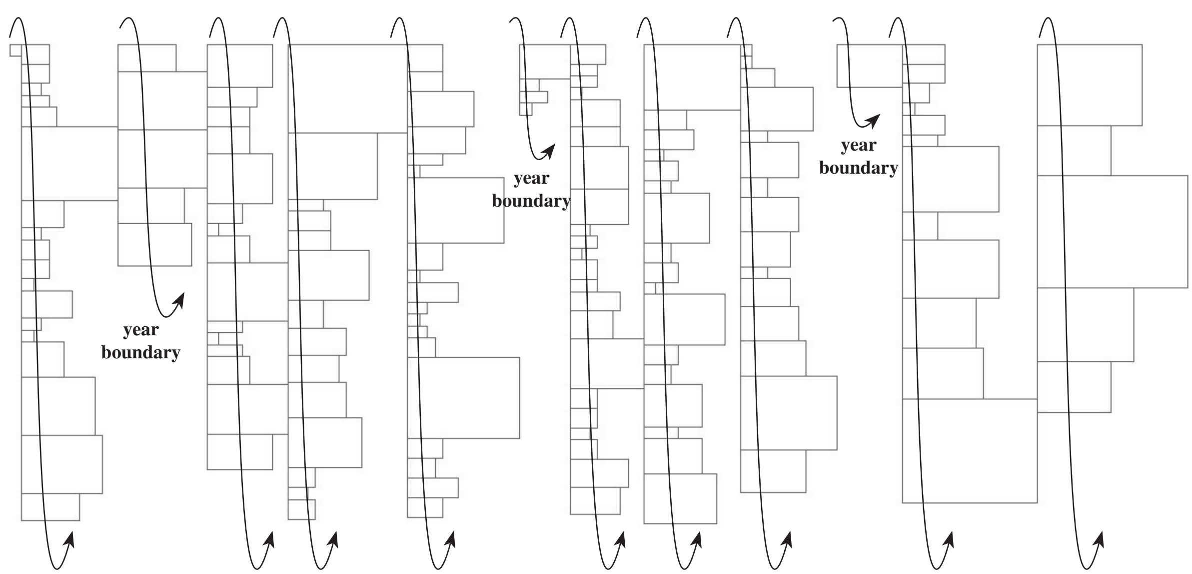


Figure 4. The time quilt layout wraps photo clusters in columns, breaking at a specified maximum column height or at year boundaries

For the collection of 5,500 photos shown in Figure 1 we used 7,000 pixels as the maximum column height.

To give more overview information, we use gradients to indicate year boundaries (Figure 1). We also break into another column when we detect a year boundary. This is similar to breaking onto a new paragraph in wrapping text.

There are other ways to achieve reasonable aspect ratios while still conveying chronological order. For instance, the clusters can be laid out in a spiral or in a zig-zag pattern. However, we chose the saw-tooth pattern because people are very familiar with the similar concept of text wrapping and it is straight forward to compare the temporal order of any two clusters: if a cluster is located to the right of another cluster, it is later in time, or if both clusters start at the same horizontal position, the lower one is later. We do not claim that this is the best way to compress the timeline. We only wish to compare *a* way to compress the timeline against the timeline layout and the space-filling layouts.

Each cluster of photos is laid out as a grid of thumbnails (when zoomed in) with an aspect ratio matching that of the screen. This choice makes maximum use of the screen space when the cluster is zoomed in, which avoids unnecessary panning. Note that with a space-filling layout, individual clusters often have unexpected severe aspect ratios although the aspect ratio of the whole visualization can be controlled. The time quilt layout can control both the overall aspect ratio as well as the aspect ratio of individual clusters, but at the cost of some whitespace in between the clusters. We believe that this inter-cluster whitespace is not wasted whitespace, but rather an emergent design element whose role is to keep the clusters from clumping together and to create a seemingly random and memorable overall pattern, facilitating spatial memory.

Representative Photos

In addition to this memorable overall pattern, we also use representative photos to provide a comprehensible overview of the clusters when individual thumbnails are too small to be recognizable and distinguishable. Figure 5 illustrates the rationale behind this design choice. Note that the use of representative photos is independent of the layout, although representative photos are more useful when the aspect ratios of individual clusters are reasonable, as can be achieved with either the timeline layout or the time quilt layout.

Figure 5. Thumbnails are recognizable at 180 images in a 700 x 600 pixel screen area (a) but became hard to recognize at 5,500 images in the same area (b); representative photos can be used to provide overview in such a case (c).

Figure 6 shows how zooming into a cluster “breaks apart” its representative photo into individual thumbnails. Further zooming in enlarges the thumbnails eventually to the corresponding full images.

USER STUDY

We conducted a user study to compare 3 layouts: a space-filling layout (quantum treemap [7]), the timeline layout, and the time quilt layout, as well as to test the effectiveness of representative photo overview.

Interfaces/apparatus

For this user study, we implemented 4 testbed browsers in Java, three of which used representative photos (classified in Table 1 and shown in Figure 9): a space-filling browser (SF), a time quilt browser (TQ), a timeline browser (TL), and a space-filling browser without representative photos (SP–) Figure 9. We ran these browsers in Windows XP Pro, SP1, on a Pentium IV 3.2 Ghz HT, 2GB RAM machine with an NVidia Geforce FX 5200 128m video card, connected to two 19” CRT monitors, each running at 1280 x 1024 pixels, 96 dpi resolution. The mouse used was a Microsoft IntelliMouse Optical USB and PS/2 Compatible mouse (with a scroll-wheel).

		Layout		
		Space-filling (q. treemap)	Combo (time quilt)	Time-ordering (timeline)
Representative Photos	Yes	SF	TQ	TL
	No	SF–		

Table 1. Testbed browsers built for user study

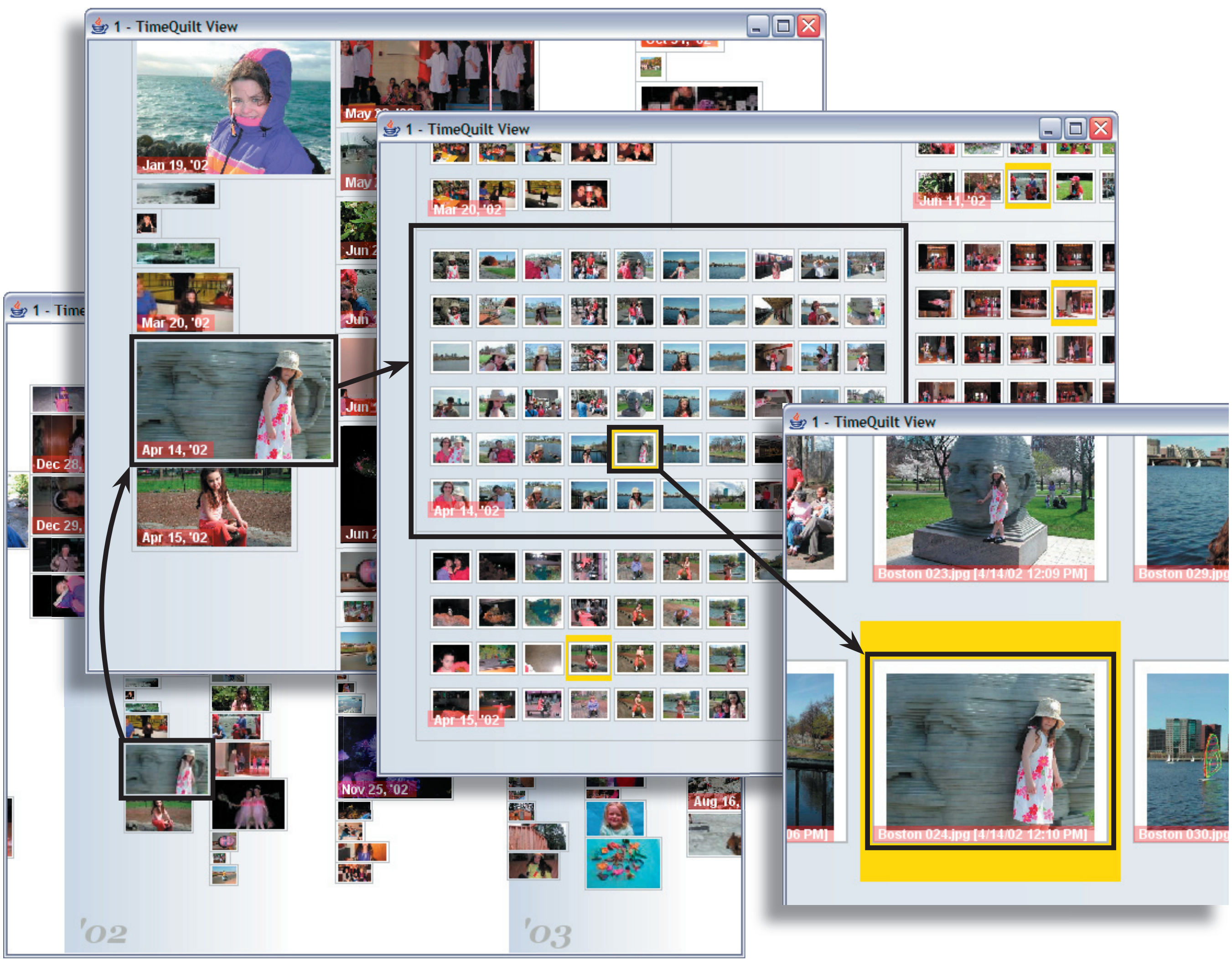
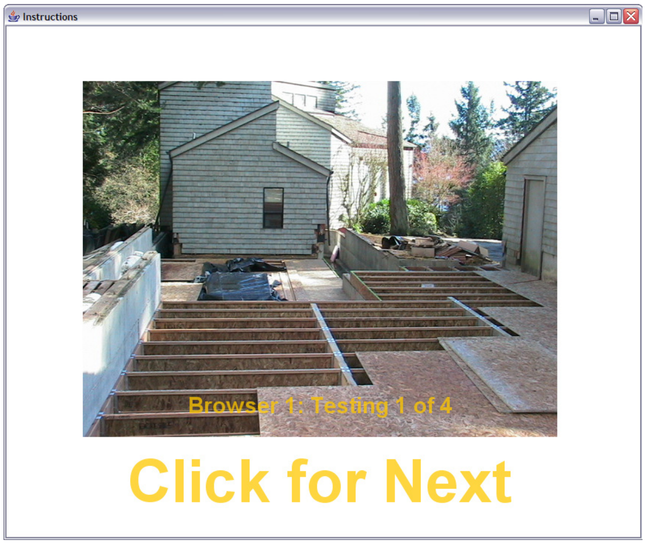


Figure 6. Zooming into a cluster rendered with a representative photo “breaks” it apart into individual thumbnails.

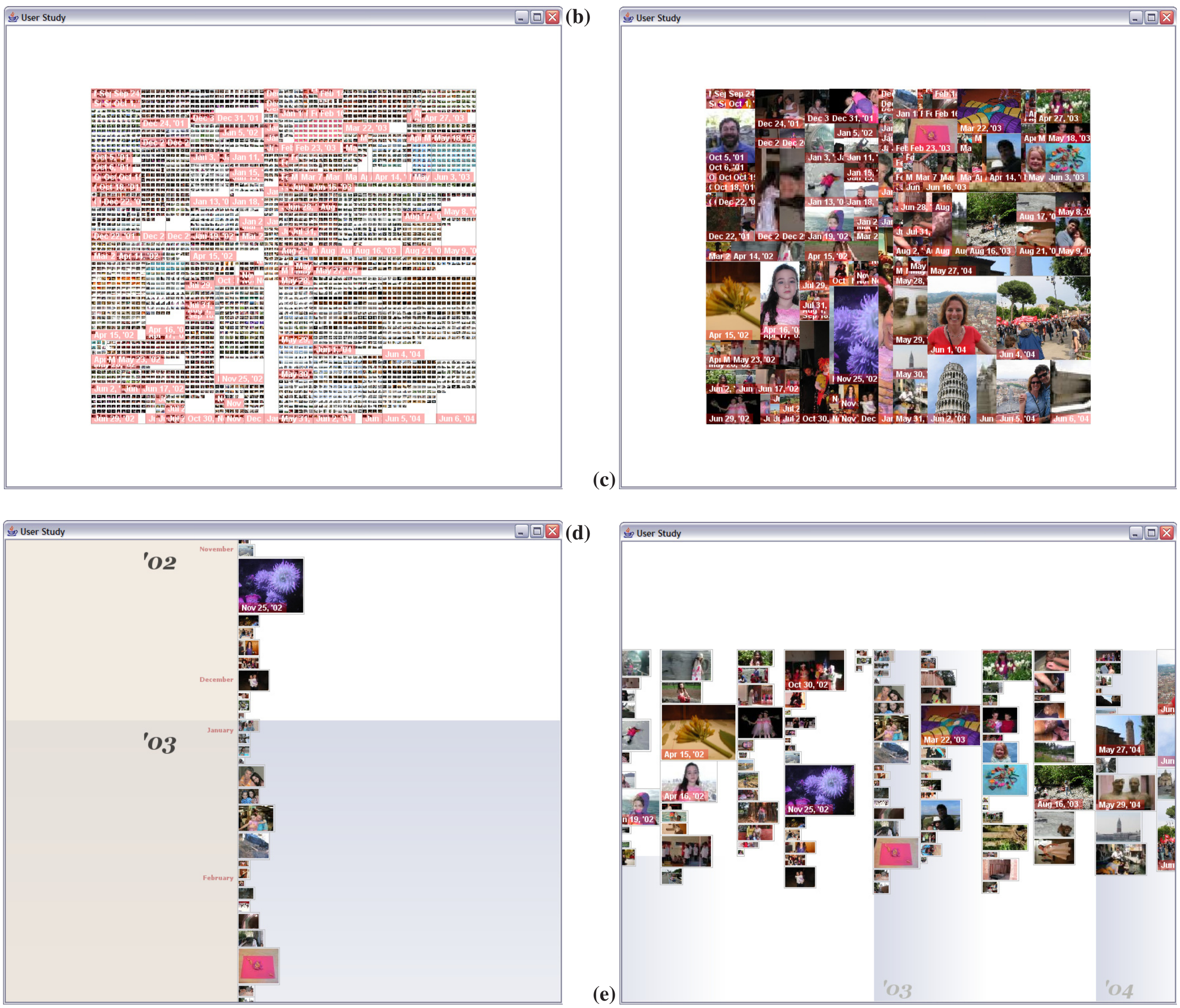
The monitor on the left showed the instruction window (Figure 9) while the monitor on the right showed one of the four testbed browsers.

All testbed browsers supported zooming through the mouse-wheel. Scrolling the mouse-wheel forward zooms into where the mouse cursor points, and scrolling backward zooms out. Panning is done through dragging with the left mouse button. Selection of a photo can be performed by left-clicking. We limited the zooming levels and the panning range to prevent the users from getting lost in whitespace (famously known as the desert fog problem [13]).

We used Platt's adaptive clustering algorithm [17]. We chose the middle photo of each cluster to be the representative photo.



(a)



(b) (c) (d) (e)

Figure 9. User study interfaces: the instruction window (a) and the testbed browsers SF (b), SF+ (c), TL (d), and TQ (e)

Task

Participants had to complete one task: find the target photo shown in the instruction window in the browser and select it. Each participant was instructed to "go for speed" while maintaining reasonable accuracy. When faced with multiple photos resembling the target photo, the participant was instructed to pick one that was reasonably close to the target photo rather than pinpointing the exact match. If the target photo was a modified version of another, original photo, s/he could select the original photo instead of the modified version. If the participant was lost after trying to find a photo for several minutes, s/he was instructed to abandon the task.

Procedure

10 people participated in the study: 2 females, 8 males, 28 to 42 years old, with an average age of 35. According to their estimates, they took anywhere from 600 to 25,000 photos a year (mean = 6,980, stdev = 8410) of topics including: family and friends, children, pets, items of interest, documentation, nature/sceneries, architecture, vacations/trips, school events, work events, outdoor events, sports events, and special events. None of these participants were familiar with any of the browsers before the study.

The participants were able to share with us photo collections ranging from 2,863 to 5,708 photos (mean = median = 3,994, stdev = 928). In a pilot study, we tested the retrieval of randomly selected pictures from a user's collection and found that this was a task that was often impossible since the randomly selected picture would often not be recognized at all. For the actual study, each participant was asked to select 28 favorite photos from the collection that s/he shared, with no more than 1 photo per event. Presumably, the user would remember something about these favorite photos and would be able to use such information to find the photos in our browsers.

We used a within-subject experimental design: each subject carried out the task 5 times (for 5 different target photos selected from the 28 favorite photos) on each of the 4 testbed browsers. In order to avoid sequence effects, the browser order was counterbalanced between subjects.

		Layout		
		Space-filling (q. treemap)	Combo (time quilt)	Time-ordering (timeline)
Representative Photos	Yes	SF 61.7 (40.5)	TQ 33.9 (20.2)	TL 60.8 (41.2)
	No	SF– 56.7 (41.5)		

Table 2. Task completion time in seconds (and standard deviation)

Each participant received verbal instruction when the study session started and an introduction to each browser before the tasks on that browser were performed. After the introduction, s/he was encouraged to explore the browser by finding 2 "training" target photos.

Upon completing the tasks for each browser, the participant answered questions regarding his/her experience with that browser. At the end of the study session, s/he completed a survey to specify their overall preference. All Likert-scale questions were on a scale from 1 (disagree) to 7 (agree). The whole session took around one hour.

Hypotheses

We had 2 hypotheses:

- Participants would complete the task faster in TQ than in SF and TL because TQ conveyed time better than SF and required less panning than TL.
- Participants would complete the task faster in SF than in SF– because SF provided a more comprehensible overview with the use of representative photos.

Results

Task completion time – Table 2 and Figure 10 summarize the average time participants required to complete the task. Confirming our first hypothesis, they achieved better task completion time on TQ than on TL and SF (44.2% and 45.1% faster respectively). A one-way ANOVA test yielded $p = 0.002$ ($F(3,173) = 5.314$).

Note that we did not count trials with time exceeding 3 minutes. In such trials, participants did not recall enough information to locate the target photos and simply resorted to panning over the entire visualizations.

The participants' comments also helped confirm our first hypothesis. While testing on SF and SF–, some said,

- "Dates are right but locations are completely wrong."
- "We have August and December next to each other... that's totally confusing."
- "Can't always go to the next day—not always next to where a given day is."
- "With the timeline, I have a linear order by which I can tell how far to go."

We were not able to derive any statistical significance from comparing the task completion time on SF and SF–.

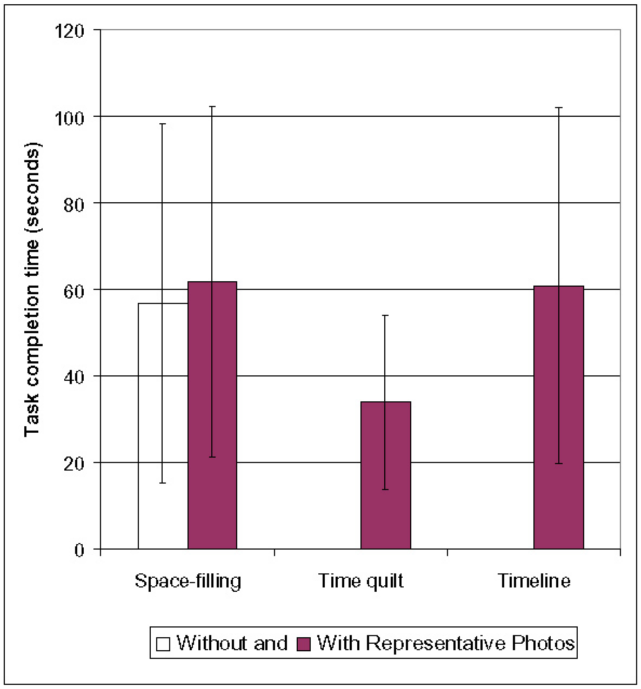


Figure 10. Average task completion time across different layouts

Subjective preference – Once again confirming our first hypothesis, the participants specified that they "preferred the arrangement of photos by dates and times over the space-filling arrangement" (Likert: M = 6.20, SD = 1.476, t-test = .009). A Friedman test on the participants' rankings of the four browsers showed that TQ was best preferred: TQ ranked 1.40, TL 2.10, SF 2.80, and SF– 3.70 (N = 10, Chi-square = 18.125, df = 3, Asymp. Sig. = .000).

The participants also specified that they "preferred the use of representative photos" (Likert: M = 5.70, SD = 1.636, t-test = 0.009) even though they did *not* find that "the representative photos were accurate representation of the clusters" (Likert: M = 4.30, SD = 1.418, t-test = 0.520). Their comments also indicated that representative photos were helpful:

- "With representative photos, I have more clues of where things are."
- "There might be a representative picture of that... it'll get me there much quicker."
- "Give me back my key photos, please!" (after switching from a browser that used representative photos to SF)
- "Bad key photos are better than nothing."

Sanity check – To verify that our user study task was realistic, we asked the participants whether they had done a similar task before ("looking for a particular photo that [they] remember something about"). All users answered Yes and specified that they had done that task frequently (Likert: M = 6, SD = 0.94).

The participants also thought that "the automatic clusters were good segmentation of [their] photos" (Likert: M = 5.20, SD = 1.317, t-test = 0.018).

Discussion

Although digital photos always carry their creation dates, the images that the participants shared with us came with unreliable dates:

- Some participants included scanned images in their photo collections and in the 28 favorites that they selected. The dates on these images were not the dates of the corresponding events.
- Some participants' cameras had faulty dates. Some pictures taken in 2004 were dated 2003.

In other cases, participants included photos taken by someone else. As a result, they found it hard to remember approximately when those photos were taken.

CONCLUSIONS

In this paper, we proposed time quilt, a novel layout for zoomable photo browsers that conveys temporal order while making better use of space than a linear timeline. We conjectured that this layout was more effective on large photo collections than the space-filling layouts used in existing zoomable photo browsers. For a large collection, without zooming first into the approximate date range when a photo was taken, visual scanning for that photo over the entire visualization is inefficient. For this reason, time quilt emphasizes temporal ordering over space filling. But space filling is also important for maximizing the amount of visual information the user can see at any time, thus minimizing the amount of panning and facilitating faster visual searches.

We observed that the participants of our user study performed the photo finding task 45% faster on a time quilt-based browser (TQ) than on a space-filling browser (SF) and a timeline (TL). We attributed this difference in task completion time to TQ's better visualization of temporal order over SF and better use of space over TL.

As a second, complementary method for scaling up zoomable photo browsers, we proposed the use of representative photos to implement semantic zooming in order to provide a more informative overview in place of the diminishing thumbnails. We found a subjective preference for this method.

In future work, we plan to verify that representative photos improve task completion time quantitatively. We would also like to better understand the trade-off between the time-ordering and the space-filling layout criteria: we would like to pinpoint the collection size at which time-ordering makes gains over space-filling.

The time quilt layout itself has much room for exploration and improvement. For example, changing the wrapping columnar layout to a zig-zag layout eliminates column breaks and reduces the amount of panning as the user scans over photo clusters sequential in time. For another example, enforcing a minimum size for representative photos makes sure that every representative photo is recognizable regardless of whether its cluster is large or small.

We believe that the seemingly random pattern resulted from a time quilt layout facilitates spatial memory in re-finding photos from a large collection. We wish to compare time quilt's effectiveness in inducing spatial memory to that of space-filling layouts, hoping to show that whitespace is not necessarily wasteful.

Finally, we would like to apply this idea of trading off space-filling for time-ordering to laying out visual information from domains other than digital photographs. We believe that time quilt can be generalized to domains in which time is a natural dimension in which people perceive information.

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