Graphicuss
Temporal Visualisation of Canvas Creation Processes

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Abstract: The use of graphical models to describe complex topics is very common in teaching, helping students build an adequate model of knowledge presented. Often, students discuss open questions on-line in forums. Backtracking of errors conducted during the creation process is hard. The individual steps of developing a solution – the temporal information – are lost. *Graphicuss* combines concepts of textual discussion systems and graphical feedback systems. It fosters better discussions and comprehension through access to the temporal information of canvases. Especially self-regulated learning benefits from the addition of temporal information; students' skill acquisition capabilities are amplified. Yet, an intuitive representation of temporal information is still required. Based on image and video processing, we investigated existing metaphors for temporal information. A series of user studies emphasises the differences of the metaphors in varying use-cases and strongly points at a candidate suitable and feasible for PCs as well as mobile devices.

1 INTRODUCTION

In computer science lectures the use of graphical models to describe complex algorithms and correlations is very common. It is very important for the students to build an adequate model of the knowledge presented in the lecture. If the students have any questions after the lecture, they can discuss them in a forum like auditorium[1] (Beier et al., 2014), StackOverflow[2], or others. However, there they can only use textual descriptions of the problem; they might be able to quote figures or pictures in the web, but they cannot discuss the single steps of developing the figure or model because they only know the final result; temporal information of the creation process is lost. Basically, these discussions never recreate the major advantage of a real-life studying session, namely creating solutions together step by step, including backtracking of errors made in the process.

At CSEdu 2017, we presented our graphical discussion system *Graphicuss* (Chen, 2016; Hara et al., 2017). It combines known concepts of textual discussion systems and graphical feedback systems into a single canvas-based application. Treating text and graphics as mere objects within a canvas allows for better discussion of concepts through temporal correlation of information in text and graphics. Thus, it applies known text-based discussion features (e.g., quoting) to the graphical level while adding temporal context. Rather than attaching an invariable image to a text or to adding new content to an otherwise unaltered image, *Graphicuss* enables users to quote up until any point in time with changes and/or amend-

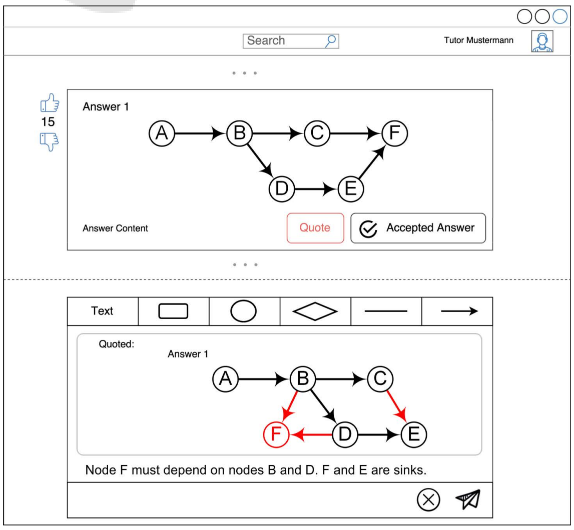

Figure 1: GUI mock-up for Graphicuss.

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[1]https://auditorium.inf.tu-dresden.de
[2]https://stackoverflow.com

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ments thereafter due to the availability of the entire creation time-line of a canvas. Therefore, *Graphicuss* provides opportunities for students to give and receive peer feedback (e.g., (Peters et al., 2017)) on their own or others learning process and learning products. By combining established didactics and learning psychology methods with new implementation concepts, *Graphicuss* supports students in mastering self-regulated learning (Zimmerman et al., 2000). The documentation of the own creation process and the final representation allows to reflect and self-evaluate ones learning activities and helps correct misconceptions for subsequent study phases. With regard to peers' solutions, the addition of temporal information is of special value for the understanding of the creation process. Allowing students to comprehend a complex canvas step by step by reproducing the creation process of a peer helps them to create an adequate mental model themselves.

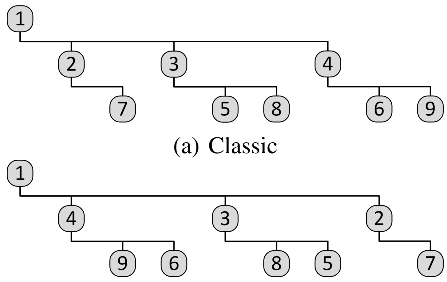
In (Hara et al., 2017) we focused on preliminary findings with respect to basic interface design and storage requirements; visualisation of temporal information was not yet investigated. E.g., Figure 1 depicts how a temporally partial quotation and amendment of a canvas can be presented to users *after* its submission. However, an intuitive representation of temporal information is required *before* and *during* the quoting process. Thus, based on existing metaphors used in image and video processing, we investigated candidates for temporal representations of progress, editing state, changes, etc. In this paper we will present our results of several user studies and propose GUI guidelines for the representation of temporal creation information.

2 RELATED WORK

We investigated different representations of temporal information in the context of text-based discussion systems (i.e., forums), collaborative editing as well as visual information hubs (e.g, YouTube[3]).

2.1 Forums

Forum systems can be divided into two types: *hierarchical systems* (e.g., photo.net Discussions[4]) and *bulletin systems* (a.k.a. *flat systems*) (e.g., StackOverflow[5]). Both types focus on a specific representation of the content. While bulletin systems emphasise the importance of topics rather than threads, it is difficult to extract temporal information with respect to the order of which posting was posted when (of course, the creation and modification time is often displayed, but the temporal order is not perceivable on a glimpse). However, associated content is clustered together. In contrast, hierarchical systems focus on a representation of the evolution of threads. The real creation history (time-line, temporal information) is often represented either *as is* (cf. 2(a)) or in a highlighted fashion *newest-on-top* (cf. 2(b)).



(a) Classic

(b) Newest-on-Top

Figure 2: *Classic* (2(a)) vs *newest-on-top* threading (2(b)).

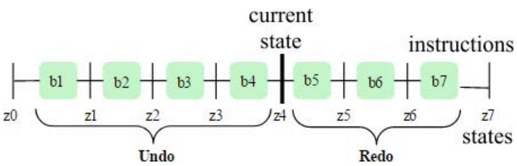
The basic idea behind both types of forum systems is easily accessible content, be it by topic or within a time-line. Nevertheless, the granularity of temporal information is set on a per-submission level. Within a submission, temporal information is not available in general. Of course, one may assume, text at the beginning of a submission was written before text at the end of a submission, but it might just be the opposite, with the author writing something and then adding further content ahead of the corresponding paragraph, etc.

2.2 Collaborative Editing

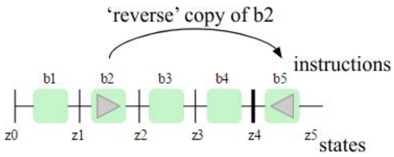
The drawing concept of *Graphicuss* is similiar to collaborative editing systems such as virtual interactive whiteboards (e.g., AwwApp[6], Scribblar[7]) or shared document systems (e.g., Google Docs[8], Microsoft Office Online[9]). However, within these systems the temporal information is provided on an in-submission (in-document) level and is utilised for local and shared undo and redo functionality. The current document composition is shared amongst the collaborators. In general, edits and submissions are represented by states and transitions between these states. A state is defined by sufficient changes to a document or by editing pauses. E.g., states may be created for each

[3]https://youtube.com
[4]https://www.photo.net/discuss
[5]https://stackoverflow.com

[6]https://awwapp.com
[7]https://scribblar.com
[8]https://docs.google.com
[9]https://www.office.com



(a) Traditional undo/redo model.



(b) Selective undo/redo model

Figure 3: *Traditional* (3(a)) vs *selective* (3(b)) undo/redo models within collaborative editing systems.

new sentence, for each word when typing slower, or single letters over a longer period of time. Linearly traversing along the states leads to a *traditional undo/redo model* (cf. 3(a)). Allowing jumps between states without direct transition leads to a *selective undo/redo model* (cf. 3(b)) which requires on-demand computation of differences between involved states. Basically, it is a direct implementation of (Berlage, 1994).

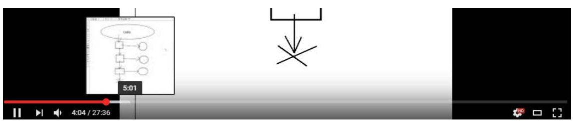
2.3 Video Sharing

The best example for the representation of temporal information is a video. With progression of time the displayed graphical information changes. A direct correlation between point in time and visual information is given, leading to a direct coupling of time-line and content. The long history of video media has lead to established and agreed-upon standards for the representation of the time-line.

Typically, a progress bar represents the entirety of the time-line with the current fill of the progress bar representing the elapsed time and the current position within the time-line (cf. Figure 4). Commonly, the progress bar is accompanied by further control means,

(a) Windows Media Player interface.

(b) YouTube Player interface.



(c) YouTube Player interface with seek bar.

Figure 4: Interfaces of Windows Media Player (4(a)) and YouTube Player (4(b)) (YouTube Player seek bar in 4(c)).

e.g. a pause/play button. If the progress bar itself can be utilised to access specific points in time along the time-line, it is commonly referred to as a *seek bar* (cf. 4(c)). For online video platforms in particular, the progress/seek bar often also provides information on the pre-fetching (buffering) future, yet to be displayed, video content (cf. grey vs red progress in figures 4(b) and 4(c)).

3 STATE-BASED METAPHORS

Besides the aspects of temporal information representation presented in the previous subsections, human expectations must be considered, too. Information must be presented in a means easily comprehensible for humans. Metaphors have proven to be an efficient means of proving information in well-known concepts to humans (e.g., (Preim and Dachselt, 2015)).

With respect to temporal information, the representation of all information is not feasible. Time progresses continuously while computers need to store the time-line discretely. Hence, a problem is granularity: should a state be created every millisecond, every second, every ten seconds? The granularity problem is accompanied by an evident storage requirements problem. Commonly, a mantra of 'as often as necessary and as seldom as possible' is followed. This leads to a state-based storing of temporal information, namely creating snapshots when sufficient changes have occurred. Of course, this matches the concepts introduced in subsection 2.2. The interesting question then is, how these states can be easily visualised. A rather simple translation of a time-line into a metaphor is depicted in Figure 5 by a slider (a seek bar) (amended with forward/backward buttons) and in Figure 6 by a slideshow. The latter metaphor is well established in photo and image applications, especially on devices with touch interfaces such as smartphones.

For interpreting temporal information as a continuous flow of changes in a document, the obvious metaphor is a video. Thus, the visualisation concepts (cf. 2.3) should apply. A simple translation of a time-line into the video metaphor is depicted in Figure 7.

However, other metaphors may be more suitable, especially with respect to the expected use-cases of

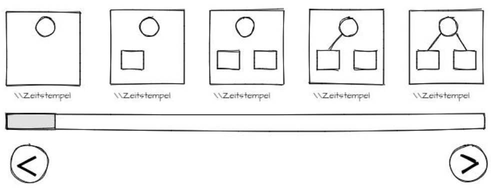


Figure 5: Slider mock-up.

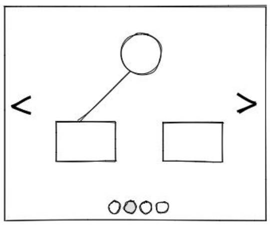


Figure 6: Slideshow mock-up.

Graphicuss. Assuming most cases are based on the states, the entire time-line is discrete. For example, *Graphicuss* allows easy creation of UML[10] diagrams by providing users with a tool box of predefined shapes (squares, arrows, etc.) for easier drawing. Each insertion of such a shape can be considered a new state in the creation time-line of a canvas.

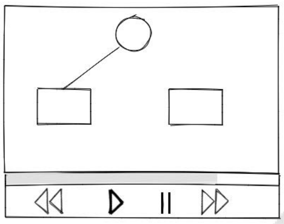


Figure 7: Video mock-up.

On smartphones a state representation with a highlight on the current state can be a beneficiary metaphor. Due to multi-tasking support, small pictographs, each representing the current state of an application, are arranged within the graphical user interface (GUI). Users can easily select from the running applications by tapping the corresponding pictograph. This concept has been around for a long time, especially also within desktop operating systems (e.g., *Flip* in Microsoft Windows, *Switcher* in Apple MacOS). Translating this concept into the context of *Graphicuss* leads to two separate metaphors: a stack (cf. Figure 8) with the current state on top of the stack and all older states laying below, and a carousel (cf. Figure 9) with the current state in the centre, older states to one side, and newer states to the other.

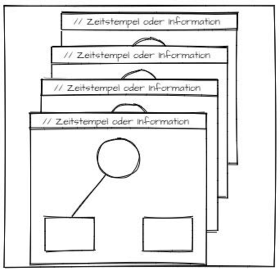


Figure 8: Stack mock-up.

[10]Universal Markup Language

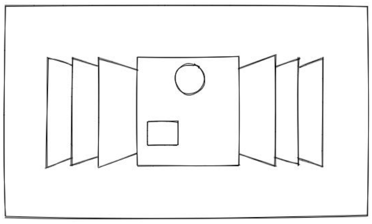


Figure 9: Carousel mock-up.

However, *Graphicuss* can not only be utilised for UML diagrams. Therefore, we assumes that different types of metaphors are suitable for different types of use-cases. We defined a set of requirements in order to select the most suitable metaphor for the representation of temporal information, namely the creation history of canvases within *Graphicuss*.

We defined five mandatory and three optional requirements to be met by the GUI. Therein, it…

- M1 …must use easily comprehensible metaphors; no explanation of how time is represented,
- M2 …must support different use-cases,
- M3 …must visualise the time-line and its direction,
- M4 …must ensure that the current state is always accessible within the time-line,
- M5 …must allow forwarding/rewinding the time-line in coarse as well as fine steps,
- O1 …could utilise large and clear icons,
- O2 …could provide control elements adaptable to different client devices, and it
- O3 …could be multi-modal (accept different types of input methods).

4 USER STUDIES

For the design process of our Graphicuss prototyp is is very important that the developed systems fulfills all requirements for the different use cases and contexts. Therefore, we objectively analysed the suitability of the different metaphors with respect to fulfilment of our defined requirements before the user studies. We aggregated our findings into a table (cf. Table 1). Unconditional fulfilment of a requirement is symbolised by a ++ (value of 2), conditional fulfilment by a + (value of 1), and dissatisfaction by a − (value of -1). The total scores (Σ) are calculated by adding the individual values of each row.

Based on these first result, one may presume that the video metaphor is the most suitable. However, the table actually only proves that all investigated metaphors are more or less suitable. There is no single best metaphor as all metaphors have some conditions attached to their suitability. Therefore, we decided to focus on the three higher rated metaphors (Slider,

Table 1: Requirements fulfilment by metaphor.

Rqmnt	Slider	Slideshow	Video	Stack	Carousel
M1	+	+	+	+	+
M2	++	++	++	++	++
M3	+	+	++	++	+
M4	+	++	++	++	++
M5	+	−	−	−	−
O1	+	+	+	+	+
O2	++	++	++	+	+
O3	++	++	+	−	−
Σ	11	10	12	6	6

Slideshow, Video) and involve users in order to determine the subjectively best option.

We investigated the metaphors' suitability by means of user studies in two iterations within controlled environments. In the first iteration (n=5), *thinking aloud* as well as *blank paper prototype* methods were utilised. This was intentionally conducted in this manner in order to determine whether users would come up with the Slider, Slideshow or Video metaphor on their own. If 'yes', it would provide proof to the suitability of said metaphors. In the second iteration (n=15), *paper-based mock-ups* as well as *Wizard-of-Oz low-fidelity prototypes* (some functionality that would be automated in the real system were manually conducted by humans) were utilised. The goal was to target specific aspects of the metaphors and investigate the users' opinions on usability as well as comprehensibility. In addition to the two iterations, we conducted interviews, asking about metaphor suitability, comprehensibility of the time-line, etc.

The first iteration of studies resulted in two intuitive metaphors: Slider and Slideshow. When asked explicitly about it in the interviews, the test subjects also deemed the Video metaphor as suitable, but they did not come up with this metaphor during the blank paper prototyping. Additionally, Video was deemed suitable only for quasi-continuous or equidistant time representation. Considering suitability for utilisation on desktop as well as mobile devices, we interviewed the test subjects whether they could imagine to utilise any of the metaphors on their PC as well as their smartphone. Overall, the first iteration and the interviews conducted resulted in the following statements:

- The representation of temporal information was comprehensible in all three metaphors.
- Most of the icons utilised in the metaphors were correctly identified. Icons for coarse rewinding/forwarding could be misinterpreted.
- The direction of the time-line (in general: left-to-right) was easily comprehensible.
- On mobile devices, the Slideshow metaphor is better suitable than the Slide metaphor.
- The Video metaphor must correlate to the actual creation time-line exactly.
- Users cannot determine the presentation speed optimal for their needs in the Video metaphor.
- Identifying differences between two states becomes increasingly complex with more states.

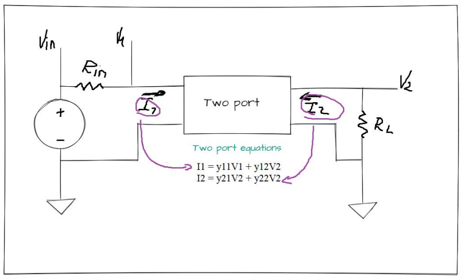


Figure 10: Canvas used in the tests.

Based on these statements, we decided to drop the Video metaphor in the second iteration. Storing the exact timestamp of what happened when in the time-line is not feasible. It requires a fine granularity of states which is not suitable for low traffic requirements, especially on mobile networks. Also, the criticism about playback speed had to be considered. In direct comparison, the Slider and Slideshow metaphors allow user to determine when they want to see a change. In the Video metaphor, they had to constantly use the pause and play controls, which basically turned the Video into a Slideshow. Therefore, only the Slider and Slideshow metaphors were investigated in the second iteration. Due to the last statement from the previous iteration, we used a complex electrical circuit drawing for our tests (cf. Figure 10).

In total, we tested three paper prototypes with the test subjects: Slider (cf. Figure 11) and two Slideshows with different controls arrangement (cf. Figure 12). Our investigations showed that the Slider metaphor is well suited with larger displays, especially on desktop or laptop computers. However, on smaller displays (e.g., smartphones), a full-screen representation was preferred by the majority of test subjects. Thus, only the Slideshow metaphor is suitable for utilisation on PCs *and* smartphones.

Our investigations also show that the previous statement regarding granularity of seeking within the time-line is important. In some situations users need to be able to *slowly* follow the time-line by navigating through it state-by-state (fine granularity), in other situations users need to be able to *skip* entire states within the time-line (coarse granularity). The Slideshow metaphor can address both situations: in

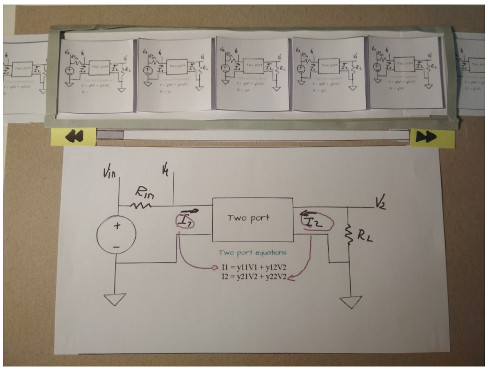


Figure 11: Slider paper prototype.

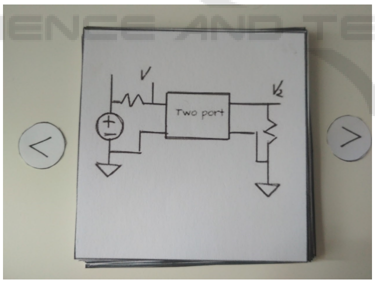
a touch-controlled environment (e.g., smartphone), the speed of swipes can determine the speed of state changes, whereas on point-and-click environments (desktop PC), different controls for different granularities can be used (cf. 12(b)).

5 CONCLUSION

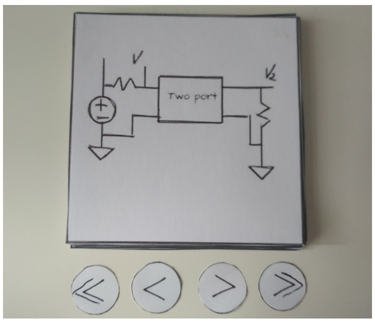
We conclude that only the Slideshow metaphor is suitable for all devices *Graphicuss* is expected to serve, namely personal computers as well as smartphones. However, as the Slider metaphor has clear advantages over the Slideshow metaphor on larger displays, it might be beneficiary to include implementations of both metaphors within *Graphicuss*. Based on the display size either metaphor can then be delivered.

The results need to be implemented into our *Graphicuss* prototype as the findings are of theoretical nature and are entirely based on blank paper prototypes, low-fidelity mock-ups, and user interviews. This is a memium-term goal as *Graphicuss* is currently undergoing a complete re-implementation in order to facilitate better compatibility with our AMCS[11] system.

In the future, we wish to further investigate the suitability of the different metaphors in different use-cases. With the new prototype, we will be able to investigate different classroom settings (e.g., lecture, tutorial) as well as different topic contexts (e.g., computer science (UML diagrams, service sketches, ...), physics (TTT curves, radiation patterns, ...)).



(a) Slideshow paper prototype, var. 1.



(b) Slideshow paper prototype, var. 2.

Figure 12: Two variants of Slideshow paper prototypes. Standard controls (12(a)) and extended controls with coarse rewind/forward controls (12(b)).

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[11] https://amcs.website – cf. CSEdu 2014-2016