Interactive and Narrative Data Visualisation for Presentation-Based Knowledge Transfer

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Abstract. In recent years, presentation tools such as Apple's Keynote or Microsoft PowerPoint play an important role in knowledge transfer. Despite the fact that over the last decade we have witnessed various technological advances and new media types, existing presentation tools still mainly support the presenter-driven delivery of static content. On the other hand, research in information visualisation illustrates that interactive data exploration and storytelling can significantly improve the extraction and transfer of knowledge from raw data sets. Our goal is to improve data-driven knowledge transfer in presentation tools by applying existing information visualisation concepts. Therefore, we derived a set of general requirements for interactive information visualisation in presentation tools. A prototype of a presentation tool which addresses these requirements has been developed based on the MindXpres presentation platform. Ultimately, the presented requirements might serve third-party slideware vendors as input for improving support for data-driven knowledge transfer in existing presentation tools.

Keywords: Presentations · Slideware · Narrative visualisation · Interactive visualisation · Data exploration

1 Introduction

The field of information visualisation investigates graphical data representations that reinforce human cognition and help us in detecting causal relationships between data. Recent technological advances led to more dynamic and interactive information visualisations. Current development therefore emphasises on providing users more control over the visualisation process in order to enable the interactive exploration and discovery of meaningful relations between data points.

Storytelling has shown to be an effective approach for sharing insights gained by studying specific data sets [1]. Facts that have been tied together as part of a story are easier to present as well as more memorable by the audience. Therefore, we have seen the rise of so-called narrative visualisations or visualisations that help us to tell stories with data [2]. For example, educational textbooks often contain various charts and diagrams in order to support the message that

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the text is trying to convey. These narrative visualisations have been adapted for recent media and are becoming more dynamic. For instance, news on the television might use animated graphs to show changes in oil prices or election results whereas online news articles might be complemented by user-controllable interactive visualisations.

A common medium used for narrative visualisations are the slide decks created with presentation tools such as PowerPoint. With more than 30 million PowerPoint presentations produced every day [3], we cannot deny the role that presentation tools play in knowledge transfer. These tools allow us to display content such as text, images or charts. Nevertheless, unlike other digital media, presentation tools do not exploit recent techniques for interactive information visualisation to their full potential. We have seen little evolution in the core ideologies of presentation tools which were originally designed for the production of physical photographic slides. For example, most slide decks are still linear sequences of spatially restricted slides with static content. However, from a technological point of view, there is no reason why some of these limitations should still apply. Visualisation techniques such as zoomable user interfaces allow us to get rid of spatial boundaries. Furthermore, hardware such as tablets, smartphones or digital pens support the non-linear presentation of content and enable various forms of real-time interactions with a presentation's content. Nevertheless, existing workarounds for implementing this functionality either require too much time and effort or force the presenter to use some third-party tools during presentation time which interrupts the flow of the narrative.

We address some of the discussed shortcomings of current presentation tools and introduce an interactive data visualisation solution for the MindXpres presentation tool. By applying well-established concepts from information visualisation and visual storytelling, we aim to provide more effective narrative visualisations in presentations. Our interactive data visualisation solution for MindXpres supports the predefinition of a series of views for a given data set as well as transitions between these views in order to support the narrative. In contrast to existing presentation tools, the visualised data and visualisation parameters can be changed between each step of the narrative. For instance, the chart type (e.g. bar chart or pie chart) can be changed, filters can be applied on the data or the focus might be adjusted. Furthermore, the same functionality remains available at presentation time, allowing the presenter to break free from any predefined visualisation series in order to explore and discuss the data without restrictions. By applying established information visualisation guidelines and techniques, the resulting presentation helps the audience to strengthen their mental model and enhances the effectiveness of knowledge transfer. In addition, our proposed approach does not only reduce the time needed to create compelling narratives based on a raw data set, but also results in a shift towards audience-driven narratives.

In Sect. 2 we discuss information visualisation and narrative visualisation concepts in more detail, relate them to existing presentation tools and discuss shortcomings of existing presentation tools. We then propose enhancements for some of these shortcomings in Sect. 3 and derive a number of general requirements for interactive narrative information visualisation in presentation tools. Section 4 provides some details about our prototype implementation for the MindXpres presentation tool, which is followed by a use case in Sect. 5 in order to illustrate some of our prototype's functionality. We conclude with a discussion and outline of future work.

2 Background

The advent of modern media such as television and computers have enabled more dynamic and interactive visualisations. Similar to these visualisations we see on television also major newspapers have adopted the concept of graphical storytelling and sometimes allow users to interact with the visualisation. For instance, the BBC[1], The Telegraph[2] and The New York Times[3] accompany some of their articles with interactive visualisations. An article in The Economist calls it "*melding the skills of computer science, statistics, artistic design and storytelling*" [4]. In this section we take a look at existing information visualisation and narrative visualisation concepts and explain why they work well. After presenting some related tools, we outline their limitations in the context of presentation-based knowledge transfer.

2.1 Interactive Visualisation

An important goal of information visualisation is to strengthen a viewer's understanding of the underlying data, which might be hard to interpret in its raw form. Abstract data representations can offer a high-level overview and help us to reinforce our mental model [5]. Such graphical representations make use of our highly developed ability to process the continuous stream of information-rich signals captured by our eyes [6]. Concepts such as shape, colour, size or distance are intuitive to us and the interpretation of some of these concepts comes naturally. Research in this domain led to Gestalt psychology, a research field that identified a series of laws helping us to understand these natural interpretations [7]. For instance, when comparing objects in a visualisation, it is clear that a larger object represents a larger quantity or something of higher importance. Similarly, objects that are spatially close to each other are likely to be more related than objects with a larger distance in between them. The field of information visualisation tries to exploit these findings in order to facilitate knowledge transfer. Few [8] proposed a classification of eight messages that one might want to show using quantitative data, together with the type of visualisation that is suitable for each message. The messages include time series, rankings, part-to-whole, deviation, distribution, correlation, geospatial messages and nominal comparison.

[1] http://www.bbc.com/news/11628973.
[2] http://www.telegraph.co.uk/news/interactive-graphics/.
[3] http://www.nytimes.com/interactive/2015/us/year-in-interactive-storytelling.html.

The formation of a mental model can further be augmented by allowing the user to interact with the data [6]. The significance of interaction while processing information was illustrated in Gibson's cookie cutter experiment [9] and is often used as a classic example to prove the relevance of interaction in information visualisation. Gibson concluded that our brain performs better as active explorer, even if the act of exploring requires additional coordination and processing. Interaction techniques in information visualisation can be seen as the features that provide users with the ability to directly or indirectly manipulate and interpret representations. Note that this also includes menu interfaces that allow users to manipulate the representation and, for instance, switch to another chart type or sort a bar chart in descending order [10]. Furthermore, Dix and Ellis [11] emphasise two important principles in interacting with visualisations. The first principle "*same representation, changing parameters*" states that users should be able to interactively change parameters of the presentation. The second principle "*same data, changing representation*" implies that a user should be able to switch between conceptually different data visualisations. Various representations can be appropriate for different types of data and each representation needs to be tuned for its purpose.

There are various academic studies about different interaction techniques such as zooming or filtering which resulted in the categorisation of frequently used techniques in information visualisation. One of the widely accepted classifications was independently proposed by both Siirtola [12] and Yi [10]. Even though the authors did not collaborate, the proposed interaction categories are very similar:

- *Select*: mark something as interesting
- *Explore*: show something else
- *Reconfigure*: show a different arrangement
- *Encode*: show a different representation
- *Abstract/Elaborate*: show more or less details
- *Filter*: show something conditionally
- *Connect*: show related items

2.2 Narrative Visualisation

Interactive visualisation techniques cover the exploration and analysis of data but there is also a need for presenting and communicating data effectively. As stated by Kosara, "*tying facts together into a story is one of the most effective ways of presenting them and making a point*" [1]. The main reason for using stories is the fact that they are known to be a popular way of conserving information and passing it on. Not only do narratives preserve and advertise information, they also act as an adhesive between facts to make them memorable [13]. Segel and Heer [2] further provide a classification of the different approaches and design techniques used in news media to visually tell stories.

In the context of presentations, narrative visualisations are mainly author driven. The scenes and scenarios are linear and predefined by the presenter, messages and conclusions are explicitly mentioned and the audience has little to no influence on the story. This contrasts with reader-driven narratives found in other contexts where there is no prescribed ordering, the free interaction and exploration is central and possible interpretations are left to the reader. Segel and Heer state that ideally, visual narrative genres must balance a narrative—intended by the author—with story discovery by the reader [2]. Kosara confirms that this also holds true for collaborative settings where stories can not only be used to support discussion and decision making, but also during the analysis process. Hence, stories can serve as a source for drawing conclusions, similar to the narrated history of an event [1].

Note that narrative visualisations can be manipulated to emphasise specific messages during free exploration. For instance, Hullman and Diakopoulos [14] identified a number of approaches and design techniques for prioritising particular interpretations in visualisations. These findings imply that narrative visualisations can be designed to deliver a predefined message without explicitly giving the message away.

2.3 Existing Visualisation Tools

Even though the visualisation of information in graphs is an important feature of current presentation tools, existing presentation solutions clearly lack the interactive or narrative aspects discussed earlier in this section. PowerPoint makes it easy to visualise numbers stored in a spreadsheet and provides a lot of freedom in terms of chart types and styling options. Nevertheless, the final result of this process is always a static graph. Of course, as with any content in PowerPoint, it is possible to apply transitions (e.g. fade in or slide out) and motion path animation effects. These effects can either be applied to the complete chart or, depending on the type of chart, to smaller parts within the chart. By using these transitions and motion path animations as a workaround, authors can compose basic narratives by, for example, making parts of a pie chart appear one by one. However, this approach has several shortcomings. First of all, it requires a major authoring effort since animations have to be manually applied to the different parts in order to achieve the desired effect. Furthermore, things might get even more complicated when changes have to be made at a later stage. In order to switch to another chart type, it might further be necessary to define multiple versions of the graph with the corresponding transitions between them. Second, if we depend on these transition effects, the result consists of a predefined sequence of states and there is no way to deviate from this fixed path. While it can be desirable to predefine a path through the data, it might also be beneficiary to have the flexibility to show alternative unprepared variations when answering unexpected questions. Last but not least, it is important to note that a chart is rendered only when the underlying data or configuration is changed at authoring time, but from then on the chart has to be considered a collection of static images. This implies that any effects only operate on the graphical level but cannot do anything that would require the components of the chart to adapt between steps. We can make the bars of a bar chart appear one by one but it is impossible to apply modifiers to the information or configuration that defines the graph. For example, we cannot just switch to another chart type, change the scale of a graph or filter out specific values as a step in the animation. There are third-party plug-ins such as oomfo[4] or think-cell[5] which add even more options for creating charts, but one has to be aware that these third-party plug-ins typically only add additional authoring and styling features for designing what will ultimately result in a static chart with the same limitations. So far we have only discussed charts in PowerPoint but we came to similar conclusions for alternative presentation tools such as Apple's Keynote[6] or Prezi[7].

In terms of academic work, there are a number of tools based on the interactive visualisation principles discussed earlier. Notable examples are VICKI [15], Spotfire [16] and GGobi [17]. While these are promising tools founded on the principles of proven concepts, they also show a number of shortcomings which make them less suited for use in presentations. First of all, these solutions were built as standalone applications and their interfaces are not optimised for use during a presentation. The presenter has to leave the presentation and switch to another application which interrupts the flow. These tools also consist of multiple windows and have complex menus that do not translate well to the limited resolution offered by most projectors. In addition, significant interaction is needed to operate the tools, requiring the presenter to focus on the software and use the keyboard or mouse to go through a series of actions to switch between desired visualisations. It is evident that these solutions focus on the interactive exploration part, but the ability to use them as narrative visualisation tools is rather limited. Commercial solutions with similar restrictions include IBM's Many Eyes [18] and Tableau[8]. Note that the previously mentioned GGobi also provides an Application Programming Interface (API) that allows programmers to embed and pragmatically interact with visualisations. There are other development frameworks such as UC Berkeley's prefuse visualization toolkit[9] for the Java programming language or the popular D3[10] JavaScript library. While these frameworks offer a broad range of features for modern data visualisation, they are usually used for building standalone applications. More importantly, they require the programming of the desired visualisation which is not suitable for the majority of presenters.

Hans Rosling's 2006 TED talk entitled 'The Best Stats You've Ever Seen' [19] is an excellent example of the fact that it is possible to build a presentation around dynamic and interactive data visualisation. During his talk, Rosling made the point that there is so much data related to human development trends but it is difficult to educate people and transfer knowledge about current issues

[4] http://oomfo.com.
[5] http://www.think-cell.com/en/products/.
[6] http://www.apple.com/mac/keynote/.
[7] https://prezi.com.
[8] http://www.tableau.com.
[9] https://github.com/prefuse/Prefuse.
[10] http://d3js.org.

if we cannot present these statistics in an accessible way. For his presentation, he used a proprietary tool (now forming part of the Gapminder[11] suite) that allowed him to animate and visualise data over time, switch between chart types or highlight areas of interest and annotate them. The success of the talk can partly be attributed to Rosling's energetic personality and compelling arguments, but also his novel approach to presenting data gained a lot of attention [1] and has been explored in great detail. Robertson later showed that animated transitions can have a negative effect on a viewer's ability to follow trends [20], but because these animated transitions are entertaining and capture the attention, they work well in front of a live audience. While Rosling's 2006 TED talk was definitely a major step in the right direction, the Gapminder series of tools also has some shortcomings. First of all, once more they are standalone applications and require a presenter to switch between presentation and tool. More importantly, these tools were specifically built for educating people about certain topics related to human development. This implies that the data sets are fixed and the functionality and visualisations are tweaked for drawing conclusions from geographic and demographic data over time. Other tools have been built for specific use cases, including the MediaViz [21] platform for visualising data relevant to online media studies. Similarly, ArtVis [22] is a tool for exploring European art over time on a map-based visualisation. GeoTime [23] represents another geography-based visualisation tool focussing on creating a visual story out of geo-temporal events. While GeoTime is one of the few tools where the creation of a narrative out of a raw data set lies in its core, its use is limited due to the focus on geo-temporal data only.

The discussed related work highlights the added value of interactive and narrative visualisations even if we have to conclude that existing presentation tools do not offer the necessary support for applying such narrative visualisations in practice. There are some workarounds such as creating multiple static charts with manually-defined transitions between them, but often presenters are not willing to make this effort and rather opt for a less dynamic narrative. Alternatively, it is possible to use stand-alone tools which were not designed to be used in the context of live presentations and can therefore not easily be applied as tools for narrative visualisations.

3 Requirements

Research in the field of information visualisation and narrative visualisation shows that the use of specific visualisation techniques can lead to improved knowledge transfer. However, as discussed earlier we see that existing presentation tools do not exploit these visualisation techniques to their full potential. Our goal is to close this gap and to apply lessons learned from interactive information visualisation as well as narrative visualisation in order to improve presentation-based knowledge transfer. Based on the presented related work and the shortcomings of existing

[11] http://www.gapminder.org/downloads/.

presentation solutions discussed in Sect. 2, we derived a set of requirements for interactive information visualisation in presentation tools:

R1: Integration in Presentation Tools. As slide decks are one of the most frequently used media for transferring knowledge in education and business settings, it is preferable to directly integrate interactive visualisations into a presentation rather than relying on third-party applications. If an interactive visualisation is not integrated into the presentation tool, the presenter is forced to switch between applications which takes time and interrupts the presentation flow.

R2: Focus on Proven Techniques and Guidelines. Popular presentation tools put their main focus on aesthetics and looks but the offered features are not always beneficial in terms of knowledge transfer. For instance, the ability to show three-dimensional bar charts or pie charts has been proven to cause longer interpretation times and may even be interpreted incorrectly [24,25]. Similarly, Tufte [26] argues that most graphical bells and whistles (what he calls "chartjunk") increase the signal-to-noise ratio and dilute the message one wants to deliver. Presentation tools should not only create visually appealing visualisations but also support the presenter in creating visualisations that focus on strengthening the viewer's mental modal and transferring knowledge more efficiently. Therefore, a presentation tool should offer features based on the message that the presenter is trying to pass on, for instance based on Few's classifications introduced earlier [8]. Note that this is not only relevant for static visualisations but should also apply to the currently non-existent interactive features by, for example, basing ourselves on Siirtola's classification of relevant tasks for data exploration [12].

R3: Interactive Visualisations as Support for Oral Narratives. When using interactive and dynamic visualisations as support for an oral narrative, it is desirable to be able to predefine a sequence of views for a given data set and to step through these views during the presentation. In addition to simple enter and exit animations offered by existing tools, it is important to be able to apply the two interaction principles by Dix and Ellis [11] introduced earlier. This implies that it should be possible to modify parameters in between the steps of a presentation (e.g. change the scale or apply a filter on the data) and to change the data representation (e.g. by switching to another chart type). By allowing the presenter to define such a sequence of states, they can synchronise the visualisation state with the oral narrative at preparation time and ensure that limited interaction with the computer is needed during the presentation.

R4: Unscripted Data Exploration. In addition to stepping through the predefined states of a visualisation, the presenter should also be able to change the representation or parameters at any time during a presentation. Segel and Heer [2] pointed out the importance of balancing the narrative intended by the author with story discovery by the reader. This also applies to certain presentation styles where questions or discussions with the audience can drive the presentation. Therefore, a presentation tool should also allow the presenter to interact with the visualisation during the presentation with the same set of interactions offered at authoring time. Since the resolution (screen real estate) and interaction is limited during a presentation, special care needs to be taken to offer the available interactions in a way that does not clutter the visualisation and can be controlled without intensive user input.

R5: Interactivity after the Presentation. As mentioned earlier, readers or audience members should not be excluded from the interaction. This does not only apply during a presentation but should be valid for a slide deck's entire lifetime. For example, in higher education slide decks are often offered as part of the study material. A student reviewing the slides at home should at least be able to play back the visualisation as it was defined by the presenter. Ideally, students should also have the option to freely navigate the data in order to clarify any doubts they may have and to strengthen their mental model by exploring the data set. Another use case is the inverted or flipped classroom setting where activities that are typically considered homework become central during class and the teacher merely guides the completion of these activities [27]. By offering students the interactive slide decks that were used in the pre-recorded lectures, they are not only able to replicate situations from the videos, but they also have a tool for further data exploration in order to come to their own conclusions.

4 Implementation

In this section we discuss the technical details of the interactive and narrative visualisation extension for the MindXpres presentation tool by revisiting the requirements presented in Sect. 3 and showing how our prototype addresses these requirements.

Requirement R1 states that the visualisation should be integrated in the presentation tool in order that the presenter does not have to switch between external third-party applications. Our interactive data visualisation prototype has been implemented as a plug-in for the MindXpres presentation tool [28,29]. MindXpres was developed to overcome the limited extensibility of well-known slideware tools such as PowerPoint or Keynote and to offer a rapid prototyping platform for novel presentation ideas. While PowerPoint offers an Application Programming Interface (API), it enforces the usage of a linear sequence of slides with relatively static content which makes it difficult to experiment with radically new ideas for next generation presentation tools. In contrast, the highly modular MindXpres architecture allows any component to be replaced and new components and functionality can easily be added. For instance, users may choose to use a plug-in that visualises content using a zoomable user interface (ZUI) or they can use a plug-in that visualises the same content in a classic linear fashion as in existing slideware.

As shown in Fig. 1, the core MindXpres engine provides various abstractions that allow plug-in creators to focus on their ideas instead of having to reimplement the basic functionality. The graphics engine, for example, provides functionality related to the visualisation of content which drive features such as the ZUI and

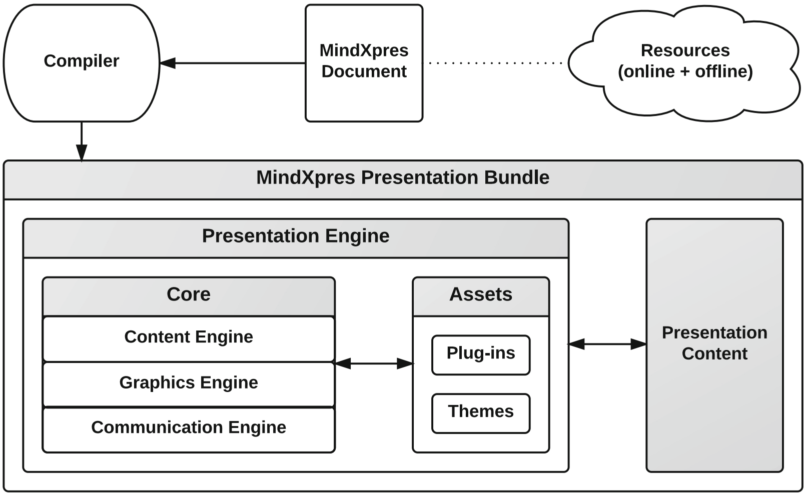

Fig. 1. MindXpres architecture.

interactive rich media visualisation plug-ins. The communication engine allows instances of a MindXpres presentation to form networks which enables plug-ins to communicate across devices and supports audience-driven functionality such as polls, quizzes or screen mirroring [30]. MindXpres uses HTML5 and related technologies for enhanced portability and plug-ins are written entirely in JavaScript. Although a graphical editor is under development, MindXpres presentations are currently defined in an XML-based declarative language similar to the LaTeX language that is used for the authoring of text documents. Listing 1.1 shows an example of a presentation in the XML authoring language. The goal is that a user can focus on the authoring of the content whereas the presentation tool deals with the layout and styling. While MindXpres comes with a default set of plug-ins for basic components such as images, bullet lists, videos or slides, it is easy to add plug-ins for new content types. Note that these plug-ins also extend the vocabulary used in the MindXpres document format. More specifically, a plug-in can add new XML tags to be used in the document format and the plug-in then takes responsibility for visualising content placed within these tags.

```xml
<presentation>
  <slide title="Vannevar Bush">
    <bulletlist>
      <item>March 1890 - June 1974</item>
      <item>Founder of Raytheon</item>
    </bulletlist>
    <image file="bush.jpg"/>
    <quote source="As We May Think (1945)">
      A record, if it is to be useful to science, must be continuously
      extended, it must be stored, and above all it must be consulted.
    </quote>
  </slide>
</presentation>
```

Listing 1.1. MindXpres presentation in XML.

In the past, MindXpres has been used for implementing new presentation components such as for the interactive visualisation of source code [31]. For the presented interactive data visualisation, we have taken a similar approach by implementing a data visualisation plug-in for MindXpres. Since MindXpres is based on client-side web technology, we did not have to start from scratch but could make use of existing visualisation libraries. As a starting point, we used Bostock's Data-Driven Documents (D3) JavaScript library [32] which supports complex data-driven visualisations through code. The library uses the widely supported SVG, HTML and CSS standards to generate the desired visualisation. D3 is a powerful solution offering control over every possible aspect, but it is also quite complex to use since even a simple static bar chart requires tens, if not hundreds of lines of code [33]. For this reason, we also use the C3.js JavaScript library[12], a D3-based reusable chart library that provides abstractions for most of the common chart types out of the box. Based on C3's API, one can control the state of a chart such as focusing on a data series, selecting data points, showing or hiding the data series or updating the data. With these features it is possible to change the chart in response to events such as user input or temporal triggers. Since MindXpres makes it possible to create highly dynamic and interactive plug-ins to integrate content directly in the slides (or other containers), *Requirement R1* is easily met.

Requirement R2 is the driving force behind the set of features and functionality that is offered to end users. We have already described how techniques and guidelines that contribute to the transfer of knowledge should be prioritised and this is reflected in what a user can do and sees as an end result. First of all, the default representations of the various charts and graphs are styled according to existing guidelines such as those by Tufte [26]. These guidelines include, for instance, the use of plain backgrounds or colour schemes that are composed of contrasting colours. We further made sure that enough graph and chart types are supported in order to represent all types of data characteristics a presenter might want to show to their audience. Therefore, we based ourselves on Few's classification [8] which defines the following ways for showing specific data characteristics:

- *Nominal Comparison*: compare categorised data in no particular order
- *Time Series*: visualise series of data over time
- *Ranking*: compare categorised data ordered by size
- *Part-to-Whole*: display categorised data as a ratio of the total
- *Deviation*: compare categorised data to a specific reference measure
- *Frequency Distribution*: show the count of occurrence in specific ranges
- *Correlation*: show statistical relationship between pairs of variables

Bar charts enable nominal comparisons, rankings, frequency distributions (histograms) and deviation (since bars can also go below the horizontal axis). Line charts further allow us to visualise time series, and the area under each line can optionally be filled with a colour. As an addition to bar charts, box

[12] http://c3js.org.

plots can also be used for showing deviation. Pie charts, regular bar charts and stacked bar charts allow the user to visualise how categories relate to the total amount of data. Finally, scatter plots are provided for showing correlation. Related work such as zGapMinder, ArtVis [22], GeoTime [23] and MediaViz [21] further highlights that geographical data should not be ignored. Our visualisation plug-in therefore supports different map-based visualisations such as bubble maps, choropleth maps as well as maps with pie chart overlays.

Requirement R3 demands that the visualisation and parameters should be changeable so that different views of the same data can be presented efficiently. The data to be used in a visualisation can be specified in two ways. It can either be directly defined in the MindXpres XML language or an external file can be provided. By default, D3 supports the loading of data in plain text, JSON, XML, HTML, CSV and TSV format. We have extended this list of formats with support for Excel spreadsheets by implementing a compile-time trigger in the MindXpres plug-in. The compiler converts any referenced spreadsheet data to JSON and bundles it with the presentation, which makes it easier for the JavaScript plug-in to process the data at runtime.

After providing a data set, the author can define the visualisation's starting state. This includes the setting a chart type, specifying the parts of the data to be shown initially as well as configuring specific chart components such as the zoom level, axes or legends. Subsequently, the author can define additional visualisation states to match their narrative. During the presentation, the presenter will be able to step through these states and the plug-in automatically applies the settings specified for each state. Note that any part of the configuration can

Table 1. Implemented abstractions for manipulating a visualisation.

Parameters	Description and abstractions
Highlighting	Highlighting and fading out specific elements[focus, defocus]
Visibility	Showing and hiding specific elements [show, hide]
Data sources	Load and unload data sets [load, unload, unload_all]
Data display	Data or group display settings [show, hide, set_name, set_colour]
Axis settings	Assign data group and display settings to axes [group, label, min, max, range]
Filtering	Apply or remove filter to data [apply_filter, remove_filter]
Selecting	Selecting or unselecting data [select, unselect]
Representation	Transform visualisation to a specified chart or map type [set_chart_type]
Grouping	Combine columns or groups into a new group [make_group]
Sorting	Sort data based on specified group [sort]
Gridlines	Settings for horizontal or vertical grid lines [set_spacing, enable, disable]
Regions	Select intervals on an axis for side by side display [add, remove]
Legend	Legend visibility and groups to be included [show, hide, set_groups]
Tooltip	Turn tooltip on or off [show, hide]
View area	View manipulation (zooming or panning) [set_zoom, set_x, set_y]
Chart size	Resize the chart to a given height and width [resize]
Chart rendering	Request a refresh or clear everything [redraw, clear]

change between states. This includes the data set, chart type as well as other parameters that cannot be changed in conventional presentation tools. In order to hide the complexity of the used D3 and C3 libraries, we provide abstractions for useful configuration changes in accordance to the interaction techniques provided by Yi et al. [10]. Table 1 highlights a list of abstractions implemented by our prototype, which make it easier for a presenter to define the transformations needed to bring the visualisation to the next desired state. Further, Listing 1.3, which is discussed in more detail later, shows an example of how a visualisation and its states are defined in the XML language. In this example the data is retrieved from an external file but the visualisation states are defined in the XML language. Note that the data could also be defined in the XML document itself and on the other hand the configuration could be defined in an external file.

While quantitative data can all be treated in the same way for operations such as averaging, grouping, filtering and visualising, additional work was required to support data representing geographical locations. When an abstraction related to geographical data is invoked, the relevant subset of data is automatically examined. If the data is numerical and within a certain range, it is assumed that the data represents coordinates and nothing further needs to be done. In the case that the data is in textual form, reverse geocoding is applied. This implies that the text is converted into coordinates in order that strings that represent a location (e.g. "*Belgium*" or "*Fifth Avenue New York*") can be used in the visualisation. In the current implementation the reverse geocoding is performed via the Google Maps Geocoding API[13] which requires a connection to the Internet. However, in future implementations we could also provide a local database for offline lookups. The result of the reverse geocoding process is a set of coordinates that can be used in the visualisation. The map-based visualisations are also based on D3.js. Our plug-in includes a file that contains the topological data needed for visualising countries and continents. These boundaries can also be used by the plug-in to classify coordinates by region. An extension called D3 Geo Projection[14] allows us to easily map geographic coordinates to pixel coordinates in the map viewport while taking the map's current projection method, scale and rotation into account. It was further necessary to define some operations specifically for coordinates, such as operations for calculating the distance between coordinates or finding the centre of a list of coordinates (the centroid).

In order to fulfil *Requirement R4*, the presenter is free to apply unscheduled abstractions at any time during a presentation. Some of the abstractions are triggered via the mouse. For example, by hovering over an element, the element is highlighted and the corresponding tooltip is shown. Similarly, data groups can be hidden or shown by clicking on the relevant group in the legend. However, note that not all interactions can be offered via non-intrusive mouse actions. For this reason we have integrated an interaction menu that allows the presenter to

[13] https://developers.google.com/maps/documentation/geocoding/start.
[14] https://github.com/d3/d3-3.x-api-reference/blob/master/Geo-Projections.md.

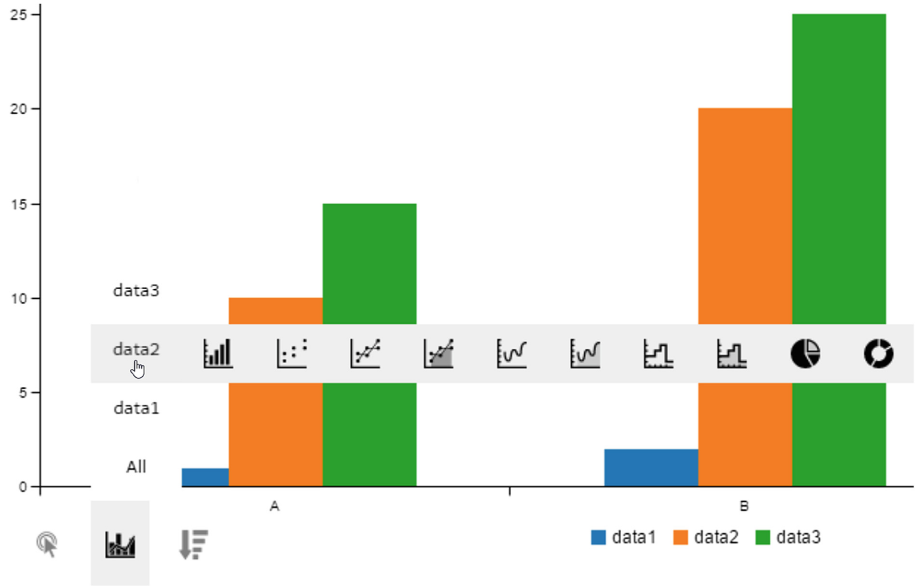

Fig. 2. Interaction menu at presentation time.

perform any of the offered interaction abstractions during the presentation as illustrated in Fig. 2.

Last but not least, *Requirement R5* has been addressed by allowing the audience to play back the visualisation at home and freely explore it. Since MindXpres is based on web technologies, a MindXpres presentation bundle can easily be made accessible online and accessed by any device running a web browser. A viewers can iterate through the predefined states as set up by the presenter, but they also have access to the menu for manually applying any of the provided abstractions. This helps a viewer to strengthen their mental model as they are free to examine the data from different angles in case something is not clear.

5 Use Case

In order to demonstrate the benefits of our interactive data visualisation plug-in, we present a short scenario that demonstrates how one can use the plug-in to create a narrative visualisation. In contrast to existing presentation tools, a presenter only needs to create one visualisation with one data set for which they define a sequence of views that support their oral narrative. This not only requires much less time and effort than existing workarounds, but it also makes it easier to apply changes at a later point in time. In the presented scenario, the goal is to compare the tax and social burdens of salaried employees in the 27 member states of the European Union. As a starting point, a JSON file that contains the relevant data for the year 2014 is used [34]. A small snippet of the

JSON content is shown in Listing 1.2. A dynamic and interactive visualisation is then used to illustrate the extra money an employer has to pay in order that an employee will receive exactly one euro after taxes. Since the presentation is going to be delivered to a Belgian audience, the presenter starts with an explanation of the tax situation in Belgium. At first, a simple chart is shown in Fig. 3(a) with a blue bar representing the one euro the employee receives.

```
[
  ["Austria",1,0.5,0.32,0.29],
  ["Belgium",1,0.62,0.5,0.22],
  ["Bulgaria",1,0.22,0.11,0.16],
  ...
  ["Spain",1,0.39,0.21,0.08],
  ["Sweden",1,0.42,0.33,0],
  ["United Kingdom",1,0.14,0.2,0.12]
]
```

Listing 1.2. A snippet of the JSON data used in the scenario.

In a next step, the presenter introduces the concept of employer social security and adds it to the chart in the form of the orange extension to the original blue bar in Fig. 3(b), in order to provide an idea of the proportions. Note that the scale of the horizontal axis automatically adjusts and now shows a linear scale from 0 to the total costs of 1.6 euro so far. The same procedure is repeated for the income tax (green) and the employee social security (red), introducing one item at a time in order to keep the audience focussed on the explanations (Fig. 3(c)). The exact values of the different parts that make up the bar are shown in a small table when the mouse cursor is hovered over the bar. In a next step, the presenter transforms the visualisation into a pie chart which shows the ratio of each part as a percentage, revealing that an employee only receives 42.7% of what the employer pays as shown in Fig. 3(d).

In order to get a better understanding of what these values mean, the presenter switches back to a bar chart and compares the Belgian with the average EU employer costs as illustrated in Fig. 3(e). In order to show the variation in employer costs across Europe, the presenter can zoom out and show all the countries in the data set side by side as highlighted in Fig. 3(f). By default the countries are ordered alphabetically and if the list is too long to fit on the screen, the presenter can drag up and down to scroll in the list. Note that at any point the presenter can zoom back to a single country, for instance Cyprus, in order to explain why it is the country with the lowest employer costs as shown in Fig. 3(g). Finally, the presenter decides to show the full list again, but this time sorted by total employer costs in order to point out the cheapest and most expensive countries from the perspective of an employer as highlighted in Fig. 3(h).

So far the presenter has only used graphs to explore the data and spatial properties have not been taken into account. For instance, it might be interesting to see whether the location plays a role and if countries that are close to Belgium have similar high taxes. Figure 4 shows an alternative map-based visualisation with Belgium and its neighbouring countries. For each country the centroid is calculated and a pie chart containing the different tax ratios is shown in the centre of the country's boundaries. Note that the presenter never had to deal

(a) One Euro received by employee

(b) Add employer social security

(c) Add income tax and employee social security

(d) Switch to pie chart

(e) Compare with EU average

(f) All countries (alphabetically)

(g) Zoom in

(h) All countries (sorted by value)

Fig. 3. Various graph-based phases of a visualisation for EU employer costs. (Color figure online)

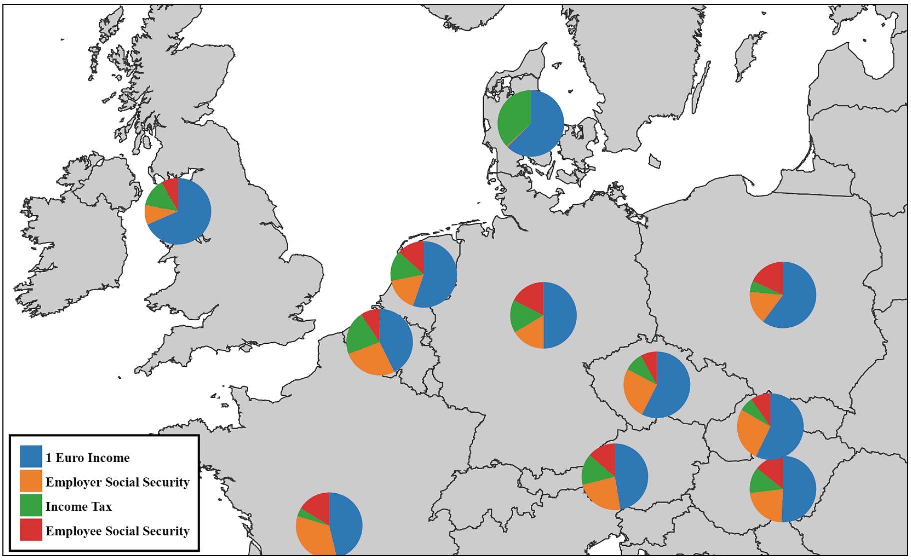

Fig. 4. A map-based visualisation of the EU employer costs.

with any coordinates as the tool automatically applied reverse geocoding based on the country names contained in the country column of the data set and deduced that the granularity of the categorisation was at the level of countries.

Note that even without the narrative, a viewer might still derive the implicit messages that the presenter would normally present orally (e.g. "*Belgium employees receive less than half of what the employer pays*", or "*employer costs in Belgium are very high compared to the rest of Europe*"). This is in line with the findings of Hullman and Diakopoulos who state that narrative visualisations can be designed to deliver predefined implicit messages [14]. It further demonstrates the potential value of our interactive data visualisation plug-in for audience members who review the slides after the delivery of a presentation (e.g. students using the slides as study material) as they can play back the sequence and come to the intended conclusions without the oral narrative.

Listing 1.3 shows how the discussed scenario has been defined in the XML-based MindXpres authoring language. The illustrated XML snippet forms part of a larger XML document defining the entire presentation. The `infovis` tag on the first line tells the MindXpres compiler and runtime engine that our information visualisation plug-in has to be invoked in order to process the child tags and render the relevant content. The `data` tag then specifies the data file to be used by the plug-in. Finally, a list of visualisation states or views are provided.

```
<infovis>
 <data file="tax_eu.csv"></data>
 <config>
  <view>
   <chart type="bar"variant="stacked"/>
   <axis dim="x"group="socialtax"/>
   <axis dim="y"group="countries"/>
   <filter group="countries"value="Belgium"/>
   <show group="socialtax"sub="income"/>
  </view>
  <view>
    <show group="socialtax"sub="security1"/>
  </view>
  ...
  <view>
   <show group="socialtax"sub="security2"/>
  </view>
  <view>
   <chart type="pie" />
  </view>
  ...
 </config>
</infovis>
```

Listing 1.3. XML definition of visualisation states.

By default the first view in the list will be used as an initial state, resulting in the chart shown in Fig. 3(a). The succeeding views contain instructions on how to adapt the visualisation for subsequent visualisation states. In this case, subgroups of data are made visible and since the chart type is a stacked bar chart, they will be added to the relevant bars. When the author wants to switch to a pie chart, the `chart` tag is used to set a new chart type. Note that any settings from previous views, such as the filter put in place to select only data from Belgium, are still valid. In this case, axis settings are also kept but are ignored as they are not relevant for a pie chart. Nevertheless, when we switch back to a bar chart in a later view, the earlier axis settings still apply. The rest of the states shown in the scenario are achieved in a similar manner and are mainly the result of applying filter and sorting instructions.

6 Discussion and Conclusion

Information visualisation has become more dynamic and interactive by adapting to recent media for content delivery. We started by discussing the benefits of dynamic and interactive visualisations and have presented the relevant concepts that contribute to their success. In particular we have shown how narratives can be used to make data more memorable and how a viewer's mental model can be strengthened by allowing them to interact with the data. However, we identified that the benefits of such interactive visualisations are currently not applied to their full potential in the context of presentation tools. This can partially be attributed to a lack of technical support. For instance, in a popular presentation tool such as PowerPoint there are many different chart types, but the result is always a static view which is unsuitable for data exploration or narrative visualisation. There are a number of workarounds including the use of basic enter and exit animations but unfortunately one cannot make changes to the underlying data or visualisation parameters during these animations.

Related work shows many interesting tools for the exploration of data but hardly any of them have been adapted for usage in a presentation. In particular, these tools are often specialised stand-alone applications with a complex user interface and have little to no support for creating visualisations that support a narrative. Based on the investigated related work and established interactive and narrative visualisation techniques, we derived a set of five requirements for interactive data visualisation in the context of presentations. We have further presented the implementation of an interactive and narrative visualisation prototype that meets these requirements and has been realised as a generic data visualisation plug-in for the MindXpres presentation tool. The discussed plug-in allows presenters to directly embed interactive and narrative visualisations into their presentation. In order to support a variety of different data sets and visualisation styles, we have defined a number of generic abstractions for changing specific aspects of a visualisation. The presenter can use these abstractions to predefine a series of visualisation states supporting their story but they can also be applied freely during the delivery of a presentation. Note that the provided abstractions are not restricted to the data representation (e.g. chart type or zoom level) but also allow the underlying data to be manipulated. For instance, data can be filtered, sorted or added in order to better fit the message the presenter is trying to deliver. Thereby, interactive visualisations as support for an oral narrative can be created with minimal effort, in contrast to existing slideware such as PowerPoint where a new graph would have to be created for each state. Our approach also shows benefits when changes have to be made to the narrative and when the visualisations need to be adapted. Since nowadays slide decks form an important part of the reference material that is provided to students, the plug-in not only allows them to play back the visualisation at home but further enables them to freely explore the data in order to clarify any questions they might have and to strengthen their mental model.

The features that our solution offers to end users are based on well-established techniques and guidelines for information visualisation. For example, we ensured to provide support for all the message types that can be visualised using quantitative data, as defined by Few [8]. This has been achieved by supporting a wide range of common chart types (and their variations) such as line, bar or pie charts as well as scatter plots. Furthermore, we support map-based visualisations such as bubble charts and choropleth maps to illustrate spatial date relations. Our current solutions also supports all the interaction techniques defined by Yi [10] except for techniques related to the *connect* principle, which would allow viewers to show items which are related to a selected one. The support of this principle has proven to be non-trivial as there is no similarity metrics that works for all data and contexts. Further investigation is needed to see how we might abstract this particular interaction technique in the future.

In correspondence with the declarative content authoring approach of the MindXpres presentation platform, the presented plug-in extends the XML-based MindXpres authoring language in order to define interactive and narrative visualisations based on raw data sets. However, in the near future we foresee a graphical authoring component. The interaction menu for real-time modifications shown earlier in Fig. 2 has potential for being used at authoring time. A visualisation sequence could, for instance, be defined as a sequence of snapshots created by using the menu to specify the desired visualisation states.

In conclusion, the presented MindXpres extension represents a major step towards applying the benefits of interactive data exploration and storytelling to the domain of presentation tools. The benefits of applying interactive and narrative visualisations in presentations has been illustrated in a use case where we also highlighted the flexibility of our approach. Even if our current prototype has been developed as a plug-in for the MindXpres presentation platform, we are convinced that our findings and proposed abstractions for data exploration are general enough and can also be applied to other presentation tools. Furthermore, the requirements that we have defined for interactive information visualisation in presentation tools might serve third-party slideware vendors as input for improving their existing products in order to improve the oral knowledge transfer when presenting specific data sets.

References

1. Kosara, R., Mackinlay, J.: Storytelling: the next step for visualization. Computer **46**, 44–50 (2013)
2. Segel, E., Heer, J.: Narrative visualization: telling stories with data. IEEE Trans. Visual Comput. Graphics **16**, 1139–1148 (2010)
3. Parker, I.: Absolute powerpoint: can a software package edit our thoughts. The New Yorker **28**, 76–87 (2001)
4. Show Me - New Ways of Visualising Data. The Economist (2010). http://www.economist.com/node/15557455. Accessed 29 Jun 2016
5. Zhicheng, L., Stasko, J.T.: Mental models, visual reasoning and interaction in information visualization: a top-down perspective. IEEE Trans. Visual Comput. Graphics **16**, 999–1008 (2010)
6. Ware, C.: Information Visualization: Perception for Design, 3rd edn. Elsevier, Amsterdam (2012)
7. Ellis, W.D.: A Source Book of Gestalt Psychology. Psychology Press, New York (1999)
8. Few, S.: Show Me the Numbers: Designing Tables and Graphs to Enlighten, 2nd edn. Analytics Press, Burlingame (2004)
9. Gibson, J.J.: Observations on active touch. Psychol. Rev. **69**, 477 (1962)
10. Yi, J.S., Kang, Y.A., Stasko, J., Jacko, J.: Toward a deeper understanding of the role of interaction in information visualization. IEEE Trans. Visual Comput. Graphics **13**, 1224–1231 (2007)
11. Dix, A., Ellis, G.: Starting simple: adding value to static visualisation through simple interaction (1998)
12. Siirtola, H.: Interactive visualization of multidimensional data. Ph.D. thesis, University of Tampere (2007)

13. Austin, M.: Useful Fictions: Evolution, Anxiety, and the Origins of Literature. University of Nebraska Press, Lincoln (2011)
14. Hullman, J., Diakopoulos, N.: Visualization rhetoric: framing effects in narrative visualization. IEEE Trans. Visual Comput. Graphics **17**, 2231–2240 (2011)
15. Dawkes, H., Tweedie, L.A., Spence, B.: VICKI: The VIsualisation Construction KIt. In: AVI 1996, Workshop on Advanced Visual Interfaces. ACM (1996)
16. Ahlberg, C.: Spotfire: an information exploration environment. ACM SIGMOD Rec. **25**, 25–29 (1996)
17. Swayne, D.F., Lang, D.T., Buja, A., Cook, D.: GGobi: evolving from XGobi into an extensible framework for interactive data visualization. Comput. Stat. Data Anal. **43**, 423–444 (2003)
18. Viegas, F.B., Wattenberg, M., van Ham, F., Kriss, J., McKeon, M.: ManyEyes: a site for visualization at internet scale. IEEE Trans. Visual Comput. Graphics **13**, 1121–1128 (2007)
19. Rosling, H.: TED Talk: Hans Rosling Shows The Best Stats You've Ever Seen (2006). www.ted.com
20. Robertson, G., Fernandez, R., Fisher, D., Lee, B., Stasko, J.: Effectiveness of animation in trend visualization. IEEE Trans. Visual Comput. Graphics **14**, 1325–1332 (2008)
21. Devezas, T., Nunes, S., Rodríguez, M.T.: MediaViz: an interactive visualization platform for online media studies. In: HIC 2015, International Workshop on Human-Centric Independent Computing. ACM (2015)
22. Dumas, B., Moerman, B., Trullemans, S., Signer, B.: ArtVis: combining advanced visualisation and tangible interaction for the exploration, analysis and browsing of digital artwork collections. In: AVI 2014, 12th International Working Conference on Advanced Visual Interfaces. ACM (2014)
23. Eccles, R., Kapler, T., Harper, R., Wright, W.: Stories in GeoTime. In: VAST 2007, IEEE Symposium on Visual Analytics Science and Technology. IEEE (2007)
24. Siegrist, M.: The use or misuse of three-dimensional graphs to represent lower-dimensional data. Behav. Inf. Technol. **15**, 96–100 (1996)
25. Fischer, M.H.: Do irrelevant depth cues affect the comprehension of bar graphs? Appl. Cogn. Psychol. **14**, 151–162 (2000)
26. Tufte, E.R., Graves-Morris, P.: The Visual Display of Quantitative Information, 2nd edn. Graphics Press, Cheshire (1983)
27. Bishop, J.L., Verleger, M.A.: The flipped classroom: a survey of the research. In: ASEE 2013, 120th American Society for Engineering Education Conference (2013)
28. Roels, R., Signer, B.: MindXpres: an extensible content-driven cross-media presentation platform. In: Benatallah, B., Bestavros, A., Manolopoulos, Y., Vakali, A., Zhang, Y. (eds.) WISE 2014. LNCS, vol. 8787, pp. 215–230. Springer, Cham (2014). doi:10.1007/978-3-319-11746-1_16
29. Roels, R., Baeten, Y., Signer, B.: An interactive data visualisation approach for next generation presentation tools: towards rich presentation-based data exploration and storytelling. In: CSEDU 2016, 8th International Conference on Computer Supported Education. SCITEPRESS (2016)
30. Roels, R., Signer, B.: A unified communication platform for enriching and enhancing presentations with active learning components. In: ICALT 2014, 14th IEEE International Conference on Advanced Learning Technologies. IEEE (2014)
31. Roels, R., Mestereaga, P., Signer, B.: Towards enhanced presentation-based teaching of programming - an interactive source code visualisation approach. In: CSEDU 2015, 7th International Conference on Computer Supported Education. SCITEPRESS (2015)

32. Bostock, M., Ogievetsky, V., Heer, J.: D3 data-driven documents. IEEE Trans. Visual Comput. Graphics **17**, 2301–2309 (2011)
33. Bostock, M.: Let's Make a Bar Chart (2013). http://bost.ocks.org/mike/bar/. Accessed 29 Jun 2016
34. Rogers, J., Philippe, C.: The Tax Burden of Typical Workers in the EU 28, vol. 17. New Direction, Brussels (2014)