

An Interactive Data Visualisation Approach for Next Generation Presentation Tools *Towards Rich Presentation-based Data Exploration and Storytelling*

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Keywords: Presentations, Slideware, Narrative Visualisation, Data Exploration

Abstract: Existing research in the field of information visualisation has shown that interactive data exploration and storytelling can significantly improve the extraction and transfer of knowledge from raw data. Established visualisation techniques help viewers to strengthen their mental model and improve the understanding of the underlying data. However, these techniques are not yet manifested in slide decks created by existing presentation tools which offer little to no support beyond static charts for transferring knowledge. Based on a detailed analysis of interactive and narrative data visualisation solutions and the shortcomings of existing presentation tools, we derived a set of requirements for interactive information visualisation in presentation tools. The presented prototype of a presentation tool for interactive data visualisation addresses these requirements and has been implemented as a plug-in for the MindXpres presentation platform. Our approach for rich presentation-based data exploration and storytelling enables the presenter to predefine a series of interactive views as support for their oral narrative, but also allows them to freely explore the data during presentation time.

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 developments therefore emphasise 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 that have been acquired by studying specific data sets (Kosara and Mackinlay, 2013). Facts that are tied together as part of a story are easier to present as well as more memorable by the audience. This is one of the reasons why we have seen the rise of so-called narrative visualisations or visualisations that help us tell stories with data (Segel and Heer, 2010). For example, educational textbooks often contain various charts and diagrams in order to support the message that the text is trying to convey. These narrative visualisations have been adapted to more recent media and are becoming increasingly dy-

namic. For instance, news on the TV 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 by presentation tools such as PowerPoint. With over 30 million PowerPoint presentations created every day (Parker, 2001), 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 would 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 the content of a presentation. Nevertheless, existing workarounds to implement this functionality either require too much time and effort or the presenter has to use some third-party tools during a presentation, interrupting 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 an existing presentation tool 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 the steps 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 audience members to strengthen their mental model and enhances the effectiveness of knowledge transfer. In addition, our proposed approach not only reduces the time needed to create compelling narratives out of raw data, but also allows for a shift towards audience-driven narratives.

In Section 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 and derive a number of general requirements for interactive narrative information visualisation in presentation tools in Section 3. In Section 4, some details about our prototype implementation for the MindXpres presentation tool are provided, which is followed by a use case in Section 5 to illustrate some of our prototype's functionality. We conclude with a discussion and outline of future work.

2 BACKGROUND

We now have a look at existing information visualisation and narrative visualisation concepts and out-

line the limitations of existing presentation tools in terms of information visualisation as well as narrative visualisation.

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 (Zhicheng and Stasko, 2010). Such graphical representations make use of our highly developed ability to process the continuous stream of information-rich signals captured by our eyes (Ware, 2012). 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 (Ellis, 1999). 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 (Few, 2004) proposes a classification consisting of eight types of messages that can be derived from a visualisation, including time series, rankings, part-to-whole, deviation, distribution, correlation, geospatial messages and nominal comparison.

The formation of a mental model can further be augmented by allowing the user to interact with the data (Ware, 2012). The significance of interaction while processing information was illustrated in Gibson's cookie cutter experiment (Gibson, 1962) 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 (Yi et al., 2007). Furthermore, Dix and Ellis (Dix and Ellis, 1998) emphasise two important principles in interacting with visualisations. The first principle "*same representa-*

tion, 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 on different interaction techniques (e.g. 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 (Siirtola, 2007) and Yi (Yi et al., 2007). 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*” (Kosara and Mackinlay, 2013). 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 (Austin, 2011). Segel and Heer (Segel and Heer, 2010) 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 (Segel and Heer, 2010). 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 (Kosara and Mackinlay, 2013).

Note that narrative visualisations can be manipulated to emphasise specific messages during free exploration. For instance, Hullman and Diakopoulos (Hullman and Diakopoulos, 2011) identified a number of approaches and design techniques to prioritise 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 Presentation 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 to achieve the desired effect. This can get even more complicated when changes need to be made at a later stage. In order to switch to another chart type, it might even 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 (e.g. oomfo¹ or think-cell²) 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 Keynote³ or Prezi⁴.

In terms of academic work, there are a number of tools based on the interactive visualisation principles discussed earlier. Notable examples are VICKI (Dawkes et al., 1996), Spotfire (Ahlberg, 1996) and GGobi (Swayne et al., 2003). While they are promising tools founded on the principles of proven concepts, they also show a few shortcomings making them less suited for usage 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. Additionally, significant interaction is needed to operate these 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 clear that these solutions focus on the interactive exploration part, but the ability to use them as narrative visualisation tools is limited. Note that GGobi also provides an Application Programming Interface (API) that allows programmers to embed and interact with visualisations pragmatically. There are other developer frameworks such as UC Berkeley's prefuse visualization toolkit⁵ for the Java programming language or the popular D3⁶ JavaScript library. While

they offer a broad range of features for modern data visualisation, these frameworks are usually used for building standalone applications. More importantly, they require the programming of the desired visualisation which is not suitable for the average presenter.

Hans Rosling's 2006 TED talk entitled "The Best Stats You've Ever Seen" (Rosling, 2006) is an excellent example of the fact that it is not impossible 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 if we cannot present these statistics in an accessible way. For his presentation, he used a proprietary tool (now forming part of the Gapminder⁷ 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 quite some attention (Kosara and Mackinlay, 2013) and has been explored in greater detail. Robertson later showed that animated transitions can have a negative effect on the viewer's ability to follow trends (Robertson et al., 2008), but because they are entertaining and capture the attention they work well in front of a live audience. While this is definitely a major step in the right direction, the Gapminder series of tools also has some shortcomings. First of all, they are again standalone applications and require us to switch from our presentation tool. More importantly, the tools were built specifically for educating people about specific topics related to human development which implies that the data sets are fixed and the functionality and visualisations are tweaked for drawing conclusions from data such as geographic and demographic data over time.

The discussed related research highlights the added value of interactive and narrative visualisations but we have to conclude that existing presentation tools do not offer the required support for applying such narrative visualisations in practice. There are some workarounds such as creating multiple static charts and manually defining transitions between them but often presenters are not willing to make this effort and rather opt for a less dynamic narrative. On the other hand, it is possible to use standalone tools which were not intended to be used in the context of live presentations and are difficult if not impossible to be applied as tools for narrative visualisation.

¹<http://oomfo.com>

²<http://www.think-cell.com/en/products/>

³<http://www.apple.com/mac/keynote/>

⁴<https://prezi.com>

⁵<https://github.com/prefuse/Prefuse>

⁶<http://d3js.org>

⁷<http://www.gapminder.org/downloads/>

3 REQUIREMENTS

Research in the field of information visualisation and narrative visualisation shows that a lot can be gained by using specific visualisation techniques when transferring knowledge. However, as discussed earlier we see that presentation tools do not exploit these visualisation techniques to their full potential. Our goal is to close this gap and apply lessons learned from interactive information visualisation as well as narrative visualisation to presentations in order to improve presentation-based knowledge transfer. Based on the presented related work and the shortcomings of existing presentation solutions discussed in Section 2, we derive 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 our 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 (Siegrist, 1996; Fischer, 2000). Similarly, Tufte (Tufte and Graves-Morris, 1983) 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 (Few, 2004). 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 (Siirtola, 2007).

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 (Dix and Ellis, 1998) introduced earlier. This implies that it should be possible to apply new 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 beforehand 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 point during the presentation. Segel and Heer (Segel and Heer, 2010) pointed out the importance of balancing a narrative intended by the author with story discovery from the side of the reader in visual narrative genres. 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. Another use case is the inverted or flipped class-

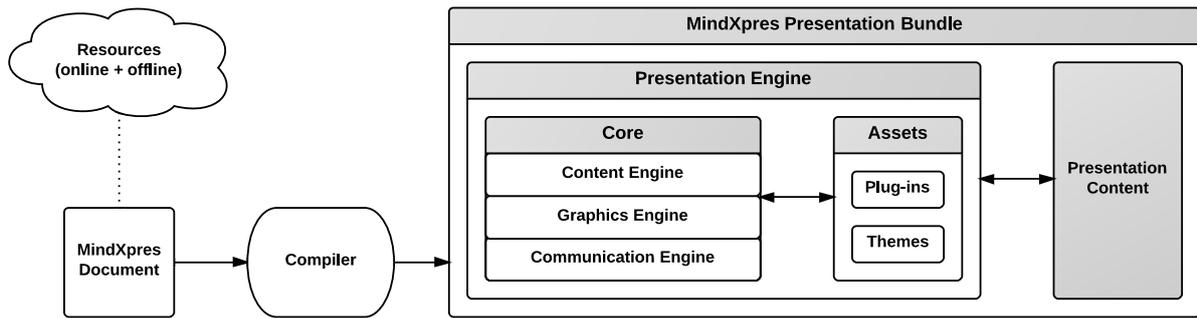


Figure 1: MindXpres architecture

room setting where activities that are typically considered homework become central during class and the teacher merely guides the completion of these activities (Bishop and Verleger, 2013). 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

Our interactive data visualisation prototype has been implemented as a plug-in for the MindXpres presentation tool (Roels and Signer, 2014b). 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 Figure 1, the core MindXpres engine provides various abstractions that allows 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 interactive rich media visualisation plug-ins. The communication engine allows instances of a MindXpres presentation to form net-

works which enables plug-ins to communicate across devices and supports audience-driven functionality such as polls, quizzes or screen mirroring (Roels and Signer, 2014a). 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 a XML-based declarative language similar to the \LaTeX language used for text documents. Listing 1 shows an example of a presentation in the XML authoring language. The goal is that a user should focus on the authoring of the content and 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 new 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. A plug-in that introduces new tags also takes responsibility for visualising content placed within these tags.

```

1 <presentation>
2   <slide title="Vannevar Bush">
3     <bulletlist>
4       <item>March 1890 - June 1974</item>
5       <item>Founder of Raytheon</item>
6     </bulletlist>
7     <image file="bush.jpg"/>
8     <quote source="As We May Think (1945)">
9       A record, if it is to be useful to
10      science, must be continuously extended,
11      it must be stored, and above all it must
12      be consulted.
13     </quote>
14   </slide>
15 </presentation>

```

Listing 1: MindXpres presentation in XML

Table 1: List of implemented abstractions for manipulating a visualisation

Parameters	Abstractions	Description
highlighting	focus, defocus	highlighting and fading out specific elements
visibility	show, hide	showing and hiding specific elements
data sources	load, unload, unload_all	load and unload data sets
data display	show, hide, set_name, set_colour	data or group display settings
axis settings	group, label, min, max, range	assign data group and display settings to axes
filtering	apply_filter, remove_filter	apply or remove filter to data
selecting	select, unselect	selecting or unselecting data
representation	set_chart_type	transform visualisation to a specified type
grouping	make_group	combine columns or groups into a new group
sorting	sort	sort data based on specified group
gridlines	set_spacing, enable, disable	settings for horizontal or vertical grid lines
regions	add, remove	select intervals on an axis for side by side display
legend	show, hide, set_groups	legend visibility and groups to be included
tooltip	show, hide	turn tooltip on or off
view area	set_zoom, set_x, set_y	view manipulation (zooming or panning)
chart size	resize	resize the chart to a given height and width
chart rendering	redraw, clear	request a refresh or clear everything

In the past, MindXpres has been used for implementing new presentation components such as for the interactive visualisation of source code (Roels et al., 2015). For the presented solution, we have taken a similar approach and realised interactive data visualisation 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 use Bostock’s Data-Driven Documents (D3) JavaScript library (Bostock et al., 2011) which supports complex data-driven visualisations through code. The library then 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 (Bostock, 2013). For this reason, we also use the C3.js JavaScript library⁸, 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.

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

⁸<http://c3js.org>

can be provided. By default, D3 supports the loading of data in plain text, JSON, XML, HTML, CSV and TSV format. We 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 but is not limited to setting a chart type, specifying which parts of the data to show initially and configuring specific chart components such as zoom level, axes or legends. Subsequently the author can define additional visualisation states to match their narrative. During the presentation, the author 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 change between states. This includes the data set, chart type and 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. (Yi et al., 2007). Table 1 highlights a list of abstractions implemented by our prototype. These abstractions make it easier for a presenter to define the transformations needed to get the visualisation to the next desired state. Listing 2 shows an example of how a visualisation and its states are defined in the XML

language. In this case, 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 and on the other hand the configuration might be defined in an external file.

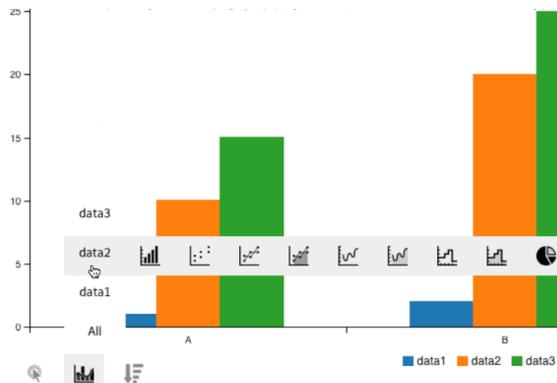


Figure 2: Interaction menu at presentation time

In addition to predefining the required states, the presenter is free to apply unscheduled abstractions at any point during the presentation. Some of the abstractions are triggered with the mouse, for instance by hovering over an element it 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 if it is shown. However, 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 perform any of the offered interaction abstractions during the presentation as illustrated in Figure 2.

5 USE CASE

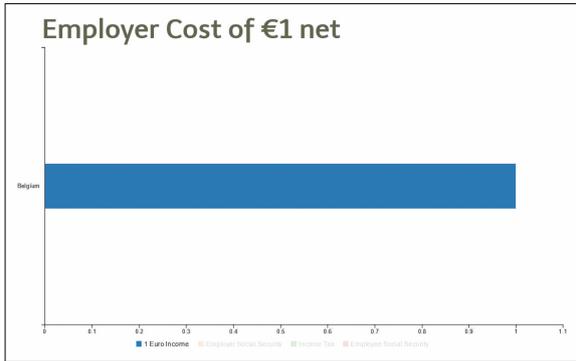
In order to demonstrate the benefits of our interactive data visualisation plug-in, we present a short scenario that demonstrates how one can use the plug-in to create a narrative visualisation. In contrast to existing presentation tools, a presenter only needs to create one visualisation with one data set for which they define a sequence of views that support their oral narrative. This requires not only much less time and effort than existing workarounds, but it also becomes 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 CSV file that contains the relevant data for 2014 is used (Rogers and Philippe, 2014). A dynamic and interactive visualisation is then used to illustrate the extra money an employer has to pay in order that an em-

ployee will receive exactly one euro after taxes. Since the presentation is 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 Figure 3a with a blue bar representing the one euro the employee receives.

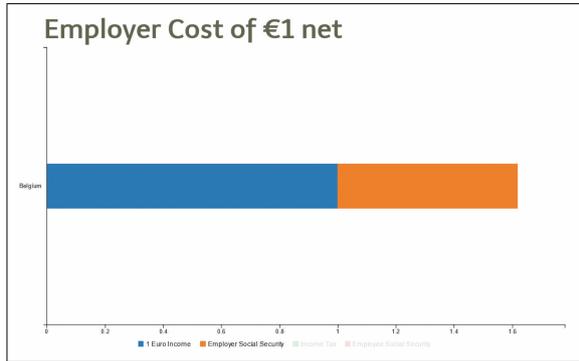
In a next step, the presenter introduces the concept of employer social security and adds it to the chart in the form of the orange extension to the original blue bar in Figure 3b, in order to provide an idea of the proportions. Note that the scale of the horizontal axis automatically adjusts and now 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 (Figure 3c). 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. The presenter then 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 (Figure 3d).

In order to get a better understanding of what these values mean, the presenter switches back to a bar chart and compares the Belgian and the average EU employer costs side by side as illustrated in Figure 3e. Next, to show the variation in employer costs across Europe the presenter can scroll to zoom out and show all countries in the data set side by side (Figure 3f). By default the countries are ordered alphabetically and if the list is too long to fit on the screen, the presenter can drag the mouse 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 (Figure 3g). 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 Figure 3h.

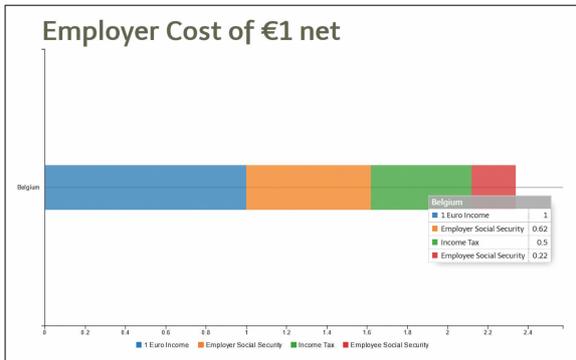
Note that even without the narrative, a viewer might still derive the implicit messages that the presenter would normally present orally (e.g. “Belgium employees receive less than half of what the employer pays”, or “employer costs in Belgium are very high compared to the rest of Europe”). This is in line with the findings of Hullman and Diakopoulos who state that narrative visualisations can be designed to deliver predefined implicit messages (Hullman and Diakopoulos, 2011). It further demonstrates the potential value of our interactive data visualisation plug-in for viewers who review the slides after the presentation (e.g. students using the slides as study material)



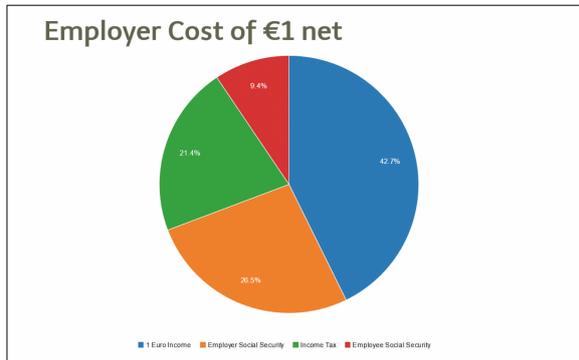
(a) One Euro received by employee



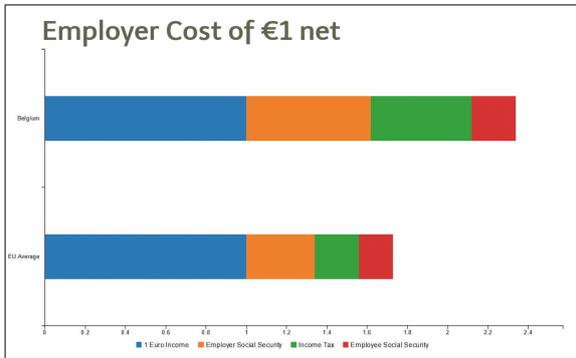
(b) Add employer social security



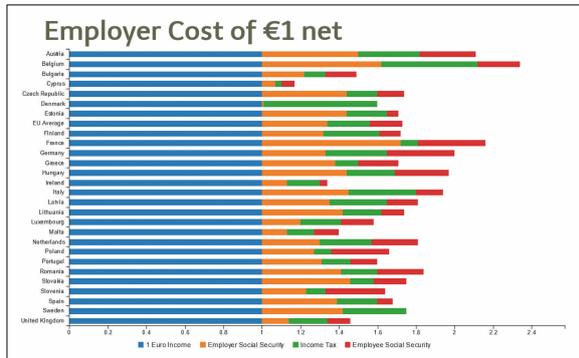
(c) Add income tax and employee social security



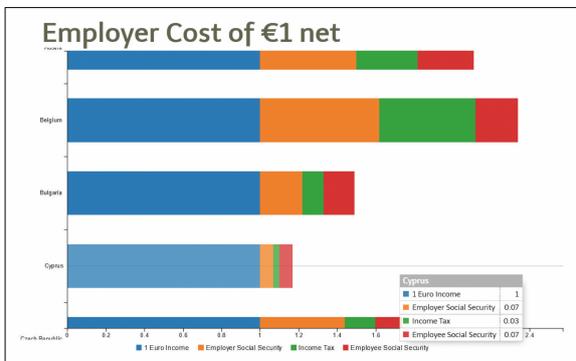
(d) Switch to pie chart



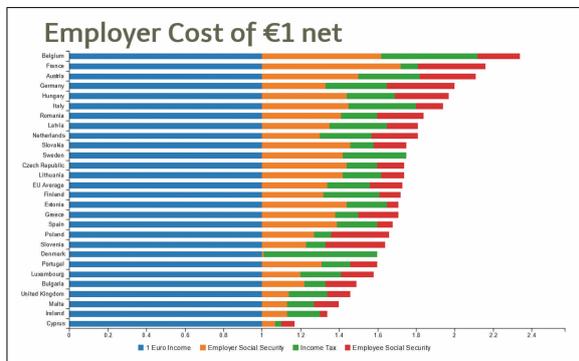
(e) Compare with EU average



(f) All countries (alphabetically)



(g) Zoom in



(h) All countries (sorted by value)

Figure 3: Various phases of a visualisation for discussing EU employer costs

as they can play back the sequence and come to the intended conclusions without the oral narrative.

```
1 <infovis>
2 <data file="tax_eu.csv"></data>
3 <config>
4 <view>
5 <chart type="bar" variant="stacked" />
6 <axis dim="x" group="socialtax" />
7 <axis dim="y" group="countries" />
8 <filter group="countries" value="Belgium"/>
9 <show group="socialtax" sub="income" />
10 </view>
11 <view>
12 <show group="socialtax" sub="security1" />
13 </view>
14 ...
15 <view>
16 <show group="socialtax" sub="security2" />
17 </view>
18 <view>
19 <chart type="pie" />
20 </view>
21 ...
22 </config>
23 </infovis>
```

Listing 2: XML definition of visualisation states

Listing 2 shows how this scenario has been defined in the XML-based MindXpres authoring language. The illustrated XML snippet of course forms part of a larger XML document defining the whole 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. Next, a `data` tag specifies the data file to be used by the plug-in. Finally, a list of visualisation states or views are provided. By default the first view in the list will be used as an initial state, resulting in the chart shown in Figure 3a. The succeeding views contain instructions on how to adapt the visualisation for subsequent visualisation states. In this case, sub-groups 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, it means that 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 sort instructions.

6 DISCUSSION & CONCLUSION

We have illustrated the benefits of interactive and narrative visualisation for knowledge transfer and have listed some well-established techniques for strengthening a viewer's mental model. However, we identified that existing presentation tools such as PowerPoint do not exploit these principles to their full potential. For instance, while different chart visualisations do support basic enter and exit animations, we cannot make changes to the underlying data or visualisation parameters at presentation time which makes it difficult to use these charts for data exploration or as narrative visualisation.

Based on established interactive and narrative visualisation techniques, we derived a set of requirements for interactive data visualisation in the context of presentations. Our interactive data visualisation solution has been implemented as a plug-in for the MindXpres presentation tool. Furthermore, we introduced a number of abstractions for useful interactions and allow the presenter to use them to predefine visualisation states or freely apply them during a presentation. Our proposed solution goes beyond what state-of-the-art presentation tools offer and our abstractions do not only support changes to the visualisation parameters (e.g. chart type or zoom level) but also enable the modification of the underlying data (e.g. filter or add data). Thereby, we ensure that interactive visualisations for oral narratives can be created with minimal effort. Finally, since MindXpres presentations can easily be shared and interactive components are also usable after a presentation has been deployed, the presented interactive data visualisation plug-in offers new opportunities for students to individually explore the data.

Our prototype supports the common chart types (and their variations) such as line, bar or pie charts as well as scatter plots. These can be used to deliver almost all of the message types defined by Few (Few, 2004) except geospatial information. In order to support every aspect of this classification, we intend to extend the plug-in with a geographical map view ensuring that data can be rendered in relation to geographical locations. Similarly our solution currently supports all interaction techniques defined by Yi (Yi et al., 2007) except for techniques related to the *connect* principle, allowing viewers to show items which are related to a selected one. As the similarity metric heavily depends on the data and context, further investigation is needed to see how we can abstract this particular interaction technique.

Last but not least, our plug-in has been developed in correspondence to the philosophy of the

MindXpres presentation platform and for now visualisations are defined via the XML-based language shown in Section 5. Nevertheless, in the near future we intend to add a graphical authoring component to our plug-in. We see clear potential in using the same interaction menu that has been shown in Figure 2 at authoring time. Ultimately, this could be paired with some “recording” features that allow the presenter to add the current state of the visualisation to the sequence of states available during the presentation.

We have presented a step towards rich presentation-based data exploration and storytelling. In a use case we further highlighted some of the benefits of our interactive data visualisation prototype. The requirements that we derived based on existing visualisation techniques might serve third-party slideware vendors as a basis for improving their products. While we decided to base the implementation of our prototype on the MindXpres presentation platform, we believe that our findings are general enough and might inspire other researchers to further investigate interactive visualisation techniques in the context of next generation presentation tools.

REFERENCES

- Ahlberg, C. (1996). Spotfire: An Information Exploration Environment. *ACM SIGMOD Record*, 25(4):25–29.
- Austin, M. (2011). *Useful Fictions: Evolution, Anxiety, and the Origins of Literature*. University of Nebraska Press.
- Bishop, J. L. and Verleger, M. A. (2013). The Flipped Classroom: A Survey of the Research. In *ASEE 2013, 120th American Society for Engineering Education Conference*.
- Bostock, M. (2013). Let’s Make a Bar Chart. <http://bost.ocks.org/mike/bar/>. Accessed: 2015-11-05.
- Bostock, M., Ogievetsky, V., and Heer, J. (2011). D3 Data-Driven Documents. *IEEE Transactions on Visualization and Computer Graphics*, 17(12):2301–2309.
- Dawkes, H., Tweedie, L. A., and Spence, B. (1996). VICKI: The Visualisation Construction Kit. In *AVI 1996, Workshop on Advanced Visual Interfaces*. ACM.
- Dix, A. and Ellis, G. (1998). Starting Simple: Adding Value to Static Visualisation Through Simple Interaction.
- Ellis, W. D. (1999). *A Source Book of Gestalt Psychology*. Psychology Press.
- Few, S. (2004). *Show Me the Numbers: Designing Tables and Graphs to Enlighten*. Analytics Press, 2nd edition.
- Fischer, M. H. (2000). Do Irrelevant Depth Cues Affect the Comprehension of Bar Graphs? *Applied Cognitive Psychology*, 14(2):151–162.
- Gibson, J. J. (1962). Observations on Active Touch. *Psychological Review*, 69(6):477.
- Hullman, J. and Diakopoulos, N. (2011). Visualization Rhetoric: Framing Effects in Narrative Visualization. *IEEE Transactions on Visualization and Computer Graphics*, 17(12):2231–2240.
- Kosara, R. and Mackinlay, J. (2013). Storytelling: The Next Step for Visualization. *Computer*, 46(5):44–50.
- Parker, I. (2001). Absolute PowerPoint: Can a Software Package Edit Our Thoughts. *The New Yorker*, 28:76–87.
- Robertson, G., Fernandez, R., Fisher, D., Lee, B., and Stasko, J. (2008). Effectiveness of Animation in Trend Visualization. *Visualization and Computer Graphics, IEEE Transactions on*, 14(6):1325–1332.
- Roels, R., Mestereaga, P., and Signer, B. (2015). Towards Enhanced Presentation-based Teaching of Programming - An Interactive Source Code Visualisation Approach. In *CSEDU 2015, 7th International Conference on Computer Supported Education*. SCITEPRESS.
- Roels, R. and Signer, B. (2014a). 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.
- Roels, R. and Signer, B. (2014b). MindXpres: An Extensible Content-driven Cross-Media Presentation Platform. In *WISE 2014, 15th International Conference on Web Information System Engineering*. Springer.
- Rogers, J. and Philippe, C. (2014). The Tax Burden of Typical Workers in the EU 28. *New Direction*, 17.
- Rosling, H. (2006). TED Talk: Hans Rosling Shows The Best Stats You’ve Ever Seen. www.ted.com.
- Segel, E. and Heer, J. (2010). Narrative Visualization: Telling Stories with Data. *IEEE Transactions on Visualization and Computer Graphics*, 16(6):1139–1148.
- Siegrist, M. (1996). The Use or Misuse of Three-Dimensional Graphs to Represent Lower-Dimensional Data. *Behaviour & Information Technology*, 15(2):96–100.
- Siirtola, H. (2007). *Interactive Visualization of Multidimensional Data*. PhD thesis, University of Tampere.
- Swayne, D. F., Lang, D. T., Buja, A., and Cook, D. (2003). GGobi: Evolving from XGobi into an Extensible Framework for Interactive Data Visualization. *Computational Statistics & Data Analysis*, 43(4):423–444.
- Tufte, E. R. and Graves-Morris, P. (1983). *The Visual Display of Quantitative Information*. Graphics Press, 2nd edition.
- Ware, C. (2012). *Information Visualization: Perception for Design*. Elsevier, 3rd edition.
- Yi, J. S., Kang, Y. a., Stasko, J., and Jacko, J. (2007). Toward a Deeper Understanding of the Role of Interaction in Information Visualization. *IEEE Transactions on Visualization and Computer Graphics*, 13(6):1224–1231.
- Zhicheng, L. and Stasko, J. T. (2010). Mental Models, Visual Reasoning and Interaction in Information Visualization: A Top-down Perspective. *IEEE Transactions on Visualization and Computer Graphics*, 16(6):999–1008.