Enhanced Interactive Spiral Display

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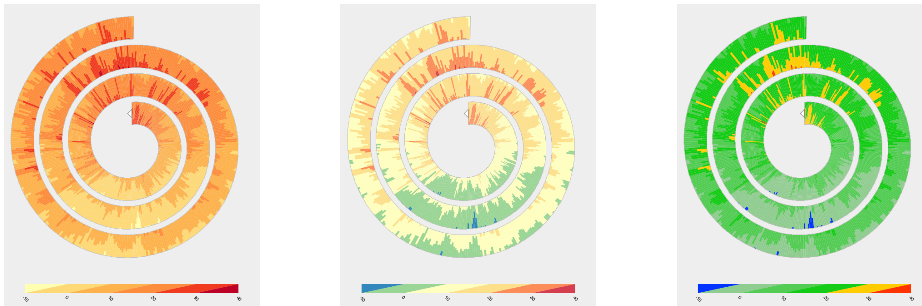

Figure 1: *Enhanced interactive spiral display – Left to right: Red sequential color scale, rainbow color scale, and custom color scale*

Abstract

Spiral displays have been developed to visualize the cyclic character of a data set. They are particularly useful for spotting seasonal patterns in time series data. This, however, requires expressive visual encoding and efficient interaction.

In this paper, we improve existing spiral displays by applying the expressive two-tone pseudo coloring. This allows users to read off data values more precisely. More importantly, we enhance our two-tone spiral display with efficient interaction facilities. These allow for easy exploration of the data space and easy adjustment of a variety of visualization parameters. Our tool is fully implemented and freely available for experimentation.

CR Categories: H.5.2 [Information Interfaces and Presentation]: User Interfaces—Graphical User Interfaces, Interaction Styles; I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction Techniques

Keywords: Information visualization, interaction, spiral display

1 Introduction

Finding seasonal patterns is a common task when analyzing time-oriented data. Analytic methods can be applied to find such patterns. However, results depend heavily on the analysis method used, and choosing the right method for a particular application is not always an easy task. Especially in cases where no or only vague hypotheses about the data exist, it is difficult to decide which automatic analysis methods might work. This is where interactive visual exploration comes into play. Visual methods can support analysts in exploring unknown data and generating hypotheses about them. Moreover, a visual representation can help in confirming results of analytic procedures or simply support the communication of analysis results to a broader audience.

In this paper we focus on spiral displays. Such representations have been shown to be helpful tools to spot cyclic pattern in time series data [Aigner et al. 2008]. In order to confirm or communicate analysis results, an expressive visual encoding is required. Classic spiral displays rely on simple color coding or glyphs. Moreover, efficient interaction facilities are required to support easy data exploration. [Aigner et al. 2008] explain that previously unknown cyclic patterns can be found with the help of interaction. But except for the use of common control panels, only little has been reported on how to interact with spiral displays.

We enhance classic spiral displays with respect to both visual encoding and interaction. We apply two-tone pseudo coloring, an expressive visual mapping that provides overview and precise detail at the same time. Our spiral displays is not a static display, but provides a variety of ways of navigating the data and adjusting the visual representation. We believe that our two-tone spiral display is an interesting and easy-to-use alternative to existing approaches.

In the next section, we will take a brief look at previous work. In Section 3, we focus on the visual aspects of our approach. Aspects of interaction are described in Section 4. Finally, we conclude and present ideas for future work in Section 5.

2 Related Work

Cyclic representations of data are helpful in many application scenarios. [Harris 1999] presents several cyclic data drawings. Among them are spiral displays. Compared to other cyclic data representations, spirals have the advantage that they can encode both cyclic and linear aspects of the data. Cyclic aspects are encoded to the cycles of a spiral. Since the order of cycles is preserved in a spiral it is possible to mentally unroll a spiral to understand linear aspects.

Spiral displays have a long history as visual depictions. Nowadays, several computer implementations of spiral displays are known in the literature.

[Carlis and Konstan 1998] present a first prototype that uses spirals as the central element of the visualization. The spiral is used to arrange visual items, which can be dots, cans, or simple bar charts. The size of these items encodes data values.

In [Hewagamage et al. 1999], the 3D form of a spiral, that is, a helix, is used to visualize spatio-temporal patterns on maps. To this end, 3D helices are placed on a 3D map display. Attached to the helices are small colored icons that represent events in the visualized time series. In order to focus on certain alignments of events, it is possible to vary the cycle length within a helix.

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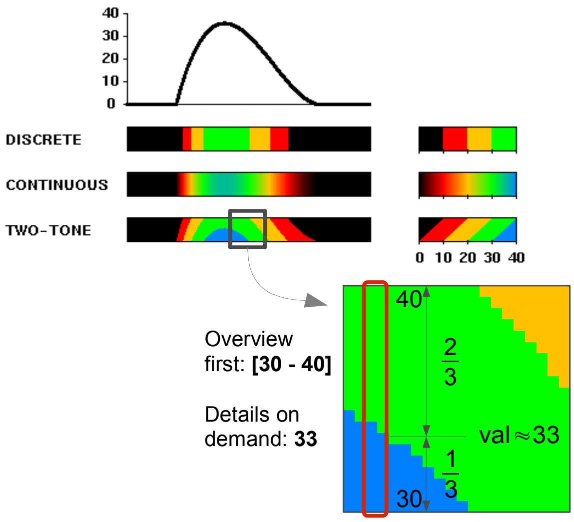

Figure 2: *Two-Tone Pseudo Coloring explained.*

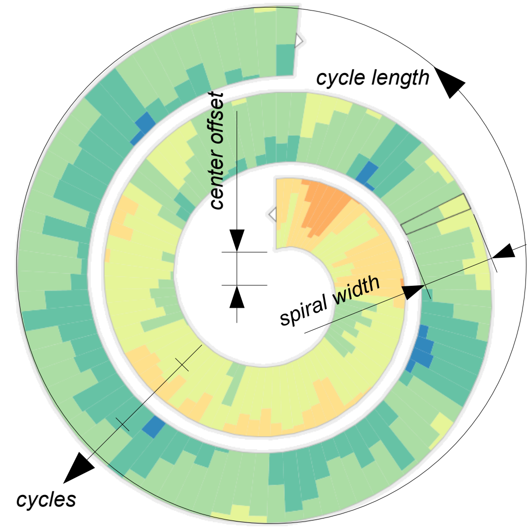

Figure 3: *Parameters of the spiral construction.*

Another use of spirals is presented by [Ward and Lipchak 2000]. They describe a tool for visualizing multivariate data. The approach is to use glyphs that encode multiple variables and to arrange the glyphs on the screen. Besides two other glyph layouts, a spiral layout is provided to emphasize the cyclic character of the data.

The spiral described by [Weber et al. 2001] uses color and line thickness to encode time series data. In order to visualize more than one variable, multiple spirals can be intertwined. An interesting concept to cope with larger time series is to combine the 2D spiral with a 3D helix.

[Dragicevic and Huot 2002] apply the spiral shape quite differently than the previously mention approaches. They combine the spiral with a clock metaphor to construct a so called SpiraClock. It is a very helpful tool to visualize upcoming events in time.

Similar to [Hewagamage et al. 1999] is the approach of [Tominski et al. 2005]. Here, the goal is to visualize space- and time-dependent data. Besides pencil glyphs for linear data, helix glyphs are offered for cyclic data. The helices use color coding and can be split into sub-bands to allow for visual comparison of multiple variables.

All these approaches underline the usefulness of spiral displays for data visualization. In the following, we will further improve them with respect to visual encoding and interactivity.

3 Two-Tone Spiral Display

In information visualization color is a very prominent visual variable. Color coding is effective for qualitative as well as quantitative data. However, discerning data values precisely is not always easy for users. Figure 2 shows examples of discrete and continuous color coding. With a discrete color scale, only ranges of colors, and hence, only ranges of data values can be identified. In contrast to that, continuous color coding is based on a scale of smooth color transitions. However, users tend to perceive a sequence of colors as a set of discrete ones [Ware 2000]. So, even with very smooth transitions, values cannot be read very accurately.

Two-Tone Pseudo Coloring (TTPC) has been introduced to address this issue [Saito et al. 2005]. TTPC uses a discrete color scale that consists of only a few colors (less than eight). In contrast to classic color coding (discrete or continuous) where each data value is mapped to one color, TTPC uses two colors being adjacent in the color scale to encode a data value. These two colors are interpreted in two steps (see Figure 2). First, the two colors guide users to a particular interval in the value range. If users find that interval interesting, they go into detail: The proportion of use of both colors encodes the precise data value. This two-step interpretation is the basis for overview+detail. While the first step relies on the spontaneous perception of color for the overview, the second step is based on the human capabilities to judge lengths, which provides for sufficient detail. Compared to other approaches, TTPC generates very compact, yet precise visual representations.

TTPC in its original form is suited to represent univariate data with linear character. We have previously married TTPC with the Table Lens approach to allow for multivariate data visualization [John et al. 2008]. However, cyclic representations using TTPC have not yet been reported on, even though the inventors of TTPC indicate that it is possible to apply TTPC to non-linear geometry.

In order to apply TTPC to a spiral display, we have to discretize the continuous shape of the spiral into cells each representing a single data value. The cells are then colored by applying TTPC. There are four parameters to control the construction of spiral cells. The first two are *cycle length* and *cycles*, which determine the number of data values to be mapped per spiral cycle and the number of cycles of the spiral, respectively. Because the relation of two colors has to be judged per cell, cells must have a certain extend. This extend is controlled via the parameter *spiral width*. Since cells become infinitely thin in the very center of the spiral, it makes sense to move the starting point for cells away from the center. This way we assure that cells can still be recognized well. The amount of translation from the center is linked to the parameter *center offset*. Figure 3 illustrates the spiral construction and the parameters involved. All these parameters, but particularly *cycle length* and *cycles*, influence the visual representation and the conclusions that might be drawn from it. This is why providing easy to use interaction methods for parameter adjustments is so important (see Section 4).

Each cell of the spiral uses TTPC to encode data. In a first step, it is necessary to determine the two colors required for the data value to be represented in a cell. Secondly, the spiral cell is divided into two parts whose sizes are computed based on TTPC. Finally, both parts are colored. We provide several predefined color scales,

Figure 4: *Color mapping – (a) Standard mapping using* $min = -7.4$ */* $max = 32.8$ *as found in the data; (b) Mapping with extended value range of* $min = -10$ */* $max = 40$*.*

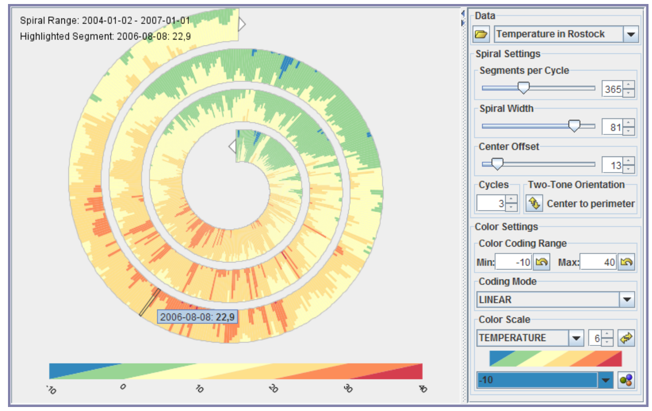

Figure 5: *The user interface – The central view shows the spiral visualization and the color legend. All visualization parameters can be adjusted in the settings panel on the right.*

which we derived from ColorBrewer [Harrower and Brewer 2003]. In addition to that, users can define their own custom color scale or adjust the existing ones (see next section). How different the visual results might be when using different color scales is demonstrated in Figure 1. The figures shows average temperatures in the city of Rostock for a period of three years, roughly a thousand data values. On the left, a red sequential color scales provides an overview of the value distribution. The rainbow color scale used for the spiral in the middle helps to discern regions in the data. On the right hand side, the user has customized the color scale to emphasize rather cold days (blue) and quite hot days (orange). In all cases, TTPC encoding facilitates overview and provides detail when needed.

4 Interactive Data Exploration

We implemented the TTPC spiral as an interactive tool that allows for manifold interaction with the data and the visual representation.

Labeling As an elementary interaction, our tool allows picking of spiral cells in order to provide labels showing data values in textual form. Upon user request, we offer a global label that shows start time and end time of the spiral to provide better orientation during browsing in time (as described next).

Browsing in time Since spiral displays address time series data, our implementation has to support browsing in time. In contrast to other tools, we use direct manipulation for that purpose. Two alternatives are provided to move in time, if not all data values fit the spiral (this depends on the size of the data set and on the parameters *cycle length* and *cycles*). The first option is to use the two small arrow-shaped buttons that are shown at each end of the spiral. Pressing such a button starts browsing through time in the selected direction. The longer a button is pressed, the faster the browsing will be. Alternatively, users can drag the mouse away from the button to control the browsing speed. The second option to browse in time is to use the keyboard. Pressing UP or DOWN keys moves one time step forward or backward in time. To move faster, users can also use PAGE UP and PAGE DOWN keys or the mouse wheel, which moves the current view a full spiral cycle in the desired direction. While mouse interaction is helpful for roughly browsing the data, keyboard controls are better suited for fine adjustments or to skip larger regions in the data. In conjunction, mouse and keyboard controls allow for efficient browsing in time.

Overview and detail By adjusting the parameters *cycle length* and *cycles*, users can determine the number of data values to be mapped to the spiral display. Apparently, larger numbers of data values provide overview, but in order to see detail only a few data values should be shown. By utilizing the browsing functionality, users can switch between different parts of the data to see detail. However, adjusting parameters and performing browsing can be inconvenient when switching frequently between overview and detail. Therefore, we offer an alternative again based on direct manipulation. By simply dragging the mouse, users can select a subset of the data for further detailed investigation. During dragging, a frame marks the selected cells. In detail mode, only the selected cells are shown. Users can then decide to continue selecting an even smaller subset of the data or return to the overview via right click. This way of switching between overview and detail requires only a few clicks and is much easier than manipulating parameters.

Color scale adjustment The way of how colors are used affects what can be seen from the visualization [Silva et al. 2007]. Therefore, it is mandatory to provide mechanisms that allow users to adapt the color coding to their particular needs and tasks. Our spiral tool supports several adjustments. The first one is to adjust the mapping range. Usually, colors are mapped based on the value range between minimum and maximum data value. However, the resulting color legend is difficult to interpret in most cases (see Figure 4(a)). A simple possibility to overcome this problem is to allow users to extend the value range for the color mapping. By choosing minimum and maximum carefully, the legibility of the color legend can be improved significantly (see Figure 4(b)).

Further ways of manipulating the color mapping include specifying the number of segments in the color scale, editing particular colors, flipping the color scale, and switching between linear and exponential mapping functions. The latter is particularly useful for data with skewed value distributions. The possibility to choose from a set of predefined color scales has already been mentioned earlier.

User interface The user interface is crucial when it comes to applying a visualization method in various scenarios. We opted for a layout that presents the spiral as the central view with a color legend on the bottom. A panel for all adjustable parameters is presented to the right of the spiral. The panel encapsulates related parameters in groups to create order among the various possibilities of adjustment. Once the user has tuned the parameters to the task at hand, the settings panel can be hidden away to fully concentrate on the visualization. Figure 5 shows the user interface of our spiral tool.

Example: How to find a cyclic pattern? We will now give a brief example of how interaction helps in finding a cyclic pattern in a human health data set. Figure 6(a) shows a spiral where the

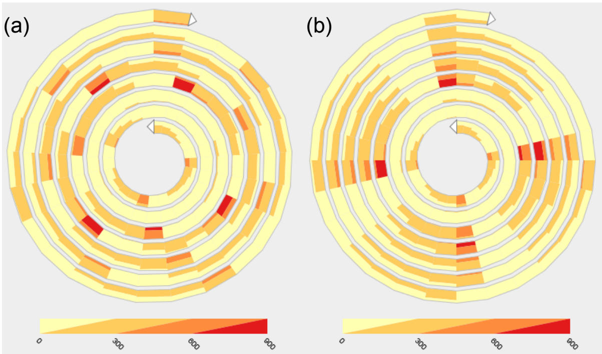

Figure 6: *Finding a pattern – (a) Cycle length* $= 25$*; (b) Cycle length* $= 28$

cycle length is set to 25 days – a clear pattern can not be seen. After adjusting the *cycle length* to 28 days in Figure 6(b) a pattern becomes obvious: It is a weekly pattern of high numbers of new infections of the respiratory reported in the beginning of a week gradually decreasing to no reports on weekends. Indeed, this is a simple pattern, but still the example demonstrates how interaction with the visual representation facilitates finding interesting things in the data.

5 Preliminary Results and Future Work

In this paper, we have presented an enhanced interactive spiral display. The novelty of our approach lies in the application of Two-Tone Pseudo Coloring (TTPC) to non-linearly shaped geometry, the spiral in our case. This combines the advantages of TTPC and spiral displays, and thus potentially better facilitates exploration of cyclic patterns in time-oriented data. A major objective was to focus on interactivity, which we think is the important aspect of data exploration. For that reason, we provide easy to use mechanisms for browsing in time and for switching between overview and detailed views. Over existing spiral displays, our tool has the advantage that it is based on direct interaction with the visual representation. More interaction, particularly adjustment of the spiral shape and manipulation of the color mapping, is possible via a well-chosen user interface. Our approach is available as a fully implemented tool, which can run either as stand-alone application or as a java applet in a web browser [Tominski et al. 2007].

Even though the spiral display we described is quite capable, there are many things that can be improved. First of all, our spiral needs to be extended to allow for multivariate data exploration. This can be achieved by intertwining multiple spirals. Secondly, even though interaction is a very powerful means to allow users to explore all aspects of a data set, relying solely on the users' capability to find suitable parameter settings for cycle lengths or colors might not always be the best solution. It makes sense to provide guidance or to make suggestions on how to set parameters to reach certain goals. Such an extension could be driven by utilizing appropriate analysis methods to find potential cyclic patterns. For more complex patterns, it might also be interesting to experiment with spirals using irregular cycle lengths, i.e., each cycle might show a different number of data elements. For adjusting the color scale automatically, one could apply the task-driven methods described in [Tominski et al. 2008].

Last but not least, we need to collect feedback from users to find possible weaknesses of our approach and to expand its strengths. We encourage users of our applet to send us their feedback.

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