06

Visualization Techniques Time Oriented Data

Notice

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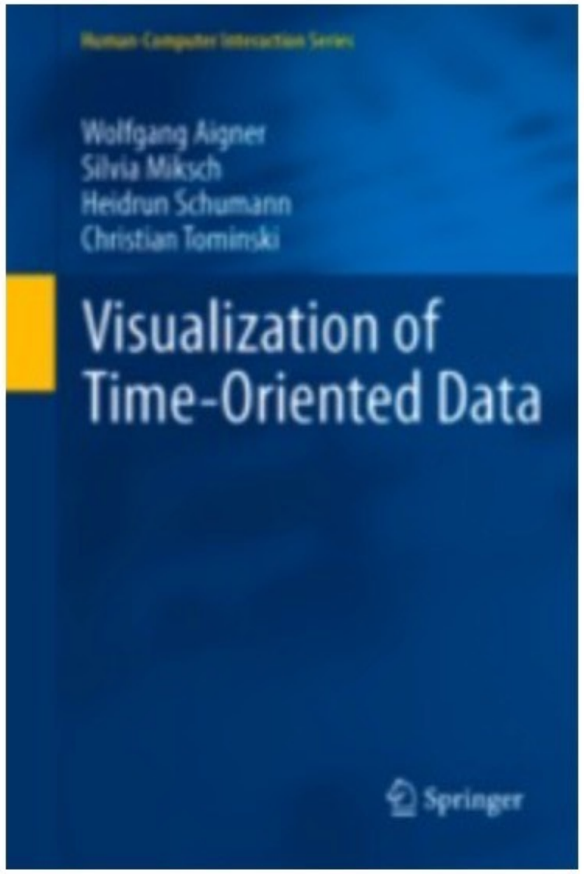
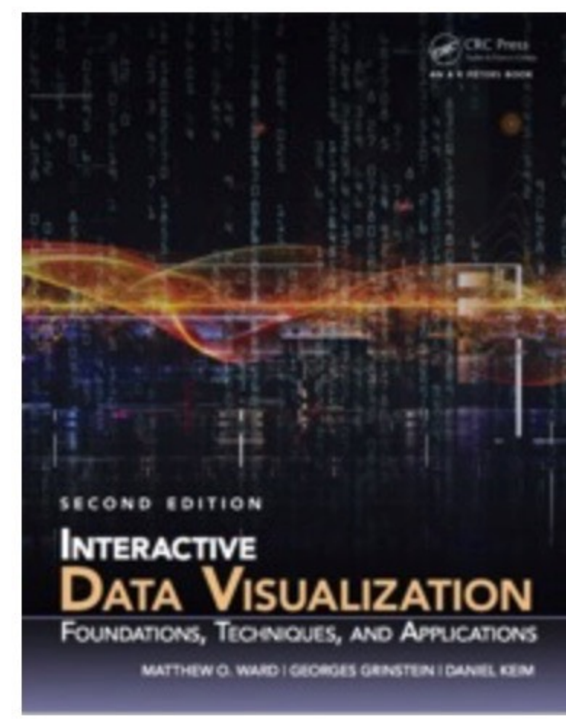
Bibliography….



Visualization of Time-Oriented Data
Wolfgang Aigner, Silvia Miksch Heidrun Schumann, Christian Tominski
2011
ISBN: 978-0-85729-078-6

Chap. 7



Interactive Data Visualization: Foundations, Techniques, and Applications
Matthew O. Ward, Georges Grinstein, Daniel Keim
2015, 2nd Edition
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Motivation

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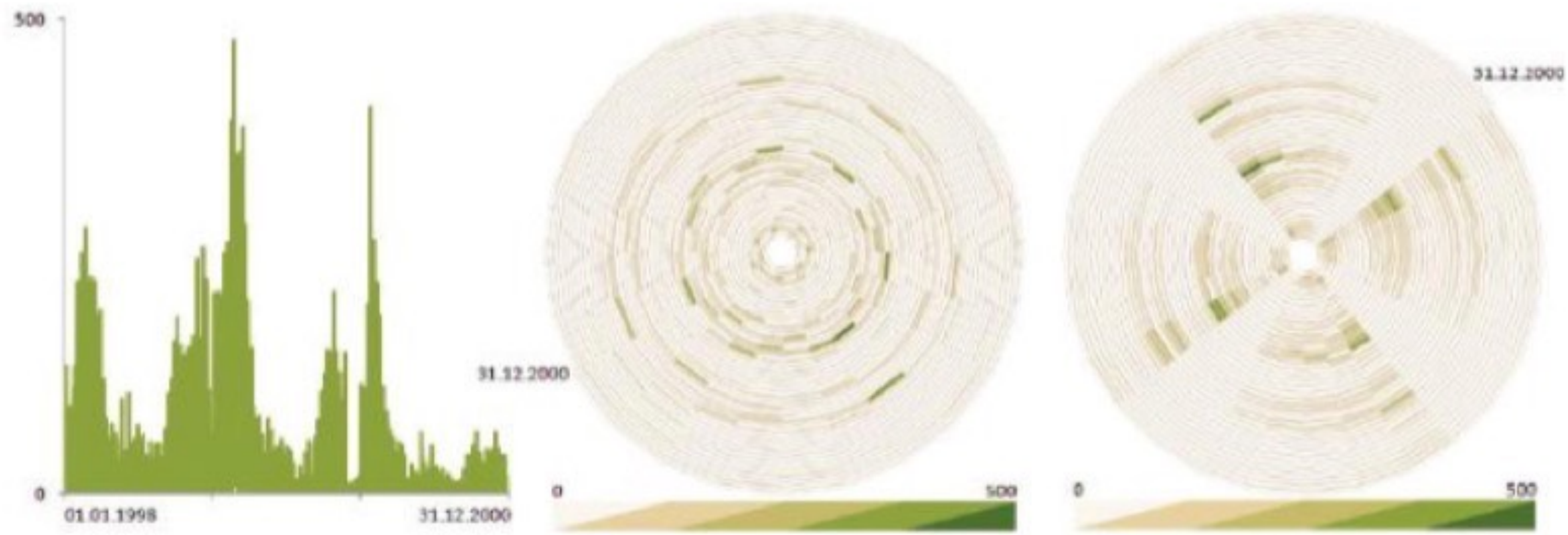

Time characteristics: linear vs. cyclic representation of time: different insights can be gained from visual representations depending on whether linear or cyclic character of the data is emphasized. (Source: Generated by the authors.)

Figure 7.1 - Interactive Data Visualization: Foundations, Techniques, and Applications

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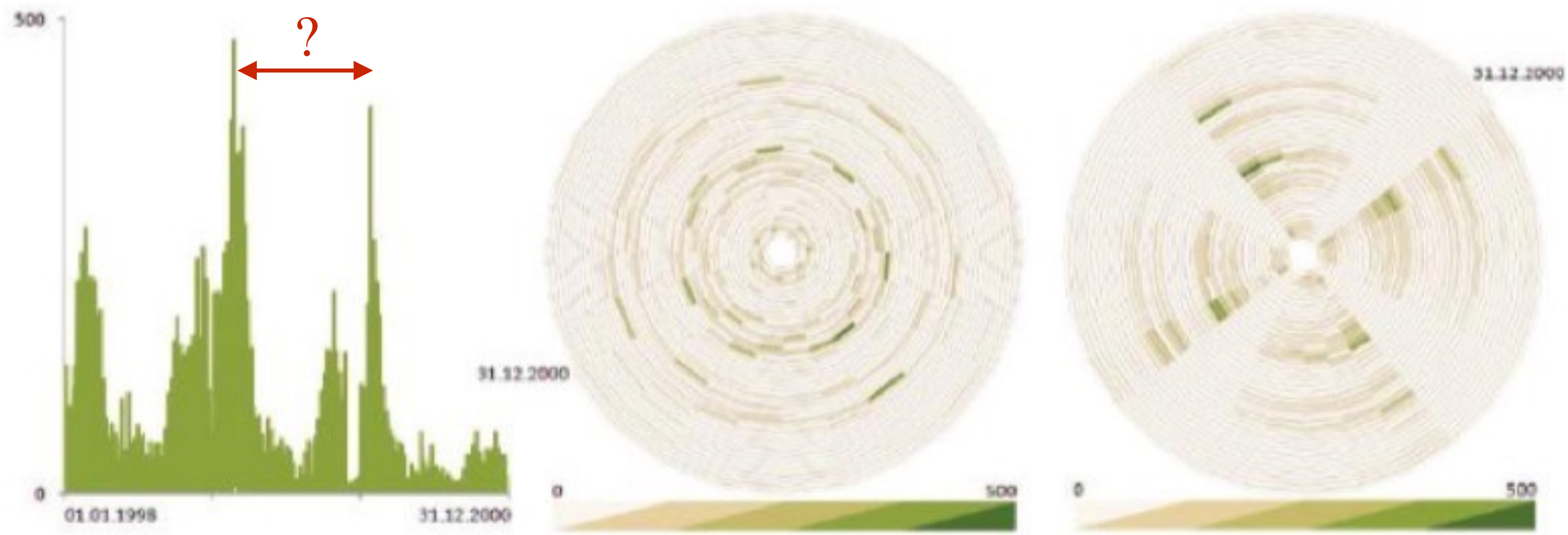

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Figure 7.1 - Interactive Data Visualization: Foundations, Techniques, and Applications

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- **Chose a visual representation that fits the data characteristics (cyclic time in this case) and;**

- **Parameterize the visual representation accordingly in order to be able to detect patterns hidden in the data.**

Characterizing Time-Oriented Data

Characteristics of Time

- **It is important to make a clear distinction between the physical dimension time and a model of time in information systems**

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- **Characteristics of Time**
- **Characteristics of Time-Oriented Data**
- **Relating Data and Time**

Characteristics of Time

Characteristics of Time

- **General aspects**
  - **Scale;**
  - **Scope;**
  - **Arrangement;**
  - **Viewpoints**

Characteristics of Time

- **General aspects**
  - **Scale;**
  - **Scope;**
  - **Arrangement;**
  - **Viewpoints**

- **Hierarchical organization of time and concrete time elements**
  - **Granularity and calendars**
  - **Time primitives**
  - **Determinacy**

General aspects of time: Scale

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General aspects of time: Scale

- **Ordinal**
  - **Only relative order relations are present (e.g., before, after, during)**
- **Discrete**
  - **Temporal distances can also be considered.**
  - **Time values can be mapped to a set of integers, which enables quantitative modeling of time values.**
  - **Are based on a smallest possible unit (e.g., seconds, minutes)**
  - **The most commonly used time model in information systems.**

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  - **Are based on a smallest possible unit (e.g., seconds, minutes)**
  - **The most commonly used time model in information systems.**
- **Continuous**
  - **A mapping to real numbers (also known as dense time).**

General aspects of time: Scope

- **Point-based**
  - Can be seen in analogy to discrete Euclidean points in space, i.e., having a temporal extent equal to zero.
- **Interval-based**
  - Relate to subsections of time having a temporal extent greater than zero.
  - Related to the notion of granularity

- For example, the time value May 1, 2014 might relate to the single instant May 1, 2014 00:00:00 in a point-based domain, whereas the same value might refer to the interval [May 1, 2014 00:00:00, May 1, 2014 23:59:99] in an interval-based domain.

General aspects of time: Arrangement

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General aspects of time: Arrangement

- **Linear**
  - **We mostly consider time as proceeding linearly from the past to the future.**
- **Cyclic**
  - **In a cyclic organization of time, the domain is composed of a set of recurring time values (e.g., the seasons of the year).**

General aspects of time: Viewpoint

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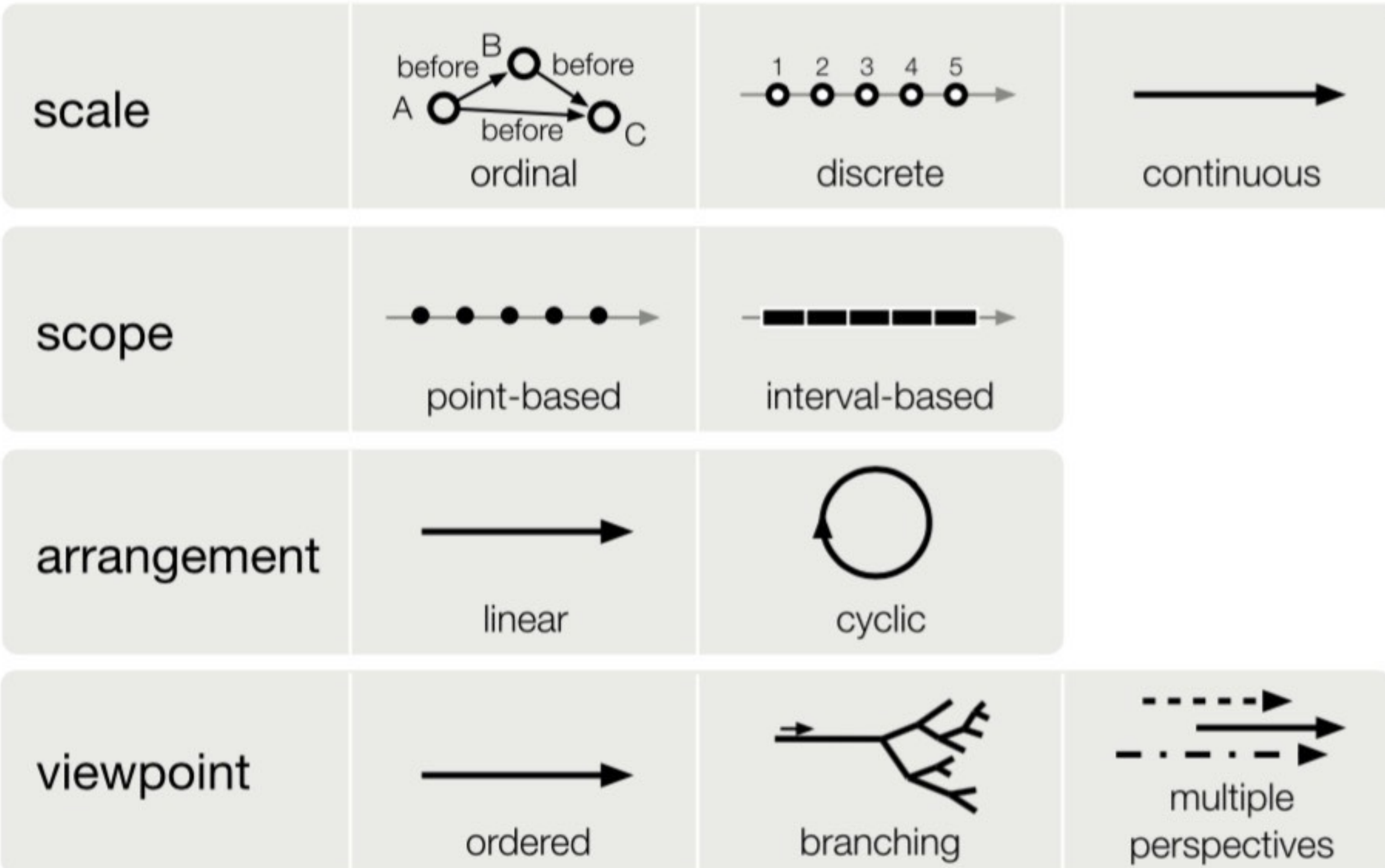
- **Branching time**
  - **Here, multiple strands of time branch out and allow the description and comparison of alternative scenarios (e.g., in project planning).**
- **Multiple perspectives facilitate simultaneous (even contrary) views of time.**
  - **Eyewitness reports that describe the same situation, each of which being slightly different,**
  - **Various statements of a disaster reported in different countries and time zones.**

Characteristics of Time



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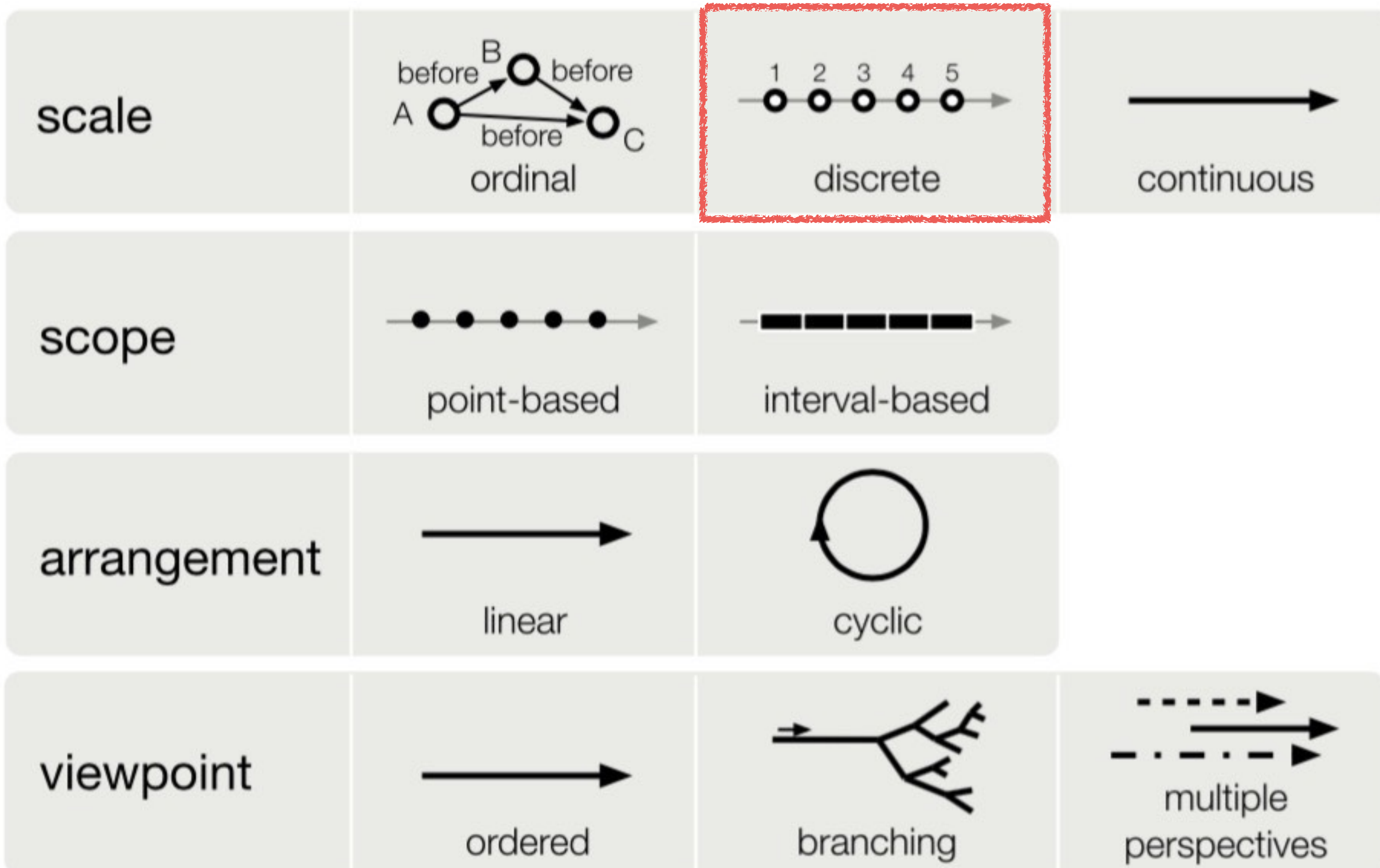

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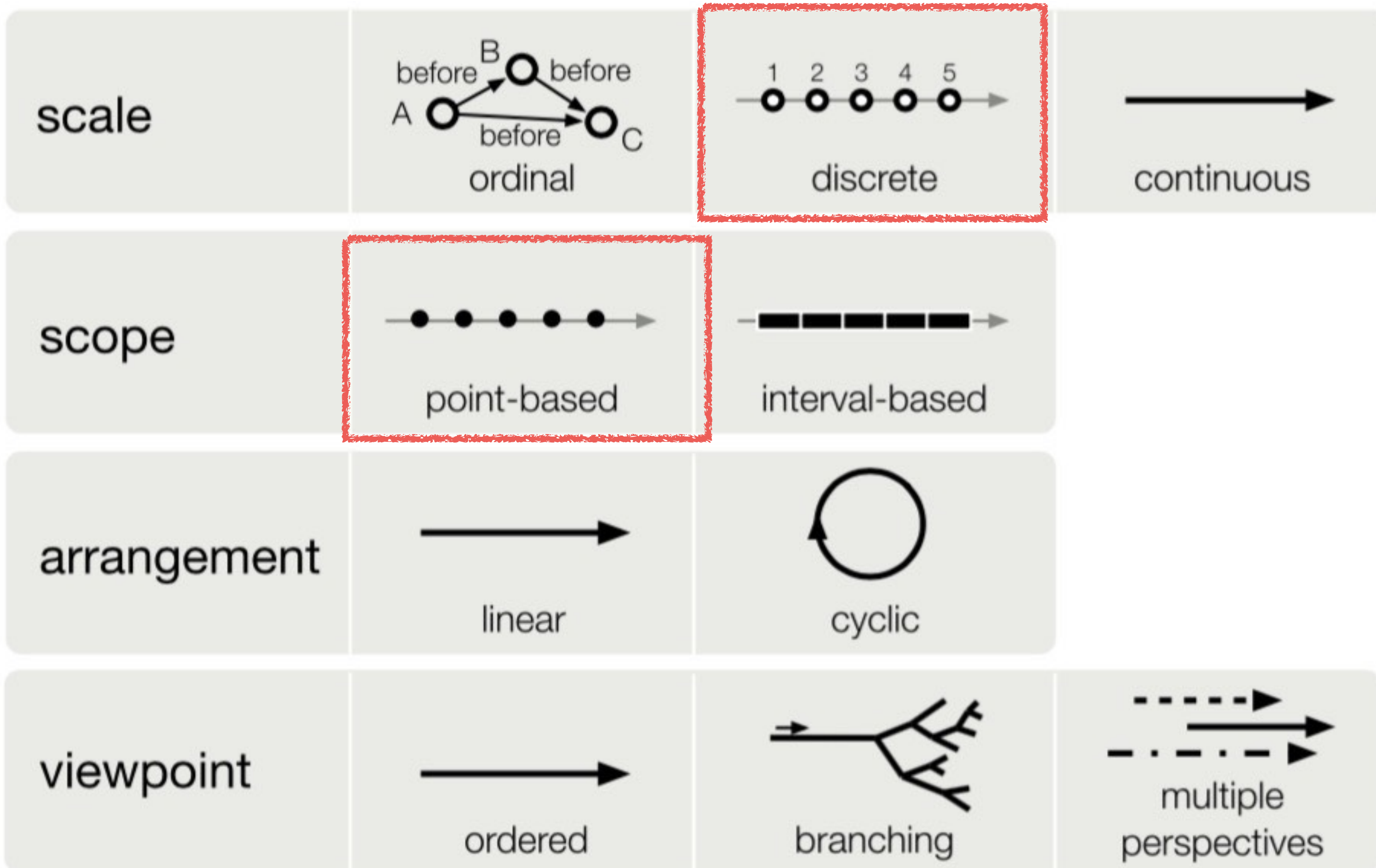

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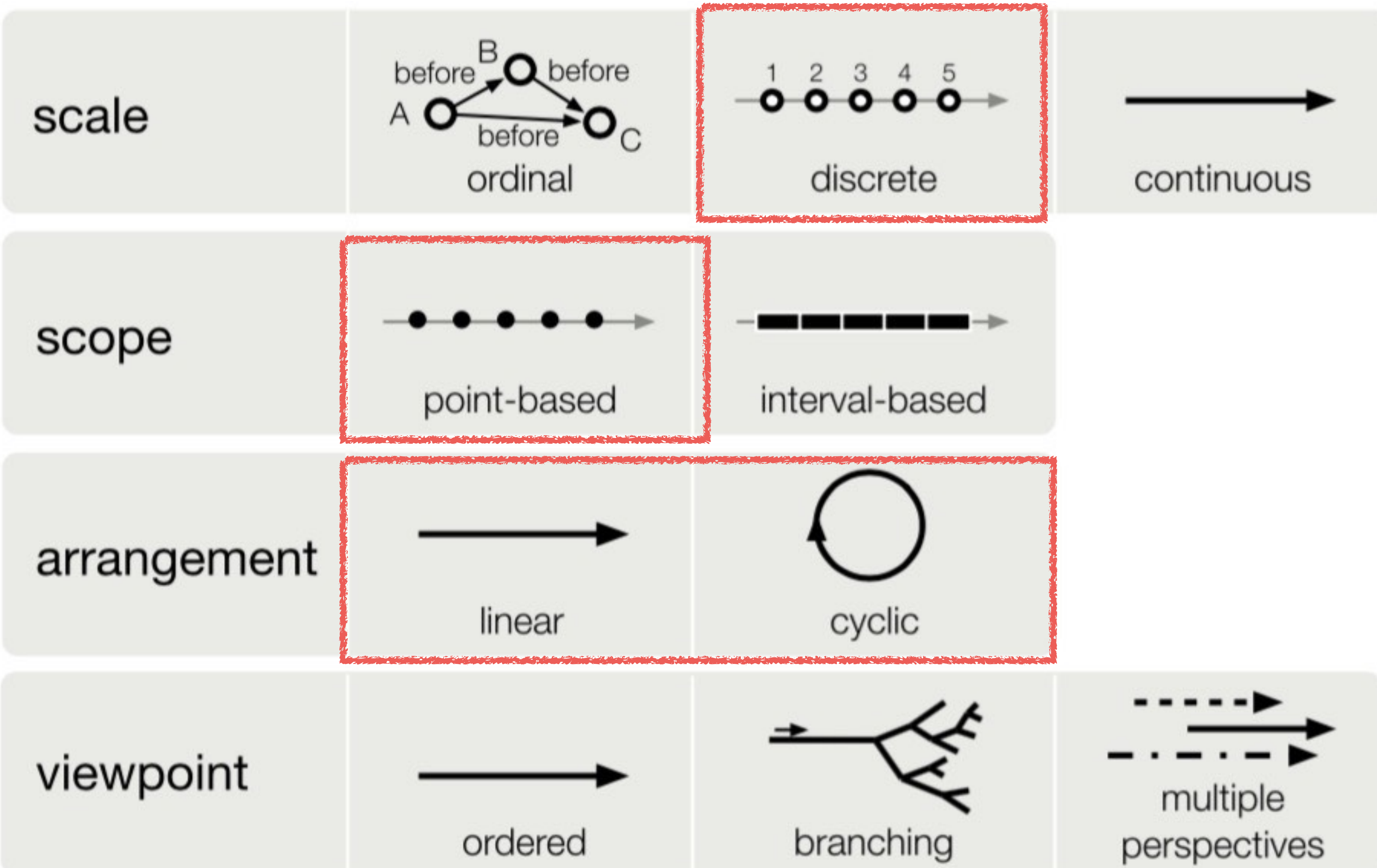

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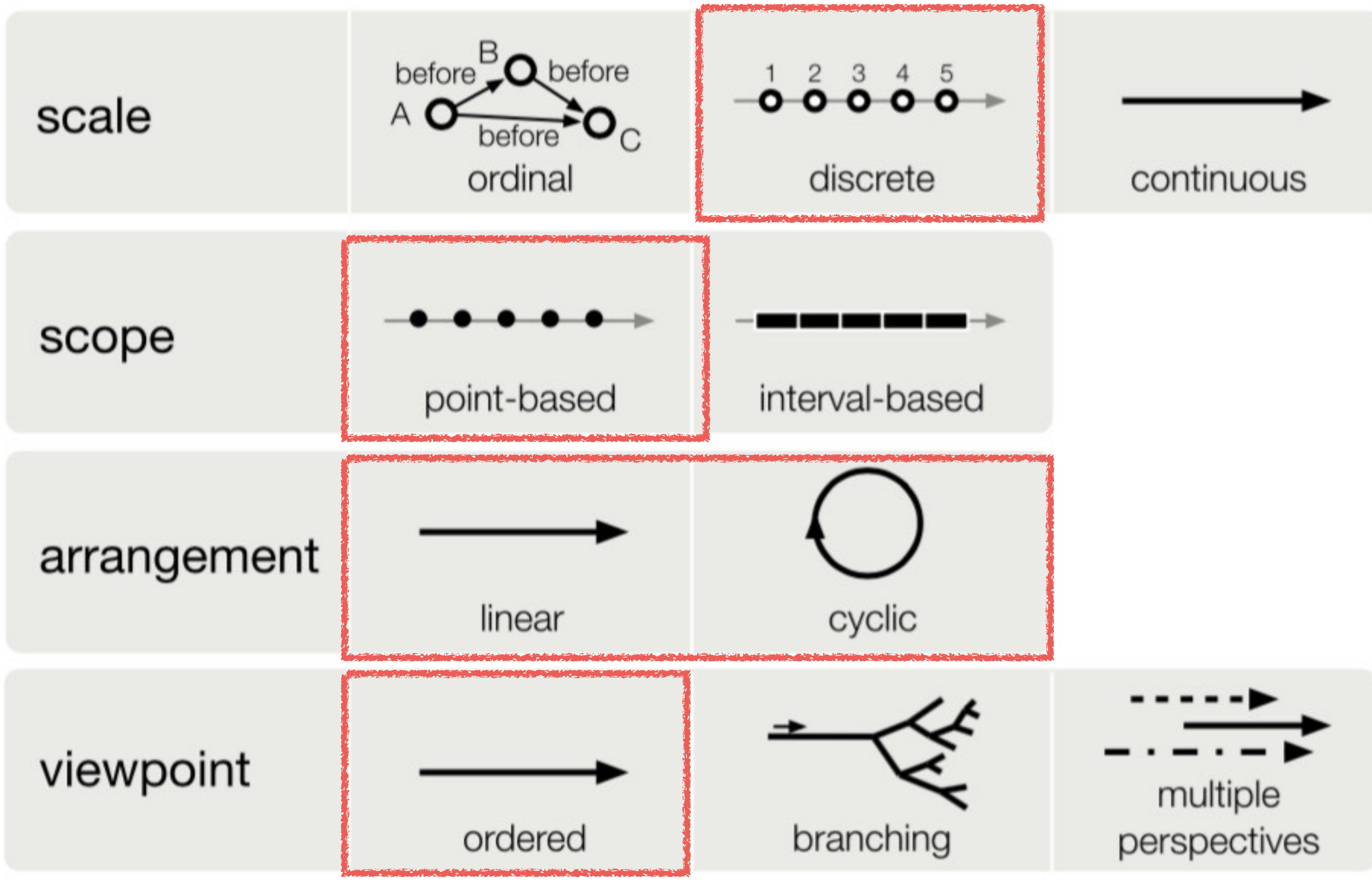

Characteristics of Time

- General aspects
  - Scale;
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  - **Granularity and calendars**
  - **Time primitives**
  - **Determinacy**

Hierarchical organization and concrete time elements

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- **Granularity**
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- There might be a single granularity only (e.g., every time value is given in terms of milliseconds)
- None if these abstractions are not supported (e.g., abstract ticks).

Hierarchical organization and concrete time elements

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  - **time primitives can be seen as an intermediary layer between data elements and the time domain.**

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  - **Anchored (absolute) primitives.**
    - **Instant and interval are primitives that belong to the first group, i.e., they are located on a fixed position along the time domain.**
      - **Instants are a model for single points in time**
      - **intervals range between two points in time**

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      - **Instants are a model for single points in time**
      - **intervals range between two points in time**
  - **Unanchored (relative)**
    - **A span is a relative primitive, i.e., it has no absolute position in time**
      - **spans are durations.**

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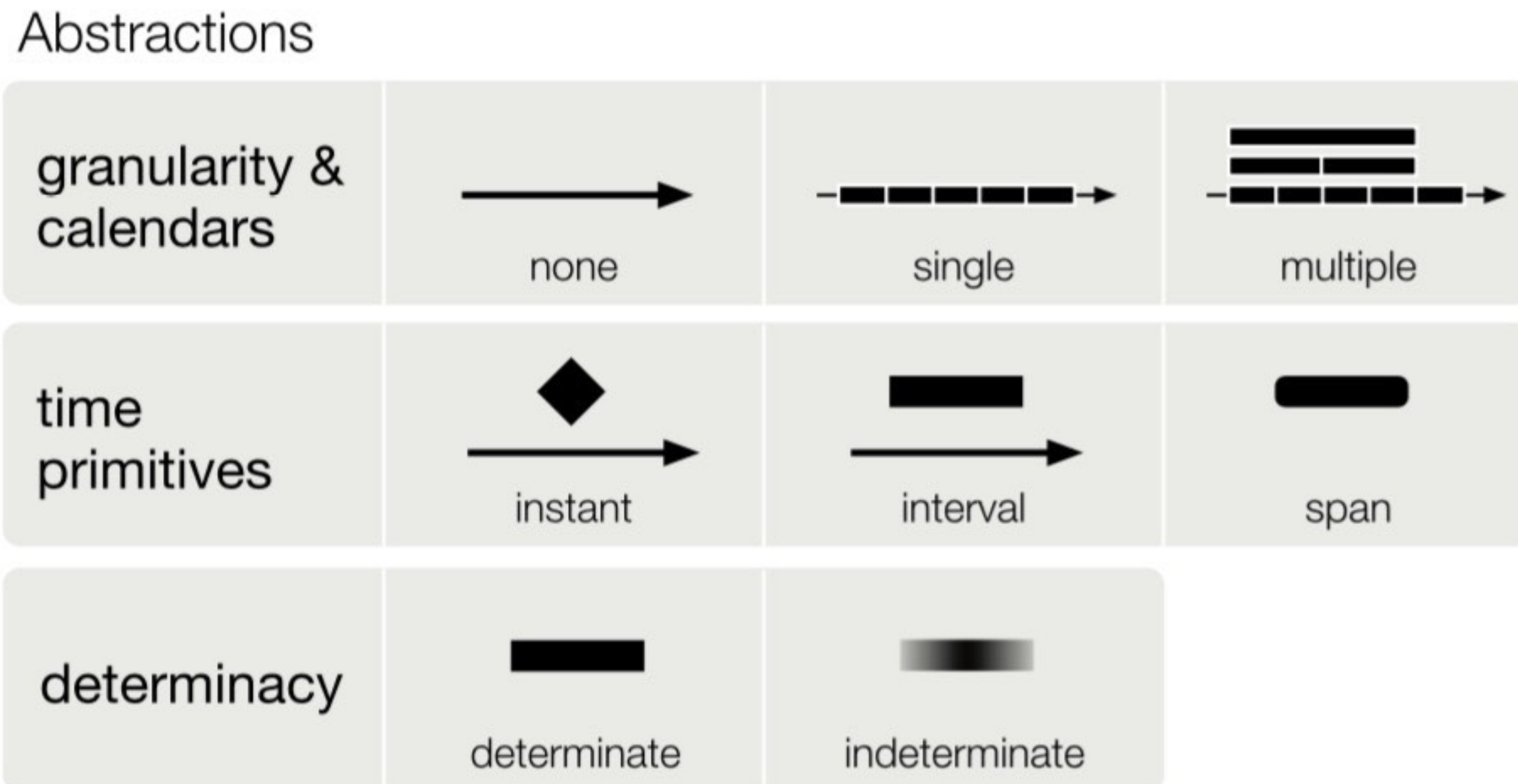
  - **Indeterminacy might be introduced by explicit specification (e.g., earliest beginning and latest beginning of an interval)**
  - **or is implicitly present in the case of multiple granularities.**

Hierarchical organization and concrete time elements



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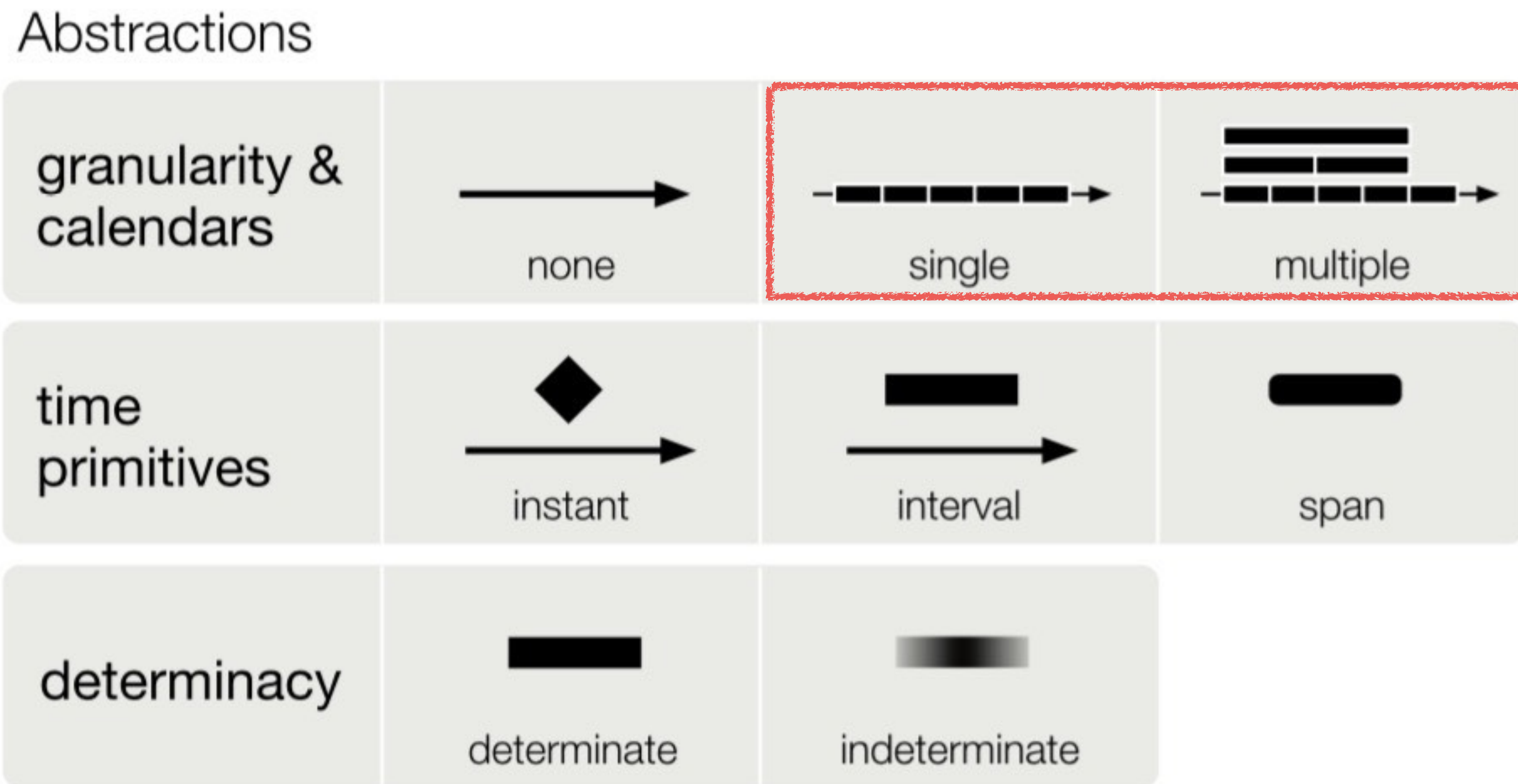

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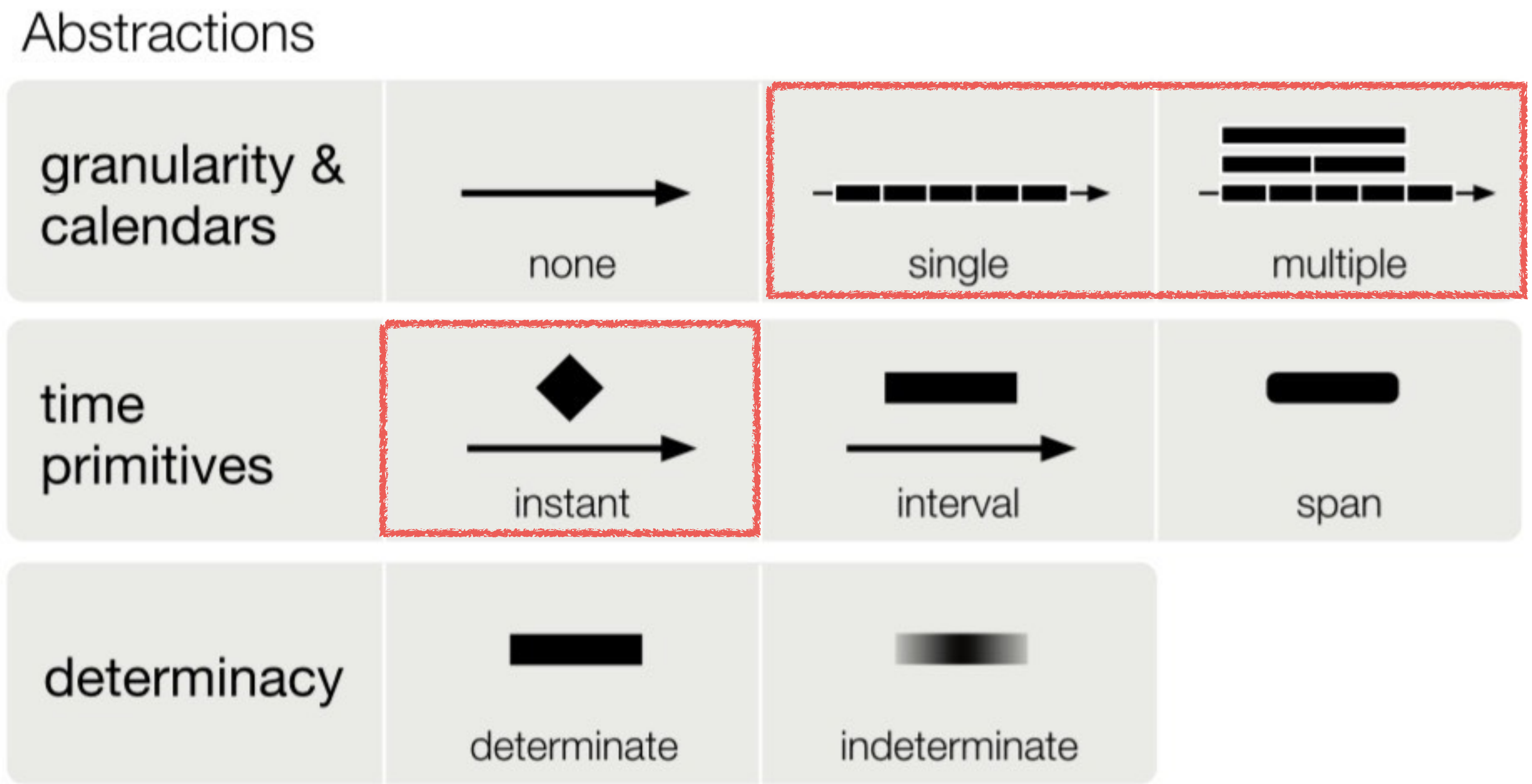

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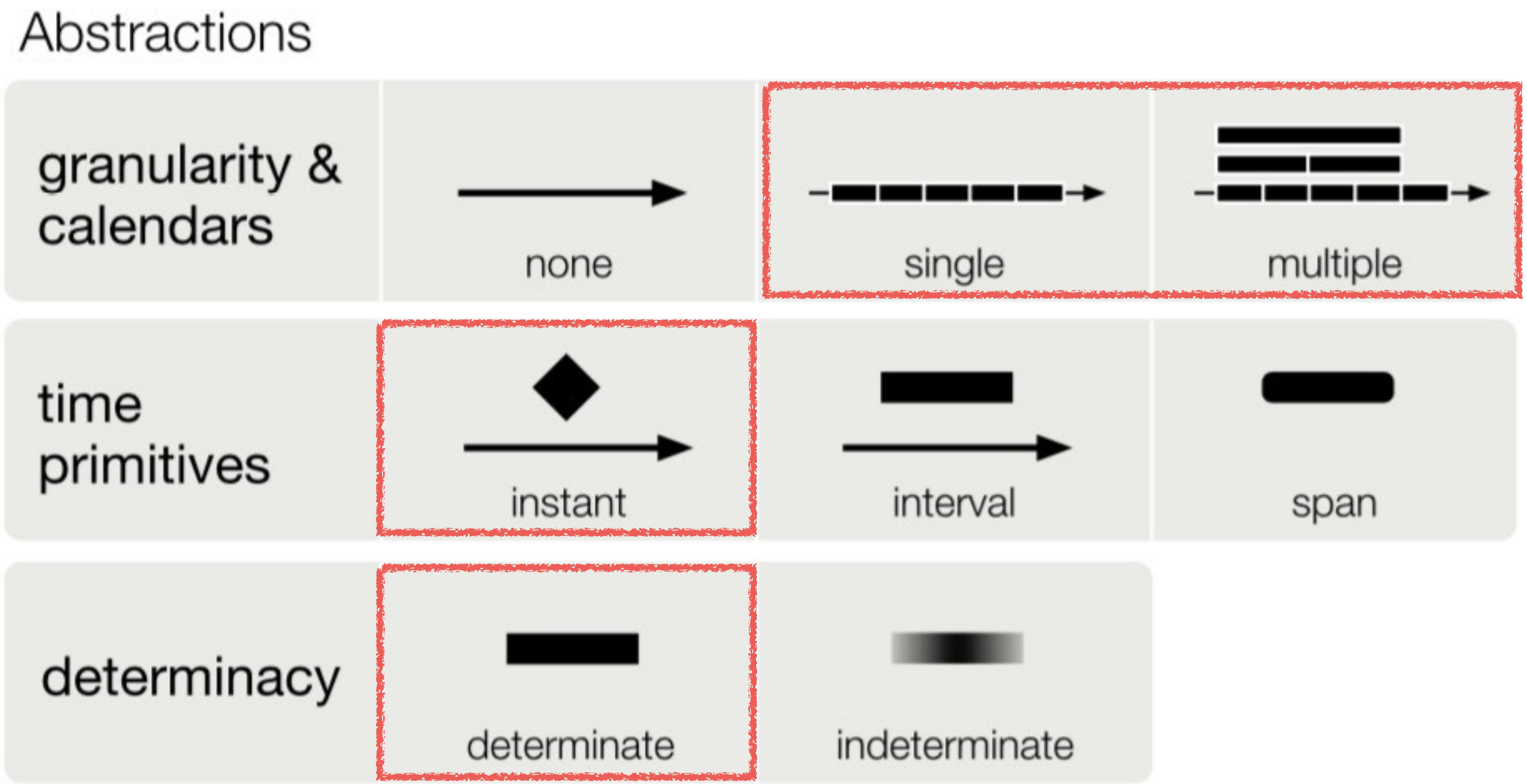

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Characteristics of Time-Oriented Data

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  - **Number of variables: univariate vs. multivariate.**

Characteristics of Time-Oriented Data

scale	3.14 3.27 4.88 quantitative	coconut banana apple qualitative
frame of reference	abstract	spatial
kind of data	events	states
number of variables	univariate	multivariate

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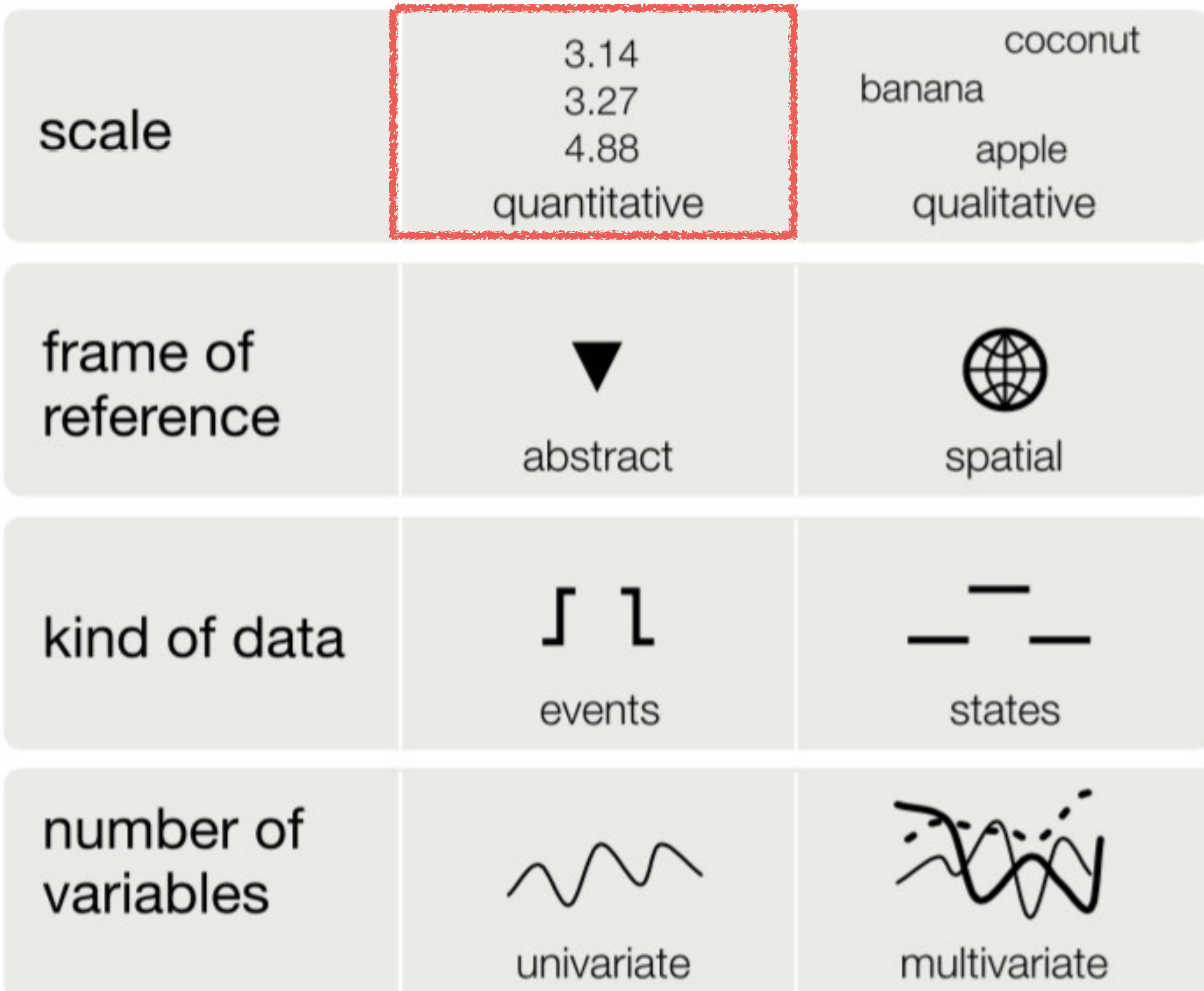

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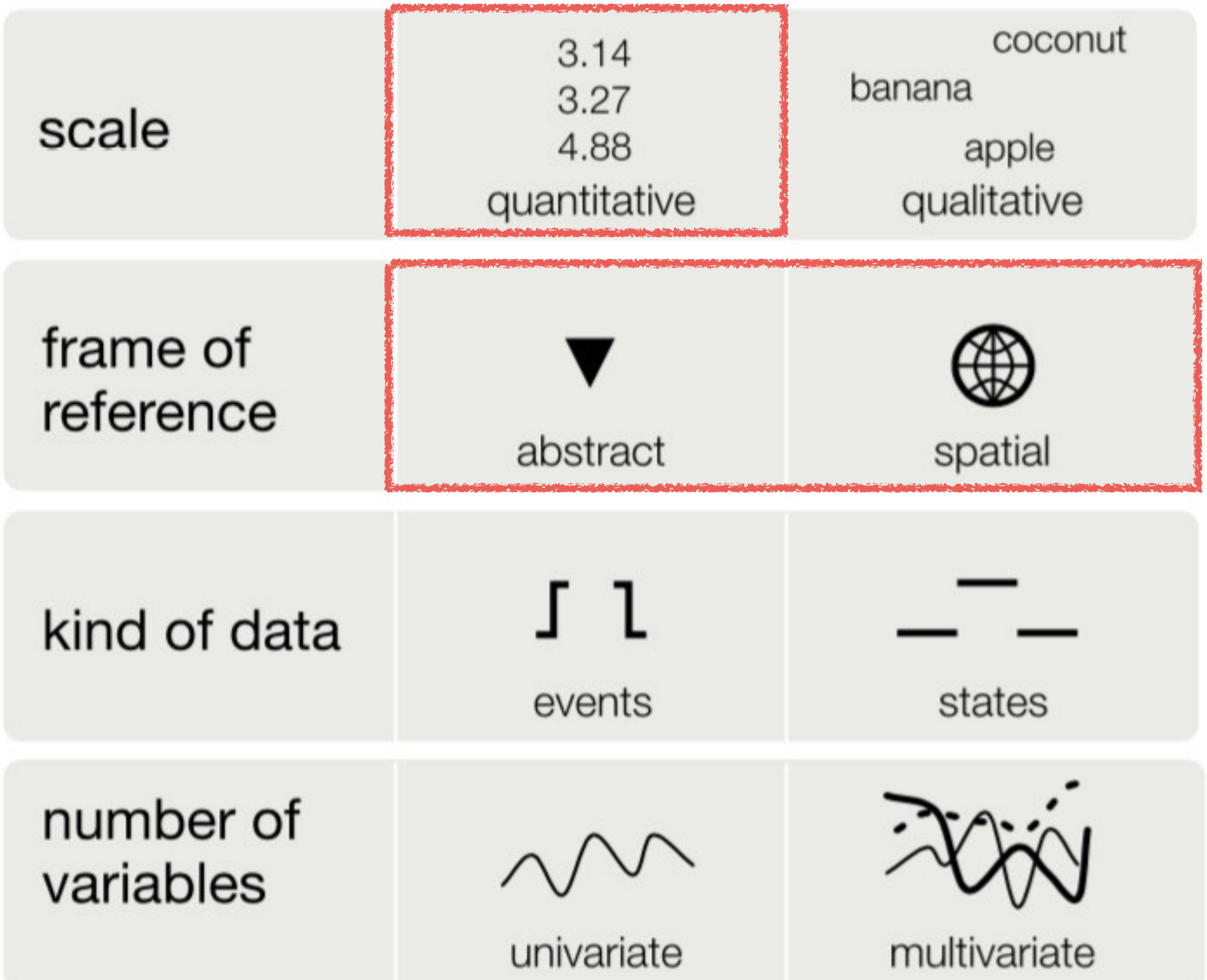

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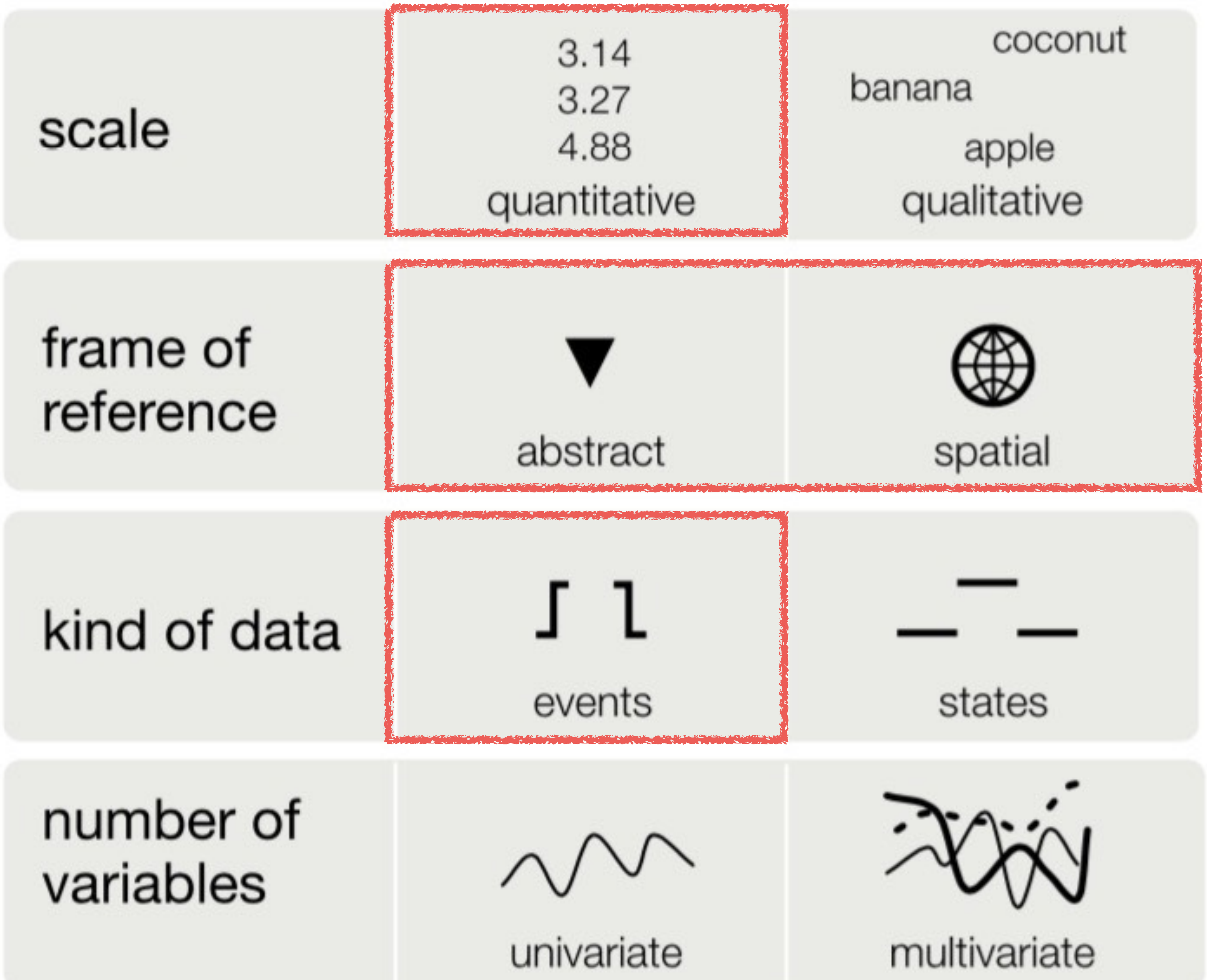

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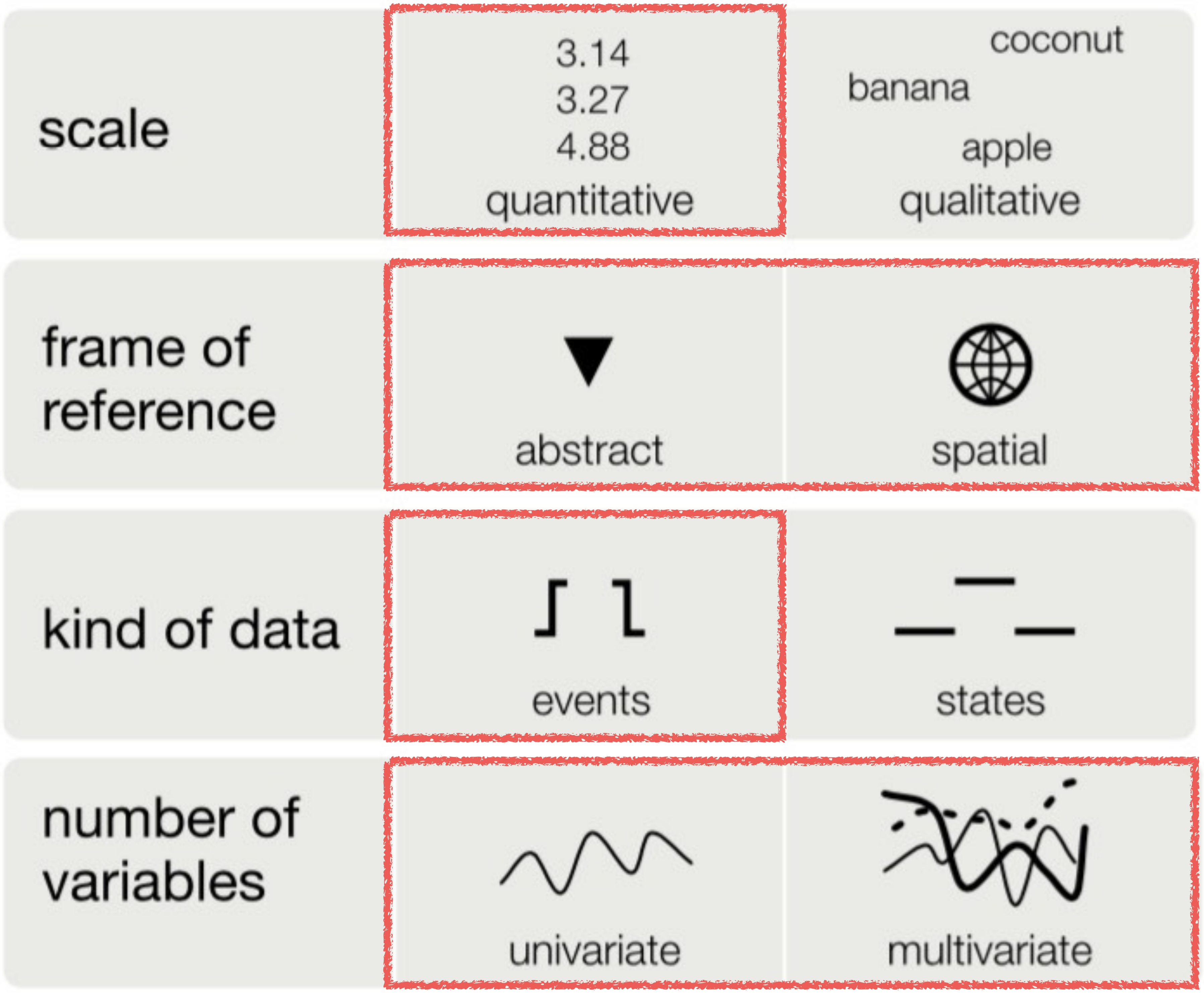

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- Characteristics of Time-Oriented Data
- **Relating Data and Time**

Relating Data and Time

- **Any data set is related to two temporal domains:**
  - **Internal time: is considered to be the temporal dimension inherent in the data model. Internal time describes when the information contained in the data is valid**
  - **External time: The external time is necessary to describe how a data set evolves in (external) time.**

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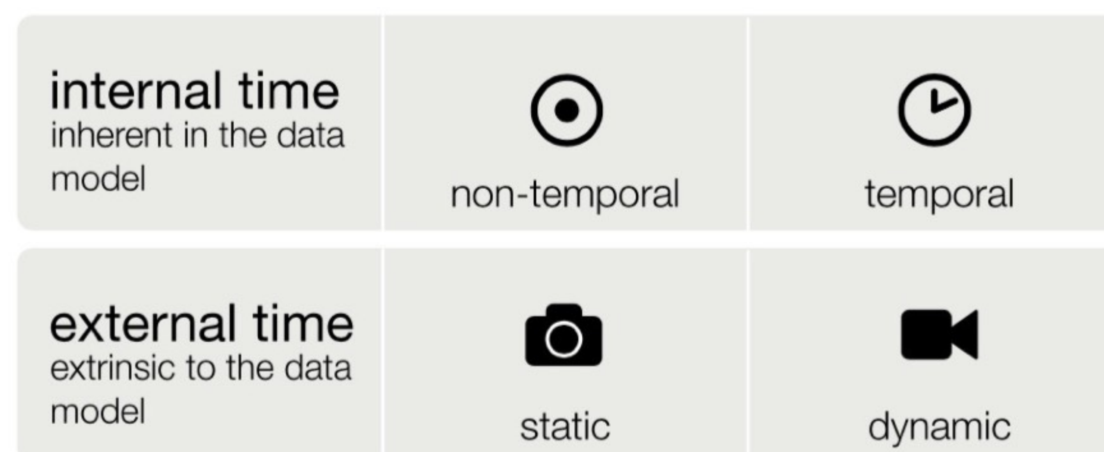

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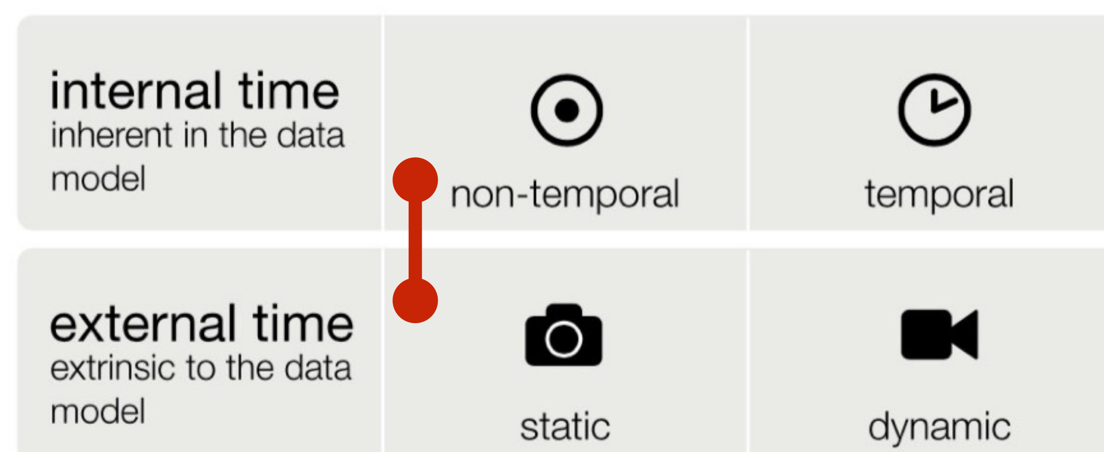

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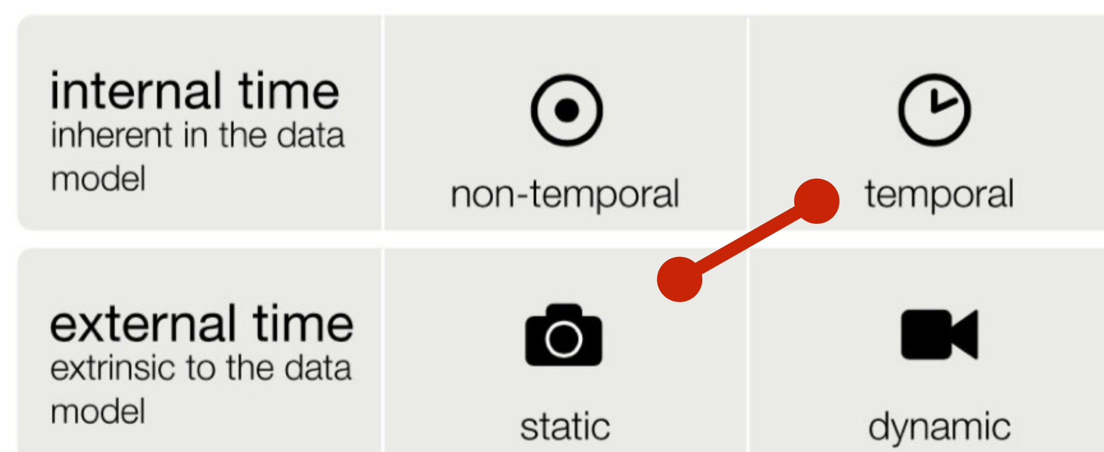

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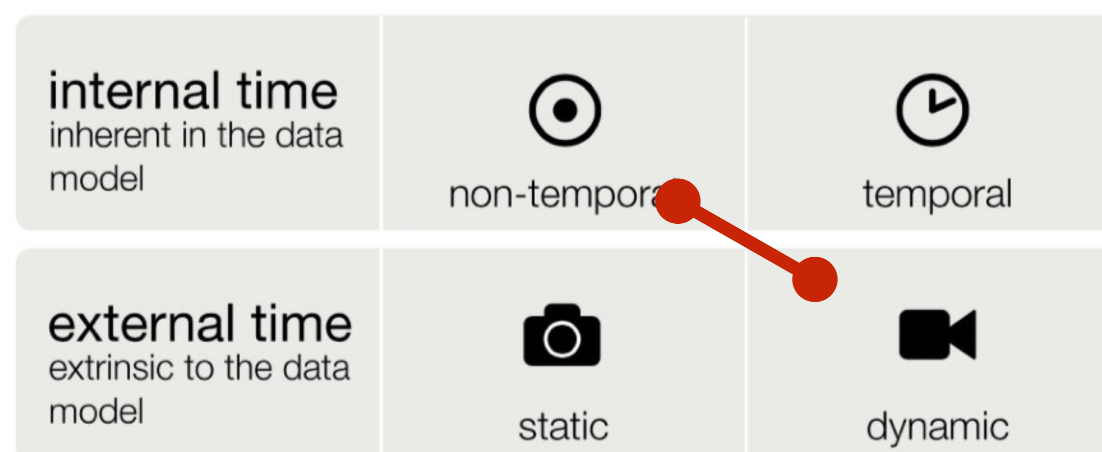

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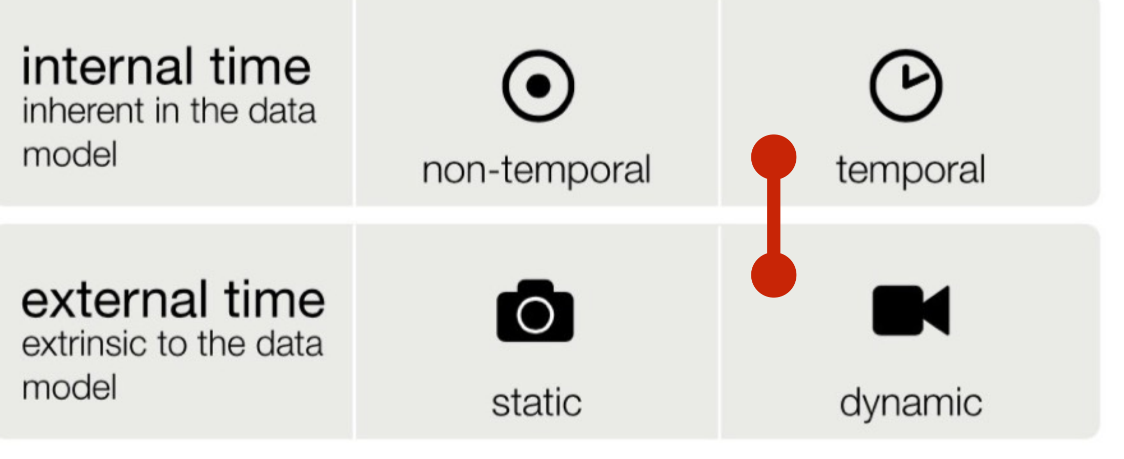

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- **Data sets can be classified as followed**
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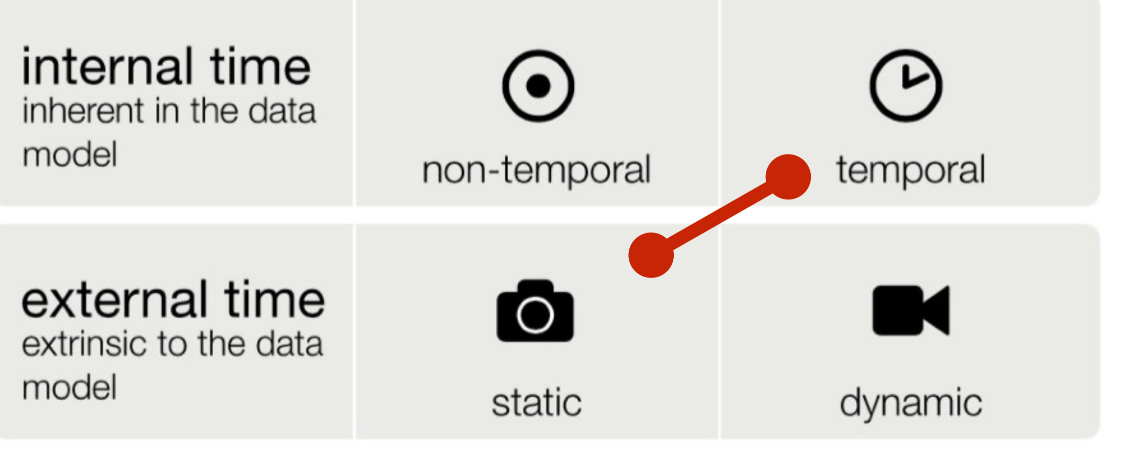
    - **Is an historical view of how the real world or some model looked at the various elements of internal time.**



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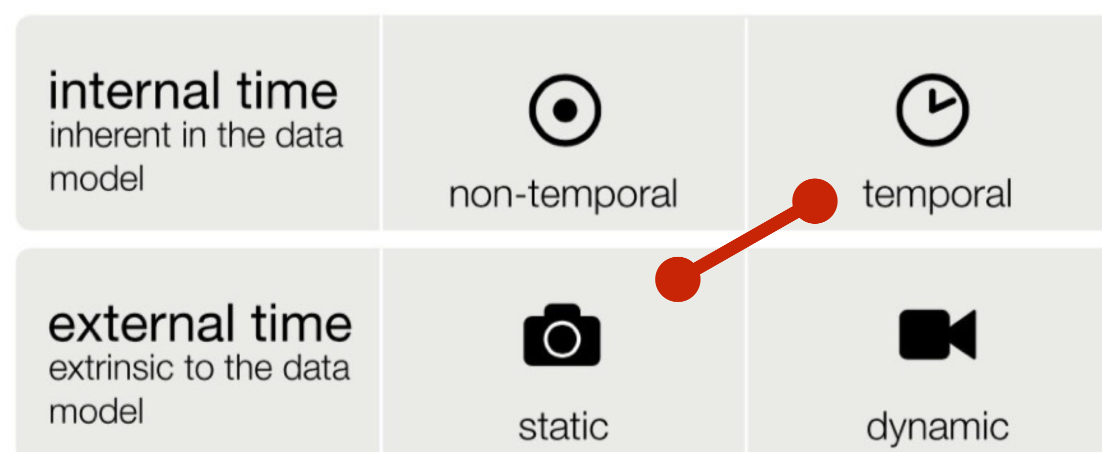
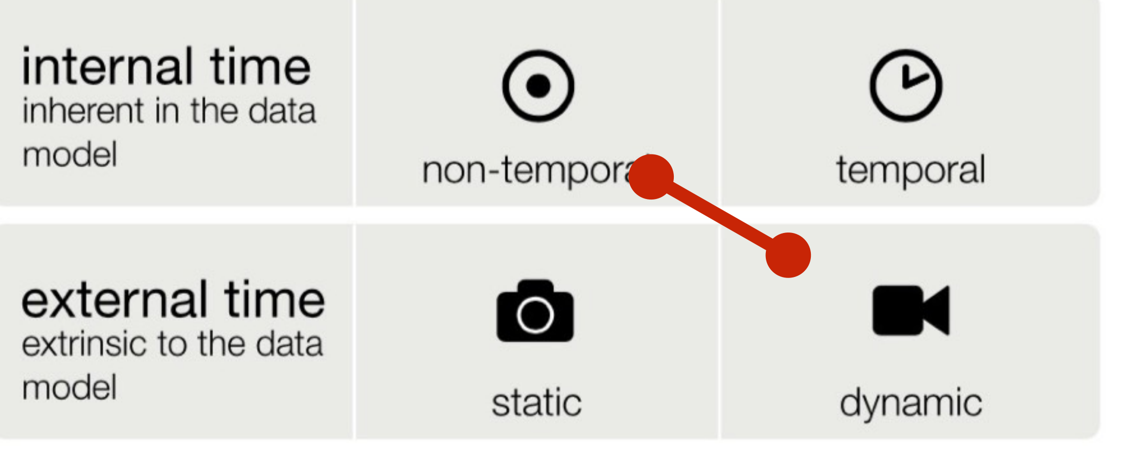
Most Common



Relating Data and Time

- **Data sets can be classified as followed**
  - **Dynamic non-temporal data: If the internal time contains only one, but the external time is composed of multiple time primitives then the data depend on the external time.**
    - **Since the internal time is not considered, only the current state of the data is preserved; an historical view is not maintained**



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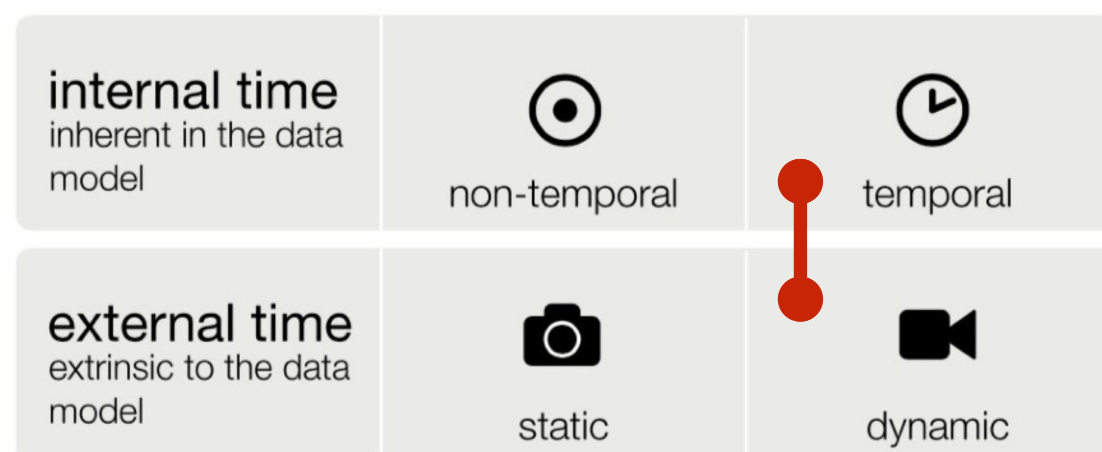
Relating Data and Time

- **Dynamic temporal data:** **If both internal and external time are comprised of multiple time primitives, then the data are considered to be bi-temporally dependent.**
  - **In other words, the data contain variables depending on (internal) time, and the actual state of the data changes over (external) time.**
  - **Usually, in this case, internal and external time are strongly coupled and can be mapped from one to the other.**



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  - **Mapping of time to time: utilize the physical dimension of time to convey the time dependency of the data. Dynamic representations.**
- **Dimensionality of the presentation space**

Visualizing Time-Oriented Data

- **Mapping of time**
  - **Mapping of time to space: time and data are represented in a single coherent visual representation. Visualizations of time-oriented data static.**
  - **Mapping of time to time: utilize the physical dimension of time to convey the time dependency of the data. Dynamic representations.**
- **Dimensionality of the presentation space**
  - **2D: have to ensure that the time axis is emphasized**

Visualizing Time-Oriented Data

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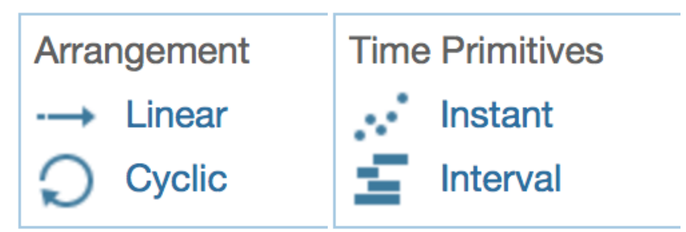
  - **Mapping of time to space**: time and data are represented in a single coherent visual representation. **Visualizations of time-oriented data static.**
  - **Mapping of time to time**: utilize the physical dimension of time to convey the time dependency of the data. **Dynamic representations.**
- **Dimensionality** of the presentation space
  - 2D: have to ensure that the time axis is emphasized
  - 3D: dedicated dimension for the time axis

- **data**
  - **frame of reference: abstract vs. spatial**
  - **variables: univariate vs. multivariate**

Categorization on TimeViz Browser [http://www.timeviz.net]

- **data**
  - **frame of reference: abstract vs. spatial**
  - **variables: univariate vs. multivariate**

- **time**
  - **arrangement: linear vs. cyclic**
  - **time primitives: instant vs. interval**



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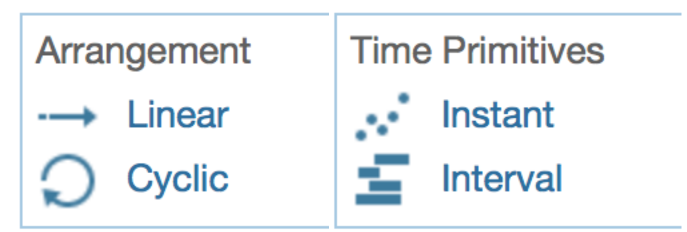
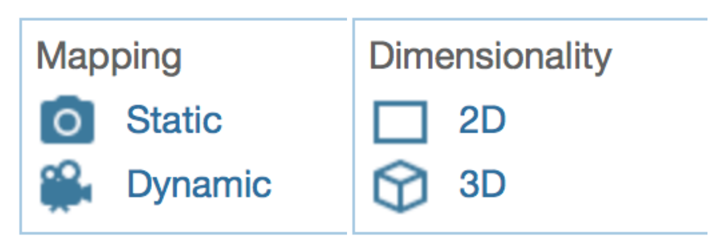


- **vis**
  - **mapping: static vs. dynamic**
  - **dimensionality: 2D vs. 3D**



Visualization techniques

- **What is presented?**
  - **Time and data**
- **How is it presented?**
  - **Visual representation**
- **Why is it presented?**
  - **User tasks**
    - **MacEachren proposed a low-level task description specifically addressing the temporal domain.**
    - **Andrienko et al. distinguishes between elementary and synoptic tasks on the first level.**

Visualization techniques

Visualization techniques

- **Examples of user tasks**
  - **existence of data element: does a data element exist at a specific time?**
  - **rate of change: how fast is a data element changing over time?**

Visualization techniques

- **Examples of user tasks**
  - **existence of data element: does a data element exist at a specific time?**
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  - **direct lookup: what is the value of glucose on March 1, 2014?**
  - **direct comparison: compare the value of glucose and the activity level on March 1, 2014.**

Visualization techniques

- Examples of user tasks
  - **existence of data element**: does a data element exist at a specific time?
  - **rate of change**: how fast is a data element changing over time?
- **Elementary tasks**: address individual data elements or groups of data.
  - **direct lookup**: what is the value of glucose on March 1, 2014?
  - **direct comparison**: compare the value of glucose and the activity level on March 1, 2014.
- **Synoptic tasks**: involve a general view and consider sets of values or groups of data in their entirety.
  - **relation seeking**: find two contiguous months with opposite trends in the values of glucose.

Examples of Visualization techniques

Examples of Visualization techniques

- **Data: Frame of Reference - Abstract**
  - KronoMiner: Using Multi-Foci Navigation for the Visual. Exploration of Time- Series Data.

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- **Time: Arrangement - Linear**
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- **Time: Arrangement - Cyclic**
  - Enhanced Interactive Spiral Display.

Examples of Visualization techniques

- **Time: Time Primitives - Interval**
  - SpiraClock: A Continuous and Non- Intrusive Display for Upcoming Events.

Examples of Visualization techniques

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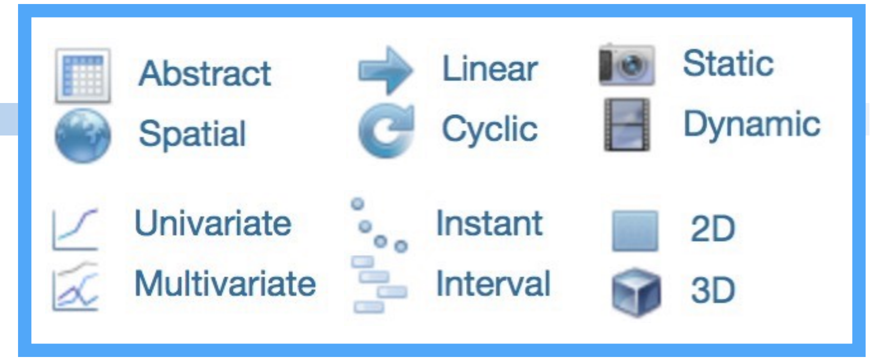
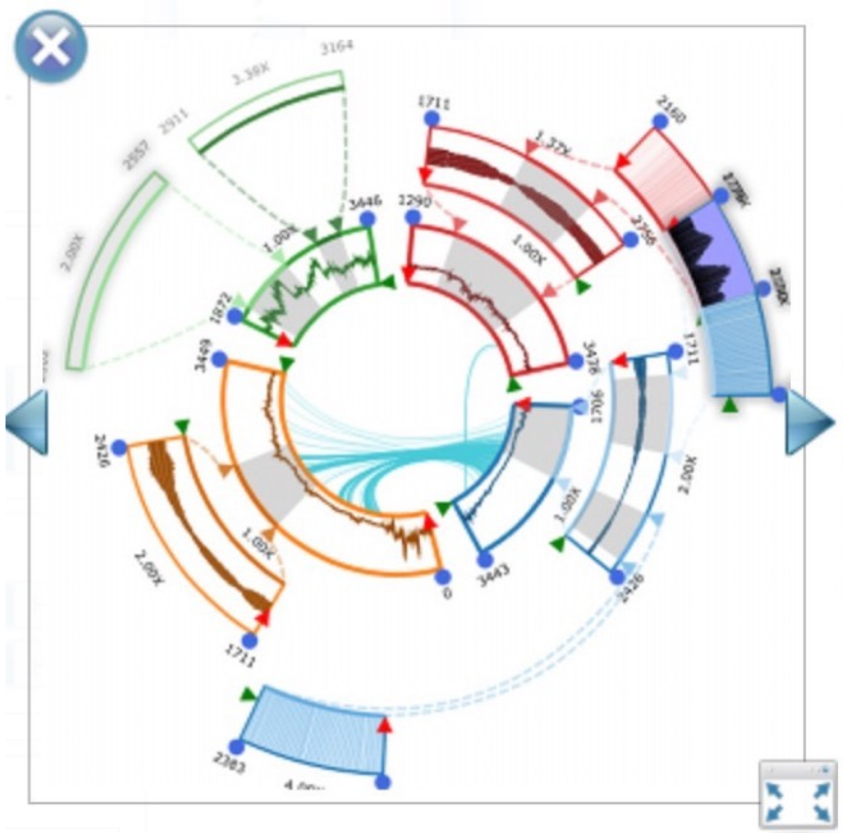
- **Visualization: Dimensionality—3D**
  - ThemeRiver: Visualizing Theme Changes over Time. => Interactive Poster: 3D ThemeRiver.

Data: Frame of Reference - Abstract





KronoMiner

Source: Image courtesy of Jian Zhao.

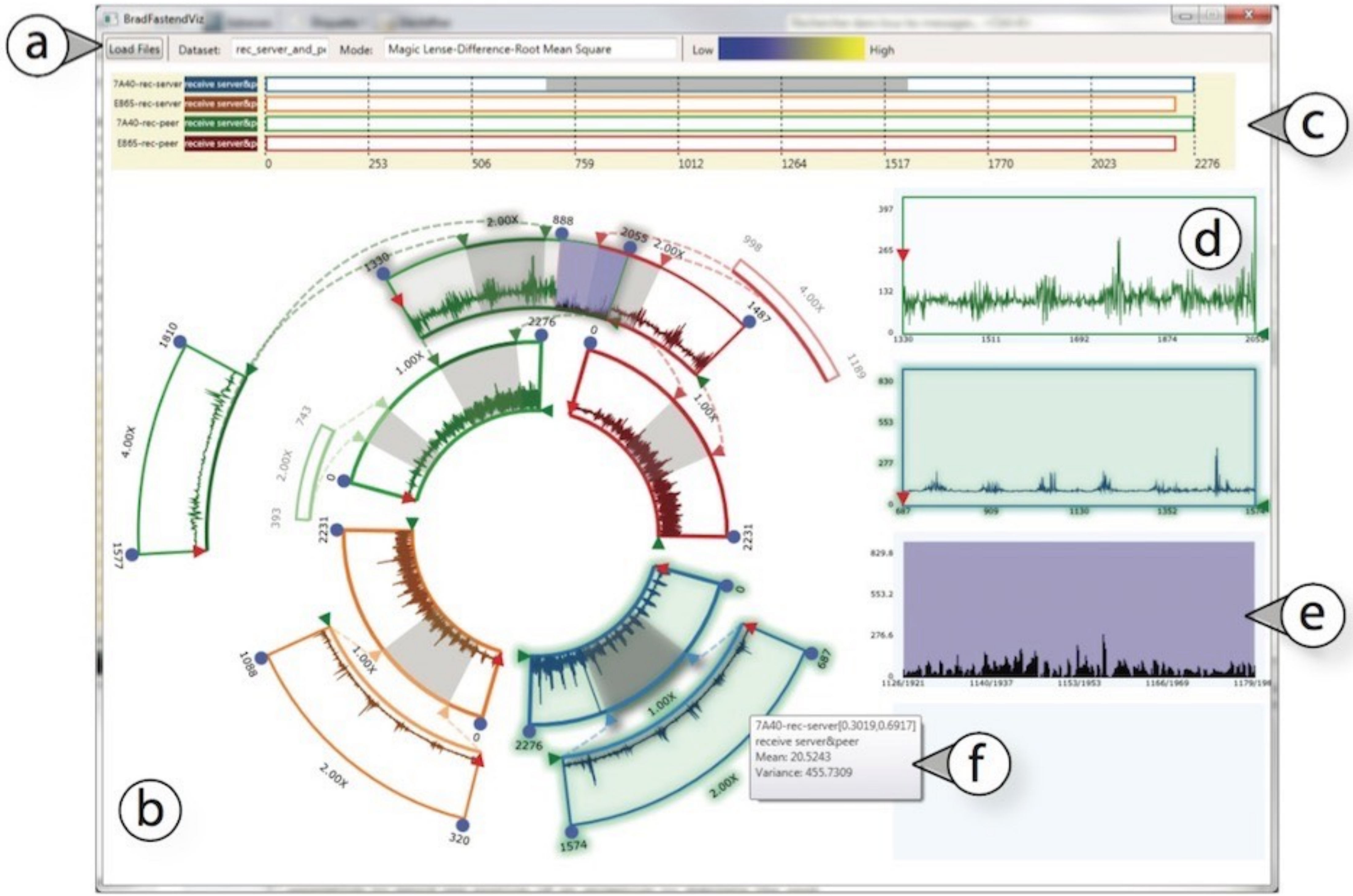
KronoMiner is a multipurpose time-series exploration tool providing rich navigation capabilities and analytical support. Its visualization is based on a hierarchical radial layout, allowing users to drill into details by focusing on different pieces. The data pieces can be rotated, dragged, stretched or shrunken in a facile manner, supporting various kinds of time-series analysis and exploration tasks. KronoMiner also introduces two analytical techniques: 1) MagicAnalytics Lens which shows the correlations between two parts of the data pieces when overlapped and 2) Best Match mode in which an arch shape is displayed indicating the matching parts of two data pieces under a specific similarity measure.

References

- *Zhao, J.; Chevalier, F. & Balakrishnan, R.: KronoMiner: Using Multi-Foci Navigation for the Visual Exploration of Time-Series Data. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI), ACM, 2011.*

- **Check the video: https://youtu.be/U0IN7vfrxi0**

Data: Frame of Reference - Abstract

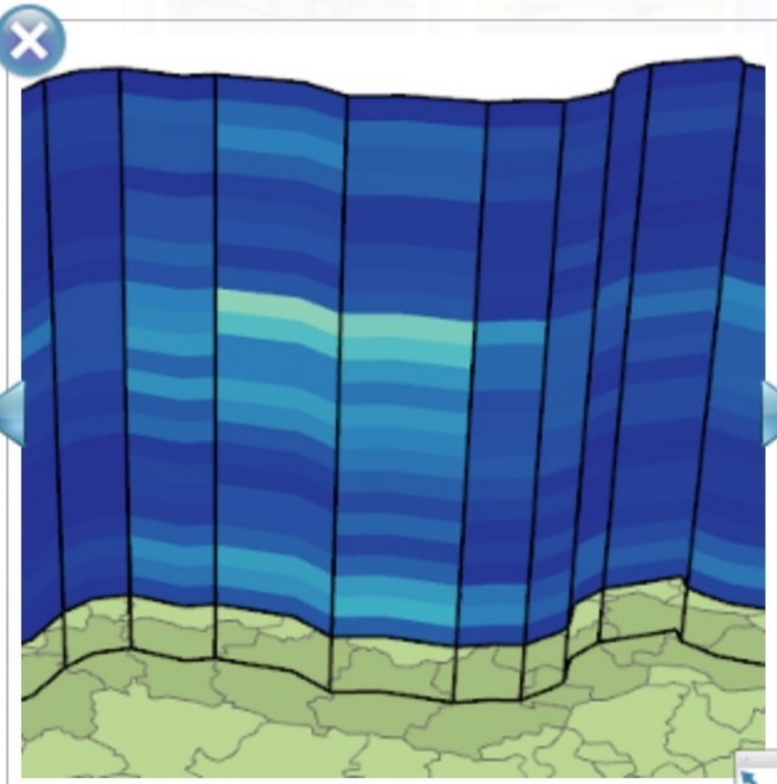


Data: Frame of Reference - Abstract

Data: Frame of Reference - Abstract

Data: Frame of Reference - Spatial

Abstract	Linear	Static
Spatial	Cyclic	Dynamic
Univariate	Instant	2D
Multivariate	Interval	3D



Great Wall of Space-Time

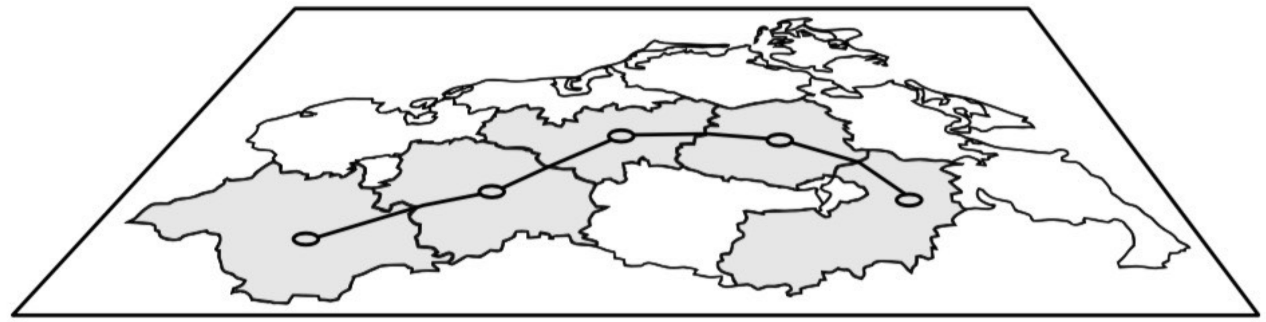
Source: Image courtesy of Christian Tominski.

Tominski, C. & Schulz, H.-J. (2012) introduce a visualization technique for spatio-temporal data that refers to 2D geographical space and 1D linear time. The idea is to construct a non-planar slice -- called the Great Wall of Space-Time -- through the 3D (2D+1D) space-time continuum. The construction of the wall is based on topological and geometrical aspects of the geographical space. Based on a neighborhood graph, a topological path is established automatically or interactively. The topological path is transformed to a geometrical path that respects the geographic properties of the areas of the map. The geometrical path is extruded to a 3D wall, whose 3rd dimension can be used to map the time domain. Different visual representations can be projected onto the wall in order to display the data. Examples illustrate data visualizations based on color-coding and parallel coordinates. The wall has the advantage that it shows a closed path through space with no gaps between the information-bearing pixels on the screen.

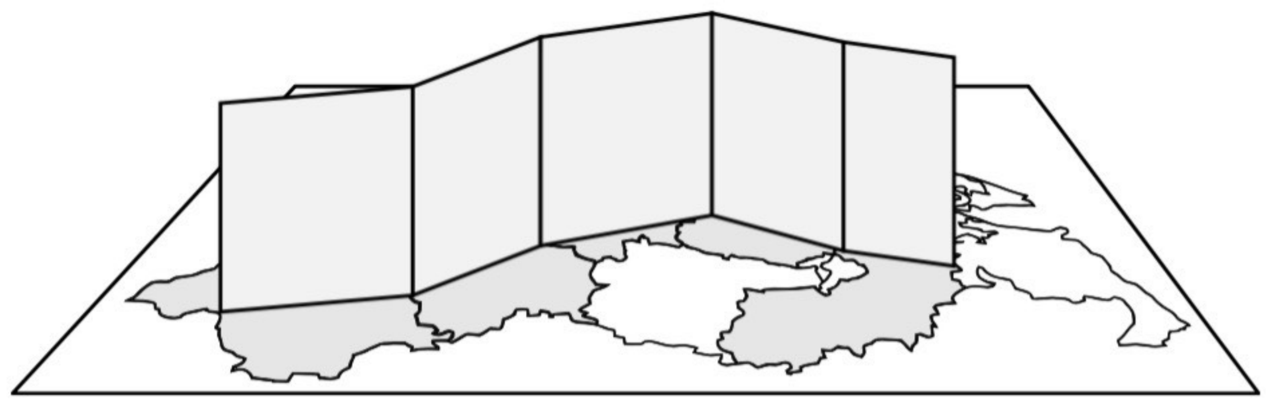
References

- *Tominski, C. & Schulz, H.-J.: The Great Wall of Space-Time. Proceedings of the Workshop on Vision, Modeling & Visualization (VMV), Magdeburg, Germany, Eurographics Association, 2012.*

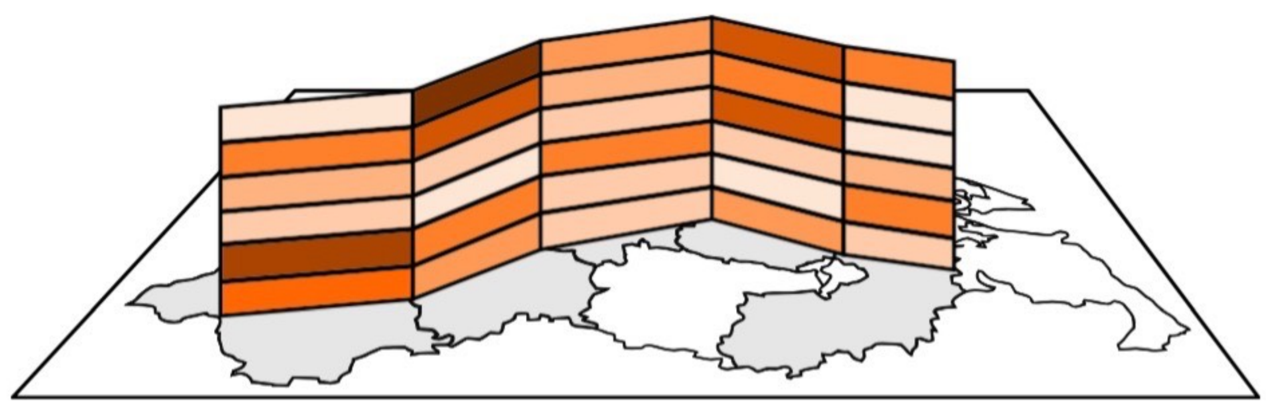
Data: Frame of Reference - Spatial



(a) Specification of a path through space.

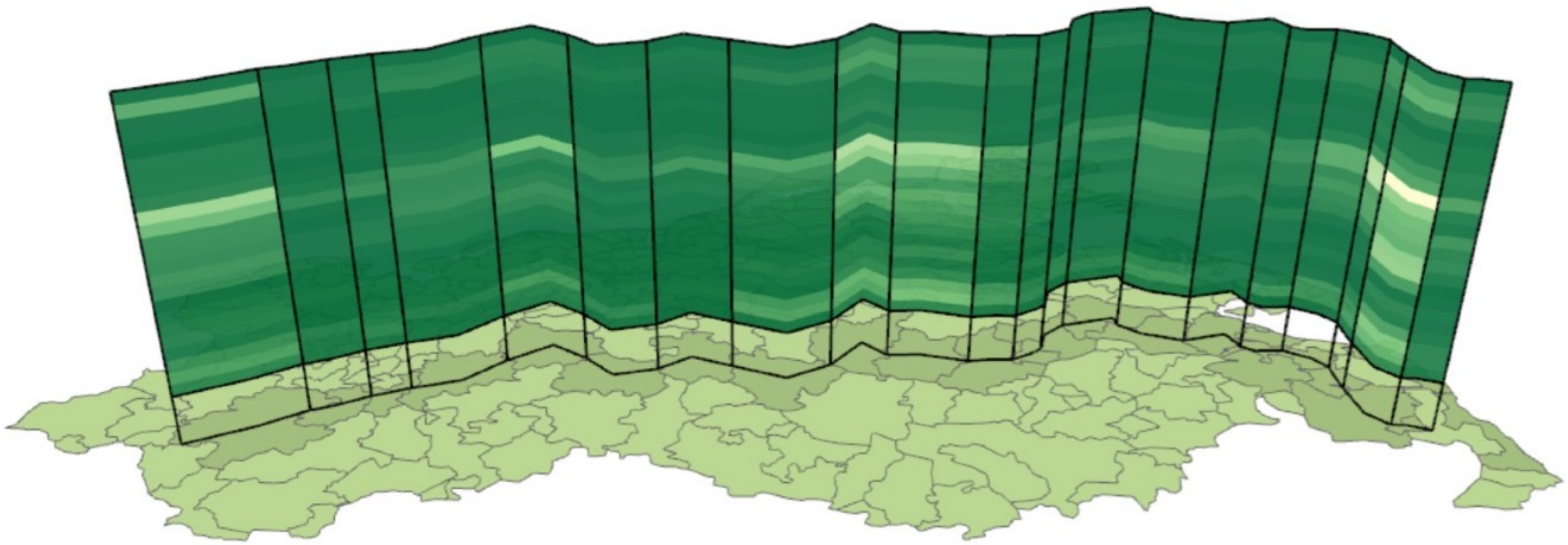


(b) Construction of a wall.

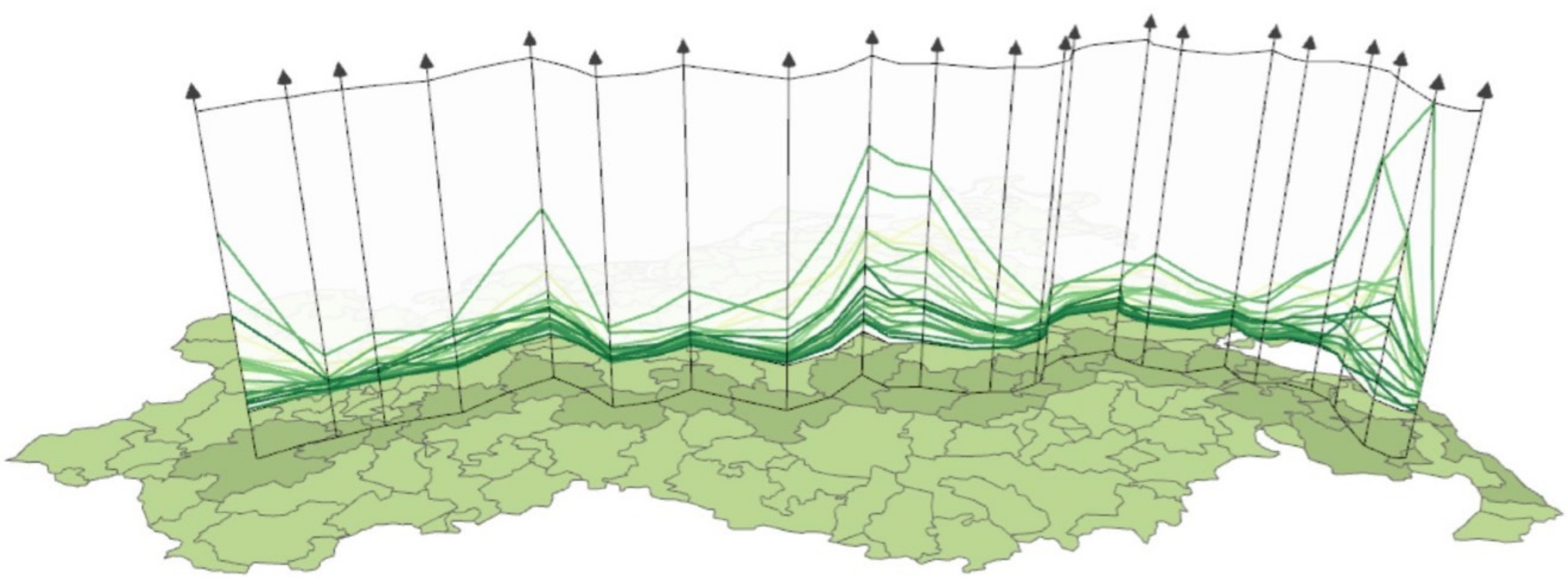


(c) Visualization of data on the wall.

Data: Frame of Reference - Spatial



(a) Color-coded bricks.

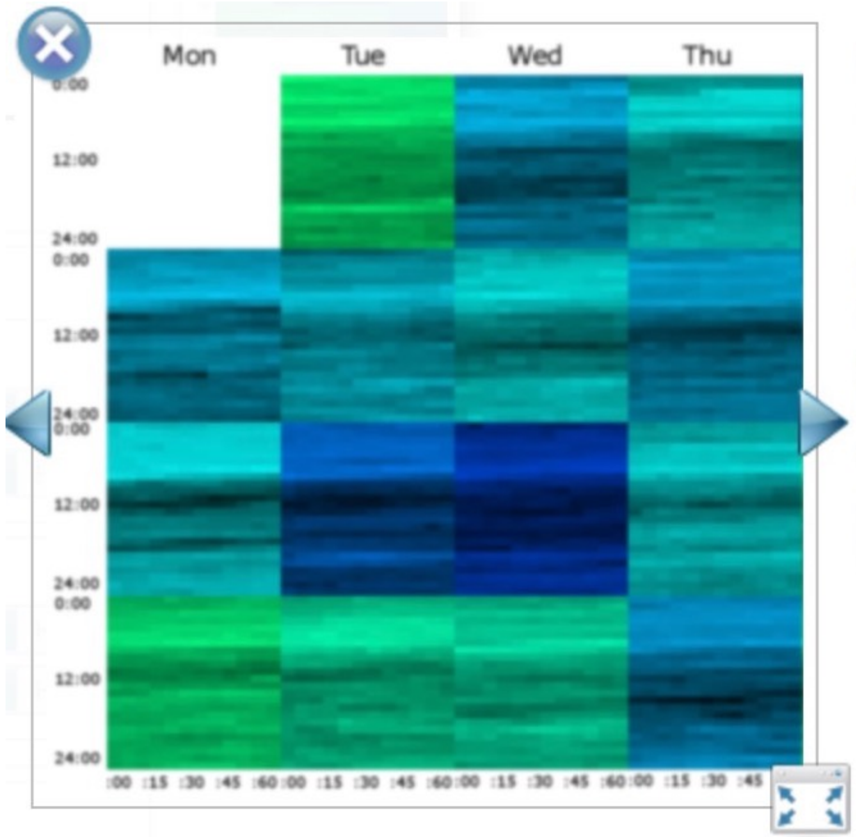


(b) Parallel coordinates style.

Figure 8: *The Great Wall of Space-Time showing the number of cases of influenza per area and month.*

Data: Number of Variables - Univariate

Abstract | Linear | Static
Spatial | Cyclic | Dynamic
Univariate | Instant | 2D
Multivariate | Interval | 3D



GROOVE

Source: Generated with the GROOVE software.

GROOVE (Granularity Overview OVErlay) visualizations as presented by Lammarsch, T.; Aigner, W.; Bertone, A.; Gärtner, J.; Mayr, E.; Miksch, S. & Smuc, M. (2009) utilize a user-configurable set of four time granularities to partition a dataset in a regular manner.That is, a recursive layout is achieved that shows columns and rows of larger blocks and a pixel arrangement within blocks for the detail structure.Following the concept of recursive patterns (see Recursive Pattern) ...
Read more in our book ...

References

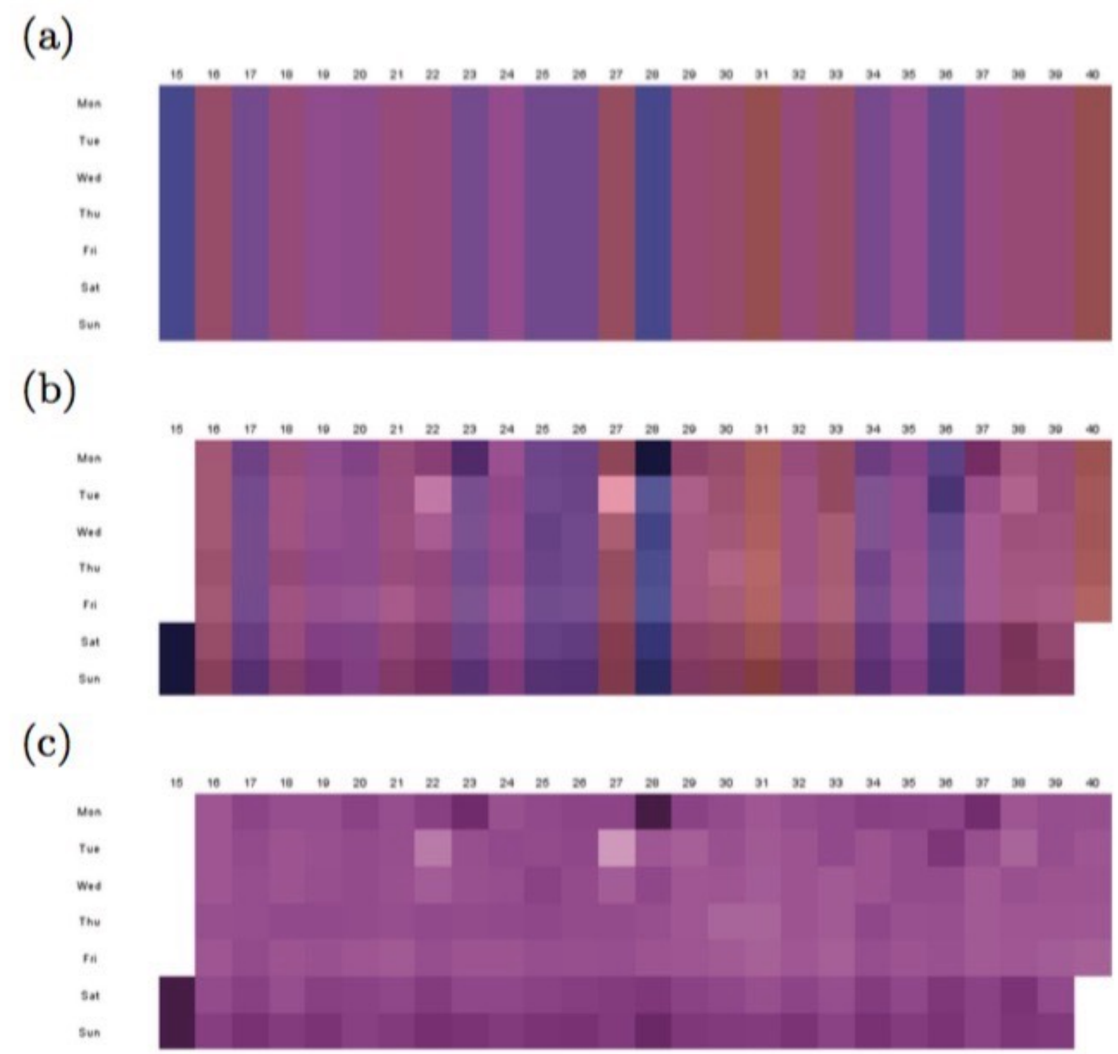
- *Lammarsch, T.; Aigner, W.; Bertone, A.; Gärtner, J.; Mayr, E.; Miksch, S. & Smuc, M.: Hierarchical Temporal Patterns and Interactive Aggregated Views for Pixel-based Visualizations. Proceedings of the International Conference Information Visualisation (IV), IEEE Computer Society, 2009.*

Data: Number of Variables - Univariate

Average weekly | Hue

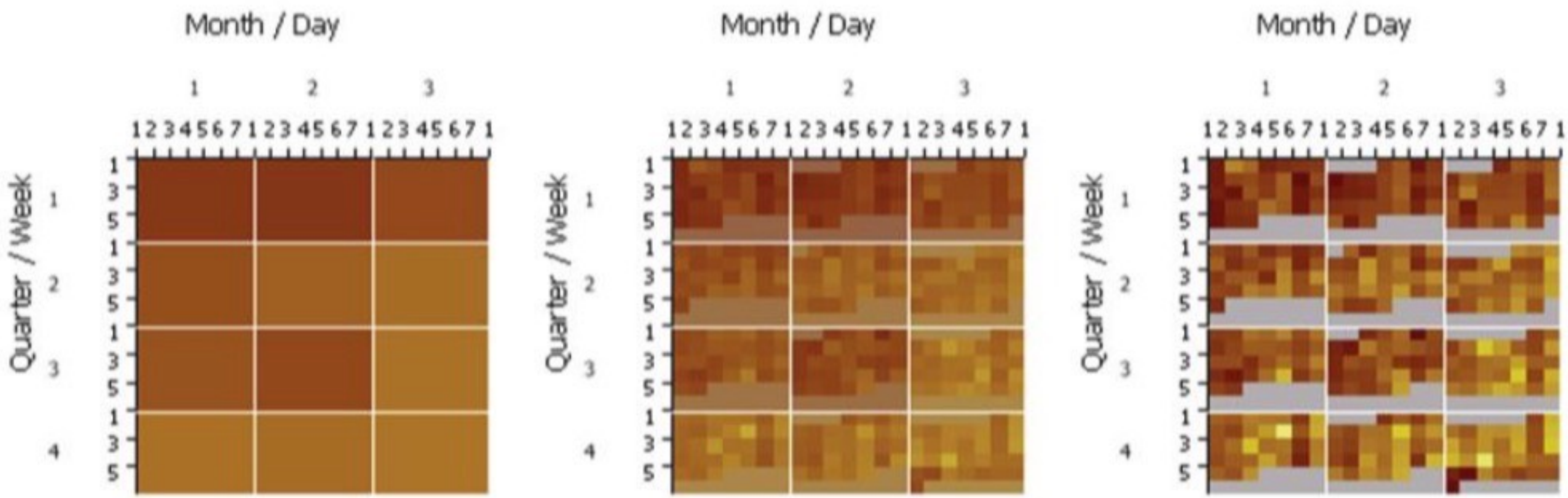
Average daily | lightness

both granularities | color overlay



GROOVE [262] visualizations combine detail and overview readings and use regular layouts based on time granularities. The example shows data from the Dodgers Loop Sensor data set [195] which is publicly available. Here a color-based overlay is plotted: (a) Average weekly traffic on a highway ramp (week of year 15 to 40) is mapped to hue from blue over purple to red. (c) Average daily traffic on the highway ramp is mapped to lightness. (b) Color overlay of both granularities. (Source: Generated with the GROOVE modules for TimeBench [339].)

Data: Number of Variables - Univariate



GROOVE [262] visualizations with opacity overlay: Here, data is plotted for daily turnover from a shop for one year; each block depicts one month: dark red represents low and light yellow represents high values. In this example, a monthly overview is combined with daily details using various opacities. (Source: Generated with the GROOVE prototype software.)

Data: Number of Variables - Univariate

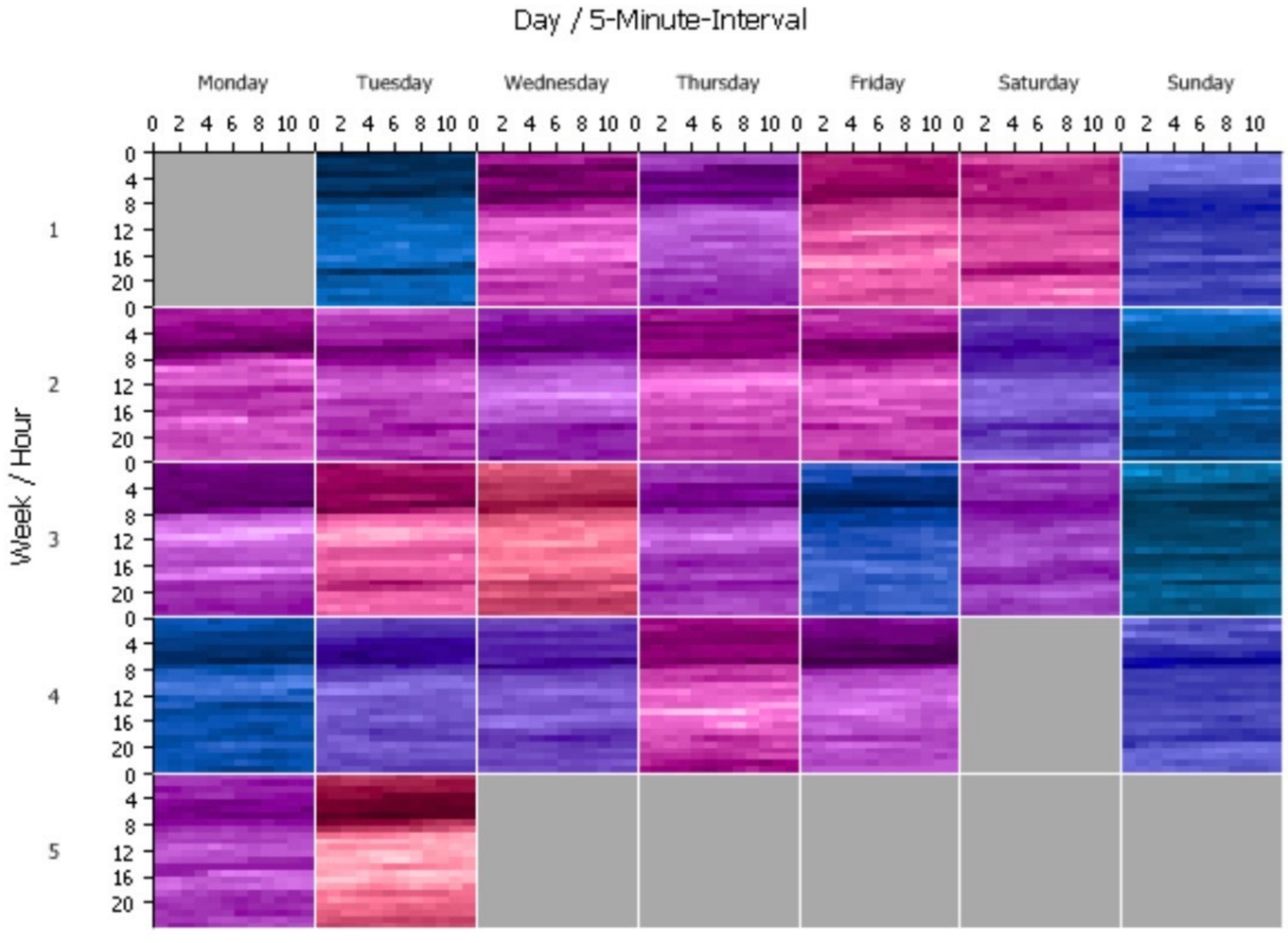
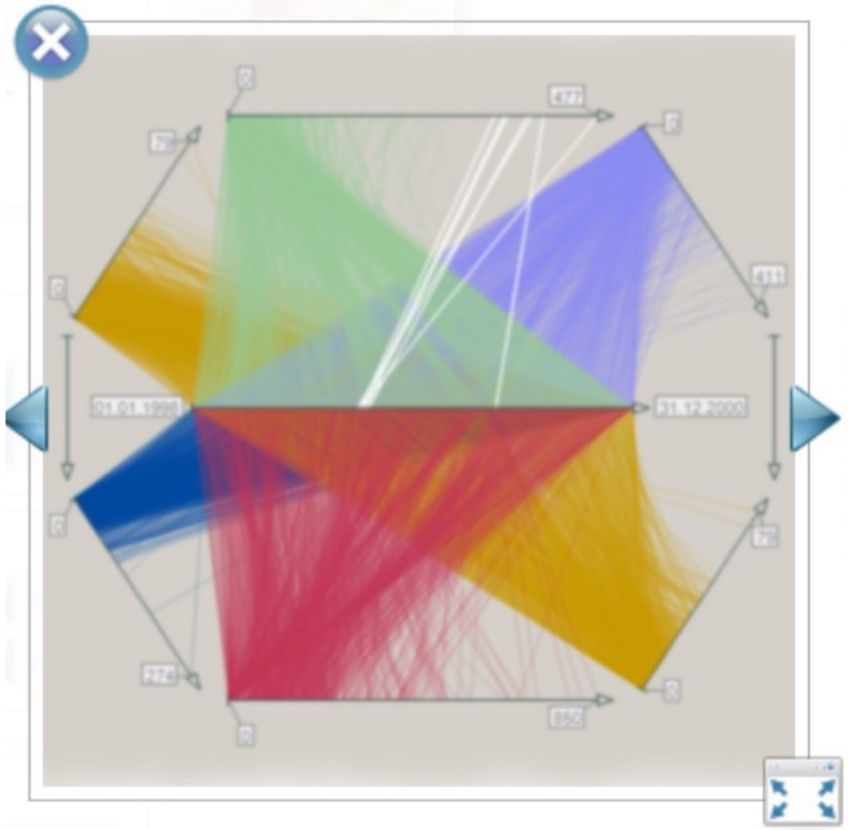


Figure 4: GROOVE with data of one month. The data is from police assignments. For intervals that are five minutes long, the number of deployed units is shown. Each block represents one day. Inside the blocks, the hours are shown in rows. Each row has one pixel for every five-minute-interval. On three days of this month, the data is missing.

Data: Number of Variables - Multivariate

Abstract	Linear	Static
Spatial	Cyclic	Dynamic
Univariate	Instant	2D
Multivariate	Interval	3D



TimeWheel

Source: Generated with the VisAxes software.

Tominski, C.; Abello, J. & Schumann, H. (2004) describe the TimeWheel as a technique for visualizing multiple time-dependent variables. The TimeWheel consists of a single time axis and multiple data axes for the data variables. The time axis is placed in the center of the display to emphasize the temporal character of the data. The data axes are associated with individual colors and are arranged circularly around the time axis. In order to visualize data, lines emanate from the time axis to each ...

Read more in our book ...

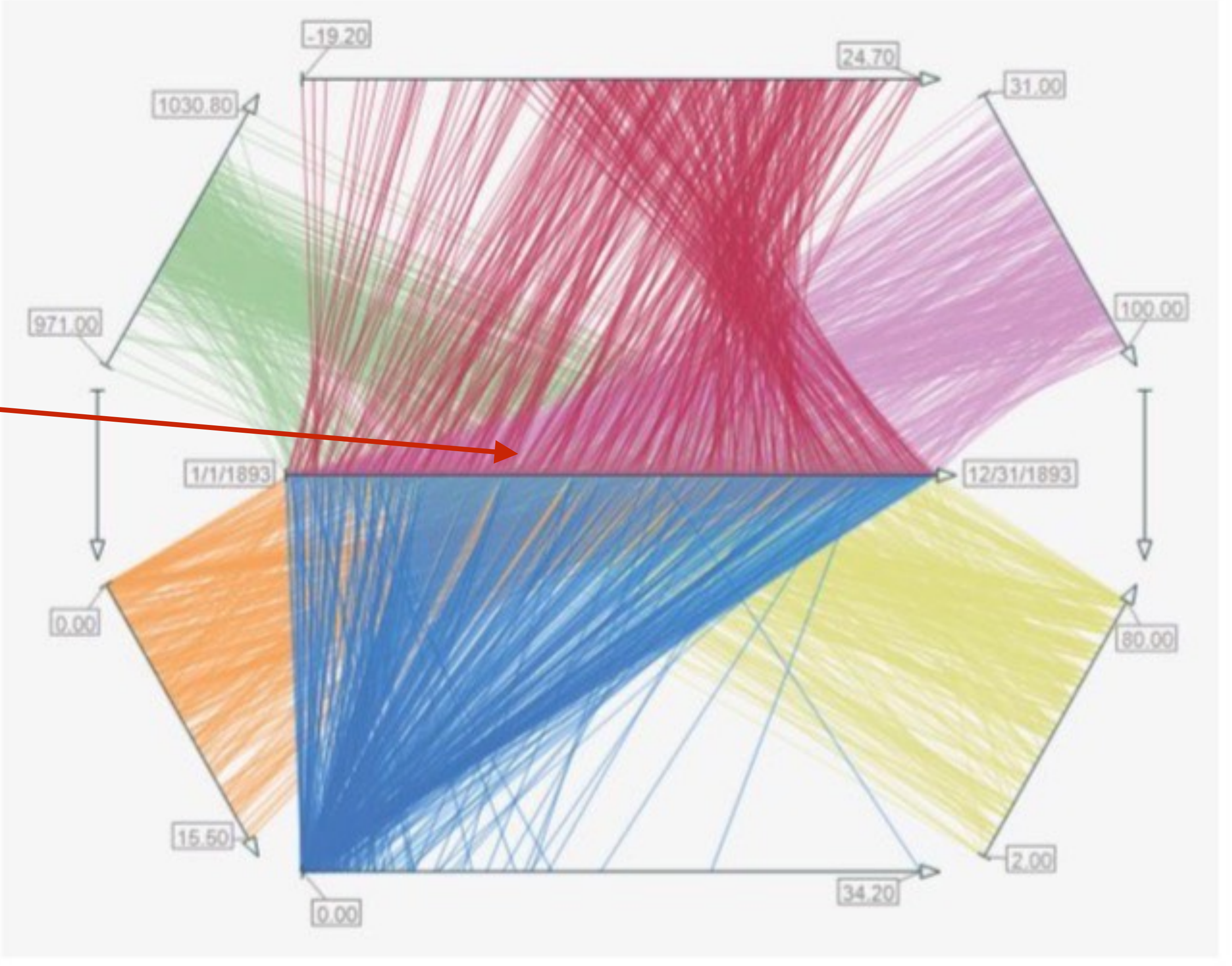
References

- *Tominski, C.; Abello, J. & Schumann, H.: Axes-Based Visualizations with Radial Layouts. Proceedings of the ACM Symposium on Applied Computing (SAC), ACM, 2004.*

- **Check the video: https://youtu.be/h67riWWgwhc**

Data: Number of Variables - Multivariate

Time Axis



The TimeWheel's [417] central axis represents time. The axes in the periphery represent time-dependent variables; eight different variables of meteorological data are plotted. In the center, the red lines show the average temperature, which is increasing in the beginning and decreasing in the end. The blue lines are rainfall. There are some outliers with high rainfall, but moderate rainfall during the whole year. (Source: Generated with the VisAxes prototype software.)

Data: Number of Variables - Multivariate

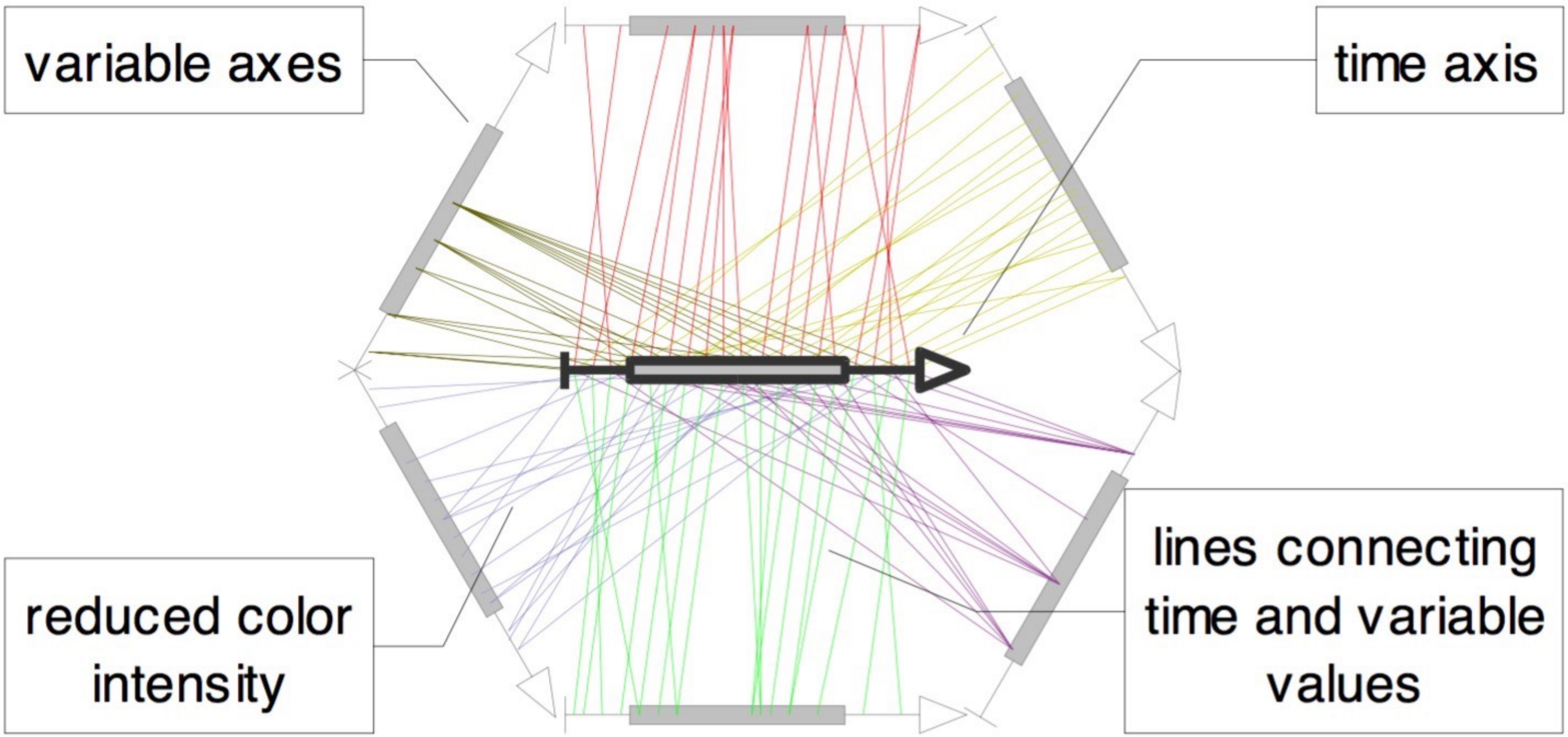


Figure 4. A TimeWheel. Six variable axes are arranged circularly around an exposed centered time axis.

Data: Number of Variables - Multivariate

- **Three types of interactive axes**
  - **scroll axis;**
  - **hierarchical axis;**
  - **focus within context axis.**

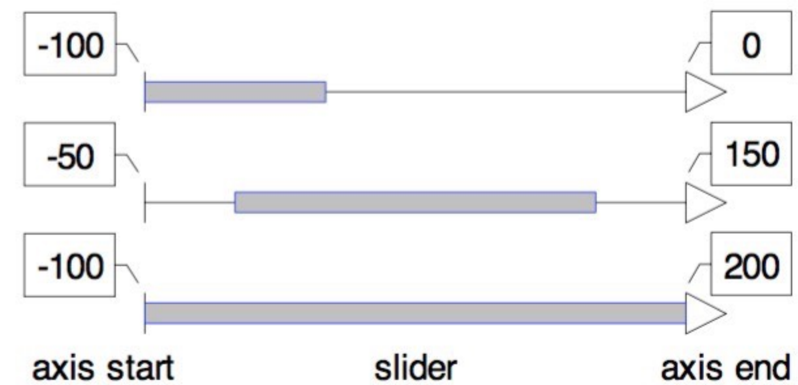


Figure 1. Differently scrolled axes for a variable with minimum value -100 and maximum value 200. The sliders width and location determine the scale of the axis affecting the range of mapped values.

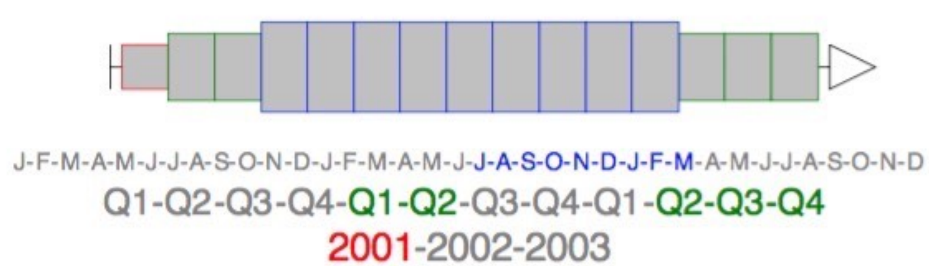
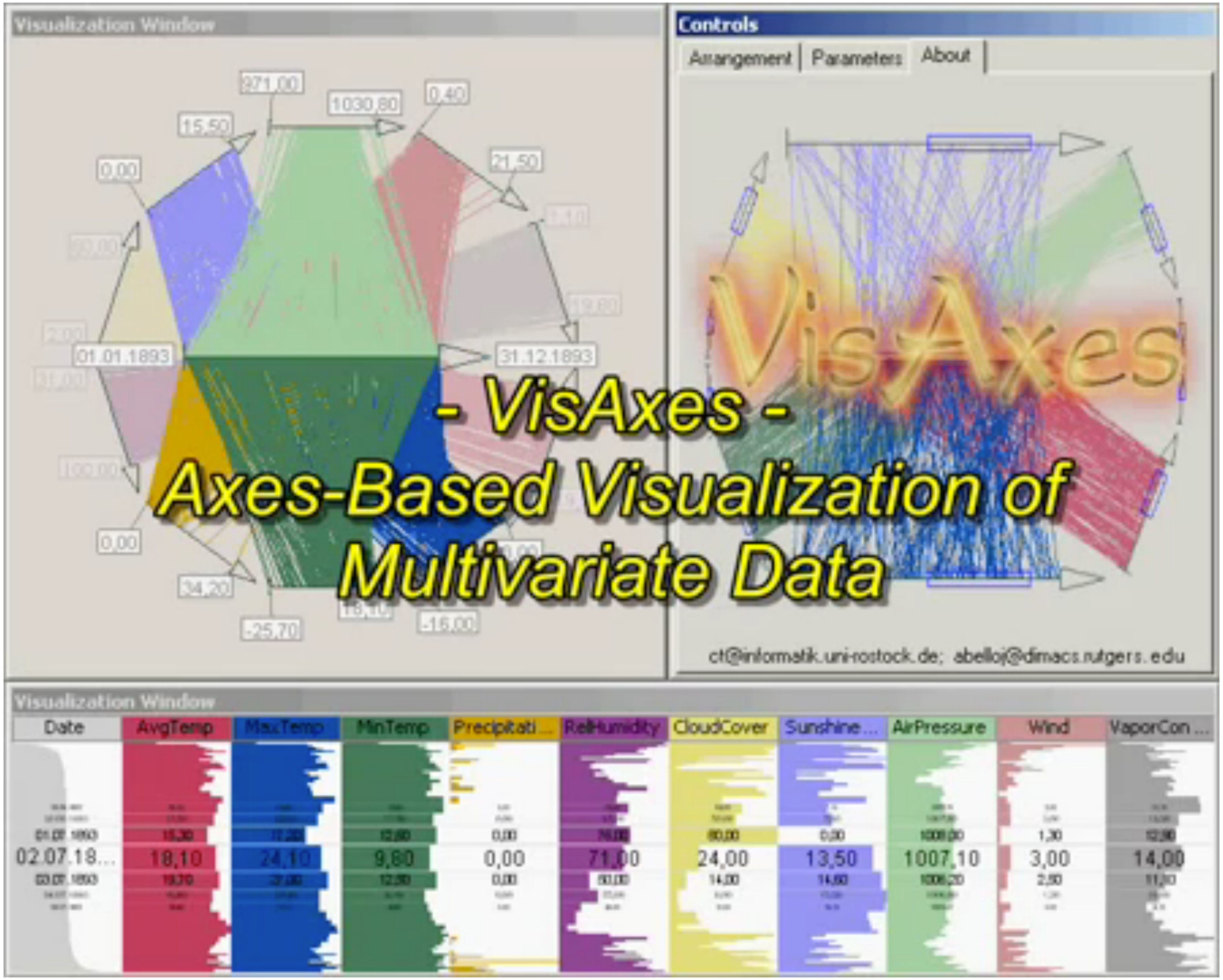


Figure 2. A hierarchical time axis after several steps of interaction. Blue, green, and red frames identify currently visible segments.

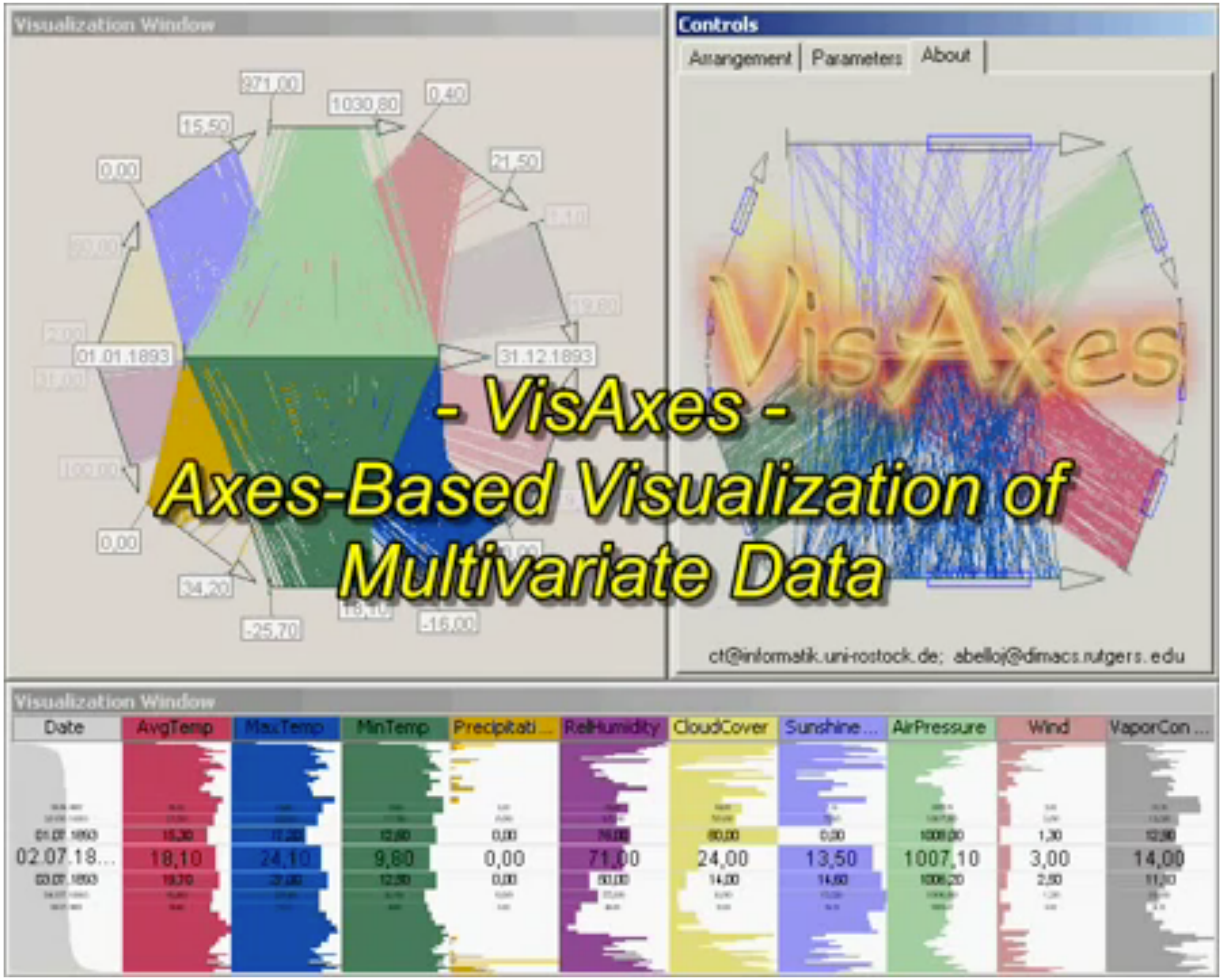
Data: Number of Variables - Multivariate

Figure 5. Screen shot of a TimeWheel. The lengths of the circular axes and the color fading are computed according the angle formed by each axis with the central axis of reference.

Data: Number of Variables - Multivariate



Data: Number of Variables - Multivariate



Data: Number of Variables - Multivariate

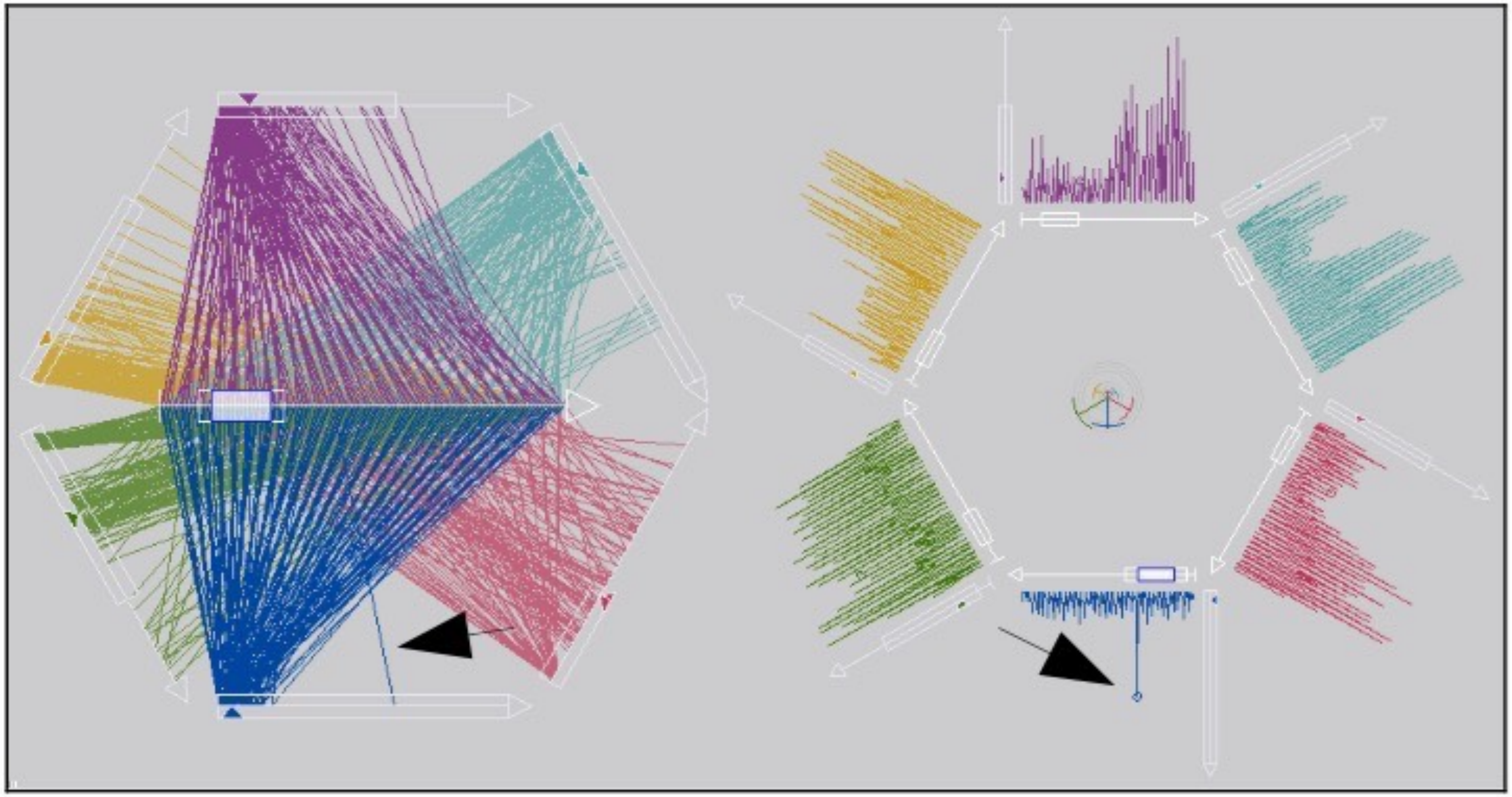


Figure 10. Complementary views of the TimeWheel and the MultiComb. The arrows point to the location of an extremal event in a stream data set containing several diseases statistics.

Time: Arrangement - Linear

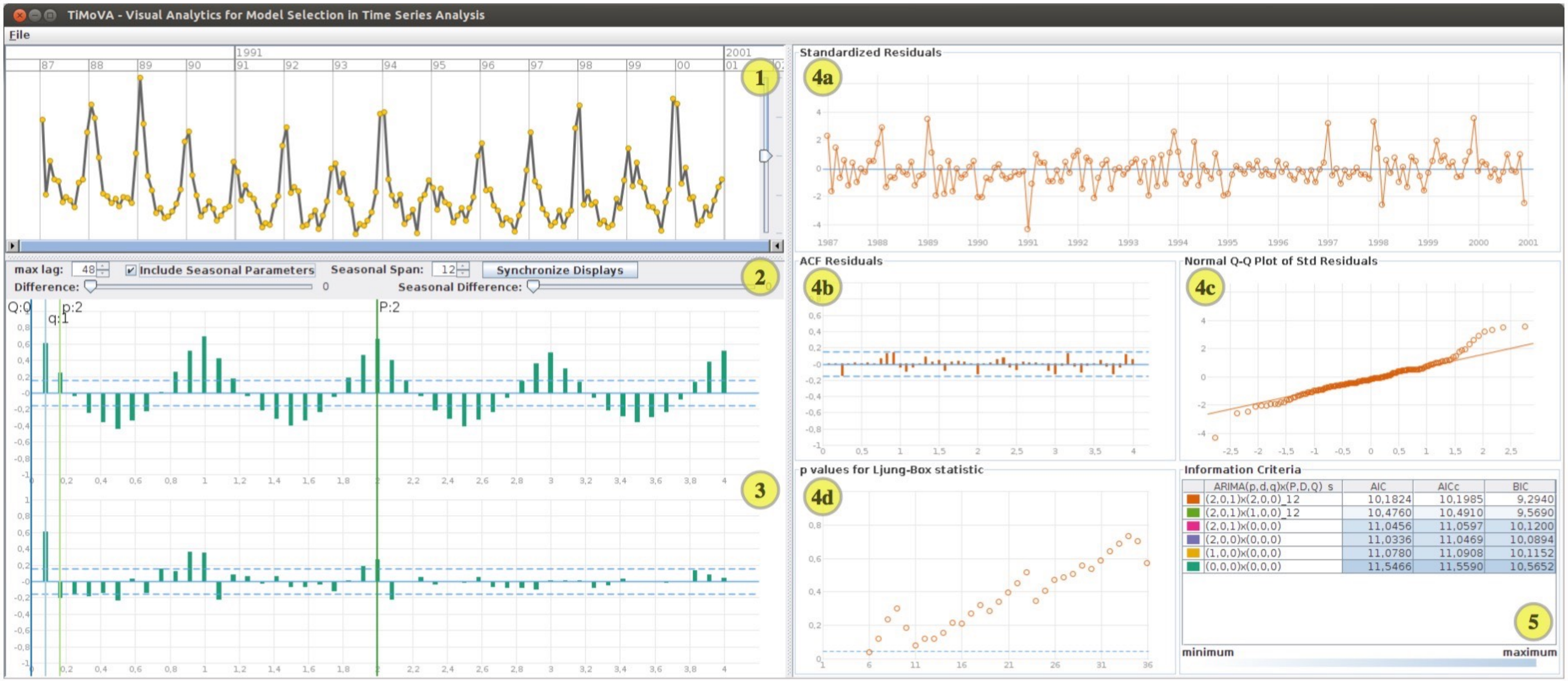


Fig. 5. TiMoVA Overview. The figure is showing the coordinated and multiple views in the user interface, where (1) is the time series plot (input data), (2) the model selection toolbox, (3) the ACF/PACF plot as well as further model selection, (4a-d) the residual analysis plots, and (5) the model history including the information criteria. The plots in the area for the residual analysis are (4a) the standardized residuals over time, (4b) the ACF of the residuals over the lags, (4c) the quantile of the standardized residuals against the quantile of the standard normal distribution, and (4d) the p-values of the Ljung-Box statistics over lags.

Time: Arrangement - Linear

Point Plot

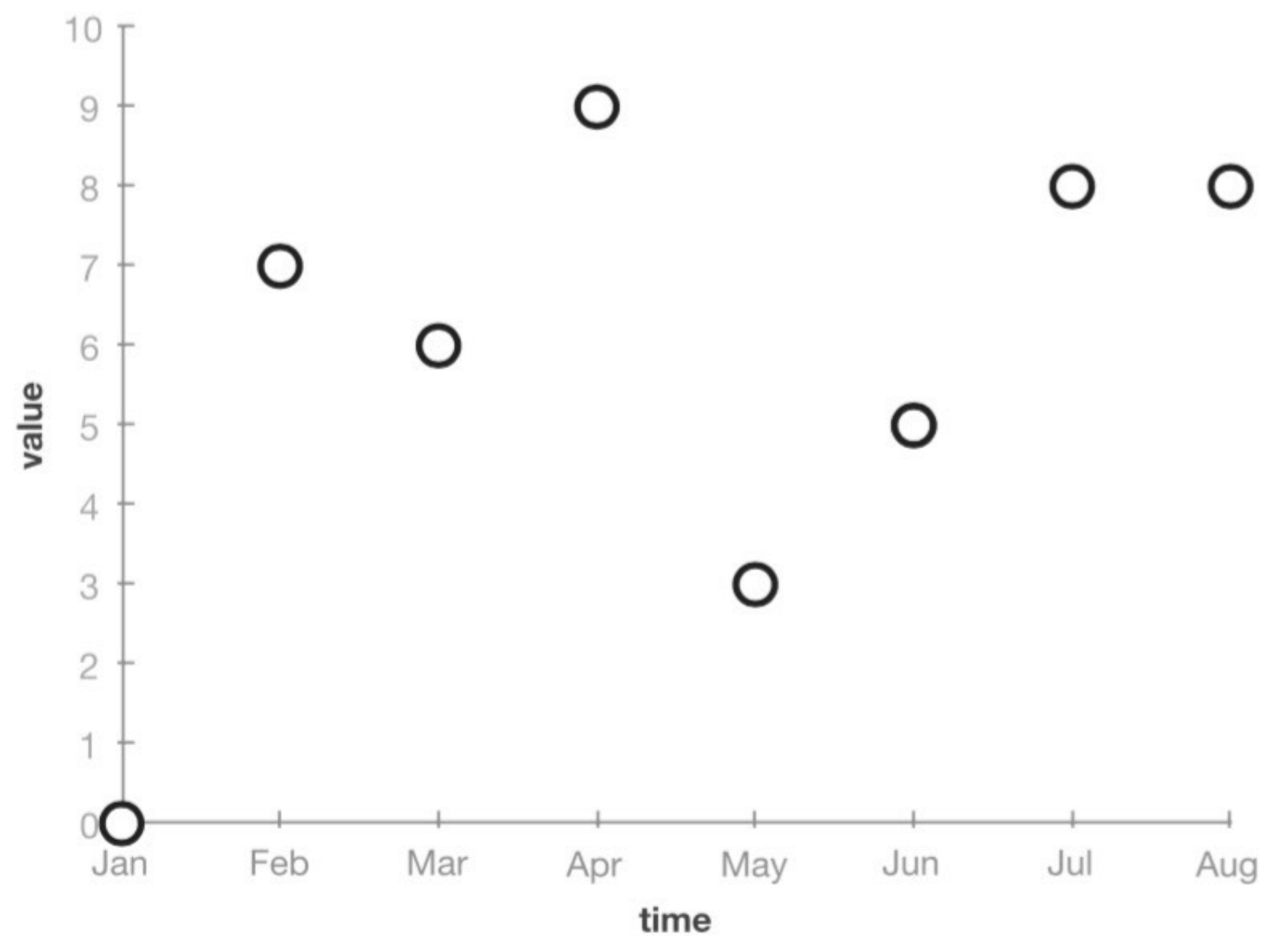


Fig. 7.1: Data are displayed as points in a Cartesian coordinate system where time and data are mapped to the horizontal axis and the vertical axis, respectively.
Source: Authors.

Time: Arrangement - Linear

Line Plot

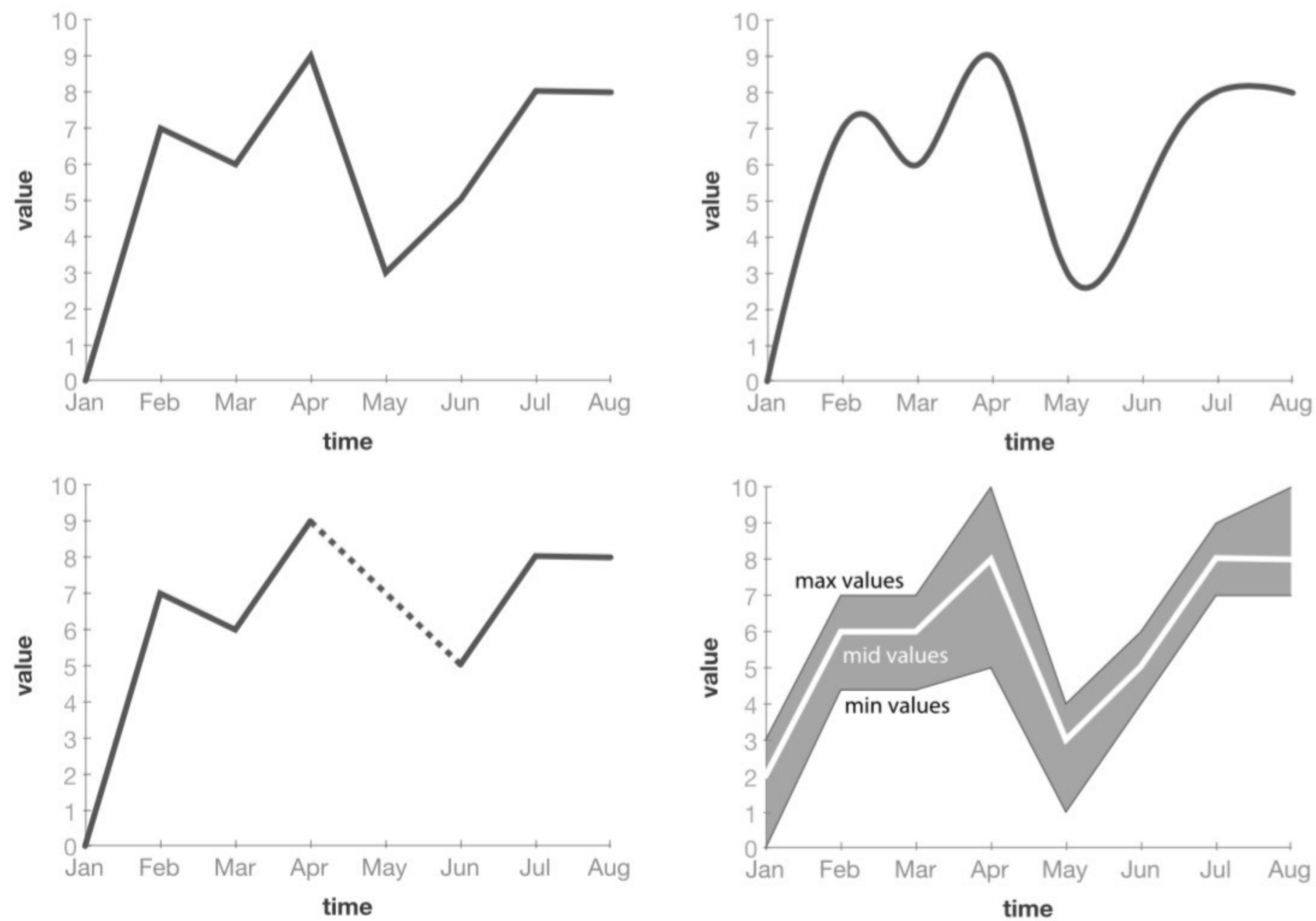


Fig. 7.2: Successive data points are connected with lines to visualize the overall change over time. (top-left: straight lines; top-right: Bézier curves; bottom-left: missing data; bottom-right: band graph).
Source: Authors.

Time: Arrangement - Linear

Bar Graph, Spike Graph

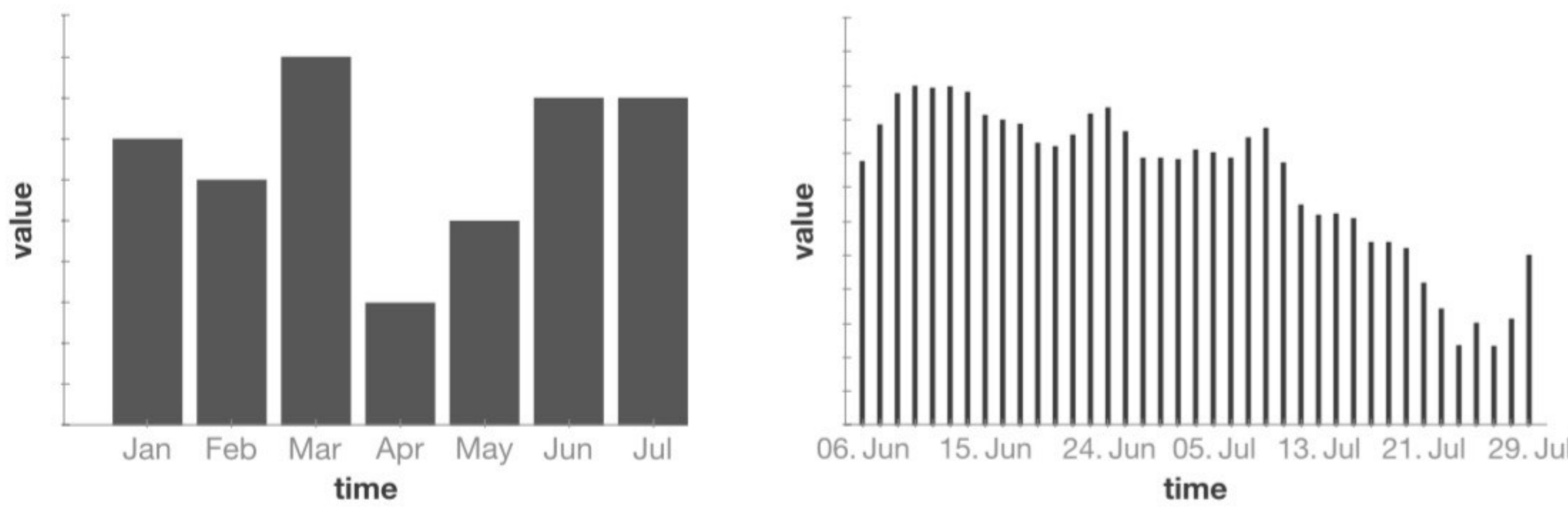


Fig. 7.3: Bar length is used to depict data values. Right: if bars are reduced to spikes the graph is also called a spike graph.
Source: Adapted from Harris (1999).

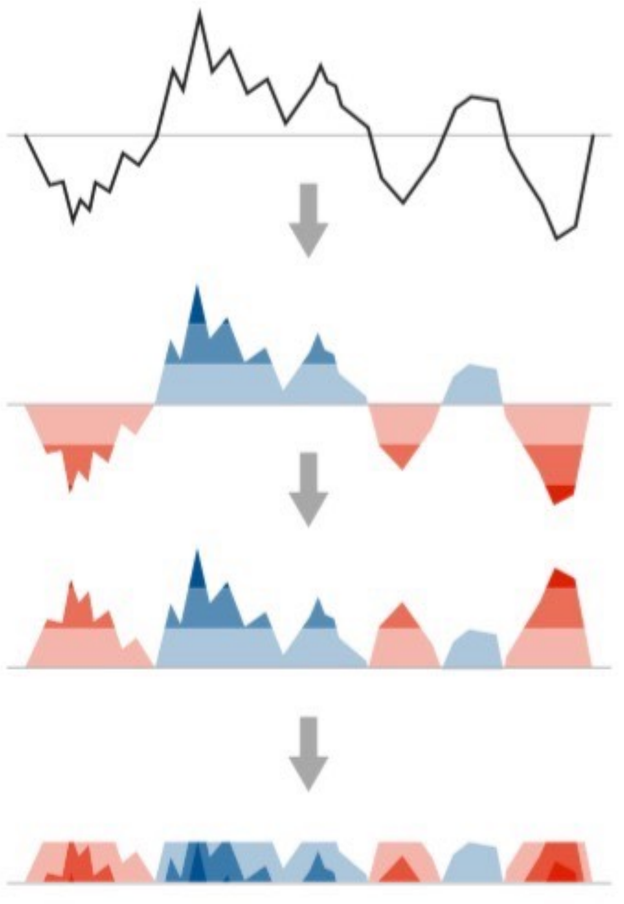
Time: Arrangement - Linear

Sparklines

Fig. 7.4: Simple, word-like graphics intended to be integrated into text visualize stock market data (top). Bottom: Soccer season results using ticks (up=win, down=loss, base=draw).
Source: Generated with the sparklines package for LaTeX.

Time: Arrangement - Linear

Horizon Graph



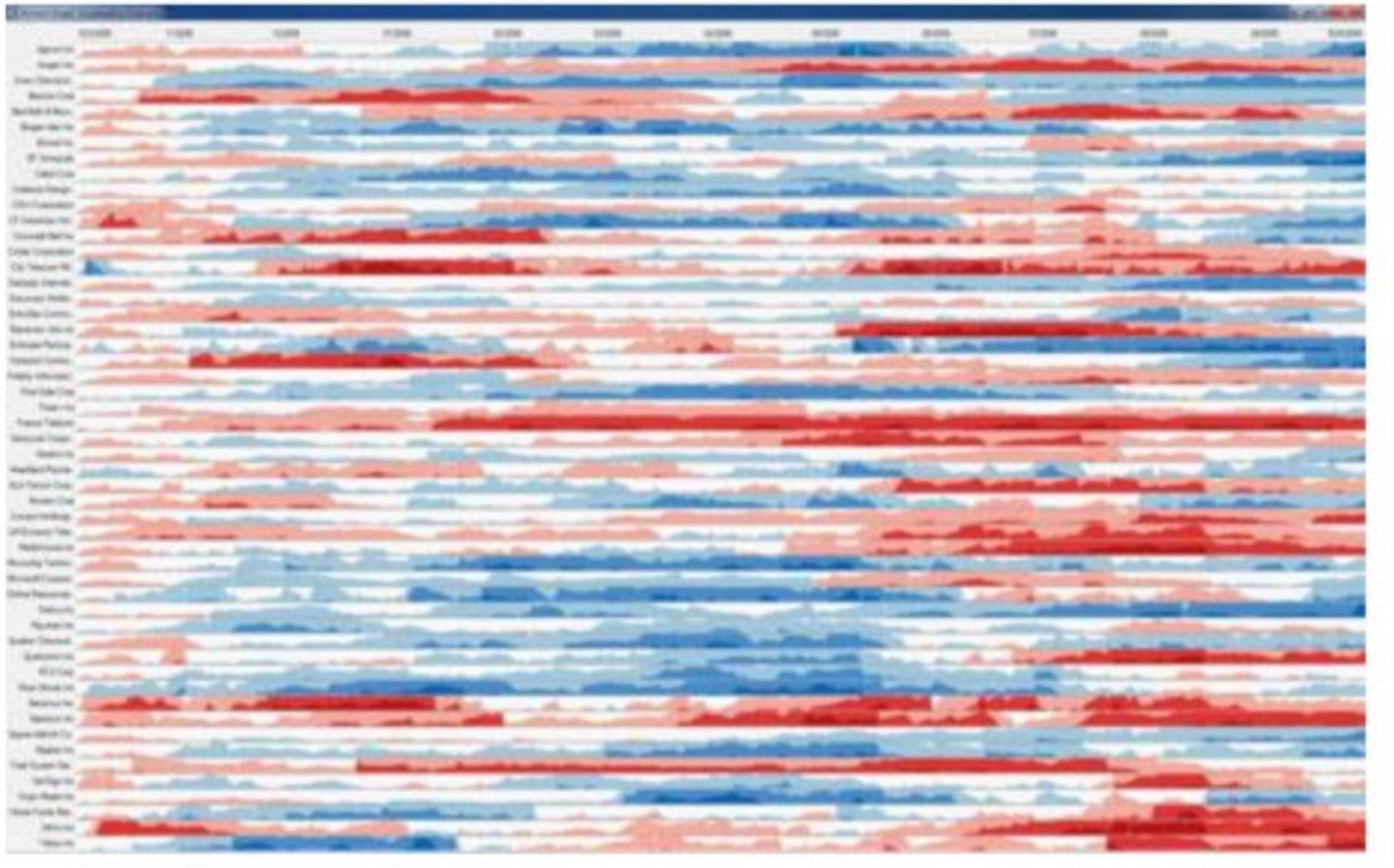
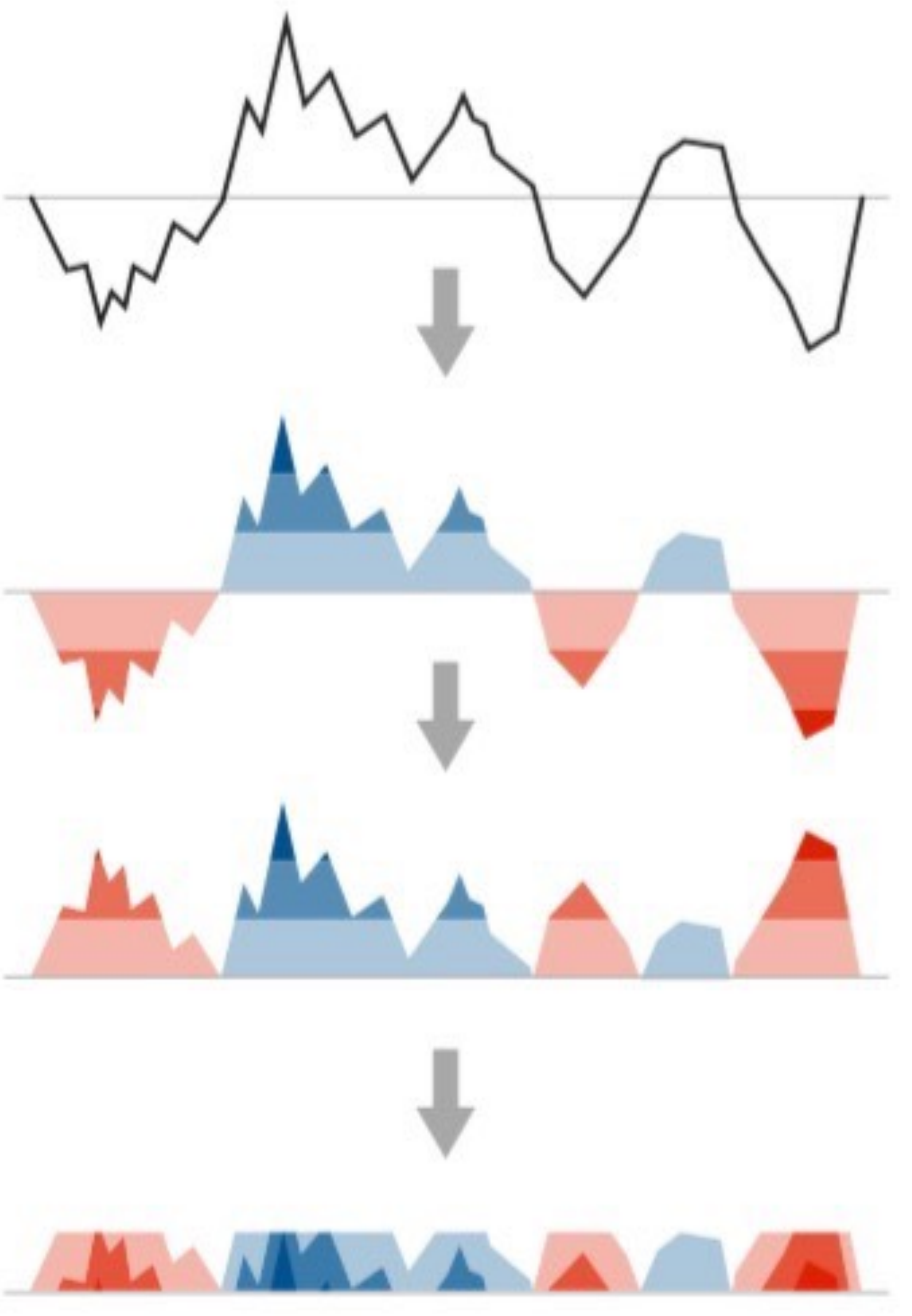
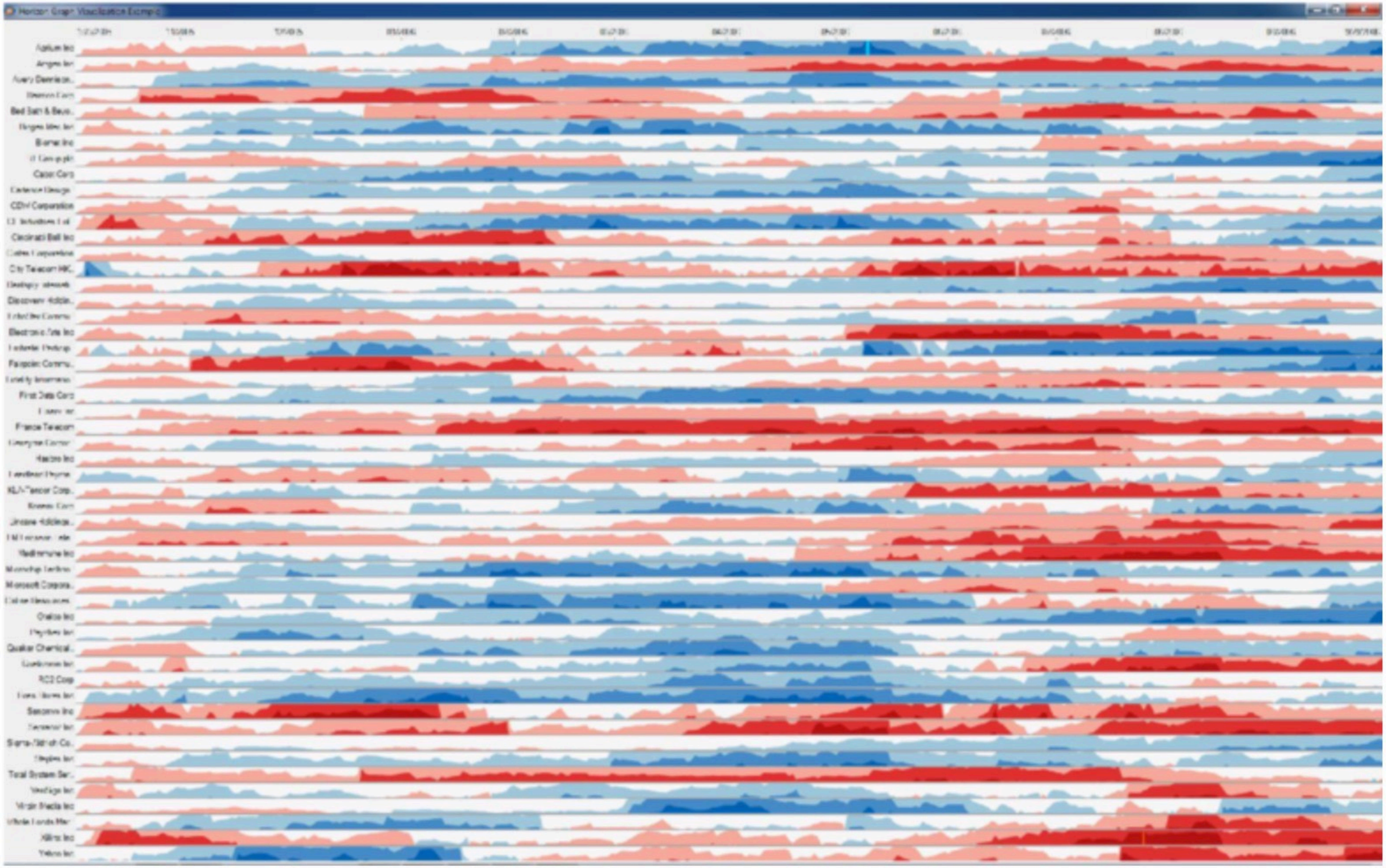


Fig. 7.6: The construction of a horizon graph from a line chart is illustrated on the left. Because horizon graphs require only little screen space they are very useful for comparing multiple time-dependent variables as shown to the right for stock market data.
Source: Left: Adapted from Reijner (2008). Right: Image courtesy of Hannes Reijner.

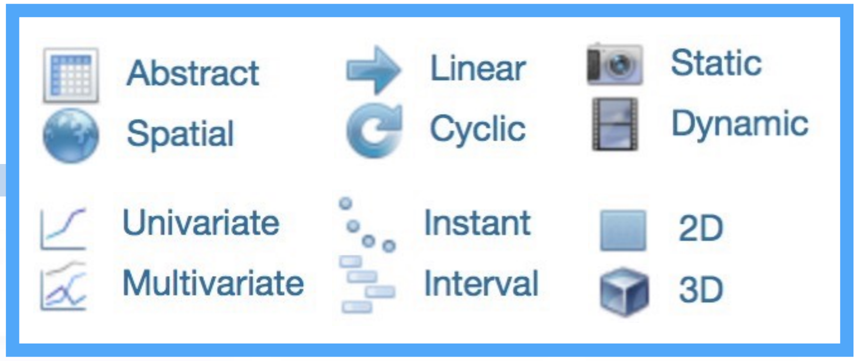
Horizon Graph

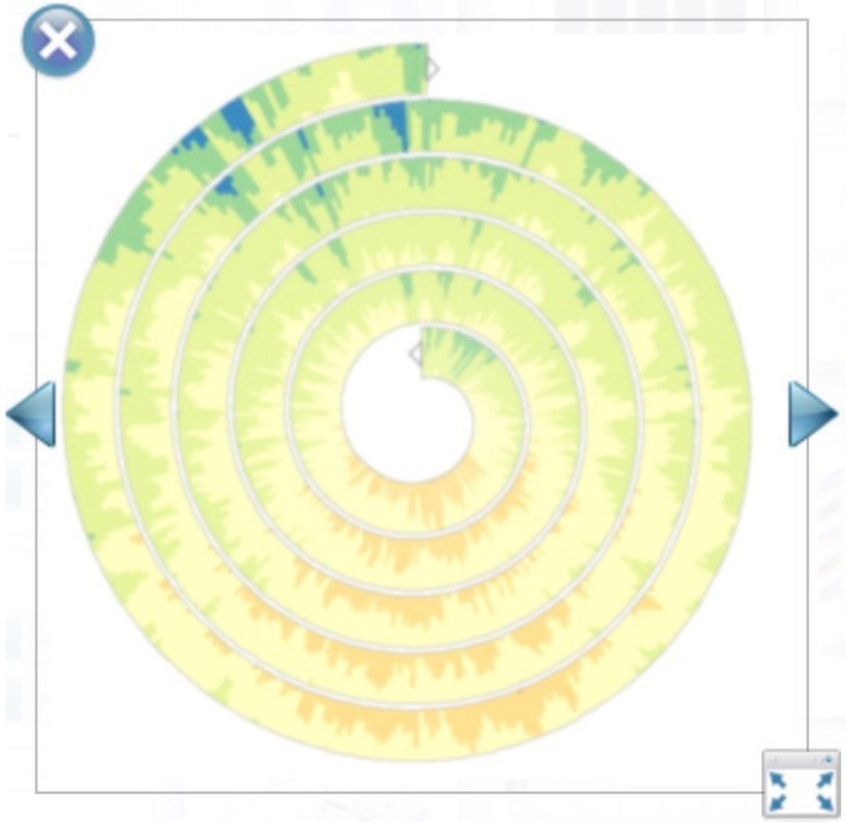


Time: Arrangement - Linear



Time: Arrangement - Cyclic





Enhanced Interactive Spiral

Source: Generated with the enhanced interactive spiral display tool.

Tominski, C. & Schumann, H. (2008) apply the enhanced two-tone color-coding by Saito, T.; Miyamura, H.; Yamamoto, M.; Saito, H.; Hoshiya, Y. & Kaseda, T. (2005) to visualize time-dependent data along a spiral. Each time primitive is mapped to a unique segment of the spiral. Every segment is subdivided into two parts that are colored according to the two-tone coloring method. The advantage of using the two-tone approach is that it realizes the overview+detail concept by design. The two colors used ...
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References

- *Tominski, C. & Schumann, H.: Enhanced Interactive Spiral Display. Proceedings of the Annual SIGRAD Conference, Special Theme: Interactivity, Linköping University Electronic Press, 2008.*
- *Saito, T.; Miyamura, H.; Yamamoto, M.; Saito, H.; Hoshiya, Y. & Kaseda, T.: Two-Tone Pseudo Coloring: Compact Visualization for One-Dimensional Data. Proceedings of the IEEE Symposium on Information Visualization (InfoVis), IEEE Computer Society, 2005.*

Time: Arrangement - Cyclic

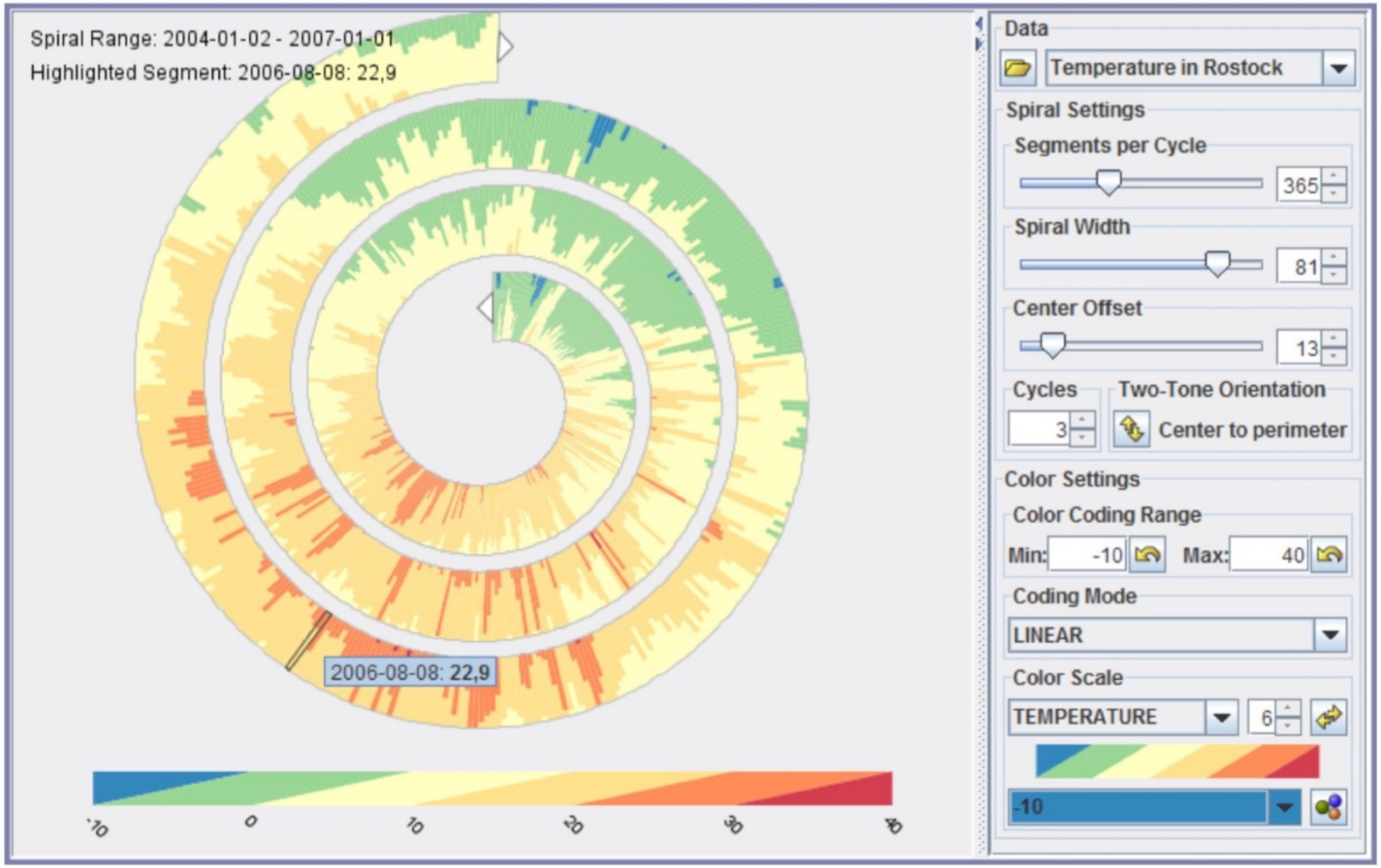


Figure 5: *The user interface – The central view shows the spiral visualization and the color legend. All visualization parameters can be adjusted in the settings panel on the right.*

Time: Arrangement - Cyclic

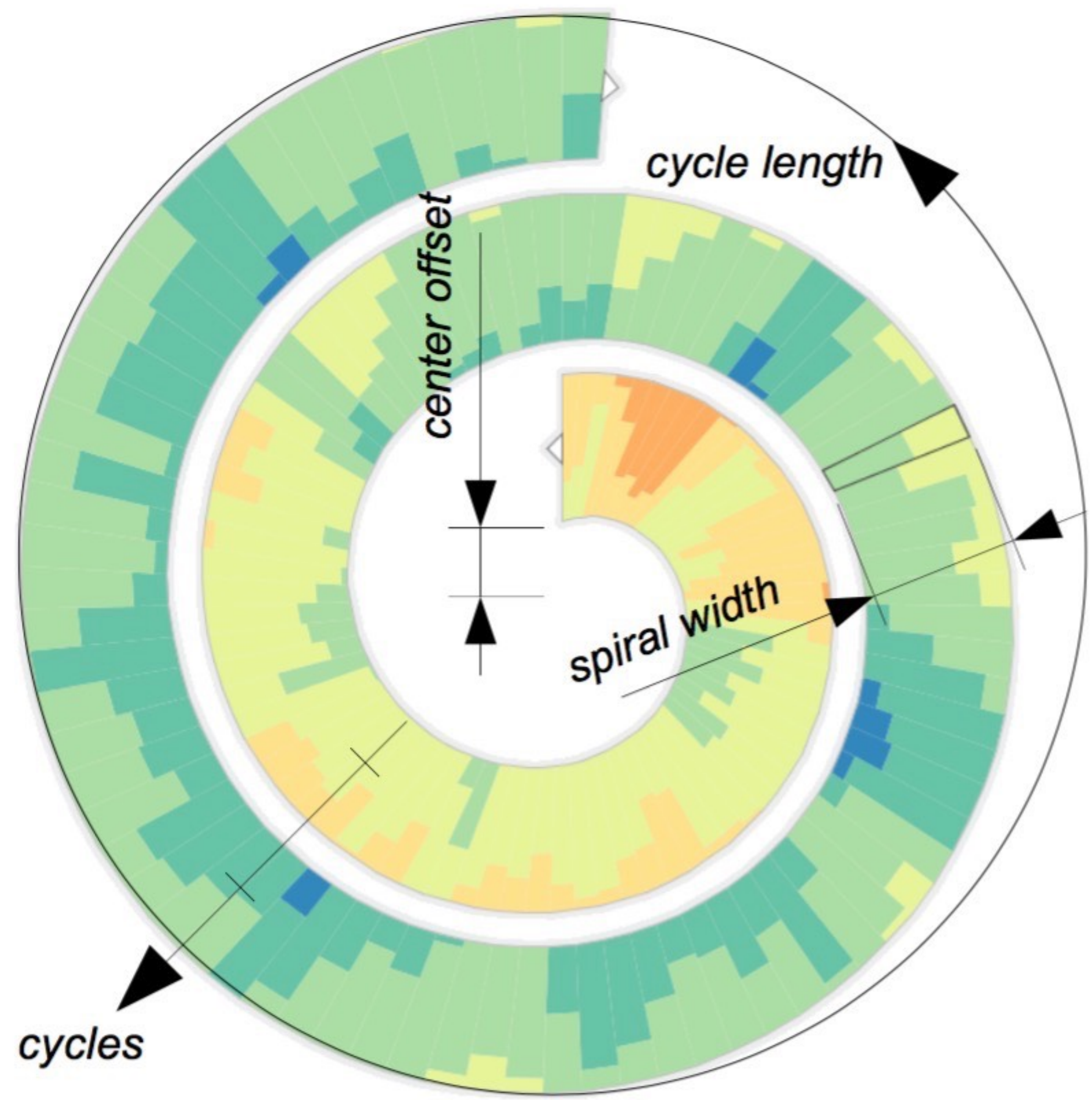


Figure 3: *Parameters of the spiral construction.*

Time: Arrangement - Cyclic

Two-Tone Pseudo Coloring (TTPC) uses a discrete color scale that consists of only a few colors (less than eight).

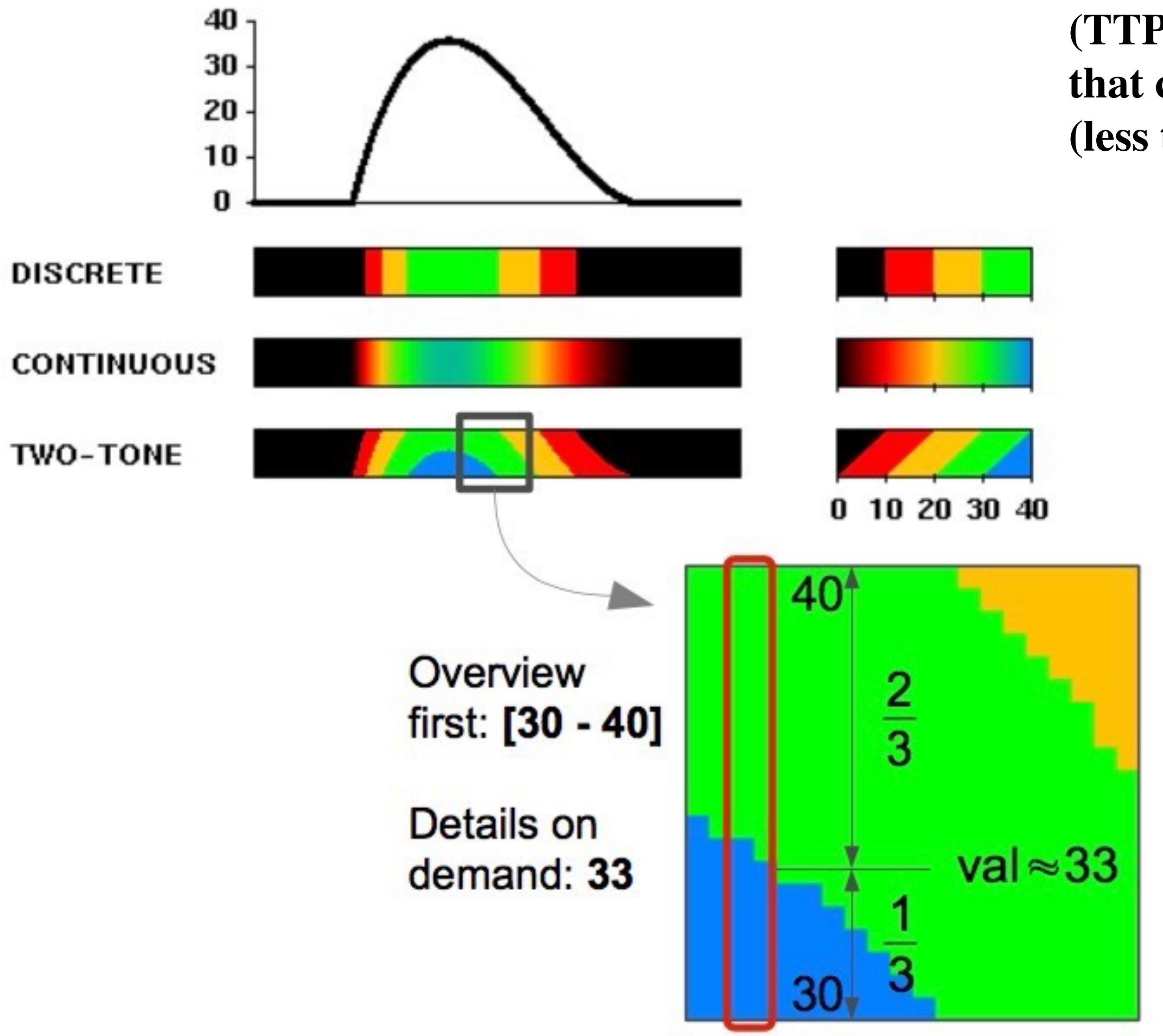


Figure 2: *Two-Tone Pseudo Coloring explained.*

Time: Arrangement - Cyclic

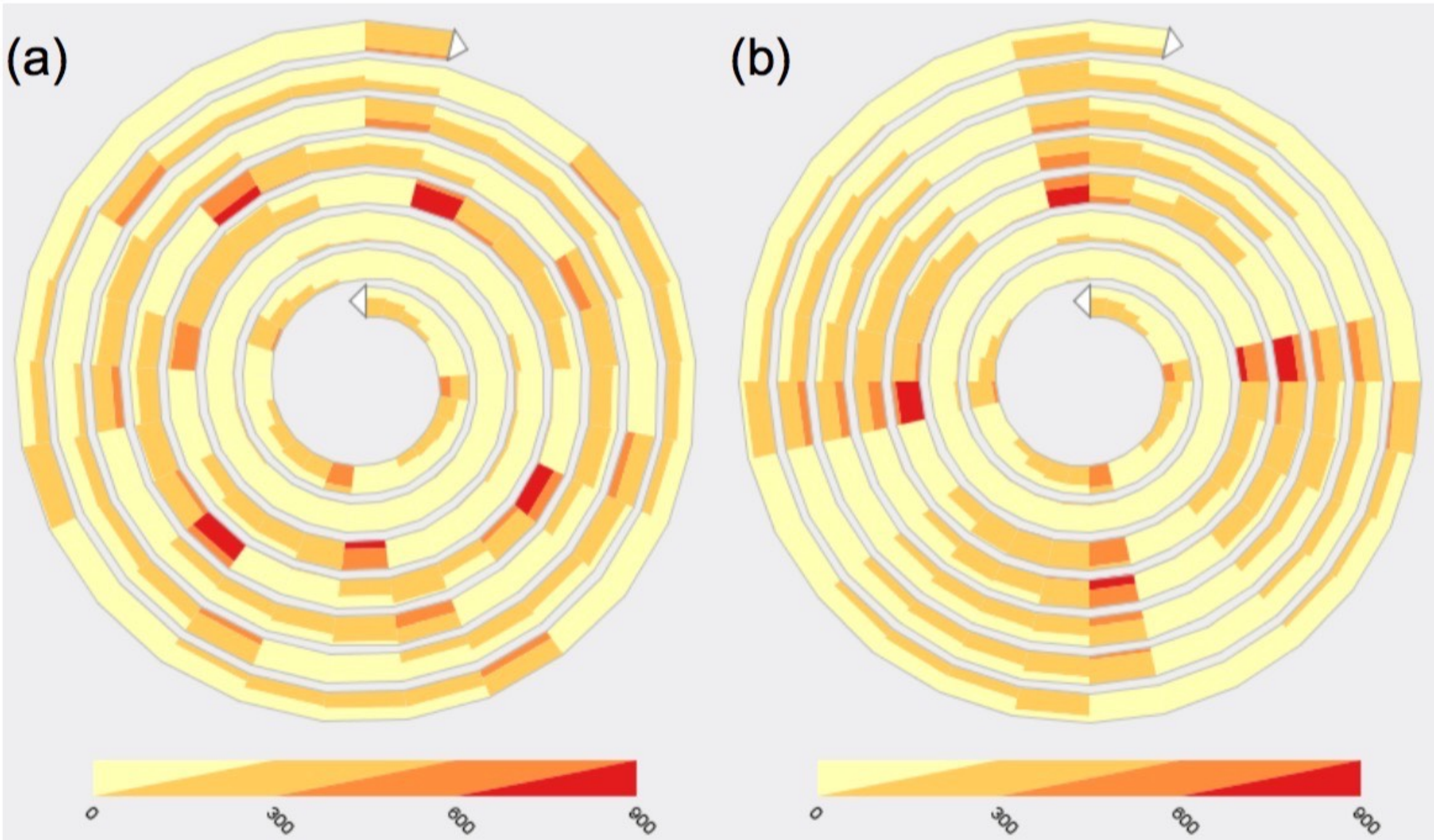
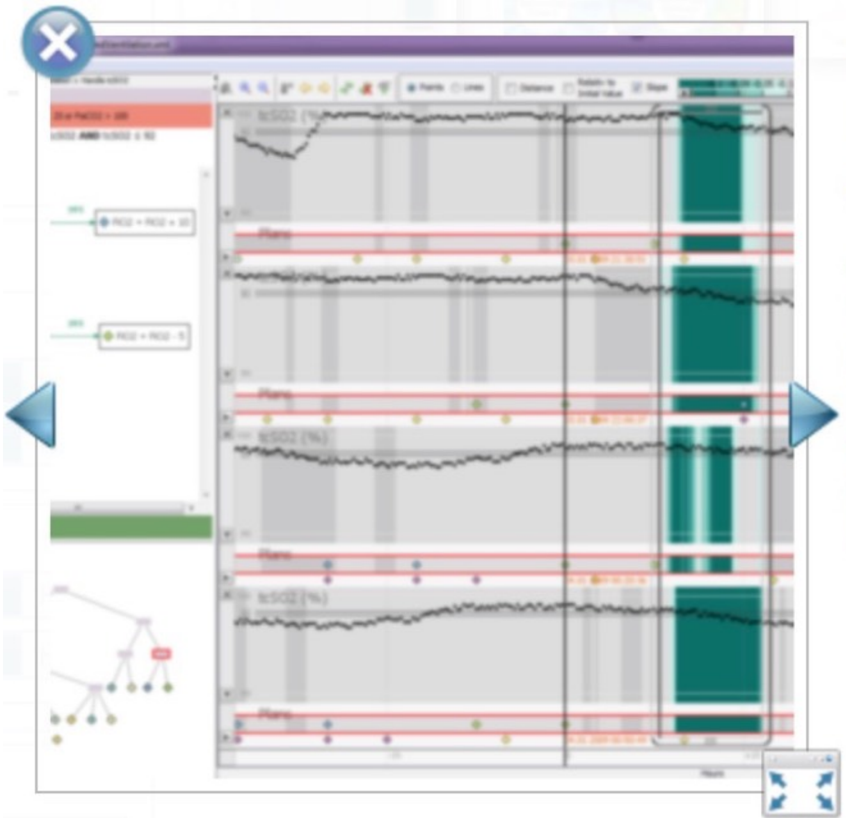


Figure 6: *Finding a pattern – (a) Cycle length = 25; (b) Cycle length = 28*

Time: Time Primitives - Instant

Abstract | Linear | Static
Spatial | Cyclic | Dynamic
Univariate | Instant | 2D
Multivariate | Interval | 3D



CareCruiser

Source: Generated with the CareCruiser software.

CareCruiser by Gschwandtner, T.; Aigner, W.; Kaiser, K.; Miksch, S. & Seyfang, A. (2011) is a visualization system for exploring the effects of clinical actions on a patient's condition.It supports exploration via aligning, color-highlighting, filtering, and providing focus and context information.Aligning clinical treatment plans vertically supports the comparison of the effects of different treatments or the comparison of different effects of one treatment plan applied on different patients.Three ...

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References

- *Gschwandtner, T.; Aigner, W.; Kaiser, K.; Miksch, S. & Seyfang, A.: CareCruiser: Exploring and Visualizing Plans, Events, and Effects Interactively. Proceedings of the IEEE Pacific Visualization Symposium (PacificVis), IEEE Computer Society, 2011.*

Time: Time Primitives - Instant

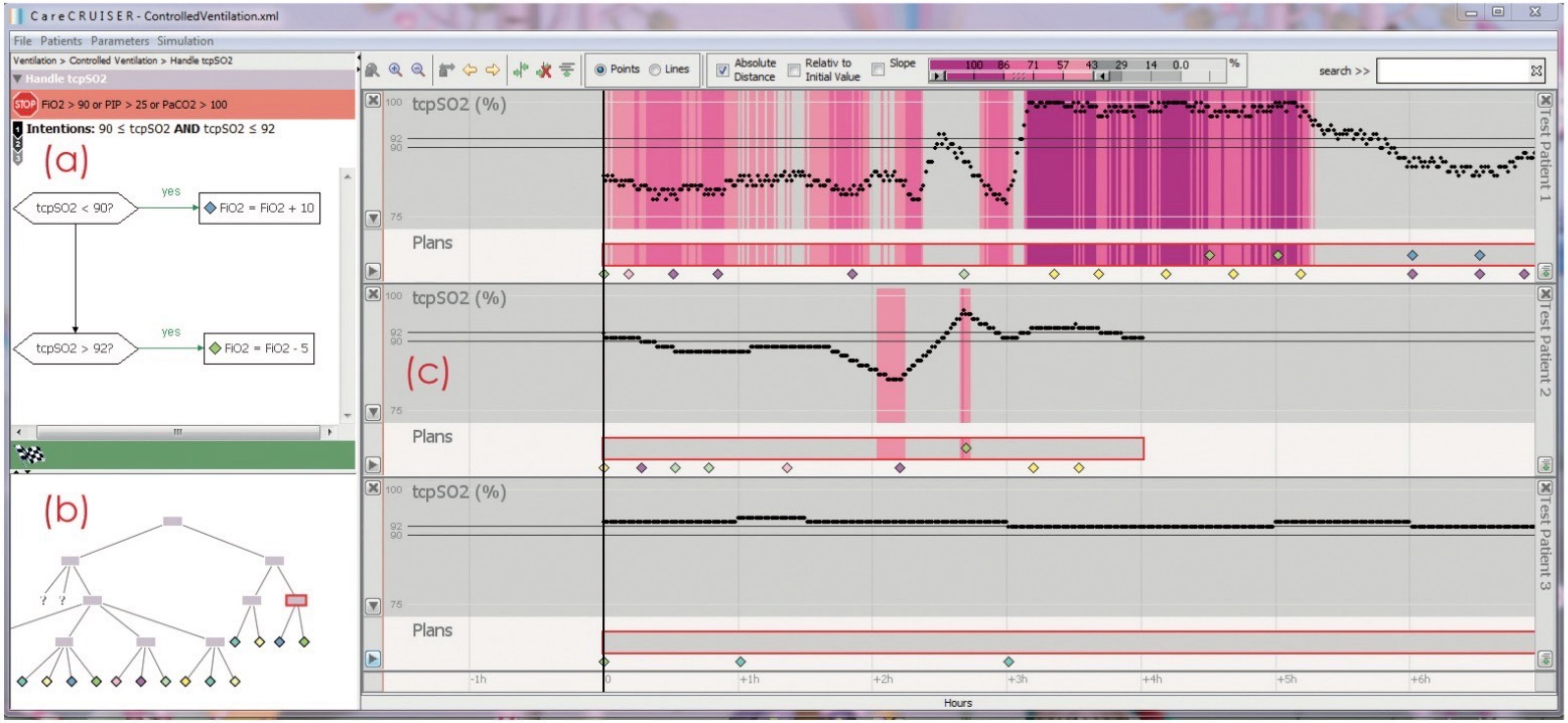

Figure 1: UI of the CareCruiser prototype. The logical view (a) communicates the logical structure of treatment plan execution by means of a flowchart-like representation [3]. The lower left part (b) displays a tree graph to visualize the hierarchical structure of treatment plans and sub-plans; the time-oriented view (c) focuses on the temporal-qualities of applied treatment plans, clinical actions, and patient parameters. We extended the time-oriented view with step-wise interactive means to explore the effects of applied treatment plans on the patient's condition. This screenshot shows one treatment plan that has been applied on three different patients (aligned vertically for comparison). The charts and treatment plans are colored according to the color scheme of the parameter values' distance to the intended value. Selecting ranges with big distance to the intended value with the range slider draws attention to critical cases and brings out the differences between the conditions of the three patients.

Time: Time Primitives - Instant

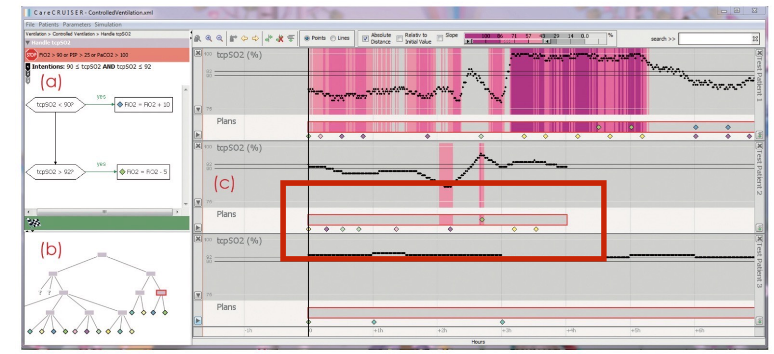

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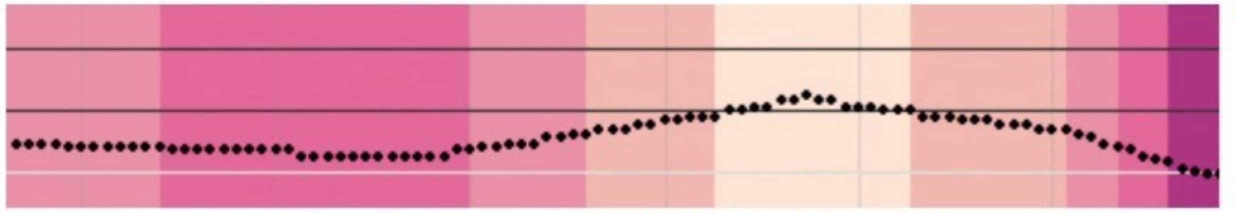
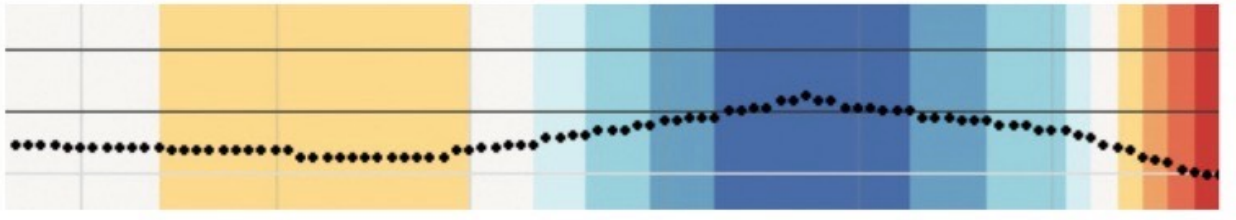
Figure 2: The gray rectangle represents a treatment plan along a time-axis containing diverse clinical actions. These clinical actions are represented by diamonds. The peak of the diamond indicates the exact point in time when the actions was applied while the body of the diamond ensures the visibility of the action. In case an action is carried out over a time span, the temporal bounds are indicated by whiskers. Clinical actions that were applied to the patient but are not part of the treatment plan are laid out below the plan body.

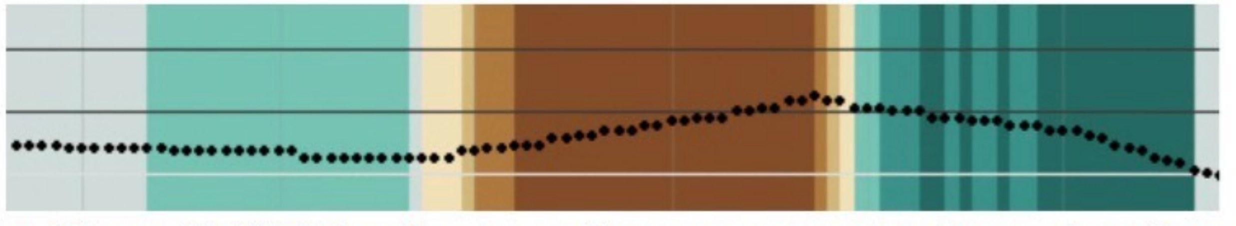
Time: Time Primitives - Instant



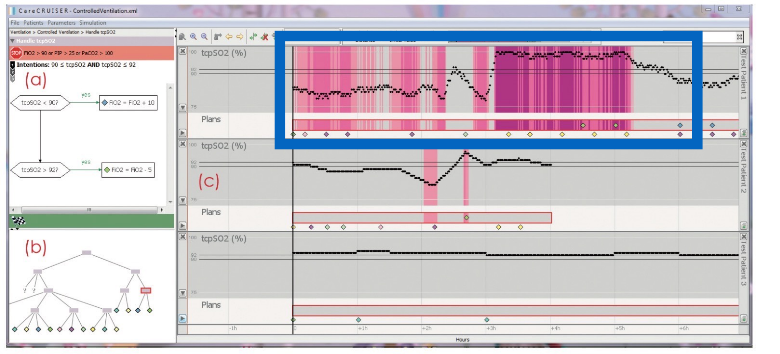
(a) Distance to intended value: Highlighting the distance of the patient's parameter values to the intended value (dark magenta: extreme values, light magenta: inside the intended value range). The range of intended values is indicated by the two dark horizontal lines. This mode helps physicians to identify critical values at the first sight.



(b) Progress from initial value: Highlighting the progress of the parameter values relative to the initial value when the treatment plan was started (white: start value, dark blue: intended value, dark red: departure from the intended value). This mode shows to what extent the applied treatment plan has the intended effect on the patient's condition.



(c) Slope: Highlighting the slope of a parameter value (turquoise: drop, brown: rise). This mode helps to identify the immediate effects of applied clinical actions. For a more robust coloring we take the mean value of seven data points to compute the slope.



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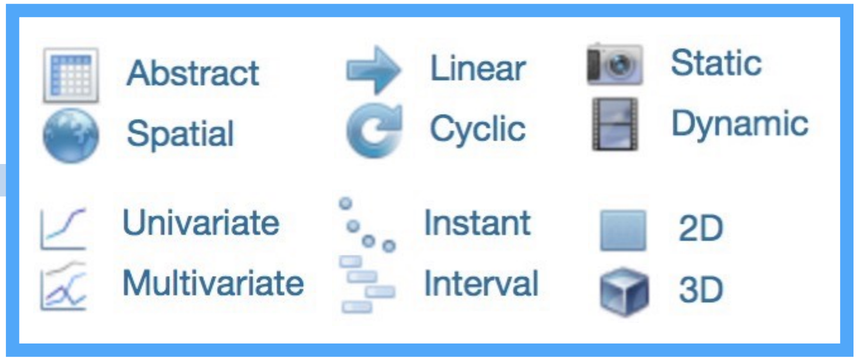
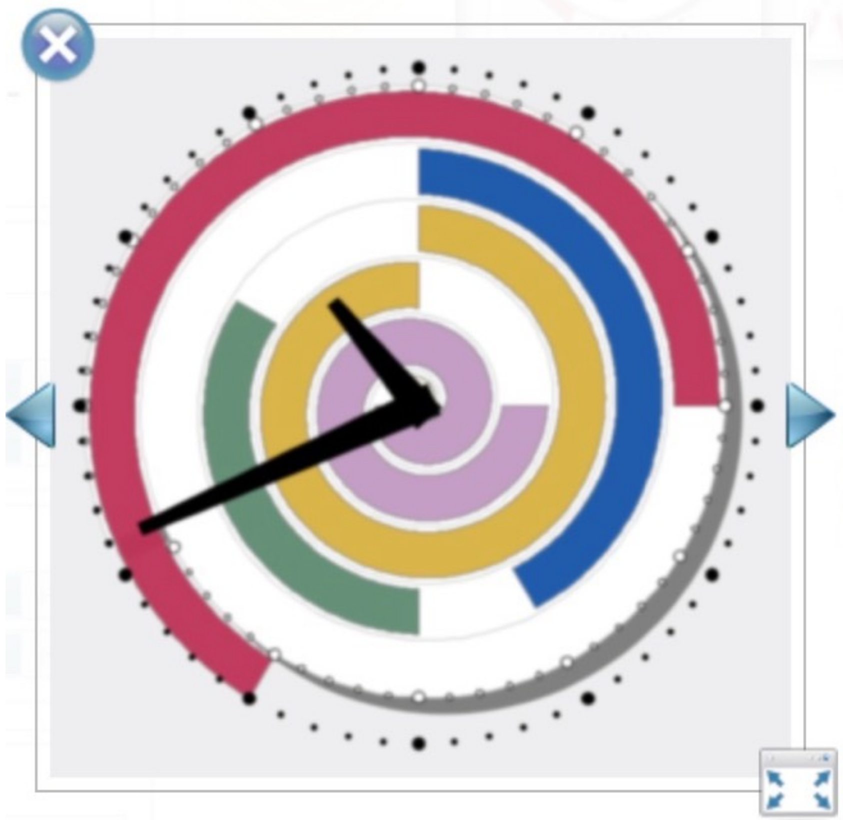
Time: Time Primitives - Interval





SpiraClock

Source: Adapted from Dragicevic, P. & Huot, S. (2002) with permission of Pierre Dragicevic.

The SpiraClock invented by Dragicevic, P. & Huot, S. (2002) visualizes time by using the clock metaphor. The visual representation consists of a clock face and two hands indicating hour and minute. The interior of the clock shows a spiral that extends from the clock's circumference toward its center. Each cycle of the spiral represents 12 hours, with the current hour shown at the outermost cycle and future hours displayed in the center (about nine future hours in Figure). Time intervals (e.g., ...
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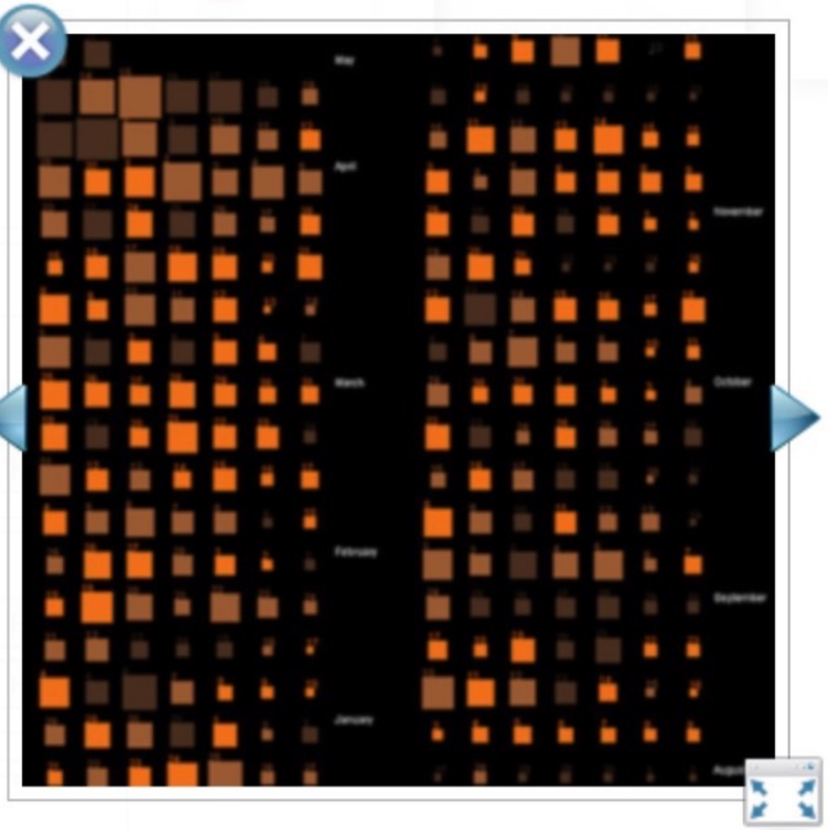
These segments show when intervals start and end.

References

- *Dragicevic, P. & Huot, S.: SpiraClock: A Continuous and Non-Intrusive Display for Upcoming Events. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI), ACM, 2002.*

Visualization: Mapping - Static

Abstract	Linear	Static
Spatial	Cyclic	Dynamic
Univariate	Instant	2D
Multivariate	Interval	3D



PostHistory

Source: Image courtesy of Fernanda B. Viégas.

Viégas, F.; Boyd, D.; Nguyen, D.; Potter, J. & Donath, J. (2004) developed PostHistory with the goal of visually uncovering different patterns of e-mail activity (e.g., social networks, e-mail exchange rhythms) and the role of time in these patterns. PostHistory is user-centric and focuses on a single user's direct interactions with other people through e-mail. The social patterns are derived from analyzing e-mail header information. So, not the content of messages, but the tracked traffic is ...

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References

- *Viégas, F.; Boyd, D.; Nguyen, D.; Potter, J. & Donath, J.: Digital Artifacts for Remembering and Storytelling: PostHistory and Social Network Fragments. Proceedings of the Annual Hawaii International Conference on System Sciences (HICSS), IEEE Computer Society, 2004.*

Visualization: Mapping - Static

PostHistory [438]. The calendar panel on the left shows e-mail activity on a daily basis, where the number of e-mails and their average directedness are mapped to box size and color, respectively. The contacts panel on the right displays the names of people who sent messages to the user. (©2004 IEEE.)

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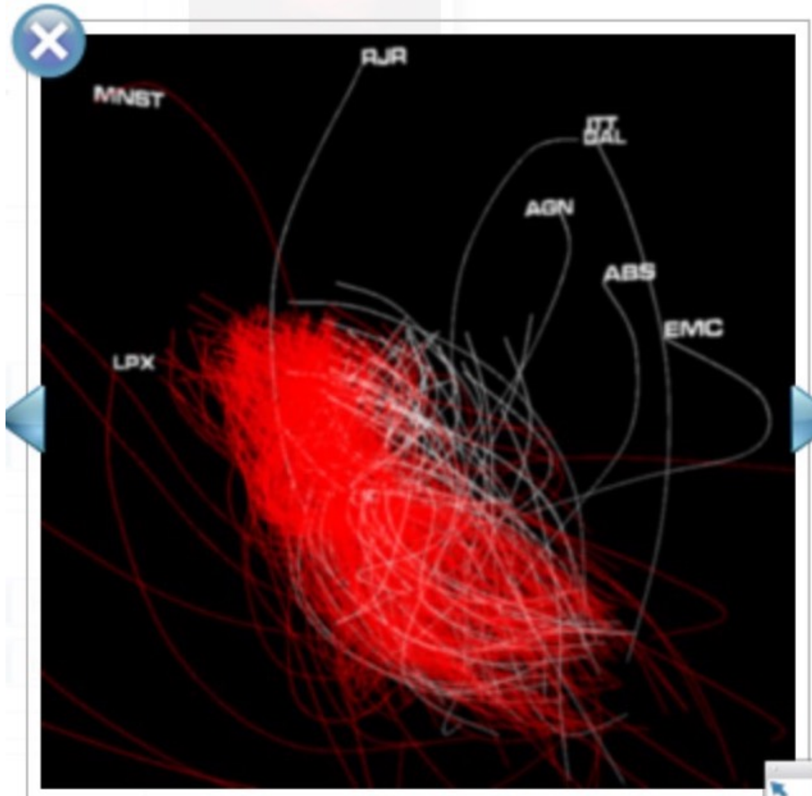
Visualization: Mapping - Dynamic

Abstract	Linear	Static
Spatial	Cyclic	Dynamic
Univariate	Instant	2D
Multivariate	Interval	3D



Flocking Boids

Source: Vande Moere, A. (2004), © 2004 IEEE. Used with permission.

Stock market data change dynamically during the day as prices are constantly updated. Vande Moere, A. (2004) proposes to visualize such data by means of information flocking boids. The term boids borrows from the simulation of birds (bird objects = boids) in flocks. In order to visualize stock market prices, each stock is considered to be a boid with an initially random position in a 3D presentation space. Upon arrival of new data, boid positions are updated dynamically according to several rules. ...

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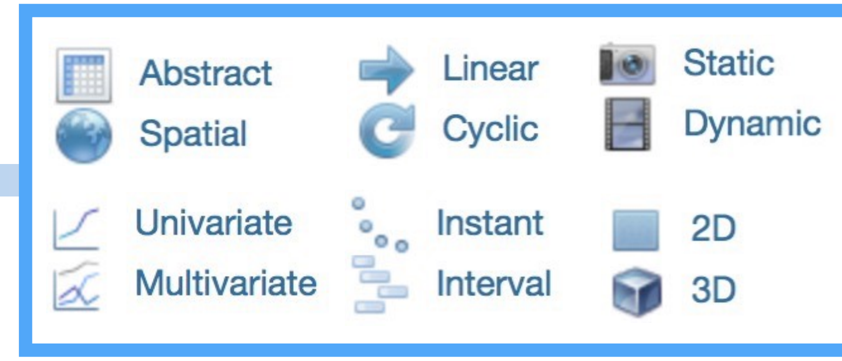
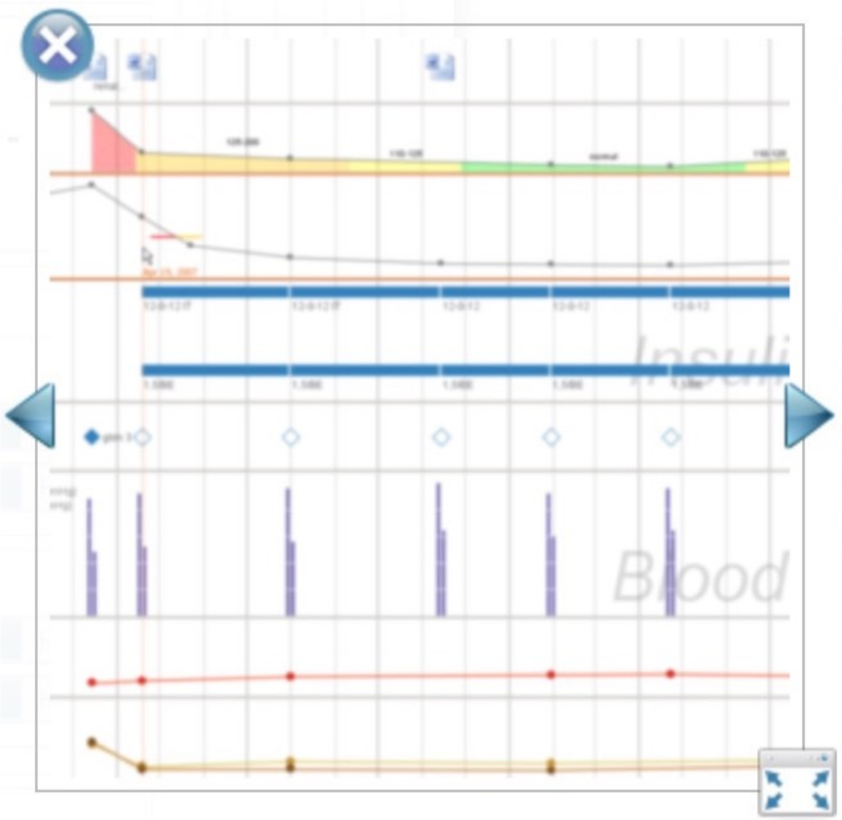
References

- *Vande Moere, A.: Time-Varying Data Visualization Using Information Flocking Boids. Proceedings of the IEEE Symposium on Information Visualization (InfoVis), IEEE Computer Society, 2004.*

Visualization: Dimensionality - 2D





VisuExplore

Source: Generated with the VisuExplore software.

VisuExplore by Rind, A.; Miksch, S.; Aigner, W.; Turic, T. & Pohl, M. (2010) is an interactive visualization system for exploring a heterogeneous set of medical parameters over time.It uses multiple views along a common horizontal time axis to convey the different medical parameters involved.VisuExplore provides an extensible environment of pluggable visualization techniques and its primary visualization techniques are deliberately kept simple to make them easily usable in medical practice: line ...

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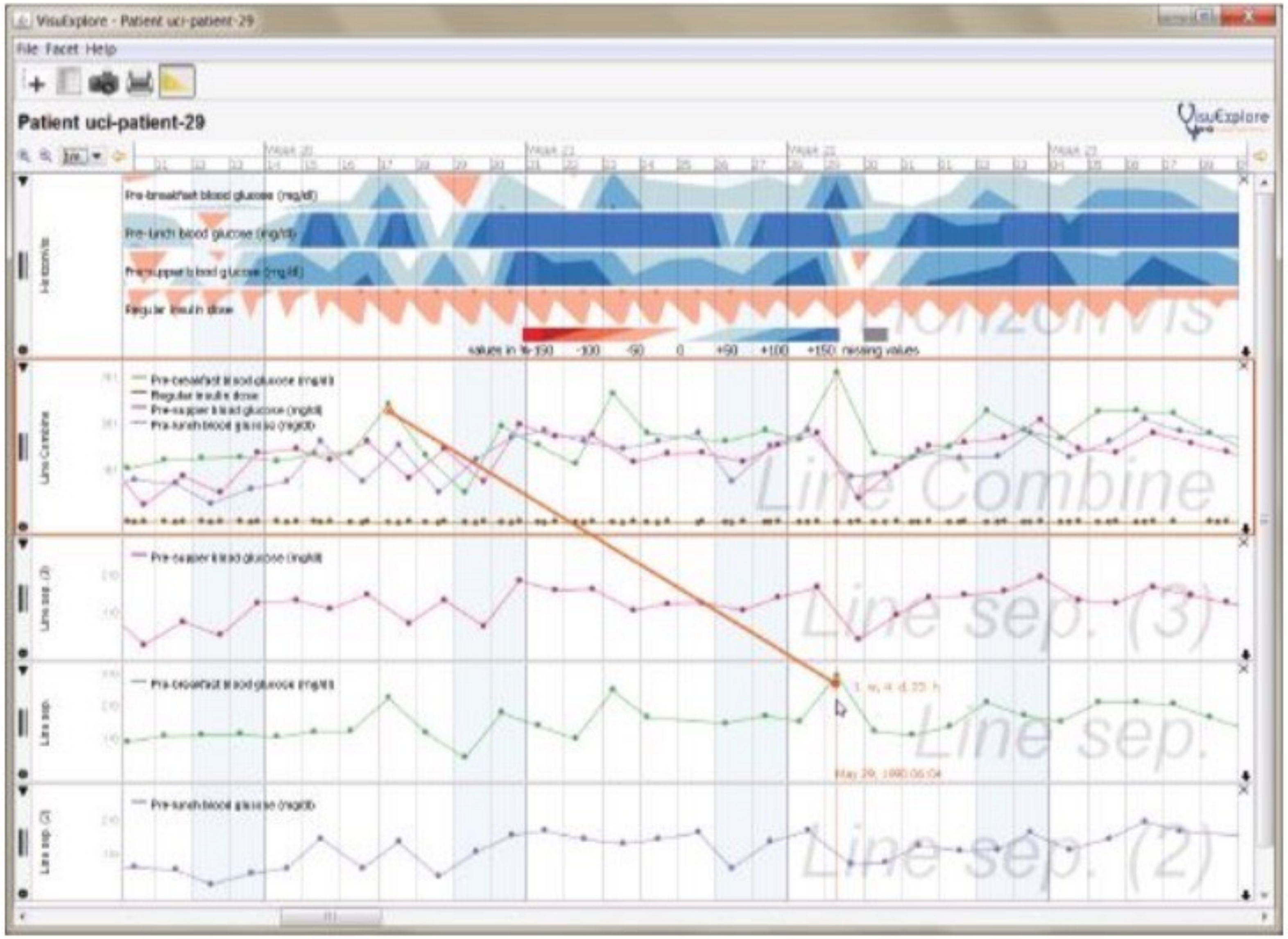
References

- *Rind, A.; Aigner, W.; Miksch, S.; Wiltner, S.; Pohl, M.; Turic, T. & Drexler, F.: Visual Exploration of Time-Oriented Patient Data for Chronic Diseases: Design Study and Evaluation. Information Quality in e-Health, Springer, 2011.*
- *Rind, A.; Miksch, S.; Aigner, W.; Turic, T. & Pohl, M.: VisuExplore: Gaining New Medical Insights from Visual Exploration. Proceedings of the 1st International Workshop on Interactive Systems in Healthcare (WISH@CHI2010), Dealer Analysis Group, 2010.*

Visualization: Dimensionality - 2D

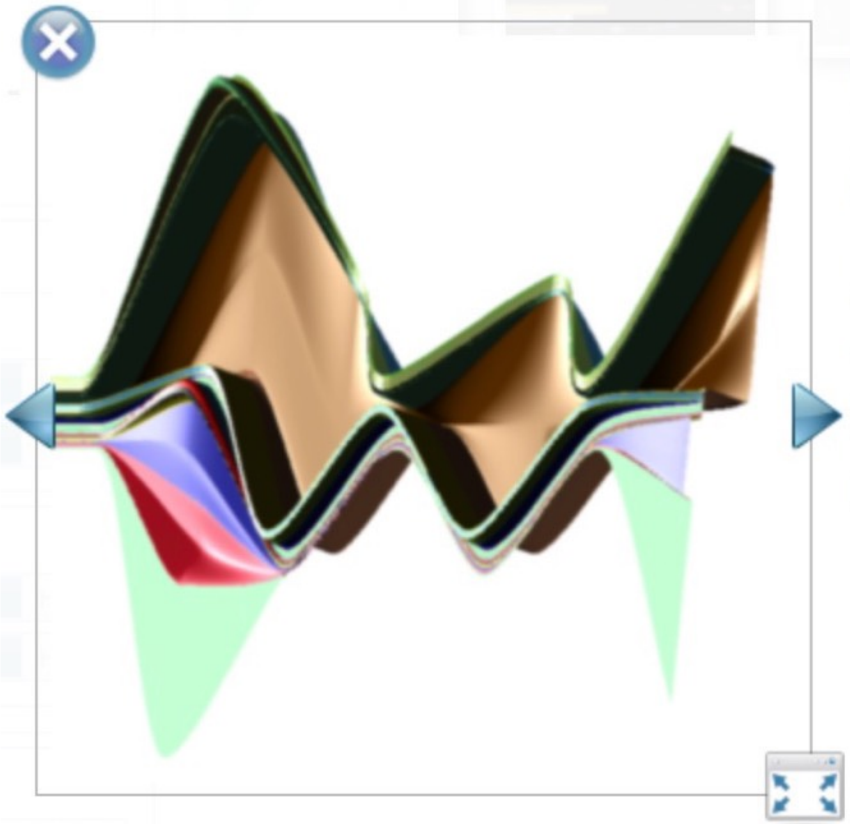


VisuExplore [338]. Simple and easy-to-understand visual representation methods using line plot, bar chart, event chart, timeline chart, horizon graphs, and line plots with semantic zoom. Here, the measure tool is illustrated: A metaphorical tape measure for the time interval between two items (also across multiple diagrams).

Visualization: Dimensionality - 3D

Abstract | Linear | Static
Spatial | Cyclic | Dynamic

Univariate | Instant | 2D
Multivariate | Interval | 3D



3D ThemeRiver

Source: Imrich, P.; Mueller, K.; Imre, D.; Zelenyuk, D. & Zhu, W. (2003), © 2003 IEEE. Used with permission.

Imrich, P.; Mueller, K.; Imre, D.; Zelenyuk, D. & Zhu, W. (2003) propose a 3D variant of the ThemeRiver technique (see ThemeRiver). The 3D approach inherits the basic visual design from its 2D counterpart: multiple time-oriented variables are encoded to the widths of individually colored currents that form a river flowing through time along a horizontal time-axis. In the 2D variant, only one data variable can be visualized per current, namely by varying ...
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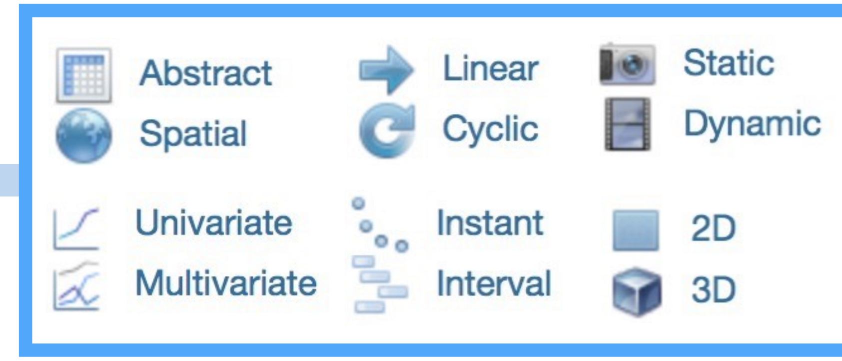
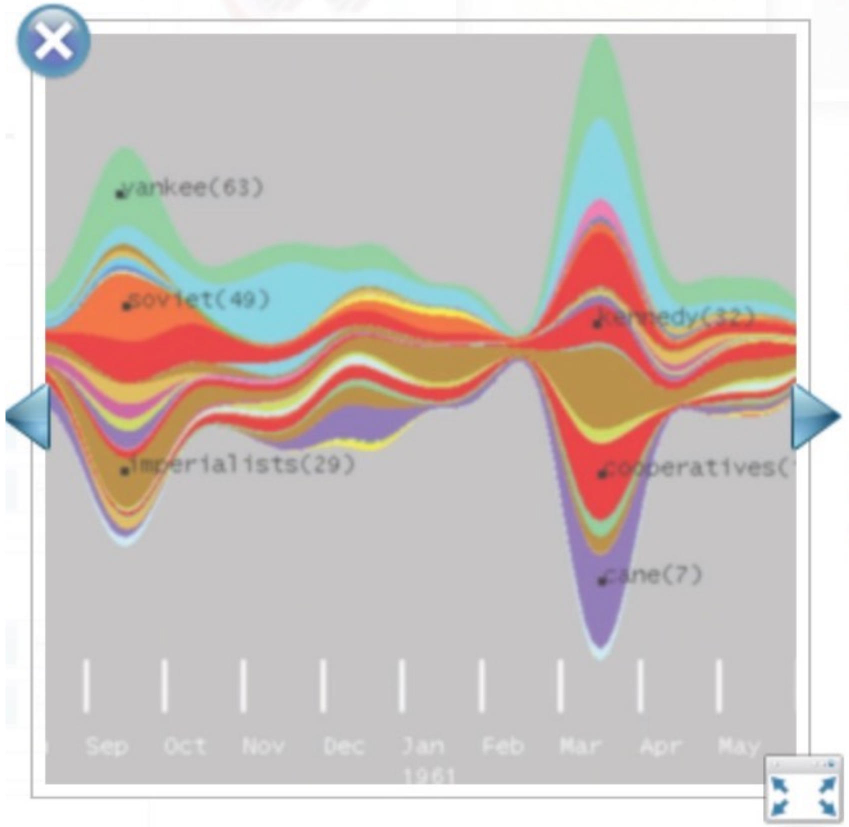
References

- *Imrich, P.; Mueller, K.; Imre, D.; Zelenyuk, D. & Zhu, W.: Interactive Poster: 3D ThemeRiver. Poster Compendium of IEEE Symposium on Information Visualization (InfoVis), IEEE Computer Society, 2003.*

Visualization: Dimensionality - 3D





ThemeRiver

Source: Havre, S.; Hetzler, E.; Whitney, P. & Nowell, L. (2002), © 2002 IEEE. Used with permission.

The ThemeRiver technique developed by Havre, S.; Hetzler, E. & Nowell, L. (2000) represents changes of news topics in the media. Each topic is displayed as a colored current whose width varies continuously as it flows through time. The overall image is a river that comprises all of the topics considered. The ThemeRiver provides an overview of the topics that were important at certain points in time. Hence, the main focus is directed towards establishing a picture of an easy to follow evolution over ...
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References

- *Havre, S.; Hetzler, E.; Whitney, P. & Nowell, L.: ThemeRiver: Visualizing Thematic Changes in Large Document Collections. IEEE Transactions on Visualization and Computer Graphics, Vol. 8, No. 1, 2002.*
- *Havre, S.; Hetzler, E. & Nowell, L.: ThemeRiver: Visualizing Theme Changes Over Time. Proceedings of the IEEE Symposium on Information Visualization (InfoVis), IEEE Computer Society, 2000.*

Visualization: Dimensionality - 3D - Starting with 2D

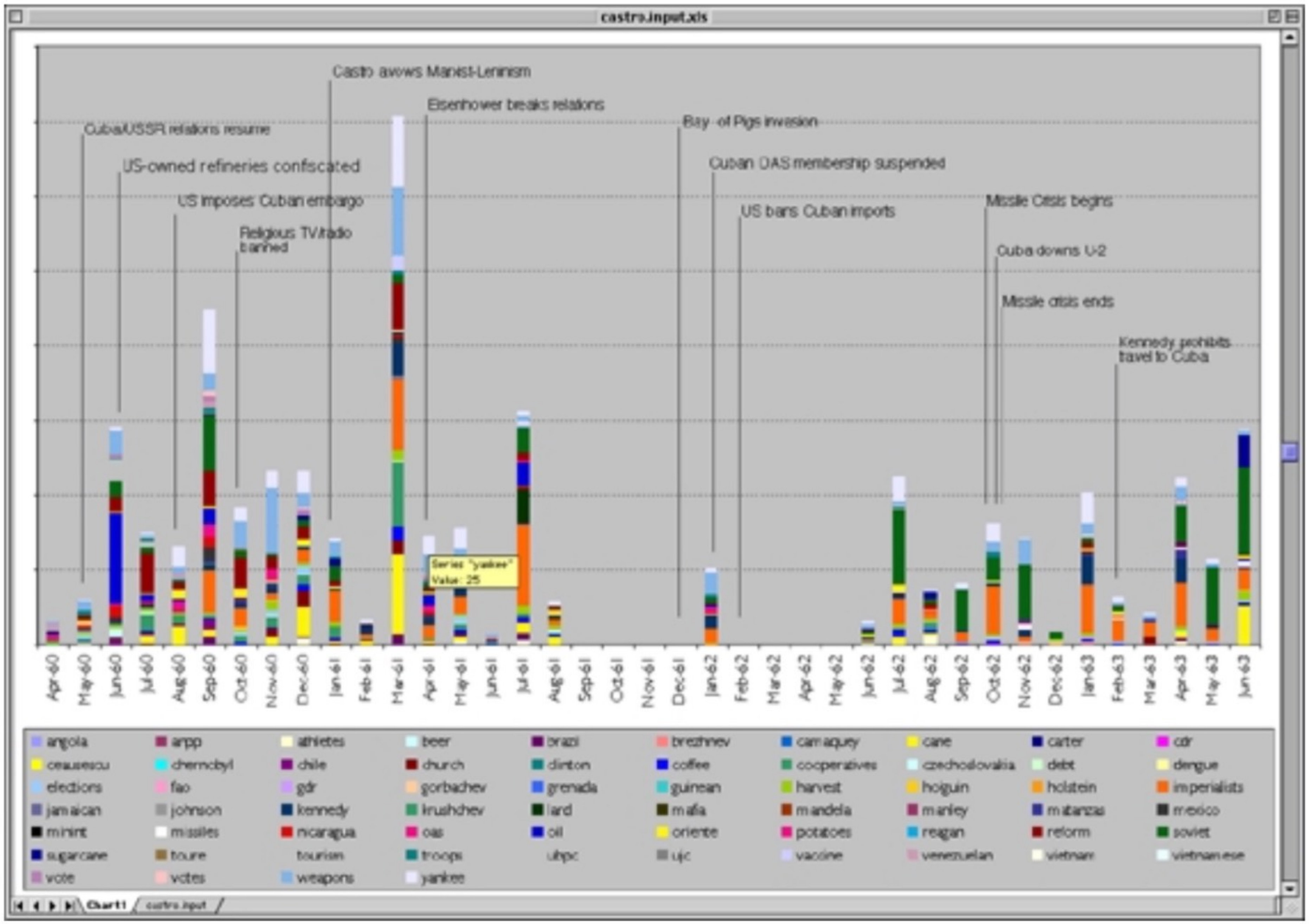


Figure 2: Like ThemeRiver™ in Figure 1, this histogram uses the Castro collection data and depicts changes in thematic content over time.

Visualization: Dimensionality - 3D - Starting with 2D

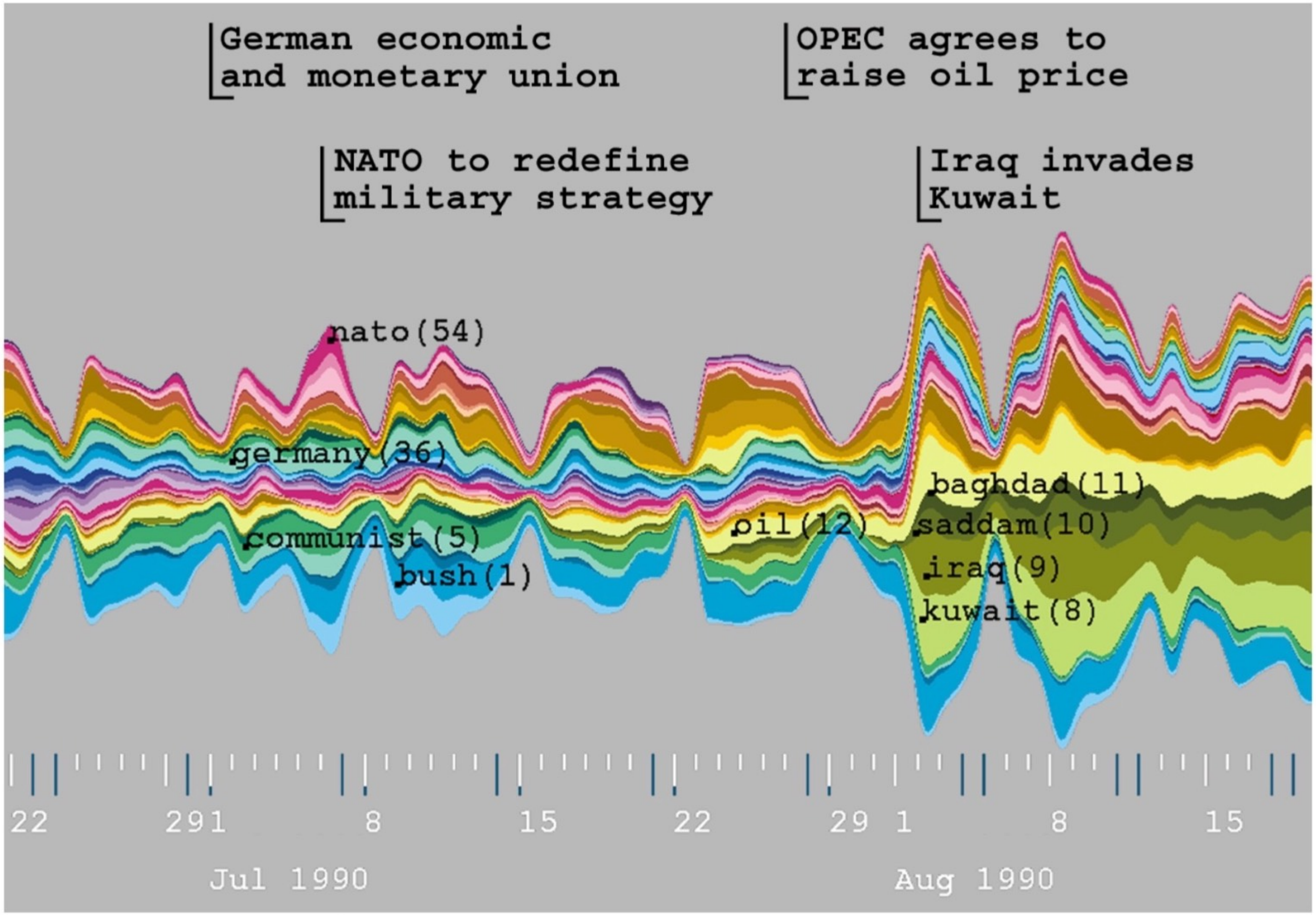


Figure 3: AP data from July - August 1990. A wide current in the river indicates heavy use of a topic, while changes in color distribution correlate to changes in themes.

Visualization: Dimensionality - 3D - Starting with 2D

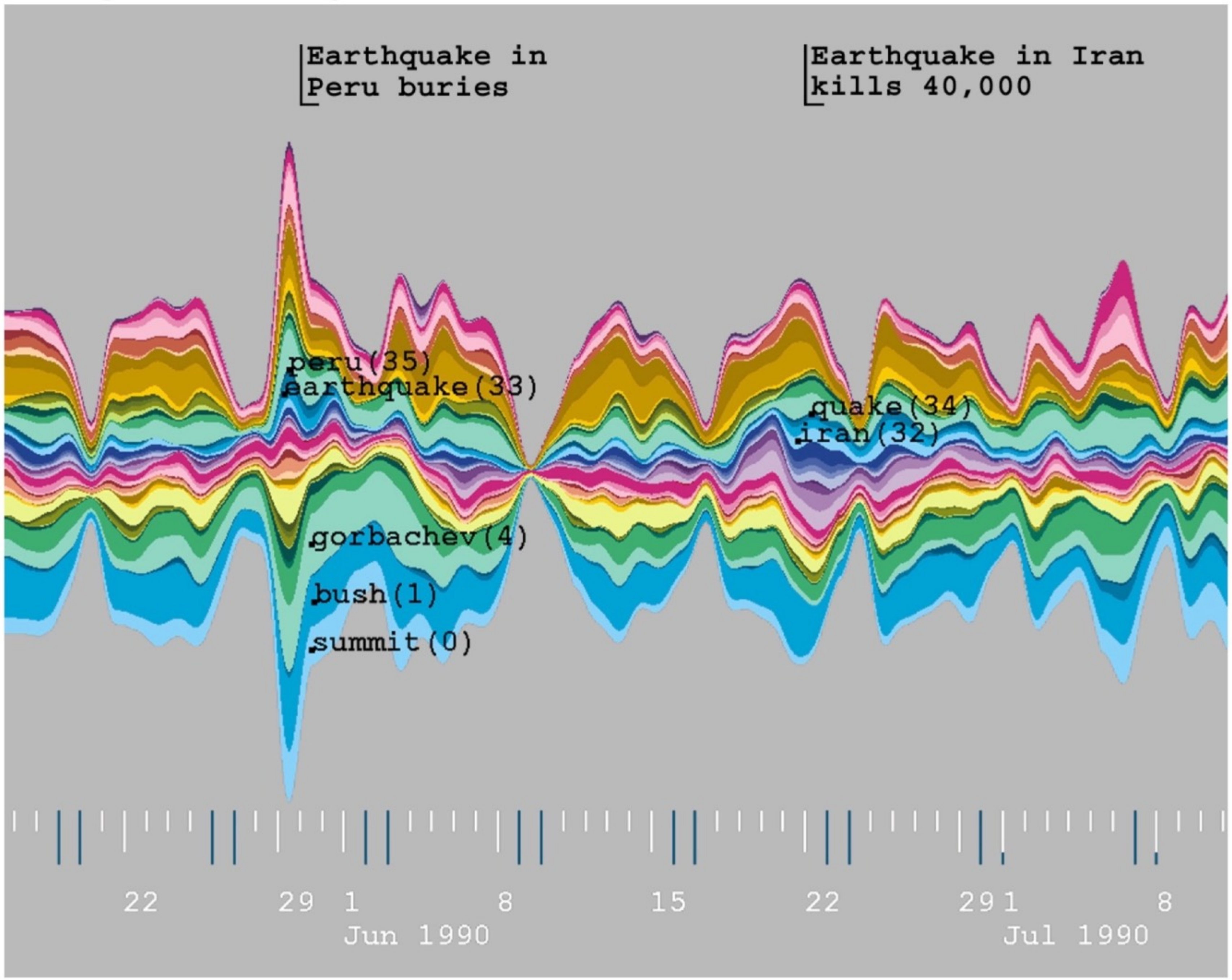
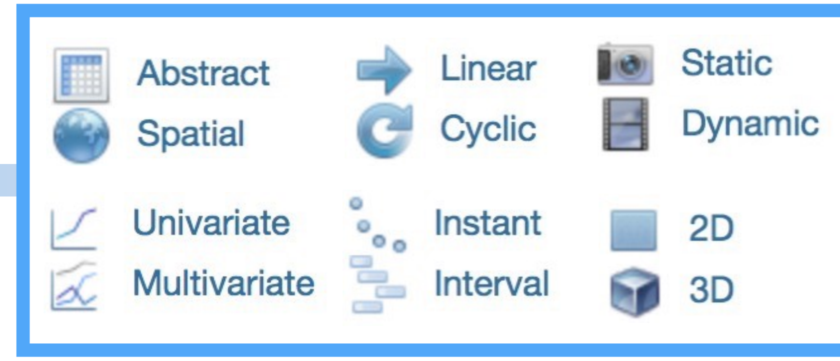


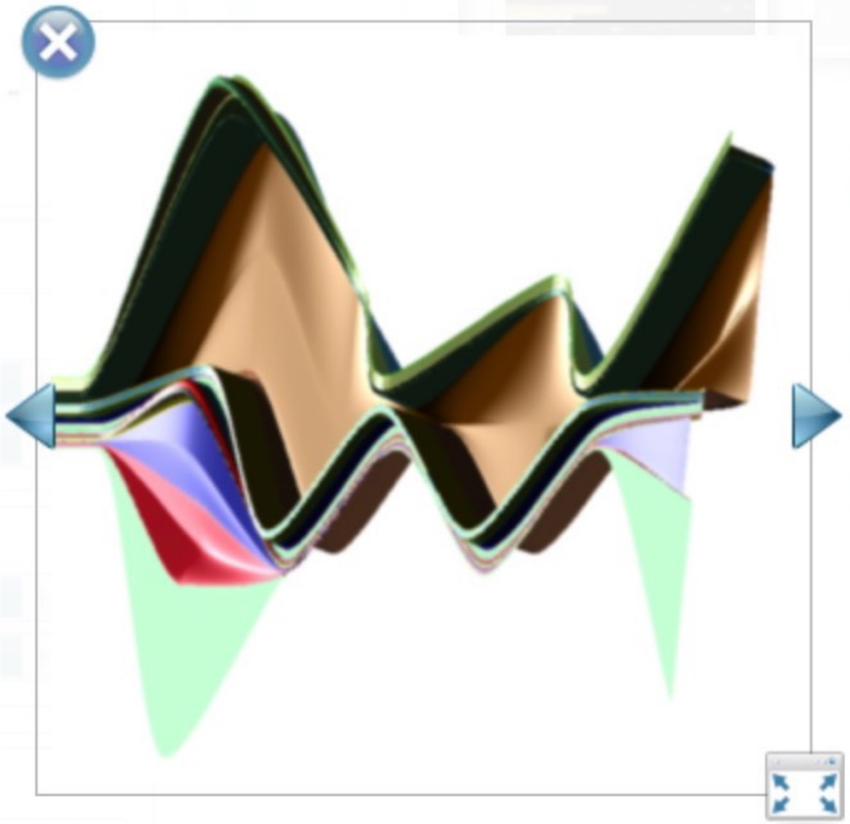
Figure 4: ThemeRiver™ of AP data from June - July 1990 identifies very different events from those revealed immediately afterwards (Figure 3).

Visualization: Dimensionality - 3D - Starting with 2D

- **The streams usually flow along the time axis and their width reflect the attribute of a particular stream at a particular point in time.**
- **This attribute can be anything worthwhile investigating, such as time fluctuations of different company stock values, ranging from simple distributions to more complex variables.**
- **The main advantage of a ThemeRiver visualization is that it portrays different data groups simultaneously, revealing their co-variance, showing how they behave together.**

Visualization: Dimensionality - 3D





3D ThemeRiver

Source: Imrich, P.; Mueller, K.; Imre, D.; Zelenyuk, D. & Zhu, W. (2003), © 2003 IEEE. Used with permission.

Imrich, P.; Mueller, K.; Imre, D.; Zelenyuk, D. & Zhu, W. (2003) propose a 3D variant of the ThemeRiver technique (see ThemeRiver). The 3D approach inherits the basic visual design from its 2D counterpart: multiple time-oriented variables are encoded to the widths of individually colored currents that form a river flowing through time along a horizontal time-axis. In the 2D variant, only one data variable can be visualized per current, namely by varying ...
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References

- *Imrich, P.; Mueller, K.; Imre, D.; Zelenyuk, D. & Zhu, W.: Interactive Poster: 3D ThemeRiver. Poster Compendium of IEEE Symposium on Information Visualization (InfoVis), IEEE Computer Society, 2003.*

Extends the ThemeRiver idea and maps a second attribute, such as the revenue of the companies, as the height of the streams

Visualization: Dimensionality - 3D

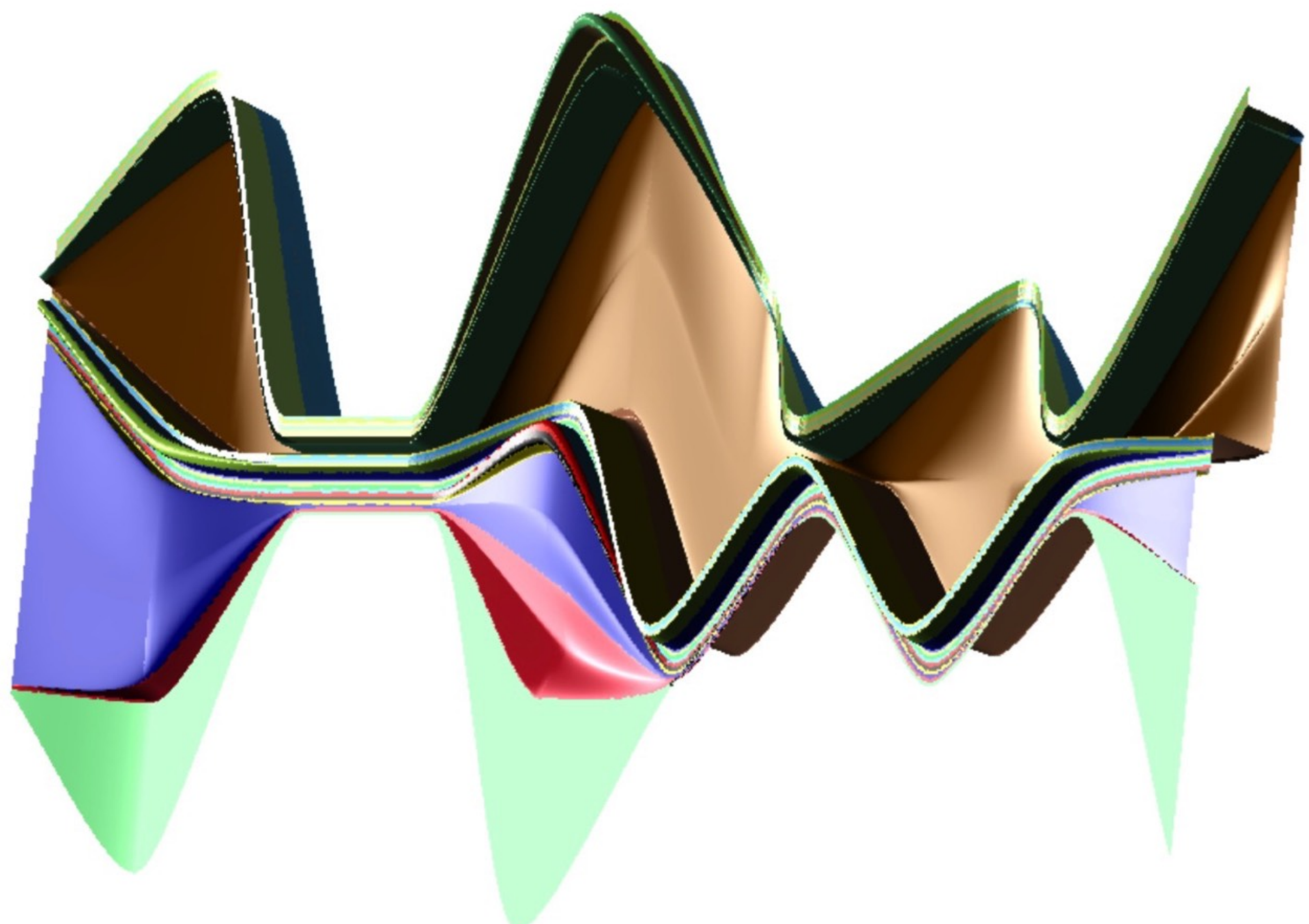
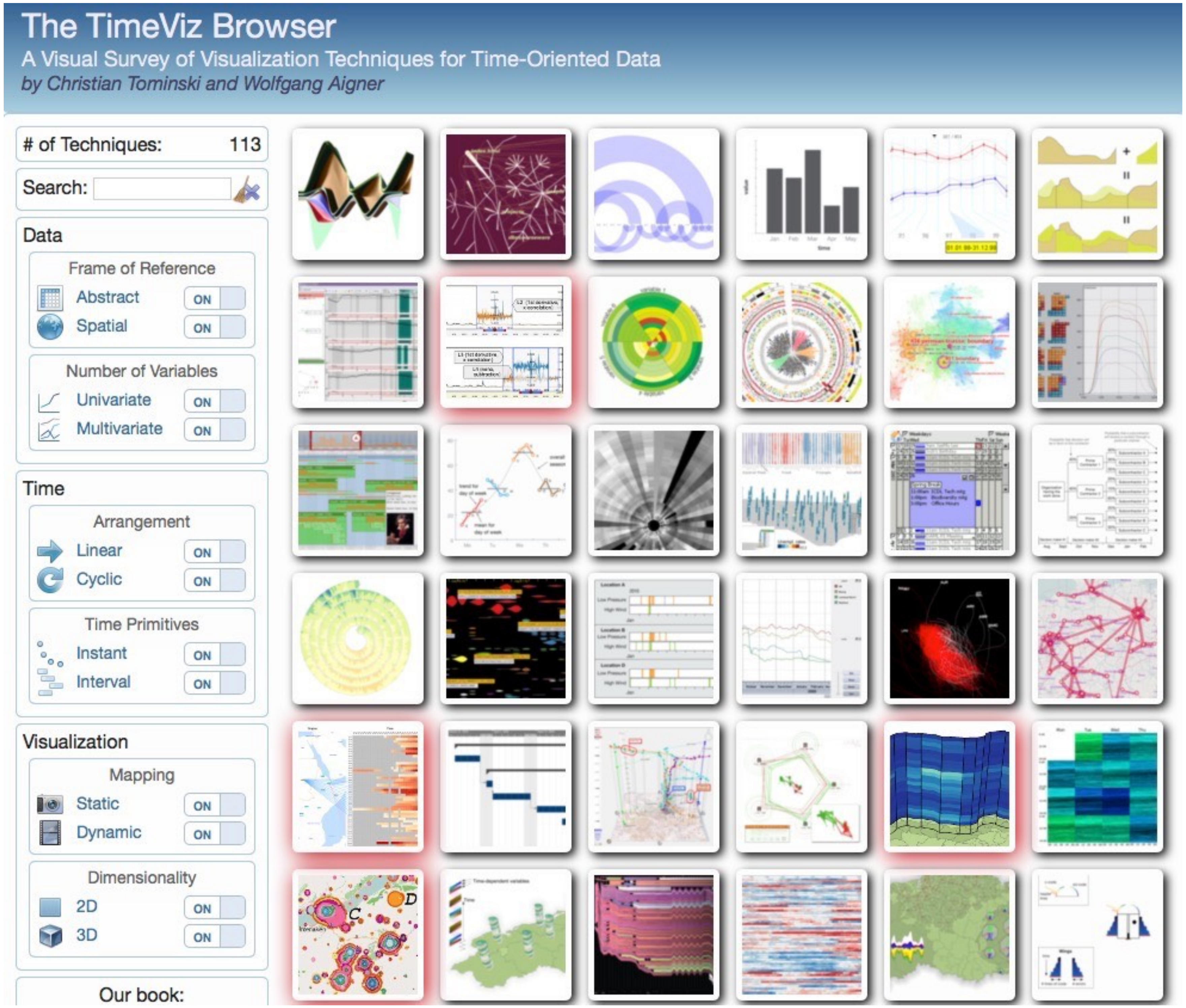


Figure 3: A 3D ThemeRiver visualization of 17 organic clusters. Width encodes overall cluster distributions (the magnitide of each cluster) and the height encodes incidence of zinc.

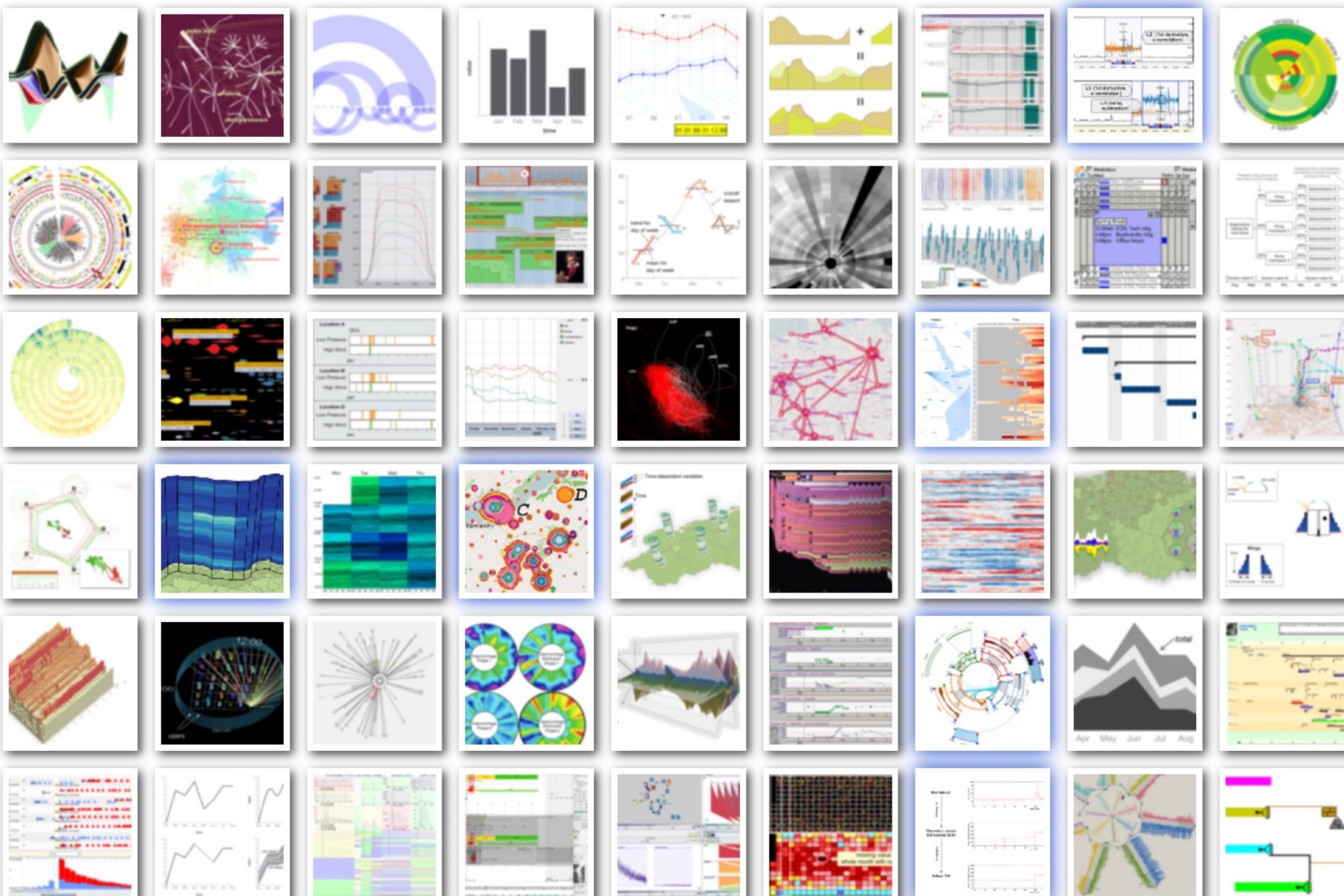
TimeViz Browser



http://survey.timeviz.net

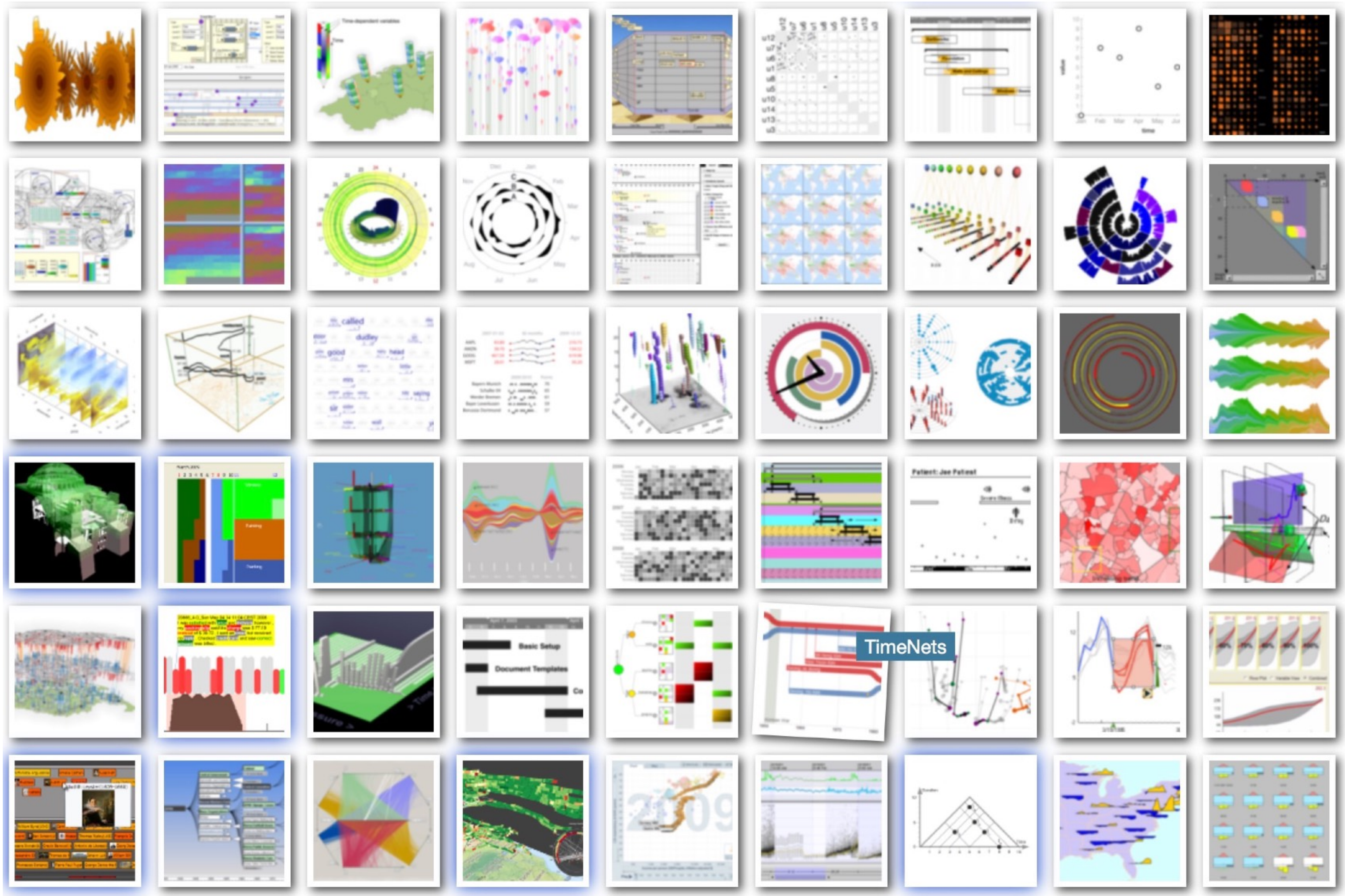
TimeViz Browser

http://survey.timeviz.net



TimeViz Browser

http://survey.timeviz.net



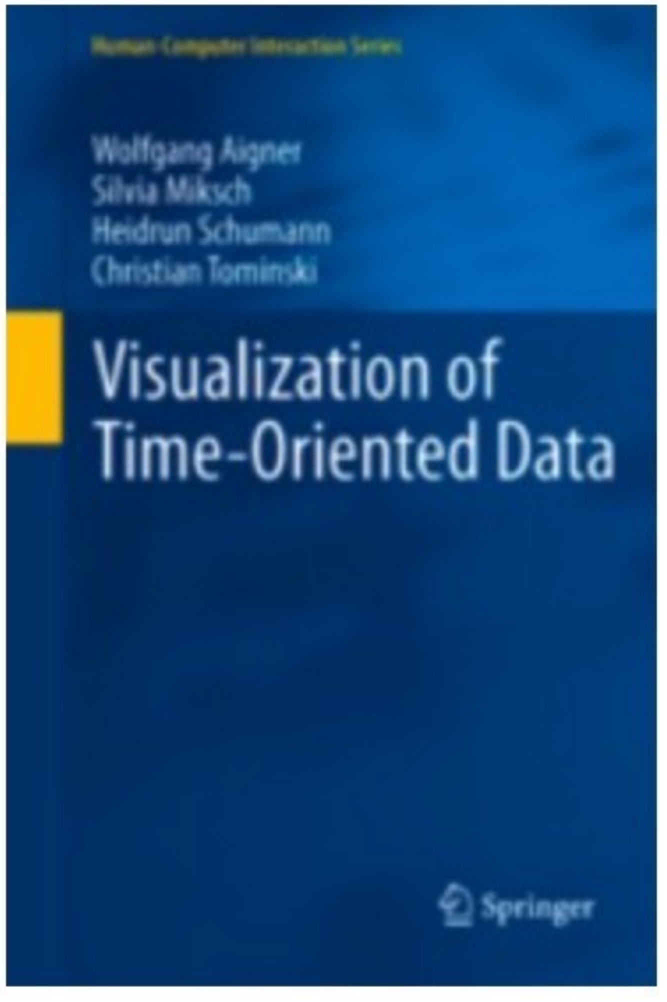
Visualization: Overview

	data				time				vis			
	frame of reference		variables		arrangement		time primitives		mapping		dimensionality	
	abstract	spatial	univariate	multivariate	linear	cyclic	instant	interval	static	dynamic	2D	3D
KronoMiner	■			■		■	■		■		■	
Great Wall of Space-Time		■	■		■		■		■			■
GROOVE	■		■		■	■	■		■		■	
TimeWheel	■			■	■		■		■		■	
Line Plot	■		■		■		■		■		■	
Enhanced Interactive Spiral	■		■			■	■		■		■	
CareCruiser	■			■	■		■		■		■	
SpiraClock	■		■			■		■		■	■	
PostHistory	■			■	■	■	■		■		■	
Flocking Boids	■			■	■		■			■		■
VisuExplore	■			■	■		■	■	■		■	
3D ThemeRiver	■			■	■		■		■			■

Table 7.1: Overview and categorization of visualization techniques.

Visualization: Overview

- **See more in**



Visualization of Time-Oriented Data
Wolfgang Aigner, Silvia Miksch Heidrun Schumann, Christian Tominski
2011
ISBN: 978-0-85729-078-6

TimeBench

TimeBench

- **TimeBench, a software library that provides foundational data structures and algorithms for time-oriented data in Visual Analytics.**
- **Site: http://www.cvast.tuwien.ac.at/TimeBench**
- **Paper: TimeBench: A Data Model and Software Library for Visual Analytics of Time-Oriented Data** by Alexander Rind, Tim Lammarsch, Wolfgang Aigner, Bilal Alsallakh, and Silvia Miksch
- **Video: https://youtu.be/BWvj8B3WHCE**

Further Reading and Summary

Further Reading

- **Pag 253 - 284 from Interactive Data Visualization: Foundations, Techniques, and Applications, Matthew O. Ward, Georges Grinstein, Daniel Keim, 2015.**