

Chapter 2

Historical Background

There is a magic in graphs. The profile of a curve reveals in a flash a whole situation – the life history of an epidemic, a panic, or an era of prosperity. The curve informs the mind, awakens the imagination, convinces.

Henry D. Hubbard in [Brinton \(1939, Preface\)](#)

Long before computers even appeared, visualization was used to represent time-oriented data. Probably the oldest time-series representation to be found in literature is the illustration of planetary orbits created in the 10th or possibly 11th century (see [Figure 2.1](#)). The illustration is part of a text from a monastery school and shows inclinations of the planetary orbits as a function of time.

To broaden the view beyond computer-aided visualization and provide background information on the history of visualization methods, we present historical and application-specific representations. They mostly consist of historical techniques of the pre-computer age, such as the works of William Playfair, Étienne-Jules Marey, or Charles Joseph Minard.

Furthermore, we will take the reader on a journey through the arts. Throughout history, artists have been concerned with the question of how to incorporate the dynamics of time and motion in their artworks. We present a few outstanding art movements and art forms that are characterized by a strong focus on representing temporal concepts. We believe that art can be a valuable source of inspiration; concepts or methods developed by artists might even be applicable to information visualization, possibly improving existing techniques or creating entirely new ones.

2.1 Classic Ways of Graphing Time

Representing business data graphically is a broad application field with a long tradition. William Playfair (1759–1823) can be seen as the protagonist and founding father of modern statistical graphs. He published the first known time-series depicting

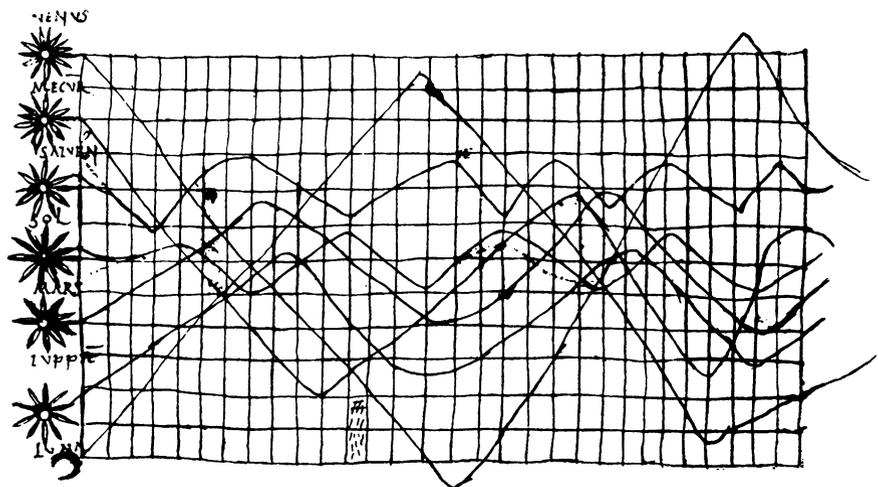


Fig. 2.1: Time-series plot depicting planetary orbits (10th/11th century). The illustration is part of a text from a monastery school and shows the inclinations of the planetary orbits as a function of time.

Source: [Funkhouser \(1936, p. 261\)](#). Used with permission of University of Chicago Press.

economic data in his *Commercial and Political Atlas* of 1786 ([Playfair and Corry, 1786](#)). His works contain basically all of the widely-known standard representation techniques (see Figures 2.2, 2.3, 2.5, and 2.4) such as the pie chart, the silhouette graph (\leftrightarrow p. 175), the bar graph (\leftrightarrow p. 154), and the line plot (\leftrightarrow p. 153).

In Figure 2.5 multiple heterogeneous time-oriented variables are integrated within a single view: the weekly wages of a good mechanic as a line plot, the price of a quarter of wheat as a bar graph, as well as historical context utilizing timelines (\leftrightarrow p. 166). Playfair himself credits the usage of timelines to Joseph Priestley (1733–1804) who created a graphical representation of the life spans of famous historical persons divided into two groups of Statesmen and Men of Learning (see Figure 2.6). The usage of a horizontal line to represent an interval of time might seem obvious to us nowadays, but in Priestley’s day this was certainly not the case. This is reflected in the fact that he devoted four pages of text to describe and justify his technique to his readers. A remarkable detail of Priestley’s graphical method is that he acknowledged the importance of representing temporal uncertainties and provided a solution to deal with them using dots. Even different levels of uncertainty were taken into account, ranging from dots below lines to lines and dotted lines.

Even earlier than both Priestley and Playfair, Jacques Barbeau-Dubourg (1709–1779) created the earliest known modern timeline. His *carte chronographique* ([Barbeau-Dubourg, 1753](#)) consisted of multiple sheets of paper that were glued together and add up to a total length of 16.5 meters. A rare version of the chart is available at Princeton University Library where the paper is mounted on two rollers

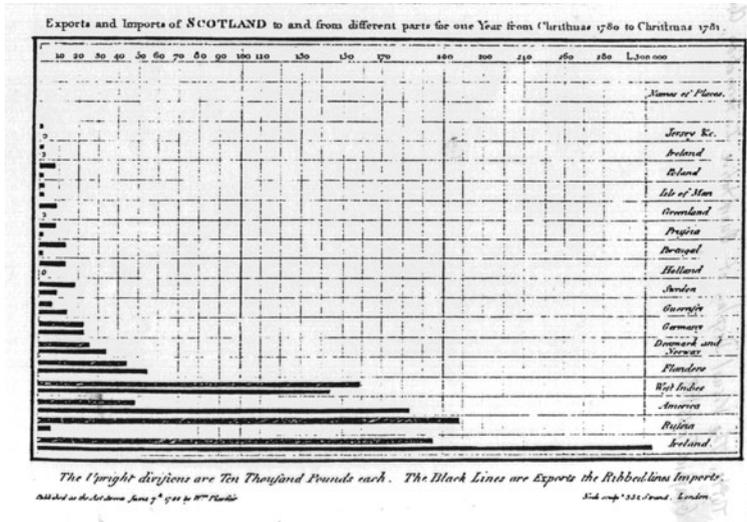


Fig. 2.2: Image from Playfair’s *Commercial and Political Atlas* (1786) representing exports and imports of Scotland during one year via a bar graph.
 Source: *Playfair and Corry* (1786).

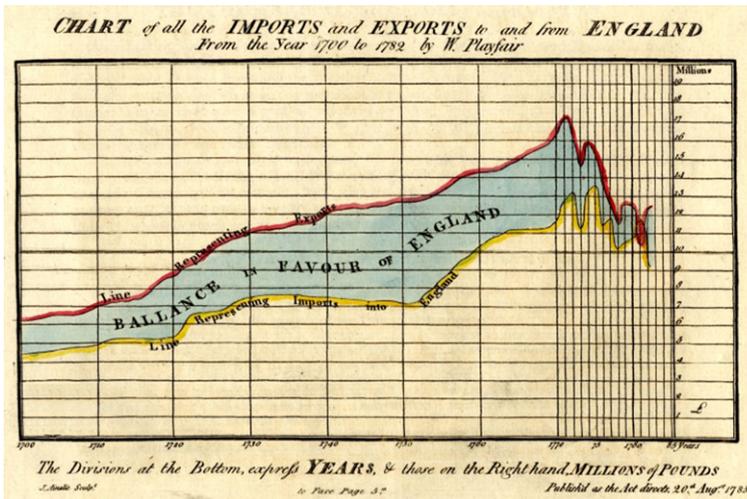


Fig. 2.3: Image from Playfair’s *Commercial and Political Atlas* (1786) representing imports and exports of England from 1700 to 1782 via a line plot. The yellow line on the bottom shows imports into England and the red line at the top exports from England. Color shading is added between the lines to indicate positive (light blue) and negative (red; around 1781) overall balances.
 Source: *Playfair and Corry* (1786).

A Specimen of a Chart of Biography.

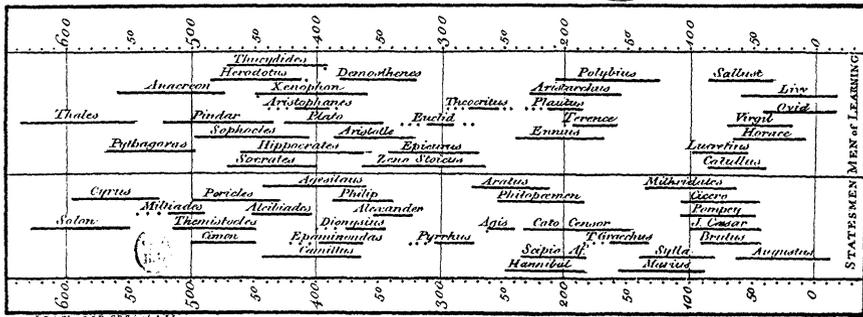


Fig. 2.6: Joseph Priestley’s chart of biography that portrays the life spans of famous historical persons using timelines.
 Source: *Priestley (1765)*.

in a foldable case that can be scrolled via two handles (see [Ferguson, 1991](#) for a detailed description).

Another prominent example of a graphical representation of historical information via annotated timelines is *Deacon’s synchronological chart of universal history* which was originally published in 1890 and was drawn by Edmund Hull (see [Figure 2.7](#)). Various reprints and books extending the original historic facts to the present and adaptations for specialized areas like for example inventions and explorations can be found in the literature (e.g., [Third Millennium Press, 2001](#)).

Charles Joseph Minard created a masterpiece of the visualization of historical information in 1861. His graphical representation of *Napoleon’s Russian campaign* of 1812 is extraordinarily rich in information, conveying no less than six different variables in two dimensions (see [Figure 2.8](#)). [Tufté \(1983\)](#) comments on this representation as follows:

It may well be the best statistical graphic ever drawn.

[Tufté \(1983, p. 40\)](#)

The basis of the representation is a 2-dimensional map on which a band symbolizing Napoleon’s army is drawn. The width of the band is proportional to the army’s size; the direction of movement (advance or retreat) is encoded by color. Furthermore, various important dates are plotted and a parallel line graph shows the temperature over the course of time.

About 25 years after Minard portrayed Napoleon's march to Moscow, the prominent historic figure Florence Nightingale used a statistical graph to show numbers and causes of deaths over time during the Crimean War. When Nightingale was sent to run a hospital near the Crimean battlefields to care for British casualties of war, she made a devastating discovery: many more men were dying from infectious diseases they had caught in the filthy hospitals of the military than from wounds. By introducing new standards of hygiene and diet, and most importantly, by ensuring proper water treatment, deaths due to infectious diseases fell by 99% within a year. Florence Nightingale tediously recorded mortality data for two years and created a novel diagram to communicate her findings. Figure 2.9 shows two of these *rose charts*. This representation is also called *polar area graph* and consists of circularly arranged wedges that convey quantitative data. Unlike pie charts, all the segments of rose charts have the same angle. Bringing the data in this form clearly revealed the horrible fact that many more soldiers were dying because of preventable diseases they had caught in hospital than from wounds sustained in battle. Not only this fact was communicated, but also how this situation could be improved by the right measures; these can be seen from the left rose chart in Figure 2.9. Through this diagram, which was more a call to action than merely a presentation of data, she persuaded the government and the Queen to introduce wide-reaching reforms, thus bringing about a revolution in nursing, health care, and hygiene in hospitals worldwide.

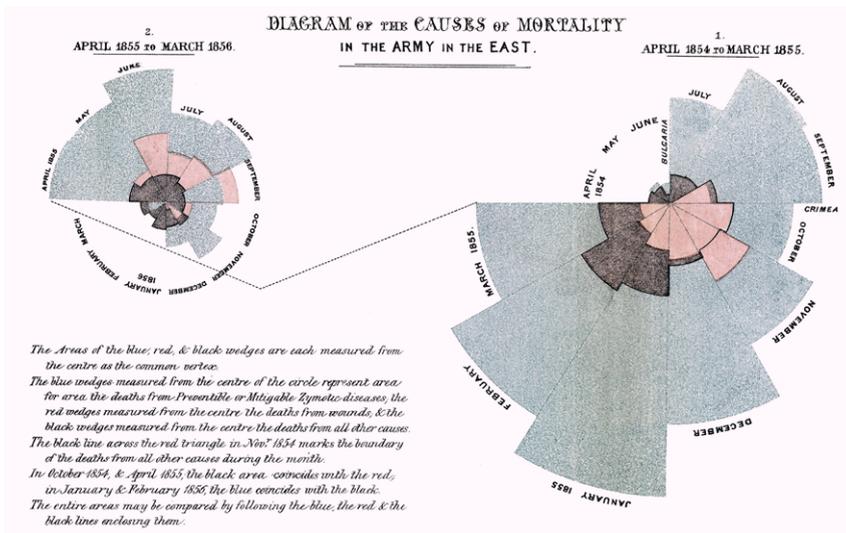


Fig. 2.9: Rose charts showing number of casualties and causes of death in the Crimean War by Florence Nightingale (1858). Red shows deaths from wounds, black represents deaths from accidents and other causes, and blue shows deaths from preventable infectious diseases soldiers caught in hospital. The chart on the right shows the first year of the war and the chart on the left shows the second year after measures of increased hygiene, diet, and water treatment had been introduced.

Source: <http://en.wikipedia.org/wiki/File:Nightingale-mortality.jpg>; Retrieved Feb., 2011.

A quite different approach to representing historical information is the illustration of the *Cuban missile crisis* during the Cold War by Bertin (1983). The diagram shows decisions, possible decisions, and the outcomes thereof over time (see Figure 2.10). This representation is similar to the *decision chart* (↔ p. 159). Chapple and Garofalo (1977) provided an illustration of *Rock'n'Roll history* shown in Figure 2.11 that depicts protagonists and developments in the area as curved lines that are stacked according to the artists' percentage of annual record sales. The *The-meRiver™* technique (↔ p. 197) can be seen as further, more formal development of this idea.

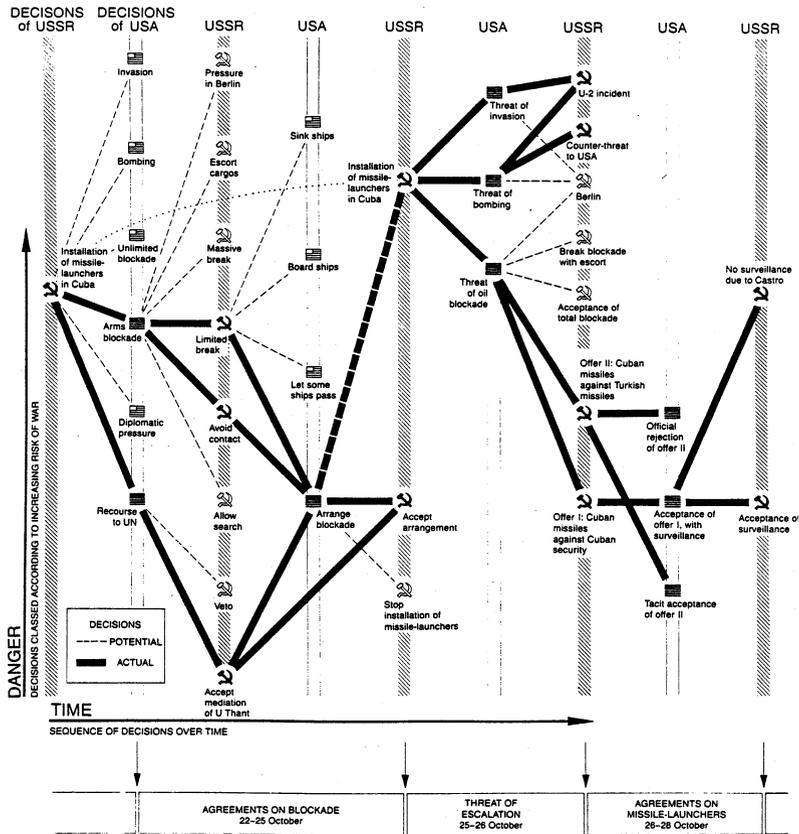


Fig. 2.10: Cuban missile crisis (threat level and decisions over time). The diagram shows decisions, possible decisions, and the outcomes thereof over time.

Source: Bertin (1983, p. 264). © 1983 by the Board of Regents of the University of Wisconsin System. Reprinted with permission of The University of Wisconsin Press.

With the advance of industrialization in the late 19th and early 20th century, optimizing resources and preparing time schedules became essential requirements for improving productivity. One of the main protagonists of the study and optimization of work processes was Frederick Winslow Taylor (1856–1915). His associate Henry Laurence Gantt (1861–1919) studied the order of steps in work processes and developed a family of timeline-based charts as intuitive visual representation to illustrate and record time-oriented processes (see Figures 2.12 and 2.13). Widely known as *Gantt charts* (↔ p. 167), these representations are such powerful analytical instruments that they are used nearly unchanged in modern project management.

Other interesting representations of work-related data can be seen in Figures 2.14 and 2.15. A record of hours worked per day by an employee is shown in Figure 2.14. It is interesting to note that both axes are used for representing different granularities of time, i.e., days on the horizontal axis and hours per day on the vertical axis. Figure 2.15 employs a radial layout of the time and allows a reading on multiple levels: the outer ring shows days without work and the inner rings show hours worked during the day, whereas the green areas indicate night hours.

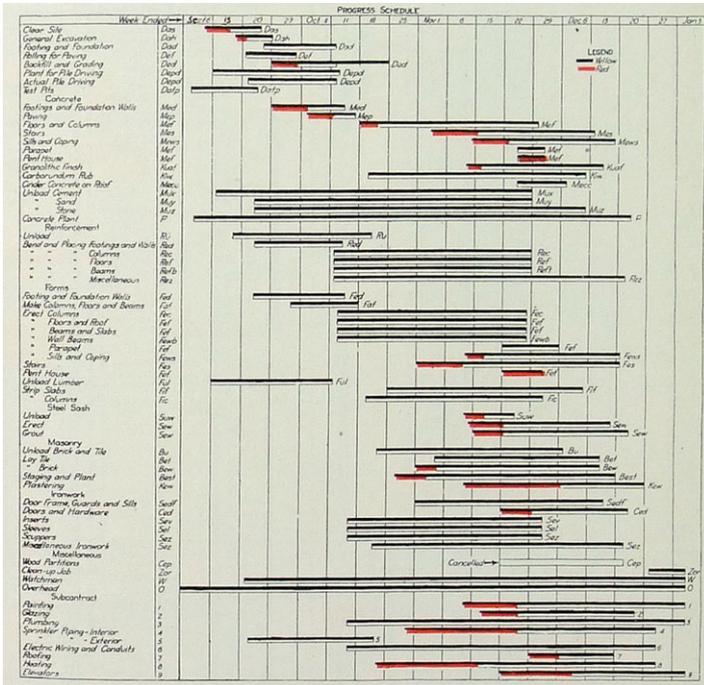
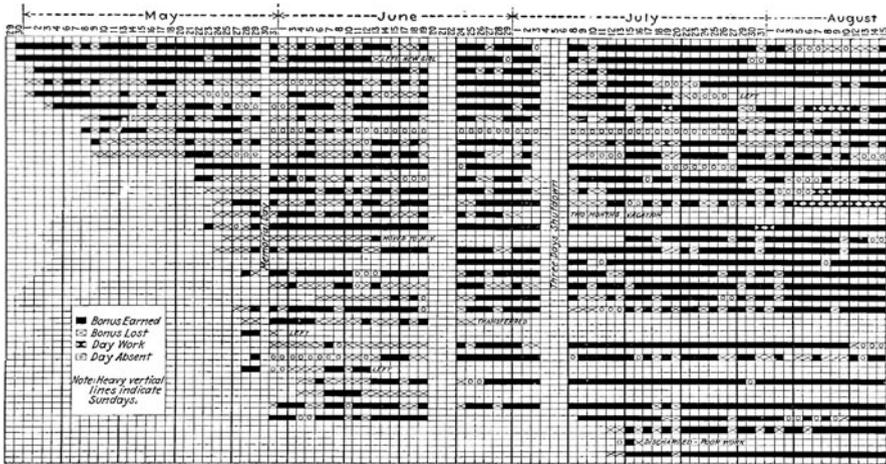


Fig. 2.12: Progress schedule based on the graphical method of Henry L. Gantt. Different work packages are shown as horizontal lines. Black lines indicate the planned timings; the actual quantity of work done is shown below in red.

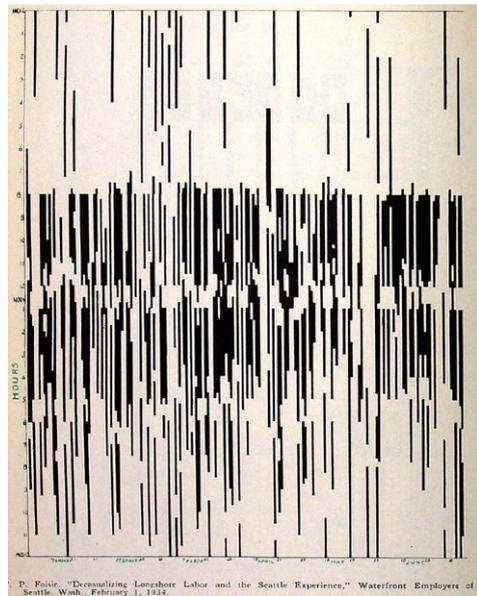
Source: *Brinton* (1939, p. 259).



Mr. H. L. Gantt, in *Journal Am. Soc. Mechanical Engineers*

Fig. 2.13: Record of work carried out in one room of a Worsted Mill by Henry L. Gantt. Each row represents one worker and gives information about whether a bonus was earned and whether the worker was present.

Source: *Brinton (1914, p. 52).*



P. Poole, "Declassifying Lighthouse Labor and the Seattle Experience," *Waterfront Employers of Seattle, Wash., February 1, 1934.*

Fig. 2.14 Exact hours and days worked in 1929 by an employee at the Oregon ports. Days are mapped on the horizontal axis and hours per day worked are represented as bars on the vertical axis. The representation shows extreme irregularities in working hours.

Source: *Brinton (1939, p. 250).*

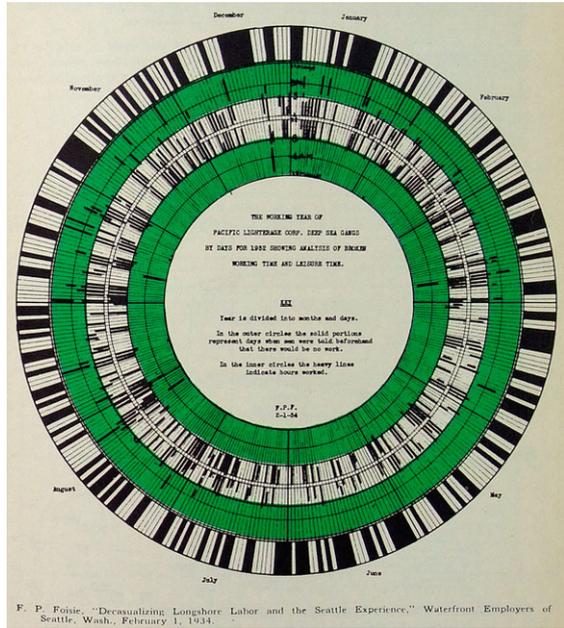


Fig. 2.15 An analysis of working time and leisure time in 1932. Uses a radial layout of time and allows a reading on multiple levels: the outer ring shows days without work and the inner rings show hours worked during the day, whereas the green areas indicate night hours.
 Source: *Brinton (1939, p. 251)*.

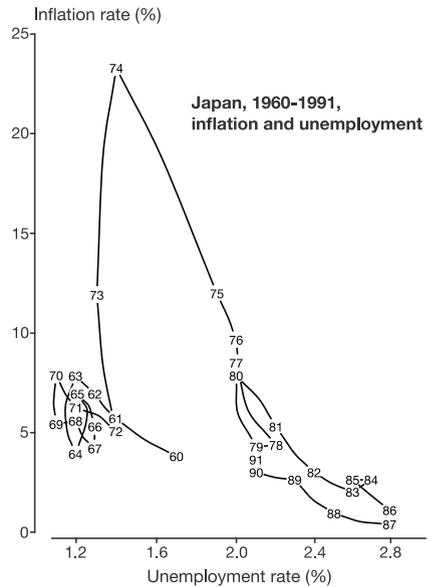


Fig. 2.16 Phillips curve. Unemployment rate (horizontal axis) is plotted against inflation rate (vertical axis). Each point in the plot corresponds to one year and is labeled accordingly. The markers of subsequent years are linked to create a visual trace of time.
 Source: *Adapted from Tufte (1997, p. 60)*. Used with permission of Graphics Press.

A quite unique representation of economic data is the so-called *Phillips curve* – a 2D plot based on an economic theory that shows unemployment vs. inflation in a Cartesian coordinate system. In this representation, time is neither mapped to the horizontal nor the vertical axis, but is rather shown textually as labeled data points on the curve. This way, the dimension of time is slightly de-emphasized in favor of showing the relationship of two time-dependent variables (see Figure 2.16). Each year’s combination of the two variables of unemployment rate and inflation rate leads to a data point in 2D space that is marked by the digits of the corresponding year. The markers of subsequent years are connected by a line resulting in a path over the course of time.

For representing positional changes within a set of elements, *rank charts* were already introduced in early statistical publications (see Figure 2.17). Elements are ordered according to their ranking and displayed next to each other in columns for different points in time. The positional change of individual elements is emphasized by connecting lines. This way, the degree of rank change is represented by the angles of the connecting lines, thus making big changes in rank stand out visually by the use of very steep lines.

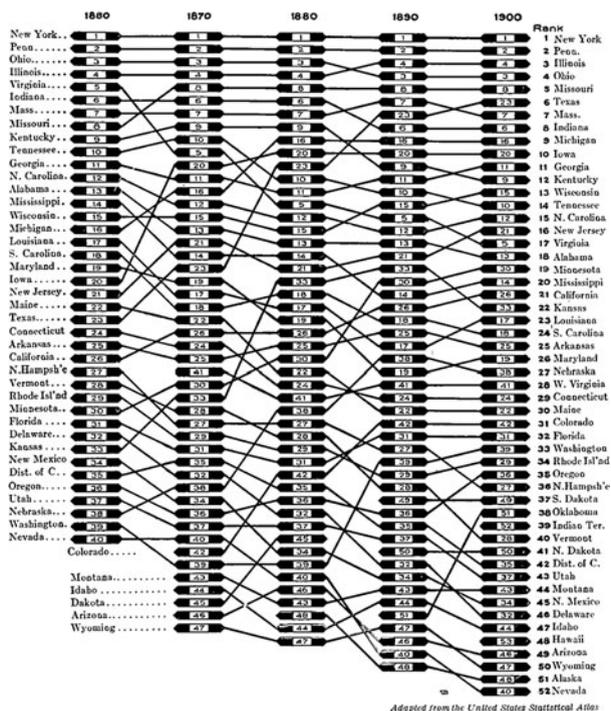


Fig. 2.17: Rank of states and territories in population at different census years from 1860 to 1900. Source: Brinton (1914, p. 65).

A remarkable representation of time-oriented information was created by Étienne-Jules Marey (1830–1904) in the 1880s (see Figure 2.18). It shows the train schedule for the track Paris to Lyon graphically. Basically, a 2D diagram is used which places the individual train stops according to their distance in a list on the vertical axis, while time is represented on the horizontal axis. Thus, horizontal lines are used to identify the individual stops and a vertical raster is used for timing information. The individual trains are represented by diagonal lines running from top-left to bottom-right (Paris–Lyon) and bottom-left to top-right (Lyon–Paris), respectively. The slope of the line gives information about the speed of the train – the steeper the line, the faster the respective train is travelling. Moreover, horizontal sections of the trains' lines indicate if the train stops at the respective station at all and how long the train stops. On top of that, the density of the lines provides information about the frequency of trains over time. This leads to a clear and powerful representation showing complex information at a glance while allowing for in-depth analysis of the data. Similar representations have also been used for the Japanese Shinkansen train line and the Javanese Soerabaja-Djokjakarta train line where the track's terrain profile is additionally shown.

Étienne-Jules Marey not only created the fabulous train schedule, but was also very interested in exploring all kinds of movement. Born in 1830 in France, he was a trained physician and physiologist. His interest in internal and external movements in humans and animals, such as blood circulation, human walking, horse gaits, or dragonfly flight, led to the decomposition of these movements via novel photography and representation methods (see Figures 2.19, 2.20, and 2.21). This photography method, which is called *chronophotography*, paved the way for the birth of modern film-making at the end of the nineteenth century.

Today, Marey is still a valuable source of inspiration. Reason enough to speak highly of him and his work:

Tirelessly, this brilliant visionary stopped the passage of time, accelerated it, slowed it down to “see the invisible,” and recreated life through images and machines.

[La maison du cinema and Cinematheque Francaise \(2000\)](#)

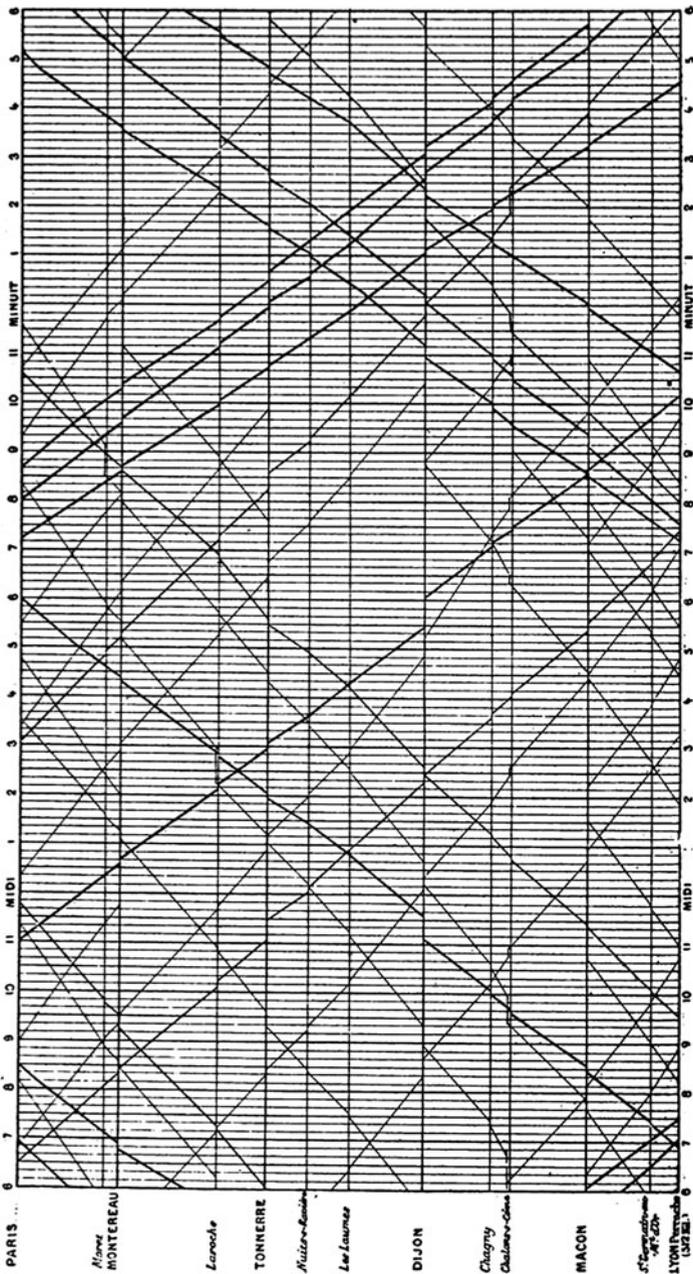


Fig. 2.18: Train schedule by Étienne-Jules Marey (19th century). Individual train stops are placed according to their distance in a list on the vertical axis, while time is represented on the horizontal axis (figure above is rotated by 90°). The individual trains are represented by diagonal lines running from top-left to bottom-right (Paris–Lyon) and bottom-left to top-right (Lyon–Paris) respectively. Source: *Marey (1875, p. 260)*.

Fig. 2.19 A person walking. Studies of movement by Étienne-Jules Marey (19th century).
 Source: *Marey (1894, p. 61).*

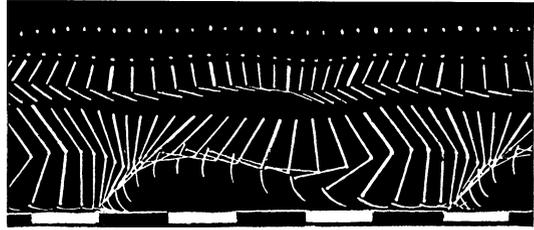


Fig. 2.20 Horse gaits. Studies of movement by Étienne-Jules Marey (19th century).
 Source: *Source: Marey (1894, p. 188).*

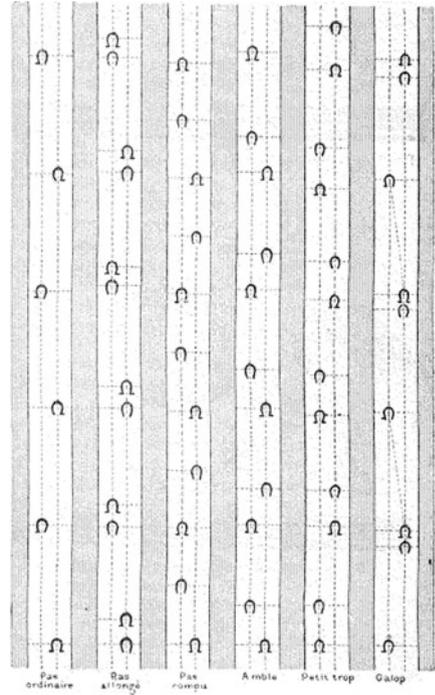


Fig. 2.21 Chronophotography. A photo of flying pelican taken by Étienne-Jules Marey around 1882.
 Source: http://commons.wikimedia.org/wiki/File:Marey_-_birds.jpg;
 Retrieved Feb., 2011.



In medicine, large amounts of information are generated which mostly have to be processed by humans. Graphical representations which help to make this myriad of information comprehensible play a crucial role in the workflow of healthcare personnel. These representations range from the *fever curves* of the nineteenth century (see Figure 2.22) and EEG time-series plots (see Figure 2.23) to information-rich patient status overviews (see Figure 2.24). Especially the graphical summary of patient status by Powsner and Tufte (1994) makes use of concepts such as *small multiples* (\leftrightarrow p. 236), *focus+context* (see p. 111), or the integration of textual and graphical information. It manages to display information on a single page that would otherwise fill up entire file folders and would require serious effort to summarize.

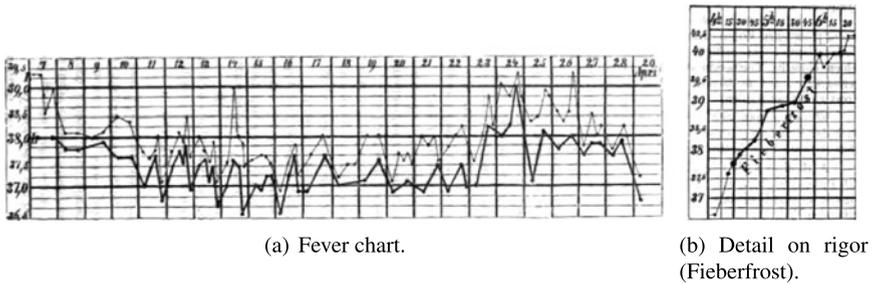


Fig. 2.22: Fever charts created by Carl August Wunderlich (1870).
Source: [Wunderlich \(1870, p. 161, 167\)](#).



Fig. 2.23 EEG time-series plot.

Source:
<http://commons.wikimedia.org/wiki/File:Spike-waves.png>;
Retrieved Feb., 2011.

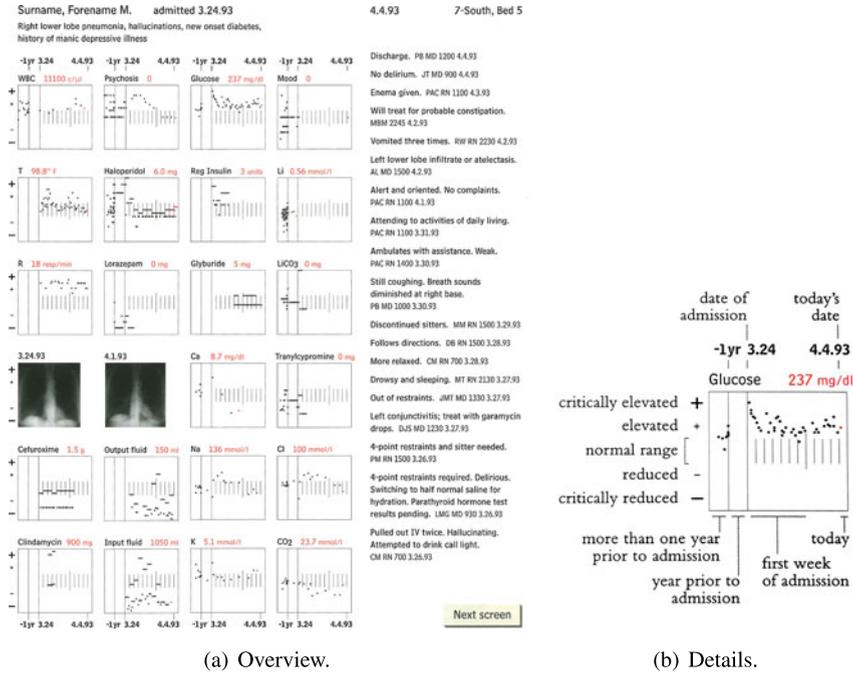


Fig. 2.24: Graphical summary of patient status by Powsner and Tufte (1994). Concise summary of patient information. Uses *small multiples*, *focus+context*, and integrates textual as well as graphical information.

Source: Tufte (1997, p. 110–111). © Graphics Press. Used with permission.

Weather and climate are further well-known application areas dealing with time-oriented data. Here, developments over time are of greater interest than single snapshots. Figure 2.25 shows the adaptation of an extremely information-rich illustration provided by the New York Times for more than 30 years to show New York City’s weather developments for a whole year. Monthly and yearly aggregates are displayed along with more detailed information on temperature, humidity, and precipitation. All in all, more than 2500 numbers are shown in this representation in a very compact and readable form. An even earlier example of a visual representation of the weather data of New York City is shown in Figure 2.26. Here, temperatures, wind velocity, relative humidity, wind direction, and the weather conditions of a single month (December, 1912) are displayed.

Weather in 1980

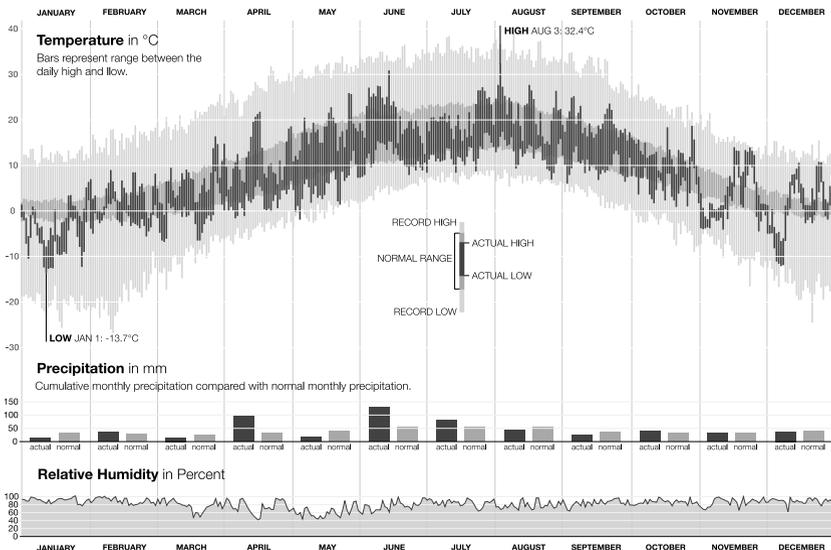


Fig. 2.25: Weather statistics for 1980. Aggregated values are displayed along with more detailed information on temperature, humidity, and precipitation. Similar illustrations have been printed annually by the New York Times for more than 30 years.

Source: Generated with the Protovis toolkit.

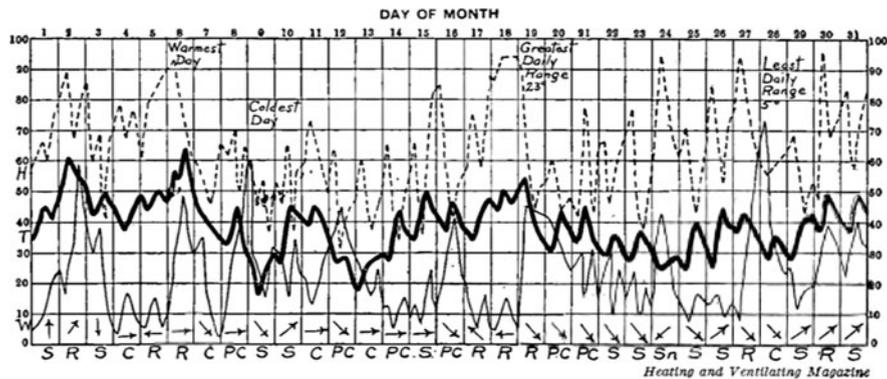


Fig. 2.26: Record of the Weather in New York City for December, 1912. The bold line indicates temperature in degrees Fahrenheit. The light solid line shows wind velocity in miles per hour. The dotted line depicts relative humidity in percentage from readings taken at 8 a.m. and 8 p.m. Arrows portray the prevailing direction of the wind. Initials at the base of the chart show the weather conditions as follows: S, clear; PC, partly cloudy; C, cloudy; R, rain; Sn, snow.

Source: Brinton (1914, p. 93).

2.2 Time in Visual Storytelling & Arts

Two disciplines that are seldom connected to time-oriented information are *visual explanations* and *visual storytelling*. Although ubiquitously used in various forms in daily life, they are rarely considered for visualizing abstract information. Visual explanations are often used in manuals for home electronics, furniture assembly, car repair, and many more (see Figures 2.28 and 2.29). Often, they are used to illustrate stepwise processes visually to an international audience to support the often poorly translated textual instructions. The stepwise nature conveys a temporal aspect and might also be applied to represent abstract information. Even older than everything we presented previously is the craft of *storytelling*, especially visual storytelling, starting from caveman paintings and Egyptian hieroglyphs to picture books and comic strips (see Figure 2.30). Time is the central thread that ties everything together in visual storytelling. Many interesting techniques and paradigms exist that might be applicable to visualization in general (see for example [Gershon and Page, 2001](#)) as well as to the representation of time-oriented information in particular.

Comics The art of *comics* is often dubbed as *visual storytelling over time* or *sequential art* (a term used by Will Eisner) because temporal flows are represented in juxtaposed canvases on a page. These descriptions already suggest that comics incorporate many concepts of time, while still retaining a static, 2-dimensional form. Scott [McCloud \(1994\)](#) analyzed many of the methods and paradigms of comics, concluding that powerful means of representing time, dynamics, and movement are applied which differ from those applied in painting or photography. Comics allow for the seamless representation of many temporal concepts that may be also applicable to visualization. Basically, the course of time is represented in comics via

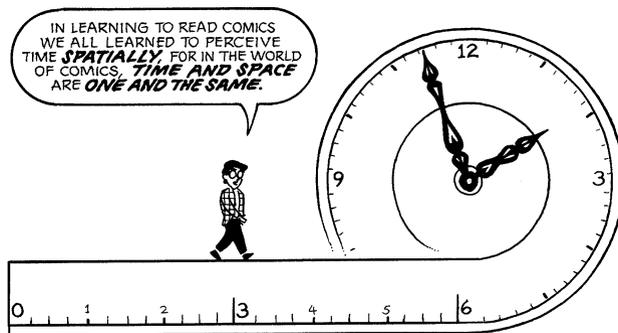


Fig. 2.27: In learning to read comics we all learned to perceive time spatially, for in the world of comics, time and space are one and the same.

Source: [McCloud \(1994, p. 100\)](#). © 1993, 1994 Scott McCloud. Reprinted with permission of HarperCollins Publishers.



Fig. 2.28: Visual explanation is used to illustrate stepwise processes.

Source: Adapted from Tomitsch *et al.* (2007).

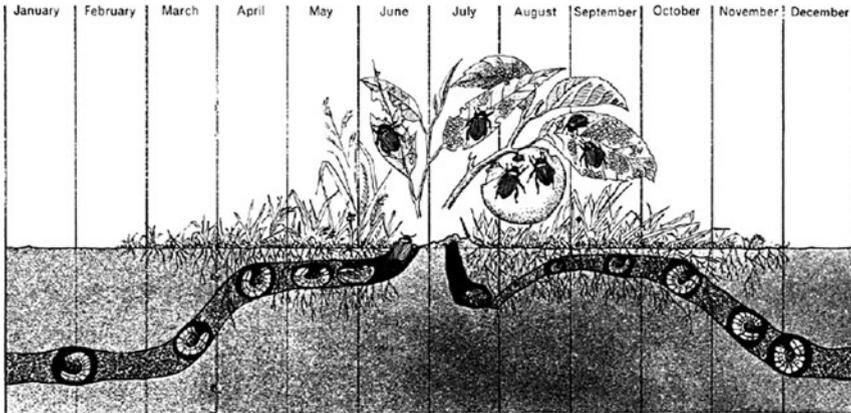
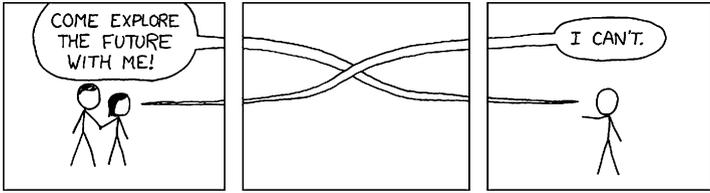


Fig. 2.29: Life Cycle of the Japanese Beetle (*Popillia japonica* Newman).

Source: Newman (1965, p. 104–105). Reproduced from Tufte (1990, p. 43). Used with permission of Graphics Press.

juxtaposition of panels. But the individual panels portray more than single frozen moments in time and are more than photos placed side by side. Rather, single panels contain whole scenes whose temporal extent may span from milliseconds to arbitrary lengths (see Figure 2.31). Not only the content of a panel sheds light on the length of its duration but also the shape of the panel itself can affect our perception of time. Even more freedom in a temporal sense is given by the transition from one panel to the next or by the space between panels, respectively (see Figure 2.32). Here, time might be compressed, expanded, rewind; *deja vu*'s might be incorporated and much more. This also implies that comics are not just simply linearly told stories. Comics are very versatile and much more powerful in incorporating time in comparison to paintings, photographs, and even film. Besides the purely temporal aspect, motion is another important topic in comics. Several visual



(a) Randall Munroe, xkcd – A Webcomic of Romance, Sarcasm, Math, and Language.

Source: <http://xkcd.com/338/>; Retrieved Feb., 2011. Image courtesy of Randall Munroe.



HTTP://REALLIFE.WEBPROVIDER.COM REAL LIFE ©1999 GREG DEAN

(b) Greg Dean, RealLife – A daily online comic.

Source: <http://www.reallifecomics.com/archive/991206.html>; Created Dec. 6, 1999; Retrieved Feb., 2011. Image courtesy of Greg Dean.

Fig. 2.30: Comics where temporal flows are represented in juxtaposed canvases on a page.

techniques, such as motion lines or action lines with additional effects like multiple images, streaking effects, or blurring are applied (see Figure 2.33). In part, these techniques are borrowed from photography. Recently, research work on generating these comic-like effects from motion pictures has been conducted as for example in [Markovic and Gelautz \(2006\)](#).

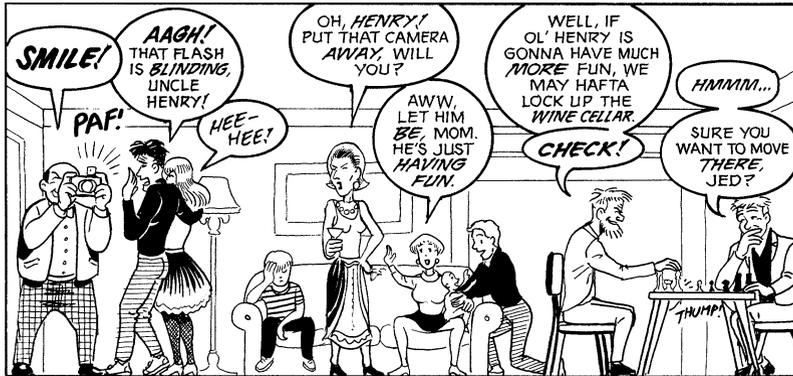


Fig. 2.31: A single comic panel contains more than a frozen moment in time.

Source: [McCloud \(1994, p. 95\)](#). © 1993, 1994 Scott McCloud. Reprinted with permission of HarperCollins Publishers.

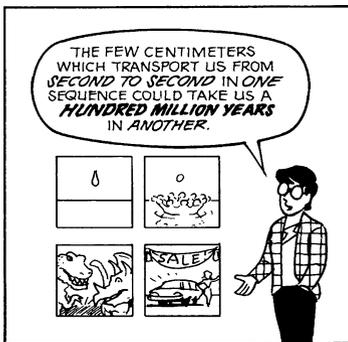


Fig. 2.32: Transitions between panels might span intervals of arbitrary length.

Source: [McCloud \(1994, p. 100\)](#). © 1993, 1994 Scott McCloud. Reprinted with permission of HarperCollins Publishers.

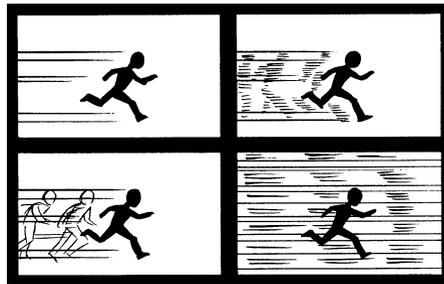


Fig. 2.33: Techniques to represent movement in comics (motion lines, streaking, multiple images, background streaking).

Source: [McCloud \(1994, p. 114\)](#). © 1993, 1994 Scott McCloud. Reprinted with permission of HarperCollins Publishers.

Music & dance Music notes are a notation almost everybody is aware of, but it is one which is rarely seen in conjunction with time-oriented information (see Figure 2.34). Nevertheless, music notes are clearly a visual representation of temporal information – even more than that. A rich set of different symbols, lines, and text constitute a very powerful visual language. Beat, rhythm, pitch, note length, pausing, instrument tuning, and parallelism are the most important visualized parameters. In fact, it is hard to imagine any other way of representing musical compositions than via music notes. Related to that, special notations are used for recording dance performances statically on paper (see Figure 2.35).

AMAZING GRACE

John Newton, 1779

Fig. 2.34: Music notation. A rich set of symbols, lines, and text visualizes beat, rhythm, pitch, note length, pausing, instrument tuning, and parallelism.

Source: <http://commons.wikimedia.org/wiki/File:AmazingGraceFamiliarStyle.png>; Retrieved Feb., 2011.

Fig. 2.35: Dance notation. Used for recording dance performances statically on paper.

Source: *Tufte (1990, p. 117)*. © 1990 Graphics Press. Used with permission.

Movies One art form that is only touched upon briefly here, but which might also offer interesting ideas for visualization, is *film*. We will present movies that exemplify how movie makers are able to transport highly non-linear stories in the temporally linear medium of film. These examples pertain to the plot of a film, and not to filming or cutting techniques.

*Run Lola Run*¹ is a movie that presents several possible successions of events sequentially throughout the film (compare *branching time* in Section 3.1.1). The individual episodes begin at the same point in time and show different possible strands of events.

The movie *Pulp Fiction*² comprises an even more complicated and challenging plot. It is a collection of different episodes that are semantically as well as temporally linked. Moreover, the movie ends by continuing the very first scene in the movie, thus closing the loop.

A further example of the use of interesting temporal constellations in film is the movie *Memento*³. The main character of the movie is a man who suffers from short-term memory loss, who uses notes and tattoos to hunt for his wife's killer. What makes the storytelling so challenging is the fact that time flows backwards from scene to scene (i.e., the end is shown at the beginning and the story progresses to the beginning from there).

Music videos are also often used as an innovation playground where directors can experiment with unconventional temporal flows such as the *reverse narrative* as used in Coldplay's *The Scientist*⁴.

Paintings A very interesting approach to overcoming the limitations of time can be found in *Renaissance* paintings. Here, sequences of different temporal episodes are shown in a single composition. Figure 2.36 for example shows a painting by Masolino da Panicale that presents two scenes in the life of St. Peter within a single scenery. While this method of showing different stages or episodes within a unifying scenery was well understood by the people at that time (the Middle Ages), it might not be as easily understood by a modern viewer. This technique provides evidence for the following statement:

[...] paintings have always been able to capture more than a fleeting moment in time.
Crabbe (2003)

The beginning of the 20th century was characterized by new findings and breakthroughs in the natural sciences, especially in mathematics and physics, such as Einstein's theory of relativity. But not only the world of science was shaken by these developments; artists also addressed these topics in their own way. Foremost among these were the protagonists of the art movement of *Cubism*, who focused on incorporating time in their artworks. They coined the term *Four-dimensional Art*.

¹ Run Lola Run (Lola rennt), written and directed by Tom Tywker, 1998.

² Pulp Fiction, written by Quentin Tarantino et al., directed by Quentin Tarantino, 1994.

³ Memento, written by J. and C. Nolan, directed by Christopher Nolan, 2000.

⁴ The Scientist, recorded by Coldplay, music video directed by Jamie Thraves, 2001.



Fig. 2.36: Masolino da Panicale, Curing the Crippled and the Resurrection of Tabitha (Brancacci Chapel, S. Maria del Carmine, Florence, Italy), 1420s. Different stages or episodes of a single person are shown within a unifying scenery.

Source: [http://commons.wikimedia.org/wiki/File:Cappella_brancacci,_Guarigione_dello_storpio_e_resurrezione_di_Tabitha_\(restaurato\),_Masolino.jpg](http://commons.wikimedia.org/wiki/File:Cappella_brancacci,_Guarigione_dello_storpio_e_resurrezione_di_Tabitha_(restaurato),_Masolino.jpg); Retrieved Feb., 2011.



Fig. 2.37 Marcel Duchamp, Nude Descending a Staircase (No. 2), 1912. The dimension time is incorporated by overlaying different stages of a person's movement. (Philadelphia, Philadelphia Museum of Art. Oil on canvas, 57 7/8 x 35 1/8' (147 x 89.2 cm). The Louise and Walter Arensberg Collection, 1950. © VBK, Vienna 2010.) Source: © 2010. Photo The Philadelphia Museum of Art/Art Resource/Scala, Florence.



Fig. 2.38 Pablo Picasso, *Portrait of Ambroise Vollard*, 1910. Many different observations are composed and partly overlaid to form a single picture. (Moscow, Pushkin Museum. © Succession Picasso/VBK, Vienna 2010.) *Source:* © 2010. *Photo Scala, Florence.*

According to [Volaric \(2003\)](#), the first documented occurrence of time as the fourth dimension appeared in Paris in 1910. As already mentioned, the concept of the n -dimensional space in mathematics and physics inspired artists to think about 4D space. Figure 2.37 shows Marcel Duchamp's painting *Nude Descending a Staircase* which incorporates the dimension of time in a very interesting way by overlaying different stages of a person's movement. Another example is Pablo Picasso's *Portrait of Ambroise Vollard* (see Figure 2.38), where many different observations are composed and partly overlaid to form a single picture. The artists wanted to put emphasis on the *process* of looking and recording over time (in contrast to taking a photo). These new ways of bringing the fourth dimension into the static domain of pictures are still a challenge to viewers today.

2.3 Summary

We have provided a brief review of relevant historical and application-specific visualization techniques and representations of time in the visual arts. Our aim was to provide an historical context for developments in this area and to present some ideas from related areas that might act as a further source of inspiration for designing visualizations. Furthermore, this chapter has demonstrated the enormous breadth of the topic which we are only able to cover in part.

Readers interested in more information about historical representations of time-oriented data and historical representations in general are referred to the wonderful books of Tufte (1983, 1990, 1997, 2006), Wainer (2005), and Rosenberg and Grafton (2010). Michael Friendly's great work on the history of data visualization can be studied in numerous articles such as (Friendly, 2008) as well as online in his Data Visualization Gallery⁵ and the Milestones Project⁶. Additionally, interesting historic facts related to time representations are discussed on the Chronographics Weblog⁷ of Stephen Boyd Davis.

Now, after setting the stage and considering various concepts and ideas from related disciplines, we will narrow our focus and present a systematic view of the visualization of time-oriented data. In this sense, we will first discuss important aspects that make the handling of time and time-oriented data possible. Following that, the visualization problem itself will be systematically explained and discussed.

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⁵ <http://www.datavis.ca/gallery/>; Retrieved Feb., 2011.

⁶ <http://www.datavis.ca/milestones/>; Retrieved Feb., 2011.

⁷ <http://chronographics.blogspot.com/>; Retrieved Feb., 2011.

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