Dynamic Visualization and Time

Markku Reunanen, marq@iki.fi

Introduction

Edward Tufte (1997, 23) asked five questions on a visualization in his book *Visual Explanations*: How many? How often? Where? How much? At what rate? At the end of the day, different representations of information try to answer these questions, regardless of the field of study or the technology in use. Be it traditional diagrams for a book or an interactive 3D application for the latest mobile gadget, the goal is to create an end result that is easy to understand, useful, and faithful to the original data.

In spite of its profound name, *dynamic visualization* simply refers to those representations that go beyond traditional *static* forms, such as printed media. Actually, most of the visualizations seen in digital media are plain static images, so being digital does not mean a lot in itself. The defining characteristics of dynamic visualization are animation, interaction and real-time – any one of these features is enough to meet the definition.

Dynamic visualization is a mundane tool in several fields, such as geology, medical science, statistics and economics (especially in the form of visual data mining). The great public has become increasingly aware of it in the form of various interactive visualizations on the Web. Often the authors are artists, hackers and activists, who want to open up people's perspectives on world events, or just play with visual representations. Artistic visualization may indeed act as a forerunner of or a comparison point to more "serious" data representations (see Viégas & Wattenberg 2007). A new player in the field is *open data*, which brings vast amounts of statistical data into everyone's reach.

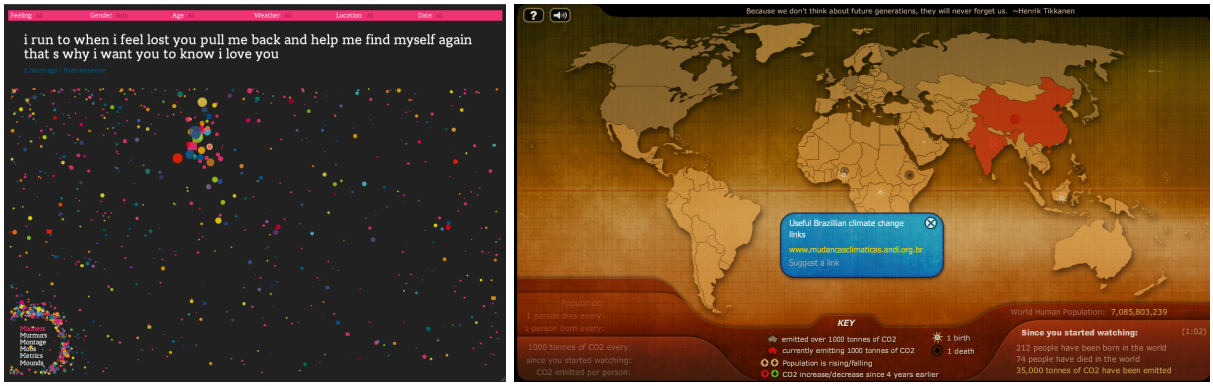

Figure 1: We Feel Fine and Breathing Earth

Figure 1 shows two examples of visualizations running inside a Web browser. *We Feel Fine* (http://www.wefeelfine.org/), developed by Jonathan Harris and Sep Kamvar, roams different blog services, collects sentences where an author describes their feelings, and visually groups similar posts together. *Breathing Earth* (http://www.breathingearth.net/), a simulation by David Bleja, depicts ecological themes, such as CO2 emissions, deaths and births in different countries. Regardless of the completely different topics, these two projects share numerous features, too: both of them can be used freely on the Web, animation is fundamental to both, the visualizations change in time, and it is possible to move to the details from the general overview.

Strengths of Dynamic Visualization

Probably the greatest strength of dynamic visualization is that it is possible to create different views to the same data. The Shneiderman (1996) *Visual Information-Seeking Mantra* crystallizes the essentials as follows: “Overview first, zoom and filter, then details-on-demand.” So, in addition to merely changing the scale of the representation visually, it is done also semantically: more details are shown on demand. In a static representation all the information needs to be visible at once, which leads to tricky problems even with relatively small datasets.

Another important strength is the real-time nature of dynamic visualization. A mundane example of it could be a temperature curve that is updated once an hour. Real-time is a wide topic – updates can happen in a fraction of a second, or in the other extreme once a year – what counts here is that we are not stuck with a fixed dataset. In addition to data retrieval, real-time is part of the presentation itself, when visual elements are brought to life by animating their properties, such as location, shape or size. The issue of time will be discussed further in the following sections.

In addition to being a tool for communication, dynamic visualization serves as a tool for exploration: grouping and regrouping of variables, highlighting and filtering support decision-making. A well-designed tool enables a process where the used observes an interesting phenomenon, forms hypotheses and immediately tests their validity. Colin Ware (2004, 317) called the process a *problem-solving loop*, which consists of a lower-order *exploration and navigation loop*, and a *data selection and manipulation loop*. In the best case interactivity can offer the user a rich and engaging experience, which could be tedious to create by static means.

Challenges of Dynamic Visualization

In addition to the strengths discussed above, it is important to be aware of the challenges that follow from moving from static to dynamic visualization. In practice, the biggest problems have to do with cost and skills. There are numerous reliable and affordable packages for dealing with, for example, statistical graphs, whereas dynamic visualization often requires time-consuming design, modification, and development of completely new tools. Digital technology becomes

obsolete quickly, so there is a constant need for updating and, eventually, replacing the technical platform with another.

In addition to just mathematical and visual skills there is a need for new know-how, most importantly on interaction and software design. The required skills can either be developed – with considerable effort – in-house or bought from the outside. All in all, the process of defining user needs, turning them into design decisions, and finally implementing a functional system, is by no means a trivial one. Examples of badly designed and implemented applications are definitely not hard to find.

Going dynamic does not somehow automatically solve the challenges involved in visualization. The freedom offered to the user does not make good design principles any less important, quite the contrary. In addition to mere freedom, we must offer meaningful default views, support natural workflows, and take into consideration the capabilities of human visual processing.

Depicting Time

Time is a central variable in almost any visualization. Events take place in time, so it is natural to depict their changes in relation to time. When is electricity consumption at its peak? When does the Christmas high season start? How has the value of a company developed during the last ten years?

Our linear concept of time, coupled with the Western reading direction from left to right, has created a strong convention, where the x axis of a graph represents time and the y axis a value dependent on time. In a two-dimensional coordinate system it is possible to show only the values of two variables at a time, and since the x axis is mainly reserved for time, there is a need to use other visual parameters, such as color, size and shape. Expanding a two-dimensional representation to the third dimension seems like an obvious solution, but especially in the case of static images it often creates more problems than it solves, by introducing clutter and occlusion. There *is* a time and place for 3D visualizations, but in those cases the data itself is spatial by nature (for further discussion, see Card, Mackinlay & Shneiderman 1999, 57–61).

Dynamic visualization provides one axis more: time itself. Events can be animated, either in real-time or with scaled time. Very slow phenomena can be sped up, or very fast ones slowed down. Any visual representation contains a story – either accidentally or intentionally – but especially in the case of dynamic visualization the possibilities for storytelling are numerous. One of the most important visualization principles proposed by Tufte (1997; 2001) is *comparison*, which can be achieved not only by multiple views, but also in time. In addition, movement is a strong to stimulus to our visual sense, which makes it a powerful means for highlighting (Ware 2004, 217).

Example: Gapminder

Gapminder World (http://www.gapminder.org/world/), developed by Hans Rosling and the Gapmider Foundation, utilizes most of the principles discussed above, and can be used as an example of a dynamic visualization that serves both basic purposes: communication and exploration. Gapminder shows UN statistics and lets the user follow how different variables have changed in time across nations and continents. It is possible to assess the interrelationships of two phenomena by freely selecting the variables for the x and y axes.

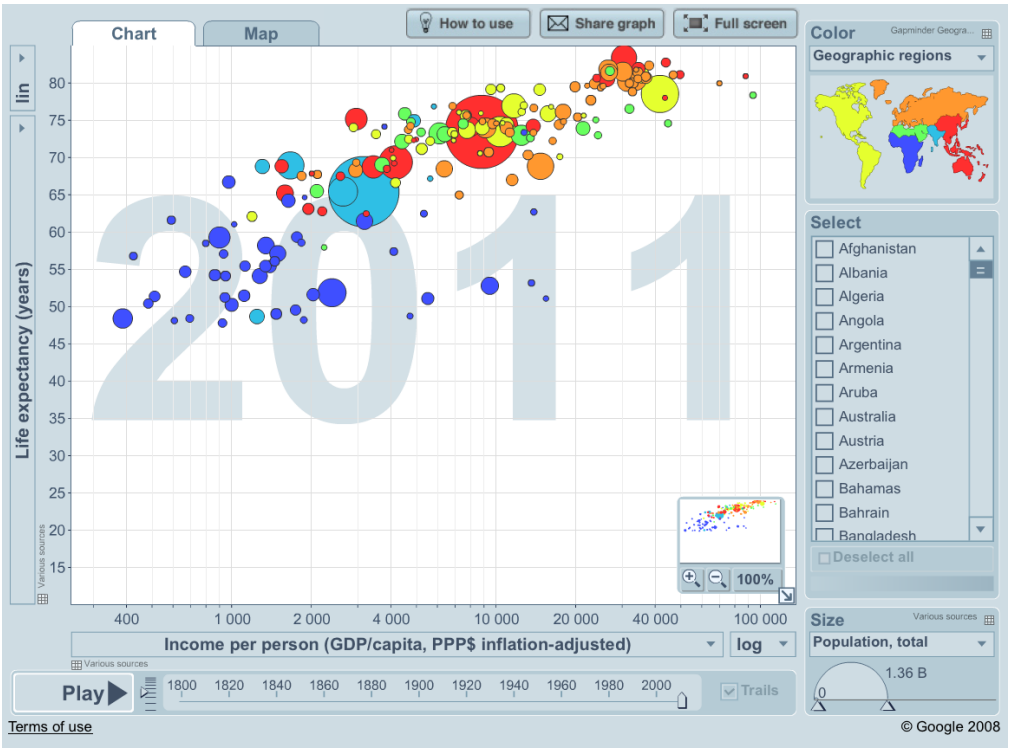

Figure 2: Gapminder World main view

The main functionality of Gapminder can be seen in Figure 2: variables can be selected for both axes, individual countries can be highlighted, the scale of the bubbles can be altered and the year selected. There are tens of datasets available on topics such as health, education and economy. Making health-related data understandable was one of the main uses right from the beginning (see Rosling & Zhang 2011). There's another tab with an interactive world map, but its uses are limited in comparison with the main view.

Next, let us consider how the principles of dynamic visualization are reflected in Gapminder. Especially the Shneiderman visual information-seeking mantra is clearly present: initially the user gets an overview of all the countries, after which it is possible to select individual countries and get to the details. The finest details of the data are not available through Gapminder, because the main focus has obviously been on large-scale changes over time. Another dynamic property is

the up-to-date dataset: UN figures from 2011 were already available in the fall of 2012.

Time is depicted through animation and a separate timeline, so the x axis could be used for other purposes. The slow movement of colorful bubbles tells dramatic stories that can be compared to real historical events. Wars, depressions and economic booms can be recognized on the graph and, most importantly, their effects on different countries can be seen side by side. Behind the minimalistic interface there is an abundance of easily accessible data, which provides a rewarding experience to anyone interested in the topic.

Conclusion

As the datasets we are dealing with get increasingly large, making them understandable becomes challenging – our cognitive skills do not improve at the same speed. Dynamic visualization offers new means for dealing with complexity, accessibility and validity. The strengths of dynamic visualization are so evident that they should be put into use, even if at the same time it brings challenges, such as the need for new workflows and skills. At the moment, when standards and tools are still under development, there is also added uncertainty since any technical solution will become outdated in a few years. At the end of the day, the need for dynamic visualization is determined by the target audience: what are the needs of the users and the most appropriate medium for them.

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