Temporal data visualizations for Air Traffic Controllers (ATC)

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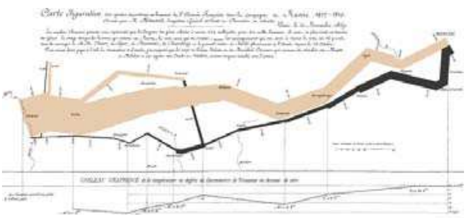
Introduction

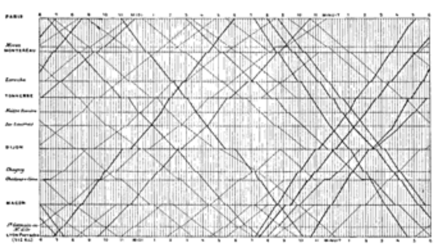
Fundamental research in visualization is concerned with the impact of presentation on visual perception and understanding [5] [6].

In current Air Traffic Control (ATC) environments, Air Traffic Controllers (ATCo) use several visualization systems: radar views, timelines, electronic strips, meteorological views, supervisions etc□ The information displayed is intrinsically temporal: aircraft positions that evolve over time, conflicts between aircraft at a given time, airspace congestions□ Each of these visualizations is rich and dynamic: it displays numerous visual entities that move and evolve over time. Furthermore, this considerable volume of information must be understandable with a minimum cognitive workload. As traffic increases and safety criteria become more demanding ATC requires this new kind of visualizations.

Our research focuses on the production of new *efficient* visualizations with temporal data. We characterize a more *efficient* visualization as one in which a greater volume of information can be perceived and understood with a smaller or equivalent cognitive workload (while at the same time reducing the error rate in the perception of the information)



Minard's visual history of Napoleon's Russian Campaign



This diagram, showing the time schedules of trains from Paris to Lyon and vice-versa, was published by Marey in his book.

Time and visualizations

Bertin [1] was the first to define representation rules that produce a non ambiguous representation: the semiology of graphics. This semiology is a complete system composed of signs and rules which permit the building of planar maps or diagrams. This system is a powerful tool to represent, memorize, understand and communicate information. It describes and explains perceptual phenomena and properties underlying the act of reading an abstract graphic. Bertin also introduces the variables that are used to code information visually: position, size, orientation, color. Bertin did not provide special rules for time representation. For us, time is just another data attribute in a dataset. However, noteworthy representations of temporal information do exist (Train schedule string-line graphics by Marey, Minard’s visual history of Napoleon’s Russian Campaign…). These graphics address a major event to show temporal data with a static representation. These views are not a simple time series (or timeline). In past works, we conducted a precise analysis designed to understand the temporal dimensions more fully. We used Bertin's work and we tried to characterize design choices [2]. Then, we tried to compare design choices with objective criteria [3]. Finally we sought new visualization to improve image efficiency

In this paper, we propose to illustrate one visual design that codes temporal information: The radar comet used by ATCo.

RADAR Comet:

It is very difficult to create a new design without any support. Nevertheless, we identify several different methods when building visual entities:

- An empirical approach: design based on trial and error methodology,
- A historical approach: design based on the continuity of previous work with a concern for adaptation to the given context,
- An ecological approach: design based on the respect of both physical and perceptual human factors
- A technological approach: design based on technological opportunities.

The design we propose to investigate is the Radar Comet. It instances all the mentioned sources of design. The first design source is the ecological design. A comet's visual properties were used for the first time in the early seventeenth century by Edmond Halley [4] (Figure 2) who coded the trade wind direction on a map. He coded the flow with a stroke. The comet has accurate design properties; it displays the direction of the shape and its tendency. The comet is composed of a bigger part, its head, and a smaller, its tail. Its head indicates the comet heading. The tendency indicates the direction. The curvature of this shape indicates if it is turning right or left and the degree of veering. This design is ecological in so far as it stems from our basic understanding of motion (drops in a puddle, shooting stars…). An ecological design is easily understandable

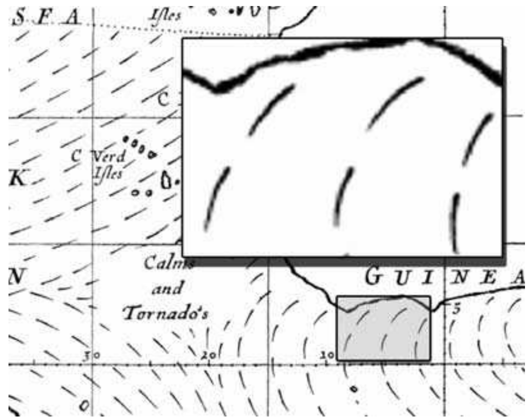


Figure 2: Halley's chart of the Trade Winds 1686.

ATC visualization derives some benefit of this comet. The design of the first radar comet is historical and technical. It is not directly based on the Halley design but on early radar equipment which relied on scope persistency (Figure 3). Old radar scopes retained the previous plot positions with the fading of the screen phosphor (ecological and technical design: the plot has a lifetime, the dot size and luminosity decrease over time). This kind of design has the same remarkable properties as the Halley-style comet: it displays the aircraft trajectory's curvature tendencies and shows if an aircraft is turning and the degree of veering. ODS is the main French radar view for the air traffic controllers. Its main goal is to display aircraft positions and to help ATCo to space aircrafts beyond the security minima. The radar track presents the aircraft positions, its speed (speed vector), name, altitude and speed as text (label). The design of the comet is built with squares, whose size varies with the proximity in time of the aircraft's position: the biggest square displays the latest position of the aircraft, whereas the smallest square displays the least recent aircraft position. Thus, in Figure 4, the shape of the comet indicates that the plane has turned 90° to the right and that it has accelerated.

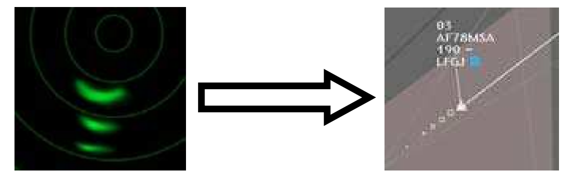


Figure 3: the shape decreases in intensity over time on a scope (left picture). ODS comet metaphor (right picture).

The positions of the aircraft merge through the effect of Gestalt continuity, in which a line emerges with its particular characteristics (curve, regularity of the texture formed by the points, etc). Furthermore, Gestalt continuity allows an occlusion resistance. This means that if there are many overlapping comets you can still distinguish each one.

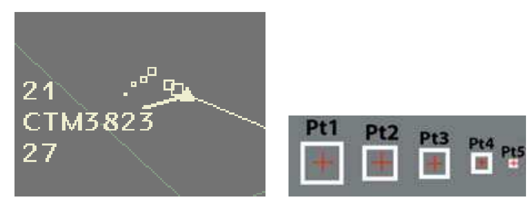


Figure 4: the French radar screen

The information coded by the comet is summarized in the following table. Italic script represents emerging information. For instance, the aircraft tendency data is not needed to draw the comet, but the comet nevertheless codes this information. The emerging process stems from the embedded time in the RADAR plot positions. The time can be easily derived into speed and acceleration.

The comet design is an efficient visualization of data time. The fact that the underlying data is temporal helps the reader to interpret naturally emergent information such as speed, tendency and acceleration.

ODS coded information	Visual code
Aircraft position	Position
ageing of each position	Size
Aircraft speed	Size (comet length)
Aircraft tendency (left, right)	Comet curvature
Aircraft acceleration	Regular/irregular point spacing
Aircraft entity	Gestalt (proximity and size)

Conclusion:

In this paper we depict only one simple visual design used by air traffic controllers but it remains noteworthy through its numerous roots and the impressively large amount of coded information. This design illustrates the emerging information process. ATC use several other interesting temporal designs.

The comet design addresses some issues: the design is efficient because it displays more information than the simple aircraft positions (emerging information). Furthermore, this design is easily understandable because is ecological (metaphor of the phosphor persistency, and the comet design).

We should be very interested in participating in any workshop focussing on temporal data, especially if it addresses representation issues. The perspective of a special journal issue is also a promising project. The representation of temporal data is a part of the work of one of our Ph.D students. Therefore, we should be eager to take part and to benefit from the opportunity to contribute our expertise and our visualization experience.

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