CEPIS UPGRADE is the European Journal for the Informatics Professional, published bi-monthly at <http://cepis.org/upgrade>

Publisher
CEPIS UPGRADE is published by CEPIS (Council of European Professional Informatics Societies, <http://www.cepis.org/>), in cooperation with the Spanish CEPIS society ATI (*Asociación de Técnicos de Informática,* <http://www.ati.es/>) and its journal Novática

CEPIS UPGRADE monographs are published jointly with Novática, that publishes them in Spanish (full version printed; summary, abstracts and some articles online)

CEPIS UPGRADE was created in October 2000 by CEPIS and was first published by Novática and INFORMATIK/INFORMATIQUE, bimonthly journal of SVI/FSI (Swiss Federation of Professional Informatics Societies)

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Cover page designed by Concha Arias-Pérez
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Layout Design: François Louis Nicolet
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ISSN 1684-5285

Monograph of next issue (October 2011)
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CEPIS UPGRADE
The European Journal for the Informatics Professional
http://cepis.org/upgrade
Vol. XII, issue No. 3, July 2011

Monograph
Business Intelligence
(published jointly with Novática*)
Guest Editors: *Jorge Fernández-González and Mouhib Alnoukari*

UPENET (UPGRADE European NETwork)

CEPIS NEWS

* This monograph will be also published in Spanish (full version printed; summary, abstracts, and some articles online) by **Novática**, journal of the Spanish CEPIS society ATI (*Asociación de Técnicos de Informática*) at <http://www.ati.es/novatica/>.

Business Information Visualization

Josep-Lluís Cano-Giner

Managers have more and more data available and less and less time to access it, as they need to make decisions quickly. Its correct representation can become a key element for facilitating decision making. The paper starts with a review of the history and importance of information visualization. We also provide an example of how this visualization can be improved, and we conclude with an account of new needs that are arising in this field, as reflected by both organizations and their managers.

Keywords: Business Intelligence, Graphical Representation, Information Visualization, Management Information Systems.

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1 Introduction

The applications used by organizations are generating ever larger amounts of information. This information is handled in real or almost real time. Knowledge creation and decision making are the two main reasons why organizations store information, along with operations support and the need to fulfil legal obligations. Both reasons depend on the criteria of individuals, who have to use the visualization of the presented information to extract key aspects that will enable them to recognize hidden patterns or trends. The visualization thus becomes the interface between computers and people's minds. The cognitive capacities of humans have limitations; by visualization we mean the process of transforming data, information and knowledge into a representation to be used in a way that shows an affinity with the cognitive capacities of human beings.

2 Examples from the History of Information Visualization

Several authors have investigated the history of information visualization, most notably Tufte [1]. Here we will look at three examples provided by three different authors corresponding to three different representations, with the aim of showing both the advantages and the disadvantages of using information visualization.

In 1786, the Scottish engineer William Playfair realized that economic transactions could easily be represented graphically. Furthermore, in his opinion, representation using time series and bar charts simplified understanding and retention. The author published his *Commercial and Political Atlas*, in which he described England's foreign trade. It also included, for the first time, a new type of graph: the pie chart. In Figure 1 we reproduce a graph of the exports and imports between England and Denmark plus Norway [2]. In it we clearly see the moment at which the sign of the balance of trade between the two countries changes, together with the growth of the balance in England's favour.

One of the most famous examples of information presentation was provided by Charles Minard, a French civil engineer who used visualization to tell the story of Napoleon's tragic march on Moscow[1] in 1812. In the diagram of Figure 2, he used a coloured bar, the width of which indicated the size of the army (originally 422,000 troops), to show how the forces gradually dwindled as they approached

[1] See <http://www.math.yorku.ca/SCS/Gallery/images/minard.gif>.

" Correct representation of data can become a key element for facilitating decision making in organizations "

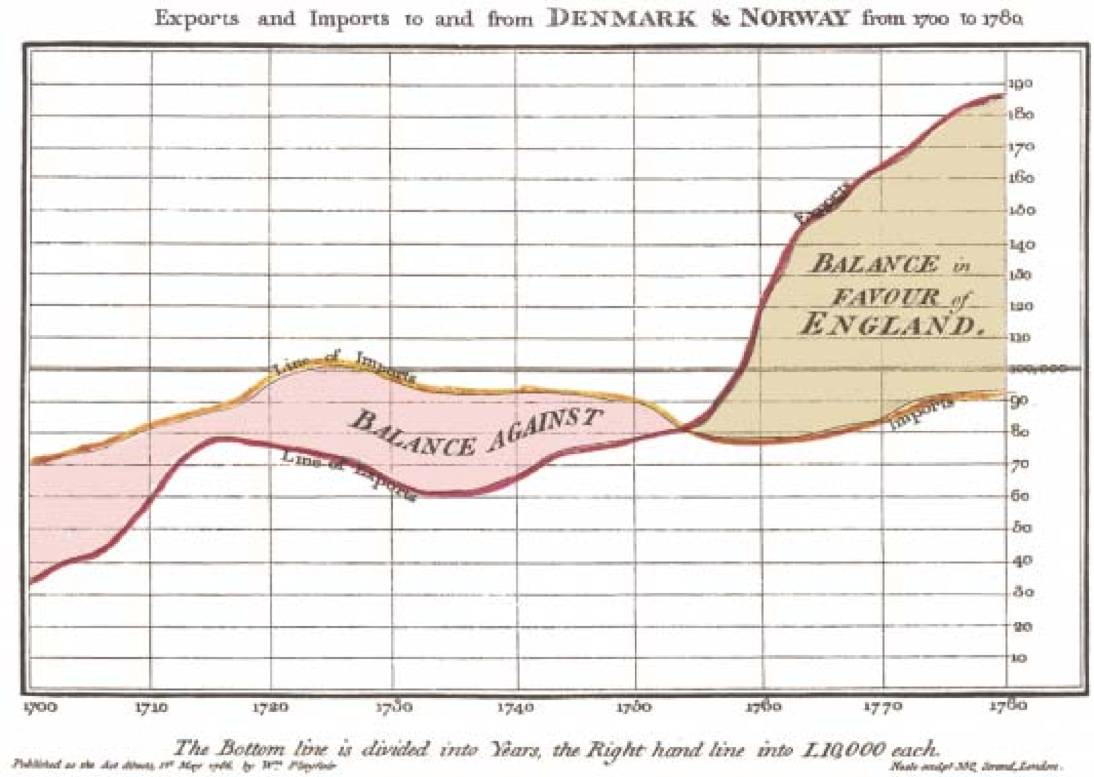


Figure1: Exports and Imports between Denmark and Norway from 1700 to 1780. [Source: W. Playfair.]

the Russian capital. In turn, another bar, this time black, indicated those who returned from Moscow (only 10,000 troops got home). At the foot of the diagram we find the outdoor temperatures, which were the soldiers' greatest problem. In the middle of the diagram, we see the widening of the black bar, due to the incorporation of stragglers who had tried to advance on the left flank, and also the dramatic narrowing when they had to cross a river with icy water. At the end of the retreat, we can compare the width of the two bars: the coloured bar representing those who set out, and the black one, those who returned. A simple diagram shows us the course of history in a very powerful manner. Robert Spence [3] wonders if we could listen to Tchaikovsky's 1812 overture and view the diagram at the same time[2].

[2] The reader can perform this exercise by accessing <http://www.youtube.com/watch?v=k-vQKZFF-9s&feature=related> [last accessed 5.1.2011]. This overture, Op. 49, was composed to commemorate the victorious Russian resistance in 1812 against the advance of Napoleon Bonaparte's Grande Armée. The overture was premiered in Moscow on 20 August 1882. The work is recognized by its triumphant finale, which includes a salvo of cannon fire and the pealing of bells.

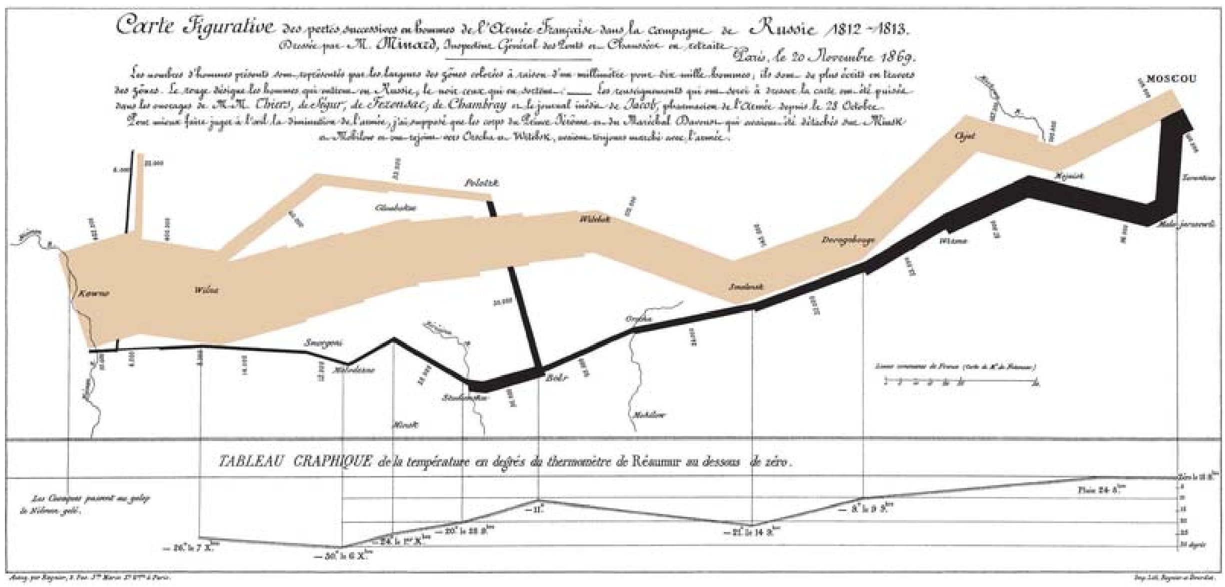


Figure 2: Map of Napoleon's Forces in the Russian Campaign. [Source: Charles Minard, 1861.]

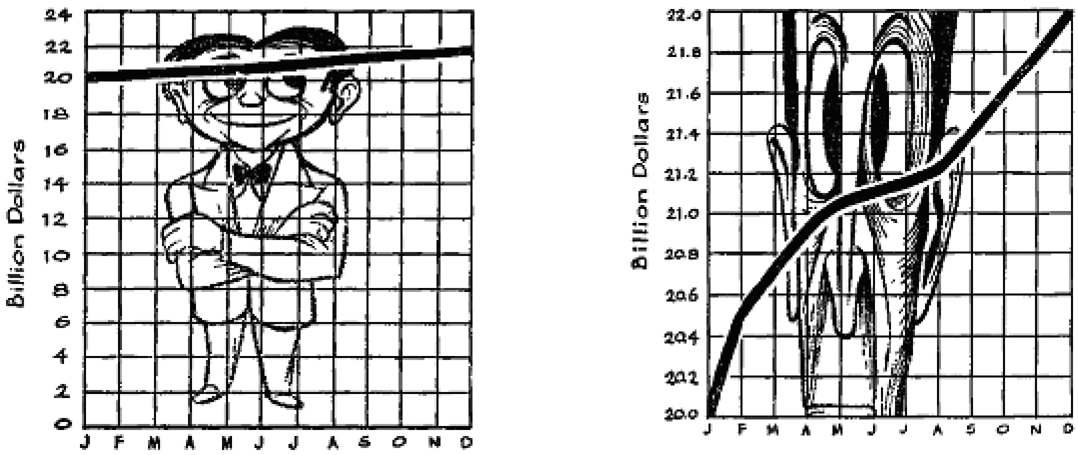
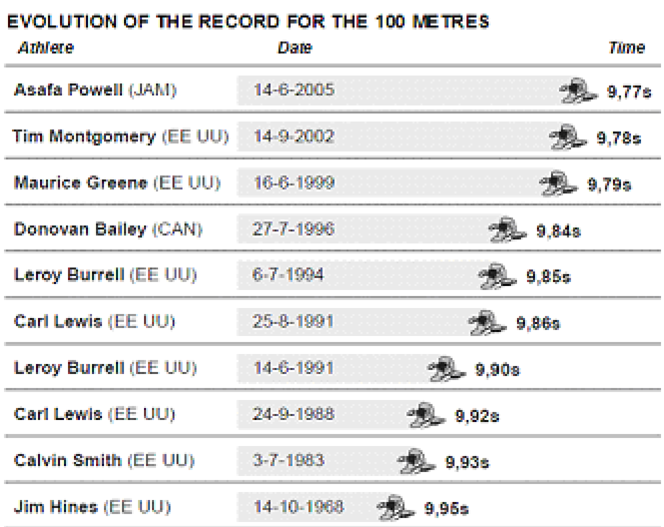


Figure 3: Graph showing how a Figure changes when the Scale of the Axis changes. [Source: Darrell Huff.]

In 1954, Darrell Huff published *How to Lie with Statistics* [4], in which he showed how the graphical representation of statistics can be manipulated to support different, sometimes conflicting, interests. Obviously his great contribution was to show us how to do it right. In Figure 3 we provide an example of the representation of a line graph that is very useful for depicting trends or forecasts. The X-axis (the horizontal one) indicates the months of the year, while the Y-axis (the vertical one) displays the volume; for example, of sales in billion dollars. In the left-hand graph the information is represented correctly: the Y-axis starts at 0 and the distances between the values of the two axes are equivalent. On the other hand, in the right-hand graph the Y-axis starts at 20, with the result that the expression of the character who appears superimposed on the graph changes to one of astonishment at the results obtained.

In reviewing three of the historical examples of information visualization we have highlighted, in the first case, the importance of representing information to grasp what is happening; in the second, that a good representation of information enables us to understand a situation better; and in the third, that if the representation of the information is manipulated, intentionally or otherwise, it can bring us to interpret the facts wrongly. If the representation is right we will be able to make the right decisions, but what will happen if someone manipulates the representation to other ends?

> “ Information visualization is defined as ‘*The use of computer-supported, interactive, visual representations of abstract data to amplify cognition*’ ”



EVOLUTION OF THE RECORD FOR THE 100 METRES

Athlete	Date	Time
Asafa Powell (JAM)	14-6-2005	9,77s
Tim Montgomery (EE UU)	14-9-2002	9,78s
Maurice Greene (EE UU)	16-6-1999	9,79s
Donovan Bailey (CAN)	27-7-1996	9,84s
Leroy Burrell (EE UU)	6-7-1994	9,85s
Carl Lewis (EE UU)	25-8-1991	9,86s
Leroy Burrell (EE UU)	14-6-1991	9,90s
Carl Lewis (EE UU)	24-9-1988	9,92s
Calvin Smith (EE UU)	3-7-1983	9,93s
Jim Hines (EE UU)	14-10-1968	9,95s

Figure 4: Graph of the Evolution of the World Record for the 100 Metre Race. [Source: El País, 15/06/2005.]

3 Visualizing Information

Information visualization is used in fields as varied as medicine, engineering, statistics, business and even sport. We have chosen the last of these to illustrate the difficulties that are – or may be – encountered in presenting information graphically, through a graph (see Figure 4) published in a well-known Spanish newspaper[3]. The graph is reproduced below as published, showing the world record for the 100 metre race through history: the athletes, their nationality, the date the new record was set, and the times. The graph also includes a grey bar together with a picture of a sprinter. The reader may be surprised to find that the

[3] The article "Huracán Powell" appeared in El País on June 15, 2005.

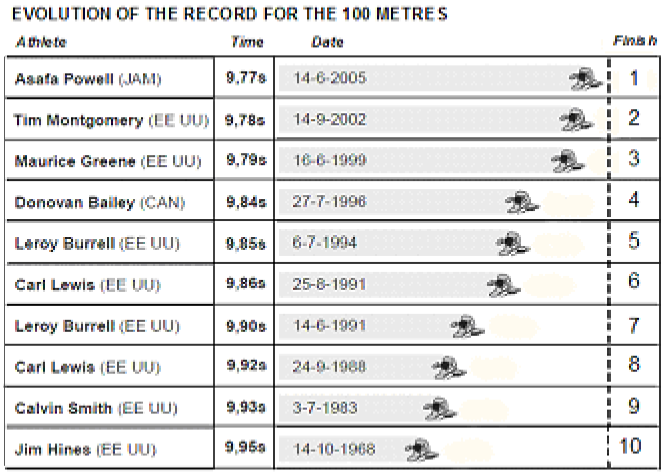


Figure 5: Proposed Graph of the Evolution of the World Record for the 100 Metre Race. [Source: Author.]

“In 1786, the Scottish engineer William Playfair realized that economic transactions could easily be represented graphically”

longest bar belongs to the fastest time. I was surprised too.

After analysing the graph for a while, I realized that what the author was trying to represent was what the finish line would have looked like if the race had been run by the 10 sprinters who held the world record for the 100 metres (Carl Lewis and Leroy Burrell broke the record twice, so they would be running in two lanes).

Working on the above graph, we could propose some improvements, for instance adding the finish line to the graph and changing the position of the times to make them easier to read and understand. We propose a possible solution in Figure 5.

Assuming that the proposed representation makes the information easier to interpret, we could now go on to ask ourselves whether the gap represented between the sprinters corresponds to the real gap. Using the data provided, we can calculate that the gap between the first record and the last would be 1.81 metres, i.e., in the 9.77 seconds that Asafa Powell took to run 100 metres, Jim Hines would have run 98.19 metres. So, does the gap between the sprinter and the finish line correspond to 1.81 metres? To answer this question we represent the distances by making use of spreadsheet graphics[4]. The result is shown in Figure 6.

[4] In Figures 6 to 10, we have omitted the presentation of values in order to facilitate understanding of the effect that we want to show with the graphic.

Figure 6: Graphic of the Evolution of the World Record for the 100 Metre Race, starting at 0 Metres. [Source: Author.]

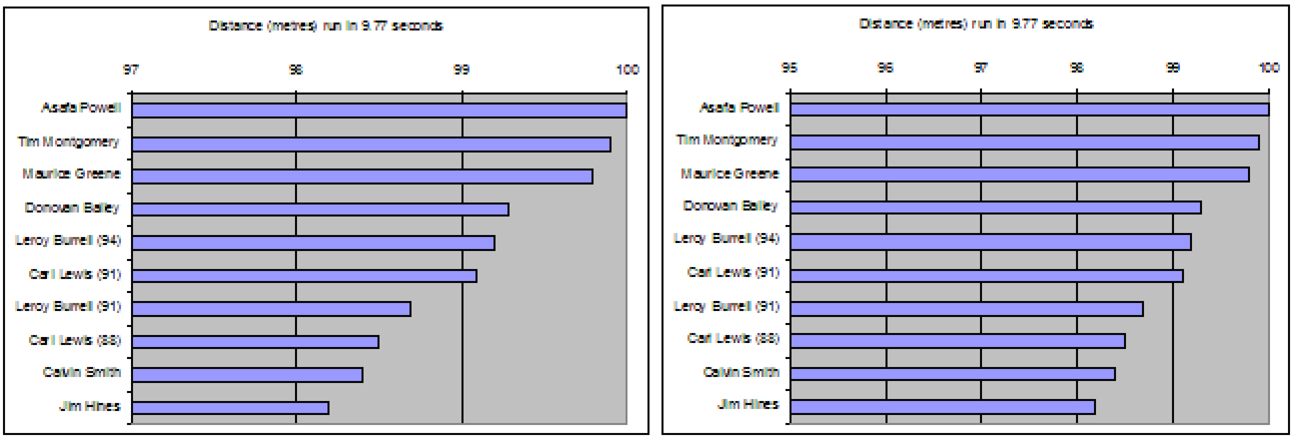


Figure 7: Graphic of the Evolution of the World Record for the 100 Metre Race, starting at 97 and 95 Metres. [Source: Author.]

It is apparent at a glance that the gaps between the sprinters have shrunk in relation to the original graph. What has happened? In the original graph the values of the X-axis are not shown, so we might wonder what value they start at.

In Figure 7 we present two graphics. The left-hand graphic starts at 97 metres, and the right-hand one at 95 metres.

If we change the lower limit of the X-axis when visualizing the graphics, the person who analyses them may interpret them differently, and this may bring them to make a different decision.

We might also ask ourselves whether distance run is really the best variable to represent the differences between the various world records for the 100 metre dash. Alternatively, we could focus on speed, i.e., metres per second, to show the difference between sprinters.

In Figure 8 we show the graphic of the speeds obtained in the 10 world records we are contemplating. In this case

> “In 1954, Darrell Huff published *How to Lie with Statistics*, in which he showed how the graphical representation of statistics can be manipulated to support different, sometimes conflicting, interests”

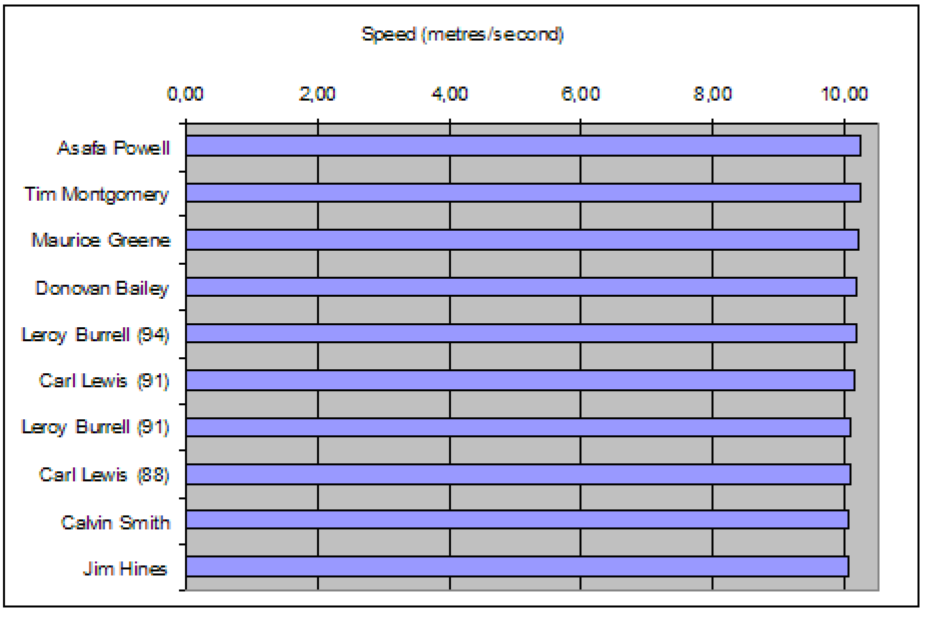


Figure 8: Graphic of Speed of World Records for the 100 Metre Race. [Source: Author.]

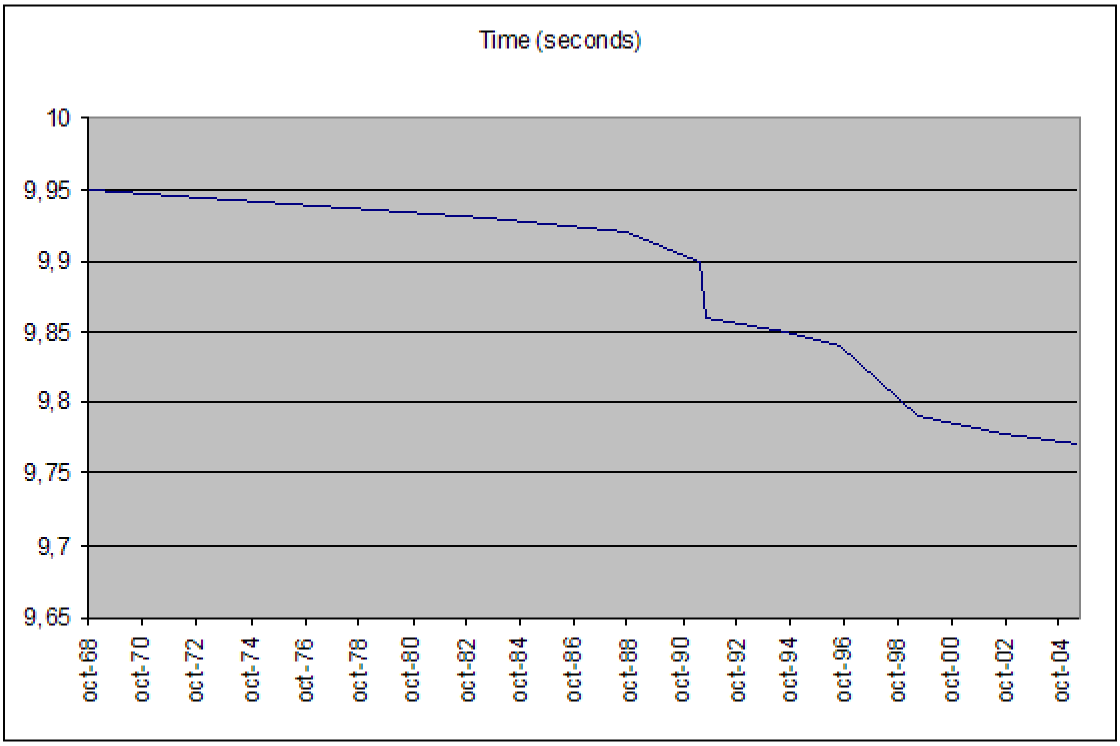


Figure 9: Graphic of the Evolution of the World Record for the 100 Metre Race, starting at 9.65 Seconds. [Source: Author.]

we only present the graphic in which the X-axis starts at 0, since if it started at some other value we would find the same as in the previous case. The difference in metres per second is only 0.19 between the first and the last.

Let us go a little further in the analysis. Returning to a historical perspective, we could ask how the 10 fastest 100 metre world records have evolved over time[5].To do this,

[5] It is very important to stress that we are not asking about how the 100 metre world record has evolved throughout history. To answer this question we would need to have all the world records, and it is not the purpose of this paper to analyse them.

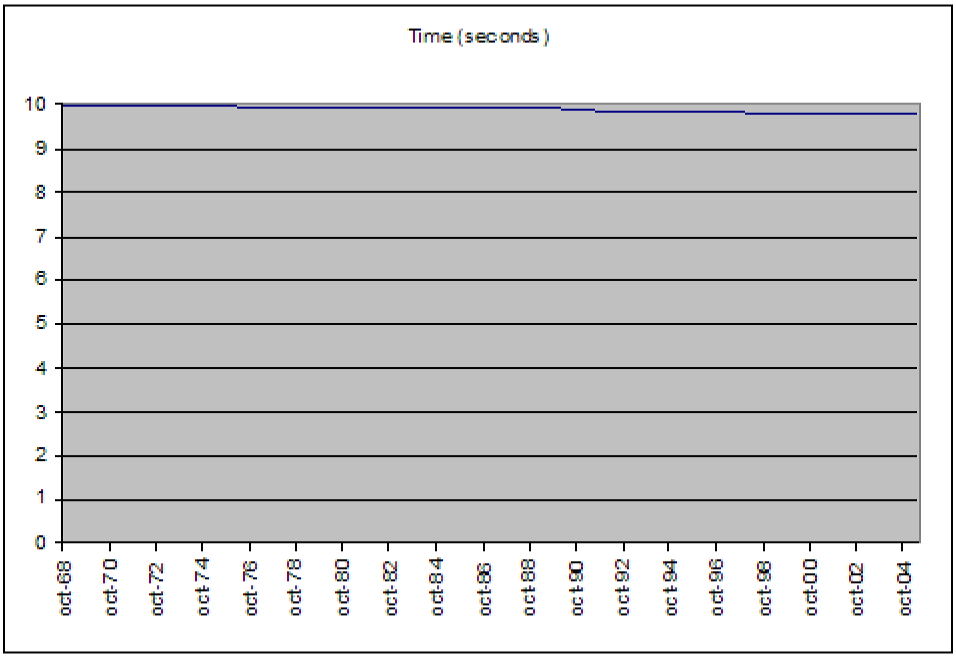


Figure 10: Graphic of the Evolution of the World Record for the 100 Metre Race, starting at 0 Seconds. [Source: Author.]

Date	Record	Athlete	Nationality	Time (seconds)	Time lag %	Speed (m/s)	Distance in metres run in 9.77s
14/06/2005	1	Asafa Powell	JAM	9,77	0,00%	10,24	100,00
14/09/2002	2	Tim Montgomery	EEUU	9,78	0,10%	10,22	99,90
16/06/1999	3	Maurice Greene	EEUU	9,79	0,20%	10,21	99,80
27/07/1996	4	Donovan Bailey	CAN	9,84	0,72%	10,16	99,29
06/07/1994	5	Leroy Burrell (94)	EEUU	9,85	0,82%	10,15	99,19
25/08/1991	6	Carl Lewis (91)	EEUU	9,86	0,92%	10,14	99,09
14/06/1991	7	Leroy Burrell (91)	EEUU	9,90	1,33%	10,10	98,69
24/09/1988	8	Carl Lewis (88)	EEUU	9,92	1,54%	10,08	98,49
03/07/1983	9	Calvin Smith	EEUU	9,93	1,64%	10,07	98,39
14/10/1968	10	Jim Hines	EEUU	9,95	1,84%	10,05	98,19

Table 1: Evolution of the World Record for the 100 Metre Race. [Source: Author.]

“If the representation is right we will be able to make the right decisions, but what will happen if someone manipulates the representation to other ends?”

	Objectives of graphics	Original graph of the world record for the 100 metre race
1	Tufte suggests that we should simply show the data. Sometimes graphic designers tend to show aggregations of data instead of the data itself.	The sprinters’ countries are given next to their names. If they are made to appear in a separate column the information will be easier to read and the preponderance of US sprinters will be better reflected.
2	He suggests that we ensure that the user is thinking about the substance of the graphic and not the graphic itself.	In order to interpret the graph it was necessary to recognize that the author was attempting to represent the finish line of a hypothetical race between the last 10 record-holding sprinters. The ranking of each record should be indicated.
3	Avoid all unnecessary decorations.	The representation of the sprinters is not necessary.
4	Compress as much information as possible into as small a space as possible.	Metres run or the speed of each record could have been included.
5	Graphics should be designed to encourage the user to make comparisons between different pieces of data.	The times are not aligned, which makes them difficult to compare.
6	Graphics should provide views of the data at many levels of detail.	As we are dealing with a single non-interactive graph, this does no apply.

Table 2: Tufte’s Principles compared to the Original Graph of the World Record for the 100 Metre Race. [Source: Author.]

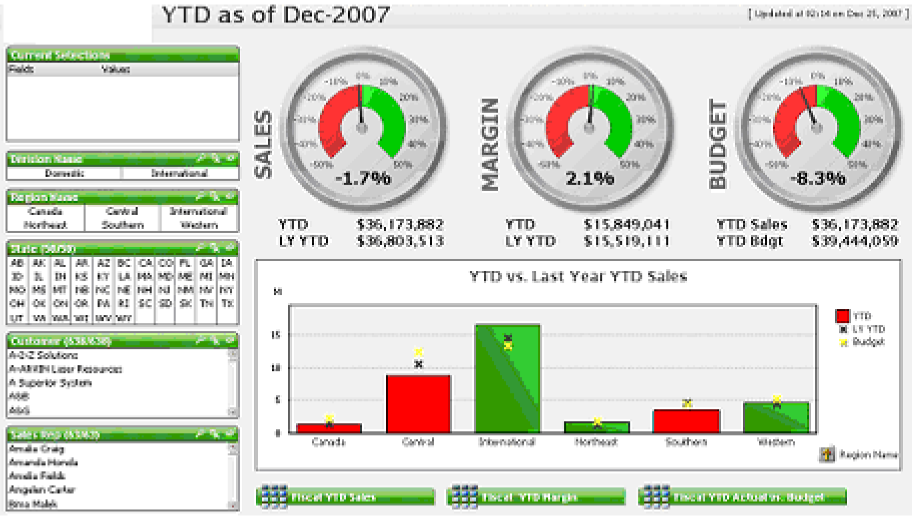


Figure 11: QlikView Dashboard Example.

the other sprinters would have run in the time it took Asafa Powell to reach the finish line.

If the conclusion is that the best way to understand this situation is to use the table with values, then this is the best representation. This decision probably comes down to personal choice, and at the same time is influenced by each person's knowledge of the results of the 100 metre event. That is to say, it depends not only on who represents the information, but also on who visualizes it. We might ask ourselves whether it always makes sense to establish an invariable format for reporting over the years, as most organizations do, on the grounds that by not changing the format they facilitate interpretation, or whether we should change it in order to achieve an improvement in the visualization if we want to find a better representation of changes that have taken place in the data.

we can use a graphic indicating the values over time. The default graphic offered by the spreadsheet is shown in Figure 9.

Again, a cursory glance might lead us to a wrong conclusion: that the record has been slashed, as the slope is steep. But if we start the Y-axis at a value of 0, the graphic changes significantly (see Figure 10).

It might look as if no times have been plotted in the above graphic. However, if we look carefully we find that there is a line between the values 9 and 10 seconds, with a slight downward slope over about 37 years.

In other words, it has taken nearly 37 years to reduce the time by 10 hundredths of a second, which means about 5 thousandths of a second each year. The second graphic seems to reflect this situation better than the first. In the extreme, two different representations of the same data can lead us to two conclusions that may even contradict each other.

Through graphical representation, we have enabled those people who were interested in the phenomenon under analysis to grasp what has actually happened in the last 10 world records for the 100 metres, the little difference there is between them, and the difficulty involved in improving on them. Perhaps it would have been better to use another sort of graphical representation: a table with the values and the calculations used to represent them graphically. Three new columns have been added to Table 1: the percentage time lag behind the fastest record, speed in metres per second, and the distance

4 Information Visualization

According to Card et al. [5], information visualization is defined as "*The use of computer-supported, interactive, visual representations of abstract data to amplify cognition*"

The authors differentiate it from scientific visualization, which is usually based on physical data.

The same authors have carried out a literature review[6], at

		Close	Max	Min
AT&T		40,28	41,34	33,30
Boeing		98,15	100,59	84,79
Citigroup		53,98	55,20	48,27
Exxon Mobil		85,94	85,94	69,56
General Electric		38,12	38,12	34,09
General Motors		34,66	36,20	28,85
Intel		24,24	24,24	18,76
Microsoft		30,49	31,11	26,63

Figure 12: Table of Changes in Market Prices. [Source: <http://www.edwardtufte.com>.]

❝ Information visualization is used in fields as varied as medicine, engineering, statistics, business and even sport ❞

> "We might ask ourselves whether it always makes sense to establish an invariable format for reporting over the years, or whether we should change it in order to achieve an improvement in the visualization"

the same time justifying how visualization amplifies cognition, or in other words, the concept of cognition (from the Latin *cognoscere*, "to know") refers to human beings' faculty of processing information through perception, acquired knowledge and the subjective characteristics that allow them to evaluate it.

Note that the proposed definition includes the term *interactive*, as nowadays representations are usually based on the use of computers, thus allowing interaction between the user and the computer application.

Those readers who wish to go deeper into the definition of *visualization*, the various technologies that support it or the relationship between cognitive theories and problem solving tasks, as well as visual representations, are referred to the paper by Tegarden [6].

In this paper, Tegarden summarizes the six objectives that any graphic should meet according to Tufte [1][7]. In Table 2, these objectives are related to the original graph of records for the 100 metres that we have used as an example.

5 Business Information Visualization

Managers need information to make decisions, and they need it to be presented in such a way as to facilitate its interpretation. To this end, organizations usually develop business intelligence projects. One of the key aspects of these projects is the correct representation of data. In the present paper we will not deal with the basic concepts of data representation. For this, the bibliographical references given below provide an ample in-depth account of this issue. Nevertheless, we will give attention to new trends and needs in visualization. One of the authors who stand out most in this field is Stephen Few [8]. In his view, the information visualization of the future will have to cope with new needs, as discussed below.

- *Dashboards and scorecards*: Managers need to be able to access data that will enable them to analyse the situation in a short space of time, in such a way that once a problem has been detected, a few clicks with the mouse are enough to get down to the right level of detail to grasp what is happening and take corrective measures. Scorecards represent perspectives of strategic areas, objectives, measures, and stoplight indicators, whereas in dashboards the information presented can vary considerably and usually includes graphical representations. In dashboards the complexity of the information visualization increases, as they can be used to present interrelated data or graphics. In most cases it is also necessary to present a large amount of information in a very limited space (see Figure 11).
- *Geospatial visualization*: When data is land-based, in situ visualization is becoming increasingly necessary. From the well-known geographic information systems (GIS) to Google Earth and various types of web services, we find media that can enable us to relate sales or expenses, for example, to geographical variables.
- *Animated scatter plots*: In some cases we need to compare two magnitudes, e.g., investment in advertising and sales over time. To do this, it is necessary to make use of a new type of representation that includes animations to convey the passing of time. One of the best examples of animated data representation is <http://www.GapMinder.org>, where we can see, for example, the relationship between income per person in different countries and their child mortality rate over time.
- *Treemaps*: One example of this type of graphical representation is the trading volume on the New York Stock Exchange, aggregated by industry in such a way as to allow the viewer to compare prices and see how they have changed from the day before (available at <http://www.SmartMoney. com>).
- *Sparklines*: This type of graphical representation is characterised by its small size and high data density. It is common practice to use several at once in order to represent different information that can sometimes be complementary. The term *sparkline* was proposed by Edward Tufte, who described them[7] as "small, high-resolution, simple, word-sized graphics". An example of a sparkline is shown in Figure 12.

> "Organizations develop business intelligence projects; one of the key aspects of these projects is the correct representation of data"

[6] Table 1.3 on page 16 of the book cited in reference [5].

[7] More examples are available at <http://www. edwardtufte.com/bboard/q-and-a-fetch-msg?msg_id=0001OR&topic_id=1>.

> " In any business intelligence project we should ensure that the graphical representation is the most appropriate one, and therefore we need specialists to this end "

■ *Representing relationships*: Sometimes we need to represent relationships among entities, such as among websites. Each entity acts as a node in a network, and has links with others. One example is Vizster showing people networks, (see <http://hci.stanford.edu/jheer/projects/vizster/early_design/>).

6 Conclusion

Information visualization needs have changed over the ages. The time available to managers to make decisions has become shorter and shorter, and new needs have arisen. As a result, researchers have proposed – and will continue to propose – new solutions to meet them. Correct representation of data should facilitate its interpretation and shorten the time managers have to spend on it, and this stands as the main purpose of information visualization.

If the information visualization is not the right one it may cause managers to make the wrong decisions. In this paper we have presented several examples in which the visualization of information in a "manipulated" fashion could lead to wrong interpretations, with the attendant increased risk of a mistake being made by management. In any business intelligence project we should ensure that the graphical representation is the most appropriate one, and therefore we need specialists who can guarantee this with the minimum information visualization. Without the right representation we will not provide the value that is expected, and we will be hard pressed to retain management's interest in using this solution.

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