Wrongfully right: applications of semantic figurative metaphors in information visualization

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ABSTRACT

Semantic figurative metaphors modify visualization models and add non-data visual cues to visualizations. They result from an authorial intent to transmit stronger messages and emotionally connect with broad audiences. This article describes how I make use of semantic figurative metaphors across three applications, discussing design decisions and the limitations of this approach.

Keywords: information visualization, visual metaphors, figurative metaphors, information design.

1. INTRODUCTION

Vande Moere and Purchase place visualization on three major axis: visualization studies, visualization practice and visualization exploration [31]. Although I made contributions in visualization studies through advancing techniques such as animating circular cartograms where motion has information properties [11]; devising a specific swarm-based edge bundling [24], or creating a model for edge-based traffic cartograms [7], I place my work on a more exploratory side of visualization. Rather than discussing how artistic my approach is, I emphasize that it is communicational and emotional driven. The three works presented here fall in the umbrella term "casual information visualization" [25]. Casual Infovis is characterized by targeting a broader audience, including a wide spectrum of users, from experts to novices. The usage pattern of these users can include both momentary and contemplative usages of the visualizations. Furthermore, the relationship of the user with the data is more tightly coupled, since the authors of casual information visualization are not strictly interested in providing analytical insights, but instead focus on providing awareness, social and reflective insights.

The visualizations presented here, range diverse topics, such as the decline of Empires, the traffic in Lisbon, and the political-corporate relations in Portugal. They present provocative perspectives on common topics, making use of semantic figurative metaphors. These metaphors try to cause an emotional response in the viewers while clearly communicating a meaningful data story. From a purist point of view [30], this comes at some expense of what is regarded good practice in information visualization – the addition of visual embellishments is regarded as superfluous, color could be used in a more sober way and some effects induce errors in the accurate portrayal of information.

> "Tufte's purist point of view is profound and compelling, but it may be overly restrictive. Information graphics have a role to play in the realm of expressive and editorial graphics. (…) They can be clean and reductive or richly expressive, creating evocative pictures that reveal surprising relationships and impress the eye with the sublime density and grandeur of a body of data."
>
> — Ellen Lupton [20, p. 199]

I argue that having a less restrictive approach to visualization can be justifiable and can result in effective visualizations. This article explains the unifying concept behind my approach – *semantic figurative metaphors* – while discussing its strengths and limitations. Furthermore, I explain the major design decisions made in light of this concept, showing that they have to be articulated with the nature of each dataset and with the message that I propose to communicate as an author.

2. SEMANTIC FIGURATIVE METAPHORS

Visual metaphors are an intrinsic part of visualization. They are models used to bring data to the cognitive space and thus structure information – they are "a set of structural properties that provide a framework for meaning" [35]. These structural metaphors can be simple models such as a pie chart that uses the metaphor of parts of a whole, a tree to depict hierarchy, a treemap to show containment [35] or a simple line graph to portray a trend [34]. Cox [6] calls these structural metaphors visaphors and reflects that they are entrenched in our culture in a way that we no longer recognize their metaphorical nature are thus interpret them as literal or conventional. They are often generic and dependent on the structure of the data, but can be highly figurative as well, such as Chernoff faces [3], trees [19], cartograms [28] or flow layouts [15].

Semantic figurative metaphors are more specialized metaphors added to these familiar structural models. They are not dependent on the structure of the data, but allude to the content of it, and thus are the concretization of the designer's own interpretation and message. For this, they have a semantic nature when the designer assumes a role as an author. Furthermore, they are figurative in the sense that they are less abstract and give more concrete and emotional visual references to connect with the audience. They are not embellishments without a purpose, but carry a well founded metaphoric intent. Perhaps a radical example of this are Nigel Holmes' charts [16], being often simple graphs integrated into illustrations that are strongly figurative on the data topic. Tufte mentions them as chartjunk [29, pp. 34-35], but Few considers them more of a well-executed and justifiable style of embellishment [14]. A question puts in how to apply these semantic figurative metaphors in more subtle ways for complex data. A good example of this is We Feel Fine [17], an application that harvests and displays emotions on the blogosphere in a series of visualizations. The authors' metaphorical intent of emotions is clear: individual data points are represented as a "playful" swarming particle system in order to show a "bird's eye view of humanity" and bars in a graph are replaced by large jiggling bulbous mounds. Neither the particles' positions nor the shape and jiggle of the bars are strictly data related, but instead reflect the authors' own view on the data and how they visually interpreted a live stream of actual people's feelings.

In my approach, implementing semantic figurative metaphors encompasses two steps – **a) adaption of the structural metaphor:** after an adequate visualization model is chosen, it is modified, namely by evading the model's rules of spatial arrangement, and making room to carry specific and new metaphors; **b) introduction of visual cues**: visual cues are added on top of the model, that modify its graphical implantations, seeking to provide a more figurative evidence of the new metaphors. The next section explains, for three applications, which structural models were chosen, how they were modified, and which design decisions were made in order to emphasize a certain message, both in light of classic principles in information visualization and this approach on metaphors.

3. Applications

3.1. Visualizing Empires Decline

The Empires Decline visualization is my first attempt on displaying information with a ludic intent, and for that, making use of very specific figurative metaphors. The main objective was to display the apogee of the Portuguese Empire and its dissolution comparatively with other great powers, mainly during the 19th and 20th centuries. Additionally, it was also important to depict anecdotes of its main competitors [23]. For that, I chose other overseas Empires that at some point in time had a land extent higher than the Portuguese, being those the English, the Spanish and the French. Rather than using, for example static Sankey diagrams [27], I chose a model of packed bubbles [32], animated through time. Packed bubbles display data points as non-overlapping circles, without major spatial constraints except that they concentrate at the center of the canvas, while having the size proportional to certain attribute of the data point. The idea to animate this visualization was to graphically emphasize independence events throughout history by motion, while alluding to a sense of aggressive competition among Empires.

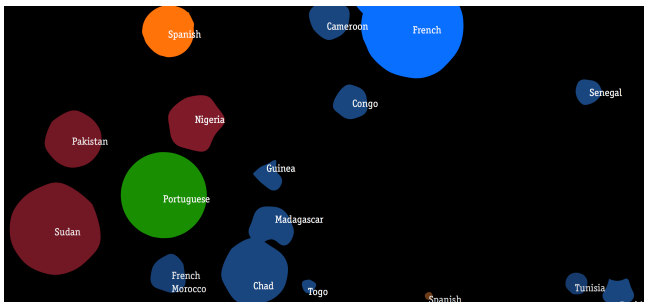

Figure 1: A snapshot of the first implementation of the Empires Decline visualization (https://vimeo.com/6437816).

3.1.1. Behavior

The system simulates the Empires as soft circular bodies, having two major behaviors: Empires collide with each other aggressively and have their shapes distorted by these collisions; and Empires give birth to new countries and shrink as time passes by. The first implementation of this projected violently each new country away from its former Empire, staying in the canvas for a few seconds and then fading away. These abrupt and strong thrusts signify the generic struggle for each independence. Furthermore, some seconds before the independence event, the system starts growing the new countries on the edge of the Empire, working as a narrative prosleptic and adding to the dramatic effect of the independence. The grown shape is then detached and projected as if 'popped' from the former Empire. Different from Empires, the new nations collide with each other but do not pack themselves. Each Empire and country tends to maintain its circular shape with an area proportional to its land extent. Although arguably negligible, due to the collisions, this area is not preserved at all times (see Figure 1). Furthermore, the thrusts of new nations amplify the number of collisions and shape deformations while causing difficulty in following some new born nations. These aspects were toned down in the refined version of this implementation, but they remain as a necessary core compromise when implementing semantic figurative metaphors.

3.1.2. Choosing color

Bertin notes that color is an excellent visual variable for the selective perceptual task, meaning that it can be used to instantly group several elements and isolate them from others [2, pp. 67-91]. As Ware also notes "using color to display data categories is usually the best choice" [33, p. 116]. Nonetheless, this selective property is effective when comparing perceptually distinct colors, but not when when comparing brighter to darker colors, in which case the ordering perceptual task takes precedence [2, p. 87]. In addition, Ware notes that there are only eight colors that are consistently named, and thus the space to use color for the selective perceptual task is very limited but enough to identify the four major Empires at play. The color attribution had to maximize color variation, in a way that avoids any type of hierarchy, but that at the same time, has a symbolic relation with each Empire.

This color attribution is not a univocal process, but much less is an arbitrary one. The national colors of each former imperialist nation were considered based on their contemporary flags, since it is a visual reference more present in public awareness than historical flags (Figure 2). As a way to attain this, I chose to give precedence to bigger Empires as I attributed the colors. There are three colors in the Union Jack of the British Empire. Red was chosen not only because it is arguably the strongest color, but because British historical maps frequently used red to highlight their possessions. If the British Empire is red, this leaves out the weld-yellow for the Spanish. Although only present since the 19th century in their flag, it has been extensively used in royal standards before. For the French Empire, the blue color was chosen as the most adequate color among the three on the current flag since it was traditionally used in pre-revolutionary coats of arms of the Kingdom of France. The current Portuguese Republican flag that appeared in the beginning of the 20th century is a bicolor green-red flag. Since other colors were already attributed to other Empires, green was chosen for the Portuguese Empire.

Figure 2: Contemporary flags of the British, the Spanish, the French and the Portuguese.

Present in two flags, is white, which was avoided as it would have appeared too bright when comparing with other colors. In fact, neither the flag's chosen colors nor their pure-hue versions were used in the visualization. Pure hues were not used because they can appear brighter or darker among themselves (e.g. a pure yellow will appear brighter than a pure blue) [2, p. 85]. The red on

the Union Jack could not be used as it would appear much brighter than the other Empires, specially against a black background and thus was toned down. The same goes for the Spanish weld-yellow as it was transformed in an orange. On the other hand, the blue on the French flag would have appeared much darker than the other colors and was shifted to a cyan while the Portuguese forest-green had to be brighten. This subjective balance was pursued in order to confer the same tone to all colors, avoiding having some more strident than others. As it can be noted in Figure 1 and 3, the colors chosen are perceptually very distant, and can hardly be arranged to establish any sense of hierarchy without an explicit color scale that forces this. Furthermore, in this first implementation of the Empires visualization, the same color hue is used between an Empire and its respective new born countries. Nonetheless, the attributed color to the new born countries is a darker version of the corresponding Empire, establishing a noticeable visual hierarchy between Empires and new nations (Figure 1).

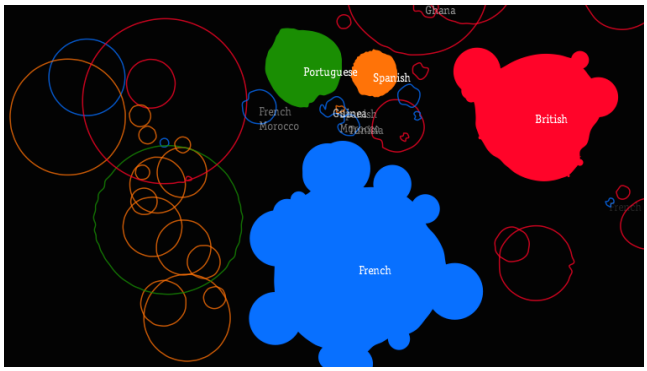

Figure 3: A snapshot of the second implementation of the Empires Decline visualization (https://vimeo.com/11506746).

3.1.3. Refinement

The refinement of this visualization is subtler, has more detailed interactions and is perhaps more elegant, yielding a slightly different metaphor: Empires dissolve themselves in new countries and the competition effect is not portrayed as fiercely as in the previous implementation.

The structural metaphor behind this refinement are Dorling or circular cartograms – maps that represent geographic regions as non-overlapping circles with a size proportional to a certain geographic variable [13]. This way, Empires and new born nations, persist on the canvas and are attracted to their geographical positions. New countries do not fade away, enabling them to portray how much of the world was once part of these four Empires. Just as in Dorling cartograms, the non-overlapping constraint used on the Empires, implies that depending on the circles' sizes, the geographic centroid of the circles might not be preserved. The new born countries do not use this non-overlapping constraint as a way to economize space, not colliding with each other, except with Empires. The new born countries are now represented only by their silhouettes, both in order to resolve juxtapositions and to display a less cluttered visual hierarchy with the former Empires (see Figure 3).

Another metaphorical behavior was added, that can make Empires diverge even more from their geographical positions, even if for a short period of time – when an Empire is about to 'give birth' to a new country it tries to travel half the way and leave it in its location [7, 8].

The resulting visualizations display several visual anecdotes, such as the apogee of the British Empire when others are comparatively very small, the caricatural obliteration of the Portuguese Empire with the independence of Brazil, or the chaotic explosion of the French when they loose all their African possessions at once.

3.2. Lisbon's Traffic

This work started as a simple visualization of trajectories for 1534 vehicles during one month, but has acquired highly figurative and dramatic metaphors in newer implementations, visualizing Lisbon as a system of pulsing blood vessels [9] and using cartograms to emphasize traffic patterns [11].

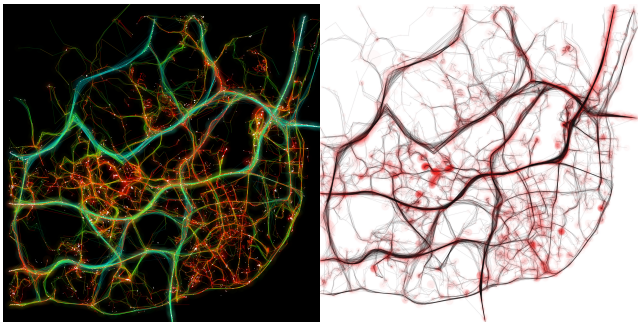

Figure 4: (Left) The visualization of trajectories (https://vimeo.com/131835197). (Right) The visualization of Clots in Lisbon's traffic (https://vimeo.com/10198615).

3.2.1. Trajectories visualization

This technique is a simple visualization of trajectories [1], where vehicles leave a dynamic trail of their positions in the last 30 minutes. The objective of the visualization was to display temporal and spatial patterns in volume, density and speed in traffic. In fact, the available data did not have enough temporal resolution to visualize any meaningful patterns if presented sequentially, day by day. In order to circumvent this, the visualization compressed the month in one single virtual day, showing all registries at once per time of the day. This approach resulted in a short narrative for the typical day in Lisbon, showing a city that illuminates at dawn, thrusts with movement and intensity in the rush hours and fades in the evening. Such portrayal was only possible with very specific graphical considerations on information representation. The vehicles' trajectories are represented by lines with vivid colors, displayed against a black canvas. This enabled to place a high salience on the trajectories together with the idea of a city that illuminates with its vehicles. The vehicles themselves are represented by very small white dots, adding graphical detail to the artifact and showing clusters of standing vehicles in certain locations.

This visualization is perhaps the one that goes more in the direction of Lev Manovich's concept of direct visualization or visualization without reduction [22]. In fact, except for the time compression above mentioned, the visualization tends to display the data as it would represent the real world, showing moving vehicles as moving vehicles and not reducing this or other aspects to more abstract forms. Instead of presenting a line graph with the number and average velocities of vehicles across time, which let

me assure tells the same story in a more abstract and quantifiable manner, it privileges spatial variables and displays a system closer to reality – an intent which aims to connect with the viewer on par with casual information visualization.

3.2.2. Trajectories color scale

Perhaps the most distinguishable aspect of this visualization is the color scale for the velocities. The trajectories have a color signifying the velocity of the vehicle, that ranges from red to cyan. It is well known according to Bertin's graphic semiology [2, p. 69] that color is not recommended to neither quantitative nor ordinal information. Nonetheless, even if Mackinlay [21] agrees with Bertin that color hue is one of the worst visual variables to show quantity, he presents color hue as the fourth best visual variable for ordinal information, after position, density, and color saturation. Additionally, Ware notes that color can be used with caution for ordinal pseudocolor sequences [33, p. 129], stating that spectrum sequences can be effective if the red, yellow, green and blue regions can match significant data classes, in which case for this visualization would be 'almost stopped', 'slow traffic', 'regular traffic' and 'good traffic' respectively. In the scale adopted, blues are never reached as they are perceptually much darker than pure reds, yellows, greens and cyans. The red-cyan color scale is justifiable given the metaphorical embedding in this specific context. The metaphor refers to traffic signals such as red is 'an almost stopped' for velocities below 10 km/h, green is a 'you are good to go' 50km/h and for velocities above, bluish greens and cyans are used. Other important aspect is that each trajectory is drawn with a certain amount of transparency, creating a more seamless composition, unveiling all the complexity of the dataset and enabling to extract visual estimates of velocities on clustered trajectories over main roads (see Figure 4).

3.2.3. Clots and blood vessels

The portrayed complexity and the presentation of the city as a system with its own routines and patterns, emerging from the behavior of individual agents, inspired to show the city with a more figurative metaphor: the city as a living organism. The very minimal initial approach consisted of changing the black canvas to a white canvas, the colored traces to pure black traces with transparency and the emphasis of problematic locations to red dots. When a vehicle circulates with a very low speed, it also leaves a trail of red circles with a certain transparency that fade away as time passes by. The result was a minimal composition, inspiring organic tones and showing low speed locations through a portrayal that alludes to actual clots in the traffic of Lisbon (see Figure 4).

This idea evolved to a more refined and complex system that displays the city as a set of pulsing blood vessels [9]. If vessels are inside an organism, then the canvas is dark. Each road was mapped to a vessel, with a pulsing motion proportional to the velocities on that road. The vessels are red, but vessels with slower vehicles are darker such as in clotted blood. Thicker vessels signify more vehicles, and implanted in them are streams of white cells. These cells or particles have also a flowing motion proportional to the speed on the vessel and a density proportional to the number of vehicles in it. This way velocity is rather encoded in motion than in color as it was before. Although more figurative than the previous ones, it can better emphasize high traffic volume on specific roads, as they get thicker and populated by more white cells (see Figure 5).

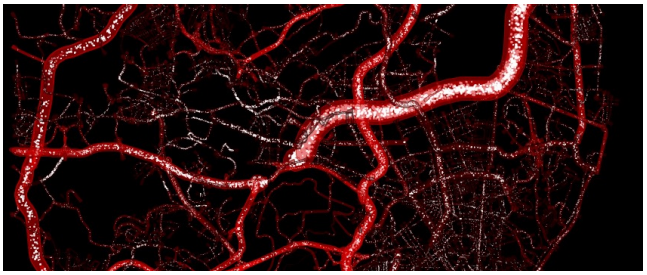

Figure 5: The visualization of Lisbon as a system of pulsing blood vessels, showing thicker roads with more traffic and more circulating cells (https://vimeo.com/131835178).

3.2.4. Dramatic cartograms

In the context of the typical day in the traffic of Lisbon, one of the most significant aspects are the morning and evening rush hours. Having this in mind, one idea was to build a visualization that emphasized this traffic behavior with a dramatic effect. To do so, I developed a special type of cartograms to show this information. Cartograms are maps where space is distorted in order to represent a statistical variable. The most common type of cartogram is the value-by-area cartogram: for example, countries on a world map can shrink and expand based on their population of GDP. For this specific dataset, the cartogram is not value-by-area but edge-based since the road map of the city of Lisbon is used as the model to distort. Instead of manipulating areas, the lengths of Lisbon's roads are altered in order to show information. What was done was to map the velocities in a road to its length, using the following time-distance metaphor: if velocities are low, we perceive farther locations, and if velocities are high we perceive shorter distances. Therefore, each road is shrunk if the velocities are high in it, and expanded if the velocities are low. This results in an overall behavior of the whole city dramatically expanding during rush hours, since it would be as if everything is much farther away, and shrinking in the evening when circulation is free of traffic constraints. Dorling notes that cartograms distort the reality and "shock" readers [13]. Cartograms have this dramatic effect, because instead of using color, value or shape to show information they manipulate positions which is systematically rated as the most accurate and strong visual variable to show quantitative, ordinal and nominal information [2 p. 69, 4, 21]. Furthermore they do so by contrasting a distorted map to a mental reference of the undistorted map, impacting viewers with a new perspective on familiar maps. It is also worth noticing that every cartogram yields an error in the depiction of information because it is generally impossible to accurately distort connected areas or edges while preserving their topology [18]. Therefore, compromises are attained that try to minimize this error. Just like semantic figurative metaphors in their very core, cartograms modify the structural metaphor of geographical maps, 'shocking' viewers by distorting their spatial awareness at the expense of inducing in slight informational errors. In fact, until the introduction of cartograms in Lisbon's traffic visualizations, semantic figurative metaphors were only being explored on the introduction of new visual cues, but with cartograms they modify the map's structural metaphor by manipulating space.

The edge-based cartogram for traffic information is innovative by itself as a technique for information visualization [11]. This technique can be applied to both the trajectories and blood vessels visualizations. It should be noticed that in my opinion the motion of the vessels and the streams of the cells together with the expansions and contractions of the cartogram are perhaps too distracting and potentially reached the limits of eccentricity when over-working figurative metaphors for visualization (see Figure 6).

The blood vessels metaphor works particularly well for Lisbon, since it is delimited by the Tagus river, resembling an individual organ. Nonetheless, the often organic disposition of roads in a city is the main motivation behind this metaphor, and thus it may be suitable for an extensive number of cities. For example, Figure 7 shows the blood vessels' metaphor applied to the city of London. In this case the system depicts more of an intricate tissue with clotting problems in the center. Adapting the system to other cities depends on their topological arrangement as well as on the dataset itself, such as the number of vehicles and its temporal resolution. London's dataset refers to 2537 vehicles, accounting for more than 8 millions of vehicles' positions, while Lisbon's refers to 1534 vehicles and about 2 millions of positions. This way, properties such as the mapping of the thickness of the vessels, or the density of cells had to be changed in order to visually accommodate the increased data density.

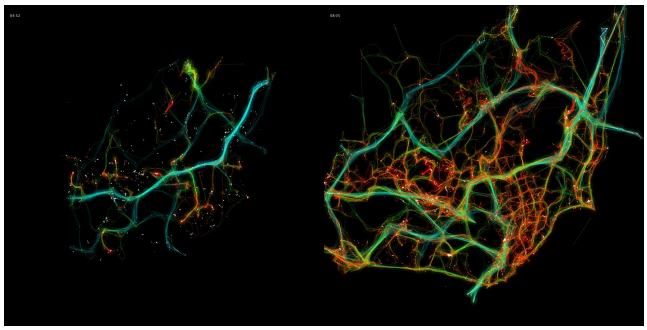

Figure 6: Snapshots of the visualization of trajectories applied on the cartogram. (Left) City compressed at dawn. (Right) City expanded during the morning rush hour (https://vimeo.com/131835139). Blood vessels version can be watched here https://vimeo.com/88842273.

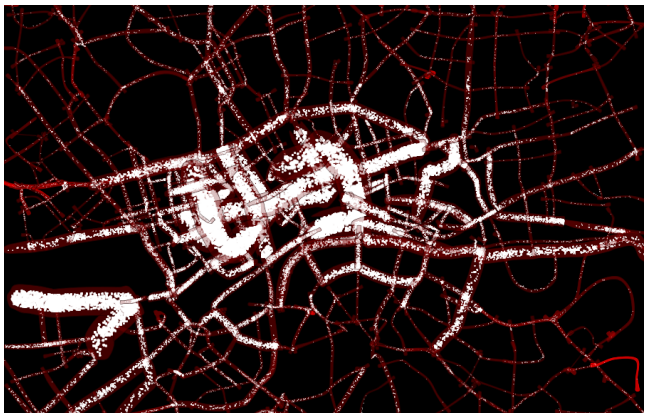

Figure 7: The blood vessels metaphor applied to the city of London (https://vimeo.com/135803141), and with the animated cartogram here https://vimeo.com/135803140.

3.3. An ecosystem of corporate politicians

Nowadays in Portugal there is a significant mistrust in the country's political class. Voting turnouts have been around 60% in legislative elections since 2009 and suspicions of political patronage and corruption are constantly present in the media. Lobbying in Portugal is illegal and therefore unravels in a parallel stage, being widely unpopular and casted in a harsh light by the media. The high availability of public information regarding this matter has been raising awareness that fuels such discontentment. Within this context, I proposed myself to make this invisible matter more visible, tailoring a provocative visual form that would engage the viewers through a serious but caricatural portrayal of the issue.

In 2010 Costa et al. published a book [5] that among an historical narration of the most influential corporate families in Portugal, contained a list of 115 politicians résumés that held high governmental positions and later transited to influential Portuguese companies. For each politician, the list describes each position held in governments and in companies, together with information on the political party affiliation. This dataset was extended until the end of 2013, based on other studies and through our own independent investigation [10]. This way the dataset was extended to 130 politicians, describing 906 corporate positions in 354 public or private companies from 1950 to 2013.

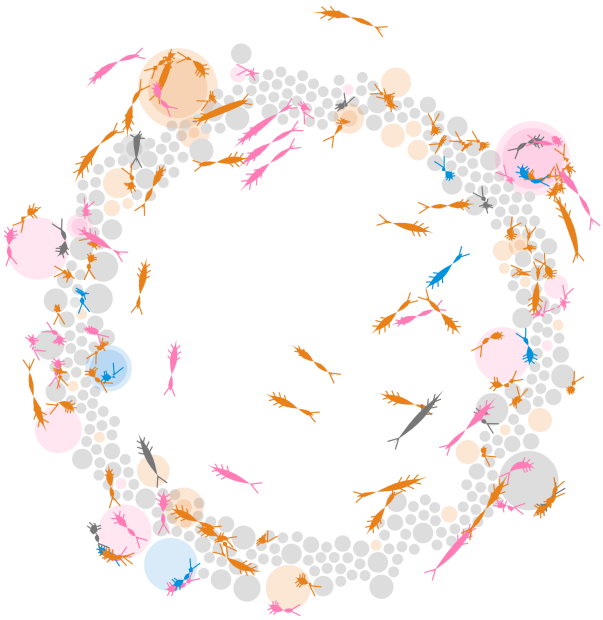

Figure 8: Snapshot of the Politicians' visualization, showing its initial state, ready to explore and interact. The visualization can be accessed in http://pmcruz.com/eco/.

3.3.1. System and Behavior

"An ecosystem of corporate politicians" uses a visualization system that represents politicians as living organisms that dynamically interact with companies. Perhaps one of the most interesting aspects of the data is that politicians often held more than ten positions in companies during time. In order to graphically convey this idea, the visualization shows a swarm of politicians that frenetically chase companies and jump among them (see Figure 8). Furthermore, in order to represent and emphasize a hectic parallel

stage, information is not presented chronologically, but instead every politician starts its jumping sequence between companies at the same time. In fact, if the information was to be conveyed chronologically there would be a big difference in corporate traffic from the 70s to the 90s. This could induce that indeed such type of traffic increased in more recent times, but the truth is simply that the data is skewed due to the recent increase of publicly available information on this matter.

The structural metaphor for this visualization is one of a radial network [2, p. 51] where companies are nodes connected through shared politicians. Instead of drawing those connections, each politician follows a jumping trajectory that connects companies through motion. Additionally, instead of having the nodes evenly disposed over a circumference, they form a belt of non-overlapping, packed bubbles (see Figure 8). They are constantly moving, although slowly, aligned with a circumference and organize themselves by means of collisions to avoid juxtapositions. Companies are hence circular nodes with an area proportional to the number of different politicians that had a position there.

Each politician has a sequence of positions in companies to attain. In order to do so, it visits the company corresponding to each corporate position. When a politician reaches out a company, starts an encircling movement that lasts an amount of time proportional to the chronological duration of that position. Even if the sequence of positions that a politician visits is chronologically ordered, the travel times are only dependent on the system behavior and have not any real significance. A politician that completes its visiting sequence, starts the sequence again. This way the system will keep running without stopping or reseting as a whole.

3.3.2. Form and color

After modifying the structural model behind this visualization, I added an important visual cue to evoke a provocative and caricatural tone by representing politician as generic insects. The anatomy of a politician consists of a head, a body or tail, a pair of antennas and three pairs of legs or spikes. The shape of the silhouette is related with the number of unique companies that the politician has to visit. This way, each silhouette is thinner or rounder depending on the politician's activity (see Figure 9). The length of the body also stretches depending on its traveling speed, conferring a more organic tone to the insect's portrayal.

In addition, a politician is also colored based on its latest political party affiliation, according to their customary colors in Portugal: pink for socialists, orange for social democrats, blue for conservatives and gray for the remaining. Those are vivid colors, and confer a sense of playfulness to the visualization, and were worked in order to have the same perceptual brightness on a white canvas.

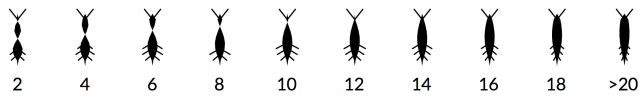

Figure 9: Varying forms of the insects depending on how many unique companies they have to visit.

3.3.3. Interaction

The viewer can interact with the system in order to extract subnarratives or anecdotes, such as the jumps of each politician and the jumps in companies that share the same politician. The user can either click on a company or a politician. When clicked on a company the system only shows the politicians that hold positions there together with other companies that once shared at least one of those politicians. When clicked on a politician, only the companies that it frequented are shown, enabling to isolate its jumping behavior while providing detailed information on its corporate and government held positions.

One ludic aspect of the interaction is being able to chase and catch politicians. The mouse pointer can attract politicians and catch them, interrupting their traveling routine. One can then either play with the insect by slowly moving the pointer and observing how it follows, or can move away and the politician will resume its jumping behavior.

4. Common traces

In these three works, I placed an emphasis both on the modifications of the structural models as well as on the addition of non-data related visual cues, in order to implement specific semantic figurative metaphors.

The Empires visualization starts by using the structural metaphor of packed bubbles and them moves to include geographic information by implementing Dorling cartograms. Both models were modified in order to include new behaviors that metaphorically allude to thrusts of independence. The visual cues added on these models result from the implementation of the graphical depiction and interaction of Empires as soft bodies. This portrayal results in a figurative evidence of competition, as the Empires deform as they collide, while conveying a sense of fragility and ephemerality.

The traffic visualization started with the standard visualization of trajectories structural model and then altered its spatial arrangement by using a dynamic cartogram. Even if cartograms are established generic models capable of depicting geo-referenced variables, the way they were implemented for Lisbon's traffic reflects an authorial intent – velocities are inversely mapped to the length of the roads, such as when they are high, the lengths compress and vice-versa. This causes the city to expand during rush hours and compress with less traffic, resulting in a more dramatic way to depict the city's daily routine. Additional visual cues and thus, figurative metaphors, were explored alluding to blood, vessels and organisms. The mechanisms that were created in order to portray the city in this organic light are independent from the data itself and reflect again an authorial intent.

The politicians' visualization relies on a networked structure. In fact, politicians connect companies among each other due to their frenetic corporate activity. Instead of using simple edges to connect companies, moving insects were added, that jump from company to company and encircle each one of them. Depicting edges through movement and reworking the arrangement of the nodes are the main modifications to the structural model, while the most figurative visual cue is the portrayal of insects with a shape related with the number of companies they visit. This resulted in a visualization that is provocative and that has satirical tones.

Table 1 synthesizes, across the three works, which structural metaphors were used, how they were modified and which specific visual cues were added in order to implement semantic figurative metaphors.

4.1. Impact

Being able to emotionally connect with the audience is one of the main motivations behind semantic figurative metaphors. There-

fore, it is of interest to report on the adoption and impact of the visualizations produced. Although not proving that the provocative nature of the metaphors, was the main reason for attention, the strong viewership and recognition suggest this. For example, the first implementation of the Empires visualization was able to gather about 300,000 views in its first two months after being online, propagating through numerous sites and blogs, and has nowadays around 684,000 views. The traffic visualizations were able to gather 68,100 views altogether and the visualization of trajectories of Lisbon was selected to be part of the "Talk to Me" exhibition in MoMA in 2011 [12]. The Ecosystem of Corporate Politicians since its debut received 170,000 views of which 110,000 were in the first two months. Considering the ten million residents in Portugal I would say that the project attained great visibility, being featured on a major Portuguese newspaper [26].

Table 1: Synthesis of the structural modifications and visual cues added to the visualizations.

	Structural metaphors	Structural modifications	Figurative visual cues added
Empires	Packed bubbles	New nations do not pack themselves and are propelled through thrusts	Circles as soft bodies
	Dorling cartogram	Nations have to travel to their locations and can be disrupted by others	
Traffic	Trajectories visualization	Space distortion using edge-based cartograms	Blood vessels with pumping motion and streams of cells
Politicians	Radial network	Packed nodes and remotion of edges	Politicians depicted as insects

4.2. Restraints

Semantic figurative metaphors carry the weight of authorial intent in visualization, subjective in itself. Additionally, they explicitly add non-data elements to visualizations in order to augment their metaphorical value. Adding non-data aspects to visualization, comes at the expense of data inaccuracies and may cause confusion in the viewers when distinguishing what is data related from what is not. Employing semantic figurative metaphors should be handled soberly and with restraint. Visualization designers should make as clear as possible what reflects the designer's own interpretation and what is the designer's message. The message, of course, should be clear and faithful to the data. Furthermore, they can even contradict the economy principle in information visualization, depending if they classify as data-ink or not – in fact, Few [14] considers that "Embellishments that represent data, even metaphorically, can themselves qualify as data ink.", given their functional value in communication.

Semantic figurative metaphors can be used in the context of casual visualization, where communication with large audiences is favored in detriment of more utilitarian usages, aiming for contemplative and momentary uses, trying to provoke awareness and reflective insights. They humanize visualizations because they are less abstract and more figurative, connecting more tightly with the audience in an emotional way. They are not models, but an approach to visualization. Each non-data metaphorical aspect should be tailored specifically for a dataset, for a structural model and for a message, and thus it is rarely generalizable.

Nonetheless, this is not a permission or advocacy on chartjunk. They should have authorial well defined communicative purposes and are not a pure add-on – implementing semantic figurative metaphors should be part of the design process since its inception. For example, the modifications on the structural model should be connected with the addition of visual cues, in light of the same metaphors. Moreover, the figurative aspect should not be extreme as it would distract from the familiar and abstract graphical languages that visualizers use to depict data – they should aim for clear, subtle and *more figurative*, visual cues. I can argue that the application of the blood vessels on the dynamic cartogram is the strongest graphically and the closest figuratively to its metaphorical domain. But it is also the farthest to the elegance of simplicity where the authorial intent superimposed the functionality of data portrayal. Although permissible, there is a point where the beauty of complexity might turn into visual confusion. Each of the three described works could have used even more intense and elaborated expressions with the excuse of an authorial intent, but they were in the most part restrained to moderated visual cues.

These applications intentionally distorted shapes, subverted the use of color, added elements not present in data and manipulated time and space to present stronger messages. It is agreed that areas in the Empires visualization are not always accurate; that using cartograms necessarily brings an error to information portrayal; that using texture together with thickness to show traffic volume in the vessels visualization is redundant; that displaying velocity through motion is not very orthodox; and that by not drawing edges on a network the visualization of patterns might be lost. All this is a consequence of implementing certain semantic figurative metaphors, which at the expense of these inaccuracies try to intensify the communication with the audience. It is an exploratory side of visualization, and should be handled with care, but never at the expense of telling the untruth.

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