Visualizing the Scale of World Economies

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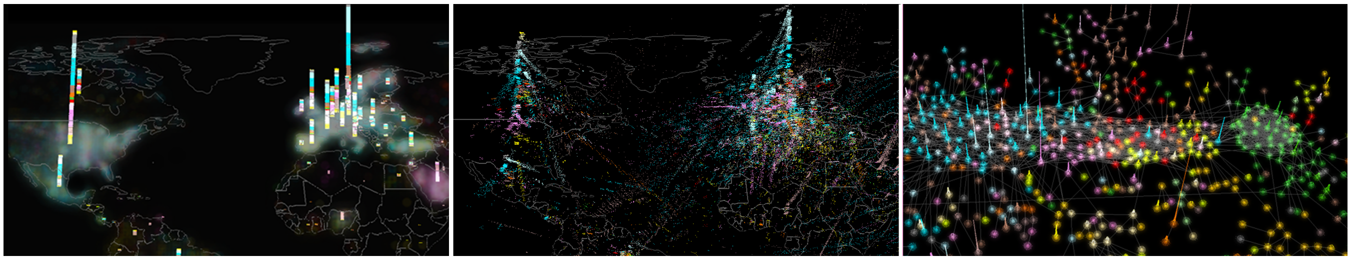

Figure 1: Our novel interactive visualization of world economies where each of the $153,000$ dots encodes $100 million of exports as geographical maps (left), node-link diagrams (right), and transitions between both (middle).

Abstract

We present the design and implementation of a novel interactive visualization of economics data. We used a dot-based representation, where each dot encodes a segment of $100 million worth of exports by countries. As total world exports cumulated to $15.3 trillion in 2012, we faced the challenge of plotting and animating 153,000 dots to generate geographical maps, node link diagrams and various stacked graphs. This poster explains our design process and the most important visual mapping decisions we made, such as strategies to display dots on a grid to create efficient visual aggregations. An online version of the visualization is available to collect feedback and make further improvements.

1 Context and Motivation

Economics data (e. g., GDP, products exports, etc.) helps us understand the state of our world, from the current health of countries' economies, to the impact of future regional trade agreements. While we are all familiar with currencies (e. g., dollars), this data remains difficult to grasp due to its magnitude (e. g., billions or trillions of dollars). For instance, total world exports in 2012 cumulated to $15.3 trillion with high disparities between countries: the United States ranks among the top exporters ($1.8 trillion), while smaller ones are down to hundreds of millions. Exports can also be diversified or specialized depending on the variety of products being exported. We are interested in improving the visual communication of the magnitude of such data, while also conveying their categories (i. e. the type of export, such as textiles, cars or natural resources) in an engaging way.

This work is motivated by our previous experience building a website with this data: The Atlas of Economic Complexity [2] using standard charts such as treemaps, geographical maps or stacked graphs in D3 and SVG. The Atlas successfully answers simple questions such as *What does the United States export?* but faces many conceptual and technical limits: space filling visualizations (such as treemaps) show the diversity of products but don't convey the magnitude of the whole economy compared to others; there is no transition between charts and even if they had been crafted, SVG would not be powerful enough to properly animate thousands of elements; geographical maps are very useful but country shapes tend to distort the encoding of quantitative values when using color.

Our goal is to explore if dot-based visualizations, that originate in early dot maps (e. g., *London epidemic map* of 1854 by John Snow where dots are cholera cases) and isotypes [4] are an efficient way to *unitize* [1] data and convey its scale. Recent systems such as Microsoft Sandance [3] already demonstrated the use of dots to display electoral data for $3,007$ U.S. counties. We aim at pushing the boundaries with more detail and types of representations, to apply them to economics data.

2 Dot-Based Design and Visual Aggregation

Our visualization is built around the idea of breaking down large quantitative values, such as trillions of dollars, into fragments of $100 million that are represented as dots. As total world exports cumulated to $15.3 trillion in 2012, we generate and animate $153,000$ dots colored by their category (e. g., textiles in green, cars in blue). Our goal is to use dot density to communicate quantitative values over geographical maps and node link diagrams. However, we quickly observed that we needed to add other graphical marks such as countries outlines (Figure 3) as some areas can be empty or very small. We followed the same process for the nodes and links in the node-link diagram, but for another reason: to communicate relational data that is not encoded with dots.

We also enhanced the dot aggregation using *visual aggregation* as rendered textures displayed as background images. This background accentuates brightness in very concentrated location (South Korea, Belgium, Qatar) without hiding our base grid on the lowest zoom levels. A similar process is used in our node-link layout: a dot cloud with large glowing circles encapsulates product communities and gets brighter in concentrated regions.

3 World Economies Visualization

The first view presented to the user is a 3D globe on which dots are displayed as a grid (Figure 2, left). The density of dots communicates the quantitative value corresponding to the total export values for each country. If a country ends up having a unique color (e. g., Bangladesh is mostly green) this means the economy is not diversified (green means textiles which is Bangladesh 91% total export). Conversely, multiple colors show the diversity of exports. The globe is used as a natural way to represent location-based data, like

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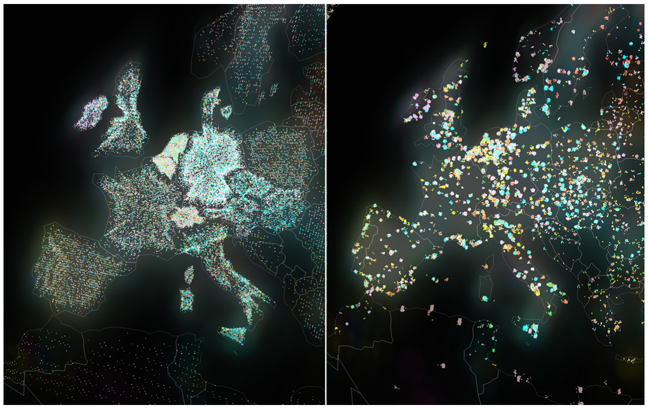

Figure 2: Strategies for encoding quantitative values as dots. Left: using uniform grid. Right: using cities as proxies of productive capabilities which lead to exports.

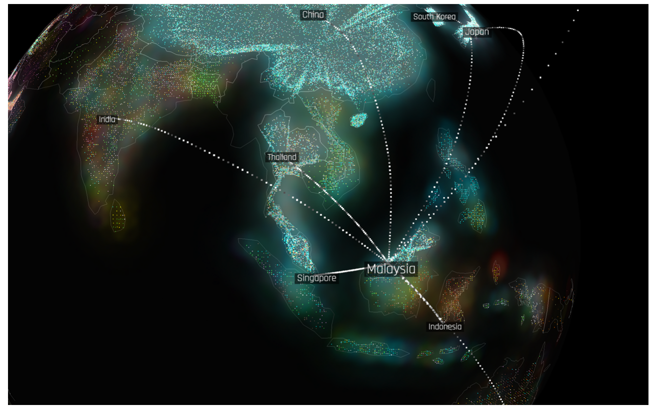

Figure 3: Selecting a country shows its label and the connections (using dotted lines) to main trade partners.

Google Earth. The system implements several views we will discuss further. It also implements standard interactive features (overview, details-on-demand, filters).

Interactive Views. The 3D globe can be turned into a 2D Mercator map and products can be stacked on top of each other to encode the total export value with the height of the stack. A country can be selected to show its main trade partners (Figure 3). The map can then be replaced by a node-link diagram that represents the likeliness of products to be co-exported together by countries (see [2] for more details on the construction of the graph). Similar to the map, products can be displayed by density or stacked vertically. More views are available (e. g., histograms, pie charts, ...) to provide more accurate comparison on a Cartesian space similar to The Atlas.

Animated Transitions. We used the same set of $153,000$ dots all accross the different views, which are smoothly animated between views and always visible (unless filtered out). Through a tweening effect and simple mathematical formulae, new positions are calculated in a transitory state. A fast in / slow out with some random delay in the animation of the dots has proved to be efficient. Regarding the duration of the dots' animation, most are updated in less than a second, but a few usually require more time which creates visual trails similar to natural motion (Figure 1, middle).

Storytelling. Since the value of $100 million is still difficult to grasp, we added a storytelling mode to introduce the dots' encoding. The mode uses an *analogy* [1] strategy to represent how many well-known, tangible product dots encode. As product, we selected a Swiss watch, which is a small object with great perceived value ($685) and the mode shows how many thousands of such product is required to create a dot.

4 Implementation Notes

The system utilizes WebGL, which enables 3D graphical acceleration within the browser. Most of the graphical operations take place in parallel within the computer's GPU, enabling rendering performance comparable to a desktop application. The Three.js library was used; which offers basic but intuitive 3D scene management. Our visualization was built entirely upon that base, all animations, layouts and camera angles had to be custom made for this visualization. It enables us to create dynamic particle systems and geometries, with specific textures and properties.

As performance is key to a good experience, many iterations were made in order to optimize the system's reactivity and fluidity. Early on we opted for custom shaders to animate particles instead of doing everything in JavaScript, which shifted the process from the CPU to the GPU and gave us a significant performance boost. The second largest bottleneck was generating the structural node-link meshes that house our dots. We used mesh-blending for edges and circular 2D textures instead of 3D spherical objects. Finally the visualization was tested on older compatible computers and different browsers. We consistently observed a good framerate.

5 Early Feedback and Discussion

We made the visualization available online `http://cid-harvard.github.io/atlas-dot-map/`. During the implementation, we constantly involved our colleagues in economics, who have different levels of literacy in visualization but who are very familiar with the dataset. We now list the main feedback we collected from them, and discuss how we addressed it.

An early challenge was to agree upon the right number of dots to use. In general, dot-based visualizations work well for a specific range of number of dots (not too many, but not too few). Since we are representing large quantitative values, we are free to encode the value by its exact number of dots or using a ratio (e. g., 1 dot equals $1/100$th of the total value). This would not have been the case if dots were representing items, such as U.S. counties like Microsoft Sandance. In our case, we picked $100 million as it is a rounded number and results in a manageable number of dots. Also, the various views overall encoded quantitative values properly with this number of dots. Another equally important challenge was the layout of the dots as uniform grids (Figure 2, left) as opposed to location-based positions (Figure 2, right) by using cities. Finally, representing connections using dots is a challenge we did not fully addressed. For the node-link diagram, we drew dotted lines (Figure 3) where dot spacing encodes values of exports to countries. Using an actual particle flow would have been more consistent with the overall dot-based design. However, it has been left to a future version as it is highly performance intensive. Also, tweaking the pace of animated particles was found to be difficult to encode the values of exports between countries.

References

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