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Social Impacts of Robotics on the Labor and Employment Market

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SOCIAL IMPACT OF ROBOTICS ON LABOR AND EMPLOYMENT MARKET

by

Kelvin Espinal

A master's capstone project submitted to the Graduate Faculty in Data Analysis & Visualization
in partial fulfillment of the requirements for the degree of Master of Science,
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This manuscript has been read and accepted by the Graduate Faculty in Data Analysis and Visualization in satisfaction of the capstone requirement for the degree of Master of Science in Data Analysis and Visualization.

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ABSTRACT

Social Impacts of Robotics on Labor and Employment Market

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Robotics have been introduced into the workplace to perform tasks that human beings have traditionally fulfilled. Complementing or substituting human labor with robotics eliminates human involvement in functions attributable to hazardous environments, heavy lifting, toxic substances, and repetitive low-level tasks. On the other hand, they are meant to be more efficient and cost-effective, saving money, time, and labor. However, since the introduction of robotics in the workforce, societal opposition has been towards this branch of technology in fear of losing employment, wages, and purpose.

Previous studies have reported an overarching societal fear that adopting robotics in the workplace and industry will progressively reduce employment and wages. This project will address the social impact of robotics on the labor and employment market. For this project to be impactful and successful, it will create a narrative set of visualizations that will be accessible generally by both academic and professional audiences providing insight into

- What are the positive or negative impacts of introducing or utilizing robotics into the workplace on employment and wages?
- What has been the progression/transition over a time that presents the adoption and induction of robotics and the effects on the labor and employment market?
- Where in the world by industry are these robotic “industrial revolutions” mostly taking effect?

These visualizations can provide insights and answer how this branch of technology and automation will affect the current and future state of employment. What is the catalyst driving the need for this industrial revolution?

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III. Code and other Deliverables

Zip file containing the contents of the GitHub repository at the time of deposit.

https://github.com/kespinal83/Capstone_Final/blob/main/Capstone_Final.zip

List of Variables

Buckets	data in buckets for visualization grouping
Cards	heatmap individual boxes
centerPos	center positioning
colors	static colors
colorscale	gradient color
datasetpicker	specific dataset selector
datasets	specific dataset selector
dayLabels	static day of week labels
days	days of week selector
end_dist	end destination of arc
flyerAltitude	arc altitude measured away from globe
graticule	intersecting lines of latitude and longitude scale
gridSize	grid size ratio
heatmapChart	heat map variable for settings and attributes
height	height of object
initRotation	rotation speed and settings of globe
legend	legend width and height variables
legendElementWidth	legend element width settings
margin	object margin settings
maxElevation	maximum elevation away from globe settings
n_segments	segments measurement
offsetX	offset measurement from x axis
offsetY	offset measurement from y axis
path	calculated path on projection
projection	projection of map type
radius	radial object sizing
scaleExtent	object size based on scale
sensitivity	sensitivity of interaction and globe animations
skyprojection	layer away from globe
start_dist	start distribution of arc points
svg	svg object in view
swoosh	arc line
timeLabels	static time of day labels
times	times of day selector
width	object width measurement

Glossary of Functions

convertToTimeStamp(): Timestamp conversion.

dash_offset(): The dash_offset is a presentation function defining an offset on rendering the associated dash array.

dash_size(): allows for geometric lines and points across the globe.

data(): This allows us to attach data of any type to DOM elements in a way that is safe from circular references and, therefore, memory leaks. Using the data() method to update data does not affect attributes in the DOM.

dragged(): function allows for dragging and interaction of globe.

flying_arc(): Controls geometric points for arc.

get lineal(): Obtain line value.

location_along_arc(): location overlap where arc exists

path_intersection(): function for events that occur at path intersection.

position_labels(): positioning of labels on the globe.

ready(): Used to make a function available after loading the document.

refresh(): Refresh data and objects during actions and events.

refresh layers(): Refresh flyers on rotation / interaction.

refreshLandmarks(): Refresh landmarks on rotation / interaction.

tsvfile(): Convert data from TSV file.

zoomed(): function for zooming capability on the object.

Note on Technical Specifications

The solutions to develop HTML and JavaScript files were Visual Studio Code, a source-code editor, transferring files to an online GitHub Desktop, and hosting the visualization in GitHub repositories. Before starting any development, a local directory for objects is created and then made available to Visual Studio Code by adding folder functionality. Consider dependencies referenced in HTML or JavaScript objects, whether reference local or web-based code bases, must be made in advance. Once files are developed or ready to be made available publicly on the world wide web, a repository is created on GitHub.com to host the files storage-wise and for Webhosting. The medium solution utilized to transfer and apply updates to files is GitHub Desktop. Also, the version of D3 is version 5, with dynamic functionality for the globe.

The repository contains an HTML file (index.html) that serves as the main page structure and brings all the different visualizations and functionality into one cohesive page. CG.html / HM.html / TL.html are all three main visualizations working independently. This allowed visualization to render and operate with their resources: one main CSS file (style.css) and various JavaScript files for visualization functionality. In addition to these files, some subfolders contain all dependencies for this project, including data files required by the visualizations. To launch this project on a local machine, end-users must first install Live Server (v5.7.5 or higher). Once the end-user has navigated to the root directory of the project files, right-click and run on any of the .html files to launch the webpage on the local services available.

Introduction

An Industrial robot is an automatically controlled, reprogrammable, multipurpose machine theoretically or physically resembling a human being and can replicate specific human movements and functions. The topic of robotics in the workforce and labor sector is a polarizing topic. Robotics have been introduced into the workplace to perform tasks that human beings have traditionally fulfilled. Complementing or substituting human labor with robotics eliminates human involvement in operations involving hazardous environments, heavy lifting, toxic substances, and repetitive low-level tasks. On the other hand, they are meant to be more efficient and cost-effective, saving money, time, and labor. However, since the introduction of robotics in the workforce, societal opposition to this technology has risen as people have feared losing employment, wages, and purpose. Previous studies have reported an overarching societal fear that adopting robotics in the workplace and industry will progressively reduce jobs and wages.

Robots' impact on the labor force varies throughout different industries, geographic areas, societies, and populations. The effect of this revolution is mainly in manufacturing industries. The automotive industry has adopted robots more than any other industry, employing 38% of existing robots and up to 7.5 per thousand workers. However, companies like Tesla can represent the future robot-to-worker ratio and have deployed in real-time production as

much as 75% of production lines are automated by robotics per factory vs. 25% humans.[1] The electronics industry employs about 15% of robots, while plastics and chemicals use 10%. Labor workers in these industries tend to see the most dynamic turnover to robotics; as we move forward, we can estimate adverse effects for workers in services, construction, etc. According to studies, While the automotive industry has adopted robotics at a more rapid pace than other sectors, whether inclusive or exclusive in studies, the impact of robotics to human ratio in several industries was consistent across the board.[2, 3]

A common misconception is that robotics started embedding itself into the workforce recently. This is not the case, as robotics started as far back as the 1950s. The first industrial robot was developed in 1954. Still, it was not mass produced or introduced into the industry, specifically the automotive sector, until 1961 in a General Motors factory to automate or assist in die casting and handling spot welding where the controller was a magnetic drum. Shortly after, fabrication of motorcycle frames and precision insertion tasks followed, which was only the beginning of discomfort for unskilled workers.

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[1] Brown, Sara. "A New Study Measures the Actual Impact of Robots on Jobs. It's Significant." *MIT Sloan*, 29 July 2020, https://mitsloan.mit.edu/ideas-made-to-matter/a-new-study-measures-actual-impact-robots-jobs-its-significant

[2] Dekle, Robert. "Robots and Industrial Labor: Evidence from Japan." *SSRN Electronic Journal*, 2020, https://doi.org/10.2139/ssrn.3670356.

[3] Acemoglu, Daron, and Pascual Restrepo. "Robots and Jobs: Evidence from US Labor Markets." 2017, https://doi.org/10.3386/w23285.

Fast forward to now where robotics is available in many industries, studies found that for every robot added per 1,000 workers in the U.S., wages declined by 0.42%. The employment-to-population ratio went down by 0.2 percentage points – comparatively, about 400,000 potential jobs were lost. Since the early 90s, the increase in robots (about one per thousand workers) reduced the average employment-to-population ratio in a zone by 0.39 percentage points, and average wages by 0.77%, compared to commuting zones with no exposure to robots, researchers found.[4] This implies that adding one robot to an area reduces employment by about six workers.

Robotics will mainly impact occupations where routine, repetitive tasks are daily. Acemoglu and Restrepo write that both sexes are affected by adopting robotics into their industry in focus; however, after analysis, it seems males are impacted more than females.[5] Specifically, for men, where there was most impact was in manufacturing and complex labor jobs versus women, albeit less were affected by the introduction of robots in non-manufacturing jobs. While some industries like healthcare have more complex robotics, robotics primarily impacts and mainly workers without college degrees far more than those with a college degree.[6] Although studies also found that robot adoption does not positively affect workers with master's

[4] Brown, Sara. "A New Study Measures the Actual Impact of Robots on Jobs. It's Significant." *MIT Sloan*, 29 July 2020, https://mitsloan.mit.edu/ideas-made-to-matter/a-new-study-measures-actual-impact-robots-jobs-its-significant.

[5] Acemoglu, Daron, and Pascual Restrepo. "Robots and Jobs: Evidence from US Labor Markets." 2017, https://doi.org/10.3386/w23285.

[6] Morikawa, Masayuki. "Firms' Expectations about the Impact of AI and Robotics: Evidence from a Survey." *Economic Inquiry*, vol. 55, no. 2, 2016, pp. 1054–1063., https://doi.org/10.1111/ecin.12412.

or advanced degrees, industrial robots do not directly complement high-skill workers, unlike other technology.

Project

The main goal of this project is to create awareness and expose a topic not commonly shared in the media. While robotics has been in various industries and workplaces for close to fifty-plus years, it is still considered a nascent technology that, when introduced or established in a workplace environment, comes with mixed feelings, and while "cool" at first to have this type of automation, there is an underlying intent and impact on the relationship of the robot and the laborer on a substitute or complimentary basis. This project attempts to visualize effectively answers the following questions:

- What are the positive or negative impacts of introducing or utilizing robotics into the workplace on employment and wages?
- What has been the progression/transition over a time that presents the adoption and induction of robotics and the effects on the labor and employment market?
- Where in the world by industry are these robotic "industrial revolutions" mostly taking effect?

In effect, I research the topic and look for key point indicators (KPI) that would be able to then cohesively visualize in a form other than text to create a semi-narrative / exploratory visualization.

Capstone Visualization

Conceptually the idea for the visualization component of the capstone is more straightforward said than done. This is to convey a complex story to an audience that may have previous knowledge or no knowledge on the topic, allow end users to interact, and be modular for future updates, whether data or visualizations. All while attempting to design an aesthetically pleasing design visualization.

The first point in creating a foundation is to research and extract data from academic papers, articles, and readily available datasets if they exist, especially before determining specific visuals and how custom to go regarding code and designs. Once data is available, in my opinion, it can drive what type of visual charts will make sense not just logically but also aid design decisions and what data points and insights might make more sense not just for the topic itself but also in conveyance to the end-user.

Initially, I knew I wanted to have an orthographic projection to convey data points across the world in an interactive, visually appealing format. As a second visualization, some form of the interactive timeline to help educate users on the impact or origin of the topic over time. Finally, the third was looking to develop a custom merge of the histogram and heatmap to help convey the effect of the issues of robotics on human workers and the labor force by more commonly associated industries across different countries.

As part of the design process, once data had been procured, the first step was to draft up a potential coherent page of all three visualizations and what functionality I may have wanted to apply for the visualization and the end-user itself. Just a forewarning, the visualization came out quite different from what was developed in the final state.

The first iteration in figure 1 was quite a departure from my style in general from a structure and design perspective. I wanted to utilize blank space while filling the screen with the central orthographic projection in an off-center view to give users a feel of continuous around the "corner" interactive exploratory feel. Initially, the idea was to have a word cloud that would display words that originate from a specific country on hover from research and data sources utilized to display what common words and attributes are used in discussions and academic data sources. This function looked more at what words were related in conversations or sentiments in that country. For instance, when hovering over Japan, we might see a negative set of terms related to robotics in the labor and work areas versus over the United States of America, We may see more positive correlated words allowing end users to observe sentiments in that country towards the topic.

Figure 1 Original draft of intended visualization

The second visualization was a simple timeline representing the chronological order of events, and the third was a heatmap with the idea of showing intensity in robotics integration over time. Functionality would allow end-users to interact by hovering over more minor visuals and bringing them into focus instead of globe visualization in a roundabout animation. However,

as I developed this visualization, I felt it was beginning to appear bland. The visualizations

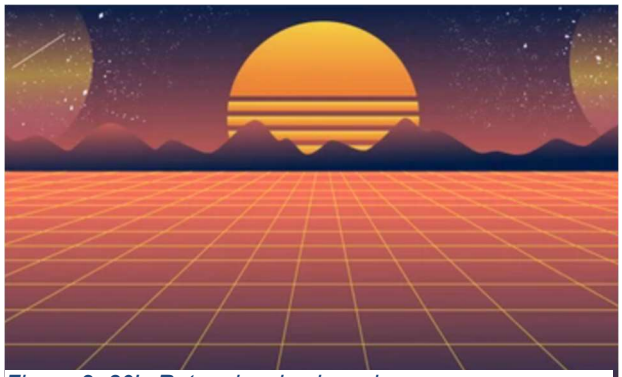

Figure 2: 80's Retro visual color scheme

appeared cluttered as where more resources and time would be spent on animation than on the actual visualization. I pursued a different approach to creating the visualization in a clean and simple design. Regarding robotics, I started to look for futuristic colors and utilize color palettes commonly associated with cyberpunk neon-style or retro 80s colors. Eventually decided to use shades of blue-white, grey, and orange based on the image in Figure 2. However, in sampling various colors, I looked for colors I had not worked with before in previous visualizations and selected more direct darker tones of the colors to set the precedence of mature visuals with a clear outlier color (orange) for indication of data points within the visualizations.

To start the overall page structure and the main visualization, I started by designing the overall page structure. To meet some of my initial requirements of a clean and structured outline, the sections within the page must be symmetrical and evenly distributed. Moving forward with the header, each line has different header styles to prioritize each title. A word wrapper technique I learned called spinny-words keeps "I am" static while cycling through a table of values that indicate common words describing human opinions and emotions found in the research papers and media reviews. I utilized flexbox technique for the border under the spinny-

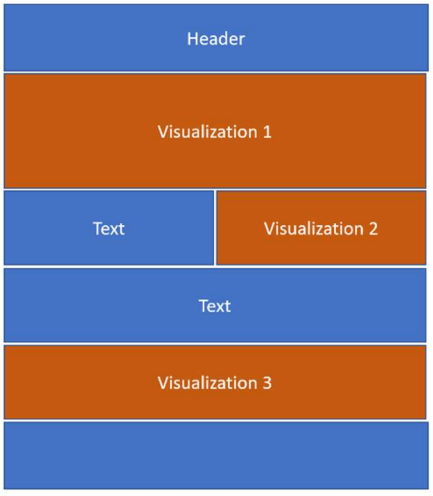

Figure 3: Page Structure design

words technique to allow for color functionality below the title. I did not just create a single line via code because I needed a way to embed the orange tag in the line to give a cohesive aesthetic detail to the visualizations.

The first visualization is an orthographic globe representing countries where robotics has been embedded in the workforce. The mindset was to show this is a worldwide subject. end-users can interact with the world to find data points for countries. Given time and resources, the idea would be that every country would have data available and enable end-users to explore more than in its current state. The topic research is relatively new, so more data and industry participation would be needed. On the hover of each country, orange will shade over and display minor metrics. I could have had the globe centered and complete; however, I intentionally chose to have the object fall into the lower right corner just to give a visual appeal and provoke interest in interaction with end-user as if, at first glance, they would try to intentionally drag the globe to the center of the screen but instead realize there are other interactions.

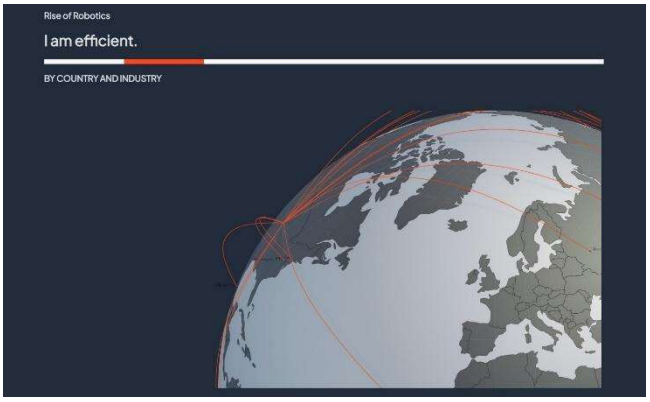

Figure 4: Main Visualization

I wanted to add a timeline to help end-users understand the change and events that led up to the current state of robotics in industry and the labor workforce. To avoid creating a more standard timeline as lines and dots, I went down an unconventional design where there is no line in the center. The size of each circle indicates the point in time and milestone relevancy in length on the hover of each historical event. A time and label of the event will appear, and the circle will slightly animate to express focus on a point in time or event. The selecting event will open to a text box, further elaborating on occasion—added functionality within the text box to exit out and reverse out back to the entire timeline for further exploration. The color utilized is the same throughout the visualization, with functions to change transparency based on interaction by the end-user.

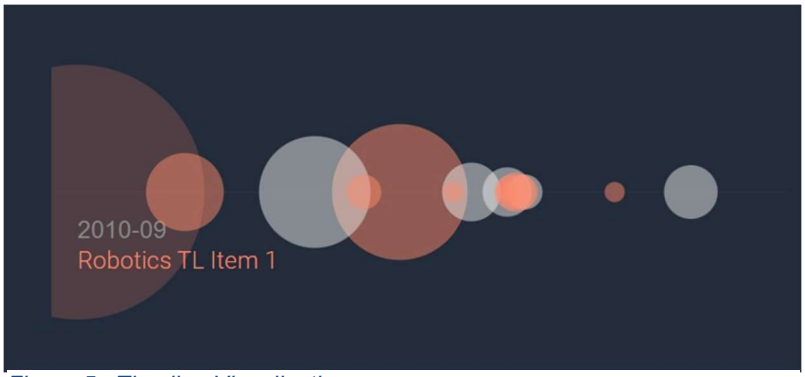

Figure 5 : Timeline Visualization

The third visualization developed was a heatmap altered to represent the industry's time and intensity of robotics. Three countries focused on were China, Japan, and the United States of America. Simply because these were the only three countries where such data was available and has warranted research due to the level of robotics integration in these three countries. The color scheme is the same throughout, and

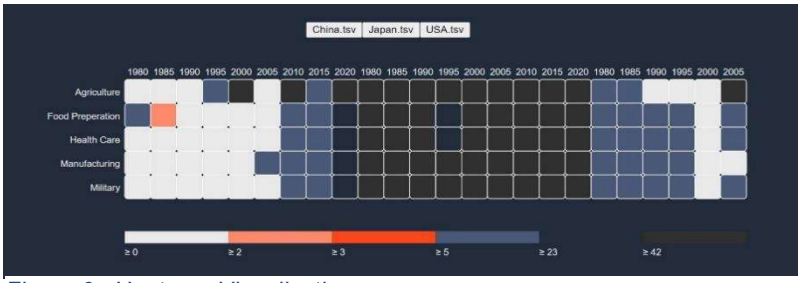

Figure 6 : Heatmap Visualization

animation bounce was added on change of country transition to create a smooth visual change versus an abrupt change in colors. Each card in the heat map has rounded edges to help the visual feel a bit more organic. My intent to add an image of a robot in that specific industry and the progression of the robot over time on hovering each “card”; however, it might confuse the user with an already detailed view of the data visual. I was not entirely convinced it would add any value to the chart other than additional interactivity that would overlay above the heatmap visualization, potentially obscuring the initial intent of the matter and the overall point of the visualization.

Study Relationship

Where this project relates to my Data Visualization studies path falls in three areas, Data Analysis, Data Studies, and Data Visualization. Combining these three focuses allowed me to culminate and develop a "finished" project where raw and research data were analyzed and converted to a visualization that conveys a more complex data process into a simple presentation for the end-user.

For Data Analysis, I applied the fundamentals of working with data where I reviewed, collected, and understood complex statistical models in research papers to manage, develop and systematically work up into a curated solution to describe, illustrate, condense, recap, and evaluate data—applied different data types in what constitutes a valid dataset that can be analyzed quantitatively and how data should be formatted to create a suitable dataset. Statistical analysis techniques learned in Professor Everson's courses were critical in reading a few research papers about embedding robotics and statistical examinations of labor and workforce. Professor Everson's statistics teachings enabled me to convey otherwise complex datasets into simple data points on a visualization that the masses can understand.

Since these are relatively nascent topics where formatted and structured data is not widely available, there was much cleanup and extraction from the text to devise and simplify the data. There were a few cases where the data was extracted from textual readings, such as research papers, articles, and scholarly papers. There are situations where specific data was pulled from other visualizations to help create a visualization in mind. With proper fundamentals in mind, I could develop clean datasets for the visualizations and associated files.

Regarding the relationship to Data Studies, I applied theoretical and ethical thought processes of how technology such as robotics impacts social, political, and cultural aspects, where our society relies on these technologies for better or worse. I wanted to present the ethical problem that the introduction of robotics is causing the human workforce with a practical yet neutral intent allowing end-users to come to their conclusions. I did not make the overall visualization feel a certain way, especially since the topic, for some, may cause mixed emotions about the idea of being "replaced." For example, I wanted to stay from attributes that would cause some form of "gloomy" dark or intent to create a dystopic future around the topic. Framing some data points to illustrate theories and opinions in books such as "The Robotic Imaginary – The Human and Price of Dehumanized Labor" by Jennifer Rhee read in Katherine Behar's class to help identify essential points and direction of visualization. Attributes include the idea that there is this coevolution of cultural and technological robots, arguing that multiple spheres of humans and robotics affect and transform each other.

For me, more importantly, the focus of the project was to challenge and apply foundations and learned skills in data visualization techniques from Professor Frymire teachings and courses. Skills learned from Dr. McSweeney's courses were also applied, not just from a design perspective but also bring in the technical components learned throughout the program to create a coherent functional visual that will help convey this topic and engage the user. Allowing the end-users to better engage with the core idea of the topic, detect patterns, and quickly gain insight into an otherwise complicated area of focus and help them come to their conclusions. I wanted to create engaging and effective information displays by utilizing web-

based technologies, including HTML, CSS, and D3.js, and applying and developing with fundamental and my iterative design process.

Evaluation

I underestimated this project in certain aspects. The more I dove into the topic with just a few research papers and articles, the more extensive and intricate the subject became. I started to explore areas I did not expect to explore, such as the socio-economic impact on the labor workforce outside of monetary or job availability indicators. I believe I can capture my audience as intended, but there can certainly be improvements.

Initially, going into this project, I thought rich research data would be abundant and already available. To my surprise, a few limitations I ran were that most existing research data is specific to the first-world represented societies and economic countries. To coincide with the US Office of Accountability - Data or better data needs to exist.[7] Some second-world countries have no data on any third-world countries at all. Even so, most research looks at major first-world countries such as the United States, China, Japan, etc., where there is more variation in the labor market and capital. The other limitation I ran into is that regardless of where robotics integrated itself into the industry, it became more "mainstream" where applicable after the late 80s and early 90s.

Regarding coding, there were a few minor setbacks in the original design. Both are due to a lack of knowledge and resource limitations. I wanted to create a rich animation

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[7] Office, U.S. Government Accountability. "Workforce Automation: Better Data Needed to Assess and Plan for Effects of Advanced Technologies on Jobs." *Workforce Automation: Better Data Needed to Assess and Plan for Effects of Advanced Technologies on Jobs | U.S. GAO*, 23 May 2019, https://www.gao.gov/products/gao-19-257.

visualization, For instance the globe in the first visualization would fly in from the corner on the page load and continue to rotate until the end-user interacts, giving complete control of the world. When the user releases the globe, it continues to turn, and countries would pulse. Another shortcoming I ran into with the visualization is that the nations would increase in size on hover or click and go back to scaled size. The problem for me was putting them together, not enabling the functionality. Once I would try to compound the different functions, individual functions would fail. To add, all three visualizations are running independently and combined into the main page by iframe containers which allow them to run fluidly. Still, if I try to have them run all three on one page, they start to slow down, load slower than expected, or have an intermittent frame rate on interaction or animations.

I did not have as much challenge with the second timeline visualization as deciding style decisions. The third visualization was just a matter of how much data I wanted to display. I did have to learn a few new functions that would enable better design and overall cohesive functions of the visualizations.

State management was one function where I felt I failed. If Japan is selected, all other visualizations will update to data from Japan. Two apparent challenges: one goes back to insufficient or partial data, and the second was running each page in iframes and sending the update through to the following HTML page was not working for me. Due to time and resources, I had to postpone to after submission for this functionality.

Subjectively the project succeeds in conveying the topic to a general audience. The other focus for me was to develop and apply visualizations creatively for end-users to explore. I tried to keep the visualizations exciting and engaging. I would like to revisit these visualizations later

when more data is available or apply a python script that goes out and scrapes the web for related data. Despite my indicated improvement points, my initial intents and foundation for the project were accomplished.

Project Continuity

Due to time and resource constraints, I would foresee a task for this project to collect more data. Not just collect as an individual, but for this project to be whole, society would have to survey and develop more data and studies around this topic, or, if data exists, make it more available. The theme throughout readings and social media is robotics in the labor workforce are efficient, accurate, and cut costs… however, that is a superficial view on the topic and a cape over what it is doing to the human workforce in its current state. Alternatively, I could foresee building a python script that would go out to the web and look for data related to this topic bringing in a database of information that could be used; however, this could go into the "big data" side of technologies and may require a more significant number of resources.

I would consider creating a better file structure and coding. Possibly with different structural in mind with the idea of fewer files, the better. Instead of multiple HTML and JavaScript files, it would work off fewer files, be more embedded, and be less resource intensive. Some of the visualizations were running poorly initially, and I ended up segregating the code; if feasible, I would address these performance issues.

On the visualization side, I would have liked to have more fluid narrative interactivity such as state management; for instance, as the end-user scrolls throughout the page, visualizations would automatically and cohesively auto-update unless the end user otherwise instructs via manual input.

When I start these projects in the draft, I tend to overshoot and then tone down the experience due to restrictions, knowledge, or just plain it does not work as imagined. When I say better and engaging, more so in the animation side of visualization, for instance, I wanted the

globe to fly over the page into position and then slowly rotate on the axis giving the end-user the feel of automated storytelling. Or the ability to interchange between visualizations in a carousel-type animation. While I understand some of the functions, I run into performance issues where the browser slows down. Programming languages outside d3.js may be a better fit for some resource-intensive visualizations and animations. That would be subject to further exploration and how far I want to take these visualizations. Consideration of structure and hierarchy of side and visualization components. Improvements to where data is versus visualizations also where symmetry works vs. not. I try to stick to symmetrical type layouts, but they may sometimes limit the creativity of object and text placement.

Overall, I think the exploratory visualization can help educate on this topic for multiple audiences, increasing awareness and maybe creating inquisitive points on the matter that end-users may miss in everyday life. It is the direction we are heading, but the only to make a difference and embrace it is to be educated on the topic.

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