
d3.js and its potential in data visualization

Creating a diagram showcase using ukrainian refugee data

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Abstract - German

Diese Arbeit gibt einen Einblick, sowie eine Einschätzung eines Codebasierten Werkzeuges zur Datenvisualisierung, der d3js JavaScript library. Es werden nicht nur das Potential, sondern auch die Vor- und Nachteile evaluiert. Weiterhin wird eine Einschätzung gegeben, wann der Einsatz dieses Werkzeuges sinnvoll ist. Um diese Einschätzungen treffen zu können, werden einige Diagramme, bezüglich der aktuellen Flüchtlingssituation, die aufgrund des bewaffneten Ukraine Konfliktes besteht, erstellt. Dafür werden zunächst die nötigen Grundlagen erklärt. Dies umfasst sowohl Daten und Datentypen, als auch Diagramme und deren Aufbau. Abschließend werden die erstellten Diagramme, sowie d3js im Diskussionsteil ausgewertet.

Da d3js in reinem JavaScript implementiert ist, lässt es sich problemlos mit anderen Frameworks kombinieren. Der Fokus von d3js liegt auf der schnellen und einfachen Manipulation von Elementen im Document Object Model. d3js ist jedoch kein Werkzeug mit dem in wenigen Zeilen Quellcode ganze Diagramme erstellt werden können. Vielmehr müssen sowohl die einzelnen Elemente eines Diagrammes, wie auch deren Position und Aussehen händisch definiert werden. Das ermöglicht ein höchstmaß an Kontrolle über das Aussehen und Verhalten der Diagramme. Es ist jedoch auch zeintensiv und erlaubt für die Implementation unübersichtlicher Diagramme. Gepaart mit der hohen initialen Lernkurve, kann die Nutzung von d3js nur in speziellen Fällen, welche die volle Kontrolle über Aussehen und Verhalten von Diagrammen benötigen, empfohlen werden.

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1. Introduction

The postmodern world produces huge amounts of data every second. Analyzing this data can lead to better-informed decision-making in every sector. Yet the vast amounts of gathered data is often hard to comprehend with the human mind. Data visualization is about finding ways to represent this data in visually appealing and easily comprehensible ways [1]. Doing this quickly, ideally instant, to always be up to date can be crucial. While it is possible to create data visualizations manually, it is common to use computer tools to help in their creation.

There are many tools available to help with the creation of diagrams for data visualization. Some of these tools have a graphical-user-interface, like Excel [2] or SPSS [3]. Other tools are code based, like R [4] or the Matplotlib [5] library for Python. As the requirements for data visualization projects can vary, it is often not easy to decide which tool best suits one's needs. Especially if one has no prior experience and is unfamiliar with the potential of the tools available. Yet knowing when to use which tool can be greatly beneficial for all parties involved. Therefore this thesis will be a deep dive into the broad possibilities of one of these code based tools, the 'd3.js'(D3) library for JavaScript. Knowing its potential, as well as the strengths and weaknesses of the tool can be greatly beneficial when deciding if it is the right tool for the job. Whilst there is a lot of information and examples on how to use D3, the available information makes use of a variety of code styles and different versions of D3. This makes it hard to properly evaluate the possibilities of D3 as a data visualization tool without using it.

To evaluate D3 and its possibilities there are three main questions that will be investigated in this thesis. What is the potential of D3 in data visualization? What are the advantages and disadvantages of using D3? When should D3 be used? To be able to evaluate these questions and get a better understanding of D3, a showcase of several different diagrams is created and evaluated throughout this thesis. This showcase is created using and visualizing refugee data of the currently ongoing Ukraine conflict. A live version of the showcase can be found at "<https://styxoo.github.io/>".

This thesis is not a comparison of D3 to other data visualization tools. It also does not evaluate different types of diagrams in their effectiveness of conveying data. Furthermore this thesis does not offer a comprehensive performance test of D3, as creating a testing framework, defining test parameters and creating a consistent test environment would go beyond the scope of this thesis.

All the theoretical background as well as the core concepts of D3, which are necessary to understand and follow along with this thesis, are described in chapter 2. Afterwards, in chapter 3, the refugee data, the implementation of each of the diagrams, as well as the showcase are described in detail. In chapter 4, the resulting diagrams are discussed and the initial questions about D3s potential and limitations evaluated. Finally, a conclusion is drawn in chapter 5.

2. Basics

In this chapter, all concepts, technologies and required backgrounds for understanding this thesis, as well as the diagrams implementations, are explained. First, data and data types are described in section 2.1. Second, diagrams, their use and how they are structured are described in section 2.2. Last, in section 2.3, D3 as the tool to create diagrams is described and its core concepts explained.

2.1 Data

As data is the main content of each data visualization effort, this section gives an introduction to data and data types. While this section only provides a general introduction to data, the specific data used in this thesis is introduced in section 3.1.

Since ancient times, humans have recorded data. Recording the ins and outs of available resources and other administrative record-keeping were one of the driving factors behind the conceptualization of writing [6]. With the introduction of computers the amounts of gathered data have grown drastically. Nowadays vast amounts of data are gathered across all aspects of life. According to Statista, the total amount of data created, consumed and stored by 2020 was already at 64.2 zettabytes and is projected to reach about 180 zettabytes by 2025 [7].

The vast amounts of data gathered in databases are often hard to comprehend and evaluate with the human mind. They are also unwieldy to present in the often limited space of articles, dashboards or other informative purposes. Therefore data visualization (Figure 2.1) is used to turn these data sets, collections of data points, into diagrams. These diagrams can easily be shown in more limited spaces, as well as allow for a quick general understanding and overview of the provided data.

Data is commonly preprocessed before turning it into diagrams. Depending on the data set and the desired result, this can mean different things.



Figure 2.1: Data visualization describes the process of turning raw data into visual representations. There can be a multitude of possible representations for a data set.

One might want to remove excess information from the data set, which is not necessary for the representation. On the other hand, additional data can be added by evaluating the existing data points. These could for example be the median of values or grouping of certain value ranges [8]. It is important to note that this preprocessing can happen with specific intentions in mind. While it is only supposed to make the representations easier and more concrete, it can be abused to make data align with desired results or to create a certain emphasis. This thesis is not too concerned with this, as the possibilities of D3 are independent of the validity and completeness of the presented data.

Even though data comes from a huge variety of sources and can express a plethora of things, there are only four different types of data [9]. They are split into two categories: categorical and numerical data. Each category has two subtypes. In the following each of the types of data are explained.

2.1.1 Categorical

Categorical or qualitative data is information collected in groups. It is often of descriptive nature. Whilst the values can be represented in numbers, like grades, they do not allow for arithmetic operations. Yet as it is possible to count the data points, it is possible to find the mode. The mode is the most frequently occurring value.

The two sub-types of categorical data are nominal and ordinal data. Each of them is described below.

Nominal data is mostly descriptive in nature. Values have no relation to each other and have no inherited order. Examples are the 'Country of origin', 'Color of paint' or 'Brand of car'.

Ordinal data is also descriptive, yet the data does have a internal order. For example different dates each describe a day, but one day also comes after another. Grades also have an internal order, as one grade is better then another. Whilst ordinal data has an ordering, the order is not necessarily equidistant. Due to its internal order, it is possible to find the median. The median is the value where half the values in the data set are higher and the other half of the values are lower.

2.1.2 Numeric

Numeric or quantitative data is all data expressed in numbers, where numbers do not represent categories. It allows for arithmetical operations and can be

split into discrete and continuous data.

Discrete data can only take certain defined values. This usually means whole numbers to represent things that can not be split up further. Discrete data is usually countable. Examples are the 'Number of Refugees' or 'Tickets sold'.

Continuous data can be measured. It can have any real number as value. Therefore fractions are possible as well. For example when measuring the temperature, or the length or weight of an object.

2.2 Diagrams

This section first provides a brief introduction to diagrams, containing an overview of the history of diagrams, where they can be found and what their potential is. How diagrams are constructed using marks and channels, as well as what needs to be considered while doing so, is described afterwards in section 2.2.2.

2.2.1 Introduction

Using graphical representations to convey data has been done by humans since the earliest cave paintings. In the 18th century William Playfair conceptualized the bar and column charts, as well as pie and donut charts [10]. Since then, diagrams have only become more common. Nowadays one constantly comes across diagrams in everyday life. They can be commonly found across all kinds of reports, information campaigns or newspapers [11]. They can also be found as part of user-interfaces in machinery or control systems. This is not only due to the fact that diagrams allow the representation of a lot of data in limited space. They can also represent the data in a more attractive ways. Additionally, data seen in diagrams is easier to remember, as "The human brain is more able to identify and comprehend relationships and patterns if data is encoded into visual forms." [12].

With the frequency of diagrams in use every day, some diagrams are, intentionally or not, inaccurately representing data. Due to the huge potential diagrams offer for the perception of data, this should be carefully considered. Edward Tufte introduced the lie factor for evaluating how accurately data is shown [13]. It is defined as the effect size in the diagram over the effect size in the data. Most sources of skewed representations of data can be prevented

by using zero baselines, equidistant axes, accurate scaling when using areas and value adjustments for monetary values to contradict inflation influences.

Yet the selection of which diagram should be used to visualize which data set is not trivial. Mostly there are several possible diagram choices for any given data set. Furthermore there is a plethora of diagrams already in use and anyone can create entirely new diagrams to suit their needs. Yet the vast majority of use cases can be covered by one of the more commonly known diagram types, like bar and column charts, pie and donut charts and line charts [14]. Due to their popularity, high-level tools like Excel or Plotly [15] provide support for these diagrams out-of-the-box [16]. More specialized diagrams might use combinations or variations of other diagram types. Other diagrams are specifically created for only one specific visualization.

2.2.2 Marks and Channels

Whilst there are countless types of diagrams, most diagrams use a combination of marks and channels to present data. Marks are used for entries in the diagram. The three possible marks are points, lines and areas. Channels describe the way specific marks encode data. While there is no definitive list of channels, the most commonly used channels are position, size, color and texture. The position in 2D can be split into the x- and y-positions. The color can be split into hue and luminescence. Each mark should use at least one channel to encode data. Otherwise it does not convey any information. For example in fig. 2.2 lines are being used as marks for each of the seven entries. It might seem like areas are used, yet the thickness of the line, and therefore the bar, only serves visual understanding and holds no relevant information. The lines use three channels to encode data. The y-position is used to represent the categorical data of which country. The hue of the bar encodes the same data. This is a bit redundant, as the country is already encoded. Yet the hue makes it easy to follow along when data is changing and bars are shifting positions. The size, in this case length, of the bar encodes the discrete data of how many refugees have crossed into this country. In fig. 2.3 areas are used as marks. Just like in the previous example the hue encodes the country and the size encodes the refugee count.

All marks can be used with all channels. But not all data types should be represented by all channels. For example nominal data should not be encoded using the size channel. The different sizes would lead to a perceived order, which does not exist in nominal data. As the channels all differ in their appearance they are also not equally good in adequately representing the data types. Therefore it is important to consider which channels are chosen to represent the given data types. According to a study by Jock

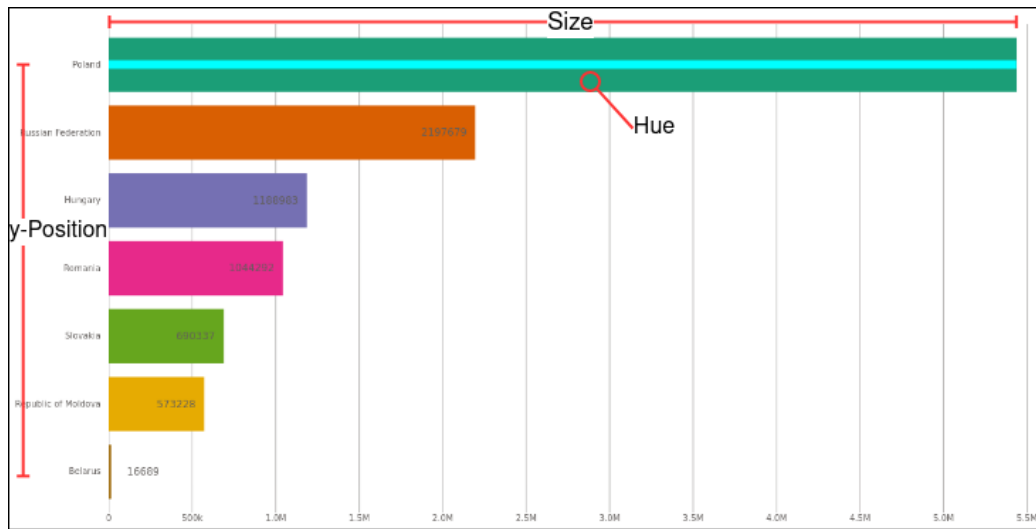


Figure 2.2: This bar chart uses lines as marks. Each bar is a single line mark. The first line mark is highlighted in cyan. The thickness has no relevance other than making the line visible. Each mark uses three channels to encode data. They are highlighted in red. The y-position and the hue are used to encode the country. The size of the line, aka the length, corresponds to the number of refugees.

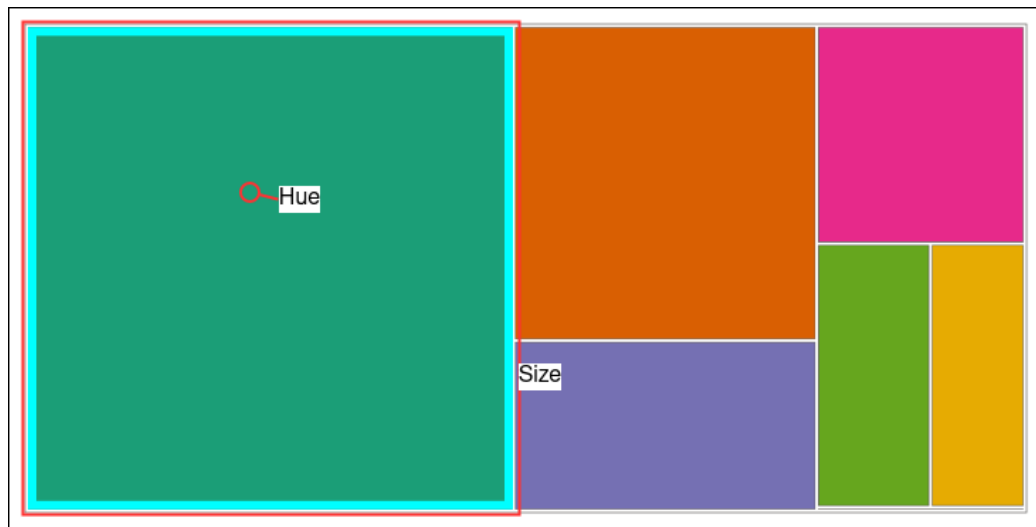


Figure 2.3: This tree map uses areas as marks. A representative mark has been highlighted in cyan. The areas use the size and hue channels to encode data. The size corresponds to the number of refugees, while the hue corresponds to the country.

Mackinlay from 1986, the position channels can always be considered the strongest channels, no matter which marks are combined with them [17]. The combination of marks and channels should be considered carefully. If chosen poorly it can lead to undermine the purpose of the diagram of easily presenting data to a viewer.

Another factor which plays a role here, is the data-ink ratio described by Tufte [13]. It describes the ratio of ink necessary for representing data over the total ink necessary for the diagram. The idea is to draw only what is necessary for showing the data, as this is the main purpose of a diagram. Whilst a lot of diagrams are digital nowadays and therefore do not require ink, diagrams should still try to get as close as possible to a data-ink ratio of one. The lower the data-ink ratio drops, the harder it gets for a viewer to see and comprehend the relevant data.

As some viewers might not be able to perceive the whole range of colors, choosing a color scale should also be carefully considered. Besides using colors which retain a high contrast even with color blindness, they should also be perceptually uniform. This means having similar hues for values close together, and more distinctively different hues for values further apart, while also having a consistent rate of change in the hue. This is especially important when trying to encode quantitative data using the hue channel.

2.3 D3.js

While there are many ways to turn data into diagrams, this thesis is about the potential of D3. Therefore this section introduces D3 by elaborating what it is and how it works.

”D3.js is a JavaScript library for manipulating documents based on data. D3 helps you bring data to life using HTML, SVG, and CSS.”[18]. The name D3 is short for data-driven documents. The D3 library was originally created by Mike Bostock and is published under the BSD-3-Clause open-source license. It is about 350kB in size. As it is fully implemented in JavaScript, it does not require a specific framework and can therefore be easily integrated into all kinds of web-based projects. Whilst D3 is not limited to using SVG, the visualization created using D3 mostly rely on SVG elements for their implementation.

D3 is not a high-level API for creating out-of-the-box visualizations. Instead, ”[it] allows you to bind arbitrary data to a Document Object Model, and then apply data-driven transformations to the document.”[18], therefore making Document-Object-Model(DOM) manipulation easier and less tedious. The DOM represents the structure of an HTML in memory and of-

fers scripts the possibility of accessing and modifying the represented HTML. D3 also provides helper functions like `scales`, to decrease the amount of mathematical equations needed to convert from the data range to the necessary coordinates in the desired visualization.

There are three main concepts that make up the core of D3. Selections, data joins and the general update pattern. All three concepts are working closely together. Whilst selections can be used without data joins and the general update pattern, these two aspects both rely on selections. Data joins can also be used without explicitly using the general update pattern. Usually all three of these concepts are used consecutively. First, a selection is created. This selection is then used to create a data join. Finally, the behaviors of the general update pattern are defined for this data join. In the following all three of the core concepts of D3, as well as scales and D3's plugins are explained.

2.3.1 Selections

A selection contains references to one or more DOM elements. These references are organized in groups. There are two functions in D3 to create a new selection: `d3.select("selector")` and `d3.selectAll("selector")`. Both functions require a selector for identifying the appropriate elements. The selectors are defined in the "W3C Selectors API" [19] and function like CSS selectors. Whilst `select` only selects a single element, the first element matching the selector, `selectAll` selects all elements which match the selector. It is important to note, that `select` also propagates the existing information of this node, whilst `selectAll` does not. Selections can also be extended or shrunk by adding or removing groups, or by combining multiple selections. `select` and `selectAll` can also be called on elements of an already existing selections. The selector will then assume the existing element as root for its selection process.

It is possible to directly access DOM elements through the selections. The respective DOM elements are linked in the groups which make up the selection. But usually this is not required, as there are predefined functions for easily modifying properties for all elements referenced in a selection. This includes the modification of attributes and styles of DOM-elements, as well as event handling.

A selection is required before a data join can be made. How this is achieved is described in the following section.

2.3.2 Data Joins

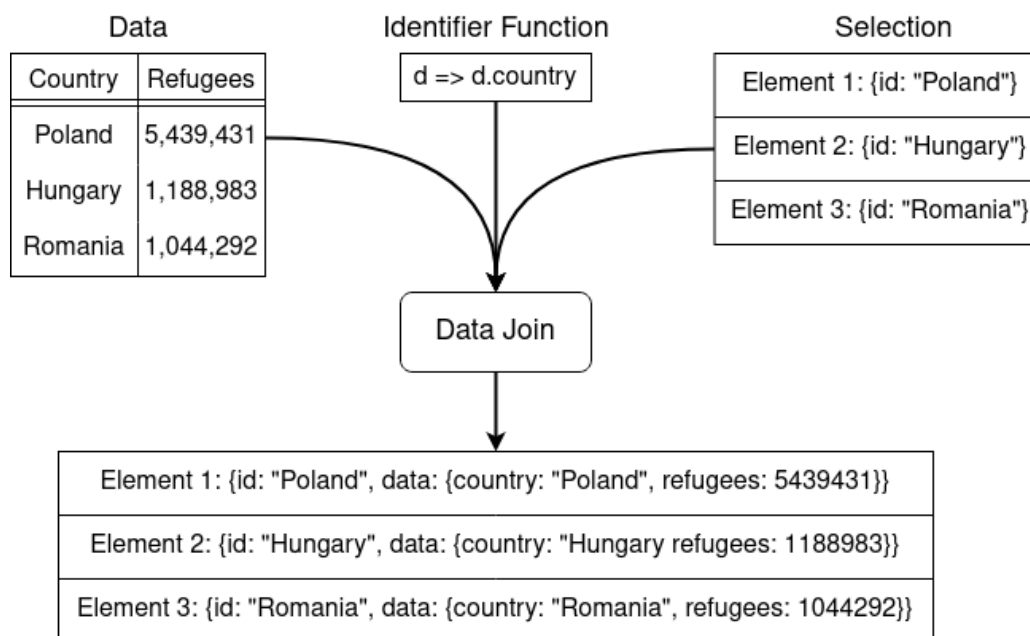


Figure 2.4: A representation of how data joins are created. A selection, consisting of DOM-elements, as well as the data need to be present first. The data join then combines the two. The identifier function is needed if the diagram is supposed to be able to update and can be specified when creating the data join. As a result the data is matched to the applicable DOM-elements using the identifier function.

Data joins are the second key feature of D3. They bind a specific data point to a specific DOM element. To create a data join, one has to first create a selection of elements. These are the elements one wants to match to specific data points. The data join is then created by calling the `.data(dataSet)` function on the selection. It takes a data set, an array of objects where each object represents a single data point, as parameter. This will bind the data points to the applicable elements in the selection. This is achieved by using an identifier function. This identifier function is called for each data point in the provided data set. The default identifier function returns the index of the current data point in the data set. If one wants to create diagrams which can respond to data changes over time, as is the case in this thesis, this is not a reliable identification. When data points are removed or added in arbitrary locations, the index will not match the elements it previously

did. Therefore a custom identifier function can be specified, as seen in figure 2.4. This function is passed as the optional second parameter of the data function. It will be called for each data point in the data set and has to return some value which will be used as the ID. This ID is saved on the element the data point was matched to. Every time the data set is updated, the data join and its underlying selection need to be called again.

As seen in fig 2.5, it can be that the number of data points does not match up with the number of elements to represent them. When there is no element matched to a certain data point, D3 will create an empty placeholder element for this data point instead. What happens to the placeholder elements is defined in the general update pattern.

2.3.3 General Update Pattern

The general update pattern is another core concept of D3. Every time a data join is created or updated, it can be made use of. The general update pattern differentiates between three different cases: enter, update and exit. For each of these cases a sub-selection is created by the data join. For each of these three sub-selections the behavior can be defined. As sub-selections are just selections themselves, they will be referred to as such henceforth. The first selection is the enter selection. It corresponds to the magenta elements in fig 2.5. All the placeholders created by the data join for data points without a matching element are in here. In the behavior for the enter selection, usually a corresponding element is created as the first step. Adding elements includes providing enough attributes to the elements, for them to be appropriately matched the next time the data join is called. Often these elements serve as the marks representing data points in the diagram. When creating an element which is a mark in a diagram, providing appropriate attributes and styles corresponds to using the desired channels for data encoding.

All the elements which are already linked to a data point and therefore identified correctly using the identifier function, make up the update selection. They are marked in cyan in fig 2.5. Specifying the behavior of the update selection allows the diagram to react to changing data by moving existing elements or changing their appearance to accommodate for other new or removed elements.

The last selection, the exit selection, is made up of all the elements previously matched to a data point, for which the corresponding data point has been removed from the data set. They are marked in orange in fig 2.5. The behavior of the exit selection is by default defined to remove the respective elements. The exit behavior can be defined if a more visually pleasing removal of elements is desired, like fading out before deleting.

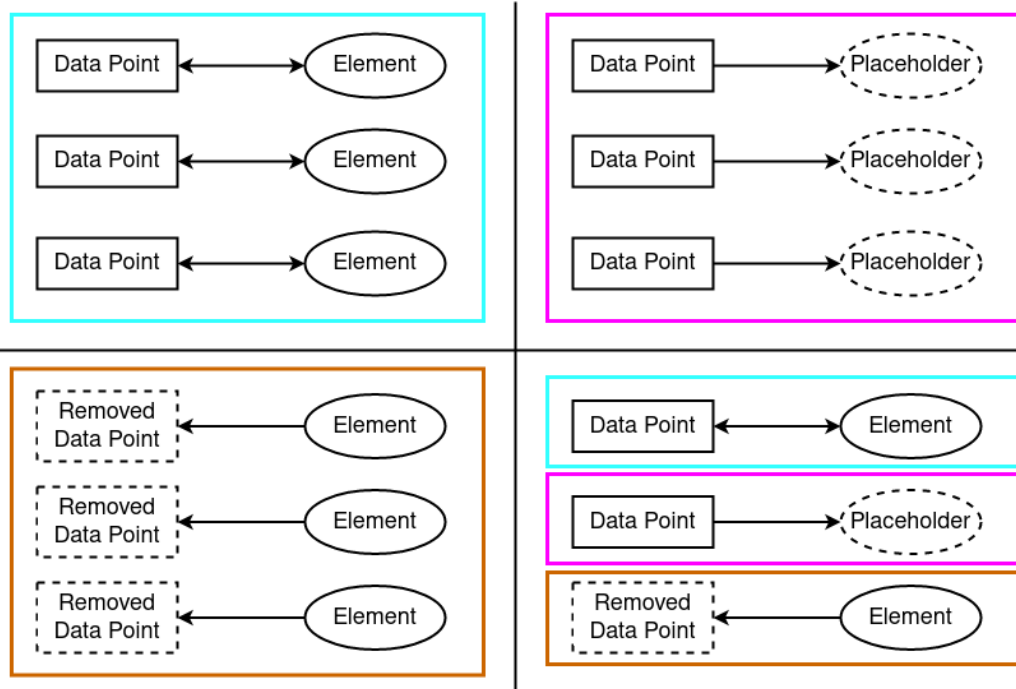


Figure 2.5: A representation of the possible cases when creating data joins. In the top left, the data join was able to match all data points to an element of the provided selection. Those cases are marked in cyan. In the top right, there are data points but no elements in the provided selection. Therefore they are matched to placeholder elements. These cases are marked in magenta. In the bottom left, the provided selection is filled with elements, but their previously matched data points have been removed. These cases are marked in orange. The bottom right shows that all three previously mentioned cases can exist in a single data join. For each of the three cases, the general update pattern can have different behavior specified.

When the goal is to create only static diagrams, which are only initially created from data, it is enough to define the behavior for the enter selection, as all data points will be matched up with a placeholder element when first creating the data join. Here the identifier function is also not important, as the created element will not need to change over time and therefore does not need to be appropriately matched by the data join. But if diagrams should be able to react to data changes and update their appearance, like in this thesis, it is important to define the update behavior as well as a proper identifier function, so elements are always matched with the same data points. It is also important to provide elements, which are created in the enter behavior, with enough information that the next time the data joins underlying selection is called, the newly added elements are selected as well.

2.3.4 Scales

Scales are a way to convert between two data ranges, like the scale factor of maps and model-kits. All scales require a domain and a range. The domain describe the input values, the range where they should map to. There are three types of scales: scales with continuous domain and range, like the example above, scales with categorical or discrete domain and range and scales with a continuous domain and a categorical or discrete range. The reason why categorical and discrete are always mentioned together, is due to the implementation of scales. As the domain and range in discrete and categorical cases can always be represented as an array filled with a set number of entries, there is no difference in the array consisting of strings or integers.

An example for scales with continuous domain and categorical range is converting percentages of correct answers in a test, continuous data, to the appropriate grade, categorical, more specifically ordinal data. An example for a scale with a categorical domain and range is sorting mail. Depending on the destination town of a letter, it will be sorted into a specific box for further processing. It is noteworthy that scales with continuous domain and range can be used in reverse as well.

While all scales require a domain, some scales can dynamically create their domain as they are being used. Each new value used for querying the scale is added to the domain if it is not included yet.

As most diagrams created with D3 are created as SVG, the scales provided by D3 are, in this thesis, mostly used to convert from the range of available data to the coordinate space in which elements should be drawn.

2.3.5 Plugins

D3 provides the most used, general functionalities in the core library. Yet there are many plugins which can be loaded to add functionalities for more specific use-cases. Plugins needs to be loaded additionally to the core library. This thesis makes use of the Sankey plugin [20], to draw the Sankey graph.

As D3 is an open-source project, the plugins available are not all created by the creator of D3, Mike Bostock. Instead a majority is created by the community using D3.

3. Implementation

In the following sections the process of creating the diagrams and the showcase are described. Understanding the implementations of the diagrams is important to be able to evaluate the possibilities, as well as the advantages and disadvantages of working with D3. There are several parts to the process of creating the diagrams and the showcase. At first the data sets to be represented are selected. In most real world usages, this is already given when having to create data visualizations. Afterwards, section 3.2.1 lists not only the implemented diagrams, but also why they have been selected. In section 3.2.2 and following, their implementation and usage of D3 is described. Finally, in section 3.3, the showcase, as well as how data updates are realized, are described.

The implementation uses the currently latest version of D3, version 7.6.1. The JavaScript code uses exclusively arrow functions which have been introduced in ECMAScript6, the specification which JavaScript is build upon[21]. The implementations live version at "<https://styxoo.github.io/>" has been successfully tested using the following operating systems, browsers and versions:

1. Windows 10:
 - (a) Opera - version 90.0.4480.54
 - (b) Microsoft Edge - version 104.0.1293.70
2. Pop!_OS 22.04 LTS:
 - (a) Firefox - version 103.0
 - (b) Chromium - version 104.0.5112.101
3. MacOS 12.4:
 - (a) Safari - version 15.5

Besides the usual code comments, all the code files created for this thesis are commented to highlight and show the working and functionality of D3 and how it is used. As not every section of code is described in this chapter, the comments provide additional help to readers trying to understand the implementations of the diagrams. Furthermore it helps developers interested in adapting the diagrams implementations for their own use.

3.1 Data sets

This section introduces the data sets used in the creation of the diagrams of this thesis. Not only does this section provide an explanation why the specific data sets have been chosen, but also explains the preprocessing which has been done and how it was achieved.

As different data types allow for different representations and require varying parts of D3, the data used in this thesis has been specifically chosen to contain both types of categorical as well as numeric data. As there are no differences in the implementation of discrete and continuous data, only discrete data is used.

All data used for the creation of the diagrams in this thesis originates from the UNHCR Ukraine refugee situation page [22]. "UNHCR stands for United Nations High Commissioner for Refugees, also known as the UN Refugee Agency. It was created in 1950 to help millions of Europeans who had fled or lost their homes during the Second World War. Today, UNHCR protects and assists millions of displaced and stateless people around the world." [23] This thesis makes use of three data sets. The first data set is about the total cumulative border crossings from Ukraine per day [24] and is in JSON format. The other two data set are about the border crossings into countries featured in the refugee response plan and about border crossings into other neighboring countries [22]. They were extracted directly as CSVs. While all data references border crossings from Ukraine and not refugees directly, the UNHCR states that "[they do] not count border crossings of individuals from bordering countries leaving Ukraine to return home (i.e. Romanians returning to Romania), nonetheless among those forced to flee Ukraine are also Ukrainian nationals with dual citizenship" [25]. Therefore this thesis will henceforth refer to the fleeing individuals that crossed the borders as refugees. The refugees per country cover a time span between february 24th 2022 up until august 16th 2022[22]. The refugees per day cover the time from february 24th 2022 until july 17th 2022[24].

As the situation in the Ukraine is still ongoing, it is hard to acquire accurate refugee data. This is also mentioned on the UNHCR situation page,

were it is stated that "Statistics are compiled mainly from data provided by authorities. While every effort has been made to ensure that all statistical information is verified, figures represent an estimate. Triangulation of information and sources is performed on a continuous basis. Therefore, amendments to figures may occur, including retroactively." [22].

To keep the implementations of the diagrams as simple as possible data preprocessing is done as the data is loaded from their respective files, to make it align with the internally used data structure. Therefore two data loader JavaScript files have been created. The first JavaScript file, the `country-DataLoader.js` reads both csv files containing information about the refugees crossing into neighboring countries. Both files are then combined to one data array containing an object, with properties for country and refugees, for each data entry. The second data loader, the `dailyDataLoader.js`, reads the JSON file containing information about the total refugees per day. This JSON file contains a lot of filler data repeating http request headers, timestamps in both unix and YYYY-MM-DD format and a brief description of the Ukraine situation as well as the data. Therefore the data loader strips all unnecessarily information away and produces a single array. This array contains an object, with properties for date and refugees, for each data entry. A section of both of the resulting data arrays can be seen in table 3.1. Both data loaders are accessed either by the respective data services which pass the data to the applicable diagrams, or by the diagrams directly. The data services, `countryDataService.js` and `dailyDataService.js`, are used by the showcase to fill the data tables in the showcase and pass along any manual data changes done in these tables to the applicable diagrams.

Country	Refugees	Date	Refugees
Poland	5439431	Feb 24, 2022	79209
Russian Federation	2197679	Feb 25, 2022	179525
...
Belarus	16689	Jul 19, 2022	9567033

Table 3.1: A preview of the two data arrays after preprocessing. The left table contains the refugees per country. The right table shows the cumulative refugees per day. Each entry in the table corresponds to one object in the appropriate data array. Each object has two properties, according to the headers of the tables. The dates in the right table are JavaScript date objects. They are shortened here for readability.

Together both resulting data sets contain most of the data types. The

number of refugees, which can be found in both data sets, is a discrete attribute. The countries in one data set are a nominal attribute. The date in the other data set is a ordinal attribute instead.

3.2 Diagrams

The following sub-sections are about selecting and implementing each diagram. As there are countless ways to show the selected data sets, a selection of diagrams was made first. Afterwards the implementations common features are explained, before providing more details of the specific implementations of each diagram.

3.2.1 Diagram selection

Two major aspects are taken into the account for selecting the diagrams. Primarily, they should all require different functionalities of the D3 library. This ensures that this thesis actually tests the broad possibilities of D3. To achieve this, four diagrams have been chosen to show the refugees per country data set. A bar chart, a donut chart, a tree map and a Sankey diagram. For the data set showing the total amount of refugees over time, a circle graph and an area graph have been chosen. Secondly, the created diagrams should be realistically usable. This means that they should be usable by for example news agencies or on the UNHCR website, as there is no point in creating unnecessarily complex and unusable visualizations.

The bar chart was chosen for implementation due to its simplicity and minimal amount of D3 functions needed. As it mostly relies on simple `rect` and `text` SVG tags, it provides a good starting point for learning D3. Additionally, it is a frequently occurring diagram. Especially considering that column charts only differ in the orientation, but are functionally the same. The bar chart was chosen over a column chart, as the horizontal orientation of the bar chart allows the viewer to read the country name and the number of refugees in one line. The main reason for choosing the donut chart was its use of the specific D3 functions for creating pie and donut charts. The donut chart was chosen over a pie chart for it's compact form while still allowing some additional information to be shown in the center. It is also used to present custom attribute tweens for animations. The usage of D3s tree map functions was the main reason for choosing the tree map. Additionally it offers a good example for including CSS styling tricks, a tooltip and event-handling using D3. Both the tree map and Sankey diagram also provide an insight into working with hierarchical data structures. The Sankey diagram

was additionally chosen to present the usage of D3 plugins. The circle graph was chosen to show more D3 scales, as well as the possibilities of using scales to create custom legends. Lastly, the area graph uses more basic D3 functions for rendering lines and areas. These have not been used before, but can prove quite powerful when creating diagrams showing trends over time.

Whilst all diagrams are presented in one showcase, each diagram is implemented to work standalone. This makes the comparison between diagrams, as well as evaluating the effort needed to create them easier. It also allows for easier adaptation if one were to use one of the diagrams as a template. Therefore all diagrams are implemented independently, using three parts: a HTML, a CSS and a JavaScript file. The HTML loads the D3 library and the applicable data loader in the header. This data loader is only used when the diagram is accessed directly. This can be done by clicking the diagram in the showcase. The body of the HTML consists of a SVG tag where the diagram will be drawn, and a script tag which loads the JavaScript file. The CSS defines the general styling of the diagram which is not dependent on the input data. The main part of the implementation is done in the Javascript section.

The JavaScript implementation follows a general pattern. At first there is a initialization section (3.2.3) which is run once as the diagram is loaded. It is followed by a render function (3.2.4) which is responsible for drawing and updating the diagram. As there is no point in drawing a diagram without data, the process of how the diagram is provided the data to show is described next.

3.2.2 Data acquisition

Each diagram has two possible ways to acquire data. This is due to the fact that they are implemented to be shown in the showcase, but also work standalone. Each diagram will first check if there is a data service available. This is true if the diagram is loaded in the showcase. If a data service is available, the diagram will register itself with the data service for data and data updates (Figure 3.1). Otherwise the diagram will access the data loader directly (Figure 3.2). This will only provide data once, as the diagram is loaded.

3.2.3 Initialization

All things which are independent of the data are done during the initialization of a diagram. It starts with setting some core variables. A reference to the SVG tag, which will be used as the container for the diagram, is made. It

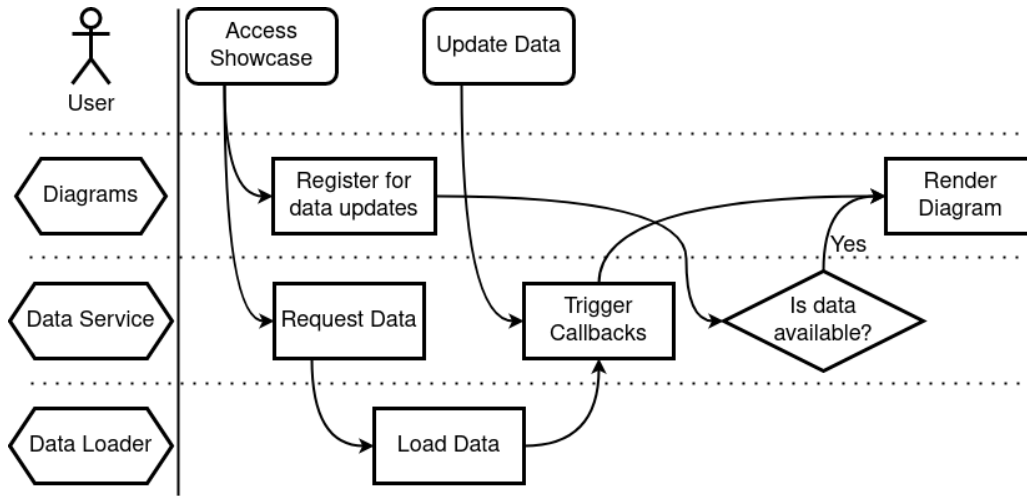


Figure 3.1: This flowchart describes the behavior when loading the showcase and when data is updated. As registering with the data service and loading the data happens simultaneously, the data service returns the latest available data to the diagram when it registers for data updates. This prevents issues which might occur due to timing.

is followed by a margin definition for all four sides, where the margin of our diagram content in relation to the container size is defined. The resulting values for `contentHeight` and `contentWidth`, which are used as space to draw the diagram, are saved.

Afterwards, there are a few SVG group elements added to the SVG container. Adding elements is achieved by calling `.append('elementName')` on an existing element. In the first case, this element is the previously stored reference to the SVG container. As the `append` command returns the newly created element, it can be directly stored in a variable for later reference. It can also be provided with attributes and styles via method chaining. The group elements added here provide a general hierarchy for different aspects of the diagram. Listing 3.1 demonstrates how this works for the bar chart. Having a proper structure in place makes working with selections easier, helps with human readability of the SVGs content and makes debugging using the browsers inspector faster. As SVG elements are drawn on top of each other depending on their hierarchical order, this can also be used to mimic layers as they would be used in drawing applications. This general hierarchy is only created to a level which is independent of the provided data and differs depending on the type of diagram. For example the bar chart has separate groups for the axes and the content, see listing 3.2, while the circle diagram has groups for the background legend and the content.

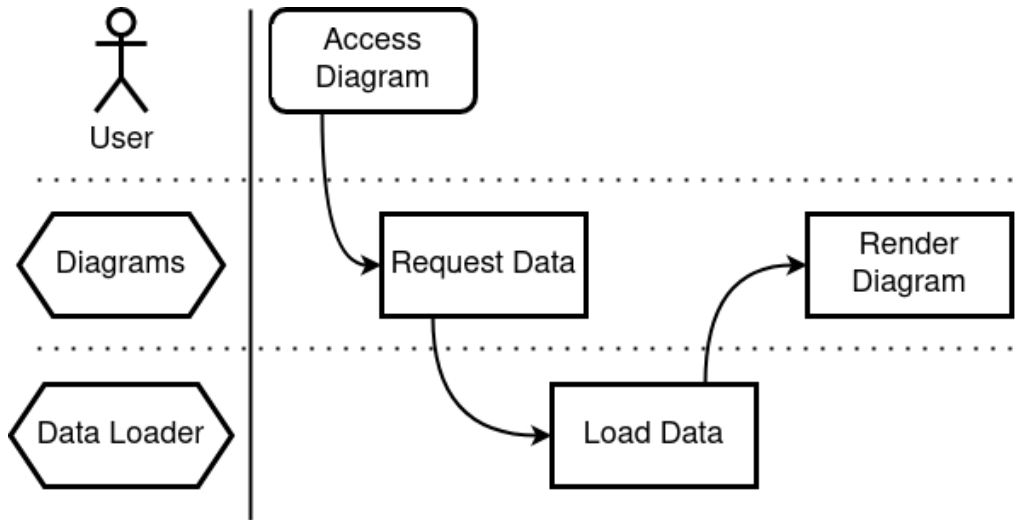


Figure 3.2: This flowchart describes the behavior when loading a diagram directly. As the diagram is unable to register with a data service, it will request the data directly from the data loader.

```
1  const diagramGroup = SVG.append('g')
2    .attr('transform', 'translate(${margin.left},${
3      margin.top})');
4  const xAxisParentGroup = diagramGroup.append('g')
5    .attr('id', 'xAxis')
6
7  const yAxisParentGroup = diagramGroup.append('g')
8    .attr('id', 'yAxis')
9
10 const contentParentGroup = diagramGroup.append('g')
11   .attr('id', 'content')
```

Listing 3.1: JavaScript code to create the hierarchy as used in the bar chart. The first line adds a new group element to the main SVG container using the `append` command. The newly added group element is saved in a constant for later references. Furthermore in line two an attribute is added to the new group element using the `attr` command and method chaining. It moves the group element from the left and top to align with the margin definition. In each of the lines four, seven and ten, another group element is added. They are added to the previously created group element. They are all stored in constants for later reference and are provided with ID's for easier identification and debugging.

```
1 <SVG>
2   <g transform=translate(118,20)>
3     <g id="xAxis"></g>
4     <g id="yAxis"></g>
5     <g id="content"></g>
6   </g>
7 </SVG>
```

Listing 3.2: The HTML structure which results from the JavaScript code in listing 3.1. The resulting tree structure clearly separates the different aspects of the diagram. Using a hierarchical approach makes not only later selections easier, but also increases human readability and simplifies debugging.

If there are data independent scales, they are defined next. A common example here is a color scale for nominal values. It is used in all diagrams showing the refugees per country. When queried, it will return a new color from the provided range for each new query value. This scale does not require a predefined domain. Instead it is dynamically defined and extended with each new value querying the scale. It is important to note that when the predefined color list runs out of new colors, it starts reusing the same color list from the beginning.

```
1 const colors = d3.scaleOrdinal(d3.schemeDark2);
```

Listing 3.3: Definition of the data independent color scale. `d3.schemeDarkv2` is a predefined list of color values which is used as the range of the scale.

If there are any static elements, they are also defined in the initialization. For example the tooltip used by the tree map or the center text fields in the donut chart. Even though the data which these fields are supposed to show is not yet known, these fields are persistent and can therefore already be created here.

Finally any general helper functions are also defined here. Both diagrams about the cumulative refugees per day make use of a date conversion function, which produces a nicely formatted date string from a JavaScript date object. The resulting strings are in the form of mmm-DD, for example Feb-07 or Jun-15.

3.2.4 Render

Following the initialization section is the render function. The render function is responsible for drawing and updating the diagram. The render func-

tion is called once in the beginning and every time the data set changes. The render function covers all data dependent tasks, including the implementation of the data joins and general update pattern. As the implementation of the render function greatly varies between the diagrams, all common features are described first. Afterwards the specifics for each diagram are described. If there are helper functions or constants required by the render function they are defined first.

As all the diagrams make use of transitions for animations, a transition is defined with a duration of 1500 milliseconds. This transition is later called for each element which should be animated. Defining the transition here allows for all later calls to not only take the same amount of time without having to change the duration in more than one position, but also to reuse the same transition instance.

Scales

The data dependent scales in this thesis are mostly used to calculate the coordinate position and sizing of elements in the diagrams. The bar chart for example defines two scales, a linear scale to find appropriate x-coordinates and a band scale for the y-coordinates of each bar. As these scales domains depend on the value range of the provided data set, it is necessary that they are redefined with every render call.

Data Joins

After the scales are defined, the data joins are created. While some diagrams, like the bar chart, only use a single data join (see A.1 line 110), other diagrams, like the circle graph, make use of several data joins (see A.5 lines 106 and 173). Usually this is in accordance to how many independent parts the diagram consists of. The circle graph uses one data join for the size legend in the background and to update the circle showing the current data as well as the text showing the current number of total refugees.

As all diagrams in this thesis can react to data changes, they have a custom identifier function. For the refugees per country data set in this thesis, the identifier function is `d => {return d.country}`.

When a data join is initially created, or when data points are added, there is not a sufficient amount of elements in the selection to pair them with data entries. D3 will therefore create empty placeholders for these elements. To make these placeholders become a part of the DOM, the `.join()` function is added after the `data()` call. There are two ways to use the join function. One can either pass a string which will result in adding a matching tag to the

DOM, or define functions for the general update pattern. When using the simple string method, the attributes and style for each new element can then be defined by method chaining. This approach is reasonable for diagrams that do not need to react to data changes. As all diagrams in this thesis implement the full extent of the general update pattern to be able to react to changing data and use the full potential of D3, the second approach is used.

General Update Pattern

When the `join` function is called, instead of passing a single string as parameter, three functions can be passed as parameters. These three functions correspond to the three cases of the general update pattern and describe their respective behavior. Each of the three functions has one input parameter, corresponding to the respective sub-selection. In the `enter` function an element is added to the DOM. In the `update` function existing elements are updated to accommodate for data changes and therefore possibly removed or newly added elements as well. In the `exit` function elements are removed. As this is the default behavior, the `exit` function definition can be omitted if no extra behavior is desired. All three functions run on all the elements of the appropriate sub-selection.

The `enter` function adds the applicable element to the SVG. Therefore the first part of the `enter` function is usually an `.append(string)` call. The string describes the tag which will be added to the DOM. Afterwards the applicable styles, attributes and sub-elements are added. This can be achieved with the `.attr("attributeName", "value")`. While styles can be added with the `.style("property", "value")` function, the same can be achieved more cleanly by predefining styles in the CSS and adding applicable classes to the element. The selector used to define the current data join, should be able to match the newly created element as well. Therefore enough attributes need to be provided. This is important when the selection is recreated for updating the diagram. When positioning and sizing a new or existing element the scales are used to compute the applicable coordinate space.

The `update` function is necessary when the diagram should be able to react to data changes. It is usually similar to the `enter` function, in that it adjusts the positioning and sizing of the elements according to the possibly changes scales.

The `exit` function is defined by default to simply remove the applicable elements. The diagrams in this thesis do not specify a more complex `exit` behavior.

All three functions can make use of animations and transitions to improve their feel. The diagrams created for this thesis only animate the `enter` and

update behavior. Why animations are useful and how they are implemented is described in the following section.

Animations

Animations can improve the feel, appeal and readability of diagrams. When a diagram is updated due to data changes, it is easier to understand and see the changes when for example bars in a bar chart shift to their new positions, instead of a seemingly entirely different diagram popping up. The animations allow the viewer to keep track of the existing entries and visually follow any changes. For example the growth or shrinking of the length of a bar in a bar chart. Animations can also be used when initially drawing the diagram, to guide viewer attention.

Animating elements in D3 is achieved by using transitions. Transitions are called on elements using the `call()` function. A transition requires a duration and can also be provided with a delay and an easing function to improve the feel. The duration and delay are both in milliseconds. Animating numerical or color values is very easy with transitions. It is only required to call the attribute or style with the target value and the transition function will calculate and show interpolated frames. This makes it very fast and easy to animate for example positioning or sizing of elements.

Instead of using the default behaviors for numbers and colors or when trying to animate other values like SVG paths, a tween function can be defined using `attrTween` or `styleTween`. Both tweens need to return a function which will be invoked for each frame of the animation, with a time value between 0 and 1, depending on the frame. The returned function must itself return a value, which is applied to the desired style or attribute every frame. In this thesis custom tweens are only specifically defined to animate SVG path tags in the donut chart (see listing 3.5).

Bar Chart

The bar chart, as well as the following implementations of the donut chart, the tree map and the Sankey graph all make use of the dataset containing the number of refugees per country they fled to.

The bar charts first defines two scales, the `xScale` as well as the `yScale` (see A.1 lines 70ff). The `xScale` is a linear scale to convert from a domain of the refugees `[0, HighestNumberOfRefugeesInAnyCountry]` to a range of the available space `[0, contentWidth]`. This allows to find the appropriate x-coordinate for any number of refugees. It is used to draw each bar to its appropriate length. The `yScale` converts from any given country to a y-

position using a scale band. Therefore the domain is defined by providing an array of all possible countries and the range is `[0, contentHeight]`. This allows the proper height positioning of each bar using the resulting y-coordinate.

The bar chart also makes use of axes. The y-axis shows the countries, while the x-axis shows the amount of refugees. D3 has predefined functions to create axes from scales. An axis in D3 consists of many ticks. By default each tick has a label and a small line indicating its position. Furthermore there is a start and end line to indicate the whole domain. The bar chart removes all the domain lines for styling reasons. The tick lines for the y-axis are also removed, as they are unnecessary here. The tick lines of the x-axis are extended to cover the whole diagrams height. This is done to have a proper reference to read out the bars length.

```
1  const xAxisTickFormat = number =>
2      d3.format('.2s')(number)
3      .replace('0.0', '0');
4
5  const xAxis = d3.axisBottom(xScale)
6      .tickFormat(xAxisTickFormat)
7      .tickSize(-contentHeight);
8
9  xAxisParentGroup.call(xAxis)
10     .attr('transform', `translate(0,${contentHeight})`)
11     .select('.domain')
12     .remove();
```

Listing 3.4: The x axis implementation of the bar chart. The first constant defines the tick format. The provided `'.2s'` means that each number will be convert to have two significant digits. As the zero value is therefore represented as `"0.0"` to match the previous rule of two significant digits, it is simply replaced by `"0"`. The second constant defines the function creating the axis. The previous tick format is passed here. Furthermore the `tickSize` is set to the height of the diagram. This way the initially small tick lines now cover the whole height of the diagram and allow for easier and more accurate readouts. Finally the `xAxisParentGroup` element, which is part of the permantent hierarchical structure of the bar chart, calls the `xAxis` function. This adds the Axis to the diagram. As a last step the domain lines are selected and removed for styling reasons. (Section from A.1 lines 91ff)

Each bar in the bar chart is composed of a SVG `rect` for the bar itself and a `text` field as the label with the precise amount of refugees. The `rect` and

`text` are both children of one group element with the `bar` class as attribute. Due to this structure, the bar chart only requires a single data join. The required selector matches all group elements with the `bar` class. In the enter sub-selection of the general update pattern, first a new group element with the `bar` class is added. Afterwards a `rect` as well as a `text` are added to the newly created group element. The `rect` is filled with the appropriate color by calling the color scale. Both elements are positioned and sized accordingly using the previously defined scales. The x-position of the text as well as the width of the rect are initialized with a zero value. These two values are animated using a transition, to reach their actual values. This way new bars always build themselves up from the left side. The text field usually tries to stick to the inner right side of the rect. In cases where there is not enough space available to the left, as the bar is shorter than the number to show, the text is placed to the right of the rect.

Elements in the update sub-selection are resized in the width and text value if the number of refugees for this country or the range of the `xScale` changed. They might also be repositioned and resized in height, as new countries are added, or old ones removed from the data set. All resizing is done using the transition for smooth animation of the changes. Elements in the exit selection are simply removed.

Donut chart

As the donut chart shows the total amount of refugees in the center, this value is computed first. This is achieved using the `d3.sum(data, d => d.refugees)` function (see A.2 line 115). It creates the sum of all entries in the data, using the `refugees` field for each entry. After calculating this value, the appropriate text field is updated to contain the new number.

As each section of the donut chart is made up of a path element, D3 provides two functions to generate pie and donut charts. The `d3.pie()` function calculates the appropriate start and end angle of each data point (see A.2 lines 112ff). A padding angle has also been specified for some spacing between the sections of the diagram. The `d3.pie()` function returns a new object which holds a reference to our original data, additionally to the new sections information.

The `d3.arc()` function is set up with an inner and an outer radius (see A.2 lines 127ff). Having an inner radius of zero generates a pie chart, whereas an inner radius greater than zero, like in this instance, creates a donut chart. The `d3.arc()` function which is set up here is later used in the general update pattern to generate SVG path objects from the pie pieces containing the start and end angles of each section.

As each section of the donut chart is made up of a `path` element nested inside a group element, the selector for the data join matches all group elements with the `arc` class. The data join is then created using the previously created pie object. In the enter selection of the general update pattern, the parent group element is created first and provided with the `arc` class. Afterwards a path element is added to this group element. This path element is colored according to the color scale. Drawing the actual arc piece is done using an attribute tween. This animates the donut chart to smoothly fill itself in the beginning. The implementation of this initial animation is almost same as the one seen in 3.5 for updating the arc sections. The only difference lies in the two `interpolate` functions using zero as initial value instead of the respective `previousStartAngle` and `previousEndAngle`, as these two values are not assigned yet.

Lastly the path elements are registered to two callbacks, `mouseover` and `mouseout` using D3s `.on()` function (see A.2 lines 171 and 178). Both these events are used to show and update the appropriate text in the center of the donut chart. The effect which creates an outline around the currently hovered over path element is not linked to these events, but instead is achieved by CSS styling.

As the update behavior of the donut chart consists only of updating the paths, it is fully described in listing 3.5. The exit behavior removes appropriate sections.

```
1  // The core of the donut animation is defined here.
2  const animate = (nodes, index, d, i, j) => {
3      nodes[index].previousStartAngle = d.startAngle;
4      nodes[index].previousEndAngle = d.endAngle;
5
6      return time => {
7          d.startAngle = i(time);
8          d.endAngle = j(time);
9          return arc(d);
10     };
11 };
12
13 [...].call(update => update.transition(t)
14     // The update animation for the donut pieces is
15     // specified here.
16     .attrTween('d', (section, index, nodes) => {
17         const interpolateStartAngle = d3.interpolate(
18             nodes[index].previousStartAngle,
19             section.startAngle);
20         const interpolateEndAngle = d3.interpolate(
21             nodes[index].previousEndAngle,
22             section.endAngle);
23
24         return animate(nodes, index, section,
25             interpolateStartAngle,
26             interpolateEndAngle);
27     }));
```

Listing 3.5: The implementation of the arc update animations. As the core of the animation is used by the enter and the update behavior, it is defined first. The new values for start and end angle are stored on the node itself. This needs to be done to be able to reference these values again for the next update, as the previous angles will not be accessible through the pie object after regenerating it for an update. Finally the function which is called for each frame of the animation is defined and returned. This function first interpolates the start and end angle values using the passed interpolation functions and the time value. This time value is in the range of zero to one, depending on how far along the animation is. These newly interpolated angles define the start and end angle of the pie piece, which is then turned into a path element by calling the `arc` function for this pie piece. As the interpolate functions `interpolateStartAngle` and `interpolateEndAngle` differ for the enter and update behavior, they are defined in the respective sections. They are passed into the core `animate` function. (Section from A.2 lines 132ff and 186ff)

Tree map

As the tree map is intended to work with hierarchical data, it requires all data points to have a link to their parent data point. There is only one data point without a link to a parent, which serves as the root element. As the refugees per country data set is not in hierarchical structure, this is simulated first. Therefore a dummy object is added to the data array. Using the `d3.stratify()` command turns the data set into a tree object by connecting each data point to a parent, in this case the dummy object (see A.3 line 108ff). The dummy element has no parent and serves as the root of the tree object. After removing the dummy element from the data again, the sum of refugees in the tree object is calculated. Using the `d3.treemap` command and providing it with information about the available space and padding between elements, it provides the trees leafs with their relevant size and position information (see A.3 line 124ff).

The general update pattern adds a `rect` for each leaf of the tree object before styling it appropriately and animating its size and position. The `mouseover`, `mousemove` and `mouseout` events are registered for showing, updating and hiding the tooltips content and position, as the mouse moves over a `rect` in the tree map. The update selection smoothly moves and resizes the rects when applicable, while the exit selection removes them.

Sankey diagram

The Sankey diagram consists of nodes and links. Therefore these two arrays are constructed first. Each node represents one country. The links describe the flow of values, in this case refugees, between nodes. This is achieved by providing a source node, a target node and the value at the target node. To be able to show a flow from the Ukraine to the other countries, the Ukraine is added as a node. All countries from the data set are added as nodes. There is also a link from the Ukraine node created for every country. The resulting arrays are provided to the `d3.sankey()` function (see A.4 line 73ff). This function is not part of the default D3 namespace. Instead it is added by additionally importing the Sankey package in the Sankey diagrams HTML page header. The `d3.sankey()` function adds additional information to the nodes and links allowing for appropriate placement of the according elements. It also adds all the links' values to create a source value for the Ukraine node.

The Sankey diagram makes use of two data joins. The first one links the nodes to appropriate group elements. During the enter behavior, each group elements is filled with a `rect` and a `text` element. The `rect` represents a node in the Sankey diagram and is sized according to the number of refugees

and styled according to the country using the color scale. To make the color scale consistent with the other diagrams, the Ukraine node is provided with a fixed color. This prevents the Ukraine node from querying the color scale and creating inconsistency with the other diagrams which do not contain a representation for the Ukraine. The `text` label contains the name and amount of refugees per country. It is placed next to the appropriate `rects`. This can be on the left or right side, depending on the x-position of the `rects`. If the `rect` is in the left half of the diagram the label is right, if the `rect` is in the right half the label is left. Both `rect` and `text` make use of transitions to smoothly build up the diagram. The `text` also makes use of a small delay to the transition by using the `.delay(100)` function (see A.4 line 124).

The second data join takes care of the links. They are matched to path elements. Each path is styled to match the country it leads to. The required SVG path is created using the `d3.sankeyLinkHorizontal()` command (see A.4 line 149). As the resulting path is only a single line, the `stroke-width` attribute corresponds to the width of the link. The links are also animated using the transition. When initially appearing, the links are provided with a delay before fading into existence after the nodes have settled in their positions. The update behavior makes sure that the links are smoothly transitioned to their necessarily position and the width adjusted as needed.

Circle graph

The circle graph, as well as the area graph described in the following section both make use of the data set about the cumulative refugees per day.

The circle graph makes use of two data dependent scales. A time scale is created using `d3.scaleQuantize()` (see A.5 line 85ff). It is used for converting the time slider value to an actual date. As the time slider value provides a value between zero and one, this domain is mapped to the range of available dates in the data set. The second scale is used to get the correct radius of the circle. Because the area of the circle corresponds to the number of refugees, it is important to not scale the radius linearly. This would lead to circle areas which do not represent the correct number of refugees. Scaling the radius linearly would introduce a lie-factor higher than one. In fact, due to the relation between a linear change in radius and a change which keeps the area consistent, the lie factor increases, the higher the amount of refugees is. To avoid this, a `d3.scaleSqrt()` is used (see A.5 line 90). The domain is set to `[0, HighestNumberOfTotalRefugees]` and the range to `[0, contentHeight/2]`. This scale is also used for drawing the background legend. This is achieved by getting the ticks of the scale and saving the appropriate values in an array. This array is rendered in circles using the first data join.

This data join draws and updates a circle and a text label for each tick.

As the actual content of the diagram does not draw one mark per data point, the refugee number for only one data entry is shown at a time. The time scale is used to determine which is the currently selected date from the time value, provided by the slider, in the range of zero to one. The resulting date is used to get the corresponding data for that date from the data set. This allows the diagram to reuse only use one circle and one text label in its representation. Therefore the second data join also looks a bit different. Instead of linking actual data, an array with an arbitrary single entry is linked to the selection. Without this single element, D3 would not draw the circle, as it assumes that there is no data to show. The identifier function also always returns the same value, no matter what data was linked. This makes sure that the same circle element is matched by the selector on each render call, as to not draw a new circle every time the diagram is supposed to update. The circle and text are both created and styled using the data which was found for the current date.

Area graph

The area graph makes use of the same time scale as the circle graph. Additionally it uses a linear scale for the y-axis and a scale band for the x-axis. The y-axis represents the number of refugees, while the x-axis shows the days. Both axes are added to the diagram in the same way as is done in the bar chart. As showing all days on the x-axis would be too dense, the values are filtered and only 15 equidistant days are shown. This is achieved by using JavaScript `filter` function for arrays and specifying a custom filter which is to be evaluated for each entry in the domain of the x-axis scale band (see A.6 line 126).

The main content of the area graph consists of two parts. One part shows the area, while the other one is the date line showing the current date. The area and the line following along the top of the area, the top-line, are two separate path elements. Their definition can be seen in listing 3.6. Because the area and line both cover the whole range of data at once, the data join, which creates and updates them, uses the same single element dummy data as the circle graph. When creating or updating the line and area, the whole data set is passed to the respective functions.

```
1  const line = d3.line()  
2    .x(d => xScaleWithOffset(d.date))  
3    .y(d => yScale(d.refugees));  
4  
5  const area = d3.area()  
6    .x(d => xScaleWithOffset(d.date))  
7    .y1(contentHeight)  
8    .y0(d => yScale(d.refugees));
```

Listing 3.6: The first constant defines the function for creating the top-line of the area graph. This is achieved by specifying functions for x- and y-values. D3 uses them to calculate the position of each point on the line. Using the arrow functions here applies this for each entry of the data set which is passed as a parameter when calling this function. When the function is called and a data set is provided, by calling `line(data)`, the line is constructed by calculating the according x- and y-positions for every data point. Defining and creating the area works in similar fashion. Yet there are two y-positions for each x-position. `y0` is the bottom of the shape, while `y1` is the top. Switching the definition of `y0` and `y1` results in a reversed direction of the SVG path describing the outline of the shape. The `d3.area()` function allows for a huge variety of shapes. Yet it is not possible to create concave ends on the right or left side of the shape, assuming left and right are oriented horizontally. Of course the created shape can be rotated and oriented using all possible SVG tags and attributes. (Section from A.6 lines 144ff)

The date line is made up of three elements. A circle element rides on the top line of the area, a vertical line to indicate the current day on the x-axis and a text label to show the days refugee value. All three parts are simply created and updated in the second data join. This data join makes use of the same kind of dummy data as seen in the previous data join and the circle graph.

3.3 Showcase

To bring all the diagrams together, a showcase has been created. In addition to containing the diagrams, it also allows for manually modifying the data used to create the diagrams. The layout of the showcase as well as how data can be modified are described in the following sections.

3.3.1 Layout

The showcase is split into two main sections. The first section is about the refugees per neighbor country they crossed into. The second section is about the cumulative refugees over time. As all diagrams in one section represent the same data set it allows for an easy visual comparison. While the left side of each of the two section holds all the diagrams, the right side contains information regarding the diagrams, as well as a possibility to view and change data. The information area always tries to stick to the top of the screen, as long as space is available.

The information area of the first section shows a legend first. This legend is implemented using D3 and reacts to data changes like the diagrams do. The information area of the second section contains a time slider. This is used to select the current date which the circle and area graph take into account.

The showcase loads each of the diagrams into a separate `iframe` tag with a consistent aspect ratio. As the diagrams are set up to use all available space in the provided container, the showcase makes sure to size the `iframe` containers appropriately. When a diagram is loaded in the showcase, it also registers with the applicable data service. This allows the data service to update the diagram as the data is changed, as is described in the following section.

3.3.2 Data Updates

Each section of the showcase has a table which allows for data manipulation. These tables are hidden when the showcase is loaded. They can be shown by ticking the appropriate 'Show Data' checkbox. Rows of data can be modified, added or removed here. The data changes here are not persistent and are therefore not saved in the original data files. While the correctness of the initial data is not guaranteed, arbitrarily changing the data entries obviously falsifies the shown data. Changes in the data are registered by the respective data service when a data update is triggered. Data updates are triggered automatically as soon as any data is changed or rows are added or removed while the 'Auto Update' checkbox is ticked. This is the default case. If one wants to change more data points before a update is triggered, the auto update option can be deselected and the manual 'Update Data' button used instead. When a update is triggered, the data service creates a new data set from the data in the table and passes it along to the applicable diagrams when calling their render function to update.

For this thesis it is important to be able to modify the data, as one of

the core features of D3 tested in this thesis is reacting to changes in data. This manual style of modifying data is probably not so common in real world applications. Yet it is easy to replace these manual data changes to regular API calls or other automatically updating data sources. As the source of the data changes does not matter for the functionality of D3, the manual approach chosen here is sufficient in demonstrating the possibilities of D3 in reacting to changing data.

4. Discussion

The discussion evaluates the results of this thesis. Therefore it is split into two parts. The first part, section 4.1, is about the diagrams and comparing them to each other. Section 4.2 contains the second part of the discussion and tries to answer the initial questions about the potential of D3 in data visualization.

4.1 Diagrams

The first four diagrams show the data about the refugees by country crossed into. While the underlying data is the same, the resulting diagrams are quite different from each other. The donut chart and tree map make it immediately obvious, that almost half of all refugees went to Poland. While this is hard to guess from the bar chart without a ruler or calculator, the vertical spacing of the nodes in the Sankey diagram also does not make this obvious. Only the donut chart and the Sankey diagram allow the viewer to immediately see the total amount of refugees. While the bar chart and tree map also contain this information, they would require the viewer to calculate it themselves, defeating the purpose of data visualization. The Sankey diagram and bar chart directly show all the numbers of refugees per country. This information can be found in the donut chart and tree map as well, but only by using the mouse to inspect the diagrams more closely. This can be a struggle when trying to get more precise data about the refugees which went to Belarus, as their amount is so small, that these two diagrams hardly show Belarus at all. While the shown legend is universally true, both the Sankey diagram and the bar chart also directly show the names of the countries, making comprehension of the data more easy. The Sankey diagram is also the only diagram which conveys the flow from the Ukraine to the other countries. The other diagrams only achieve this through context, not in their actual graphic.

When data is updated, all four diagrams smoothly transition to their new states. This makes the changes quite easy to follow and pleasant to look at.

The tree map can sometimes be a bit confusing, as the different rectangles can shift across each other.

The two diagrams showing the cumulative refugees per day, are quite different from each other. While the circle graph actually only ever shows the value for a single day, the area graph shows the whole extend of the data with an extra indicator for the current day. Due to the scaling of the radius in the circle diagram it can also be quite hard to read the number of refugees from the legend, especially for smaller values. The area graph does a much better job of not only consistently showing not the number of refugees on the selected day, but also the development of the refugee count over time. Therefore it struggles with accurately showing the current date. This is easier in the circle chart, as it is simply displayed at the bottom.

When data is updated, the circle graph can be completely unaffected. Only when the data for the currently selected day is changed, or the size legend adjusts itself, changes can be seen. Because of the way that the functions used to create the line and area of the area graph work, the updates of the area graph are only easy to follow when values are adjusted. When days are added and removed it is hard to follow along, due to how the line and area are created by D3.

4.2 D3

The tree initial questions presented which this thesis tries to answer were: What is the potential of D3 in data visualization? What are the advantages and disadvantages of using D3? When should D3 be used? All three of these questions will be evaluated and discussed separately in the following discussion, beginning with the question of what D3s potential is.

Looking at the created showcase, D3 can obviously be used to create many different types of diagrams. Looking at the examples found online, D3 has their own showcase of projects, makes this even more apparent. From simple bar and pie charts, over visualizing hierarchical data using tree maps or Sankey diagrams, like the ones created for this thesis, all the way to map based diagrams using various projections[26], physics enabled bubble graphs[27] and pseudo 3D animations[28]. Of course D3 can also be used to created animations which do not necessarily serve data visualization purposes, like the tadpoles example[29]. Due to D3's low level approach, fast speed, and the general update pattern, D3 can be used to create all visualizations one can imagine and have them react to data changes in real time. As D3 is built around simple DOM manipulation, it can also be used for other use cases. One can create HTML tables and populate them with data. One

can make small animations to add visually appealing aspects to a website. Or maybe one can adapt the scales for their own needs of converting data. But what are the advantages and disadvantages of D3?

When working in a web environment, it is always easy to start using D3. Its independence from any framework and its pure JavaScript implementation, make it possible to include D3 in any web-based project. On the other hand, if one is not already working on a web-based project but still wants to use D3, one has to deal with all the additional overhead of working with a web technology stack. Whilst importing the D3 library is really easy, the initial learning curve is everything but easy. Without first internalizing the core concepts of D3 and SVG, it is impossible to make any kind of visualization. While this is true for any framework or technology, the concept of the data joins and the general update pattern seem especially abstract. Yet it is crucial to understand it when a diagram is supposed to react to data changes. While learning the basics of D3 is quite a big hurdle, it can be broken down by first creating only static diagrams. This can be achieved without a deeper understanding of the general update pattern. While D3's low-level approach is cumbersome to comprehend initially, it actually allows D3 to be very flexible. In addition, while there are a lot of examples and tutorials, they are often too complex to understand as a beginner, or use varying versions of D3 or JavaScript styles. Besides some functionalities of D3 being obsolete in newer versions, the different styles of JavaScript can be additionally confusing when the developer is not familiar with the evolution of JavaScript. Once one understands how D3 works, it can be quite fast to create basic diagrams. Once one properly understands the general update pattern and selections, it is also not too difficult to react to data changes. Yet trying to animate diagrams can become tricky. It depends on the elements which are used and which attributes need to be animated. As all elements have to be manually specified, one has full control over the appearance and behavior of the diagrams. This allows D3 to adapt to any existing style guides, yet is also very time consuming. It also allows creating diagrams with a high lie-factor or a bad data-ink ratio. This risk can be mitigated using a more high-level library. High-level libraries also allow for the automatic creation of legends, instead of having to create them manually as was done in this thesis.

Another concern might be the performance of D3 when dealing with many marks in a diagram. Therefore the limits of smooth animation of the bar chart and the tadpoles example[29] were briefly tested. Of course these results vary from device to device. In this case, it was possible to smoothly animate up to approximately 1200-1300 tadpoles. The bar chart is harder to evaluate. The singular bars approach, and partially pass, the limits of a singular pixel in thickness, and therefore their visibility on the screen, with

this number of entries in the diagram. While this thesis does not provide a proper performance test and comparison with other visualization libraries performances, it can be safely assumed that performance will not be an issue for most diagrams.

So when should one use D3? This depends on the task at hand. If the goal is to create some diagrams as a one time job, D3 is unnecessarily complex. Tools like Excel can easily excel here. Even when working with a web project, D3 is probably too complex. Most developers will find all necessary functionality using libraries like Chart.js[30] or the Plotly JavaScript library, which is actually built on top of D3 to offer a more high level approach to data visualization. Both these open-source libraries allow creating some of the most common diagrams without having to learn all the quirks of D3. Yet if someone is to create a custom visualization or wants more fine control over all aspects of a diagram, D3 can handle it. Nevertheless, due to the high initial learning curve getting into D3 can only be recommended when the creating custom visualizations, which high level libraries can not provide.

5. Conclusion

While D3 is an immensely powerful tool, learning and understanding the core concepts of D3 took a surprisingly long time. While there are many examples, the inconsistencies in D3 versions as well as JavaScript versions were quite confusing. Having never worked with D3 and only having very limited experience with JavaScript, it took a fairly long time to get used to both. Even now, if I was tasked to create some simple diagrams, I would probably use a more high-level library. Unless the required diagrams require the full potential of D3. A few parts have been especially cumbersome. While animating updates with transitions is usually easy, creating a smooth animation for the donut chart took longer than expected. Having to work with the custom attribute tweens and storing information on the DOM element itself, made this even more confusing. Yet this was in part due to my lacking proficiency in working with JavaScript and the differences between function declarations using arrow functions and the function keyword. I was also unable to animate the area graph in a way where the date line follows the line along the top of the area. Furthermore it would be nice if the date line would be draggable using the mouse. This is something which can most certainly be done. But not by me in the time span of creating this thesis. Creating the right selections and sub-selections when implementing the general update pattern also is not always easy. While drawing a diagram initially is usually an easily achievable feat, making sure that update behavior reuses existing elements is sometimes tricky. The widespread use of D3 at least helped finding information on common issues, which was very helpful for bug fixing.

While the implementation doesn't differ for using discrete and continuous data, it would still have been nice to show this in an actual example. Another interesting aspect which is not explored by this thesis, is working with maps and projections. A map could also have easily shown the refugee streams.

Due to the currentness of the data, the UNHCR was updating their situation page as well. One of the effects of this was that the terminology they used changed from initially mentioning refugees, to later solely mentioning border crossings. This can actually still be seen when looking at the raw

data JSON file, which contains the cumulative number of refugees per day. It contains a description clearly mentioning the data being about refugees. As the diagrams and showcase were implemented before writing the text for this thesis, the renaming was glossed over, as all the created work would have to be redone. This is also why the code files always mention refugees.

Finally, while it was interesting to work with D3 and get to know its immense potential, it is devastating to see that, yet again, millions of people have been displaced by unnecessary violence and aggression.

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A. Appendix

A.1 Bar Chart - JavaScript

```
1  /**
2   * This script was created as part of a bachelor thesis.
3   * The results can be found here: https://github.com/
4   * Author: Luis Rothenhäusler
5   * Last edit: 25th August 2022
6   *
7   * This file contains the JavaScript implementation of the
8   * bar-chart.
9   */
10 /**
11  * In this first section, some data independent constants
12  * are defined.
13  */
14 // This creates a reference to the SVG container on the
15 // HTML page. This will contain the whole diagram.
16 const svg = d3.select('#mainFrame')
17   .attr('height', innerHeight)
18   .attr('width', innerWidth);
19
20 // The margin definition for the diagram. The content is
21 // padded from the sides using the margins.
22 const margin = {
23   top: 20,
24   right: 20,
25   bottom: 20,
26   left: 118
27 };
28
29 // contentWidth and contentHeight store the available
30 // coordinate space for the content of the diagram.
31 const contentWidth = innerWidth - margin.left -
32   margin.right;
```

Appendix A. Appendix

```
28 const contentHeight = innerHeight - margin.top -
    margin.bottom;
29
30 /**
31  * This section defines the hierarchy of the diagram.
32  * This makes later selections and debugging in the
    browser inspector easier.
33  */
34 const diagramGroup = svg.append('g')
35     .attr('transform', 'translate(${margin.left},${
    margin.top})');
36
37 const xAxisParentGroup = diagramGroup.append('g')
38     .attr('id', 'xAxis');
39
40 const yAxisParentGroup = diagramGroup.append('g')
41     .attr('id', 'yAxis');
42
43 const contentParentGroup = diagramGroup.append('g')
44     .attr('id', 'content');
45
46 /**
47  * This section defines the color scale used to color
    elements according to their country.
48  * It can be defined here, as it is independent of the
    data
49  */
50 const colors = d3.scaleOrdinal(d3.schemeDark2);
51
52 /**
53  * The render function is defined here.
54  * It is called to initially draw the diagram, as well
    every time the data changes and the diagram should
    update.
55  */
56 const render = data => {
57     console.log('Rendering bar chart');
58
59     /**
60      * The following defines the transition which is used
        for all animations.
61      */
62     const t = svg.transition()
63         .duration(1500);
64
65     /**
66      * Here all the required scales, which are dependent
        on the data, are defined.
67      */
```

```

68      // The xScale is used to convert from the number of
        refugees to the applicable x coordinate.
69      // It is also used while creating the x-axis legend.
70      const xScale = d3.scaleLinear()
71        .domain([0, d3.max(data, d => d.refugees)])
72        .range([0, contentWidth])
73        .nice();
74
75      // The yScale is used to convert country to the
        applicable y coordinate.
76      // It is also used while creating the y-axis legend.
77      const yScale = d3.scaleBand()
78        .domain(data.map(d => d.country))
79        .range([0, contentHeight])
80        .padding(0.2);
81
82      /**
83       * This section is responsible for creating the x and
        y axes of the bar-chart.
84       */
85      // This creates the y-axis from the scale and adds it
        to the diagram. It also removes the domain and tick
        lines.
86      yAxisParentGroup.call(d3.axisLeft(yScale))
87        .selectAll('.domain, .tick line')
88        .remove();
89
90      // This defines the function responsible for
        formatting the x-axis ticks.
91      const xAxisTickFormat = number =>
92        d3.format('.2s')(number)
93        .replace('0.0', '0');
94
95      // This creates the x-axis taking the formatting into
        account. Also tick lines will be drawn over the
        whole diagram.
96      const xAxis = d3.axisBottom(xScale)
97        .tickFormat(xAxisTickFormat)
98        .tickSize(-contentHeight);
99
100     // This adds the x-Axis to the diagram, positions it
        accordingly and removes the domain lines.
101     xAxisParentGroup.call(xAxis)
102       .attr('transform', `translate(0,${contentHeight})`)
103       .select('.domain')
104       .remove();
105
106     /**

```

```

107      * This is where the actual content of the diagram is
108      * drawn.
109      * Therefore, a data-join is created and the behavior
110      * of the general update pattern is specified.
111      */
112      contentParentGroup.selectAll('g .bar').data(data, d =>
113      {return d.country})
114      .join(
115      // This describes the behavior of the enter
116      // sub-selection of the general update
117      // pattern.
118      enter => {
119      // A group element is added for a new bar
120      const bar = enter.append('g')
121      .attr('class', 'bar')
122
123      // The rectangle is added to the bar. It
124      // is styled, positioned and animated.
125      bar.append('rect')
126      .attr('width', 0)
127      .attr('height', yScale.bandwidth())
128      .attr('y', d => yScale(d.country))
129      .attr('fill', d => colors(d))
130      .call(enter => enter.transition(t)
131      .attr('width', d => xScale(
132      d.refugees))));
133
134      // The text is added to the bar. It is
135      // provided the refugee value, as well as
136      // positioned and animated.
137      bar.append('text')
138      .text(d => d.refugees)
139      .attr('class', 'barText')
140      .attr('text-anchor', 'end')
141      .attr('dy', '0.32em')
142      .attr('y', d => yScale(d.country) +
143      yScale.bandwidth()/2)
144      .attr('x', 0)
145      .call(enter => enter.transition(t)
146      .attr('x', d => {
147      // If the rectangle is too
148      // small, the text is placed
149      // to the right of it
150      const scaleValue = xScale(
151      d.refugees);
152      return (scaleValue - 60 > 0) ?
153      scaleValue - 10 : 60;
154      })));
155      },

```

```

142          // This describes the behavior of the update
           sub-selection of the general update
           pattern.
143      update => {
144          // The rectangle is selected and updated
           in position and size.
145          update.select('rect')
146              .call(update => update.transition(t)
147                  .attr('width', d => xScale(
148                      d.refugees))
149                  .attr('height', yScale.bandwidth()
150                      )
151                  .attr('y', d => yScale(d.country))
152                      );
153
154          // The text is selected and updated in
           value and position
155          update.select('text')
156              .text(d => d.refugees)
157              .call(update => update.transition(t)
158                  .attr('y', d => yScale(d.country)
159                      + yScale.bandwidth()/2)
160                  .attr('x', d => {
161                      const scaleValue = xScale(
162                          d.refugees);
163                      return (scaleValue - 60 > 0) ?
164                          scaleValue - 10 : 60;
165                      }));
166      },
167      // This describes the behavior of the update
           sub-selection of the general update
           pattern.
168      // Applicable elements are simply removed.
           This is also the default behavior and doesn
           't need specification.
169      exit => exit.remove()
170  );
171  };
172
173  /**
174   * This section tries to subscribe to the
           country-data-service for data updates.
175   * The diagram will not work without the
           country-data-service.
176   */
177  try {
178      parent.registerCountryDiagramRenderCallback(render);
179      console.log('Could successfully subscribe to the
           country-data-service for data updates.');
```

```
174 } catch (e) {
175     console.log('Could not subscribe to the
176                 country-data-service for data updates. ' +
177                 'Data is loaded directly.');
```

A.2 Donut Chart - JavaScript

```
1  /**
2   * This script was created as part of a bachelor thesis.
3   * The results can be found here: https://github.com/
4   * Author: Luis Rothenhäusler
5   * Last edit: 25th August 2022
6   *
7   * This file contains the JavaScript implementation of the
8   * donut-chart.
9   */
10 /**
11  * In this first section, some data independent constants
12  * are defined.
13  */
14 // This creates a reference to the SVG container on the
15 // HTML page. This will contain the whole diagram.
16 const svg = d3.select('#mainFrame')
17   .attr('height', innerHeight)
18   .attr('width', innerWidth);
19 // The margin definition for the diagram. The content is
20 // padded from the sides using the margins.
21 const margin = {
22   top: 20,
23   right: 20,
24   bottom: 20,
25   left: 20
26 };
27 // contentWidth and contentHeight store the available
28 // coordinate space for the content of the diagram.
29 const contentWidth = innerWidth - margin.left -
30   margin.right;
```



```

31 // The radius of the donut is set to use as much space as
    available.
32 const radius = d3.min([contentHeight/2, contentWidth/2]);
33
34 /**
35  * This section defines the hierarchy of the diagram.
36  * This makes later selections and debugging in the
    browser inspector easier.
37  */
38 const diagramGroup = svg.append('g')
39   .attr('transform', 'translate(${margin.left},${
    margin.top})');
40
41 const contentParentGroup = diagramGroup.append('g')
42   .attr('id', 'content')
43   .attr('transform', 'translate(${contentWidth/2},${
    contentHeight/2})');
44
45 const diagramParentGroup = contentParentGroup.append('g')
46   .attr('id', 'diagram');
47
48 /**
49  * This section adds all the necessary text fields for
    showing the total refugees,
50  * as well as the refugees for the currently hovered over
    country.
51  */
52 // The following adds the text to display when no section
    is hovered over.
53 const totalTextGroup = contentParentGroup.append('text')
54   .attr('id', 'totalTextGroup')
55   .attr('display', true);
56
57 totalTextGroup.append('tspan')
58   .text('So far a total of')
59   .attr('dy', '-2.3em')
60   .attr('x', 0);
61
62 const totalTextSpan = totalTextGroup.append('tspan')
63   .text('TotalNumberHere')
64   .attr('class', 'important')
65   .attr('dy', '1.3em')
66   .attr('x', 0);
67
68 totalTextGroup.append('tspan')
69   .text('refugees have fled')
70   .attr('dy', '1.1em')
71   .attr('x', 0);
72

```

```

73 totalTextGroup.append('tspan')
74   .text('Ukraine')
75   .attr('class', 'important')
76   .attr('dy', '1.3em')
77   .attr('x', 0);
78
79 // The following adds the text to display if a section is
   hovered over.
80 const currentTextGroup = contentParentGroup.append('text')
81   .attr('id', 'currentTextGroup')
82   .attr('display', 'none');
83
84 const currentNumberTextSpan = currentTextGroup.append('
   tspan')
85   .text('CurrentNumberHere')
86   .attr('class', 'important')
87   .attr('dy', '-0.5em')
88   .attr('x', 0);
89
90 currentTextGroup.append('tspan')
91   .text('refugees have fled to')
92   .attr('dy', '1.1em')
93   .attr('x', 0);
94
95 const currentCountryTextSpan = currentTextGroup.append('
   tspan')
96   .text('DestinationCountryHere')
97   .attr('class', 'important')
98   .attr('dy', '1.3em')
99   .attr('x', 0);
100
101 /**
102  * This section defines the color scale used to color
   elements according to their country.
103  * It can be defined here, as it is independent of the
   data
104  */
105 const colors = d3.scaleOrdinal(d3.schemeDark2);
106
107 /**
108  * The render function is defined here.
109  * It is called to initially draw the diagram, as well
   every time the data changes and the diagram should
   update.
110  */
111 const render = data => {
112   console.log('Rendering pie chart');
113
114   // The total refugees are calculated and the according

```

```

115         center text is updated.
116     const totalRefugees = d3.sum(data, d => d.refugees);
117     totalTextSpan.text(`${totalRefugees}`);
118
119     /**
120      * This section defines all helper functions and
121      * constants necessary for creating the diagram.
122      */
123     // The pie function generate start and end angles for
124     // each data-point.
125     const pie = d3.pie()
126       .value(d => d.refugees)
127       .padAngle(0.015)(data);
128
129     // The arc functions is used to convert pie sections
130     // into SVG paths.
131     const arc = d3.arc()
132       .innerRadius(radius * .6)
133       .outerRadius(radius);
134
135     // The core of the donut animation is defined here.
136     const animate = (nodes, index, d, i, j) => {
137       nodes[index].previousStartAngle = d.startAngle;
138       nodes[index].previousEndAngle = d.endAngle;
139
140       return time => {
141         d.startAngle = i(time);
142         d.endAngle = j(time);
143         return arc(d);
144       };
145     };
146
147     /**
148      * The following defines the transition which is used
149      * for all animations.
150      */
151     const t = svg.transition()
152       .duration(1500);
153
154     /**
155      * This is where the actual content of the diagram is
156      * drawn.
157      * Therefore, a data-join is created and the behavior
158      * of the general update pattern is specified.
159      */
160     diagramParentGroup.selectAll('g .arc').data(pie, d =>
161       {return d.data.country})
162       .join(
163         // This describes the behavior of the enter

```

```

        sub-selection of the general update
        pattern.
156     enter => {
157         // A group and a child path element are
            added and styled.
158         enter.append('g')
159         .attr('class', 'arc')
160         .append('path')
161         .attr('fill', d => colors(d.data))
162         .call(enter => enter.transition(t)
163             // The initial animation for the
                donut pieces is specified here.
164         .attrTween('d', (section, index,
            nodes) => {
165             const interpolateStartAngle =
                d3.interpolate(0,
                    section.startAngle);
166             const interpolateEndAngle =
                d3.interpolate(0,
                    section.endAngle);
167
168             return animate(nodes, index,
                section,
                    interpolateStartAngle,
                    interpolateEndAngle);
169         })))
170         // The behaviour on the mouseover
            event is specified to update the
            center text accordingly.
171         .on('mouseover', (e, d) => {
172             currentNumberTextSpan.text(
                d.data.refugees)
173             currentCountryTextSpan.text(
                d.data.country)
174             currentTextGroup.attr('display', '
                true')
175             totalTextGroup.attr('display', '
                none')
176         })
177         // The behaviour on the mouseover
            event is specified to update the
            center text accordingly.
178         .on('mouseout', () => {
179             currentTextGroup.attr('display', '
                none')
180             totalTextGroup.attr('display', '
                true')
181         });
182     },

```

```

183          // This describes the behavior of the update
           sub-selection of the general update
           pattern.
184      update => {
185          update.select('path')
186              .call(update => update.transition(t)
187                  // The update animation for the
                    donut pieces is specified here.
188              .attrTween('d', (section, index,
                    nodes) => {
189                  const interpolateStartAngle =
                    d3.interpolate(nodes[index
                    ].previousStartAngle,
                    section.startAngle);
190                  const interpolateEndAngle =
                    d3.interpolate(nodes[index
                    ].previousEndAngle,
                    section.endAngle);
191
192                  return animate(nodes, index,
                    section,
                    interpolateStartAngle,
                    interpolateEndAngle);
193              }));
194      }
195  );
196 };
197
198 /**
199  * This section tries to subscribe to the
           country-data-service for data updates.
200  * The diagram will not work without the
           country-data-service.
201  */
202 try {
203     parent.registerCountryDiagramRenderCallback(render);
204     console.log('Could successfully subscribe to the
           country-data-service for data updates. ');
205 } catch (e) {
206     console.log('Could not subscribe to the
           country-data-service for data updates. ' +
207         'Data is loaded directly. ');
208
209     loadCountryData(render)
210 }

```

A.3 Tree Map - JavaScript

```
1  /**
2   * This script was created as part of a bachelor thesis.
3   * The results can be found here: https://github.com/
4     Styx0o/styxoo.github.io
5   * Author: Luis Rothenhäusler
6   * Last edit: 25th August 2022
7   *
8   * This file contains the JavaScript implementation of the
9     tree-map.
10  */
11 /**
12  * In this first section, some data independent constants
13    are defined.
14  */
15 // This creates a reference to the SVG container on the
16    HTML page. This will contain the whole diagram.
17 const svg = d3.select('#mainFrame')
18   .attr('height', innerHeight)
19   .attr('width', innerWidth);
20
21 // The margin definition for the diagram. The content is
22    padded from the sides using the margins.
23 const margin = {
24   top: 20,
25   right: 20,
26   bottom: 20,
27   left: 20
28 };
29
30 // contentWidth and contentHeight store the available
31    coordinate space for the content of the diagram.
32 const contentWidth = innerWidth - margin.left -
33   margin.right;
34 const contentHeight = innerHeight - margin.top -
35   margin.bottom;
36
37 /**
38  * This section defines the hierarchy of the diagram.
39  * This makes later selections and debugging in the
40    browser inspector easier.
41  */
42 const diagramGroup = svg.append('g')
43   .attr('transform', 'translate(${margin.left},${
44     margin.top})');
45
46 const contentParentGroup = diagramGroup.append('g')
47   .attr('id', 'content');
```

```

40 const treemapParentGroup = contentParentGroup.append('g')
41   .attr('id', 'treeMapParent');
42
43 /**
44  * This draws a background rectangle for the tree-map.
45  */
46 contentParentGroup.append('rect')
47   .attr('id', 'contentBackground')
48   .attr('x', 0)
49   .attr('y', 0)
50   .attr('width', contentWidth)
51   .attr('height', contentHeight)
52   .attr('fill', 'none');
53
54 /**
55  * This section creates and hides the tooltip,
56  * which is used to display information about the
57  * currently hovered over country.
58  */
59 // A secondary small SVG created and added to the body.
60 const tooltip = d3.select("body")
61   .append('svg')
62   .attr('height', 50)
63   .attr('width', 400)
64   .attr('id', 'tooltip')
65   .style('position', 'absolute')
66   .style('z-index', 10)
67   .classed('hidden', true);
68
69 // The tooltips background is styled here.
70 const background = tooltip.append('rect')
71   .attr('height', 50)
72   .attr('width', 100)
73   .attr('rx', 10)
74   .attr('ry', 10);
75
76 // The tooltips text field is created here.
77 const tooltipText = tooltip.append('text')
78   .attr('y', 20)
79   .attr('x', 5)
80   .text('Some text');
81
82 /**
83  * This section defines the color scale used to color
84  * elements according to their country.
85  * It can be defined here, as it is independent of the
86  * data
87  */
88 const colors = d3.scaleOrdinal(d3.schemeDark2);

```

```

86
87 /**
88  * The render function is defined here.
89  * It is called to initially draw the diagram, as well
      every time the data changes and the diagram should
      update.
90  */
91 const render = data => {
92     console.log('Rendering tree map');
93
94     /**
95      * This section is responsible for the required
      preprocessing of the data,
96      * as the tree-map is intended to work with
      hierarchical data.
97     */
98     // A dummy parent object is created here. It's
      necessary for simulating hierarchical data.
99     const parent = {
100         "country": "Dummy Parent",
101         "refugees": 0
102     };
103
104     // Adds the dummy parent to the data.
105     data.push(parent);
106
107     // This turns the data provided into a hierarchical
      data structure.
108     const root = d3.stratify()
109         .id(d => {return d.country})
110         .parentId((d) => {
111             if (d.country === 'Dummy Parent')
112                 return undefined
113             else
114                 return 'Dummy Parent'
115         })(data);
116
117     // The dummy parent is removed from the data again, as
      it is no longer needed.
118     data.pop();
119
120     // The total amount of refugees is calculated here.
121     root.sum(d => {return d.refugees});
122
123     // The data is converted into leaves used to draw the
      tree-map.
124     d3.treemap()
125         .size([contentWidth, contentHeight])
126         .padding(4)(root);

```



```

127
128     /**
129     * The following defines the transition which is used
130     * for all animations.
131     */
132     const t = svg.transition()
133         .duration(1500);
134
135     /**
136     * This is where the actual content of the diagram is
137     * drawn.
138     * Therefore, a data-join is created and the behavior
139     * of the general update pattern is specified.
140     */
141     treemapParentGroup.selectAll('rect').data(root.leaves
142         (d => {return d.data.country}))
143         .join(
144             // This describes the behavior of the enter
145             // sub-selection of the general update
146             // pattern.
147             enter => {
148                 // A rect is added for a leaf of the
149                 // tree-map. It is positioned, styled and
150                 // animated.
151                 enter.append('rect')
152                     .attr('x', 0)
153                     .attr('y', `${contentHeight}`)
154                     .attr('width', 0)
155                     .attr('height', 0)
156                     .attr('fill', d => colors(d.data))
157                     .call(enter => enter.transition(t)
158                         .attr('x', d => { return d.x0; })
159                         .attr('y', d => { return d.y0; })
160                         .attr('width', d => { return d.x1
161                             - d.x0; })
162                         .attr('height', d => { return d.y1
163                             - d.y0; })))
164                 // The mouseover event is specified to
165                 // show the tooltip and update its
166                 // text accordingly.
167                 .on('mouseover', (e, d) => {
168                     tooltip.classed('hidden', false)
169                     tooltipText.text(`${d.data.country}
170                                     \nRefugees : ${d.data.refugees}
171                                     `)
172                     const textWidth = tooltipText.node
173                         ().getBBox().width
174                     background.attr('width', textWidth
175                                     + 10)

```

```

160         })
161         // The mousemove event is specified to
            update the tooltips position
            accordingly.
162         .on('mousemove', e => {
163             const position = d3.pointer(e)
164             tooltip.style("top", (position
                [1]+0)+"px");
165             if (position[0] > contentWidth/2)
                {
166                 const rect = tooltip.select('
                    rect')
167                 const width = rect.attr('width
                    ')
168                 tooltip.style("left", (
                    position[0] - width + 10) +
                    "px");
169             } else {
170                 tooltip.style("left", (
                    position[0] + 35) + "px");
171             }
172         })
173         // The mouseout event is specified to
            hide the tooltip.
174         .on('mouseout', () => {
175             tooltip.classed('hidden', true)
176         })
177     },
178     // This describes the behavior of the update
179     sub-selection of the general update
180     pattern.
181     update => {
182         // The applicable rects are animated to
183         resized and repositioned.
184         update.call(update => update.transition(t)
185             .attr('x', d => { return d.x0; })
186             .attr('y', d => { return d.y0; })
187             .attr('width', d => { return d.x1
188                 - d.x0; })
189             .attr('height', d => { return d.y1
190                 - d.y0; })))
191     }
192     );
193 };
194
195 /**
196  * This section tries to subscribe to the
197  country-data-service for data updates.

```

```
193  * The diagram will not work without the
      country-data-service.
194  */
195  try {
196    parent.registerCountryDiagramRenderCallback(render);
197    console.log('Could successfully subscribe to the
      country-data-service for data updates.');
```

```
198 } catch (e) {
199   console.log('Could not subscribe to the
      country-data-service for data updates. ' +
200     'Data is loaded directly.');
```

```
201
202   loadCountryData(render)
203 }
```

A.4 Sankey Graph - JavaScript

```
1  /**
2   * This script was created as part of a bachelor thesis.
3   * The results can be found here: https://github.com/
      Styx0o/styxoo.github.io
4   * Author: Luis Rothenhäusler
5   * Last edit: 25th August 2022
6   *
7   * This file contains the JavaScript implementation of the
      sankey-diagram.
8   */
9
10 /**
11  * In this first section, some data independent constants
      are defined.
12  */
13 // This creates a reference to the SVG container on the
      HTML page. This will contain the whole diagram.
14 const svg = d3.select('#mainFrame')
15   .attr('height', innerHeight)
16   .attr('width', innerWidth);
17
18 // The margin definition for the diagram. The content is
      padded from the sides using the margins.
19 const margin = {
20   top: 20,
21   right: 20,
22   bottom: 20,
23   left: 20
24 };
25
26 // contentWidth and contentHeight store the available
```

```
    coordinate space for the content of the diagram.
27 const contentWidth = innerWidth - margin.left -
    margin.right;
28 const contentHeight = innerHeight - margin.top -
    margin.bottom;
29
30 /**
31  * This section defines the hierarchy of the diagram.
32  * This makes later selections and debugging in the
    browser inspector easier.
33  */
34 const diagramGroup = svg.append('g')
35   .attr('transform', 'translate(${margin.left},${
    margin.top})');
36
37 const contentParentGroup = diagramGroup.append('g')
38   .attr('id', 'content');
39
40 const linksParentGroup = contentParentGroup.append('g')
41   .attr('id', 'links');
42
43 const countriesParentGroup = contentParentGroup.append('g'
44   )
45   .attr('id', 'countries');
46
47 /**
48  * This section defines the color scale used to color
    elements according to their country.
49  * It can be defined here, as it is independent of the
    data
50  */
51 const colors = d3.scaleOrdinal(d3.schemeDark2);
52
53 /**
54  * The render function is defined here.
55  * It is called to initially draw the diagram, as well
    every time the data changes and the diagram should
    update.
56  */
57 const render = data => {
58   console.log('Rendering sankey');
59
60   /**
61    * This section is responsible for the required
    preprocessing of the data,
62    * as the sankey-graph is intended to work with
    hierarchical data.
63    */
```

```

64     // The nodes and links necessary for creating a sankey
        diagram are created from the provided data.
65     const nodes = [{name: 'Ukraine'}];
66     const links = [];
67     for (const d of data) {
68         nodes.push({name: d.country});
69         links.push({source: 'Ukraine', target: d.country,
            value: d.refugees});
70     }
71
72     // The sankey function adds information to the data
        allowing the nodes and links to be drawn.
73     d3.sankey()
74         .nodeId(d => d.name)
75         .nodeAlign(d3.sankeyJustify)
76         .size([contentWidth, contentHeight])({nodes, links
            });
77
78     /**
79      * The following defines the transition which is used
        for all animations.
80      */
81     const t = svg.transition()
82         .duration(1500);
83
84     /**
85      * This is where the actual content of the diagram is
        drawn.
86      * Therefore, two data-joins are created and their
        behavior of the general update pattern is
        specified.
87      */
88     // The first data join is used to draw the nodes of
        the sankey graph.
89     countriesParentGroup.selectAll('g .country').data(
        nodes, d => {return d.name})
90     .join(
91         // This describes the behavior of the enter
            sub-selection of the general update
            pattern.
92         enter => {
93             // A new group element is added for each
                country
94             const country = enter.append('g')
95                 .attr('class', 'country');
96
97             // The rect representing the country is
                created, positioned, sized, styled and
                animated.

```

```

98         country.append('rect')
99         .attr('x', 0)
100         .attr('y', d => d.y0)
101         .attr('width', 0)
102         .attr('height', d => d.y1 - d.y0)
103         .attr('fill', d => {
104             // To be consistent with the other
105             // diagrams, the Ukraine does not
106             // query the color scale.
107             if (d.name === 'Ukraine') {
108                 return '#0057B8';
109             } else {
110                 return colors(d);
111             }
112         })
113         .call(enter => enter.transition(t)
114             .attr('x', d => d.x0)
115             .attr('width', d => d.x1 - d.x0));
116
117         // The label text is added, provided with
118         // the appropriate text, positioned,
119         // styled and animated.
120         country.append('text')
121         .text(d => `${d.name}: ${d.value}`)
122         .attr('x', 0)
123         .attr('y', d => (d.y0 + d.y1)/2 + 5)
124         .attr('text-anchor', d => d.x0 <
125             contentWidth/2? 'start' : 'end')
126         .attr('opacity', '0%')
127         .call(enter => enter.transition(t)
128             .attr('x', d => d.x0 <
129                 contentWidth/2? d.x1+10 :
130                 d.x0-10))
131         .call(enter => enter.transition(t).
132             delay(100)
133             .attr('opacity', '100%'));
134     },
135     // This describes the behavior of the update
136     // sub-selection of the general update
137     // pattern.
138     update => {
139         // The countries' rectangle is animated to
140         // resize and reposition
141         update.select('rect').call(update =>
142             update.transition(t)
143             .attr('height', d => d.y1 - d.y0)
144             .attr('y', d => d.y0));
145
146         // The countries' text label is animated

```

```

135         to reposition and update its value.
136         update.select('text').call(update =>
137             update.transition(t)
138             .attr('y', d => (d.y0 + d.y1)/2 + 5))
139             .text(d => `${d.name}: ${d.value}`);
140     }
141     )
142     // The second data-join is used to draw the links
143     // between the nodes.
144     linksParentGroup.selectAll('path').data(links, d => {
145         return [d.source.name, d.target.name]})
146     .join(
147         // This describes the behavior of the enter
148         // sub-selection of the general update
149         // pattern.
150         enter => {
151             // A path is added for each link. It is
152             // also styled and animated.
153             enter.append('path')
154             // D3 constructs the appropriate SVG
155             // path from the information available
156             // in the link.
157             .attr('d', d3.sankeyLinkHorizontal())
158             .attr('stroke', d => colors(d.target))
159             // The stroke-width represents the
160             // width of the link and depends on
161             // the data.
162             .attr('stroke-width', ({width}) =>
163                 Math.max(1, width))
164             .attr('fill', d => colors(d.target))
165             .attr('opacity', 0)
166             .call(enter => enter.transition(t).
167                 delay(500)
168                 .attr('opacity', '50%'));
169         },
170         // This describes the behavior of the update
171         // sub-selection of the general update
172         // pattern.
173         update => {
174             // The SVG paths are recalculated and the
175             // width adjusted.
176             update.call(update => update.transition(t)
177                 .attr('d', d3.sankeyLinkHorizontal())
178                 .attr('stroke-width', ({width}) =>
179                     Math.max(1, width)))
180         }
181     );
182 };

```

```
167
168 /**
169  * This section tries to subscribe to the
170    country-data-service for data updates.
171  * The diagram will not work without the
172    country-data-service.
173  */
174 try {
175   parent.registerCountryDiagramRenderCallback(render);
176   console.log('Could successfully subscribe to the
177     country-data-service for data updates. ');
178 } catch (e) {
179   console.log('Could not subscribe to the
180     country-data-service for data updates. ' +
181       'Data is loaded directly. ');
182   loadCountryData(render)
183 }
```

A.5 Circle Graph - JavaScript

```
1 /**
2  * This script was created as part of a bachelor thesis.
3  * The results can be found here: https://github.com/
4    Styx0o/styxoo.github.io
5  * Author: Luis Rothenhäusler
6  * Last edit: 25th August 2022
7  *
8  * This file contains the JavaScript implementation of the
9    sankey-diagram.
10 */
11 /**
12  * In this first section, some data independent constants
13    are defined.
14  */
15 // This creates a reference to the SVG container on the
16 // HTML page. This will contain the whole diagram.
17 const svg = d3.select('#mainFrame')
18   .attr('height', innerHeight)
19   .attr('width', innerWidth);
20
21 // The margin definition for the diagram. The content is
22 // padded from the sides using the margins.
23 const margin = {
24   top: 20,
25   right: 20,
26   bottom: 30,
```



```

23     left: 20
24 };
25
26 // contentWidth and contentHeight store the available
    coordinate space for the content of the diagram.
27 const contentWidth = innerWidth - margin.left -
    margin.right;
28 const contentHeight = innerHeight - margin.top -
    margin.bottom;
29
30 // The factor by which the legend values should be divided
    for easier readability
31 const legendScaleFactor = 100000;
32
33 /**
34  * This section defines the hierarchy of the diagram.
35  * This makes later selections and debugging in the
    browser inspector easier.
36  */
37 const diagramGroup = svg.append('g')
38     .attr('transform', 'translate(${margin.left},${
    margin.top})');
39
40 const legendParentGroup = diagramGroup.append('g')
41     .attr('id', 'legend');
42
43 const contentParentGroup = diagramGroup.append('g')
44     .attr('id', 'content');
45
46 // This text is added to inform about the scaling of the
    legend.
47 legendParentGroup.append('text')
48     .text('* scale in 100,000 refugees')
49     .attr('class', 'description')
50     .attr('x', contentWidth)
51     .attr('y', contentHeight);
52
53 /**
54  * This section defines a helper functions necessary for
    creating the diagram.
55  */
56 // This function converts a JavaScript date object into a
    string of the style Feb-07 or Jun-15.
57 const dateToDisplay = date => {
58     const day = date.getDate();
59     const month = date.toLocaleString('default', { month:
    'short' });
60
61     let dayString = day;

```

```

62     if (day < 10) {
63         dayString = '0' + dayString;
64     }
65     return [month, dayString].join('-');
66 }
67
68 /**
69  * The render function is defined here.
70  * It is called to initially draw the diagram, as well
71  * every time the data changes and the diagram should
72  * update.
73  */
74 const render = (data, time01 = 0) => {
75     console.log('Rendering circle chart');
76
77     /**
78      * The following defines the transition which is used
79      * for all animations.
80      */
81     const t = svg.transition()
82         .duration(1500);
83
84     /**
85      * Here all the required scales, which are dependent
86      * on the data, are defined.
87      */
88     // The time scale is used to convert between the time
89     // value of [0, 1], to the actual date.
90     const timeScale = d3.scaleQuantize()
91         .domain([0, 1])
92         .range(data.map(d => d.date));
93
94     // The radius scale provides the appropriate radius
95     // for a given number of refugees.
96     const radiusScale = d3.scaleSqrt()
97         .domain([0, d3.max(data, d => d.refugees)])
98         .range([0, contentHeight / 2]);
99
100    /**
101     * This section is responsible for drawing the
102     * background size legend of the diagram.
103     * This is achieved using a data-join and specifying
104     * the general-update-behavior.
105     */
106    // The ticks are extracted from the time scale.
107    const ticks = radiusScale.ticks(10).filter(d => d !==
108        0);
109    let tickData = [];

```

```

102     for (let i = 0; i < ticks.length; i++) {
103         tickData.push({ id: i, value: ticks[i] });
104     }
105     // A data-join is responsible for drawing the ticks.
106     legendParentGroup.selectAll('g').data(tickData, d => {
107         return d.id })
108         .join(
109             // This describes the behavior of the enter
110             // sub-selection of the general update
111             // pattern.
112             enter => {
113                 // A group is added and styled for each
114                 // tick.
115                 const tick = enter.append('g')
116                     .attr('opacity', '0%')
117                     .call(enter => enter.transition(t)
118                         .attr('opacity', '75%'));
119
120                 // Each tick is provided a circle, which
121                 // is positioned and sized appropriately
122                 tick.append('circle')
123                     .attr('cx', contentWidth / 2)
124                     .attr('cy', d => contentHeight -
125                         radiusScale(d.value))
126                     .attr('r', d => radiusScale(d.value))
127                     .attr('class', 'legend');
128
129                 // Each tick also provided with a text
130                 // label to show the quantity.
131                 tick.append('text')
132                     .text((d, i) => {
133                         let value = d.value /
134                             legendScaleFactor;
135                         if (i === tickData.length - 1) {
136                             value += '*';
137                         }
138                         return value;
139                     })
140                     .attr('dy', '-0.1em')
141                     .attr('x', contentWidth / 2)
142                     .attr('y', d => contentHeight - 2 *
143                         radiusScale(d.value));
144             },
145             // This describes the behavior of the update
146             // sub-selection of the general update
147             // pattern.
148             update => {
149                 // The circle for each tick is animated to
150                 // change position and size accordingly.

```

```

139         update.select('circle').call(update =>
140             update.transition(t)
141                 .attr('cy', d => contentHeight -
                    radiusScale(d.value))
142                 .attr('r', d => radiusScale(d.value)))
143             ;
144
145         // The text label value is updated and its
146         // position change animated.
147         update.select('text')
148             .text((d, i) => {
149                 let value = d.value /
150                     legendScaleFactor;
151                 if (i === tickData.length - 1) {
152                     value += '*';
153                 }
154                 return value;
155             })
156             .call(update => update.transition(t)
157                 .attr('y', d => contentHeight - 2
158                     * radiusScale(d.value)));
159     }
160     ,
161     // This describes the behavior of the exit
162     // sub-selection of the general update
163     // pattern.
164     exit => {
165         // Each element is faded out using
166         // animations, before being removed.
167         exit.call(exit => exit.transition(t)
168             .attr('opacity', '0%'))
169             .remove();
170     }
171 )
172
173 /**
174  * This is where the actual content of the diagram is
175  * drawn.
176  * Therefore, a data-join is created and the behavior
177  * of the general update pattern is specified.
178  */
179 // The current date is found using the time scale.
180 const unixTime = timeScale(time01)
181 const datum = data.find(d => d.date === unixTime)
182 contentParentGroup.selectAll('g .content').data([0],
183     () => [0])
184     .join(
185         // This describes the behavior of the enter

```

```

sub-selection of the general update
pattern.
176 // This behavior is used only for the first
time the diagram is drawn.
177 enter => {
178   // A group element is added
179   const content = enter.append('g')
180     .attr('class', 'content')
181
182   // A circle is added, positioned, sized,
    styled and animated accordingly.
183   content.append('circle')
184     .attr('cx', contentWidth / 2)
185     .attr('cy', contentHeight)
186     .attr('r', 0)
187     .attr('fill', 'red')
188     .attr('opacity', '50%')
189     .call(enter => enter.transition(t)
190       .attr('cy', () => contentHeight -
        radiusScale(datum.refugees))
191       .attr('r', () => radiusScale(
        datum.refugees)))
192
193   // A text is added to the bottom and
    provided with the correct value of
    refugees.
194   content.append('text')
195     .attr('x', contentWidth / 2)
196     .attr('y', contentHeight + 17)
197     .text(datum.refugees + ' refugees by '
    + dateToDisplay(datum.date));
198
199 },
200 // This describes the behavior of the update
sub-selection of the general update
pattern.
201 update => {
202   // The circle is animated to update in
    position and size.
203   update.select('circle')
204     .call(update => update.transition(t)
205       .attr('cy', () => contentHeight -
        radiusScale(datum.refugees))
206       .attr('r', () => radiusScale(
        datum.refugees)));
207
208   // The text value is updated
209   update.select('text')
210     .text(datum.refugees + ' refugees by '

```

```

                                + dateToDisplay(datum.date));
211         }
212     )
213 };
214
215 /**
216  * This section tries to subscribe to the
217  *   daily-data-service for data updates.
218  * The diagram will not work without the
219  *   daily-data-service.
220  */
221 try {
222     parent.registerDailyDiagramRenderCallback(render);
223     console.log('Could successfully subscribe to the
224                 daily-data-service for data updates. ');
225 } catch (e) {
226     console.log('Could not subscribe to the
227                 daily-data-service for data updates. ' +
228                 'Data is loaded directly. ');
229     loadDailyData(render)
230 }
```

A.6 Area Graph - JavaScript

```

1  /**
2  * This script was created as part of a bachelor thesis.
3  * The results can be found here: https://github.com/
4  *   Styx0o/styxoo.github.io
5  * Author: Luis Rothenhäusler
6  * Last edit: 25th August 2022
7  *
8  * This file contains the JavaScript implementation of the
9  *   sankey-diagram.
10 */
11
12 /**
13  * In this first section, some data independent constants
14  *   are defined.
15  */
16 // This creates a reference to the SVG container on the
17 //   HTML page. This will contain the whole diagram.
18 const svg = d3.select('#mainFrame')
19     .attr('height', innerHeight)
20     .attr('width', innerWidth);
21
22 // The margin definition for the diagram. The content is
23 //   padded from the sides using the margins.
```

```

19 const margin = {
20     top: 20,
21     right: 20,
22     bottom: 30,
23     left: 70
24 }
25
26 // contentWidth and contentHeight store the available
    coordinate space for the content of the diagram.
27 const contentWidth = innerWidth - margin.left -
    margin.right
28 const contentHeight = innerHeight - margin.top -
    margin.bottom
29
30 /**
31  * This section defines the hierarchy of the diagram.
32  * This makes later selections and debugging in the
    browser inspector easier.
33  */
34 const diagramGroup = svg.append('g')
35     .attr('transform', 'translate(${margin.left},${
    margin.top})');
36
37 const xAxisParentGroup = diagramGroup.append('g')
38     .attr('id', 'xAxis')
39
40 const yAxisParentGroup = diagramGroup.append('g')
41     .attr('id', 'yAxis')
42
43 const contentParentGroup = diagramGroup.append('g')
44     .attr('id', 'content')
45
46 contentParentGroup.append('g')
47     .attr('id', 'dateLine')
48
49 /**
50  * This section defines a helper functions necessary for
    creating the diagram.
51  */
52 // This function converts a JavaScript date object into a
    string of the style Feb-07 or Jun-15.
53 const dateToDisplay = date => {
54     const day = date.getDate();
55     const month = date.toLocaleString('default', { month:
        'short' });
56
57     let dayString = day;
58     if (day < 10) {
59         dayString = '0' + dayString;

```

```

60     }
61     return [month, dayString].join('-');
62 }
63
64 /**
65  * The render function is defined here.
66  * It is called to initially draw the diagram, as well
67  * every time the data changes and the diagram should
68  * update.
69  */
70 const render = (data, time01 = 0) => {
71     console.log('Rendering circle chart')
72
73     /**
74      * The following defines the transition which is used
75      * for all animations.
76      */
77     const t = svg.transition()
78         .duration(1500);
79
80     /**
81      * Here all the required scales, which are dependent
82      * on the data, are defined.
83      */
84     // The time scale is used to convert between the time
85     // value of [0, 1], to the actual date.
86     const timeScale = d3.scaleQuantize()
87         .domain([0, 1])
88         .range(data.map(d => d.date))
89
90     // The y scale is used to calculate a y coordinate
91     // from a given refugee number.
92     const yScale = d3.scaleLinear()
93         .domain([0, d3.max(data, d => d.refugees)])
94         .range([contentHeight, 0])
95         .nice();
96
97     // The x scale is used to calculate a x coordinate
98     // from a given date.
99     const xScale = d3.scaleBand()
100         .domain(data.map(d => d.date))
101         .range([0, contentWidth])
102         .padding(0.2);
103
104     // this is used to offset the calculated x positions,
105     // so they align to the center of a date-line.
106     // As the scale is a scaleBand, they would otherwise
107     // be offset slightly to the left.
108     const xScaleWithOffset = d => {

```



```

100         return xScale(d) + xScale.bandwidth() / 2
101     }
102
103     /**
104      * This section is responsible for creating the x and
105      * y axes of the area-graph.
106      */
107     // The y-axis is created from the scale. Additionally,
108     // the tick size is specified to cover the whole
109     // background.
110     const yAxis = d3.axisLeft(yScale)
111       .tickSize(-contentWidth)
112
113     // The y-axis is added to the diagram, but the domain
114     // lines are removed.
115     yAxisParentGroup.call(yAxis)
116       .selectAll('.domain')
117       .remove();
118
119     // This defines the function responsible for
120     // formatting the x-axis ticks.
121     const xAxisTickFormat = date =>
122       dateToDisplay(date)
123
124     // This specifies the modulo value to be used, so that
125     // the resulting axis has 15 ticks.
126     const tickModulo = Math.floor(data.length / 15)
127
128     // This creates the x-axis. The values are filtered so
129     // only 15 values appear.
130     const xAxis = d3.axisBottom(xScale)
131       .tickFormat(xAxisTickFormat)
132       .tickSize(-contentHeight)
133       .tickValues(xScale.domain().filter((d, i) => {
134         return !(i % tickModulo) })))
135
136     // The x-axis is added to the diagram, positioned to
137     // the bottom and has its domain line removed.
138     xAxisParentGroup.call(xAxis)
139       .attr('transform', `translate(0,${contentHeight})`)
140       .select('.domain')
141       .remove();
142
143     // All x-axis labels are moved a small bit further
144     // towards the bottom.
145     xAxisParentGroup.selectAll('text').attr('transform', `
146       translate(0,${10})`)

```

```

137
138  /**
139   * This section defines more helper functions
140     necessary for creating the diagram.
141   * As these require the scales, they are defined here.
142   */
143   // This function creates a SVG line for a dataset,
144     where each points x and y values are calculated as
145     defined.
146   const line = d3.line()
147     .x(d => xScaleWithOffset(d.date))
148     .y(d => yScale(d.refugees));
149   // This function creates a SVG line enclosing an area
150     for a dataset.
151   // Each x, as well as the higher and lower y positions
152     values are calculated as defined.
153   const area = d3.area()
154     .x(d => xScaleWithOffset(d.date))
155     .y0(contentHeight)
156     .y1(d => yScale(d.refugees));
157   /**
158   * This is where the actual content of the diagram is
159     drawn. This consists of an area and a line atop.
160   * Therefore, a data-join is created and the behavior
161     of the general update pattern is specified.
162   * The enter behavior is only executed once, as the
163     diagram is loaded.
164   */
165   contentParentGroup.selectAll('g .areaGroup').data([0],
166     () => [0])
167     .join(
168       // This describes the behavior of the enter
169       sub-selection of the general update
170       pattern.
171       enter => {
172         // A group is added for hierarchical
173         purposes.
174         const areaParent = enter.append('g')
175           .attr('class', 'areaGroup')
176
177         // The area is drawn in the diagram.
178         areaParent.append('path')
179           .attr('class', 'area')
180           .attr('d', area(data))
181
182         // The top-line is drawn above the area in

```

```

174         the diagram.
175         areaParent.append('path')
176         .attr('class', 'topLine')
177         .attr('d', line(data))
178     },
179     // This describes the behavior of the update
        sub-selection of the general update
        pattern.
180     update => {
181         // The area is recreated and transitions
        to the new path.
182         update.select('.area')
183         .call(update => update.transition(t)
184             .attr('d', area(data)))
185
186         // The top-line is recreated and
        transitions to the new path.
187         update.select('.topLine')
188         .call(update => update.transition(t)
189             .attr('d', line(data)))
190     });
191
192     /**
193     * This section is responsible for the date-line. It
        is drawn and updated using a data-join.
194     * The enter behavior is only executed once, as the
        diagram is initially drawn.
195     */
196     // Using the time scale, the current date is found.
197     const unixTime = timeScale(time01)
198     const datum = data.find(d => d.date === unixTime)
199
200     contentParentGroup.selectAll('g .dateLine').data([0],
        () => [0])
201     .join(
202         // This describes the behavior of the enter
        sub-selection of the general update
        pattern.
203         enter => {
204             // A group element is added for the
            date-line.
205             const dateLine = enter.append('g')
206             .attr('class', 'dateLine')
207             .attr('transform', 'translate(${
                xScale.bandwidth() / 2},0)')
208
209             // The circle which intersects the
            date-line and top-line is added,

```

```

210         positioned and sized.
211     dateLine.append('circle')
212         .attr('class', 'dateLineDot')
213         .attr('cx', xScale(datum.date))
214         .attr('cy', yScale(datum.refugees))
215         .attr('r', 6)
216
217     // The line is added to the date-line.
218     dateLine.append('line')
219         .attr('class', 'dateLineLine')
220         .attr('x1', xScale(datum.date))
221         .attr('x2', xScale(datum.date))
222         .attr('y1', yScale(datum.refugees))
223         .attr('y2', contentHeight)
224
225     // The text showing the current refugee
226     // number is added above the date-line.
227     dateLine.append('text')
228         .attr('class', 'dateLineText')
229         .text(datum.refugees)
230         .attr('x', xScale(datum.date))
231         .attr('y', yScale(datum.refugees) -
232             10)
233 },
234 // This describes the behavior of the update
235 // sub-selection of the general update
236 // pattern.
237 update => {
238     // The circle is transitioned to its new
239     // position.
240     update.select('circle').call(update =>
241         update.transition(t)
242         .attr('cx', xScale(datum.date))
243         .attr('cy', yScale(datum.refugees)))
244
245     // The line is shifted and adjusted in
246     // length.
247     update.select('line').call(update =>
248         update.transition(t)
249         .attr('x1', xScale(datum.date))
250         .attr('x2', xScale(datum.date))
251         .attr('y1', yScale(datum.refugees)))
252
253     // The text value is updated and
254     // repositioned.
255     update.select('text').call(update =>
256         update.transition(t)
257         .text(datum.refugees)
258         .attr('x', xScale(datum.date))

```

Appendix A. Appendix

```
248             .attr('y', yScale(datum.refugees) -
249                     20))
250         }
251     };
252
253     /**
254     * This section tries to subscribe to the
255     *   daily-data-service for data updates.
256     * The diagram will not work without the
257     *   daily-data-service.
258     */
259     try {
260         parent.registerDailyDiagramRenderCallback(render);
261         console.log('Could successfully subscribe to the
262                     daily-data-service for data updates. ');
263     } catch (e) {
264         console.log('Could not subscribe to the
265                     daily-data-service for data updates. ' +
266                     'Data is loaded directly. ');
267     }
268     loadDailyData(render)
```
