COM 480 - DATA VISUALIZATION

SpoTeamFy Report

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I - Project Study

Driven by a passion for music, our primary objective was to create a website that would immerse users in an interactive and enjoyable musical experience.

With this vision in mind, we explored various datasets and we discovered the *1 Million Playlists dataset* released by Spotify. This dataset served as the cornerstone of our project.
However, we were confronted with a pressing question: How could we leverage this vast collection of tracks in a distinctive manner? A lot of work has already been conducted in the field, including the creation of recommendation systems and basic data visualization techniques for audio features. But we wanted to go further, we wanted to propose something new, fresh and original.

We then get the idea to link music to emotion. Indeed, music has always been a powerful medium for expressing emotions. Who hasn't turned to melancholic tunes after a breakup, or enjoyed lively and joyful music while celebrating with friends? This insight serves as the guiding principle for our project: investigate and understand the intricate link between music and emotions.

But how ? That was the biggest challenge we faced during the first phase of our project. It may appear evident that certain tracks convey sadness while others exude joy. The question was : how can we develop an algorithm capable of categorizing Spotify tracks based on the emotions they evoke?

The first step was to find a dataset that associates tags with Spotify tracks : *The Musical Sentiment Dataset* (MuSE). These tags would allow us to link descriptive words to each track, which can then be used to associate it with an emotion.

Then, we tried to apply a clustering algorithm to the tracks based on their audio features available through the Spotify API. Our intention was to employ the corresponding tags to associate a distinct emotion with each cluster. However, we were faced with a first problem. The clustering did not work, and this with any combination of features.

K-means clusters after PCA

Therefore, we had to devise an alternative strategy to cluster the tracks based on emotions. After extensive research, we found the *NRC Emotion Lexicon* dataset. This lexicon comprises English words and their associations with the eight basic emotions from Robert Plutchik's theory (anger, fear, anticipation, trust, surprise, sadness, joy, and disgust), as well as two sentiments (negative and positive). The discovery of this dataset greatly impacted our project, as it provided a valuable resource to associate emotions directly with each track by utilizing its associated hashtags.

Equipped with the information gathered from these datasets, we embarked on the data preprocessing phase with a clarified objective in mind.

II - Preprocessing

The preprocessing focused on the 3 datasets introduced earlier. To augment our dataset, we used Spotify's developer API, which provided audio features including acousticness, loudness, and energy, among other measures.

The final objective of the preprocessing was to associate a unique emotion to each track. To do so, we filtered the tracks from the *MuSe* dataset based on the presence of corresponding tags in the *NRC* dataset. Next, we mapped each tag to an emotion vector. For instance, the word "holiday" could be represented as [1, 0, ..., 0, 1], where the first coordinate corresponds to Joy, the second to Trust, and so on. Due to the presence of multiple tags associated with each track, a custom algorithm was developed to merge the emotion vectors corresponding to these tags and return the most likely emotion associated with each track.

Challenges faced.

The main challenge we encountered during this phase of the project was the lack of data. Indeed, for our project to succeed, we needed complete data on the tracks, the presence of relevant tags in the NRC dataset and the availability of Spotify IDs to retrieve audio features from the API. Thus, some tracks had to be filtered out to meet these criteria and a large amount of data was lost. We still managed to work with 12,991 tracks, 486,729 playlists and 1,437 tags. One of the consequences of the lack of data was that, at the end of the pre-processing, the dataset was not balanced enough for our taste, with some emotions containing many more tracks than others.

Even if we had enough data to present a relevant analysis, we would have liked to work more on the preprocessing, to obtain a wider range of tags associated with the tracks (for example via Twitter using the popular hashtag #NowPlaying).

However, the objective of the project being data visualization, we preferred to focus our efforts on the next steps of the project: the design and implementation of our website!

III - Design and Visualization Strategy

After finalizing the preprocessing and merging all the information into a single file, the next step was to identify the key insights and determine the most relevant information to present to the users of our website. Two questions were therefore raised:

- What type of users should we target?
- What are the most significant insights from our data?

During phase III of the project, we approached the questions in a parallel manner.

1. Understanding the Target Audience and Adapting Visualizations

Target audience.

To provide a meaningful solution to our problem and address the question of "What is the link between music and emotions?", it was crucial for us to identify our target audience.

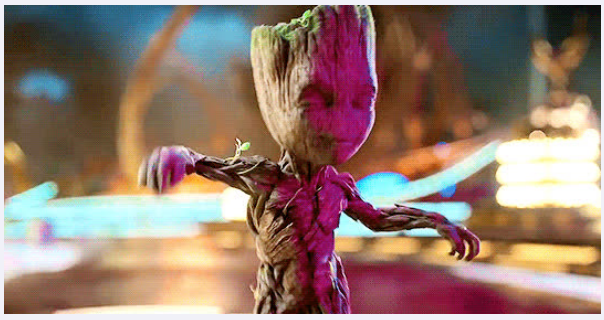
Music on the one hand, and emotions on the other hand, are universal and appeal to everyone, so it seemed obvious to us to propose a site that addresses the largest audience possible. That's why we defined our target audience as the general population, with a specific focus on Spotify users and music enthusiasts.

Furthermore, we presented our website to family and friends, gathering feedback throughout the project to adapt our visualizations for the targeted audience.

Tone.

Our primary target audience for the website was the general public, which also included music enthusiasts. With this in mind, we aimed to create an engaging and captivating online experience. To achieve this, we avoided adopting an overly academic approach. Instead, our focus was on delivering a fun, vibrant, and colorful universe that aligned with the essence of our website's theme: music and emotions.

To guide users through the fascinating universe of music and emotions, we decided to introduce a delightful mascot: Baby Groot. With his cheerful presence, Baby Groot serves as a friendly guide, bringing a smile to the user's face and providing instructions on navigating the website. He accompanies users on their exploration and guides them to make full use of the interactive elements and features.



With our project target and desired tone established, we then conducted an analysis of the data to identify the emerging insights. Our goal was to extract valuable information we wanted to communicate to our target audience.

Adapting visualisations.

During this phase of the project, we faced the task of presenting a substantial amount of data with diverse attributes related to 12 different emotions to our users. This posed a significant challenge as we needed to find an effective way to present this information clearly and concisely to users who may not have expertise in data visualization.

To ensure a clear and intuitive representation of each emotion across the website, we assigned a distinct color and emoji to every emotion. To make the design more appealing while maintaining clarity of information, we created a sequential color palette made of subtle variations of the main color assigned to each emotion.

We also opted for an interactive layout that dynamically adjusts based on the user's selected emotion. This approach enables users to delve deeper into one specific emotion, without feeling lost in a sea of information about multiple emotions at the same time.

To ensure the user-friendly nature of our website, we made a deliberate choice to avoid complex visualizations that might confuse or overwhelm users. Instead, we focused on creating interactive visualizations that are easy to understand. We also incorporated explanatory texts to our visualizations, ensuring users are guided and not left feeling lost or confused.

2. Data Insights and Website Elements Definition

In this phase, our focus was on conducting in-depth data analysis to extract key insights from the collected data. We used these insights to define the most effective visualizations to communicate the information to our target audience.

First, we analyzed the tracks' distribution among emotions. Some of the emotions did not contain enough tracks so we decided not to include them in our project (e.g. submission, surprise,...).

Then, we analyzed the links between the different emotions through the tracks representing them. For this, we implemented a graph where each track was represented by a node. Two nodes were connected by a weighted edge indicating the number of times the two tracks appeared in the same playlist.

Then we grouped nodes by their emotions and retrieved the number of links between each group. Many insights appeared to be very interesting because some emotions were much more connected than others. For example, Love was connected to Sadness at 43%, while it was connected to Trust at 1%. We therefore decided to exploit this insight and represent these connections using a chord diagram on our website.

We also conducted an analysis of the audio features of tracks, obtained from Spotify. Our objective was to explore whether certain features, such as energy or loudness, exhibited equal distribution across different emotions. However, our findings revealed that this was not the case. For instance, we observed that the loudness feature had a significantly higher value for Optimism compared to Love or Fear. We created an animated bar chart that illustrates how these features varied between different emotions. Additionally, to provide users with a comprehensive overview of each emotion, we developed a second bar plot that compared the percentage distribution of each feature for every emotion.

As the pre-processing of our data was mainly based on the tags assigned to the tracks, we felt it was important to present them to users. Thus, we included a wordcloud on our website to give a representative insight into the data we used to create the emotional clusters and to provide a glimpse into the themes that define each emotional landscape.

To enhance the music-centric experience of our website, we decided to incorporate an exciting feature: direct access to playlists corresponding to each emotion. We made that playlist interactive so that users can switch between the main genres represented in the selected emotion.

To add even more interactivity to our website, we also decided to present the 10 most representative artists of each emotion. We have also retrieved the artists' images from Spotify as well as their biographies from Last.fm to provide real insight to our audience rather than a simple ranking with ultimately meaningless information.

IV - Website Design

1. Tools to be used

One of the group members had a background in web development. She therefore proposed additional tools to facilitate the creation of the website structure :

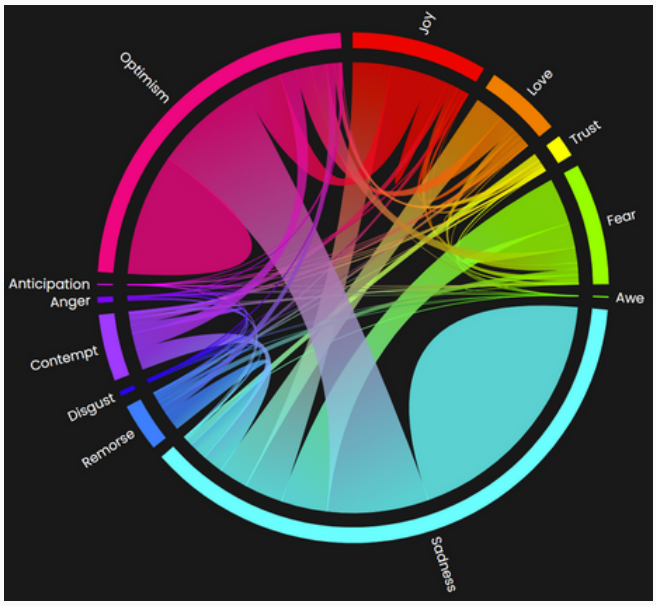
- **Vue.js** : a Javascript framework specialized for website development
- **Vuetify** : a Vue.js framework to create customizable components
- **Trydo** : a Vuetify template with predefined reusable components and CSS style
- **Netlify** : a platform to host our website

With all these resources, we could easily put the website online and start our project with a solid base of tools that would facilitate the implementation later on.

2. Implementations of visual elements

We present the 4 sections of the website, the challenges we faced in the implementation and the design decisions that were taken to achieve the final result.

Section 1 - Chord Diagram.



As the first element of our website to be created, we encountered some difficulties during its implementation, because we did not have much experience with D3.js and it is, let's be honest, a complex library to master at the beginning, even if it becomes more accessible after a bit of practice.

One of the main challenges faced on the chord diagram was the fact that it is originally designed to describe directional flows (for instance the flow of people moving from one country to another). Thus the path connecting an entity to another is filled with the color of the source entity.

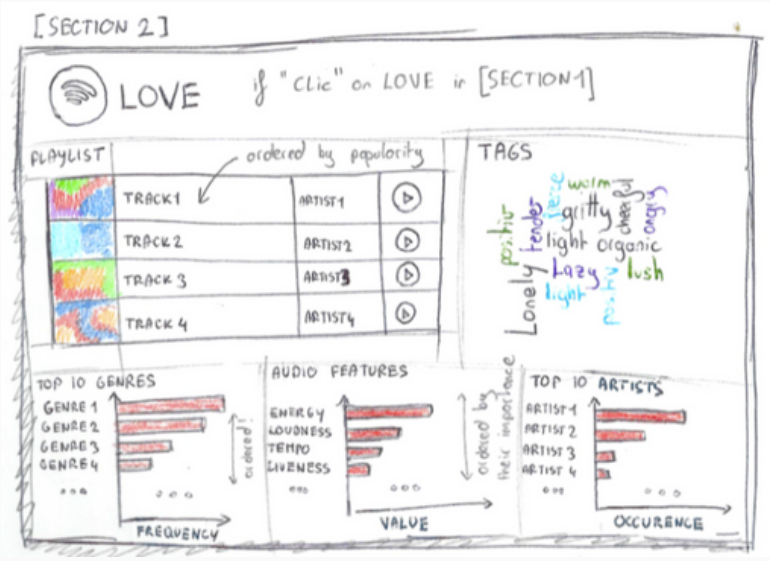
However, to model the links between emotions via the tracks they contain, we were dealing with a bidirectional information flow. We therefore had to find a strategy to show that the information was symmetrical. To do so, we chose to color each path with a linear gradient, allowing a smooth transition from one entity to the other. However, the implementation was complex because linear gradients are... linear, whereas our paths were curved. So we had to use our good old trigonometry formulas to adapt them to the chord diagram.

We have also completed this chart with a lollipop chart so that users have a visual reference to support their reading of the graph. Indeed, it is more complex with a human eye to compare surfaces with each other. This basic chart therefore helps the user to understand more easily which are the strongest links between the emotions. This chart was not present during the elaboration of the first sketches but it seemed essential to us to add it afterwards to facilitate the user's comprehension.

Section 2 - Presentation of the selected emotion.

When the user clicks on an emotion, this section dynamically adapts and presents insights specifically related to the selected emotion. Its content provides a comprehensive understanding of the emotion's characteristics. Users can explore a wordcloud representing the key tags, a bar chart comparing audio features, a bubble chart highlighting the top 10 artists, a playlist and a bar chart showcasing the five most represented genres.

One of the main issues here was the positioning of the elements so that the user would have a good overview of all the features present in the data set while keeping it clear and simple. We did a lot of testing on the arrangement of the different elements, as the rendering was quite messy during the trials. The positioning as well as some of the chart types were revised after Milestone 2 in order to give a more suitable layout to the website.
In the first sketches we made, we had not thought that a lot of information would be present in that section.



All the elements had to be represented in a more compact way and the same type of charts was supposed to be used for many elements (artists, audio features, top genres).
But very quickly, we decided to completely redesign the information for three reasons:

01 ## A design question

On one hand, the information was not clear and the user's attention was lost among all these visualizations (need for a new layout); on the other hand, the rendering was not very beautiful with 3 similar charts, knowing moreover that we were going to remake a barchart in the section 3 (new types of charts was needed)

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02 ## A technical question

After having discussed with our entourage, the majority of the feedback was in favor of a customizable mood playlist according to the users' favorite genres. We therefore made the genres chart interactive, so that the playlist updates when the user clicks on his favorite style. In order to keep our section coherent, we had to divide it into two sub-sections, one representing the tracks of the emotion in a general way, the other one adapting itself according to the selected genre.

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03 ## A user experience question

We wanted to add text and descriptions to the different charts to make them more understandable for our audience. As the charts became more complex and took up more space with the additional details, a redesign of the elements was necessary.

The other challenge we faced was the fact that all the charts were not connected to each other and were implemented in different files. How to make sure that the users' interactions with a specific chart were transmitted to all the charts ? To do so, we had to play in a smart way between the tools offered by Vue.js and D3.js. Variables were created at the global level of the application thanks to the Vuex Store (https://vuex.vuejs.org/guide/). A change in one of the components could therefore be reflected in all the components of our website.

Section 3 - Comparison of audio features across emotions.

This section presents a comparison of the audio features through the different emotions.

The main challenge for the member of the team who developed this section was to master D3.js on the one hand, Vue.js on the other hand, and to use these two tools simultaneously. Indeed, having no previous knowledge of Vue.js, he had to learn in a very short time the basic concepts of this framework.

Moreover, the fact of creating an interactive barchart was a real challenge because many interactions had to be linked to pass from one audio feature to the other: change of the bars to always remain in order from the largest value to the smallest, change of the scales on the y-axis for some of the features, change of the labels on the x-axis.

The height of the bars is defined by the average value of the selected feature over all tracks labeled with the corresponding emotion. In order to get a more statistical view of these mean values, confidence intervals were added to the top of each bar to give an idea of how certain the means are. These confidence intervals were created using the bootstrap and the length of the interval was chosen to obtain a 95% CI. All of these processing steps were performed in a python notebook and the values were saved as .json files.

The design of this chart was chosen in such a way to facilitate its understanding. First, we added a description for all of the features in order to remind the reader of the feature he is displaying. Then, we also sort the bars in descending order to easy the comparaison between the different emotions. The confidence intervals were also added to better compare the values. If the reader needs more precision about the values on the chart, he just has to mouseover the bars to see the features values. The last thing that we add to better compare the different features is min-max normalizing the values to get a fixed y-axis between 0% and 100%.

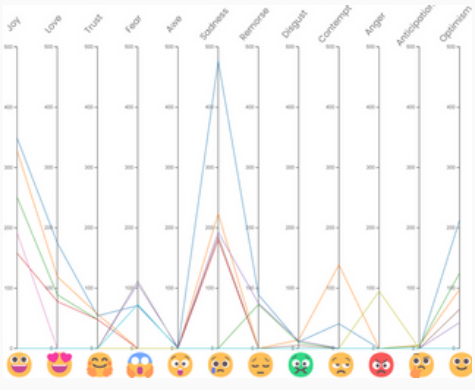
Section 4 - Comparison of music genres across emotions.

This section intends to compare musical genres across different emotions through a **circular-packing** chart

Creating circular-packing chart like the one showcased in the website can pose several challenges. Firstly, the data needs to be structured in a specific way to represent the distribution of musical genres across different emotions. This involves transforming and aggregating the raw data to create the necessary structure with emotion, genre and corresponding percentage. The percentage indicates the proportion of tracks belonging to each genre out of all the tracks categorized under that emotion. Secondly, designing and positioning the nodes to represent the genres and their sizes correspond to the percentage of each genre within a specific emotion. Achieving an aesthetically pleasing arrangement while avoiding node overlap involves implementing force simulation techniques, such as attraction and collision forces, which can be intricate to set up correctly. Additionally, the interactive features of the chart, such as dragging nodes and displaying tooltips, require event handling and coordination between the data and the visual elements. Ensuring smooth and responsive interactions can be challenging, especially when dealing with a large number of nodes or complex data structures. Furthermore, styling the chart with appropriate colors, sizes, and visual cues to represent emotions and genres adds another layer of complexity. It requires careful consideration of color schemes, contrast, and readability to create an engaging and informative visualization. Lastly, debugging issues, optimizing performance, and ensuring responsiveness can be time-consuming and require thorough testing.

Overall, creating a circular-packing chart like this involves a combination of data processing, visual design, interaction implementation, and testing. Overcoming the challenges associated with each of these aspects is essential to deliver a seamless and visually appealing user experience.

A trial was conducted to compare genres across emotions using a parallel-coordinates plot. The code for this chart can be found in the github repo. However, one of the main challenges was the sparsity of the data. Not all genres were present in every emotion, and in most cases, certain emotions had zero values for specific genres. As a result, the parallel-coordinates plot did not provide informative insights due to lack of data points. To address this limitation, a designing decision was made to replace it with the circular-packing chart described above.



To go further

With the limited time available, we were not able to pursue all of our ideas. The more the work progressed, the more ideas flourished.
Just to name a few :

Website.

- Creation of a section where users can select their favorite music genre. Upon selecting a genre, the entire website dynamically adjusts to align with the chosen musical style to provide a tailored user experience.
- Creation of a section where users can enter the link to their Spotify playlist and discover insights about the emotions conveyed by their selection of tracks

Preprocessing.

- More in-depth tag search to increase the size of our dataset and avoid losing too much data during the preprocessing phase, ensuring more reliable results and more balanced data.
- Elaboration of a more complex algorithm to assign a unique emotion to each track based on the associated emotion vectors. One idea was to develop a deep learning algorithm to identify the audio features of each emotion's tracks (that have already been labeled) in order to classify new tracks without hashtags afterwards.

Peer assessment.

Esraa.

- Data Insights (EDA)
- Design & Visualization Strategy
- Implementation of Section 4
- Report (Section 4)
- Video

Damien.

- Project Study
- Data Preprocessing
- Design and visualization strategy
- Report (only section 3)
- Implementation of Section 3
- Small part of website
- Video (Introduction & Conclusion)

Joanne.

- Project study
- Data Preprocessing
- Understanding the Target Audience and Adapting Visualizations
- Data Insights and Website Elements Definition
- Tools to be used
- Website Design and Implementation
- Implementation of Section 1, 2
- Report (except Sections 3 and 4)