Analysis of the Interaction of Music and Emotions with the Help of EEG

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Task

Music-emotion recognition (MER)

- **hypothesis:** music, a universal medium transcending cultural barriers, evokes a wide spectrum of emotions through distinct neural pathways
- by analyzing EEG data, we aim to identify **specific brainwave patterns** associated with **various emotional states** elicited by music
- **motivation**: understanding these neural pathways is crucial for developing advanced emotion recognition systems, enhancing therapeutic approaches in mental health, and improving human-computer interaction interfaces
- **goals:** 1) train a model that is able to **properly classify the emotions** from the EEG data, 2) **study the geometric and topological structure** of the brain waves and other associated objects (spectrograms, attention maps, etc.)

Literature review

MER, MER + EEG

- **existing methods nowadays**:
  - do **not delve into the topological nature** of the brain waves (surveys [1], [2])
  - **lack interpretability** or complexity: existing classifiers are able to predict an emotion, but are not able to reveal any hidden high-level features in the data (surveys [1], [2], [3])
  - offer an **unsophisticated «emotion model»** — all human emotions in such approaches are described through two or four categories, which is not enough for a proper analysis [1], [3]

Literature review

TDA + EEG, graph-based models + EEG

- Graph-based models were previously applied to the EEG data, but **not in the context of MER** [4], [6], [9]
- **Graphormer** [6] **was not tested on the EEG data**, while providing three types of spatial encoding that are useful for our problem
- TDA-based approaches also were previously used with the EEG data, but **not in the context of MER** [5], [7], [8], [10]
- **thus, we state that the notion to approach the MER-EEG task using TDA and graph-based methods is novel and promising**

Approach

Graph-based solution

- **Graph Neural Networks (GNNs)** have emerged as a promising tool for analyzing complex, structured data

- **Graphormer** [5], a novel approach that enhances the performance of GNNs by incorporating concepts from Transformers (such as **attention** — a specific layer that describes relationships between objects)

- the key insight of Graphormer lies in **effectively encoding the structural information of graphs** into the model => this feature may be efficiently transferred to the task of music-emotion recognition

- **attention maps** may contain important hidden information about the wave structure

Approach

Topological Data Analysis

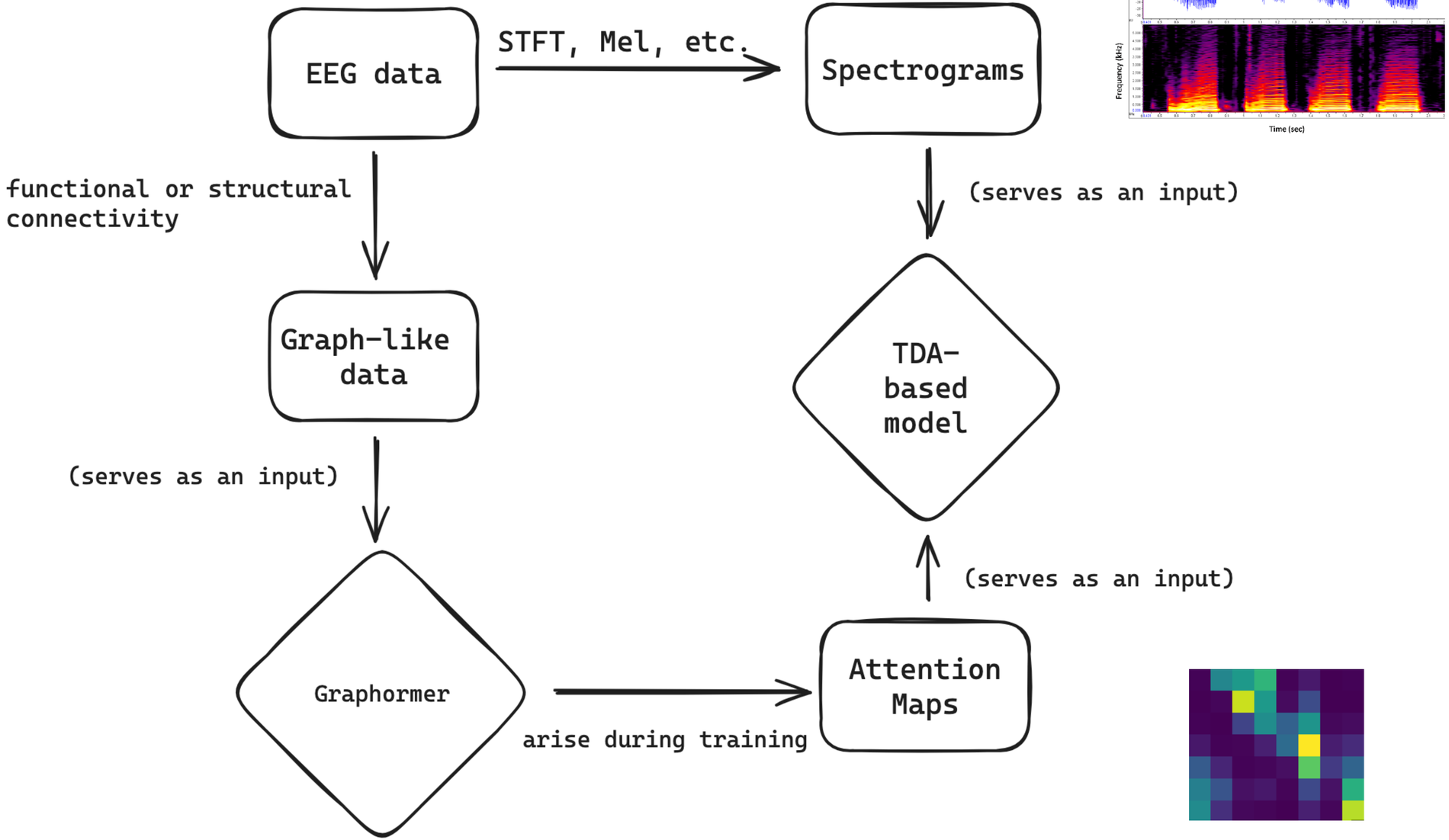
- **Topological Data Analysis (TDA)** is a relatively recent development in the field of data science and machine learning, focusing on understanding the **shape (topology**) of data

- TDA seeks to uncover patterns, structures, and relationships within data that **traditional analysis methods might overlook**

- by perceiving EEG datum as a time series, we are able to create descriptions of **persistence of connected component**s (in the temporal dimension, described with components' birth and death)

- these components constitute more **complex topological structures** that may also be taken into account

Pipeline


EEG data
STFT, Mel, etc.
Spectrograms
functional or structural connectivity
(serves as an input)
Graph-like data
TDA-based model
(serves as an input)
(serves as an input)
Graphormer
arise during training
Attention Maps

Amplitude
Frequency (kHz)
Time (sec)

Expected results

- TDA-derived features will provide **significant improvements in emotion classification performance** compared to models trained on traditional EEG features alone

- the application of graph-based neural networks is expected to efficiently manage the high-dimensional nature of EEG data, **capturing the complex spatial-temporal relationships**

- through the analysis of the **Graphormer's attention maps**, novel **biomarkers associated with specific emotional states elicited by music** are expected to be identified

References

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Thank you for your attention!

Q&A