BABEŞ-BOLYAI UNIVERSITY CLUJ-NAPOCA

FACULTY OF MATHEMATICS AND COMPUTER SCIENCE

SPECIALIZATION COMPUTER SCIENCE

DIPLOMA THESIS

Emotion Based Music Player

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2019

UNIVERSITATEA BABEŞ-BOLYAI CLUJ-NAPOCA

FACULTATEA DE MATEMATICĂ ȘI INFORMATICĂ

SPECIALIZAREA INFORMATICĂ

LUCRARE DE LICENȚĂ

Player muzical bazat pe emoție

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2019

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Introduction

The past few decades have brought a rapid and continuous technological evolution which has impacted the everyday life of a vast majority of people. Its benefits are astounding, making almost everything easier and available at the touch of a button. From the comfort of their own houses, people can access important services like education, work, entertainment and shopping. However, all of this is coming at a crucial price: physical and mental health. This change encouraged unhealthy habits, many people spending increasing amount of time in environments that require prologue sitting, thus limiting their physical activity. Many applications were developed in this direction, reminding users to take regular breaks, to stand up and to do tiny exercise. The intended application, *Espressivo*, focuses on the mental and psychological aspect of this issue by taking advantage of the tremendous benefits of music on the human brain and its relation to everyday emotions. By providing a user-friendly way of finding musical recommendations based on emotions, the application can be used as a tool for improving memory, productivity, creativity and for relieving stress and anxiety.

The first chapter of the paper, after the introduction, focuses on theoretical aspects regarding neurology of music, using various studies to describe its beneficial effects on the human brain as well as how and why it is associated to emotions. It is followed by a chapter presenting relevant aspects of the technologies that were used to create the application. The third chapter includes a short overview of the application together with its use cases and describes thoroughly the architecture of the system and implementation technicalities. A complete step-by step guide to using the application is presented in the fourth chapter. Finally, the last chapter concludes the paper and presents different possibilities for further development.

2. The Relation between Music and Emotions

Music has played a central role in cultures and rituals around the world throughout human existence. It can be defined as an art of sound in time that expresses emotions and concepts in vital forms through the elements of harmony, color and rhythm. It is a common phenomenon that crosses all nationality, race, and cultural boundaries. Whether in movies, concerts, supermarkets, restaurants or nature, we experience music every day of our lives, often with some kind of accompanying reaction, such as joy, calm, frustration or nostalgia. [26]

2.1 Neuroscience of Music

The evolution of the modern mind is generally believed to be closely connected to the evolution of language. Language represents a system of spoken or written symbols through which people express themselves as members of a social group and participants in their culture. It is the means by which, within and across generations, we learn and pass on information, ideas and competences. While appearing to have similar features of a language, music is far more powerful than that. It is a universal *language of emotion*. This is due to the fact that music is more connected to the brain structures that are involved in memory, motivation, reward and especially emotion.

Humans experience sounds before they learn to talk. Before the development of different areas from the brain, specialized in vision, speech and hearing, which will occur later in life, a baby sees the world as a combination of colors, sounds and feelings. An unborn baby can hear low-pitched sounds such as heartbeats, blood pumping through vessels or breathing and also high-pitched sounds such as the voice of his mother. Hearing is the only sense that helps him to prepare for life after birth by forming a strong bond with the mother. [6][9][26]

2.1.1 An Evolutionary Perspective

Being a fundamental part of human evolution, music has helped us to learn a lot about our origins and the brain. In terms of both size and structure, there can be no doubt about the greater development of our cognitive attributes, closely linked to our brain's evolutionary developments. Through these genetic-environmental adaptations over several million years, bipedalism, the use of fire, the development of effective working memory and our vocal language have all emerged.

Creating and responding to music and to dance to the beat of time are two features of our world that are universal and have been a feature of an earlier evolutionary development. Our ancestors began to articulate and gesticulate feelings somewhere along the evolutionary path, with very limited language but with considerable emotional expression: denotation before connotation. In other words, meaning given by music came to us before the one given by words.

The ability of music to transmit emotions felt by all, but specific to an individual may suggest that it has been created as a way to understand individual and group feelings, especially in the midst of social uncertainties.

In addition to its direction and motivation of human attention, the ability of music to create and maintain social relationships is likely to have been incredibly important to pre-modern human survival. If taken outside of the modern entertainment context, music has provided an imperative social tool throughout the evolution process, representing one of the many ways that differentiate humans from other species. [25][34]

2.1.2 Effects of Music on the Brain

The past decade has witnessed an explosion in research activities involving music perception and performance and their correlates in the human brain. Investigations of music and brain became a shared element in the fields of psychology, musicology, and neurology, starting from the late-nineteenth century. This interest has led to a new branch of music psychology, called neuroscience of music. [12]

Neuroscience of music is the scientific study exploring the way nervous system reacts to music. It includes research activity on how music listening, reading, writing, performing or composing access and stimulate specific cerebral circuits

Investigation in this field has grown in recent times with the support of modern neuroimaging techniques, such as functional magnetic resonance imaging (fMRI), transcranial magnetic stimulation (TMS), magnetoencephalography (MEG), electroencephalography (EEG), and positron emission tomography (PET).

The concepts of brain substrates underlying music processing have drastically changed in the last five decades. Over the years, a simple left-versus-right-hemisphere dichotomy has been proposed by traditional theories, with music being processed in the right part of the brain and language in the left one. This idea has been challenged by scientists whose studies have emphasized a more modular organization of human cognition. They have proven that different concepts of music are processed in different, although partly overlapping neuronal networks of both hemispheres. [9][34]

Moreover, studies have shown that nonmusicians process music differently than musicians. Professional musicians exhibit left hemispheric preponderance, processing music primarily in the left frontotemporal lobes while amateurs as well as nonmusicians exhibit a right hemispheric preponderance, bilaterally activating the frontal lobes and the right temporal lobe.

Listening to music has considerably high effects on the brain, activating almost all its parts. Major computational centers include the sensory, auditory, motor and visual cortices, as well as the cerebellum. It activates pathways within a complex structure located immediately beneath the medial temporal lobe of the brain, called the limbic system. This system is involved in a variety of functions, such as emotion, behavior, motivation, long-term memory and olfaction.

It also activates regions in the front part of the cortex which are activated when preforming altruistic acts. That is, when a person puts somebody else's welfare in front of his own. Also, when people are singing together and especially when they are improvising, a hormone called oxytocin is stimulated. Oxytocin is associated to empathy, trust and relationship building.

Music has tremendous benefits on our mind and body. It affects blood pressure and heart rate, it reduces pain, fatigue and stress levels and can help to decrease depression, agitation and anxiety while improving cognitive functions, motivation, language skills, emotional well-being and quality of life. [3][31][34]

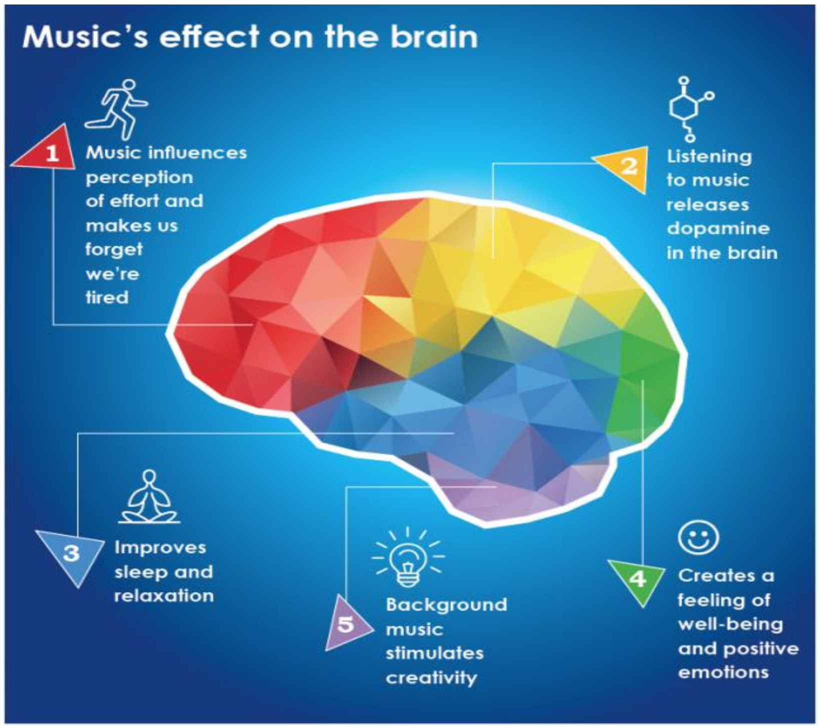

Figure 2.1 Music's effects on the brain [14]

Memory

Music therapy has become a popular method to alleviate symptoms and evoke memories of patients struggling from different types of dementia, Alzheimer's disease and other chronic cognitive and physical impairments. The use of personalized playlists can unlock deep memories and enable patients to converse, socialize and stay present.

Some individuals, who seemed incapable of speaking, could sing or dance to their favorite songs, while others were able to recall where and when they listened to them. Music appears to open doors to the human memory vaults.

Recent studies have proven that music not only helps people to retrieve stored memories, but also contributes to the formation of new ones. They showed that healthy elderly people performed better on memory and logical reasoning tests after several weekly courses in which they did moderate physical exercise accompanied by music. It has been proven that music enhances short-term, working and remote episodic memory. [10][20][31]

Productivity

The relation between background music and efficiency in performing repetitive tasks has been the subject of many studies along the years. They have provided abundant evidence that music can drastically increase the level of productivity when performing such tasks. Background music improves accuracy, enhances cognitive task performance and makes the completion of nonmusical tasks more efficient, even in unfavorable conditions produces by machine noise. Some of these studies have been conducted on some specific occupations.

Data collected from forty-one male and fifteen female software developers working at four different Canadian companies showed that they came up with better ideas and produced better work more efficiently when they listened to their favored music. [22]

Another study was made in the field of medicine. Fifty male surgeons aged between 31 and 61 years, who reported that they usually listen to music during surgery, were divided into three groups. The first group performed surgical procedures while listening to its favorite songs, the second one listened to the music that has been chosen by experimenter and the third one did not listen to any music. For all physiological measures, autonomic reactivity was significantly lower in the music condition chosen by the surgeons than in the music condition chosen by the experimenter, which in turn was significantly lower in the condition of no-music control. Similarly, task performance speed and accuracy were significantly better in the music condition chosen by the surgeon than in the experimenter-selected music condition, which was also significantly better than the condition of no-music control. [4]

Music was also used to facilitate performance under pressure in sport. Chocking is defined as a critical deterioration in the performance of routine processes as a result of an elevation in levels of anxiety under pressure, resulting in poor performance. Perceptions of chocking and cognitions associated with the effects of the music lyrics have been examined in another study. Three experienced female basketball players completed 240 free throws in an A1-B1-A2-B2 structure with A phases being low-pressure conditions and B phases being high-pressure conditions. Music interventions occurred in the B2 stage. Music decreased self-awareness, allowing participants to minimize explicit execution monitoring and decrease overall distraction. [3][8][24]

Creativity

For the twenty-first century, creativity can be considered one of the key competencies. It gives the ability to address the opportunities and challenges that are part of our fast-changing and complex world. Although previous studies have demonstrated the beneficial effect of music on cognition, the effect of listening to music remains largely unexplored in creative cognition.

Divergent thinking is the process of generating creative and different ideas by exploring many possible solutions in a short amount of time. Several directions of a concept are followed in order to provide many ideas, which in turn will lead to more ideas. This method of thinking is often used in conjunction with convergent thinking which consists in sorting and evaluating ideas by analyzing the comparing advantages and disadvantages.

In a study, divergent and convergent thinking were measured by using creativity exercises in different conditions. Participants tried the exercises in silence and also with background music that evoked four distinct emotions: happiness, sadness, calm and anxiety. The results suggested that participants who listened to happy music came up with more creative and innovative solutions that the ones who listened to the other three kinds of music or no music at all. [3][28][30]

Stress and relaxation

Music has tremendously relaxing effects on mind and body. By lowering the cortisol level, which is the main stress hormone in our bodies, relaxing music can alleviate stress. Also, it contributes to the quality of our relaxation by acting like a natural distraction from everyday problems.

Many studies had as central point the relation between music and stress. In one of them, sixty healthy female participants with an average age of 29 years were randomly divided into three groups that took a standardized psychosocial stress test. Prior to the test, the members of the first group listened to relaxing music, the members of the second group listened to water ripple sound while the members of the last group did not listen to music. Examiners evaluated salivary cortisol, heart rate, respiratory sinus arrhythmia as well as the perception of stress and anxiety of all subjects. The results showed that listening to music impacted the psychobiological stress system. The response to stress factors of the volunteers who listened to relaxing music was significantly lower than the one of the participants who listened to water rippling sound and no sound at all.

Music brings hope, power and control in life. Sad music can also be extremely benefic in some scenarios. It can have a cathartic effect when going through hard times. [3][31] [32]

2.2 Emotional Responses to Music

Emotions play an important role in human existence. They are evolved mechanisms that have performed significant functions in human survival throughout the evolutionary process. Emotions are experienced daily during interpersonal communication and interaction, in good and bad days, in leisure activities and also as a response to art, movies and music.

Several studies have suggested that influencing emotions is the most prevalent reason for listening to music. Music is used by listeners to change and release emotions, to match their current emotion, to comfort themselves and to relieve stress. Also, because positive affect can increase cognitive performance, many of the cognitive benefits of music are, in fact, the result of its effect on emotions. [23]

The process through which sounds of music are permeated with meaning, in the form of expressive intentions on the part of a musician and emotional responses on the part of a listener, has a central point in trying to understand musical emotions. These emotions add personal meaning to the processes of perception and cognition by connecting the music to the listener's life experiences.

Emotions also play a crucial role in composing and performing music. A large number of musicians have demonstrated the importance of emotions in learning, interpreting and writing music. In reality, it was because of their valued emotional experiences with music from an early age that made many artists chose to become musicians. [27]

Despite the important role of emotions in the process of creating music and the fact that the capability of music to evoke strong emotions has fascinated humans since ancient Greece, the subject has not occupied a central position in music psychology until recent times. It was only in the last two decades when it started receiving its well-deserved attention, after being neglected during the 1960s, 1970s and 1980s. Since then, a lot of studies devoted entirely to emotions in music have contributed to the rapid development of the field.

A common sentiment among music listeners is that knowing too much about it might destroy its magic, and thus many musicians are reluctant to talk about emotions in regard to music. However, this could be a little too late, music being already used to manipulate the emotions of listeners in society. [18]

Many studies were made on the topic of the influence of music in making decisions. One of these took place in a Swedish electronics shop. The results showed that the customers spent on average eight minutes more in the store and paid more money on products when there was background music played in the background, as opposed to silence.

Other studies were made in wine shops. They found that people choose and purchase more expensive wines when classical music is played in the background. More intriguingly, playing characteristically French music increased sales of wines from French while playing German music increased sales of wines originating from Germany. [2][35]

Also, another experiment explored how 63 people make financial investments while listening to low-tempo music, high-tempo music and no music at all. The results were very surprising. Participants who listened to fast-tempo and arousing music made safer investments than the other ones who listened to calm music or did not listen to music. Moreover, volunteers who perceived the music they were listening as disturbing also made safer investments. [16]

2.2.1 Which Emotions Does Music Express?

Music has the power to evoke the full range of human emotions, from nostalgic, sad and tense to calm, happy and joyous. The process of perceiving emotions by listeners is subjective. It is inappropriate to claim that a person is wrong and thus, any emotion can be perceived in a piece of music. However, a common view in music research suggests that music is expressive of a particular quality only when there is some minimum level of agreement among listeners. The reason for this is that, presumably, the similar impression in different listeners can be caused by some characteristics of the actual music.

Moreover, despite the fact that many musicians want listeners to perceive their music in the way they intended it, any correspondence between the perception of the listener and the emotional result intended by the composer or performer is not required for the notion of expression. [19][23]

As there are many different approaches to conceptualize expression in music, there are different ways investigate which emotions music can express. Several studies used the simplest method for finding these emotions, which is directly asking the participants.

	Kreutz (2000)	Lindström et al. (2003)	Juslin and Laukka (2004)
Subjects	**50 students**	**135 expert musicians**	**141 volunteers**
No. of emotions	**32**	**38**	**38**
RANK ORDERING			
1.	**Happiness**	**Joy**	**Joy**
2.	**Sadness**	**Sadness**	**Sadness**
3.	Desire	**Anxiety**	**Love**
4.	Pain	**Love**	Calm
5.	Unrest	Calm	**Anger**
6.	**Anger**	Tension	**Tenderness**
7.	**Love**	Humour	Longing
8.	Loneliness	Pain	Solemnity
9.	**Fear**	**Tenderness**	**Anxiety**
10.	Despair	**Anger**	Hate

Only the ten most highly rated emotions in each study have been included in the Table. Those emotion categories that correspond to the basic emotions are set in bold text. (Anxiety belongs to the "fear family," and tenderness to the "love" family, see, e.g., Shaver et al., 1987.) The original lists of emotion terms contained both "basic" and "complex" emotions, as well as some terms commonly emphasized in musical contexts (e.g., solemnity).

Figure 2.2 Ratings of the extent to which specific emotions can be expressed in music [17]

Figure 2.2 presents data from three of them, in which volunteers were asked to choose the emotion expressed by a song from a long list of emotion labels. Despite the differences in samples (musicians, students, random volunteers), happiness, sadness, fear, anger, tenderness and love were all among the top-ten emotions. [17][18]

2.2.2 Classifications of Emotions in Music

There are two main approaches for conceptualizing emotions in music in psychology: categorical and dimensional.

The categorical approach

According to the categorical approach, emotions can be divided into categories that are distinct from each other. This theory comes in many different forms. One of them is associated to the concept of basic emotions. Researchers have suggested that all humans have an innate set of basic emotions, such as happiness, sadness, anger, disgust, fear and surprise, which are recognizable among all cultures. They are also called discrete emotions, because of their capability of being distinguished by the facial expressions and biological processes of an individual.

Other subdivisions of the categorical approach are the component-process theories and the music-specific models. The component-process theories suggest that the number of categories for emotions is given by the number of all possible outcomes of the appraisal process. The music-specific models assume that everyday emotions are different from the categories of emotions in music and, moreover, they are unique to music.

The correlation between commonly used expression marks in music scores and basic-emotions labels was demonstrated in a study made in 2003. Psychology students and professional performers were asked to rate varied classical songs with regard to twenty emotion labels rated as feasible in the context of musical expression and twenty expression marks rated as common by music experts. Results presented in Figure 2.3 showed the significant correlation between them. [17][19]

Expression mark	Emotion label	Correlation (r)
Dolce	Tenderness	0.98*
Espressivo	Desire	0.85*
Furioso	Anger	0.92*
	Disgust	0.79*
Grave	Sadness	0.88*
Scherzando	Happiness	0.76*
Spiritoso	Surprise	0.94*
Temoroso	Anxiety	0.97*
	Fear	0.82*

*$p < 0.01$.

(based on Juslin and Wiik, submitted).

Figure 2.3 Examples of correlations between commonly used expression marks in music scores and basic-emotion labels used by psychologists [17]

The dimensional approach

The main alternative to categorical models is a dimensional approach. Dimensional theories conceptualize emotions based on their placement along broad and continuous dimensions such as valence, arousal and potency. Just like the categorical approaches, dimensional theories have different forms.

A very popular form, called the circumplex model, suggests that emotions are a mixture of two core dimensions: valence and arousal. Orthogonally situated in the affective space, the two dimensions represent pleasure-displeasure and activation-deactivation continuums.

There are also some variations of the circumplex model. The Watson and Tellegen's model (1985) has combined the two dimensions by rotating the model by 45 degrees. Two new dimensions were obtained in this way: Positive Affective (PA) which is the combination of negative valence and high arousal, and Negative Affective (NA) which combines negative valence and high arousal.

Another variation was suggested by Thayer (1989). In this model, the arousal dimension was reorganized into energic arousal (EA) and tense arousal (TA) based on the two separate psychobiological systems that are responsible for energy and tension. [19]

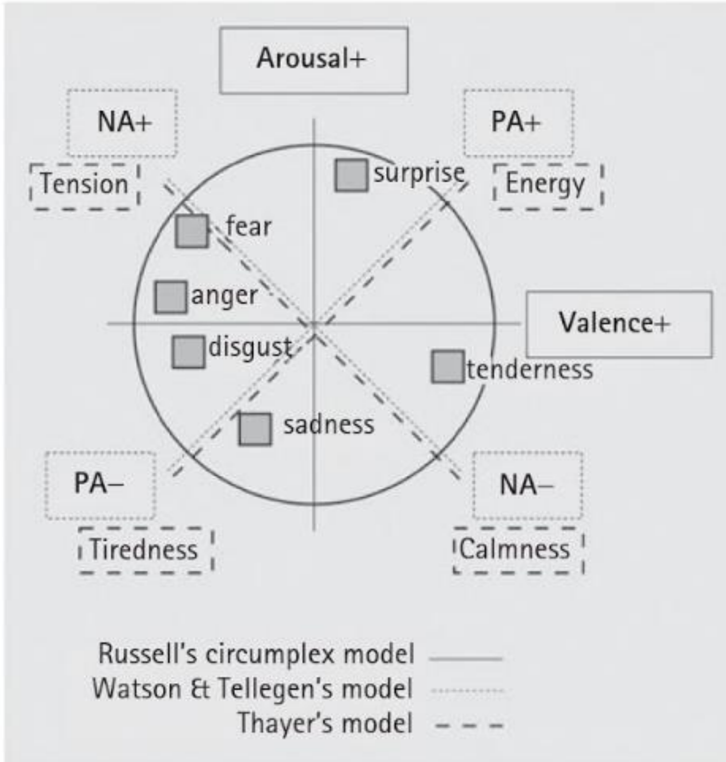

Figure 2.4 Integrated illustration of two-dimensional models with the most common basic emotions attached [19]

2.2.3 Musical Expectations

The structure and order imposed by the brain on a sequence of sounds creates an entirely new system of meaning. Music appreciation is linked to the ability to process its underlying structure, that is, to predict what will happen next in the song.

Humans get familiar to different musical styles and patters and acquire statistical knowledge about the properties of the song structure. Many people can sing along to a song by predicting its next parts, even if they heard it for the first time. That happens because of the musical knowledge about the probability of musical patterns, which creates expectations.

The violation or realization of these expectations influences the cognitive and emotional experience. By knowing the expectations of the audience and controlling when these expectations will or will not be met, many skilled composers manipulate the emotional factor of a song. [7][13][21]

Realization

All songs have a section in their structure that represents an emotional peak. When listening to music, the brain anticipates and expects it. During the anticipation phase, a substance called dopamine is released in different parts of the brain. When this emotional peak arrives, there is a burst of dopamine in the parts of the brain that are associated with reward.

Dopamine, one of the main neurotransmitters in the brain, is an organic chemical released by neurons to send signals to other nerve cells. It is most commonly recognized for its role in reward and pleasure, but also plays an important role in focus, motivation, emotional resilience and cognitive flexibility. Being considered one of the “hormones of happiness”, it is released by reward-driven behavior and pleasure-seeking activities.

This pleasure evoked by music is associated with a phylogenetically old reward network that helps to ensure the survival of the individual and the species. It activates the dopaminergic mesolimbic reward pathway, the mediodorsal thalamus, ventromedial orbitofrontal cortex, pre-genual anterior cingulate cortex and amygdala.

The relation between music and the release of dopamine has been the subject of a study conducted by a team of researchers from Montreal. From the 217 individuals who volunteered to be part of the experiment, the scientists chose ten, who most reliably got chills when listening to instrumental music. Their brain activity was monitored while they were listening to their playlist of favorite songs. Researchers were able to obtain an impressively precise portrait of the effects of music on the brain by combining the PET and FMRI methodologies.

One of the first things they discovered is that dopamine is released in both the ventral and dorsal striatum. However, this was not a big surprise, as these areas have been associated with the response to pleasurable stimuli for a long time.

Beside this, there was one particularly interesting finding which emerged from a closer study of the timing of the response. The scientists analyzed what happens in the anticipatory phase, represented by the seconds before the emotional climax when participants got the chills. What they found is that the listener’s favorite moments in a song are preceded by a prolonged increase of activity in the caudate. There was evidence of relatively greater dopamine activity in the caudate immediately before the climax of emotional responses. Being interconnected with the motor, sensory and associative regions of the brain, this sub-region of the striatum is involved in learning associations of stimulus-response and mediating the reinforcing qualities of rewarding stimuli.

Being set off by temporal cues signaling that a potentially pleasurable auditory sequence will arrive in a song, the anticipatory phase can trigger euphoric emotional expectations and create a sense of reward prediction. This reward is completely abstract and can involve factors such as a sense of resolution and suspended expectations.

The peak emotional response evoked by hearing the desired sequence of sounds in a song represents the liking or consummatory phase. It is correlated to fulfilled expectations and accurate reward prediction. The longer the pattern we expect is denied, the greater the emotional release when the patter arrives.

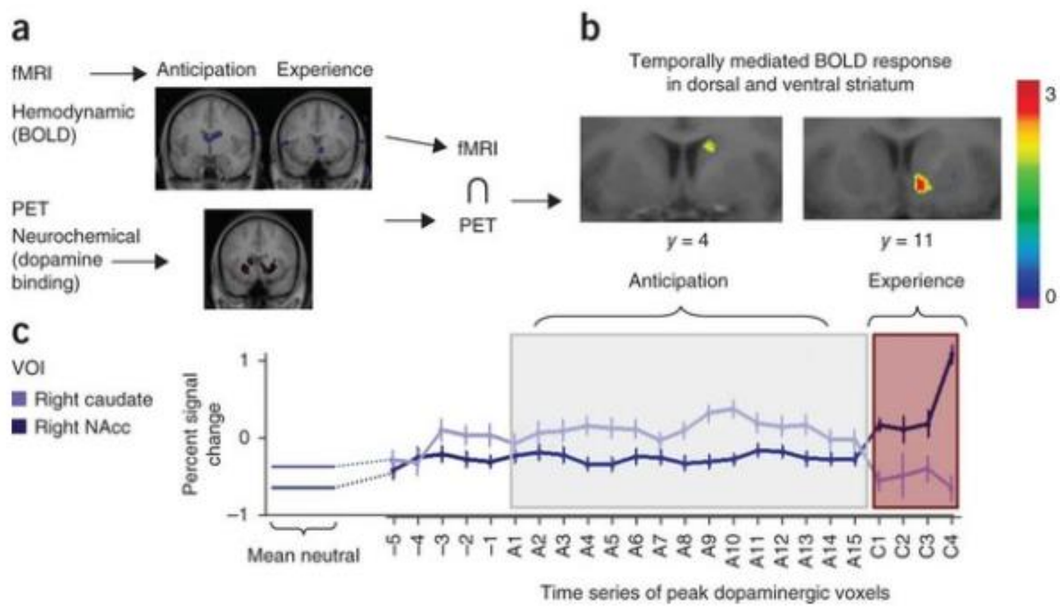

Figure 2.5 Combined fMRI and PET results reveal temporal distinctions in regions showing dopamine release [21]

The results of the study showed that both the anticipatory phase and the consummatory phase involve dopamine release, but in different parts of the striatum, which have different functional roles and connectivity. [7][13][21]

Violation

Music contains fine and precise violations of grammar and timing and, because we know that they are not threatening, the frontal lobes ultimately identify these violations as a source of pleasure. Performers and composers often take advantage of this phenomenon and manipulate emotional arousal of the listeners. This is done by intentionally violating expectations in different ways or by delaying the predicted outcome, by slowing tempo or inserting unexpected notes, before the resolution to be heightening the motivation for completion.

A chord is just a chord when it is played on its own. However, when it is played in a sequence of chords, it has an entirely new meaning. Each song has a key that it is played in, that represents of a major or minor scale around which the song revolves. It includes a tonic note that resolves the musical tension that precedes it, serving as the final resolution. If an Ab major chord is played in the middle of a song that is in the key of C, a key that does not have the Ab chord in it, it is so unexpected that it changes everything.

The unexpected creates a lot of tension, because the brain knows that a moment associated with pleasure is about to come in a song, but it does not know when and what is going to happen. [7][13][21][26][35]

2.2.4 Learned Associations

One of the reasons for the emotional response to music is that people learned to associate musical patterns to emotional contexts. For example, features of a happy song may have been used in a happy movie which made people who watched it laugh and smile. Because we learned to associate those features and reactions with the specific emotion, listening to that song evokes happiness.

Music is similar to human behavior. When we experience sadness, we tend to move at a slower pace and to be less active and because of that we associate songs that have these characteristics with the same emotion. This also happens to happiness and all the other emotions.

Therefore, different features of a song can be associated with different emotions. Songs that are in a major key are considered to be happy while songs that are in a minor key are considered sad. Songs that have a slower tempo, the speed of the piece which derives directly from the average beat duration, are sad, while songs with a faster tempo evoke happiness. [7][13]

There are also different emotive expressions of the key a song is played in. They are all presented in Figure 2.6. The symbol "♭" is used to denote flat, while "#" is used to denote sharp.

Key	Characteristic
C major	Innocence, purity
C minor	Love
D♭ major	Grief
C# minor	Lamentation, repentance
D major	Triumph
D minor	Melancholy, illusion
E♭ major	Devotion, love
D# minor	Anxiety, distress
E major	Joy
E minor	Naivety
F major	Complaisance, repose
F minor	Depression

Key	Characteristic
G♭ major	Relief
F# minor	Resentment and discontent
G major	Peace, calm
G minor	Displeasure, uneasiness
A♭ major	Death, judgment, grave
G# minor	Struggle, grumbling
A major	Contentment
A minor	Tenderness
B♭ major	Cheerful love, hope
B♭ minor	Disgruntlement, displeasure
B major	Anger, rage, desperation
B minor	Patience

Figure 2.6 Characterization of musical keys

3. Technology Stack

This chapter describes the main frameworks and APIs used for creating the application.

Figure 3.1 Logos of the main technologies used for creating the application

3.1 Angular

Angular is a TypeScript-based open-source framework and platform developed by Google for building client applications. Its core and optional functionality is implemented as a set of TypeScript libraries that are imported into applications.

An angular application is defined by a set of building blocks called *NgModules*. They provide collect related code into functional sets and provide a compilation context for components. An angular application typically contains many functional modules, and has at least a root module called *AppModule* which provides the bootstrap mechanism that launches the application.

Angular components define classes which include application data and logic. They are associated with HTML templates which define views to be displayed in a target environment. Also, they use services, which provide specific functionality that is not directly related to views. For making the code more reusable, modular and efficient, service providers can be injected into components as dependencies. Components and services are classes which have a decorator that marks their type and provides metadata for telling Angular how to use them. [5]

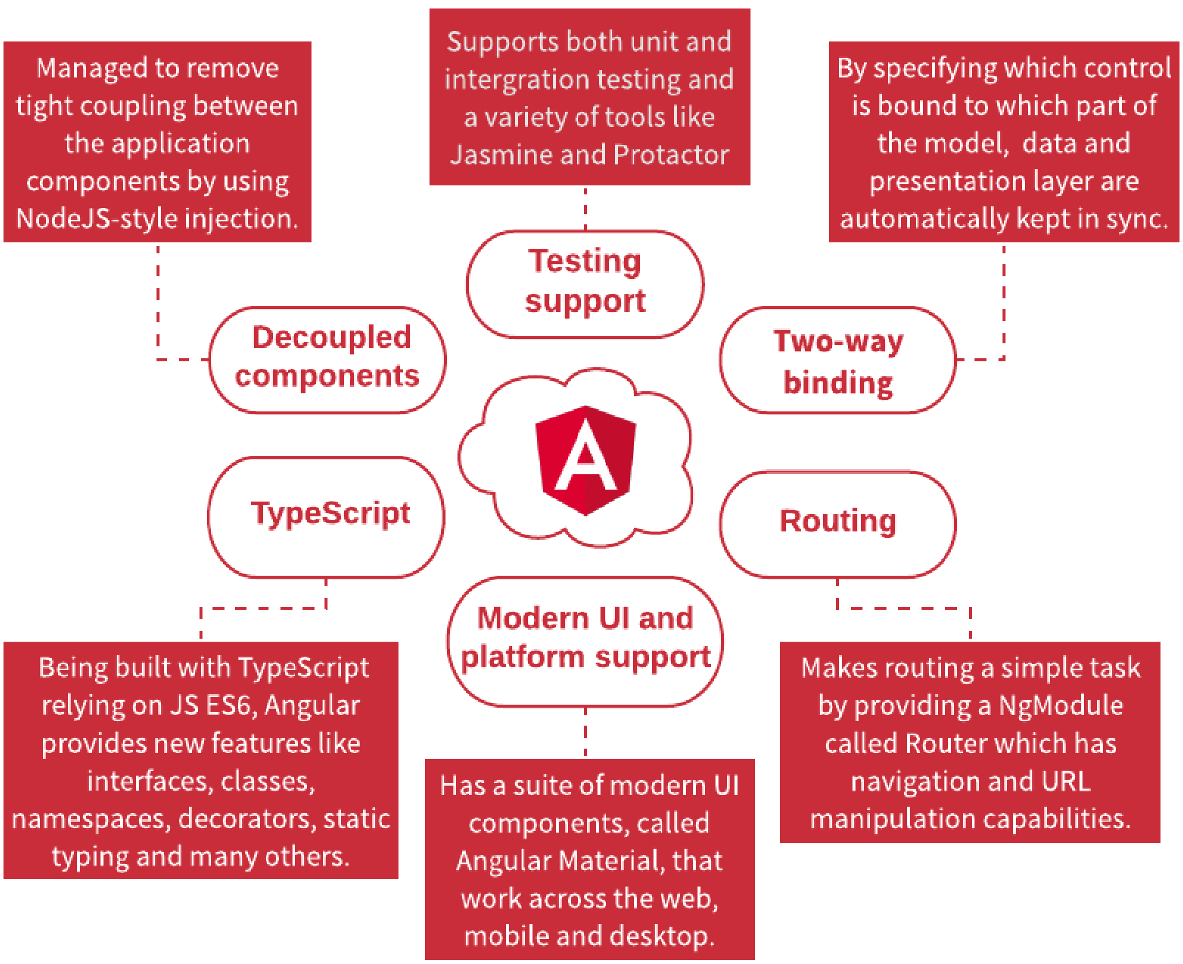

Figure 3.2 Advantages of Angular

3.2 .NET Framework

The .Net Framework is a software development platform developed by Microsoft for creating applications for web, Windows, Windows Phone, Windows Server and Microsoft Azure. It is composed of two main components: the .NET Framework Class Library, which provides a library of tested, reusable code that developers use in their applications and the common language runtime (CLR), which is an application virtual machine that provides services such as memory management, security and exception handling. [1]

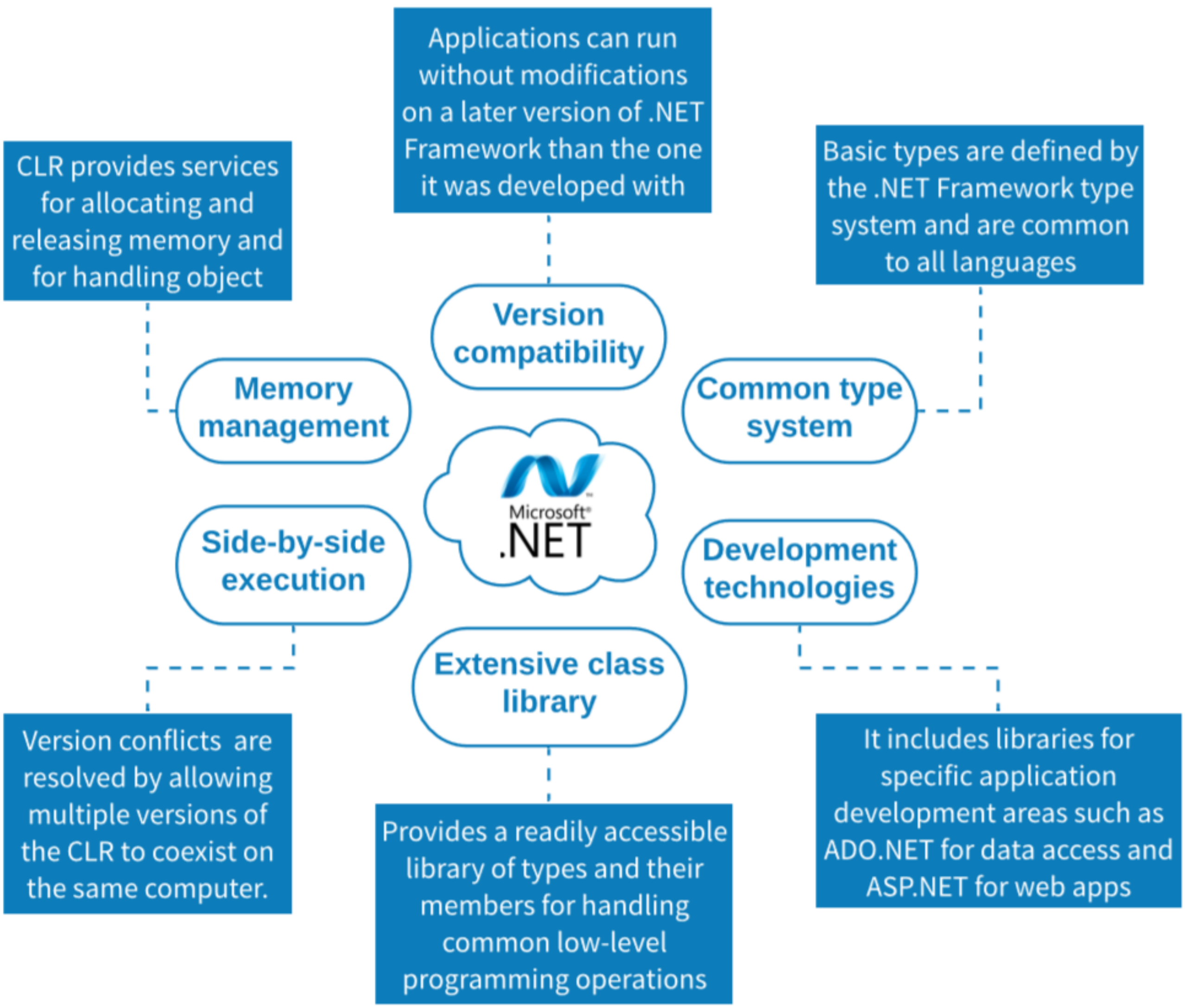

Figure 3.3 .NET Services

3.3 Face API

In many different software scenarios, the ability to process human face information is essential. Scenarios include security, mobile applications, robotics, image content analysis and management and natural user interface.

The cloud-based Face API is an Azure Cognitive Service which provides advanced algorithms that are used to recognize, detect and analyze human faces in images. Every call requires a subscription key which needs to be passed through a query string parameter or specified in the request header.

Supported image formats are JPEG, PNG, BMP and GIF (first frame) and the allowed image file size ranges between 1KB and 6MB. For an image, up to 64 faces can be detected and analyzed, being ranked by face rectangle size from large to small. Some of the face attributes returned for each detected face include:

- **Smile:** a number between 0 and 1, representing smile intensity.
- **Gender:** male or female.
- **Age:** an estimated "visual age" number in years representing how old a person looks like.
- **Emotion:** a number between 0 and 1, representing emotion intensity including anger, contempt, disgust, fear, happiness, neutral, sadness and surprise. [11]


```
{
   "faceAttributes":{
      "smile":1.0,
      "gender":"female",
      "age":21.0,
      "emotion":{
         "anger":0.0,
         "contempt":0.0,
         "disgust":0.0,
         "fear":0.0,
         "happiness":1.0,
         "neutral":0.0,
         "sadness":0.0,
         "surprise":0.0
      }
   }
}
```


Figure 3.4 Face attributes recognized from image

3.4 Spotify API

Spotify Web API is based on simple REST principles and provides endpoints that return, directly from Spotify Data Catalogue, JSON metadata about music, albums, artists and tracks. Also, through selective authorization, it provides access to user related data, like music and playlists. The base address of the API is *https://api.spotify.com/v1* and each endpoint has its own unique path. Unsuccessful responses return, apart from the response code, a JSON object containing the HTTP status code and a short description of the cause of the error.

3.4.1 Client Credentials Authentication

Authorized requests to the Spotify platform require permission to access data. Three parties are involved in the authorization process: the Spotify server (server), the application (client) and the end user data and controls (resource). Client Credentials flow is used in server-to-server authentication and provides access only to the endpoints that do not access user information.

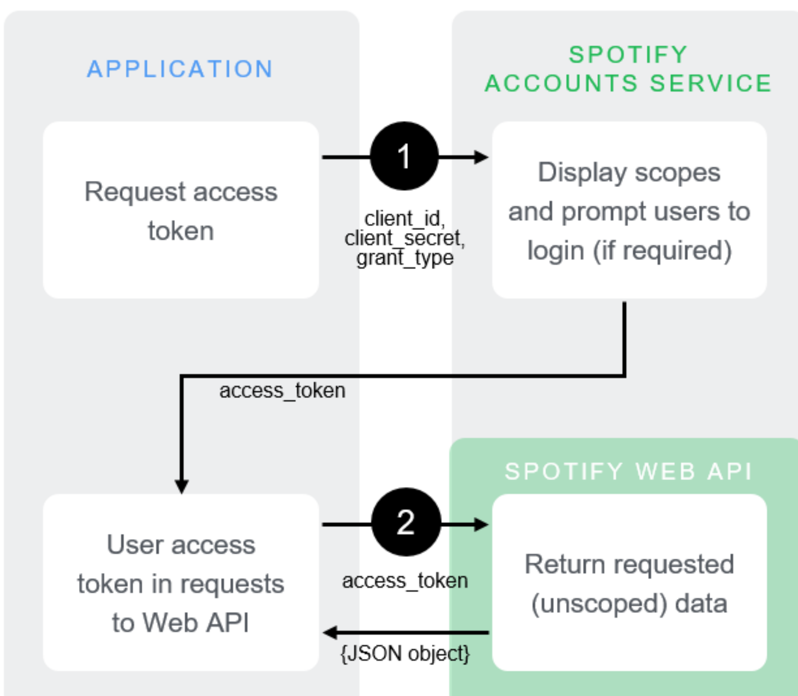

Figure 3.5 Spotify Client Credentials Flow [29]

By using *Client ID* and *Secret Key*, an *Access Token* is retrieved and must be used to make requests to the Spotify Web API endpoints. For retrieving the token, a request is sent to the *https://accounts.spotify.com/api/token*. The body of this POST request must contain, encoded in *application/x-www-form-urlencoded* format, a parameter called *grant_type* which is set to *client_credentials*. The header of the request must contain a parameter called *Authorization* which has as value *Basic* followed by the base 64 encoded string that contains the *Client ID and Client Secret Key*: *Basic <base64 encoded client_id:client_secret>*. This token must be passed as a parameter in the header of all requests in the following format: *Authorization: Bearer <token>*.

3.4.2 Recommendations Based on Seeds

A GET request to the https://api.spotify.com/v1/recommendations returns a list of musical recommendations for a given seed entity and matched against similar tracks and artists. Up to five artist id, track id and musical genre values can be provided as seeds in any combination. If the information about the provided seeds is sufficient, tracks will be returned together with data about artists, title and album images. The endpoint also receives as parameters different attributes regarding the emotional expressivity of the recommended tracks.

- **Valence:** value from 0.0 to 1.0 describing the musical positiveness of a track.
- **Danceability:** describes how suitable a track is for dancing, with 0.0 representing least danceable and 1.0 most danceable.
- **Energy:** the perceptual measure of intensity and activity of a track, measured from 0.0 to 1.0
- **Loudness:** the overall loudness of a track in decibels (dB), typically ranging between -60 and 0 db.
- **Mode:** the modality of a track with 1 representing major and 0 minor.
- **Tempo:** estimated overall time signature of a track measured in beats per minute. [29]

3.3 YouTube API

YouTube provides many different API’s for embedding functionality into websites and applications. Some of the most important ones are the Data API and the Player API.

3.3.1 Data API

The YouTube Data API provides access to functions that are normally executed on the YouTube website. It can be used to insert, update, delete and retrieve resources and fetch search results. A resource has a unique identifier and represents an individual data entity that comprises part of the YouTube experience. The base URL for the host that processes Data API requests is *https://www.googleapis.com/youtube/v3* and every request must either or provide an OAuth 2.0 token or specify an API key (with the key parameter).

One of the exposed endpoints is *https://www.googleapis.com/youtube/v3/search*. A GET request returns a collection of search results that match the specified query parameters. A search result contains information about a YouTube video, channel, or playlist, such as id, title, description, thumbnails, content details and many others.

3.3.2 Player API

The YouTube Player API allows the embedment and control of a YouTube video player in a website. The API's JavaScript functions offer the possibility to queue videos for playback, play, pause and stop those videos, adjust the player volume, seek to a specified time in the video and retrieve information about the video being played.

The API provides two main functions: *onYouTubeIframeAPIReady* and *onStateChange*. All applications that use the Player API must implement the *onYouTubeIframeAPIReady* function. It will be called as soon as the page has finished downloading the JavaScript for the API, which enables the creation of a player object for displaying and controlling a video. The *onStateChange* function is called whenever the player's state changes. The API passes an event object to this function which specifies, in a property called data, an integer corresponding to the new player’s state: -1 (unstarted), 0 (ended), 1 (playing), 2 (paused), 3 (buffering), 5 (video cued). [36]

4. Software Development

The purpose of this chapter is to present a short overview of the application, followed by its use cases, architectural design and implementation details.

4.1 Overview

Espressivo is a web application designed for providing musical recommendation based on facial emotions. It relies on the strong relation between music and emotions, which has been proved in many different studies in the past decade. The system uses the technologies presented in the previous chapter and combines three modern API's for creating what seems a simple concept, at the first glance, but with prodigious benefits on the human mind.

The application has a simple and original graphical interface for making the user experience as pleasant as possible. It allows the user to select an image from the local device and to take a picture by using the webcam, if available. All the faces from the provided image are analyzed for detecting the expressed emotion. The predominant emotion of the image is then computed based on the average value of all recognized emotions. Attributes of the tracks that will be recommended to the user are configured based on this predominant emotion. The recommendation algorithm uses the favorite artists and musical genres of the user to provide custom and accurate results. The final step in the process consists of the creation of a music player with simple controls, containing the recommended tracks.

4.2 Use Cases

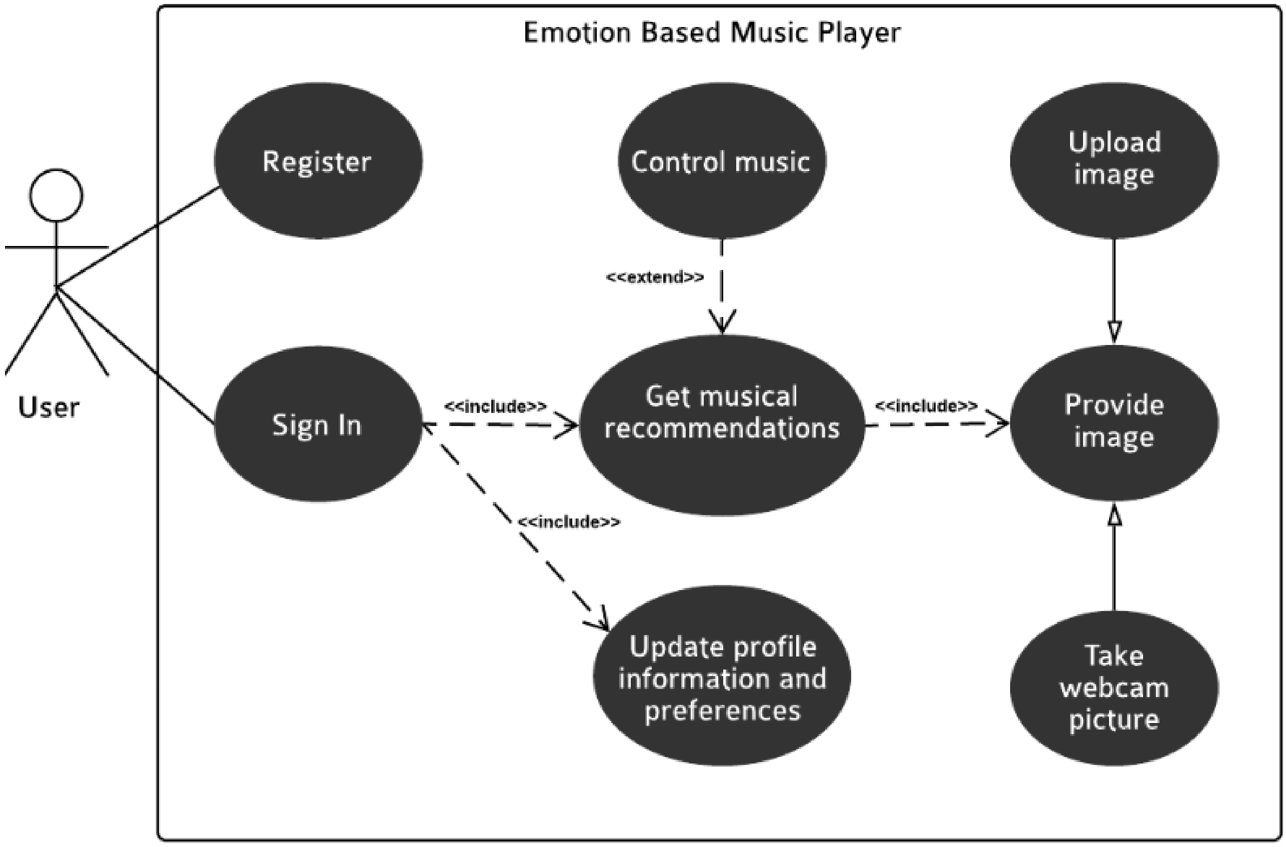

Figure 4.1 Use case diagram

The use case diagram presented in Figure 4.1 depicts a high-level overview of the relationship between use cases, the actor and the system. It provides a simple and graphical representation of what the system is supposed to do. The single generic actor, the user, can interact with the application in many different ways. It can create an account, log in and update its profile information and musical preferences. Also, it can be involved in the main use case of the application, song recommendation. It can select an image by using a locally stored file or the webcam, if the system succeeds in finding one. Also, the user can control the music player containing recommended tracks that was created by using one of the many different available audio controls.

4.3 Design and Implementation

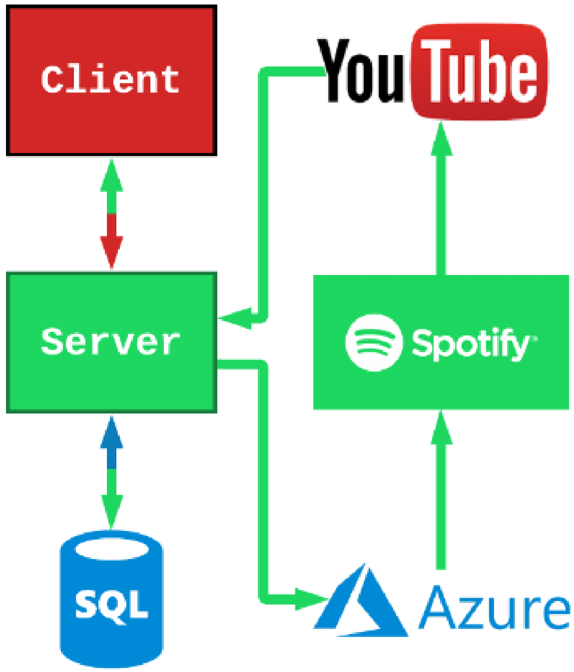

Figure 4.2 Architectural design of the application

The client-server model is a distributed application structure in which clients and servers exchange messages in a request-response messaging pattern. It is a producer-consumer architecture where the server can manage several clients simultaneously and delivers most of the resources and services to be consumed these clients. While client and server may reside in the same system, they often communicate over a computer network on separate hardware.

The application has three-tier architecture, which is a variety of the client-server model. It consists of a presentation tier, an application tier, and a data tier. The presentation tier, also called the client tier, is built using the Angular framework (html5, scss and typescript), occupies the top level and consists of the graphical user interface which is accessible through a web-browser and displays content relevant to the end user. It communicates with the Application Layer through REST API calls. The Application Layer is written in .NET and encapsulates the functional business logic which drives the application's core capabilities. The data tier comprises the Microsoft SQL Server database system and the Data Access Layer. By modularizing the layers, this architecture provides many benefits for the development and production environment. It allows an easier replacement and update of a specific part of the application, independently of the other parts. [33]

4.3.1 Database

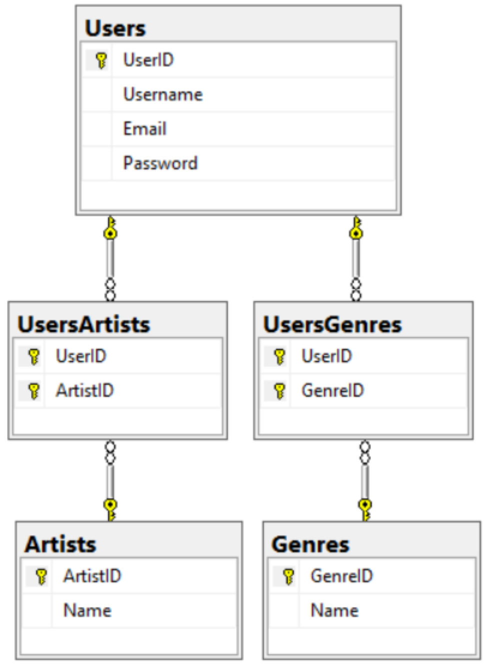

Figure 4.3 Database architecture

Figure 4.3 describes the architectural design of the SQL Server database of the application. The purpose of this database is to store information about users and their musical preferences for using them as seeds for retrieving musical recommendations. The main table in the database is the *Users* table, which stores user data, like *Username*, *Email* and *Password*. Each user of the application has a unique id which is used as the primary key of the table. The username and email of a user are unique, and the password is stored in an encrypted form. The *Artists* and *Genres* tables are used to store information about various artists and musical genres. These tables have a many-to-many relationship with the *Users* table. The application can have multiple users and each user can have many favorite artists and genres. Also, each artist and genre can be a favorite of multiple users. *UsersArtists* and *UsersGenres* are association tables that map together the *Users* table and the *Artists* and *Genres* tables.

The operations made on these tables are done using stored procedures. There are stored procedures for inserting, updating, removing, reading by id and reading all entities of each table. There are also some more complex procedures for special cases. Figure 4.4 illustrates the procedure for returning five random artists and genres of a user, to be used as seeds for retrieving accurate musical recommendations.

```
CREATE PROCEDURE [GetRandomSeeds]
    @UserID UNIQUEIDENTIFIER
AS
BEGIN
    DECLARE @genresTable as table([Name] NVARCHAR(100) NOT NULL);
    INSERT INTO @genresTable exec [UsersGenres_ReadByUserID] @UserID

    DECLARE @artistsTable as table([ArtistID] NVARCHAR(50) NOT NULL, [Name] NVARCHAR(100) NOT NULL);
    INSERT INTO @artistsTable exec [UsersArtists_ReadByUserID] @UserID

    SELECT TOP 5 *
    FROM
    (
        SELECT [ArtistID],[Name] from @artistsTable
        UNION
        SELECT NULL as [ArtistID],[Name] from @genresTable
    ) seeds
    ORDER BY NEWID()
END
GO
```

Figure 4.4 Stored procedure for random combinations of five artists and genres

4.3.2 Server Side

The server of the application is built using the .NET framework because it provides an easier communication with the SQL Server database through ADO.NET and with the client through the Web API Layer and also an easier implementation and integration of the JSON Web Token authentication. It has a layered architecture, each layer representing an independent and self-contained component created as a separate project. The implementation conforms to the SOLID principles, components having a single, well-defined purpose and low coupling, being easily replaceable and extendible without altering any of the existing properties of the application. This approach also promotes high cohesion, the components of a module being directly related to the module’s intended functionality. This increases the code maintainability and reduces risk when making change. Figure 4.5 presents all the layers of the application as well as the main API flow.

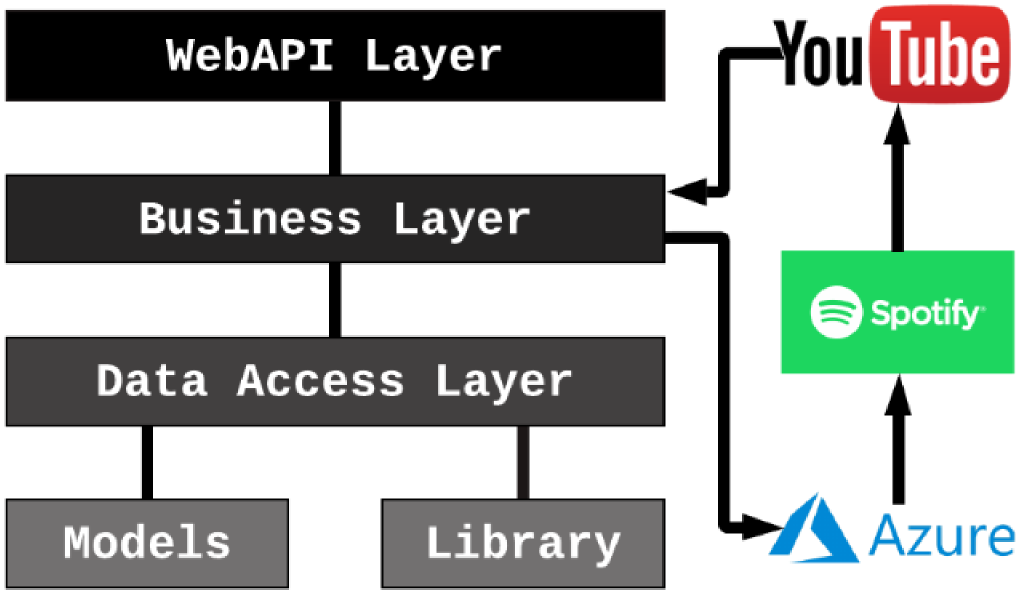

Figure 4.5 Architectural design of the server

Models

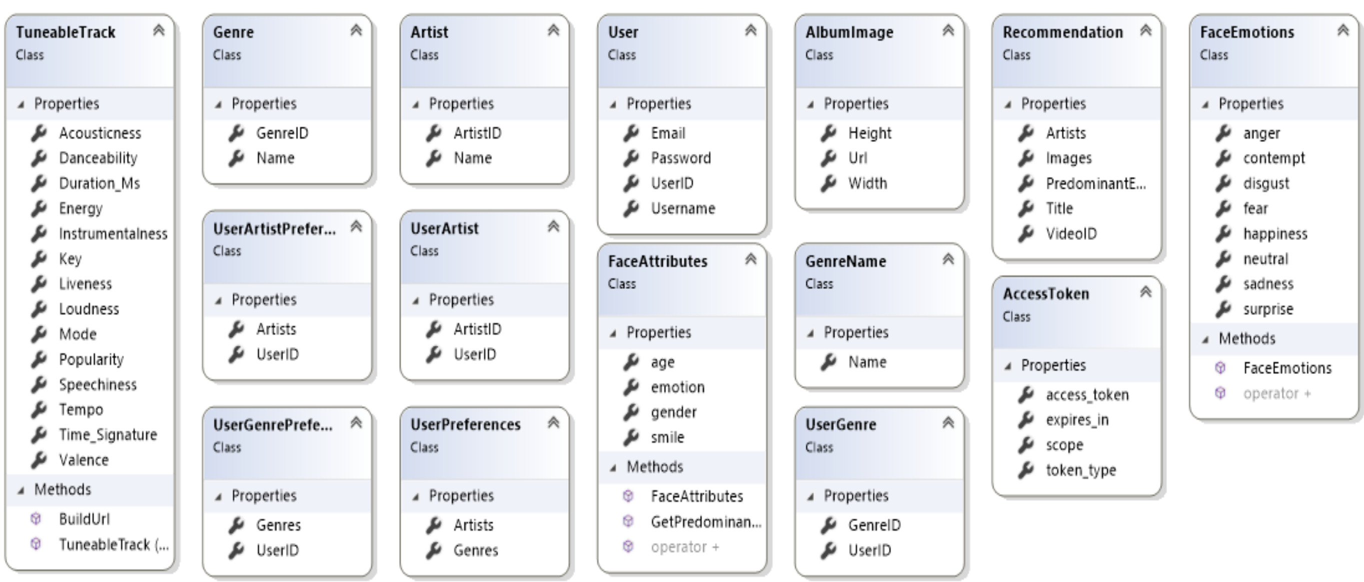

Figure 4.6 Class diagram of the models

The Models Layer contains the main entities to be used throughout the application. Each model has its private fields represented as properties, which are members providing a flexible mechanism for reading, writing, and computing their value. Even they seem similar to public data members, they are actually special methods which enable an easier access to the data and promotes flexibility and safety of methods. Through the *DataContract* and *DataMember* attributes, the models can be serialized and sent to client through Web API. Some of the models also include methods that are specific to them and provide custom functionality, such as operator overloading.

Data Access Layer and Library

The Data Access Layer (DAL) helps separate data-access logic from business objects, being used to manage the connection between the server and the database and to provide data to the Business Layer. This is accomplished by exposing database-independent method signatures to the Business Layer. They are methods that operate on data, in the data tier, using database engine specific code but not exposing any database specific parameters or return types. Instead of calling the data tier, the Business Layer calls the DAL every time it needs to access data. This approach decouples the Business Layer from the Data Layer, making it database independent. Thus, it is very easy to create and integrate another DAL for a different database without modifying any other layers.

The class diagram of the DAL is presented in Figure 4.7. For each entity from the database, a different class inheriting from the *DALObject* class is created, containing methods for all the possible operations of that entity. *DALContext* represents a wrapper class, containing access properties for all DAL objects and being used in the Business Layer. These properties are implemented using the lazy loading design pattern, which means that the initialization of the objects is deferred until the point at which they are needed. Therefore, if an entity is not used, it will never be initialized. Also, the base class and the wrapper class implement the *IDisposable* interface for releasing unmanaged resources. The *DALObject* class contains a *DALContext* field, allowing the created DAL classes, specific to the database models, to access each other's properties.

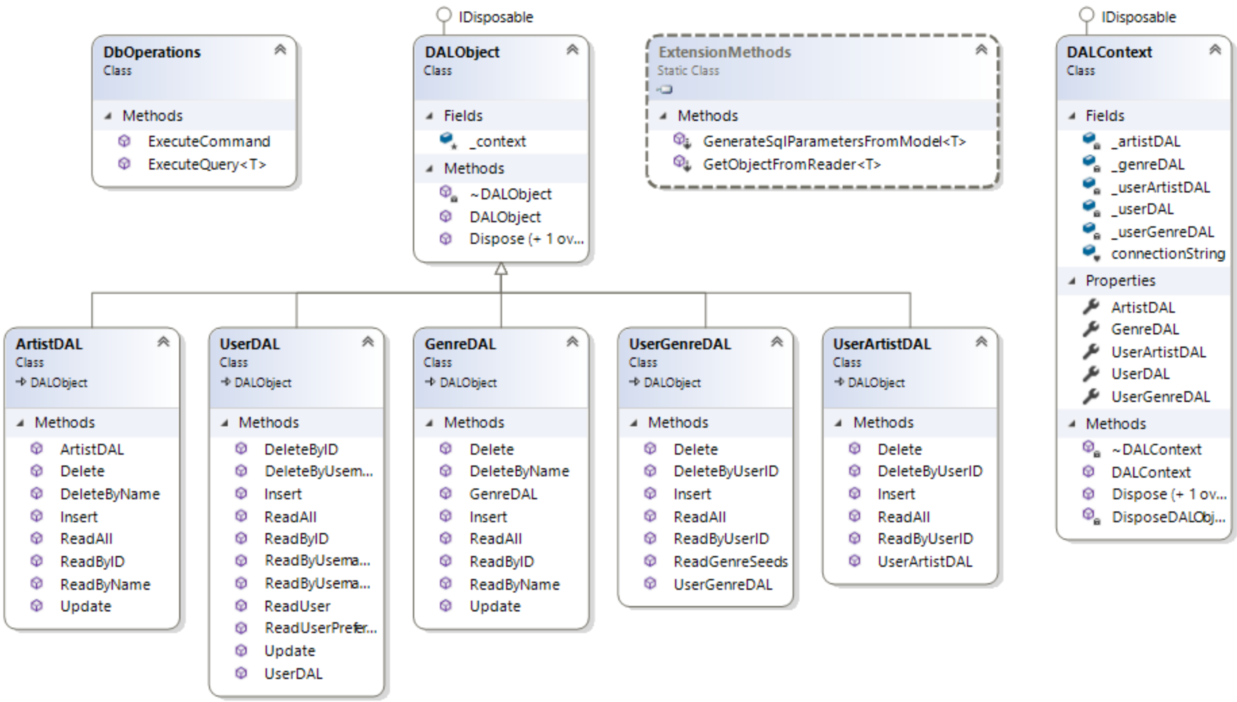

Figure 4.7 Class diagram of the DAL Layer

ADO.NET technology is used for connecting to the database and retrieving, handling and updating data. It provides the most direct and consistent method of accessing data within the .NET Framework. It separates data manipulation from data access into discrete components that can be used together or separately. For simplicity and to increase code maintainability, the ADO.NET methods for connection to the database were implemented using reflection and generics. Reflection provides the capability of obtaining type information about objects at runtime. It can be used to create an instance of a type, to bind the type to an existing object, to get the type from an existing object and to invoke its methods. Also, it enables the access to the attributes of fields, types, methods and properties.

There are two main methods in the application for executing database stored procedures: *ExecuteCommand* and *ExecuteQuery*. The difference between them is that *ExecuteCommand* handles operations which do not have to return a result, like insert, update and remove, while

ExecuteQuery is used for retrieving data from the database and storing it in a collection. Both of them receive as parameters the connection string of the database, which is stored in the *Web.config* file for an easier global access, the name of the stored procedure to be used for the operation as well as its parameters stored in an array.

For performing operations in a generic way, two extension methods from the Library module are used. Extension methods enable the capability of adding methods to existing types without modifying, recompiling them or creating a new derived type. The first extension method is called *GetObjectFromReader* and it is added to the collection of methods of the *SqlDataReader* type. It is called when retrieving data from the database by using a reader and its purpose is to create models based this data. It receives a generic type parameter, creates a new object of that type, iterates through the properties of it by using the *DataMember* attribute, sets their value to the corresponding value from the reader, and returns the newly created object.

```
public static T GetObjectFromReader<T>(this SqlDataReader reader) where T : new()
{
    T element = new T();
    Type type = element.GetType();
    List<PropertyInfo> TypeProperties = type.GetProperties().ToList();

    foreach (PropertyInfo property in TypeProperties)
    {
        DataMemberAttribute attribute = property.GetCustomAttributes(typeof(DataMemberAttribute), true).FirstOrDefault()
            as DataMemberAttribute;

        if (attribute.Name == null || Convert.IsDBNull(reader[attribute.Name]))
        {
            continue;
        }
        property.SetValue(element, reader[attribute.Name], null);
    }
    return element;
}
```

Figure 4.8 GetObjectFromReader extension method

The second method is called *GenerateSqlParametersFromModel* and it is an extension of all models of the application. Its role is to convert the properties of the models into SQL formatted parameters to be used in database stored procedures. It receives a generic type parameter representing a model, iterates through its properties by using the *DataMember* attribute, and returns a list of corresponding *SqlParameters*. The *SqlParameter* is created using a parameter name, which is composed of the "*@"* character followed by the name, and its value.

```
public static List<SqlParameter> GenerateSqlParametersFromModel<T>(this T model)
{
    List<SqlParameter> parameters = new List<SqlParameter>();
    var properties = typeof(T).GetProperties();

    foreach (var property in properties)
    {
        DataMemberAttribute attribute = property.GetCustomAttributes(typeof(DataMemberAttribute), true).FirstOrDefault()
            as DataMemberAttribute;

        if (attribute.Name == null || property.GetValue(model) == null)
        {
            continue;
        }
        parameters.Add(new SqlParameter(string.Format("@{0}", attribute.Name), property.GetValue(model)));
    }
    return parameters;
}
```

Figure 4.9 GenerateSqlParametersFromModel extension method

Business Layer

The Business Layer is part of the application tier and contains all the functional logic for the core capabilities of the application. Its role is to execute the entire logic and to process all interactions between the Web API Layer and the DAL. Despite having more classes, the structure of the Business Layer is the same as the one of the DAL. There are business objects encapsulating the data and business processing logic for the main entities. They all inherit from the *BusinessObject* class which has a *BusinessContext* field. The *BusinessContext* is a wrapper class, containing properties for all business objects, implementing in a lazy-loading manner. It also contains a *DALContext* field, for accessing the methods of all DAL objects. Each business object has access to methods of all the other business objects as well as all the other DAL objects. Also, like in the DAL, the base class and the wrapper class implement the *IDisposible* interface for releasing unmanaged resources.

The Business Layer also contains classes for working with the *Face* (Emotion Recognition), *Spotify* (Recommendation) and *YouTube* APIs. For each of them, a business object was created and included in the DALContext. There are also the *RecommendationClient*, *YoutubeClient* and *EmotionRecognitionClient* classes. They are responsible for executing the REST calls to the external API's and returning the received data. Before executing the actual calls, the authorization mechanisms, like subscription keys and tokens, are configured. Also, there are two classes called *EmotionRecognitionUrlBuilder* and *RecommendatioUrlBuilder* which are responsible for creating the URLs for the calls by inserting the provided parameters. These URLs are used by the client classes when executing the calls. The class diagram of the Business Layer is presented in Figure 4.10.

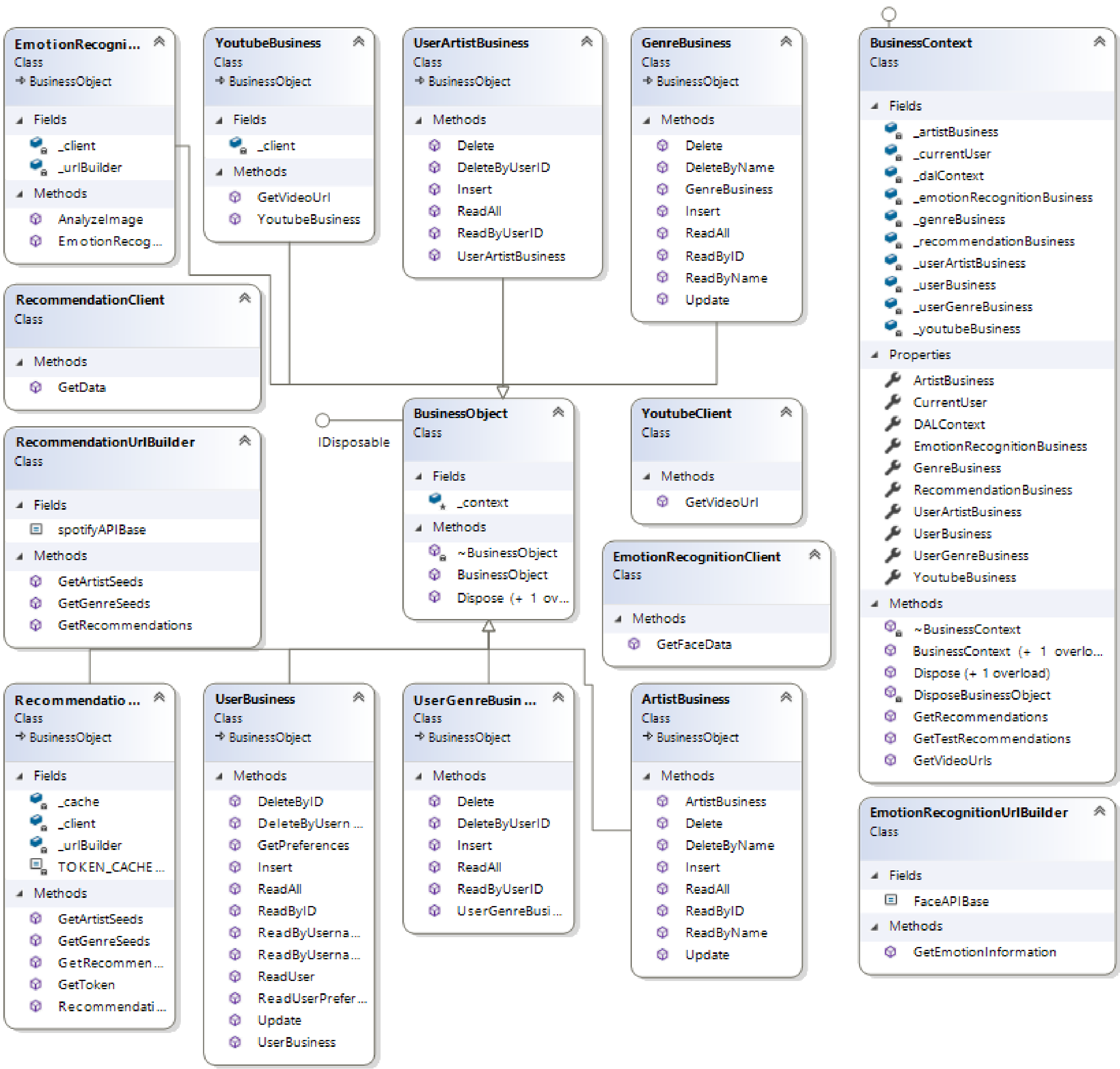

Figure 4.10 Class diagram of the Business Layer

The Business Layer is also responsible for executing the entire external API flow, which is presented in Figure 4.11. This logic is implemented in the *DALContext* class, as it represents the main operation in the entire application. The three API's are used to return musical recommendations that can be played in a browser based on the facial emotions recognized from a picture.

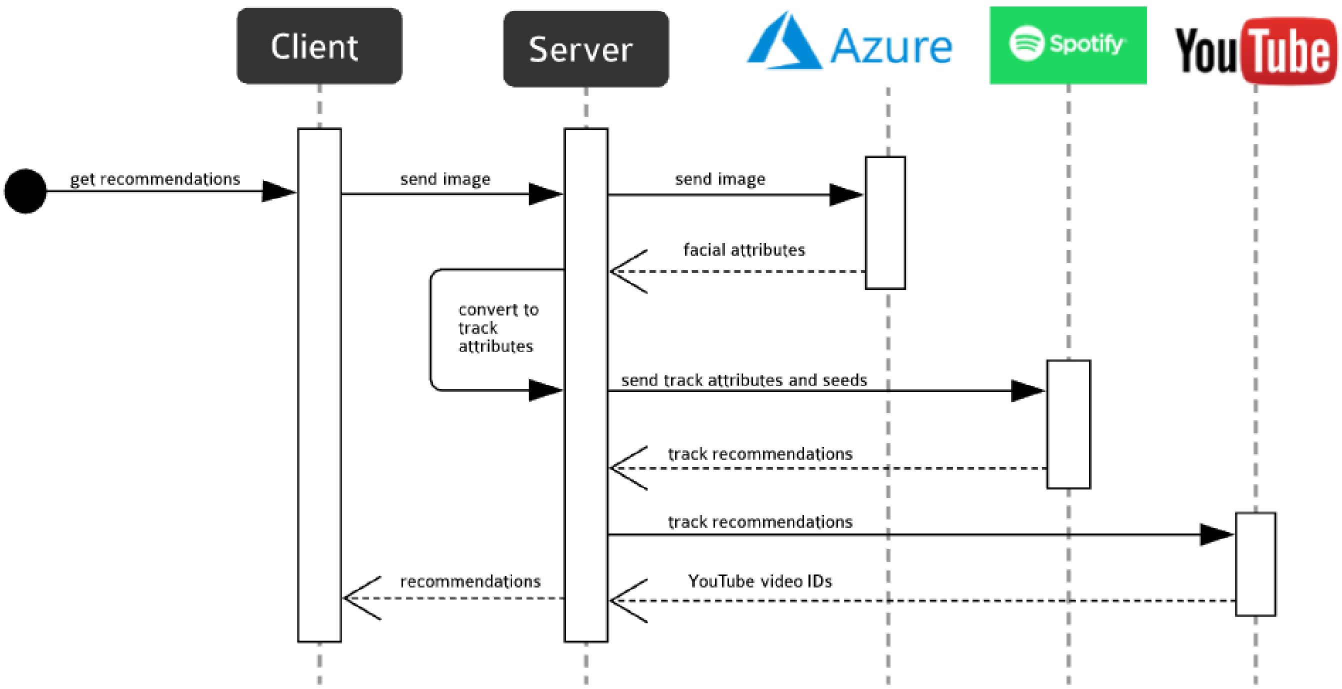

Figure 4.11 Get recommendations sequence diagram

The flow starts from the Client Layer with the user uploading an image or taking a picture using the webcam. This image is then sent to the server by using a REST API call. Based on this image, the server must return a list of recommended tracks. The first API that is used in this process is the Azure Cognitive Service Face API. The server receives the image and sends it to this API through a POST request, which returns a JSON array containing facial attributes for all detected faces. This array is deserialized to create a model which contains the average values of the facial emotions for all faces. This is accomplished by overloading the *"+"* operator to compute the average values of two models and then adding up all models. They are values ranging from 0.0 to 1.0 representing the intensity of each emotion: neutral, happiness, anger, contempt, fear, disgust, sadness and surprise. For using the Spotify API, which comes next in the process, these values must be converted into track attributes: valence, energy, danceability, loudness, mode and tempo. The conversion is done using the predominant recognized facial emotion. The predominant emotion is represented by any emotion besides *neutral* having a value greater than 0.3. If there is no such emotion, it is considered to be *neutral*. Figure 4.12 presents how the track attributes are computed for each emotion.

```
case "neutral":
    Valence = random.NextDouble() * 0.2 + 0.4;
    Energy = random.NextDouble() * 0.2 + 0.4;
    Danceability = random.NextDouble() * 0.2 + 0.4;
    Loudness = random.NextDouble() * 0.2 + 0.4;
    Mode = random.Next(0, 2);
    Tempo = random.Next(95, 116);
    break;
case "happiness":
    Valence = random.NextDouble() * 0.1 + 0.9;
    Energy = random.NextDouble() * 0.1 + 0.9;
    Danceability = random.NextDouble() * 0.3 + 0.7;
    Loudness = random.NextDouble() * 0.6 + 0.4;
    Mode = 1;
    Tempo = random.Next(120, 201);
    break;
case "anger":
    Valence = random.NextDouble() * 0.3 + 0.2;
    Energy = random.NextDouble() * 0.4 + 0.6;
    Danceability = random.NextDouble() * 0.3 + 0.6;
    Loudness = random.NextDouble() * 0.2 + 0.8;
    Mode = random.Next(0, 2);
    Tempo = random.Next(120, 201);
    break;
case "contempt":
    Valence = random.NextDouble() * 0.3 + 0.1;
    Energy = random.NextDouble() * 0.4 + 0.2;
    Danceability = random.NextDouble() * 0.3 + 0.2;
    Loudness = random.NextDouble() * 0.4 + 0.3;
    Mode = 0;
    Tempo = random.Next(85, 111);
    break;
case "fear":
    Valence = random.NextDouble() * 0.2 + 0;
    Energy = random.NextDouble() * 0.2 + 0.1;
    Danceability = random.NextDouble() * 0.2 + 0.25;
    Loudness = random.NextDouble() * 0.2 + 0.65;
    Mode = random.Next(0, 2);
    Tempo = random.Next(115, 136);
    break;
case "disgust":
    Valence = random.NextDouble() * 0.2 + 0.3;
    Energy = random.NextDouble() * 0.2 + 0.75;
    Danceability = random.NextDouble() * 0.2 + 0.4;
    Loudness = random.NextDouble() * 0.2 + 0.7;
    Mode = random.Next(0, 2);
    Tempo = random.Next(85, 131);
    break;
case "sadness":
    Valence = random.NextDouble() * 0.15 + 0;
    Energy = random.NextDouble() * 0.15 + 0;
    Danceability = random.NextDouble() * 0.3 + 0.2;
    Loudness = random.NextDouble() * 0.4 + 0.3;
    Mode = 0;
    Tempo = random.Next(80, 111);
    break;
case "surprise":
    Valence = random.NextDouble() * 0.2 + 0.8;
    Energy = random.NextDouble() * 0.2 + 0.8;
    Danceability = random.NextDouble() * 0.4 + 0.6;
    Loudness = random.NextDouble() * 0.6 + 0.4;
    Mode = random.Next(0, 2);
    Tempo = random.Next(110, 201);
    break;
Loudness = 1 - Loudness * (-60);
```

Figure 4.12 The conversion between predominant emotion and track attributes

These values together with the user's favorite artists and genres as seeds are used to make the Spotify API request, which returns a list of track recommendations. The title and artists of each track is used to retrieve the YouTube video id of the track, by making a request to the YouTube Data API search endpoint. The last process consists of creating an array of recommendations which is sent back to the client together with the predominant emotion. Each recommendation object contains information about the title, artists, YouTube video id and album images of a track.

Web API Layer

The Web API Layer acts as a connector between the client and the server. Controllers containing endpoints for all operations were created for each model. The client makes REST requests to these endpoints, optionally sending parameters in the header or body of these requests and retrieving data. All these controllers have an authorization filter applied as an attribute, allowing only authorized users to access the endpoints. All these controllers are inheriting from a class called *MainApiController* which contains a *BusinessContext* member and information about the currently logged in user. The layer also includes classes needed in the Jason Web Token authorization and for encrypting passwords.

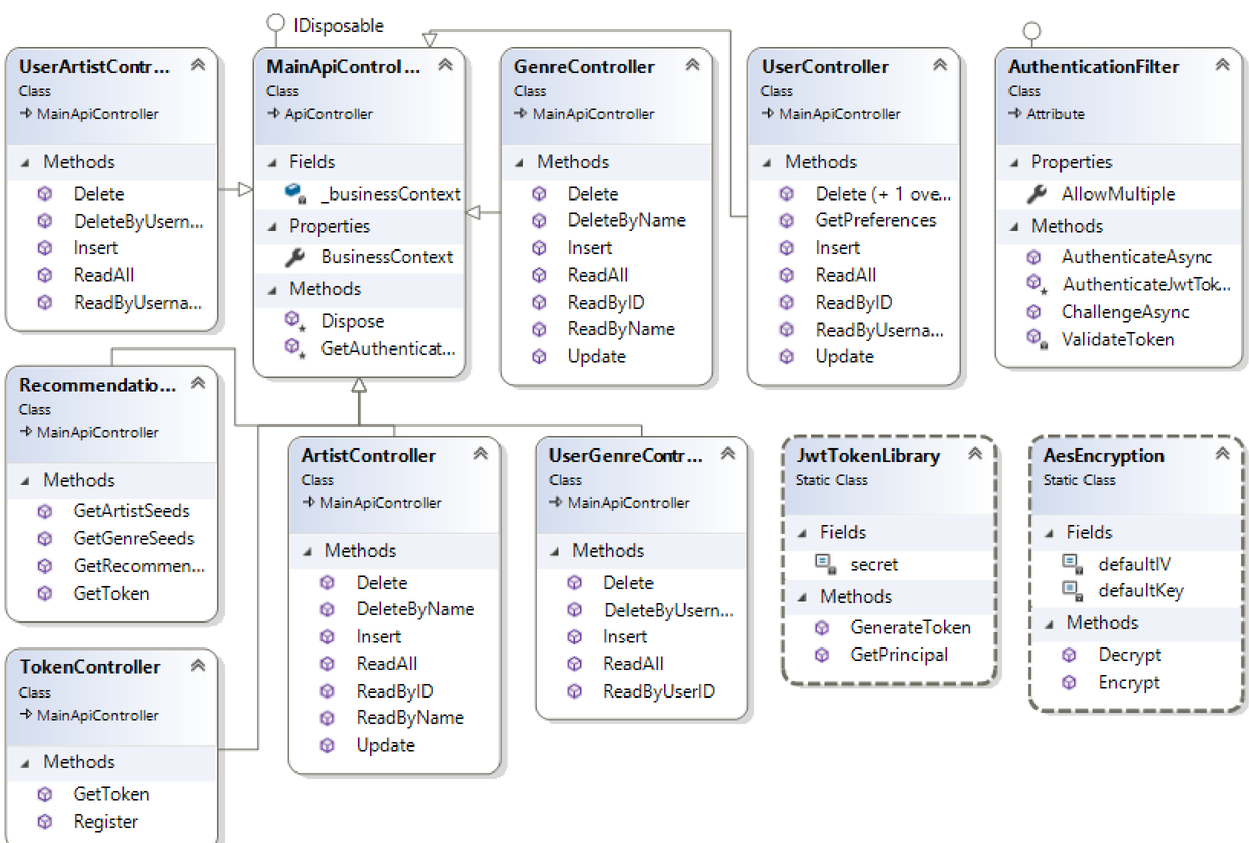

Figure 4.13 Class diagram of the Web API Layer

4.3.3 Client Side

The client represents the Presentation Layer and consists of the graphical user interface built using the Angular framework. Angular promotes reusability and modularity, its architecture being based on multiple modules, components and services. Each module has a HTML file, a SCSS file for styling and a TypeScript file for scripting. Typescript provides more features than JavaScript, like static typing, interfaces, classes, decorators and many others. Also, SCSS represents an extension over the traditional CSS, including features such as variables, nesting selectors, mixins, style imports and style inheritance.

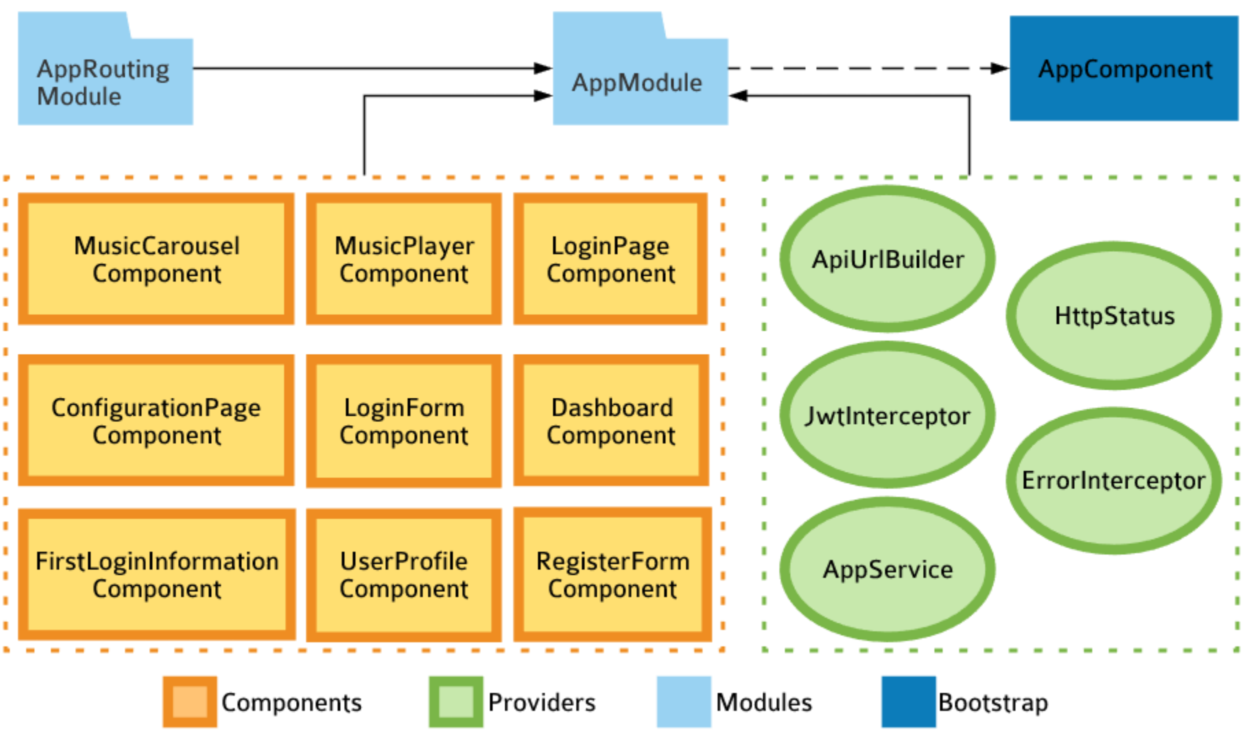

Figure 4.14 Module diagram

AppModule is the root module of the application, residing in a file named *app.module.ts* and providing the bootstrap mechanism for starting the application. Various modules and providers were included here, to be globally used throughout application.

The *AppRouting* module handles the routing of the application by specifying path patterns which, when matched by the URL, redirects the user corresponding component.

Redirecting is also done using the Angular Router, which enables navigation from one view to a different one.

The simple and extremely user-friendly UI of the application was created using technologies like jQuery, Bootstrap and Angular Material. jQuery is a JavaScript library which provides an easy-to-use API for document manipulation, event handling and animation. Bootstrap is a framework which includes HTML and CSS based design templates for creating responsive applications. Angular Material provides a set of responsive, modern, well-tested and accessible UI components based on the Google's Material Design Specification.

The application is composed of various reusable components. The *LoginPage* component handles first page seen by the user. It uses the *LoginForm* and the *RegisterForm* components and it handles the sign in process. The fields of the two forms are validated using Angular Validation. The Dashboard component represents the main page of the application and contains a *ConfigurationPage* component and a *MusicCarouselComponent*, only one of them being displayed at a time. The *ConfigurationPage* component handles the image selection functionality. It allows the user to select or drag-and-drop a local image and to take a picture using the webcam, if it is available. The *MusicCarousel* component is used for displaying the recommended tracks in a user-friendly manner. Songs are displayed in a carousel, using Angular2-Carousel with album images as items, allowing the user to change them by clicking on a different slide, dragging the entire carousel and using the arrow keys. This component includes a *MusicPlayer* component which is used for playing and controlling the audio in the page. It uses the YouTube Player API and allows the user to play and pause the song, seek to a specific moment and adjust volume by dragging and clicking on the corresponding bars, and to loop the currently playing song. The *UserProfile* component allows the user to change update profile information such as username and email and also to select favorite genres and artists. As the seeds are vital to the process, the *FirstLoginInformation* component is only displayed after the first log in and compels the user to select at least one artist or genre.

There are some specific modules that are shared by the other modules called providers. The *AppService* provider is responsible for making HTTP requests to the server by using the enpoints returned by the *ApiUrlBuilder* provider. The *ErrorInterceptor* intercepts all failed requests and displays the returned error by using a *SnackBar*. Different error codes and messages are sent from the server, for differentiating the cause of the error. The *JWTInterceptor* provider is used in the authentication process.

4.3.4 Authentication

The authentication process is done using the JSON Web Token approach. JWT is an open standard which defines a self-contained and compact way for transmitting information between client and server as a JSON object in a secure manner. The token encapsulates information as claims and can be trusted and verified because it is digitally signed using an encryption method. [15]

The process starts with the user introducing its username and password to log in to the application. These credentials are then sent to the server which validates their correctness by matching them with the information stored in the database. The password must be encrypted before this validation as it is stored in an encrypted form. The encryption is done using AES, which is part of the *System.Security.Cryptography* namespace of the .NET framework.

If the user credentials are correct, a JWT is generated and returned to the client. The token contains the id, name and email of the user stored as claims, an expiration time and it is signed using the HMAC algorithm. The client receives the token as stores it together with the user information in the local storage. Thus, all the components have access to the information of the currently logged in used. Once the user is logged in, all requests to the server must include the provided token. This is implemented with the use of an interceptor. The JWTInterceptor provider intercepts all requests and inserts the token in their header in the following format: *Authorization: Bearer <token>*. On the server side, authentication was implemented using an attribute applied over all controllers. When an endpoint is accessed, the request must pass through an authorization filter first. This filter verifies the integrity and correctness of the token and creates and creates an IPrinciple object storing the information of the user and being used in the Business Layer.

5. Usage Flow

The purpose of the following chapter is to present a complete step by step guide to using the application. Everything starts from the login page which is the first view that the user will encounter. A new user will have to create a new account by providing a username, an email address and a password.

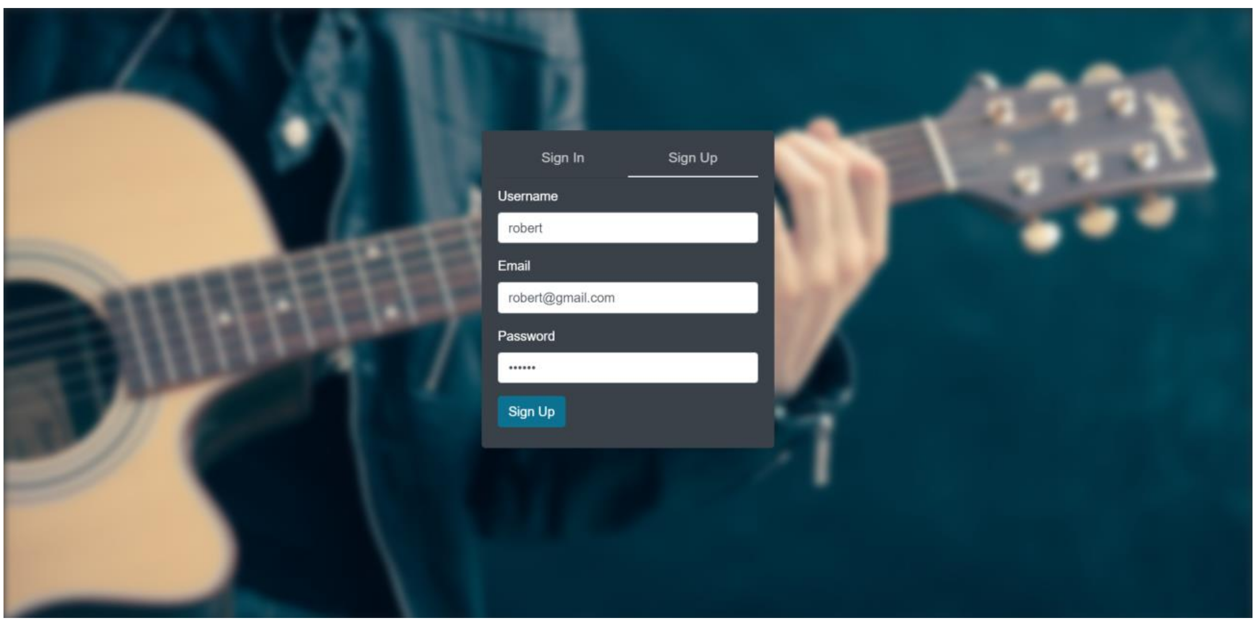

Figure 5.1 Authentication page

If the user is an existing one, it can use its previously created credentials to log in to the application. If the credentials do not have a valid form or are incorrect, an error message will be displayed at the top of the page.

After the login process, the user will come across a different view for selecting its musical preferences. The main panel from the page is divided into two sections: genres and artists. For the first section, the user can select its favorite musical genres from the presented ones, by checking the boxes placed in front of their title. Clicking on a checked box will unselect the genre. The second section allows the user to select up to 125 favorite artists. This is done by typing the name of the artist in the search control and selecting the preferred option from the ones that are displayed. Each selected artist will appear under the search control, next to an icon used for the remove operation.

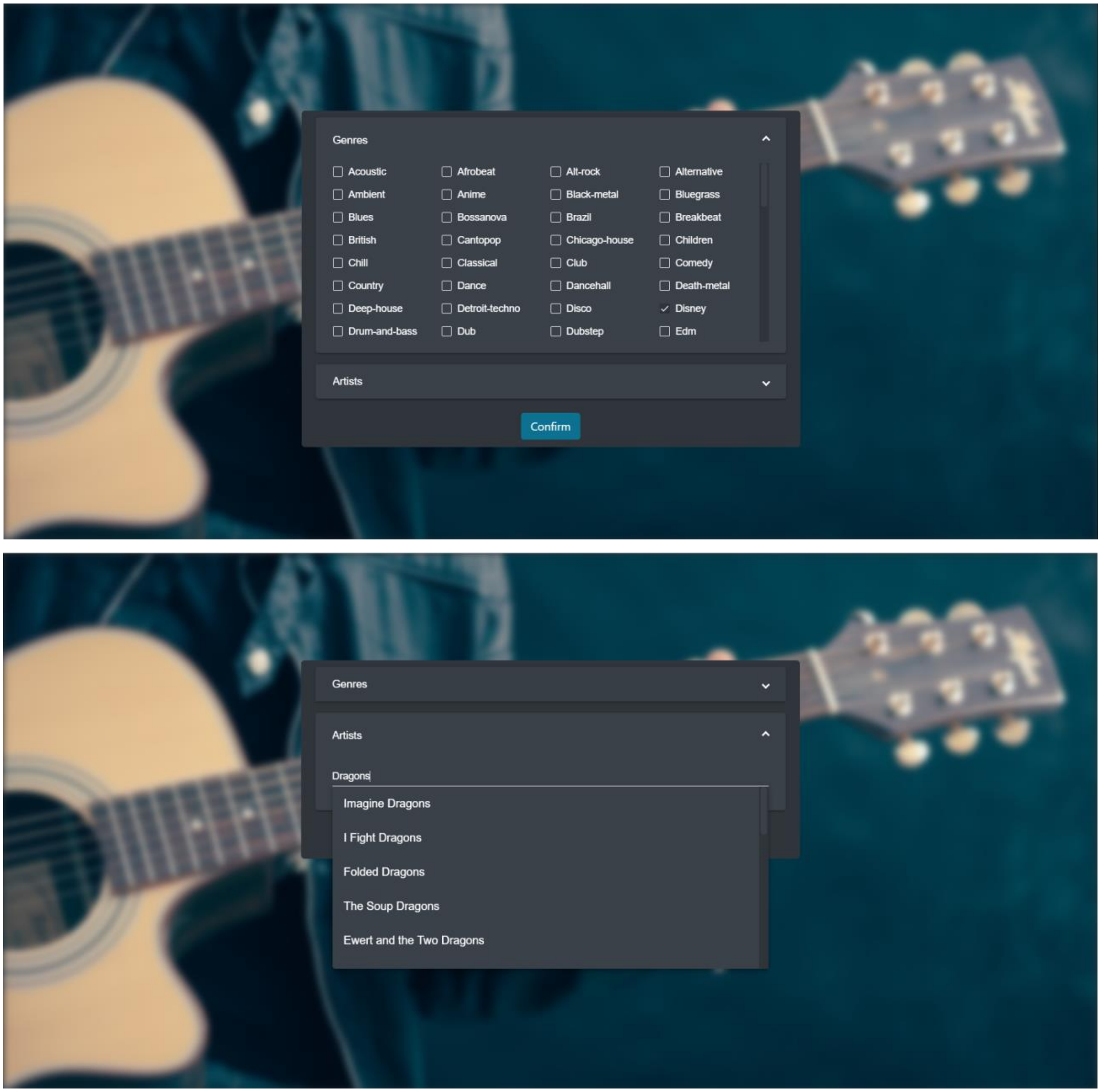

Figure 5.2 Preference selection page

After selecting its musical preferences and clicking on the *Confirm* button, the user is redirected to the main page of the application. Here, it has the possibility to provide an image that will be used in the emotion recognition process. A locally stored image can be uploaded by clicking on the *Add Image* button or by dragging the image and dropping it over the specified area. Also, for simplicity and rapidity, the user can take a webcam picture by clicking on the *Use webcam* button. If no available webcams are discovered, the button will not be visible. If the user is not satisfied with the uploaded image, it can remove it by clicking the button situated in the top-right corner of the image.

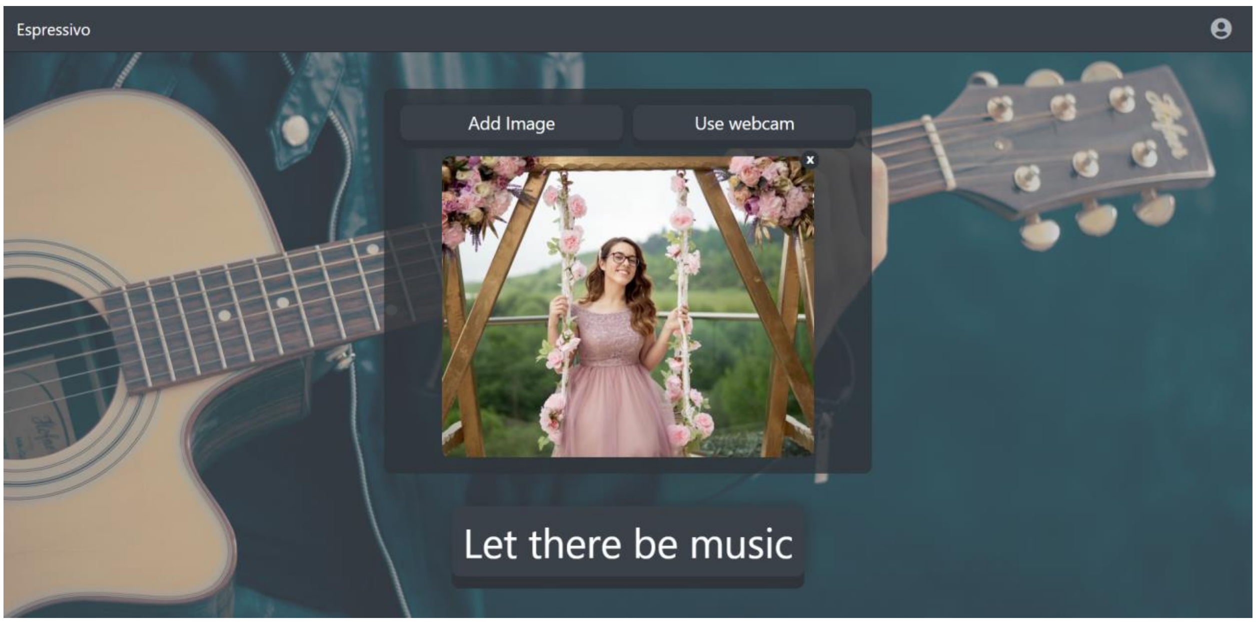

Figure 5.3 Image selection page

By providing an image and clicking on the *Let there be music* button, the user will see the musical player that has been created. The recognized emotion from the image will be displayed in the center of the navigation bar, at the top of the page. The button situated in the top-right corner of the screen offers the possibility of updating profile information and preferences and signing out of the account. The user can control the music player by dragging the slides, using the arrow keys and also by using the available audio controls that are displayed. There are controls for changing the volume, pausing and playing the current song, seeking to a specific moment in it and also playing the next or previous song. When a song has finished, the player will automatically play the next song in the playlist. For avoiding this, the user has the option to loop the current song. The user can click on the arrow situated in the top-left corner of the screen to return to the previous page.

Figure 5.4 Main page

6. Conclusions and Future Work

Music plays a central role in human existence, crossing all race, cultural and nationality boundaries. Creating music and responding to it are two universal features of our world. Moreover, it is highly probable that its ability to develop social relationships has been incredibly important to pre-modern human survival. The past decade has witnessed an explosion in research activities involving the strong relation between music and emotions in the field of neurology, musicology and psychology. Both have played a crucial role in the evolutionary process, helping humans learn about the brain and the development of the cognitive attributes, closely linked to it. The capability of music to transmit emotions particular to an individual but felt by all, suggests that is has been created as a way of understanding feelings, especially in the midst of social uncertainty.

Being a music recommendation application, Espressivo is much more than a regular music player. What makes it different is its underlying concept, which is based on this strong relation between music and emotions. The application combines modern API's to create a simple concept with tremendous benefits. Its intended purpose is to counteract negative effects like stress, anxiety and frustration, which appear as a result of spending a lot of time in front of a computer or any other device. Moreover, it provides an efficient method for improving creativity, productivity, memory and for helping in the relaxation process.

The modular architecture of the application allows its functionality to be easily extended without altering any of the existing properties. One of the possible improvements would be the integration of a musical preference system based on artificial intelligence and machine learning for increasing accuracy. Also, image recognition can be substituted by video recognition for providing musical recommendations in real time.

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