

Automatic Mood Classification for Music

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requirements for the degree of Master of Arts

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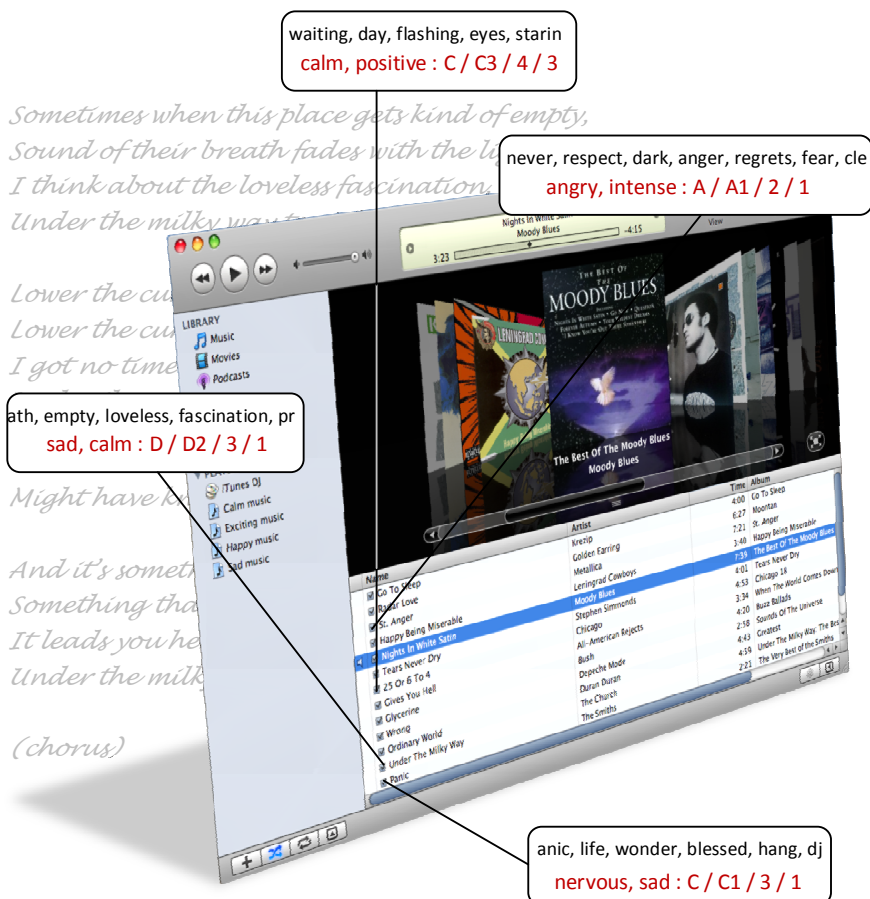
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Preface

This Master's Thesis concludes my studies in Human Aspects of Information Technology (HAIT) at Tilburg University. It describes the development, implementation, and analysis of an automatic mood classifier for music.

I would like to thank those who have contributed to and supported the contents of the thesis. Special thanks goes to my supervisor Menno van Zaanen for his dedication and support during the entire process of getting started up to the final results. Moreover, I would like to express my appreciation to Fredrik Mjelle for providing the user-tagged instances exported out of the MOODY database, which was used as the dataset for the experiments.

Furthermore, I would like to thank Toine Bogers for pointing me out useful website links regarding music mood classification and sending me papers with citations and references. I would also like to thank Michael Voong for sending me his papers on music mood classification research, Jaap van den Herik for his support and structuring of my writing and thinking. I would like to recognise Eric Postma and Marieke van Erp for their time assessing the thesis as members of the examination committee. Finally, I would like to express my gratitude to my family for their enduring support.

Pieter Kaners

Tilburg, June 2009

Abstract

This research presents the outcomes of research into using the lingual part of music for building an automatic mood classification system. Using a database consisting of extracted lyrics and user-tagged mood attachments, we built a classifier based on machine learning techniques. By testing the classification system on various mood frameworks (or dimensions) we examined to what extent it is possible to attach mood tags automatically to songs based on lyrics only. Furthermore, we examined to what extent the linguistic part of music revealed adequate information for assigning a mood category and which aspects of mood can be classified best.

Our results show that the use of term frequencies and $tf*idf$ values provide a valuable source of information for automatic mood classifications for music, based on lyrics solely. The experiments in this thesis show that the information extracted from the linguistic aspect of music provides sufficient information to the system for an automatic classification of mood for music tracks. Furthermore, our results show that mood prediction on the arousal/energy aspect of mood are the best ones to arrive at a good classification, although predictions on other aspects of mood such as valence/tension and combinations of aspects lead to almost equal accuracy values for the performances of the classification system.

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1. Introduction

This section covers a brief introduction to the field of music. A historical overview is given to obtain some insight into the transition from analog to digital recording, i.e. the early beginnings of music and the changes through the decades towards the music business nowadays. Section 1.1 describes the ancient beginnings of music, which is continued by fitting a theoretical description of the transitions to digital music in section 1.2. At the end of this chapter, the current developments in digital music are discussed.

1.1 Analog music: a look in the past

We will first take a brief look at events in the history of music. We discuss the beginnings of music in section 1.1.1, changes in use of language and music are discussed in section 1.1.2, and section 1.1.3 describes the changes in storage of music up to the twentieth century.

1.1.1 The beginnings of music

As long as human beings have been communicating with each other, music has existed. Kunej & Turk (2000) state that “there is no doubt that the beginnings of music extend back into the Paleolithic, many tens of thousands of years into the past.”

In the beginning music was not more than vocal sounds made to communicate with each other (Kunej & Turk, 2000). The usage of musical instruments such as the flute together with primal screams and other vocal sounds were the first means people used to communicate. Later these squeeks, screams, and shouts changed to vocal pronounciations: the beginnings of human language. As language developed, so did music: words, evolved out of the ancient screams, were wrapped in a melodious way.

Music can be a tool for people to communicate with each other, consisting of messages wrapped in a melodious and rhythmic manner. Like talking or writing it contains information which can be sent to the addressee, in case of music to the listener. The communicative use of music, for example to inform or entertain, changed over time.

1.1.2 Changes in the use of language and music

During the middle ages music was used to send messages over a longer distance, for instance, by troubadours remembering and reproducing stories on long journeys. The so-called troubadour song held a message, and by using rhyme and melody it was easy to remember.

It is common knowledge that language as a communication tool has changed over time, for example by changes in dialects or by adding and fading out words in the vocabulary. For music, the same holds true. At first, each musical appearance was unique, unrecorded, and used purely for communicative senses. Later on it changed to mass reproduction and entertainment. So, in retrospect we conclude that language changed and therefore the music.

1.1.3 Changes in storage

Since the 19th century the way music was stored has changed considerably. Before the 19th century there was no actual music storage at all: the music played and sung could not be recorded and storage could only take place in the mind. In order to let more people hear it, it had to be physically played over and again.

With the invention of the phonograph in the 1860s, people could record music and replay it at a later time and a different location. In the 20th century the gramophone, and the invention of the cassette tape thereafter, made music more accessible to the mass. A stimulus to this development was the improved recording quality and the more portable players. The changes in storage had many ramifications. The cassette initiated an era in which people could record music themselves, which was not possible with the phonograph and the gramophone.

1.2 Digital music: a brief overview

In the twentieth century the way music was stored changed from the analogue mode to the digital music recording. After the invention of the compact disk, digital music storage became widespread and music distribution changed.

1.2.1 Invention of the compact disk

In 1980, the Dutch electronics company Philips started manufacturing the compact disk. It was invented and further developed by the Philips NatLab in Eindhoven, the Netherlands. It was one of the first approaches to digital music recording. Whereas systems prior to 1980 recorded in analogue mode, the compact disk stored the music digitally. In the analogue mode, the peaks and valleys grooved in the record are converted by electronical impulses to reproduce the analogue music waves. In the digital recording mode, the music is converted into binary code (Philips Research, 2008).

With digital recording many copies can be made while keeping the same sound quality of the original source recording. In contrast to the compact disk, copies on magnetic tapes or vinyl recordings suffer from a considerable loss of sound quality. The compact disk has blurred the boundary between the concepts of 'original' and copy for music recording, as every copy of a recording on a compact disk has an equal sound quality and the original source can not be distinguished from the

copies. Moreover, the compact disk has additional advantages, namely (1) records on tape can be damaged or erased more easily by magnets, and (2) vinyl recordings can be warped or scratched which impacts sound quality.

The launch of the compact disk led to a spectacular leap in pre-recorded music sales. There was a relative short period of transition from analog to digital music. In 1996 nearly three-quarters of Dutch households owned a CD player and an average of 65 CDs each, while ten years earlier the percentage was just 5% (Hansman, Mulder & Verhoeff, 1999).

1.2.2 The MPEG-1 Layer 3 format

In addition to the digital compact disk format, in 1992 a new digital music format was introduced: the MPEG-1 Layer 3 (now called: MP3) format. It was based on digital storage, and used a new compression technique. The technique was perfectly suitable for storage on personal computer harddrives. Recording on sources with interchangeable media such as compact disks now became less popular. In contrast to songs on pre-recorded compact disks which cannot be removed or changed, MP3 files can be erased from the computer's harddisk and new recordings can be made immediately. Properties of MP3 files, for instance, the filename or the enclosed ID3-tag, can also be modified (see section 2.1.1).

1.2.3 Digitalisation through the world wide web

In the 1990s multimedia became more common. All multimedia resources became digitised with the rise of the World Wide Web only a few years later. The World Wide Web is a layer on the Internet, first developed in 1989. The Internet started as ARPANET in the 1960s, a network of military devices and computers communicating with each other. Later this network expanded and resulted in what we now call the Internet. It links personal computers together, enabling communication of files. Afterwards the World Wide Web, the graphical shell, was developed, and multimedia was linked together.

For instance, on the World Wide Web music tracks were shared, which made the MP3 format popular due to the compressed size of the files. MP3 became widespread by 1996 and quickly took hold among active music fans (Haring, 2000).

1.2.4 Improved music distribution

A legal experiment occurred in the form of NAPSTER's peer-to-peer sharing network, where users could find and download songs for free. The files were not stored on the server, instead NAPSTER linked computers and enabled download and share of music files from one computer (peer) to another through a user-friendly interface. Moreover, this decentralized way boosted the music

sharing and enabled sharing files in other formats, such as video and later on electronic books (Haring, 2000).

Shortly thereafter, digital music was distributed by online music services such as ITUNES¹ and Beatport², where the music listener pays for a non-tangible product: the digital download. Mc Hugh (2003) stated that “the maturing distributed file sharing technology implemented by Napster has first enabled the dissemination of musical content in digital form, permitting customers to retrieve stored music files from around the world.”

1.2.5 Current music development

The use of music and distribution of it is still developing. Celma & Lamere (2007) state that we have seen an incredible transformation in the music world by the transition from albums and compact disks to individual MP3s and mixes. Together with online music services we see collections of several million songs on the Internet. The experiences of Pirate Bay³, a website used by millions to exchange movies and music, are an example of the current technological developments and the legal reactions on this development by the intellectual property right holders. Four men behind this Swedish file-sharing website have been found guilty of collaborating to violate copyright law in a landmark court verdict in Stockholm (Curry & Mackay, 2009).

On the one hand music has had a pushed approach for centuries: one had to listen to the music being served. For instance, at marches, meetings and events the audience had no control over what music was being played and listeners requesting tracks at radio stations had only marginal influences on the playlists.

On the other hand nowadays you can listen to music that you want to hear and react on that kind of music through the Internet: the pull-method. The one-way approach mentioned above, where listeners had hardly any influence on music playlists, changed to some kind of control by the listener throughout the last decades. Inventions such as the gramophone, cassette, compact disk, and portable music players made the user select the tracks being played. The modern digital world with internet, digital music, and collective sharing created a platform where everybody can export playlists, radio streams, and music preferences.

In a growing world of online music stores, digital sounds, collaborative listening, and musical interactions, it is important to have an efficient organisation of the music itself. In terms of search and retrieval methods it is essential to have an organised library with music that can be classified in different ways, such as tempo, genre, age, or mood. Due to the fact that the World Wide Web is growing fast, increasingly more data becomes available daily. This development requires an efficient organisation in order to let users find the information they are looking for. At the same time the enlarging databases provide us with more information we can use to organise our own files.

¹ <http://www.apple.com/itunes>

² <http://www.beatport.com>

³ <http://piratebay.org>

2. Motivation

Many aspects of the music itself (such as lyrics, genre, key or era) are shared on the Internet. They are available to other users. The following three issues have advantages for music information retrieval: (1) the added value of correctly assigning properties to music, (2) ordering the properties and (3) sharing the content on the web. Section 2.1 describes the properties and organisation of music collections. Thereafter the aim of this thesis is stated in section 2.2 with a problem statement, two research questions and a thesis outline.

2.1 Organisation of music collections

This section treats the assignment of correct properties for music tracks, access and retrieval of music collections and recommendation systems. Subsection 2.1.1 describes the assignment of properties to music tracks. The access and retrieval of files in music collections is discussed in subsection 2.1.2. In subsection 2.1.3 music recommendation systems, Web 2.0 involvement and tagging of music is described.

2.1.1 Assigning properties to music tracks

Digital music can hold information such as artist, track name, year, and album in the source, in the form of ID3-tags. These tags are metadata in the MP3-file, telling the audio software on the computer the characteristics of the file (for instance, title, artist, length, format, audio codec, and genre).

When ID3 was introduced in 1996 for use with the MP3 format, it could only store a limited number of bytes with selected information per field (artist, year, publisher, etc.) as metadata, and it was not compatible with international tokens. It soon was called ID3v1. After the implementation of ID3v2, a new version storing information in a variable number of dimensions, the metadata was stored in the beginning of the audio file. It featured additions, such as a comment field and fields for website links and cover art. The ID3v2-tag lyrics can also store lyrics. They can be used to let the audio program inform the listeners on the lyrics of the music track to which the user is listening.

ID3-tags can be imported into the computer and then assigned to the relevant music tracks. The properties are read automatically from the metadata on the compact disk without human intervention. Moreover, automatically downloading properties for music tracks from online libraries can be handled by audio software.

If no tags are given, properties can be found or searched for on the Internet by the user. For instance, this may happen in online music databases such as Discogs⁴, Allmusic⁵ or Last.fm. So, at times, the tags will be found automatically provided that they are enclosed in the source.

⁴ <http://www.discogs.com>

⁵ <http://www.allmusic.com>

Otherwise, the user can obtain the information by searching through the Internet manually. In many other cases the information can be found in an automatic manner via tailor made applications.

2.1.2 Music collections: access and retrieval

Playlists and music collections have to be organised in the best possible way in order to find the relevant information effectively. Preferably, the search process is based on a wide variety of properties. By correctly assigning properties to the music, the categorisation, access and ordering of the files can be done in a more natural, straightforward way. For instance, books in physical libraries have been arranged on keywords (comparable with tags), genre or era. Organising digital music files will be done at the same way, i.e. natural and effective for people.

However, the final arrangement in a physical library, based on keyword, is static. When someone wants to see an overview of books written by the same author and afterwards the range of books written in a particular genre or era, the person has to re-organise the collection dynamically.

Compared to the organisation of information in a library, digital files can be easily re-arranged to other classes or categories; for instance, files sorted on genre criteria can be re-arranged according to another category, based on artist or year. The indexes can be built in case they are needed. This can be done by selecting different criteria such as filenames, key metadata or tags. Therefore the indexes are changeable for other points of view, or as Andric & Haus (2006) state: "The music collections of today are more flexible. Namely, their contents can be listened to in any order or combination –one just has to make a playlist of desired music pieces."

"Today's music listener faces a myriad of obstacles when trying to find suitable music for a specific context" (Meyers, 2007). As the multimedia content is growing, and digital music libraries are expanding at an exponential rate, it is important to secure effective information access and retrieval. Meyers (2007) also states that "the need for innovative and novel music classification and retrieval tools is becoming more and more apparent".

Finding an efficient, straightforward and hierarchical organisation with access to an increasing amount of data and files (in this case music tracks) is a challenging problem. When browsing or searching through the huge database of songs of an individual music listener, new tools are essential to meet the user's requirements on the file management level.

By using new classification and retrieval tools, music listeners will see relevant output by these tools that meet their requests. For instance, a proper playlist may be built or the organisation of the music collection based on genre or key is presented in time for an interesting audience. Music listeners require new ways to access their music collection, such as alternative classification taxonomies and playlist generation tools (Meyers, 2007).

2.1.3 Recommendation and tagging of music

A relatively new field of exploring music is defined by online recommendation systems, such as Last.fm⁶ and Pandora⁷. They let the user discover new music based on similar characteristics to the music currently owned by the user. These systems provide recommendations for music listeners, helping them to discover new music (cf. Celma & Lamere, 2007).

Pandora provides music recommendations based on human analysis of musical content, with features such as vocal harmonies and rhythm syncopation. Recommendations on Last.fm are based on social tagging of music (see section 3.4.2). This is considered as a valuable resource for music information retrieval and music classification (Meyers, 2007). Online music recommendations are briefly discussed in section 3.6.

Moreover, online recommendation and social tagging are characteristics of Web 2.0, a term which describes the increase of interactivity on the World Wide Web. Web 2.0 is seen as a new stage where users interact with each other through collaboration on web content (Oreilly, 2007). Search engine optimisation, social tagging and interactive web applications are examples of this concept.

Because of new possibilities and techniques in the digital era, communication takes place in new fields, especially in the Web 2.0 environment. People will offer, find, and interact with online music content. They communicate in a new way by reacting on the online content, for instance, via tagging or comments, or by offering information of personal music tastes. Social tagging (see section 3.4), and active sharing of multimedia content, put the communicative meaning of music to a new level.

2.2 Problem statement and research questions

In this section we describe the aim of the thesis, viz. automatic assignments of mood-based tags of songs in a database. To reach this aim we deal with a formalized problem statement in subsection 2.2.1. Two research questions (RQ1 and RQ2) are introduced thereafter in subsections 2.2.2 and 2.2.3 respectively. Finally, a deliverable is described in subsection 2.2.4.

2.2.1 Problem statement

Music can be classified in many different ways: genre, timbre, tempo, artist, trackname, year, loudness, and so on. Much research has been done in the context of music classification techniques (Liu, Lu & Zhang, 2003; Meyers, 2007; Yang, 2007). Classification on several musical aspects gives efficient organisation outcomes on those characteristics. The classifications can help to organise the music tracks in the way that is preferred by the user. One particular type of classification, the one we are going to look at here, is mood classification, also referred to as music emotion classification (Yang et al., 2007).

⁶ <http://www.last.fm>

⁷ <http://www.pandora.com>

Main Goal

The main goal of this research is the automatic assignment of mood-based tags for songs in a users' music database. We want to let a system tag the moods for music, based on lyrics. Although much research is performed on music emotion classification based on musical aspects such as key, timbre and genre, there is no specific focus on music mood classification that is based solely on the linguistic part of music. Therefore we look at the language level of music: using the lyrics and leaving out other musical aspects such as timbre, key or instrumental parts. We express the research idea in figure 1, where five aspects are given.

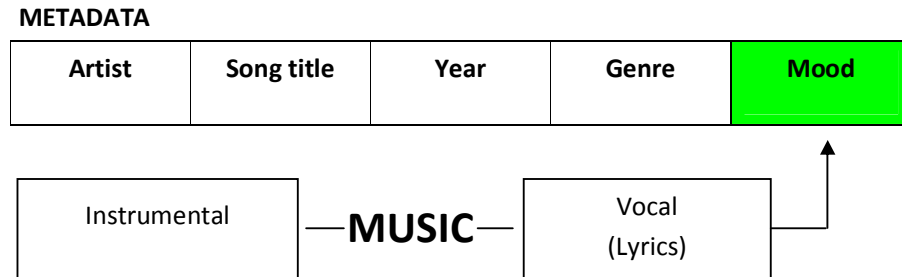


Figure 1: Expression of our research idea: using the linguistic part of music for mood categorisation.

The only metadata being used for mood classification in this thesis is the lyrical data. Mood is a dimension, but also a kind of metadata of music besides other aspects such as song title or genre, (see again in figure 1).

Problem Statement

We concentrate on the lyrical part, which we assume can express the mood. Given this motivation, we introduce our problem statement. Our formalized problem statement reads:

To what extent is it possible to attach mood tags to songs based on lyrics automatically?

We are using the lingual part of music, because it is relatively easy to collect, and we know that text can transfer emotions (see section 3.2). We would like to design a system that will tag music tracks automatically, in order to reduce the time consuming manual tagging of individual songs by users.

2.2.2 Research question 1

From the above reasoning and our main goal, a first research question is stated as follows:

RQ1: In how far can the linguistic part of music reveal sufficient information for categorising music into moods?

In this thesis we only take hold of the lyrical part of music. Our aim is to see whether the lyrical part of music can provide sufficient information to tag music tracks. Although the other kinds of musical information can also help with expressing or revealing a certain mood or state of emotion, this type of information is not taken into consideration in this thesis but it can be done so in future work (see section 8.2).

2.2.3 Research question 2

Moods can be categorised in several ways. In this thesis we are using four different mood categorisations: the Arousal, Moody, Valence and Thayer divisions (see section 3.7.2). Given this differentiation, we state a second research question.

RQ2: What aspects of mood can be classified best based on lyrics alone and with what granularity?

The answer to this question can lead to the mood categorisation that gives the best classification values, based on the properties of mood which determine the partitioning.

2.2.4 A preferred deliverable

The final stage in this research is the development of a music mood assignment system which automatically assigns a mood to a song after analysing the lyrics. With this process the user does not have to tag the whole music database on the computer manually, as it will be generated automatically for all songs. Furthermore, creating playlists based on moods can be done automatically and shared on the Internet for collaborative listening.

2.3 Research methodology

In order to design a system that tags music based on moods automatically, we study the field of machine learning. By using (1) machine learning techniques with features extracted out of a dataset and (2) suitable evaluation techniques, the goal of this thesis can be approached. The research questions and the problem statement will guide our research.

To achieve the aim of this thesis and find answers to the research questions, a theoretical background in the research area of music emotion classification has to be agreed upon.

Possibly, there are many perspectives. After performing a literature survey in respectively chapters 3 and 4, we will choose our research approach and start collecting data in order to set up the experiments. With the experimental data consisting of plain text, analysis of the lyrics can be done in an easy and effective manner. Several scripts and programs have to be built up in chapter 5.

In order to extract information from the collected lyrics, two stages of viz. (1) cleaning up the text and (2) extracting features have to be performed. An overview of the several steps of machine learning and classification techniques, will help to set up the experiments in chapter 5.

Test- and training rounds using a system based on machine learning techniques in chapter 6 should give results with answers on the research questions in chapter 7. A final conclusion can take place afterwards in chapter 8.

The research methodology is stated as follows:

- Reviewing the literature → chapters 3 and 4
- Implementation and deriving the experiments → chapter 5
- Performing the experiments → chapter 6
- Analysing the results → chapter 7
- Evaluating and answering research question 1 and research question 2 → chapter 7
- Evaluating and answering the problem statement / thesis conclusion → chapter 8

2.4 Thesis outline

In this chapter, it was made clear why new classification techniques for music are subject to research. The idea of automatically classifying music tracks based on moods by exploring the linguistic part, was formalized by a problem statement and two research questions. These questions form the basic outline of the research reported in this thesis.

The outline of this thesis is as follows. An introduction describing the beginnings of music and the transition from analogue to digital recording are the subject of chapter 1. Chapter 2 deals with the motivation and implementation of a problem statement and two research questions. In chapter 3 the scientific background is discussed. It forms a step to the implementation of the research design background. Chapter 4 deals with (1) the description of classification techniques, (2) the use of frameworks and (3) the approach of fulfilling the aim of this thesis. In chapter 5, the approach used to process the data is described. Access and preprocessing on the data are discussed, and the actual classification tests are prepared. The actual experiments and tests with their results are the subject of chapter 6. Chapter 7 continues with an evaluation of the results in the experimental environment. The conclusions and discussion topics are presented in chapter 8.

3. Scientific background

As this thesis builds on mood categorisation of music, first the distinction between moods and emotions is discussed in section 3.1. In sections 3.2 the following step, the overlap of human language and moods, is described. Then section 3.3 describes the overlap of human language and music (lyrics). Section 3.4 focusses on mood tagging for music tracks, and section 3.5 gives a summary on creating playlists based on characteristics such as mood tags. Star rating, one approach to music categorisation is discussed in section 3.6. Furthermore, the field of music recommendation is cited. Finally, section 3.7 reviews the addition of images and colours to music tracks and the description of a mood-tag application called MOODY.

3.1 Human moods and emotions

Human beings are continuously being exposed to emotions and moods. A mood is a kind of internal subjective state in a person's mind, which can hold for hours or days. The American psychologist Robert E. Thayer (1982) has done research on moods and the behaviour of humans regarding to moods.

According to results in his research, mood is a relatively long lasting, affective or emotional state. In contrast to an emotion, its duration takes place over a longer period of time and individual events or stimuli do not have a direct effect in changing a mood. Where emotions, such as fear or surprise, can change over a short period of time, mostly by a particular cause or event, moods tend to last longer.

Siemer (2005) states that moods, in contrary to emotions, are not being directed at a specific object. "When one has the emotion of sadness, one is normally sad about a specific state of affairs, such as an irrevocable personal loss. In contrast, if one is in a sad mood, one is not sad about anything specific, but sad "about nothing (in particular)"."

In addition, Robbins & Judge (2008) state that emotions are intense feelings that are directed at someone or something, whereas moods are feelings that tend to be less intense than emotions and lack a contextual stimulus. Both emotions and moods are elements of affect: a broad range of emotions that people experience.

To distinguish the use of moods instead of emotions in this thesis, we assume that an emotion is a part of the mood. Several emotions can occur in a mood, which is the global feeling. In this thesis we look at music tracks. Music tracks have an overlaying feeling in the form of a mood, with several emotions which can change during the musical periods (see section 3.4).

Thayer's arousal-valence emotion plane

Thayer (1982) claims that a mood contains elements of two dimensions: energy and tension. On the arousal-valence emotion plane that Thayer developed, the model of mood displays a 4-level emotion plane with the dimension valence (derived from the tension dimension) on the x-axis and the arousal element (the energy dimension) on the y-axis. Both axes can have a positive (high) and a negative (low) value.

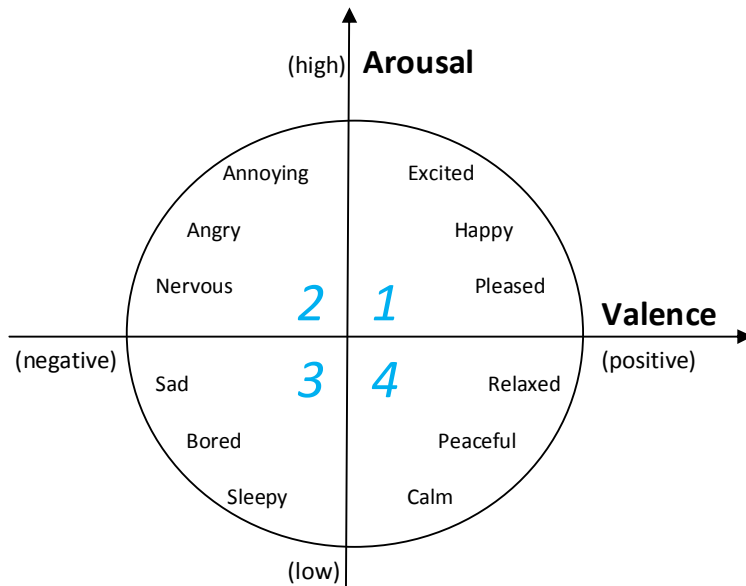


Figure 2. Thayer's arousal-valence emotion plane.

As can be seen in Figure 2 (Yang et al, 2007), Thayer's arousal-valence emotion plane displays several moods in the four different classes. These moods can have a negative valence (the tension dimension), such as the mood "sad" or "angry", or a positive valence representing moods such as "relaxed" or "happy". The arousal element, linked to the energy dimension, on the y-axis distinguishes the different moods from calm and quiet behaviour at the bottom, to intense and powerful at the top of the figure.

3.2 Language and mood

As moods are present in our daily life, people can express certain moods in written and spoken language. Not only vocal communication, but also non-vocal communication like body language and expressions can express moods. Humans tend to extend the way they describe certain things being in a certain mood (Beukeboom & Semin, 2005). A person who is in love for instance, can use bright, happy and joyful words to describe one's mood. Also without describing the mood itself, one can extract a certain mood out of the words used and the meaning attached to it.

Much research has been done on influence of mood on lexical words (Bower, 1981; Chastain et al, 1995; Piercey & Rioux, 2008). It has been proved that mood does affect lexical access, where "it is assumed that when a person is in a particular mood, activation will spread to lexical items that are congruent with their mood" (Piercey & Rioux, 2008).

A mood is based on exclusively subjectively experienced mental events. The definition of moods makes reference to the (presumed) underlying dispositional basis of these mental events (Siemer, 2005). Humans are aware of experiencing a mood, and it can have effect on the language used in conversations and global communication. Therefore the mental state of the speaker can be expressed through speech and language.

Because language can hold emotionally or affectively loaded words through expression by humans, mood categorisation based on the words and attitude of the sender or speaker can be done (Chastain et al, 1995). Conversations, utterances, and attitudes (i.e. reactions on stimuli) produced by a person can be analysed by another person and then classified even though the addressee is not necessarily experiencing the same mood. The language used, with additional body language and expressions, can reveal the mood a person experiences.

Meyers (2007) states that the most common of the categorical approaches to emotion modelling is that of Paul Ekman's basic emotions, which encompasses the emotions of happiness, sadness, anger, fear, surprise and disgust (Ekman 1992). In addition to this categorisation, Thayer's dimensional approach (see section 3.1) can help classify the language used and extract the mood the speaker is experiencing and intending to reveal.

3.3 Language and music (lyrics)

Analogously to the written and spoken communication in daily life, music lyrics can express mood states of the writer. The text contains words and phrases that express moods and emotions. Similar to the way people tend to show characteristics of a certain mood in their communication towards another, so do music tracks. Both instrumental tracks and songs with lyrics can express feelings or emotion.

A musician can have the intention to give a music track a certain feel, with emphasis on a certain mood. Think of a heavy metal artist who wants his track to be listened to as a sad, intense track, or a pop band recording a new track which has to be happy and calm. In order to reach this, the songwriter can put words in the lyrics of the track which tend to characterise that type of mood.

By implementing content in the lyrics such as emotionally loaded sentences and words such "*death*", "*dark*", or "*miserable*" the track can have a sad, intense load. Words like "*fun*", "*joy*", and "*party*" can characterise the text, and furthermore the song, as a happy track in a calm manner.

Emphasizing mood in lyrics

Compared to written natural language, lyrics can also contain lexical items which emphasize a certain mood, items that are activated by the sender (the artist or songwriter) who has the intention of transferring a mood. We assume that the lyrics are the indicators of certain moods, which can be exposed without the musical tracks and musical characteristics, such as tempo, key, and timbre.

In addition, we assume that lyrics alone can express moods, and the instrumental parts emphasize the feelings exposed in the text. Although we mention the instrumental part of music here, we will focus on the linguistic aspects of music.

Although the emphasis in spoken language (the voice, loudness and pitch in the song) may also be important to extract and discover emotional loads, the contents of the words or phrases can have an emotional level without being spoken. For instance, words such as “*happy*” or “*dead*” do not have to be pronounced to have an emotional load.

Where emotionally loaded words and phrases can be used in spoken natural language to emphasize a certain feel or emotion, the same can be done in written language. Emotions and moods can be expressed in texts and from that point it can be used in music by implementing emotionally loaded words and phrases in lyrics.

So the plain lyrics, the text in the song itself, is used for mood categorisation in this thesis. We want to test whether the use of lyrics (or text) provides sufficient information for assigning moods to music tracks in general, and whether the textual aspects in lyrics can be seen as representatives for spoken and written natural language regarding the expression of moods.

3.4 Mood tagging for music tracks

As in daily life moments in time can be categorised by mood. Music tracks have a time spanning appearance which can be seen as a moment or period, where a mood (or field of mood) is felt. Koopman & Davis (2001) state that the musical period is a continuous time with a same mood which is assumed to be there for the whole track, and music presents a continuous process itself. “People do not merely perceive a succession of patterns in music; we experience musical parts as being connected parts packed into a dynamic whole.”

A musical track has a stated play time, the track has one mood which characterises the whole track. Therefore we assume that a song has exactly one mood. This forms the base for the description in subsection 3.4.1, where the assumption of one mood for a song is explained. The concept of social tagging is discussed in subsection 3.4.2.

3.4.1 Different events, one mood

People can have different emotions at a time but are experiencing a certain mood. For instance, when someone is in a sad mood, someone can be angry for a moment or feeling happy when reacting on a particular event, i.e. receiving a present. Although the emotions are present for a short period of time, the overall mood remains the same. This is also noticeable in music: a song is based on parts with a mood which can be attached to the whole track in general. Although an artist can sing about a person who felt happy in the past in a sad song (i.e. the chorus), the overall mood of the song remains sad. Therefore a music track has several emotions which are being linked together into a whole track, which tends to have one certain mood.

Because these moods are related to the way a song is played, together with the affective parts in the lyrical content and present in a stated period (i.e. the individual track or the whole playlist on the album with the same classified mood), people can specify a mood the same way they tend to feel a mood period in daily life (Liu et al., 2003). Therefore mood tagging for music tracks can be a powerful tool to mirror daily emotions in music preferences. Mood tagging and tagging in general is a relatively new way of expressing one's feelings or thoughts.

3.4.2 Social tagging

According to Tonkin (2008), "social tagging, which is also known as collaborative tagging, social classification, and social indexing, allows ordinary users to assign keywords, or tags, to items." Tagging is the process of assigning keywords to (mostly digital) items such as photos, folders, documents, video or music. It is a form of indexing, in which the user attaches keywords which are typically freely chosen instead of used from a controlled vocabulary.

Social tagging is the collaboratively describing and classifying of items, which results in an item taxonomy called '*folksonomy*', a portmanteau of folk and taxonomy (Vander Wal, 2005). The count of tags for an item can differ from one (global) tag, for instance, "*nature*" for a photo of a forest, to tens of keywords, for example on a graduation photo with all names of the persons, date, time, place and so on. As there is no controlled vocabulary, any term may be used and any number of terms may be used on a particular item.

Social tagging taxonomies are subdivided into broad folksonomies and narrow folksonomies. Where many people tag the same objects with their own tags in a broad folksonomy (i.e. music tagging on Last.fm), a narrow folksonomy consists of many people tagging their own objects with their own tags, such as Flickr⁸ for online photos or YouTube⁹ for videos.

Tags attached to items can be made visible for everyone on the web. Tagging digital items such as music tracks (i.e. genre, year, artist, album) helps ordering files, and lets other users take over information and interests.

3.5 Creating playlists

Because we identify with music, it can affect us in a powerful way (Koopman & Davies, 2001). We tend to be attracted to listen to music compilations that match our current mood, or to listen to music that has the preferred emotional level and/or the opposite (desired) mood of the one we are in at the time of listening. One way of listening to music with regard to emotional levels is the generation of mood-based playlists, which is described in subsection 3.5.1. Reasons for creating music playlists is discussed in subsection 3.5.2, and 3.5.3 deals with automatic playlist generation.

⁸ <http://www.flickr.com>

⁹ <http://www.youtube.com>

3.5.1 Mood-based music playlists

Although mood classifications can differ from person to person, music tracks will almost have the same emotional meaning or load in a certain mood field. As stated in subsection 3.4.3, people can specify a mood the same way they tend to feel a mood period in daily life (Liu et al, 2003). People tend to organise music tracks in particular classifications, of which one can be personal mood favors. The organisation of music tracks based on moods is one example of playlist creation.

The final result of creating mood playlists will end up in a list of tracks that have been tagged the same mood. These playlists can add value to the current mood of the user or can change the mood in the most bright insight. For instance, when someone is feeling sad, listening to a music playlist with excited/happy mood classified tracks can help changing the persons' mood over time.

Even without proper mood tags for music as introduced here, people are creating playlists based on moods. Studies by Voong & Beale (2007) show that "many choose to create playlists grouped by mood, for example, by naming a playlist "relaxing"."

3.5.2 Reasons for creating playlists

People share their playlists in order to exchange favours and interests in certain types of music. Exchange of music among the people was always an important social interaction, but with the large collections of MP3 music it became much more intensive than ever (Andric & Haus, 2006). Not only the sharing of music interests makes creating playlists popular, also the individual music needs in certain contexts affects the decision to create personal playlists.

Andric & Haus (2006) state that "many social contexts, like for example, working place, or driving a car, do not allow for wasting too much time on choosing music. On the other side, the relaxing role of music, and the intensified need for leisure and idleness in the relaxing moments, lower the will for making intellectual effort for selection of appropriate musical contents."

Pauws & Eggen (2002) state that "current music players allow playing a personally created temporal sequence of songs in one go, once the playlist or program has been created". After a playlist has been created, someone can play the sequence of songs again for personal purposes, or for sharing with other people.

However, choice and assembling of adequate playlists is time consuming. Some parts of music collections are often acquired without detailed examination of their contents, and the sheer size of the music collections overwhelmingly exceeds a person's ability to recall which compositions comply best with the current mood (Pauws & Eggen, 2002).

In order to simplify the creation of playlists, it is important to have correctly tagged instances in the music library. With correct metadata in the ID3-tags, finding similar songs and music parts and putting them in a playlist can get easier. The selecting procedure for individual music needs, ending up in a playlist, is much easier when the user can find the music files easily, with detailed information held with the contents (Andric & Haus, 2006).

3.5.3 Automatic playlist generation

In recent years automatic playlist generation has been introduced to cope with the problem of tedious and time consuming manual playlist selection. Meyers (2007) states that “with the advent of portable music players and the growth of digital music libraries, music listeners are finding it increasingly difficult to navigate their music in an intuitive manner.” So besides time consuming, browsing through the whole music library manually to select songs for the playlist is felt to be difficult by most music listeners.

Andric & Haus (2006) distinguish two forms of automatic playlist generation: based on hints and based on constraints. They differ in interaction with the user: the first approach lets the user specify one or several songs as hints or let the user seed songs. With the second form, the system chooses songs based on constraints, which are given by the user who specifies some constraints on the choice of songs.

Automatic playlist generation based on constraints is for done for example by Apple’s music software ITUNES¹⁰. It generates playlists based on criteria the user has already given, such as year, genre, artist, play counts, keywords, newest songs, and star rating (see figure 3).



Figure 3: Creating automatic generated playlists in ITUNES.

With the increased size of personal music libraries, many songs are lost in the masses: people have large amounts of music that they never listen to, a phenomenon labelled as *The Long Tail* (Anderson, 2004). Generating music playlists automatically can expose the songs from this long tail and let the user explore the ‘lost music’.

¹⁰ <http://www.apple.com/itunes/tutorials/#playlists-smartplaylists>

3.6 Star rating and music recommendation

In addition to formal metadata in digital music tracks, such as key, era, or genre, music tracks can also be classified in terms of rating, which can be seen as personal metadata. The user can rate an individual track or compilation, mostly in terms of stars count ranging from one star (disliked by the user, not listened to regularly) to 5 stars where the user likes the track and will play it regularly.

This rating system gives insight into the considerations of an individual music recommendation, as the user has told the system the kind of tracks he/she liked or disliked.

Exploring music goes beyond the known tracks on the users' computer or in a cd library. Given the rating and the correct tags which can categorise the music track such as genre, era, and artist, recommender systems such as Last.fm and Pandora can recommend unknown music similar to the known music the person likes, based on several characteristics.

These systems try to provide the user with a more enjoyable listening experience. As Celma & Lamere (2007) state, "music recommender systems serve as the middle-man in the music marketplace, helping a music listener to find their next 5-star song among millions of 0-star songs."

But star rating does not seem to be a particular useful feature, as nearly 60% of 56 participants indicated in a user research (Beale & Voong, 2006). The star rating system is regarded as inadequate, and Beale & Voong (2006) therefore conclude that "users would like a way of managing their music by mood".

3.7 Music, mood and colour

In the recent years, much research has been performed in the field of colour representation for music tracks and moods (Barbiere, Vidal & Zellner, 2007; Beale & Voong, 2006; Voong & Beale, 2007; Geleijnse et al, 2008). Besides music, colours are related to emotions in a consistent manner, where one can assign a colour to an emotion or mood in general, out of a range of colours.

Supported by psychological theories, Voong & Beale (2007) state that colour is often associated with moods and emotions and that it provides a natural and straightforward way of expressing something about a song. By extending the graphics user interface of Apple's music software ITUNES with colour selection per song, Voong & Beale (2007) found evidence in their studies that mood categorisation by associating moods with colour, helps users to create playlists with more ease. They state that "users reason about colour associations with a high degree of accuracy, showing that the tagging system aids recall of music."

In this section the use of colour for distinctions in music and mood is discussed. Subsection 3.7.1 deals with the addition of images to music. Section 3.7.2 captures the use of color in Moody's mood tagging framework.

3.7.1 Adding images to music

So mood categorisation for music, based on colours, proves to be an efficient tool for categorisation and playlist generation. Furthermore, research by Geleijnse et al. (2008) focusses on enriching music by adding lyrics, automatically separating the music track in segments, and assigning colour and images to the track. Lyrics are assigned to the segments or so-called *stanza's* (for instance, verse-chorus-verse-chorus-bridge-outro). By extracting and selecting keywords in these added lyrics, their system can browse through Google Images¹¹ or Flickr¹² to find images and colour schemes which enrich the music being played. The images shown are based on a vast percentage of a particular colour pattern.

3.7.2 MOODY's mood tagging framework

As stated above and proved in research, people find it rather easy to attach a colour to a music track or a collection of music tracks in general. This forms the base of the music tag application MOODY¹³, created by Crayonroom. MOODY is an application which lets the user tag songs in iTunes in order to generate mood-based playlists manually. Smart playlists, as described in subsection 3.5.3, based on moods, can also be generated automatically when all ID3-tags contain MOODY's mood tags.

The tags the users attach to songs are written in the *comments* field of the song's ID3-tag, and can be exported via the Internet to the MOODY database. The records in that database can be imported for untagged songs on the users' computer which are identical to the ones in the MOODY database.

For manually tagging of music tracks with MOODY, a user can choose between 16 fields of mood. These colours are representing the moods of the songs, as far as it's the user's mood judgement. The colours used in the MOODY application are similar to the hue colours of mood (Albert, 2007).

The colour patches are paired with a letter for the row and a number for the column, where the "Moody tag" represents a colour: for instance, the tag "A1" represents the colour red, characterising the song in terms of mood as being very intense and sad. Each MOODY tag has a different colour.

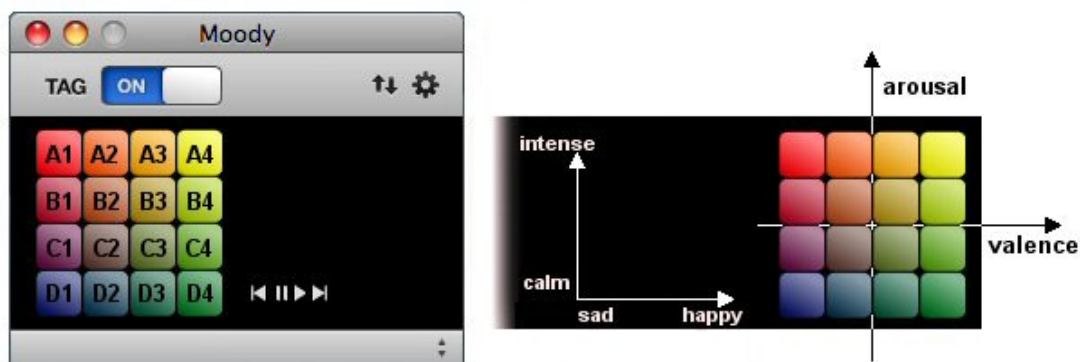


Figure 4: The Moody application and the integration of the framework into Thayer's model.

¹¹ <http://images.google.com>

¹² <http://www.flickr.com>

¹³ <http://crayonroom.com/moody.php>

As can be seen in figure 4, these colour patches and the mood representation on the left side can be layed over Thayer's arousal-valence emotion plain, presented in section 3.1.

So the fields the MOODY application works with are the same as in Thayer's emotion-valence plane, but enriched with hue colours to distinguish the moods, as it is easier for a user to tag with colours rather than tagging with keywords (Voong & Beale, 2007).

The arousal/valence distribution based on moods by Thayer (1982) is the same as the distinction in moods used in this thesis, as we use data taken from the MOODY application (discussed in subsection 5.1.1). The moods in our data range from "*angry*" and "*nervous*" to "*happy*" and "*excited*" on the upper half (the high-arousal area) and from "*sad*" and "*sleepy*" to "*relaxed*" and "*calm*" on the low-arousal area. The mood taxonomy the MOODY application uses is based on blocks with letters A-B-C-D and numbers 1-2-3-4. Separated by the arousal- and valence aspect, they correspond with the fields on the Thayer arousal-valence emotion plane (see figure 2 and figure 4).

4. Research design

This chapter describes the way that the concepts of mood, frameworks, and tagging of music as classification tools are implemented in a research design. Section 4.1 describes the implementation of machine learning techniques for categorisation and classifications. Section 4.2 covers a global overview of the theoretical design of a classification tool, based on machine learning techniques. In section 4.3 a common evaluation technique called k -fold cross-validation is discussed.

4.1 Machine learning

The aim of this thesis is the automatic assignment of mood tags for music, based on lyrics. The word *automatic* in this context means that the users do not have to classify themselves: the system will classify based on machine learning techniques.

Machine learning is the covering term for using developed techniques and algorithms to let a computer learn a specific job. With the use of algorithms a machine can learn, and work without the need of specific human control within a certain task. Information is extracted automatically on statistical and computational basis.

The term ‘learning’ in machine learning holds the gaining of new information from the current task, which is stored to improve the results in upcoming events where the same task is executed. The system stores information of the seen (test-) instances and applies the collected information for upcoming new items. When a new instance is encountered, in order to assign a target value for this new instance the system examines its relationship to the previously stored examples (Mitchell, 1997).

Different learning techniques apply to machine learning. Subsection 4.1.1 deals with concept learning. The inductive learning hypothesis is briefly discussed in subsection 4.1.2. Thereafter, in subsection 4.1.3 a machine learning system called TIMBL is introduced. The concept of k -Nearest Neighbours is covered in subsection 4.1.4. Finally, subsection 4.1.5 deals with the k -fold cross-validation evaluation technique.

4.1.1 Concept learning

Within machine learning a common used technique is concept learning, which holds the basis of learning through comparing new concepts with ones seen earlier. “Concept learning can be formulated as a problem of searching through a predefined space of potential hypotheses for the hypothesis that fits best the training examples” (Mitchell 1997). This learning method, also called instance-based learning, is used in nearest neighbour methods regarding machine learning (see section 4.1.4).

4.1.2 The inductive learning hypothesis

The inductive learning hypothesis as described by Mitchell (1997) assumes that any hypothesis found to approximate the target function well over a sufficiently large set of training examples will also approximate the target function well over other unobserved examples. So a system can predict a mood class (which is the target function in this thesis) by comparing the new instance (an unobserved example) against the observed training examples.

4.1.3 TiMBL: Tilburg Memory Based Learner

In this thesis the TiMBL program is used for classifications. TiMBL, which stands for Tilburg Memory Based Learner, is a machine learning software package which implements a family of Memory-Based Learning techniques for discrete data. It stores a representation of the training set explicitly in the memory, thus the term Memory Based in the name. New classifications are made by extrapolating from the most similar stored cases.

In other words, at classification time there is the extrapolation of a class from the most similar items in the memory to the new test item (Daelemans et al, 2007). This technique for classification has similarities with the core k -Nearest Neighbour (k -NN) classifications, on which most machine learning applications are based.

4.1.4 k -Nearest Neighbours

In a spatial room or n -dimensional plane the count of used features determines the count of dimensions. With instances (classified items) represented as dots, the k items with the closest distance to the new unseen item are kept as the k -Nearest Neighbours.



Figure 5: Examples of n -dimensional planes, with one to multiple dimensions.

The properties of these items (represented in figure 5 as gray dots with a positive or negative mark) are seen as more or less similar to the new unseen instance (represented as the red dot with the question mark). Therefore the classification of the known items, which can have different classes, is seen as representative for the same classification of the new unseen instance.

In this thesis the spatial room consists of the number of used features (see subsection 5.2.4) with k lyrics represented as grey dots. Each lyric in the n -dimensional plane has a mood class, determined by the feature values. Each time a new lyric is implemented, represented as the red dot, its properties are compared to the feature values in the spatial room. The k lyrics closest to the new lyric are seen as representatives, and their mood classes are used for the classification of the new lyric. For instance, if the new lyric has almost similar feature values as the lyrics with mood class C in the *Arousal* division in its neighbourhood, classification can occasionally lead to attachment of mood class C for the new lyric.

Distances from the new unseen item to all stored known dots (which are stored in memory in the training phase) are computed and the k closest samples are selected. So a new instance or dot is classified by a majority vote of its neighbours in the feature space, with the new item being assigned to the class most common amongst its k -Nearest Neighbours.

Voting only takes place during the actual classification phase, where the test sample (the unknown instance) is represented as a vector in the feature space. During the training phase the known items and respective feature vectors are only stored.

4.1.5 k -Fold cross-validation

One technique to show the system's performance on predicting classifications for unknown data is cross-validation. Cross-validation is the statistical practice of dividing data into partitions or subsets, such that the analysis is initially performed on a single subset which is seen as the test dataset. The other subsets in the form of training data are retained for subsequent use in confirming and validating the initial analysis. Afterwards the statistical outcomes show the overall performance of the system for computing and analysing data it has not seen before; the new data.

The data is subdivided in folds for training- and test stages (see section 5.2). All folds minus one ($k-1$) are set as training samples, where the fold being left out is used as test data. In other words: each fold (k) can be used as test set, where the other ($k-1$) sets are put together to form a training set. With each computation leaving one fold out and combining the other folds, k settings with other training data sets and testing data sets are computed.

After the computation, the average accuracy across all k -trials is computed. With this technique, the so-called k -fold cross-validation, each of the k subdivided data sets is used in a test set exactly once, and gets to be in a training set $k-1$ times.

4.2 Theoretical design of a classification tool based on machine learning

Now that the concept of machine learning is described, a global overview of a classification tool is presented in this section. In this overview the concept of machine learning is visualised to expose the different stages of processing. The distinction between the training- and testing phase is visible. The data used in training mode is extracted out of the database, as the same is done for testing purposes.

Figure 6 shows an automatic mood assignment framework based on machine learning techniques. It uses a database, which is divided into train- and test subsets for machine learning.

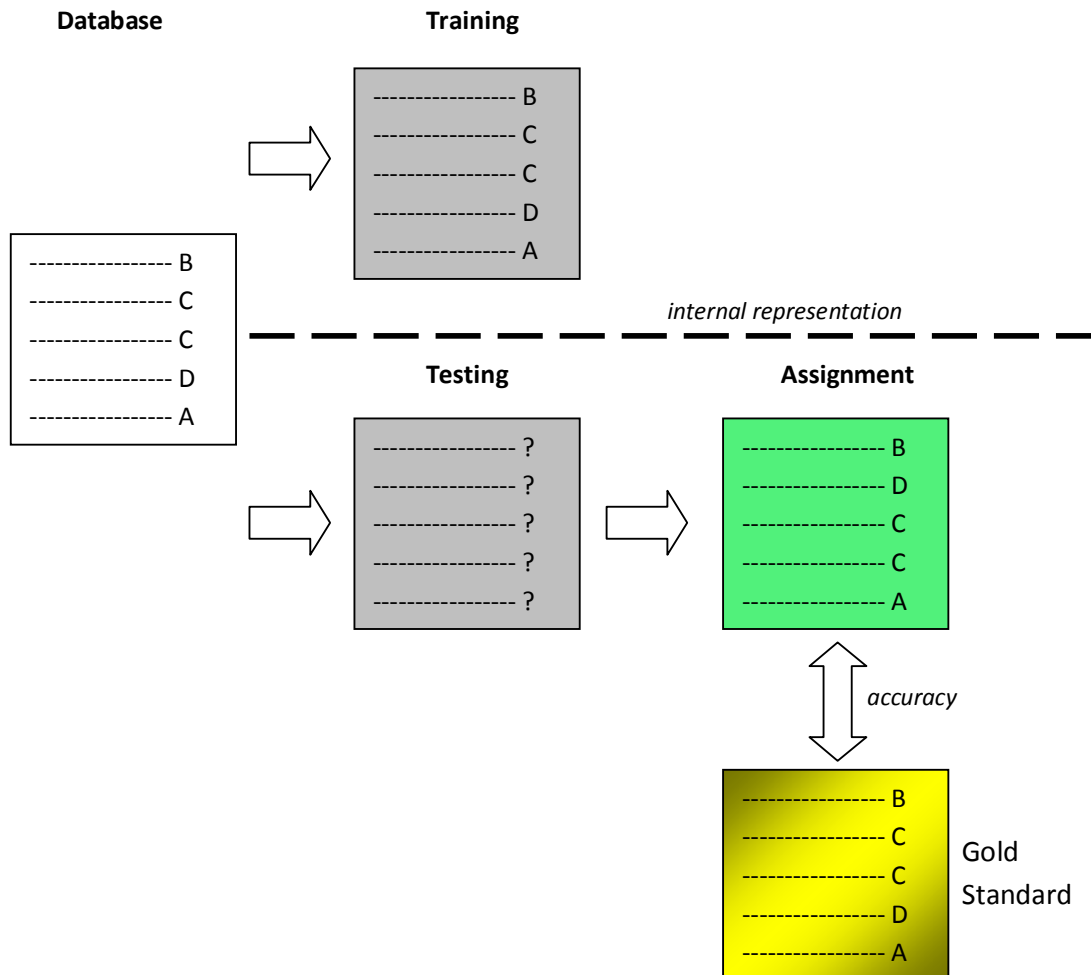


Figure 6: Automatic mood assignment framework: a global overview of a machine-based learning technique.

In training mode the system will work with the training dataset and set the given classifications against the known features, which we state (the tags manually attached by users of the MOODY application). In figure 6 we implement the Arousal division with the A-B-C-D mood classes to expose the working of an automatic mood tagging system.

The test set has no classifications, and here the system will try to predict classifications based on the stated mood division and the given features for these unknown files. In this phase the *k*-Nearest Neighbour classification method is implemented and executed. At the assignment stage the outcome of the system is the assignment of a classification to the test items. Finally, these predictions can be compared against the real classifications (the *Gold Standard*) resulting in the accuracy of the system.

5. Implementation

This chapter deals with the implementation of the research design. Section 5.1 covers the collection of the data used for the experiments. The extraction, export and cleanup of data is described.

Section 5.2 continues with the feature construction, with the generation of features and explanation of the tf*idf technique.

5.1 Data collection

Until recently, music listeners could read the lyrics of the songs they were listening to by checking, for example, the paper inlay in the compact disk. As more music is bought digitally via the Internet nowadays, printed lyrics on compact disk inlays are getting rare. A new way of enclosing lyrics is the storage of text in the digital MP3-file itself, by implementing an ID3-tag (as stated in subsection 2.1.1).

However, lyrics written in ID3-tags in the MP3-files are not yet generally accepted by either players or providers of digital music at the moment, although this may change in the near future. Therefore other ways to get the lyrics of the songs are being used by music listeners.

One way of obtaining the lyrics is searching through the Internet. Collected lyrics and other information about the albums, artists, and songs can be found on the web. Websites with huge collections of lyrics on the Internet have expanded the last couple of years. At these gateways one can find lyrics i.e. by artist, album or genre.

The advantages of a lyrics database on the Internet consist of (1) hierarchical storage and access for the user, (2) linking to similar artists/songs/albums, (3) straightforward management and (4) lots of capacity due to the small data size of plain text.

This section covers the collecting of data for the experiments. The use of MOODY data and the extraction of lyrics from online sources is discussed in subsection 5.1.1. The next step, exporting and cleaning up the collected data, is described in subsection 5.1.2.

5.1.1 Data extraction

As this thesis focusses on lyrics and experimenting with the lingual content of music, i.e. on word levels and other textual characteristics, the lyrics have to be found first. The music tracks of which the lyrics are taken from are generated out of the MOODY database. MOODY provides access to the tag data. The records on the MOODY server are used for this research and picked out at random. The extracted data with user-tagged moods consists of 10,000 lines with records, containing the name of the artist, the name of the song, and the corresponding user-tagged mood.

Each record consists of an artist name and the name of the song, which are useful for the lyrics extraction phase. The lyrics extraction phase works as follows: first a separate record in the mood-tags database is read, which provides the artist and the title of the song of which the lyrics have to

be found. These two parameters are put in a dynamic link of eight different online lyrics databases which are used as the lyrics sources.

The script automatically extracts the lyrics from the Internet when found in the database of one of the sources. The choice of using eight different online lyrics databases was made after having several rounds of finding lyrics through the script. Each time the sources were expanded with new sources in order to find more lyrics from the records in the MOODY database used in this thesis. After using eight online lyrics databases, 5,631 lyrics were found.

For each source, addresses are downloaded and searched through for valid content until the lyrics are found. As the records in the MOODY database consists of instrumental music as well as songs in foreign languages, no lyrics are found for these records in our implemented lyrics sources.

We encountered a problem with whitespaces in the database records. Sometimes whitespaces in, for instance, the artists name did not match with the way the artist name is spelled on the lyrics sources. For instance, a record was not found in the lyrics sources, because the artist name in the data record was spelled "*arcticmonkeys*" instead of "*arctic monkeys*". Due to several other spelling variations in the data for artist names, such as "*acdc*", "*ac-dc*" or "*ac dc*" for the artist AC/DC, we had to change the lyrics extraction script.

We implemented conversions in the script to improve the results, such as changing whitespaces to underscores, and deleting quotation marks. It did not improve for some instances in the database records and it would take too much time to change all individual records that were not found.

Because the HTML-pages of the lyrics databases consist of a large amount of HTML markup, images and unfamiliar code, the source code of the lyrics page has to be cleaned. This is done by searching down the HTML-tree until the real lyrics text section is found. These lyrics, enclosed in a pre-specified HTML-tag, are exported.

5.1.2 Exporting and cleaning up the data

The lyrics are exported as plain text. The reason for choosing plain text instead of XML, HTML or other formats was the readability and the ease of manipulation of the plain text for further operations. The plain text only shows the textual volume where no markup is needed. For further operations in the feature construction stage there was no need for textual attributes such as fonts, boldface, colour and other markup, therefore the plain text was the best suitable format to work with.

The lyrics are cleaned up by translating HTML-entities, removing unwanted text which is not part of the lyric (for instance, informational terms for website users such as "*chorus*" and occurrences of "*For more lyrics go to ...*") and removing unimportant whitespaces and empty lines.

By cleaning up the lyrics, we encounter some problems. First of all informational metadata is deleted, which tells us for instance, where a chorus starts, a bridge ends and how many times a sentence sung by the artist has to be repeated. Any occurrence of i.e. "*4x*", "*bridge*" or "*repeat until fade out*" in a chorus is thrown away, although these parts of a lyric are of importance for re-playing the music track.

These referrals can have influences on the experiments, but ambiguity arises here. We do not know how many times a sentence has to be repeated until the fade out, nor do we know where the chorus sentences start and end, without listening to the actual track. Taking care of this metadata for individual lyrics is also time consuming, and therefore we decided to delete these sentences.

On textual grounds, these occurrences are not of importance for the kind or the overall mood of a text. Therefore the deletion of those aspects does not discourage us from experimenting on proper lyrical grounds, as these textual elements do not yield problems for further analysis of the plain text with lexical items exposing mood intentions.

5.2 Feature construction

As the lyrics are successfully extracted and stored, these texts with attached mood indication (done manually by users of the MOODY application) are set as the training examples. To let a system train with examples, features have to be extracted from the text. These features will characterise certain aspects of the record, based on weights. With a certain pattern in the features, combined with the weights of the known items with attached mood, the system can train itself to classify unknown instances in future phases.

For the training phase, all found lyrics are partitioned into mood classes ranging from A1 to D4, based on the MOODY framework (see section 4.1) and implemented in Thayer's arousal-valence plane. We are using 4 divisions with different classifications: first the *Moody* division with 16 classes ranging from A1 to D4. The second division is the *Arousal* division, where all lyrics are subdivided in 4 classes A, B, C and D. The valence division consists of the classes 1, 2, 3, and 4. Finally, the *Thayer* division combines the *Moody* divisions and the arousal/valence plane (see figure 2) in 4 classes, for example Thayer class 2 consisting of lyrics tagged A1, A2, B1 or B2.

Feature extraction phases are performed on these 4 different divisions. The text files are stored in directories which are named after the mood class, for instance, the lyrics of "Elvis Presley - Jailhouse Rock" with MOODY tag "B2" is stored in B2 in the *Moody* division, in B in the *Arousal* division, in 2 in the *Valence* division and for the *Thayer* division it is put in 2. Based on this arrangement, features could easily be extracted and distinguished from each other in classes and divisions. The final distribution of lyrics for the divisions' classes is shown in table 1.

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Table 1: Distribution of lyrics per class for each division.

With the lyrics partitioned in division classes, information can be extracted from the collected data. This section describes the generation of features from the lyrics. Subsection 5.2.1 deals with the generation of features such as character count, word count and line count. The term frequency and tf*idf technique is described in subsection 5.2.2. In subsection 5.2.3 an explanation of the different use of tf*idf techniques for feature construction is discussed. Finally, subsection 5.2.4 covers a normalisation implementation and a feature overview.

5.2.1 Generating features

For testing- and training phases, several features are generated. The first feature is line count, where the count of lines in each lyric in each training subdivision is computed and implemented in a list; the list of feature “*lc*” in the training subset. The second feature is word count (*wc*), with a list of total words per lyric. The third feature is the character count, with the count of all characters in a single lyric being put in the feature list “*cc*”.

It might be possible that one of these features (or a combination of the features) describes some important characteristics per class for weighting. The values can tell something about the lyrics and the subsequent class if the values of the features per class differ from each other on a big scale. One or more features can be identifiers for categorising certain classes, but also for the experiment of showing certain characteristics on these features (word count, line count and character count) itself.

Word counts and line counts can be of importance as identifiers for certain kinds of music, so we have assumptions in that field. It could be that lyrics of music tracks in a calm manner can contain fewer words than nervous or excited tracks.

This is extrapolated as we can use fewer words in daily life to express a calm, peaceful mood in our messages compared to messages regarding excitement or joy. Think of a conversation with someone who is sleepy and tired, compared to a conversation where you ask someone who feels excited to tell you how that person experienced the day. The last conversation will probably end up with more words.

Another assumption can be that music tracks labelled “*angry*” can have less sentences (line counts) than *pleased*, *happy* tracks. Although these thoughts are just assumptions which are not grounded, we can use the features to see if in this context these assumptions can be true. Therefore we are going to take a look at this point.

5.2.2 Term frequency and inversed document frequency

The fourth feature holds the tf*idf values. The standalone term frequency values are used as a fifth feature. The use of tf*idf values is a powerful technique to emphasize the importance of a term in a document, compared to all documents in the database (Ramos 2003).

The term frequency (tf) in a document measures the number of occurrences of that term in a document.

$$tf_{i,j} = \frac{n_{i,j}}{\sum_k n_{k,j}}$$

This formula measures the importance of term t_i in document d_j , with $n_{i,j}$ occurrences of the term in document d_j , divided by the sum of the number of occurrences of all terms in the document d_j .

The inverse document frequency (idf) measures the importance of the term in the whole collection of items.

$$idf_i = \log \frac{|D|}{|\{d_j : t_i \in d_j\}|}$$

In this formula the number of all documents D is divided by the number of documents where the term (t_i) appears, and taking the logarithm of that quotient (Crestani et al, 2001).

After computing these weights, they are multiplied to get the tf*idf value:

$$tfidf_{i,j} = tf_{i,j} * idf_i$$

This tf*idf weight shows the relevance of the document for the term compared to the other documents: the higher the tf*idf value for term t_i in that particular document, the higher the document will be sorted in a resulting list of documents in the database based on relevance. The higher the position of the document in the vector, the more relevant the document is for the given term t_i .

If term t_i appears in all documents, or in most of the documents in a large database, the tf*idf weight has a low value. The term t_i is less important, as it does not judge for listing documents on its own: the term t_i does not distinguish the importance of documents compared to others, as term t_i appears in all documents.

These terms with their tf*idf weights are important for the upcoming phases: the terms with a high tf*idf weight are seen as important identifiers for a class. When an unknown lyric is analyzed, the lyrics are searched through and afterwards all terms are looked up in the tf*idf frequency lists per class, where tf*idf scores of the terms for each class are held.

The tf*idf value in each class is stored in a new list with the term and the corresponding tf*idf values for all classes as attributes. After analysing all terms in an unseen lyrics, the more counts of a term combined with a high tf*idf value in a particular class, can help judging the unknown lyric as a whole as a potential candidate for classifying in that particular class. Together with the other features, the overall tf*idf result as a feature for can participate in attaching the mood value of a particular class to a new, unseen lyric.

5.2.3 The use of tf*idf weights

The tf*idf technique is used differently in this thesis than it is normally used. In general, tf*idf is used for ranking documents based on terms: the documents with the highest tf*idf value for (a) certain term(s) are ranked on top. On information retrieval grounds, the documents on top are of more importance for a user (who is sending a query with term t_i), than the documents which have lower tf*idf weights of that term.

In this thesis we are not looking at the word level (with terms for judgements) but at the document level. Although one or more terms can also judge for assigning mood to a lyric, the collective weights for all terms in a document/lyric are used as a feature for classifying. Each lyric is seen as a collection of terms which have individual tf*idf weights, but there is no overall ranking on the collection of documents afterwards.

So terms with a tf*idf value are not seen as stand-alone identifiers for ranking documents or showing the importance of documents regarding the high tf*idf value of the term up front in this thesis. As mood tags are attached to the found lyrics, the terms are seen as identifiers for the mood classes the lyrics are in. In other words, the overall terms in the lyrics judge for classification. All terms in new unseen lyrics are compared to the terms with tf*idf values for each class in the lyrics database and the total weights of tf*idf values can judge for a certain class.

In this thesis we are dealing with moods, which are seen as the documents. As the features are divided per class in the training database, the tf*idf values for term t_i will characterise the attached mood of that document, the lyric. For instance, the term t_i has a high tf*idf value in class X compared to the other classes. Therefore when the term t_i occurs in an unseen lyric, it will have a weight which can occasionally lead to the assignment of mood Y based on the tf*idf values, combined with weightings on other features.

For the tf*idf feature, the lyrics in the subdivided mood classes are analysed through a tf*idf value generator. This process ends up in a list of tf*idf values, ranging from high values on top to low values, with the tf*idf value followed by the term.

We expose the problem of upcoming tf*idf features having the value “0” regularly. This takes place when several words in a lyric also occur in most of the other lyrics. While we are dealing with a relative small number of classes in this thesis, it is likely that several terms in lyrics appear in all classes, where the lyrics per class represent the documents.

As stated above, for calculating the idf-value of the tf*idf algorithm the log of the sum of all documents D , divided by the number of documents where the term (t_i) appears in, is taken. If term t_i appears in all documents, the count of all documents is equal to the count of documents with term t_i . When taking the logarithm of 1 (all documents: ‘ D ’ divided by the same value ‘ $D(t_i)$ ’ of documents where term t_i appears) the outcome is 0. So in this case term t_i appears in all classes, and therefore the tf*idf value of term t_i calculated on the database equals 0.

In order to cope with this problem, we implement the Laplace smoothing method, also known as “*add-one smoothing*”, in the tf*idf calculator script. Before calculating the idf value, +1 is added to the number of documents D .

Mirrored, this means the value of all documents D is divided by $D-1$, which results in a positive value. Taking the log of $(D+1) / D(t_i)$ now gives a small value higher than 0. This still allows for the term frequency factor, even though it is only a little bit.

5.2.4 Normalisation and feature overview

Differing text length between lyrics can give a distorted view in the feature values, as one short lyric can have a high tf or tf*idf value for term t_i which occurs, i.e. once in a text, whereas in the other lyric this term t_i is found a couple of times, but in a larger text. To cope with the distortion, normalisation is implemented to get representative values for the feature values. The values are divided by the total count of words in the lyric. Including normalisation, nine features, including Laplace smoothing and normalisation are identified. An overview of the features and their explanation can be seen in table 2.

| feature | explanation |
|---------------------------|--|
| cc | Character count: total count of characters per lyric |
| wc | Word count: total count of words per lyric |
| lc | Line count: total count of lines per lyric |
| tf | Term frequency per lyric |
| tfidf | Term frequency / inversed document frequency formula |
| tfidf1 | The tf*idf formula with +1 smoothing (add one / Laplace smoothing) |
| tf_n / tfidf_n / tfidf1_n | Normalisation on the tf/tfidf/tfidf1 calculations: values divided by the total term count per lyric |

Table 2: Description of the features used in this thesis.

After generating the different features, all data and metadata is collected and training- and testing phases can take place.

6. Experiments and tests

This chapter uses the implementation of machine learning (ML) as described in chapter 4 and 5 to test the performance of assigning moods to music tracks based on lyrics solely. In section 6.1 the experimental setup is explained, with the used features and TiMBL settings. Explanation of running the training- and testing phases is discussed in section 6.2. Section 6.3 covers the test results. The conclusions on the test results in section 6.4 form the chapter conclusions, which feeds the upcoming chapter 7 with the evaluation.

6.1 Experimental setup

With all features generated and set, all preparations for the machine learning phases, are done. By stating the features to be used, and applying the TiMBL settings, the machine learning system can perform training- and test phases.

The TiMBL machine learning software executes 3 phases automatically. In the first phase it reads the datafiles, where features and classes are stated and gain ratio's are computed. So the records in the feature directories are read and algorithms are applied to catch regularities between several records in a class.

Phase two holds the learning from the datafiles, where the classifications are set, and based on these classifications the features are analysed. These classifications are not set in the third phase (testing), where the analysis of the new instances is matched with the feature values and the corresponding classifications which are being used in the training phase. Finally, in the third phase, the trained classifier is applied to the test set.

6.1.1 TiMBL settings

An experiment with testing and training phases included is started by executing TiMBL with two files: the training data and the testing data. In both the training and testing phases, the IB1 algorithm is used.

For the experiments TiMBL is used with the default settings. Similarity between instances in the test- and training data is computed as weighted overlap. TiMBL sets the default feature weighting as Gain Ratio.

As stated in section 4.1.5, 10-fold cross-validation is set for evaluation on the system's performance on predicting classifications.

6.1.2 Used features

As mentioned in section 5.2, divisions (*arousal/valence/moody/thayer*) are partitioned, in which a fold hierarchy is made. Each fold consists of the values of the features: word count per lyric (*wc*), line count per lyric (*lc*), character count per lyric (*cc*), the term frequency values (*tf*), values of the *tf*idf* formula (*tfidf*) and finally the *tfidf1* feature which holds the values for the *tf*idf* +1 (add one smoothing, also known as Laplace smoothing) technique. Normalisation is applied to the *tf*-, *tfidf*- and *tfidf1*- values, where the values are divided by the number of terms in the new lyric in order to generalise these values for classification.

All possible occurrences of feature pairs are generated through a script and fed to the TiMBL program, which determines the used features. The output of the TiMBL program shows the accuracy and results for each feature pair.

6.2. Experiments and test results

For all divisions in this thesis, training- and testing experiments are performed with all possible feature vectors. As we state the data to be used for training- and testing sessions through a script, executing the commands is done automatically. TiMBL performs the stages mentioned in section 6.1 and the output is written.

A total of 20,440 experiment rounds is performed: $(2^9 - 1)$ feature pairs * 10 folds * 4 dimensions. It leads to 2,044 results, disregarding the 10-fold cross-validation.

6.2.1 Baseline

Test results are stored in a stated directory, where the used feature pairs and accuracy values are extracted. A distinction is made between results on tests running on basic features and advanced features in this section. The basic features are character count (*cc*), word count (*wc*), line count (*lc*) and all possible combinations. The advanced features include term frequency (*tf*), *tf*idf* values (*tfidf*), added smoothing (*tfidf1*) and normalisation techniques (*tf_n/tfidf_n/tfidf1_n*), together with all possible combinations.

To compare the test results, a baseline is calculated to compare the system's performance against a standard. The baseline forms the expected value of classifications without weighting. When no weightings or features are set, the largest class in a division is likely to be selected by the system because it has the highest probability to be classified correct in that class, which contains the most items. The baseline is calculated by dividing the number of items in the largest class (see table 1) by the overall value of items. The baseline for each division is shown in table 3.

6.2.2 Test results using basic features

We first look briefly at the results with the use of basic features without the advanced features. As can be seen in table 3, mean accuracy values of a basic feature as stand-alone classification feature are below the baseline in most cases. The combinations of features in feature pairs do not yield for better performance of the basic features. Therefore the assumptions made in subsection 5.2.1 are not true.

| basic features | mean accuracy (+ standard deviation) | | | |
|-----------------|--------------------------------------|--------------|--------------|--------------|
| | Arousal | Valence | Thayer | Moody |
| <i>baseline</i> | 33.28 | 31.74 | 29.76 | 11.54 |
| cc | 30.12 (.177) | 29.02 (.108) | 28.15 (.192) | 9.73 (.669) |
| wc | 31.44 (.836) | 32.59 (.162) | 28.16 (.165) | 11.06 (.109) |
| lc | 31.81 (.145) | 29.37 (.169) | 27.58 (.853) | 9.85 (.843) |
| cc+wc | 29.02 (2.26) | 28.84 (.171) | 28.47 (2.00) | 8.77 (.901) |
| cc+lc | 29.61 (.113) | 27.77 (.174) | 26.94 (.174) | 8.12 (.779) |
| wc+lc | 28.92 (.128) | 28.43 (2.05) | 27.01 (.108) | 7.74 (.908) |
| cc+wc+lc | 28.42 (.169) | 27.65 (.196) | 27.03 (.184) | 8.08 (.841) |

Table 3: Test results with best performance for basic features.

6.2.3 Test results using advanced features without basic features

The next results show the system's performance on classifications based on advanced features. In addition to the conclusion regarding the use of basic features above, results show that the basic features decrease the system's performance on predicting the right class when using advanced features. The use of advanced features, without the use of the basic features, results in much higher accuracy rates, which can be seen in table 4.

| advanced features | mean accuracy (+ standard deviation) | | | |
|-------------------|--------------------------------------|--------------|--------------|--------------|
| | Arousal | Valence | Thayer | Moody |
| <i>baseline</i> | 33.28 | 31.74 | 29.76 | 11.54 |
| tf | 33.36 (.181) | 31.77 (.125) | 29.85 (.147) | 11.45 (.119) |
| tfidf | 77.18 (1.02) | 76.26 (2.03) | 75.79 (1.34) | 70.89 (1.51) |
| tf+tfidf | 77.23 (1.02) | 76.29 (2.07) | 75.85 (1.37) | 70.89 (1.50) |

Table 4: Test results with average performance per advanced feature.

The accuracy values using the term frequency (*tf*) as stand-alone feature differ slightly from the baseline mentioned in section 6.2.1. The use of *tfidf* as stand-alone feature and the combination of the term frequency- and *tf*idf* feature (*tf+tfidf*) end up in improved results, where the accuracy rates are much higher with a peak at 77% in the *Arousal* division. Even in the *Moody* division, where classification is done on 16 classes compared to 4 classes in the other divisions, an accuracy of 70.89% is shown with the use of the *tfidf* feature. The outcomes of classifications on all divisions shows much improvement when using the advanced features, and accuracy values in the divisions using the *tfidf* feature are much higher than baseline values.

All smoothing - and normalisation features (*tf_n*, *tfidf_n*, *tfidf1*, *tfidf1_n*) return the same values for mean accuracy and standard deviation as the normal *tf* and *tfidf* feature. Furthermore, results on all feature pairs using the *tfidf* feature return the same mean accuracy and standard deviation as the stand-alone *tfidf* feature. Therefore these features and their pairings are not included in table 4.

The use of the *tfidf* feature differs on the factor *accuracy* (*tfidf* used: 64.12, *tfidf* not used: 45.94, $t(2518) = -21.885$, $p < .001$). The average accuracy with features implementing the *tf*idf* techniques is significantly higher than the average accuracy without the use of the *tfidf* feature.

The final results are shown in table 5, where the systems' best performance on classifying new, unseen lyrics is presented. It shows that the features consisting of term frequencies (*tf*) and the *tf*idf* formula (*tfidf* or normalised *tfidf_n*) are of much importance for the best performance on automatic mood classification.

| division | used features | highest accuracy |
|----------|--|------------------|
| Arousal | <i>tf</i> + <i>tfidf</i> or <i>tf</i> + <i>tfidf_n</i> | 79.64 |
| Moody | <i>tf</i> + <i>tfidf</i> or <i>tf</i> + <i>tfidf_n</i> | 72.34 |
| Thayer | <i>tf</i> + <i>tfidf</i> or <i>tf</i> + <i>tfidf_n</i> | 78.05 |
| Valence | <i>tf</i> + <i>tfidf</i> or <i>tf</i> + <i>tfidf_n</i> | 80.67 |

Table 5: Test results with the system's highest accuracy and used features per division.

Comparing the accuracy values (using the basic features) in table 4 with the accuracy values using the advanced features in table 5, the results show that the use of *tf*idf* techniques and term frequencies end up in much higher accuracy values in all dimensions, ranging from 72% in the *Moody* division up to 80% in the *Valence* division. In all dimensions the highest accuracy values are significantly higher than the baseline values.

The average accuracy rate using the *tfidf* feature for division *Arousal* is 77.23 (1.02), which is significantly above the mean score of 64.12 ($t(628) = -17.672$, $p < .001$, equal variances assumed). In the *Moody* division, the classifications with a mean accuracy of 70.89 (1.50) are significantly higher than the mean score of 64.12 ($t(628) = -17.359$, $p < .001$, equal variances assumed). The use of the *tfidf* feature also increases the performance of the system in the *Thayer* division. The performance in the *Thayer* division (75.85, 1.37) is significantly higher than the mean score ($t(628) = -17.251$, $p < .001$, equal variances assumed). Finally, the classifications on the *Valence* dimension (76.29, 2.07) are also significantly higher than the mean score ($t(628) = -17.190$, $p < .001$, equal variances assumed), with the use of the *tfidf* feature.

When comparing the results of the *Arousal* and *Valence* division, the accuracy of the system did not differ significantly between these divisions ($t(638) = 7.646$, $p < .001$, equal variances assumed).

7. Evaluation and discussion

In this chapter, evaluation takes place. The test results in chapter 6 are subject to evaluation, where the scientific background of chapters 3 and 4 is implemented. Section 7.1 covers the evaluation of the test results. In section 7.2 the theories and scientific background are compared to the outcomes to conclude the first research question, as the same is done for the second research question in section 7.3.

7.1 Evaluation

The test results in section 6.2 show significant differences between uses of feature pairs. Out of 2,044 results, the tests using the *tfidf* feature or the *tf+tfidf* combination perform the best in all divisions. Classifications using the *Arousal* framework with the use of features based on *tf*idf* techniques and term frequencies end up in the most satisfying performance.

7.2 Answer to RQ1

In section 2.2.2 we introduced the first research question, on which we describe the answer in this section. The first research question was stated:

RQ1: In how far can the linguistic part of music reveal sufficient information for categorising music into moods?

We may conclude that basic features such as word count and line count do not reveal sufficient information for judgements on mood categorisation. The results show that the use of basic features such as character count, word count and line count do not yield for higher accuracy rates. The information extracted out of lyrics which consist of text characteristics such as character counts, word counts, line counts or the combination of these features is insufficient and decreases the overall performance when using advanced features.

As the highest scores are achieved without using one of the *cc/wc/lc* features, we may conclude that these factors do not extract sufficient information out of the lyrics for the system to perform better. This outcome reveals that there is not much difference in the text length between lyrics in different classes; there is no clear difference in values between classes in this thesis.

However, the use of mainly *tf*idf* values on lyrics does indeed reveal sufficient information for assigning mood categorisations. Test results prove that the system's performance increases dramatically when implementing the *tf*idf* formula on lyrics, where at best a mean of 76% of the classifications is correct. The use of the *tf+tfidf* feature pair ends up in the best performance, although it slightly differs from the results using the stand-alone *tfidf* feature.

The outcomes of the experiments confirm our assumption that words can reveal and describe moods. The *tf*idf* calculation, which set higher values to words that characterise a class (and the

subsequent mood), is proven a powerful feature in this thesis. As it calculates on word level, and applies higher scores to words characterising a certain mood or class compared to others, the final calculation and weighting for a new lyric results in adequate classifications. Regarding the higher accuracy values when using the *tfidf* feature, we may conclude that both the term frequency (*tf*) and *tf*idf* techniques provide the system with important information for automatically classifying moods for music tracks.

When comparing the results on the systems' lowest and highest performance rates, we see that there is no significant difference between the mood divisions. The use of the advanced features show high accuracy rates up to 80% with a mean accuracy of 77% in the *Arousal* division, whereas in the other divisions mean accuracy values also reach 71% (*Moody* division, consisting of 16 classes) to 76% (*Valence* division). Based on the similarities between these divisions, we may conclude that the lingual part of music reveals equal information on the valence/tension level for mood classification as on the arousal/energy level.

The statement Beukeboom & Semin (2005) made, indicating that mood affects word choice and that lexical items can express moods, is supported by the results in this thesis. The high accuracy of the system using *tf*- and *tfidf* features shows that there are distinct words in the lyrics (with high *tf*idf* scores) which judge for certain moods. These terms or words in lyrics can be compared to triggering lexical items in one's mind for expressing mood. The music artist or songwriter can have the intention to express a mood in the music track, and the mood affects the word choice in the lyric. These mood-affected words are revealed by the *tf*idf* formula which calculates high values for words which are representative for certain mood classes.

Furthermore, it supports the research by Liu et al. (2003), namely the statement that "people can specify a mood the same way they tend to feel a mood period in daily life, because moods are related to the way a song is played, together with the affective parts in the lyrical content and present in a stated period." The emphasis on the lyrical content in their statement has a precipitation in this thesis, where we may conclude that moods, reflected in written text, is felt the same way in music as in daily life. The lyrical content of a music track can expose this mood, as written or spoken text does. People tend to tag a mood to a music track with ease, as they can characterise a mood in written or spoken language. These mood tagged instances form the basis for the data used in this thesis.

7.3 Answer to RQ2

Regarding research question two, mentioned in section 2.2.3, we compare the test results with the theories in chapters 4 and 5 to answer this question.

RQ2: What aspects of mood can be classified best based on lyrics alone and with what granularity?

Our results show that tests in the *Arousal* division end up in the highest accuracy values (see table 4). We focus on the accuracy rates using advanced features, as the ones using basic features give no significant differences between divisions (see section 6.2.2). With an average accuracy of 77.26% using the advanced features, the system performs the best on classifications in the *Arousal* division.

We may conclude that mood classification can be performed the best on the arousal element for our system. In other words, mood classification on the energy dimension, which is stated as the y-axis on Thayer's arousal-valence emotion plane, can be classified the best. It holds the vertical layered blocks on MOODY's framework, consisting of the characters *A-B-C-D* which determine the distinction in moods on the energy aspect.

On lingual grounds, the system can classify the best when classification is based on the high-low distinction on the arousal/energy characteristic. So regarding content of lyrics, there's a distinction between energy-loaded words: lyrics of music tracks having an overall high-arousal mood (*annoying*, *excited*) contain other words than the ones having an overall low-arousal mood, which is stated as *sleepy* or *calm*. As the $tf*idf$ formula is of much importance for the best results, we may conclude that energy-loaded words appear in lyrics that have high $tf*idf$ values. These features help to distinguish the classes on the arousal dimension and assigning a mood categorisation.

Although classification using the arousal element ends up in the highest accuracy rates, these results are not significantly better than the system's performance on the other dimensions, as can be seen in table 4. With a mean accuracy of 76.29%, the classifications on the *Valence* division are slightly less accurate than the classifications in the *Arousal* division. In the *Moody* division, where the system attaches mood tags on 16 instead of 4 classes, the system performs with an average accuracy of 70.89%, using the advanced features *tf* and *tfidf*.

Given these outcomes, we may conclude that there is no significant difference in classifications between the divisions *Arousal*, *Moody*, *Thayer* and *Valence* for our system. As we use data with user-tagged mood attachments out of the MOODY database (see subsection 5.1.1), an extrapolated conclusion can be drawn that, regarding Thayer's arousal-valence emotion plane, people do not experience more difficulty in tagging music tracks manually on the arousal/energy level as for valence/tension level or vice versa, although manual mood tagging by users of the MOODY application was not done with decision making on the lyrical part of music.

8. Conclusion

In this chapter the final conclusions are stated. It goes back to the second chapter, where a problem statement for this thesis was stated, which in turn was divided into two research questions. In this chapter these questions are answered, starting in section 8.1 with the answers on the research questions. Section 8.2 describes the answer on the problem statement, and in section 8.3 a final conclusion is drawn. Finally, section 8.4 covers the suggestions for future research and limitations in this thesis.

8.1 Research questions

The answers on RQ1 and RQ2 in sections 7.2 and 7.3 respectively show that the lingual part of music in the form of lyrics reveal sufficient information to end up with classifications with an average accuracy of 75% (using advanced features) in automatic mood classifications performed by our system. We have to take into consideration that with an accuracy of 80% at best, the system still attaches a wrong mood tag to 1 out of 5 music tracks (see the description on future work in section 8.4). But seen from the point of the lyrical metadata of music solely exposing mood, it proves that much information for classifying the mood of a music track is stored in the lingual data.

As the classifications are performed using the information extracted out of music lyrics, our test results show the use of tf*idf techniques and term frequencies as powerful tools for extracting important information for classification tasks by the system. Lyrical content in the form of words can describe moods as in spoken or written language. They are highlighted as the terms with high tf*idf values are important characteristics for a mood class, which in turn is of importance for classification using *k*-Nearest Neighbour methods.

Regarding differences in accuracy of classifications by the system between the used mood divisions *Arousal/Moody/Thayer/Valence* in this thesis, our test results show that automatic classification on the arousal aspect (arousal/energy) can be performed the best by our system. The terms extracted out of the lyrical data in this thesis exposed more information on the arousal aspect, which results in the best performance in the *Arousal* dimension.

The linguistic information of music does expose sufficient differences between classes in all mood divisions for classification, regarding the slight differences in accuracy values between the divisions. Where tf*idf techniques and term frequencies are seen as powerful tools in the divisions, and being used as features held responsible for significant better performance of the system, these extracted features do yield for satisfying classification performances in the *Arousal/Moody/Thayer/Valence* divisions.

8.2 Problem statement

By analysing the test results and implementing the conclusions on the research questions in section 8.1, we can answer our problem statement. The problem statement mentioned in section 2.2.1 reads:

To what extent is it possible to attach mood tags to songs based on lyrics automatically?

The test results prove that the lingual metadata of music in the form of lyrics provides the system sufficient information to classify with a system performance of 80% at best. Both term frequencies and tf*idf values contribute to the highest accuracy rates.

Extracting information out of the lingual metadata of music tracks for basic features, such as character counts, word counts, and line counts, does not provide the automatic mood classification system sufficient information to perform with satisfying classification outcomes.

The use of tf*idf values and term frequencies, extracted out of the lingual metadata, contributes to significantly better performances of the system in the classification stages. With use of these advanced features the automatic attachment of mood tags based on lyrics can be done in a sufficient manner with better results in prospect when extending and feeding more extracted musical metadata to the system.

Regarding the aspects of mood that are classified the best, we may conclude that automatic attachment of mood tags to songs based on lyrics can be done the best on the arousal/energy aspect, where the distinction between high arousal (annoying, excited) and low arousal (sleepy, calm) is made. Classifications on the *Moody* division with 16 independent classes showed satisfying results which are significantly higher with implementation of the tf*idf techniques. Finally, automatic mood classification on both the *Thayer* and *Valence* division, show performances that are slightly less accurate than the best performances in the *Arousal* division (with the arousal/energy dimension ranging from low arousal, for example, sleepy or calm, to high arousal, such as excitement and anger). Comparing accuracy rates of all divisions, results show that sufficient information on the arousal aspect or valence aspect (or combinations of these in the Thayer division) is found in the lingual data.

It can be concluded that the lingual part of music, with the emphasis on using tf*idf techniques, reveals a large amount of information for automatic mood categorisation on music, but it lacks additional information for the system in the classifying process for ending up with a high accuracy regarding the systems' performance and significant outcomes. More information besides the analysed features used in this thesis is needed in order to gain better outcomes and improved classifications. Automatic mood classifications based on the linguistic aspects of music solely does not yield for satisfying results yet.

8.3 Final conclusion

The research presented in this thesis is an attempt to design, implement and evaluate a mood-based classification system for music based on lyrics. The main goal is the automatic assignment of mood-based tags for songs in a users' music database, based on lyrics. By automatically assigning mood tags to the music properties, users can experience their music without the hassle of assigning mood properties to all songs in a music collection manually. It can let users simplify the creation of playlists based on moods, and let them listen to music tracks in a new way and rediscover songs in *The Long Tail* in a large music collection.

The results show that the *tfidf* feature improved the results significantly in this thesis. It shows the importance of the *tf*idf* formula for (music) information retrieval fields, as it is a powerful tool to emphasise the importance of keywords and lexical items regarding the ordering and classification of instances in classes or hierarchies. This conclusion goes along with the statement by Ramos (2003). The use of basic features such as word counts do not yield satisfying results, as the system's accuracy performs below the baseline.

Although the system's performance on predicting and assigning mood to music tracks based on lyrics solely is not suitable (yet) for adequate output, results show that assigning of mood can be done in an automatic manner without human intervention. It will decrease the effort of creating mood playlists and can let the listener experience music tracks in a new way. In order to improve the results, other musical characteristics in the field of music emotion recognition have to be implemented besides the linguistic part, such as tempo, key or genre. With this added information, the system's performance on automatic mood classification for music is likely to be more progressive.

Taking the description above in consideration, a final conclusion on this research can be drawn. The system in this thesis, tagging music tracks automatically based on textual grounds, showed encouraging results with an accuracy of more than 80% using the *tfidf*- and *tf*-features. The outcomes prove that the lingual part of music reveals much information on mood-exposing grounds.

We have to take note that a mean accuracy of 77% on automatic attachment of mood tags based on lyrics does not offer a bright insight, as we can not compare that value to human performances. If tagging is performed by humans, standard deviations between users is present. The mood tags assigned by users of the MOODY application, which were set as the Gold Standard, are influenced by these standard deviations between humans.

Continuing on this statement, one of the weaknesses in this classification system lies in the use of only lingual elements of music. With the use of other music characteristics such as key, genre or tempo, the system's performance can be enriched and can result in more accurate classifications. As tools for extracting features out of music tracks (such as tempo and key) are getting more accurate, and research continues on improving these extraction techniques, accuracy on classification systems using these features will also improve.

8.4 Future research

A number of limitations apply to this research and can be held for future work. First, the implementation in this thesis was only performed with a database consisting of the gross of lyrics with English as the main language. Future work is to extend the work by enlarging the lyrics database with multiple languages. Here we can ask questions about what differences are noticeable regarding tf- and tf*idf values and overall results between languages. Furthermore we could extend the lyrics sources in order to find and extract more lyrics, and building up a larger database for the experiments.

Second, we made choices regarding the selection of classes and divisions. The *Arousal*-, *Valence*- and *Thayer*-division were conducted out of the *Moody* division/framework, where other classes could have been used. Choosing other divisions or more specific arrangements by fields of mood could give new insights.

In this thesis the system works on perfect classifications. Especially in the *Moody* division, where the distances between the 16 classes is relatively vague and no specified borders are set, the mood classification can be tolerable in cases where the system marks the classification as wrong (i.e. where the system assigned the tag “B1” to a music track instead of “B2”). We did not focus on this aspect, as it is difficult to compare the individual classifications with the original mood attachments, which can have a mutually short distance in the classes. Moreover, detailed information on standard deviation values of the users of the MOODY application can be analysed or implemented to get insight in the way humans attach mood tags to music tracks.

As mentioned in section 2.2.2, besides lyrics, other kinds of musical information can help expressing or revealing a certain mood or state of emotion. Although these musical aspects are out of scope for this thesis, it can give new insights and results when implementing those analysed characteristics in our system.

One particular aspect of language we did not cope with is ambiguity, which is also present in lyrics of music tracks. Take for example the *Leningrad Cowboys*’ track “*Happy Being Miserable*”, which has an underlying meaning, like other songs having lyrical content with a broader meaning. This can not be exposed by the use of term frequency and tf*idf formulas, nor do automatic text analysis programs provide sufficient outcomes, as language ambiguity is a problem which can only be discovered the best by humans.

At this point we can not foresee whether it is possible to reach 100% similarity in the future between automatic mood classifications and manually tagged mood classifications by humans.

Emotions and language are not to be understood by systems the same way it is felt by humans.

The possibilities of extracting more important information out of the lyrical text and ending up with higher system performances on automatic mood classifications based on the lingual part of music can be held for future work.

In this thesis we had to cope with lots of mood-tagged songs lacking lyrical content: instrumental music in the database. As we rely on categorisation by analysing the lingual part of music solely, we had to leave these instances behind. The appearance of instrumental music in this thesis with moods tagged by users of the MOODY application, slightly confirms that music tracks contain mood characteristics, even if there is no lingual part in the music track. It supports the conclusions made in other research fields of music emotion classification that other aspects such as key, genre, instruments and timbre express moods in music.

The research mentioned in section 2.2.1 has shown that music emotion classification based on tempo, key and timbre gave significant results. Enriching the used features in this thesis with acoustic or nonlinguistic data, extracted out of audio files by other music classification tools, would be a definite improvement on the accuracy in our music mood classification system.

In contrary, this thesis shows that the use of the linguistic part of music, analysed through tf*idf formulas and other techniques, can be an effective addition to the music emotion classification techniques already available.

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