ASL

Automatic Smiley Labeling

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Abstract

Facial expressions play an important role in human communication giving real substance to face-to-face interaction in real life speech. For many years researchers have been involved in automatic recognition and generation of facial expressions.

Motivated by this issue, we investigate the design of a system that is able to recognize the emotional character of the speech, being able to enhance it adding facial expressions that convey its sense. The recognition is automatic which means that it doesn’t need subjective human annotations. The lexical database, Wordnet, and some scripts to access it are used to classify the emotional words in a 2D-space. This space allows us to classify the words according to their degree of pleasure and their degree of activation. Calculating the distances between the words in this space we conclude which facial expression conveys better the emotion of speech.

To develop an automatic system that analyzes human emotions from a text is a difficult task, but the Automatic Smiley Labeling system or ASL has been tested and found to be a viable approach for this purpose based on the lexical meaning of the words.

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Preface

This master thesis describes the research I have done at the Man-Machine Interaction (MMI) group at Delft University of Technology. I joined MMI group the last six months in the framework of Socrates exchange program. This project completes my master degree in Telecommunication Engineering started at the faculty of ETSETB at UPC (Universitat Politècnica de Catalunya) in Barcelona. The facial expression recognition is one of the main research topics in the MMI group. This report covers the research and work I did on designing ASL (Automatic Smiley Labeling) an application that recognizes the emotional character of speech.

Acknowledgements

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To my grandparents

Chapter 1: Problem definition

The goal of this thesis is the design and development of the Automatic Smiley Labeling system or ASL. Section 1.1 introduces the subject of this work. Section 1.2 describes the problem setting in which the development of the ASL is set. Section 1.3 gives an overview of the thesis assignment.

1.1 Introduction

Facial expressions play an important role in human communication. Facial expressions can be used to regulate dialogues, to stress a verbal message or even replace a verbal message and they are able to convey the emotions of the speaker. Some expressions as happiness, sadness, disgust, anger, fear and surprise are universal. All over the world people use similar expressions with the same semantic interpretation. But most of the expressions are subjective and context dependent.

For many years researchers are involved in the automatic recognition of facial expressions. Most researchers are focused on the recognition of the shape of mouth, eyes and eyebrows. At this moment most researchers favored a probabilistic approach based on Bayesian belief networks and using classifiers as Support Vector machines or Relevance Vector Machines.

Since 1990 there is a project running in the MMI group of TUDelft focused on the automatic recognition and generation of facial expressions. One of the subprojects is the design and implementation of a facial expression dictionary (FED) (Jongh, E., 2002) Similar to a word based dictionary the idea is to generate a non verbal dictionary, the words are the facial expressions, the “spelling” of the non verbal words is described by (de-) activation of facial muscles and every facial expression is semantically interpreted using different context.

A last step, which is not yet fully implemented, is the look-up facility. Given a non-verbal word, i.e. a picture of a facial expression, it would be nice to have the facility to look up the meaning in the FED. This requires that the FED should be filled by most commonly used expressions. Next there should be an automatic analysis of facial expressions and finally a classifier is needed to decide on which facial expression is shown.

1.2 Problem overview

One of the limitations we have at the moment is that all facial expressions in the FED corpus are labeled manually. This means that FED is based on subjective data. Next, the FED corpus contains a limited number of expressions. The selection of expressions is rather arbitrary and not based on a corpus of real life recordings of human communication. Finally, facial expression recognition becomes difficult due to some problems.
For example, it is difficult to interpret a facial expression if it is mixed with another one, i.e. two expressions appear at the same time. Moreover, some expressions are universal, i.e. they have been shown to be recognizable across cultures (such as happy, sad…), but most are cultural and context dependent.
Recent applications have been designed in order to analyze emotions from a text and display a facial expression to convey the message such as BEAT by Casell (Casell, et. al, 2001) and My-Eliza by Fitrianie (Fitrianie,S., 2003). They used a manual predefined list of emotion words stored in a database; they parsed word by word and checked it with the database.
For these reasons, we want to develop an automated system in order to make this process more objective and consistent.

1.3 Thesis assignment

This thesis describes the design and implementation of an Automatic Smiley Labeling (ASL) system. A system that is able to add emotion pictures ("emoticons") to a text automatically.
This project is built up in the following five steps.

1st Step: Literature research
Literature research based on the psychological part of the project such as humans emotions, the face and its expression and how we can model and analyze them in communication systems. Chapter 2 will give an overview of all this theoretical background.

2nd Step: Recording studies
Analyze recorded dialogs of two participants. They were requested to perform dialogues on different topics and were requested to show as many expressions as possible (Wodjel, A., 2000). Chapter 3 describes the experiments done to find the on/off set of facial expressions without using reference to text of dialogue and finally, identify these expressions and label them. It also explains the recording analysis with the reference text creating a database with all the words found and all emotional situations a person can be involved in.

3rd Step: Classification
Chapter 4 focuses on the techniques used to measure and place the found expressions in a 2D-space classifying them in bipolar dimensions ‘pleasantness’ and ‘activation’.

4th Step: Database
According to the results of the previous steps, the fourth step concentrates on the implementation of a database by using XML language not only including the words but also the relations between them and the extracted results. Chapter 5 describes the design of this database and the whole system.

5th Step: System implementation
Chapter 6 describes the system’s implementation and data manipulation. ASL receives a text and using the techniques described before, displays an appropriate facial expression to convey it.

Chapter 2:Literature research

This chapter briefly introduces the theories that have played a role in the development of this thesis. The first two sections give an introduction on the basic concepts of emotions and facial expressions. Then, the third section describes the principles to represent and analyze facial expressions. Finally, the fourth section presents the most used methods to classify this kind of expressions.

2.1 Emotions

According to Desmet (Desmet, P.M.A., 2002) to define the word emotion it is important to distinguish it from other affective states like moods, sentiments or emotional traits. In some particular cases a person may be unaware of the cause of his emotion. Emotions arise very quickly and last only for a short period of time. On the contrary, moods have a relatively long-term character referring to the tendency of a person to feel an emotion, i.e. is a state of mind or temper with a long-term character. Emotional traits are long-term personality characteristics. Sentiments are dispositional states that may persist throughout a lifetime, but involve a person-object relationship like emotions. Sentiments are our likes and dislikes or our attitudes towards particular objects or events.

Emotions can be also distinguished from reflexes that are a brief event that cannot be completely inhibited like an emotional response. Emotions are personal and temporal, that is different people experience different emotions towards the same context at different points in time. Emotions can be mixed, that is sometimes we feel more than one emotion simultaneously. The analysis of the human expressions becomes more difficult due to this fact. Emotions may be elicited by internal and/or external stimuli (such as events in the environment or some change within a person).

An emotion is a process which involves various components such as memories, feelings, physiological responses, autonomic nervous system, brain responses, verbal responses and facial expressions, being this last the most interesting for our study.

2.1.1 Emotional words

By the term “emotional word” we understand words which are used to express an affective state (e.g. proud, sad, scared etc.) or their use can awake an emotion. Of course whether a given word awakes any emotion in a particular person depends also on other factors: mood of this person, his sentiments and memories or in what kind of situation a given word is used.
The facial expression which is shown for a given emotional word depends also on the context, not only on the word itself. It is caused by the fact, that a given word used in various situations can have different meaning. Although the use of an emotional word does not exclusively determine the displayed facial expression, we can observe some correlation between categories of emotional words and facial expressions linked to the emotional words from these categories.

2.2 Facial expressions

Darwin (1872) argued that certain emotional expressions are innate and the same for all people; but evidence of universals in facial expression does not prove that they are innate. Universal connections between expressions and emotions could arise from learning which has a high probability of occurring in all cultures or from a functional role of the movements in the emotional situation. However, other evidence also supports the hypothesis that innate, biological factors mold some facial expressions.
Finally, recent evidence (e.g., Ekman, Soreson & Friesen 1971) has indisputably shown that there are constants across cultures in the emotional meanings of certain facial expressions.
Ekman and Friesen found six emotions to have universal facial expressions, namely anger, disgust, happiness, sadness, fear and surprise. Most of the existing facial animation systems use this set of emotions.
Facial expressions reveal our emotions, i.e., they are a physical representation of our emotions.
Facial expressions serve not only as the primary channel to express one’s emotion, but they also improve communication (Pelachaud, C., 1998). Each expression provides very different information. Our face can also express attitude toward our own speech (such as irony) or toward the interlocutor (such as submission). Seeing faces, interpreting their expression, understanding speech are all part of our development and growth.
Facial expressions occur continuously during speech, both complementing and reinforcing the information delivered in the audio channel. Ekman differentiates between facial expressions used as emotional signals and as conversational signals. In our work we will use only the affects displays, that is, the facial expressions of emotions. We dispense with facial expressions such as biological requirements of the face or conversational signals to accentuate or emphasize speech.
Some emotions do not differ in facial expressions at all (e.g. “sad” and “melancholy”) or are very difficult to differentiate with facial expressions (Desmet, P.M.A., 2002). Further, the same facial expressions which convey emotions or mood of a person can also be correlated to an intonation or context of a message.

On the other hand, it is difficult to interpret a facial expression if it is mixed with another one, i.e. two expressions appear at the same time. Moreover, some expressions are universal, i.e. they have been shown to be recognizable across cultures (such as happy, sad…), but most are cultural and context dependents.

Analyzing the facial expressions, we take into account that an emotional experience is a direct result of a change of the body. The most important source of change is the set of muscular movements produced by facial muscles. They provide the most substantial changes in facial appearance over short time durations. As a result, they contribute noticeably to nonverbal communication.

2.3 Methods to represent and analyze facial expressions

There are many possibilities to represent a facial expression such as pictures, videos, smileys, facial characteristic points or active Action Units (see section 2.4).

Kobayashi and Hara develop a method for automatic facial expression recognition. In this model the position of 30 points so-called FCP's (Facial Characteristic Point) are located around the contours of the mouth, eyes and eyebrow (see figure 2.1). These 30 FCP's correspond to 30 of the 44 AU's of the FACS system. The other 14 AU's correspond to the movement of the cheek, chin and wrinkles, but from experiments we know that people don't pay attention to them when classifying facial expressions. In our FED system, the classification is semi-automated.

The FCP's are placed manually by user by clicking on the picture. Initially, the coordinates of the FCP's are given by the relative position with respect to the origin of the coordinate system of the picture. Before the FCP feature vector can be used for facial expression recognition, the FCP's all have to be normalized to take into account for variations in size, position and in-plane orientation of the face by transforming the FCP's in a Facial Coordinate System.

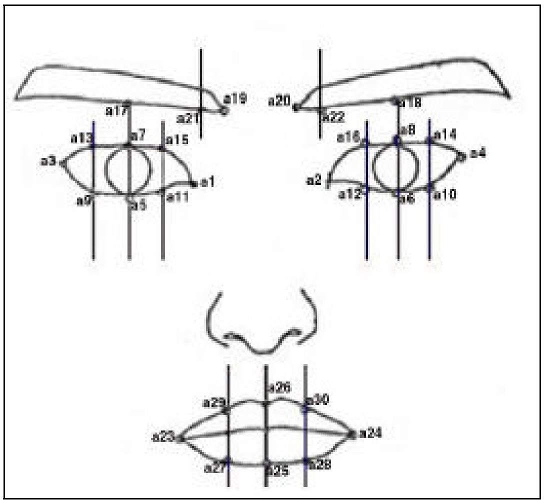


Figure 2.1: The FCP's in the face model Kobayashi and Hara

Closely related to the representation through AU's, the most popular method used today by researchers is the face model based on Facial Animator Parameters or FAP´s. They are based on the minimal perceptible actions; therefore it is very useful if we are trying to animate faces. There are 68 FAP´s divided into 10 groups based on different parts of the face.

2.4 Methods to classify facial expressions

In recent years many models have been developed in order to classify facial expressions. Most of them are based on the changing contours of the mouth, eyes and eyebrows. The eyes and the mouth are the most critical areas of the face due to their features.
The findings on the universality of 6 basic emotions inspired researchers to try and find a way to measure facial expressions, so that emotions could be objectively measured (instead of relying on the subjective interpretation of an observer).
Probably the most prominent and most used technique to emerge is the Facial Action Coding System (FACS) developed by Ekman and Friesen in 1978. In their research they define 44 so-called Action Units (AU's). FACS assigns to each muscle movement an "action unit" number.
An action unit is the smallest visibly discriminable change in facial movement. Each AU describes the movement of certain muscle(s) of the face. Every facial expression can then be described in terms of which AU's are active.

Russell (Russell, J.A., 1980) placed the facial expressions in a 2D space, in a circular form called the *Circumplex of Emotions*. In his approach emotions are defined by 2 coordinates of pleasure and arousal. He used a psychological approach to plot emotion words based on the changing of geometrical features of human expressions when expressing a certain emotion type. He claimed that people can use the 2D space to analyse the emotion tendency of each word and their expression in a glance.

Yamada and his colleagues (Yamada et al., 1993) used canonical discriminant analysis to visualize the 6 basic expressions and coded in the form of MPEG-4 like parameters. They found three major canonical variables, the first one for lifting the eyebrow and opening the mouth, the second for pulling up the corners of the mouth and the third one for the position of the eyelids and eye corners. The importance of the eye region is clear from the work of Yamada et al.

Another method often used for classification in facial expression recognition systems is a rule -based expert system. It contains a knowledge base with information about facial expression features stored in the form of logical if-then rules. The facial features of the unknown facial expression are given as input into the knowledge base and the facial expression label is determined through logical inference.
Neural networks can also be used as a classification method. The neural network is trained by using a set of images that have been correctly classified as a certain emotion by a human expert. After training, the neural network can be used to correctly classify new images of which the corresponding emotions are unknown.

Kobayashi and Hara used a 60-100-100-6 feed-forward neural network to classify facial expressions. The 60 inputs correspond to the normalized coordinates of each of the 30 FCP's. The output layer contains one neuron for each of the six basic emotions Happiness, Anger, Sadness, Disgust, Surprise and Fear. The neural network is trained using so called *ideal Ekman sets*. The normalized feature vectors are given as input to the neural network along with the correct output during training. After training, the neural network is capable of correctly classifying facial expressions of which the emotion category is unknown.
As explained before we have 30 FCP's in a 2D-space. This means that every facial expression can be represented as a vector in a 60-dimensional space. To explore this space in a visual way we have to reduce this vector space to a 2-dimensional space. PCA (Principal Component Analysis) can be used as a data reduction technique. All the points of the 60-dimensional space are plotted on 2-dimensional space of the first two principal components in such a way that as much of the variation of the points is preserved.

Another technique used for the statistical analysis is Sammon mapping which is an iterative nonlinear projection method. It provides a mapping from a high-dimensional vector space onto a 2-dimensional output space. As a result a complete 2D array of intensity values of the image can be used to represent the facial expression information.

A number of categorization mechanisms can be used. With template-based classification, the unknown facial expression is compared with templates representing the classification categories (for example the 6 basic emotions). The image is classified into the category of the template to which it is closest. More advanced classifying techniques are Support Vector Machine or its probabilistic variant called Relevance Vector Machine.

Chapter 3: Analysis of recorded data from dialogues

This chapter describes the experiments in order to develop the 2nd step of the thesis. The purpose of this step is to analyse recorded dialogues of two participants and find the facial expressions that the participants show. The first section explains the first experiment done in order to analyse only the expressions according to their appearance. The second section focused on the analysis of emotional words according to their meaning.

3.1 Appearance analysis

The objective of the first analysis is to find the on/off set of facial expressions in a dialogue without any reference to text, i.e., analyse them according to their appearance, not their meaning or function in the speech.

3.1.1 Experimental material

The recorded data selected for this analysis is made up of two sessions (one with a male and the other for a female). Each session consists of 10 sets of recordings. The fragments contain dialogs between two characters from a popular Polish juvenile book, where the persons are involved in a large variety of situations.
The video sequences are converted and stored as MPEG-2 stream. They are sampled at 25 frames per second and saved with 645KB/sec bit rate. The resolution is 720x576 pixels and colour depth 24 bits per pixel.
We used MGI VIDEO WAVE III to analyse the data recordings. This tool allows us to extract the start time and the end time of each expression. Microsoft Excel and Visual Basic are used to process the data.
The first goal is to assess facial expressions; which can play the role of non-verbal word. So a facial expression is supposed to have a semantic meaning, either an emotion or a communicative function.
In order to be in agreement with other participants and to extract coherent and objective results we based our labelling on the 41 expressions of Desmet (Desmet, P.M.A, 2002).

We give to the participants a picture with all the emotions and the respective facial expression and a list of synonyms of each one (see Appendix A). Although the label of the facial expressions is not important at this moment, we asked the participants to identify also the expression is. We will use this data in next researches. These expressions are classified in octants of the *Circumplex of Emotions created* by Russell (Russell, J.A., 1980). The two orthogonal axes in the Circumplex represent the dimension 'pleasantness' and 'activation'. The bipolar dimension (horizontal) 'pleasantness' ranges from unpleasant (e.g. sad) to pleasant (e.g. happy). The dimension activation (vertical) is defined as physiological arousal, and ranges from calm (e.g melancholy) to excite (e.g. euphoric). Consequently, with these dimensions, expressions can be classified in eight octants.

3.1.2 Participants

We choose as our target group 10 students. They are from different countries and study in different faculties of TUDelft. With the assumption that they have different nationalities we tried to minimize the possible influences of unconscious translation of the expressions from their own-languages, that is, the cultural dependency.

3.1.3 Experimental design

By visual inspection of the fragments we assessed easily classifiable types of facial movements. We don't pay attention to the movements which are requirements of the speech or facial expressions that don't represent an emotion. For example, the eyes' blinking that is inevitable when people talk is not considered as an expression.
Firstly, we use a pilot participant to validate the design of the experiment. This participant is allowed to ask any question or help to the test supervisor during the test. His results won't be used as data for our experiment. Detailed initial instruction for how to perform the tasks are given to the participants. The participants are asked to analyze two fragments (we assigned randomly to the participants two of the ten fragments we have) of the video recording (one of the male's one and the other of the female's one).
They should identify which frames contain facial expressions and extract exactly when the expression starts and the time when it ends. Afterwards, they have to distinguish each expression and assign it a label of the given list. They write down all this information that will be analysed by the experimenter.

3.1.4 Data analysis

For the results of the first experiment, we don't use the labels participants assigned to the facial expressions, because we want to base our analysis on the expressions' appearance and not in the meaning. We analysed if in a specific fragment there is an expression or not. We use the start and end times of the expressions. In order to examine this data, we designed some macros that make the evaluation easy. They allow us to place the times of the facial expressions found by two raters in two parallel timelines, along with another timeline that shows the agreement between the two raters.

Figure 3.1 shows an example, where the red and green colours represent both raters and yellow the agreement between them in 4 fragments.

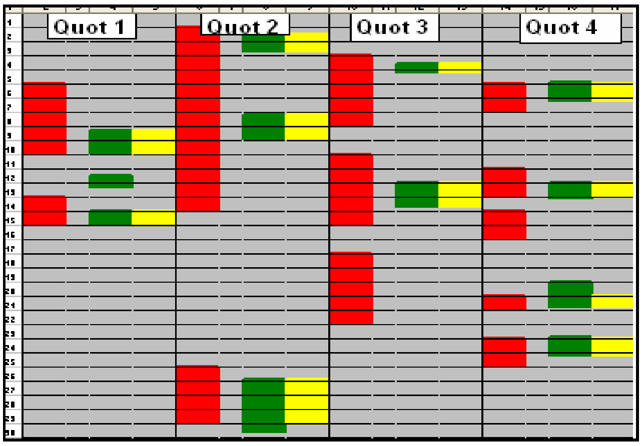


Figure 3.1: Example of timeline agreement

Agreement between raters means that there is overlapping between the frames they found a facial expression. Is not necessary that the start and end times coincide, if there is overlapping between both rater's answers it computes its agreement. If in one selected frame more than one frame is selected in the other rater's solution, like in quot 2 in figure 3.1, the agreement is the number of maximum frames selected. In this case rater 1 (red color) found a long frame while rater 2 (green color) found two different expressions within the long frame, so it counts if two expressions are found by both raters.
According to this, we can calculate the agreement using:

Definition 3.1

$$\rho = \frac{\#\ \text{Expressions found by both raters}}{\#\ \text{Max. expressions found}}$$

For example, in the figure above, the agreement for quot 1 is ρ=2/3=0.67, for quot 2 is ρ=3/3=1, for quot 3 is also ρ=2/3=0.67 and for quot 4 is ρ=4/5=0.8.

3.1.5 Results and conclusions

To conclude consistent results it is necessary to take into account the knowledge background about the field that each rater has. Rater A works knowing the context and the Polish language that is used in the dialogues' original version. Rater B and rater D don't know the text reference as well as the participants in the experiment. Their labelling is based in 41 alias words of Desmet. Rater C used the English translation of the text reference to label the facial expressions.
After evaluation of the agreements between all raters the following table shows the results.

Table 3.1: Agreement between 2 raters (1st approach)

	Rater A	Rater B	Rater C	Rater D	10 participants
Rater A	-	20%	39%	-	-
Rater B	20%	-	39%	75%	42%
Rater C	39%	39%	-	-	-
Rater D	-	75%	-	-	53%
10 participants	-	42%	-	53%	-

Assuming that the analysis of Rater A and Rater C were influenced by the context, i.e., they know the dialogue and they used the text reference, we expect that their results differ from the rest of raters. Rater D and Rater B have a higher agreement due to the fact that they don't know the meaning of the words in the dialogue, and they just examine if there is or not a facial expression. The rates between the 10 participants of our experiment and Rater B or Rater D are lower. The reason of this fact is because each fragment is examined by only one participant. On the contrary, Rater D and Rater B analysed all fragments.
We expect that the values of the agreement increase if we calculate the agreement for each fragment and then the average of all fragments. Finally, we can briefly summarize the results in the table below:

Table 3.2: Agreement between 2 raters (final results)

Rater1	Rater2	Agreement
Rater A	Rater B	20%
Rater A	Rater C	39%
Rater C	Rater B	39%
Rater D	Rater B	75%
Rater D	10 participants	61%
10 participants	Rater B	48%

We can observe that the value of agreements in table 3.2 is slightly higher than in table 3.1. We can conclude that the emotions represented by facial expressions are subjective information. People can interpret the facial movements in different ways. Moreover, it is difficult to analyse a dialogue because we don't know the context. We can confuse the facial expressions with movements that are requirements of the speech (such as open and close the eyes). On the other hand, if we know the context we are influenced by the meaning of the words and not just by the appearance that is the purpose of this part of the thesis. To summarize, the multiples influences people have such as cultural dependency, context background make it difficult to study facial expressions. The human psychology is a wide field difficult to evaluate due to many influences and effects.

3.2 Semantic analysis

In the second part of this study, the words that people use to label the expressions found in the recordings are the starting point in order to build up a database. It is important to collect as many words as possible in order to cover all the situations people could be involved in. This database also has to cover the words people use in these circumstances.

Firstly, we began with a table of all the data compiled from the labelling we had done with the facial expressions of the recordings and the emotional words found in the text reference. This data is organized and set into 17 groups; each one represents an environmentally case. Obviously, the number of situations is extensible as well as the amount of words in it. Nevertheless, we found some drawbacks to build the table. The first one is that when people talk they don't use the words that label their emotions. For example, if a person is happy, he/she is used to explain the cause of happiness without telling literally: *I'm happy.* This kind of words is used in the narrative part of the text, e.g., *he said terrified*. Another problem is that the facial expressions are usually prompted by outside causes, for instance, when the individual reads some words or is stimulated by others' statements. For this reason, we used the text reference of the dialogues. We tried to find the words in the dialogue that could be the trigger for the consequently facial expression. Moreover, the words that people use to convey the conversation have to be included. For example, a facial expression which expresses understanding comes along with an emotional word such as *Oh!, sure, yes.* Having collected as many words as possible from the dialogues we have completed this data using the thesaurus searching synonyms for all the words collected. It was also useful to use the 347 Dutch words used in Desmet's experiments. The cultural dependency influences again in the translation process. There are some words as *forlorn* (translated literally from the Dutch: *vleugellam*) that are not so common in English language, but rather synonyms like *unhappy*, or *lonely* are more common, so we used in our database.

Finally, the following table was completed:

Table 3.3: Words data

Explanation	Words	synonims (thesaurus)	visual thesaurus connection	steamed words
Polite, sociable, greetings, deferent	Pleasantly surprise, kind interest,Halllo? romantic, passionate and tender voice, satisfaction,How are you? Sociable, Would you like…?gladly	appreciating, welll, fit, light-hearted, gentle, humane, bening, good-hearted, cordial, good-natured, good-tempered, sweet-tempered, tender, composed, consideration, attention,courtesy, regard, respect, calm, relax, serene,untroubled, imperturbable	**polite**: civil, courteous, gracious, nice, niceness, politeness, mannerly, well-mannered, gentle, cultivated, cultured, civilised, civilized	pleasantly surprise, kind, satisfy, glad, appreciate, well, fit, gentle, humane, bening, cordial, tender, compose, consider, attention, courteous, regard, respect, calm, relax, serene, untrouble, close, familiar, social, comfortable, appetive, cozy
Surprised with other statement	not feel well, worried,dramatic voice, scared, fear,shivers, as fast as possible, frightened, afraid, nonsense, disability, sick, dying,oh, my god!disgust, horrible scream, terrible, distrurbed,strange noise, crashed dully,annoying	puzzle, confuse, bewildered, fear, appalled, disbelief,afraid, anxious,disturbed,frightened,tense, tormented, troubled,upset, unquiet,absurdity,foolishness,stupidity, stuff,babble, drivel, jabber, jabberwocky, skimble-skamble,moribund,in extremis,expiring	**worried:** disquieted, distressed, disturbed, upset **fear**: regret, awe, veneration, worry,concern, care, dread, fright	unpleasantly surprise, worry ,dramatic, scare, fear, shiver, frighten, afraid, nonsense, disability, sick, dye, disgust, horrible, scream, terrible, distrurb, annoy, confuse, hesitate, puzzle, appall, disbelief, upset, trouble, doubt, disconcert, fierce
disbelief	any problem, disbelief, impossible	distrust,doubt,incredulity,mistrust,scepticism, unbelief,puzzle, confuse, hopeless,unthinkable,intolerable,unacceptable,unreasonable,inadmisible, doubtful, uncertain	**disbelief:** incredulity, skepticism, unbelief, mental rejection	disbelief, incredulous, puzzle, confuse, uncertain, hope, unthinkable, intolerable, unaccepted, unreasonable, inadmisible, doubt, uncertain, impossible
Finally understood	Oh!, under-standing, Sure, to seem clear	accept, comprehend, catch, follow, take in, take, clearly, clear, plain, evident,apparent, palpable,certain, unquestionable, obvious, positive, explicit	**understand**: translate, interpret, read, infer, emphatise, emphatize, sympathise, sympathize, realise, realize, see	accept, comprehend, catch, follow, take in, take, clear, plain, evident, apparent, palpable, certain, unquestionable, obvious, positive, explicit, sure, understand, Oh
Agreement	agree, be possible, right, Ok, yes, true	admit, recognize, accede, consent, yes,coincide, accord,nodded, all right,very good, very well, yes,approved,correct, fine	**agreement**: speech act, concord, arrengement, correspondence, accord, understanding, agree	agree, admit, recognize, accede, consent, coincide, accord, nodd, all right, good, well, yes, approve, correct, fine
Offended	Astonished, speechless	full surprised,stupefy, amazed, astounded, dumbfound, flabbergasted, displeased, discontented,dissapointed,fed up, frustated, unfulfilled, ungratified, unhappy, unsatisfied, upset, humiliated, dazed	**surprised:** stunned, astonished, amazed, astonied, astounded, gobsmacked, goggle-eyed, openmouthed, popeyed, startled, dumbfounded, flabbergasted, stupefied, thunderstruck. Dumnbfounded, jiggered	astonish, full surprise, stupefy, amaze, astound, dumbfound, flabbergast, displeased, discontented,dissapoint ,fed up, frustate, unfulfilled, ungratify, unhappy, unsatisfied, upset, daze, speechless, ofend, insult, humiliate
irritated by one's behaviour	irritated, disturbed, alarmed, indignant, talk nonsense, little menace,dissatisfied, dissapointed	choleric, furious, irascible, irritable, pissed off, angry, annoyed, disturbed, displeased, exasperated, flustered, out of humour	aggraveted, provoked, hot under the collar, incensed, outraged, indignant, umbrageous, irate, ireful, smouldering, smoldering, black, livid, irascible, choleric, wrathful,wroth,angered, enraged, infuriated,maddened, furious, wild	irritate, disturb, alarme, indignant, talk nonsense, dissatisfy, dissapoint,choleric, furious, irascible, pissed off, angry, annoy, displeased, exasperate, flustered, out of humour, hot, provoke, frustate
despair, sadness, isolated, frustated	sad,obstinately refused, compassion, troubled,begged hopelessly,someone crying, voice in tears, feel pity, grimly, don't worry, everything will be all right, isolated,discreetly disregarding the world around him, terrified, infectious	unhappy, depressed, down,gloomy, glum, grieved, misfortune,pain, sorrrow, torment, sufffering,implore, pray,request, petition,supplicate,despairing, desperate, disconsolate, helpless ,melancholy,regret,sad thing, shame, worried, shiver, tremor,alarmed	**desperate**: heroic, do-or-die, dangerous, unsafe, dire, imperative, unfortunate **sad**: sorrowful, distressing, deplorable, lamentable, pitiful, sorry, distressing, melancholy, melancholic, tragicomical, tragicomic, yearning, heavyhearted,wistful	grief, sad,obstinate, refuse, compassion, trouble ,beg hopelessly cry, tears, pity, grimly, worry, isolate, terrify, disease, virus, tremble, depress, mean, eagerly, despair, unhappy, sorrow, deplorable, lamentable, melancholic, tragic, down, pain
Surprised with other statement	all right, pleasantly surprised, good, great, fine, nice, satisfied, fascinated, admiring	satisfactory,favourable,ideal, opportune,appreciating, well, fit, lighthearted, amazed, attracted to,treasure, adore,value,delight in, relaxed,fulfilled, comfortable		all right, pleasantly surprise, good, great, fine, nice, satisfy, fascinate, admire, adore, delught, attract
think one hilarious, funnny, hapiness	darling,well, joyful, happy, tasty, great,funny, laugh, crazy	dear,love,sweetheart,treasured,adorable, agreeably,nicely,happily, successfully,correctly,properly,rightly,suitably, cheerful, glad, gratified, jovial, merry, pleased, over the moon,satisfied, terrific, delicious, appetizing, delectable, flavourful, good	**happy**:euphoric, content, cheerful, contented,bright, elysian,paradisaic, paradisal, elated, joyful, joyous, halcyon, golden, felicity, happiness, glad, blissful, prosperous, laughing, riant, felicitous, blessed **funny**: funnily	happy, funny, joyful, cheerful, great, well, tasty, crazy, euphoric, content, bright, joyous, felicity, glad, prosperous, laugh, comic, hilarious, dear, love, treasured, adorable, nice, success, correct, humor, terrific, merry, jovial, pleased, delicious
getting mock by others	ironically	sarcastic,satirical,mocking, mordacious	**sarcastic**: black, sardonic,grim,mordant,satiric, wry, critical, saturnine, satirical, disrespectful,caustic, remark, irony, sarcasm, satire, barbed, biting, mordacious, nipping, pungent	mock, ironic, sarcastic, satire, mordacious, sarcasm
paying attention, interested	curious, interrupt, what happen?, concentrated	fixate, focus, settle, wonder, fascinated	**curious**: interested, wondering, speculative, questioning, inquisitive, inquiring	curious, interrupt, concentrate, fixate, focus, settle, wonder, fascinate, interest, attention
complaining, disgusted	grumble, disturbed, protest, disgust, contempt	dissaproving-of, disagreement, aversive, despise, alarmed, nervous, irked, aversion, object	**disgust**: nauseate, churn up, sicken, revolt,repel,gross out, dislike, fed up, sick of , tired of	grumble, disturbed, protest, disgust, contempt, disagree, dissapoint, alarme, irked, objext, aversion
inspired		enthusiastic, elate, exhilarate, spirit up, stimulated, excited, fire, devoted, eager, hearty, obsessed, passionate, arden, euphoria, energetic, agitated, impetuous	**inspired**: divine, elysian	enthusiastic, elate, exhilarate, spirit up, stimulate, excite, fire, eager, hearty, obsess, passionate, arden, euphoria, energetic, agitate, impetuous
stimulated		provoke, quicken, energize, vitalize, motivated, move, innerve	**stimulated**: aroused, stirred. stirred up	provoke, quicken, energize, vitalize, motivate, move, innerve, stimulate, arouse, stir
eager		impatient, breathless, anxious, heated, hot, ambitious, intent	**eager**: avid, great, zealous, anxious,dying, impatient,hot, raring, overeager	impatient, anxious, heated, hot, ambitious, intent, eager
bored, sighing		dispirit, tired, covetous, acquisitive, desirous, grabby, grasping, itchy, prehensile, exhausted, fatigued	**bored**: blase, world-weary **sigh**: suspire, sound, suspiration, let loose, utter, let out, emit	dispirit, tire, covetous, acquisitive, desire, grabby, grasping, itchy, prehensile, exhauste, fatigue, sigh, suspire, bored

Chapter 4: Emotion words classification

This chapter describes the work around the development of the 3rd step of the thesis. The purpose of this step is to classify emotional words and plot them into 2D emotion space of pleasure vs. activation (arousal). The classification was based on the meaning of each word and relation between words. The 2D emotion space would then be used to measure the emotion tendency of an utterance both its possible pleasure and activation.

4.1 The Pleasure and Activation Degree of Emotional words

In the English language researchers have reported lists of 200 to 300 words that are used to cover the full range of emotions. The meaning of these words contains a degree of pleasure and a degree of activation. When some of these words are arranged in a sentence, the sentence also contains these degrees of pleasure and activation that appears because of the combination of theses words. On the other hand, humans have inner capability to sense these degrees automatically. We are already equipped through learning process the ability to formulate this type of words in a sentence to express emotion and its degree of activation.
Recent attempts to analyse the degree of pleasure and the degree of activation of emotion words have been done by Russell (Russell, J.A., 1980) and Desmet (Desmet, P.M.A, 2002). Both depict these degrees on 2D space of pleasure vs. activation. Russell used a psychological approach to plot emotion words based on the changing of geometrical features of human expressions when expressing a certain emotion type (see figure 4.1). He claimed that people can use the 2D space to analyse the emotion tendency of each word and their expression in a glance.

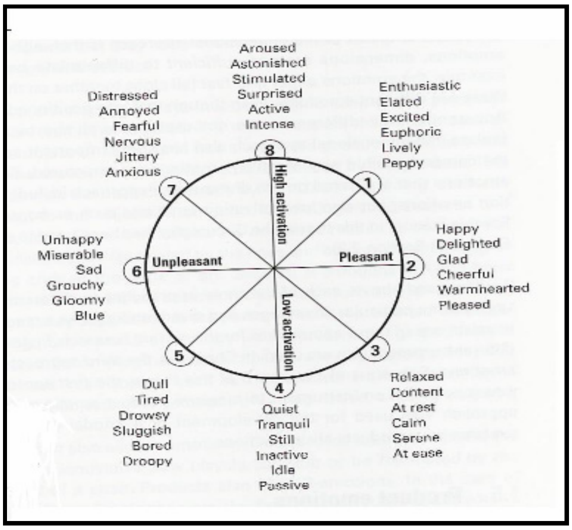


Figure 4.1: Russell's Circumplex of Emotions

Based on Russell's research, Desmet divided the 2D space into eight octants and conducted experiments. He used 347 emotion words (collected from three books (Davitz, J.R., 1969), (Fridja, N.H., 1980), (Ferh, B., 1984)). Trough three experiments he collected 41 emotion words that were not ambiguous. He asked his participants to depict these words on one of the octants (see figure 4.2). Desmet claimed that these emotion words were used by people to express their emotion toward a product. Both researches were performed to analyse quantitative values of emotion words based on the social value that was learnt during interaction with others or objects in daily life. However, for automatic reasoning by human-emotion assessment system, qualitative data would be more efficient. For this purpose, we used the approach of Kamps (Kamps, J. et al., 2002). The following describes our method.

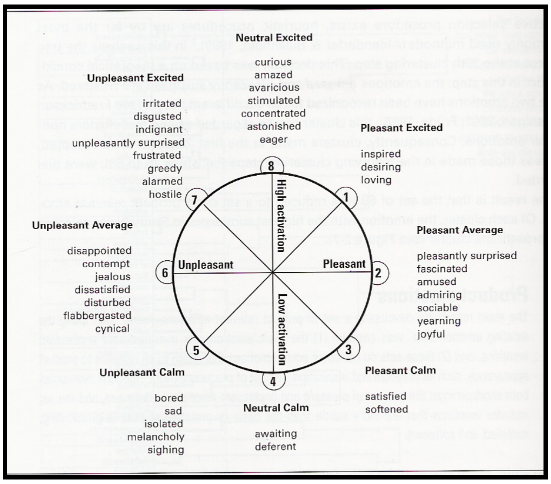


Figure 4.2: Desmet's classification

4.2 EVA experiment

The traditional notion of word meaning used in natural language processing is literal or lexical meaning as used in dictionaries and lexicons. Kamps et al. brought other notions of meaning into natural language processing. In particular, they were interested in the differences between the relatively objective notion of lexical meaning, and more subjective notions of emotive or affective meaning. For this purpose, Wordnet was exploted (Miller, G.A., 1990). Wordnet is a lexical database for the English language organized into synonym sets. It has a differential theory of meaning: the meaning of a concept is determined by its place relative to other concepts. They used the synonymy relation to establish the relatedness. In particular, the synonymy or Synset relation in Wordnet represents the coincidence of lexical meaning. The following are rules that we used to calculate the relatedness value from:

Definition 1: Two words w_0 and w_n are n-related if there exists an (n+1)-long sequence of words $(w_0,w_1\ldots w_n)$ such that for each i from 0 to n-1 the two words w_i and w_{i+1} are in the same Synset (i.e., w_i and w_{i+1} are synonyms).

The distance called MPL is defined as the number of the Synsets there are between the two given words.

Definition 2 Let MPL be a partial function such that $MPL(w_i;w_j) = n$ if n is the smallest number such that w_i and w_j are n-related.

For example, there exists a 5-long sequence {good; sound; heavy; big; bad}. So, we have that MPL(good; bad) = 4.

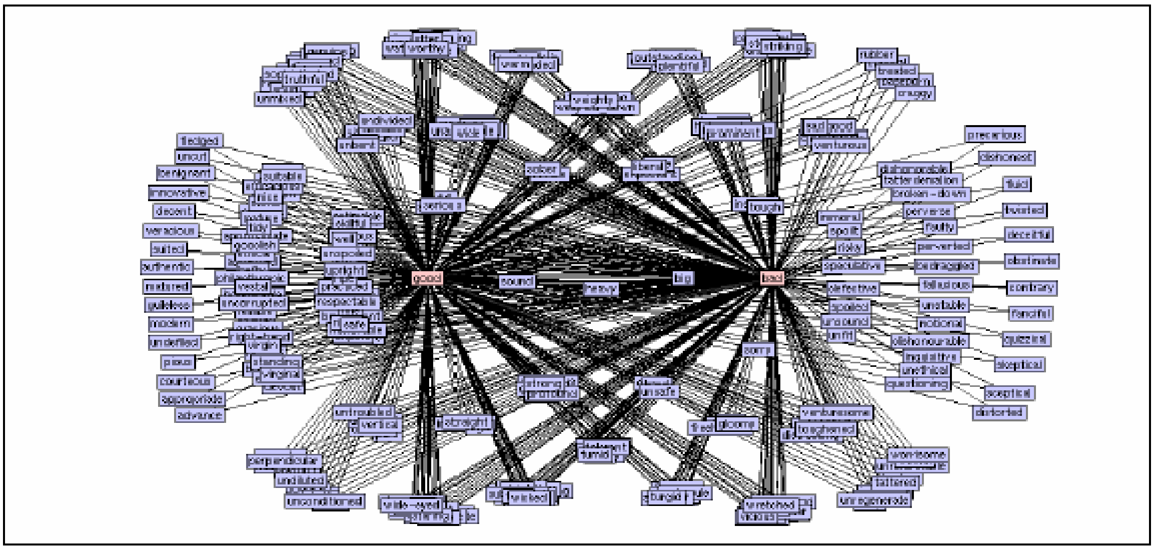


Figure 4.3: MPL of some adjectives to 'bad' and 'good' in Wordnet

For each word, we can consider not only the distance to 'good' but also the shortest distance to the antonym 'bad'. To materialize this impression they defined a three argument function TRI that measures the relative distance of a word to two reference words.

Definition 3:

$$\mathrm{TRI}(w_i; w_j, w_k) = \frac{\mathrm{MPL}(w_i, w_k) - \mathrm{MPL}(w_i, w_j)}{\mathrm{MPL}(w_k, w_j)}$$

Where w_i is the word to be analyzed and w_j and w_k are the reference words.

Kamps claimed that the three major factors of the affective or emotive meaning are the evaluative factor (good-bad), the potency factor (strong-weak) and the activity factor (active-passive). We add the pleasantness factor (pleasant-unpleasant) to our study.

***Definition 4*:**

EVA(w) = TRI(w_i; good; bad)

Every word will be assigned a value ranging from -1 (words on the 'bad' side of the lexicon) to 1 (words on the 'good' side of the lexicon). Values close to 1 are normally used to express positive opinion as values close to -1 to express negative opinions.

In the same way, we can define the function for the potencial factor

Definition 5:

POT(w) = TRI(w_i; strong; weak)

4.2.1 Material

We used the list of emotion words found in the recordings. Since the original dialogue was in Polish, we use both Polish version and the English translation to be sure that these emotion words were used to convey certain facial expressions.
As metioned before, we used Wordnet as our lexical reference system that was inspired by current psycholinguistics theories of human lexical memory.
Particulary to access Wordnet, we used some packages that were written in Perl, such as:

a. The Lingua::Wordnet module developed by Dan Brian .This module provides a library to access and manipulate the Wordnet lexicon. Lingua::Wordnet impersonates the basic Wordnet API functions for searching and retrieving data, as well as adding, editing, and deleting synsets.
b. The Lingua::Wordnet::Analysis developed by Dan Brian .This module provides a library to add numerous high-level extensions to the system.

These modules allow access to the Wordnet lexicon from Perl applications, as well as manipulation and extension of the lexicon. In order to use the modules, the database files must first be converted to Berkeley DB files using the 'scripts/convertdb.pl' file. There are some facts that explain the reason of this conversion. The first one is that data retrieval is faster with the hash lookup than with binary searches.

Moreover, converting databases allows optional manipulation of data, including adding and editing synsets. Developers can use the Wordnet databases without needing to compile the Wordnet API and browsers, allowing Wordnet to run on any Perl/Berkeley DB-capable platform.

Figure 4.4 shows how to perform de lookup function in Wordnet using the Lingua:wordnet facilities.

```
@synsets = $wn->lookup_synset( TEXT, POS [,NUMBER] )

Assigns a list of synset objects (Lingua::Wordnet::Synset). TEXT is the word we are looking for.
POS is word’s type that can be 'n' (noun), 'v' (verb), 'a' (adjective). Without NUMBER,
lookup_synset() will return all matches in POS. NUMBER indicates the sense, that is the entry in
the dictionary.
```

Figure 4.4: Lookup function

Obviously we program the access routines with Perl language. There are around 100 words we have collected that don’t appear in Wordnet database or there isn’t enough information about their synonyms in it. As a complement to the lexical information of Wordnet we use Collins Thesaurus and the Visual Online Thesaurus along with the Desmet classification in octants.

4.2.2 Development and Data Analysis

As explained in chapter 3, we build up a table with emotional words. We decided to use only adjectives for our study in order to obtain more logical and consistent results. For this reason we made a stemming process with all the words we had. Finally, we only used the list of adjectives extracted from the stemmed data. Adjectives modify or elaborate the meaning of other words (like *exquisite* in an *exquisite taste*). The adjectives are of particular interest for determining the semantic orientation of subjective words (Hatzivassiloglou, V. et al., 2000).

In order to classify the data we determined to plot it on different 2D spaces. We used different bipolar dimensions whose ranges are:

- Good-Bad
- Active-Passive
- Strong-Weak
- Pleasant-Unpleasant

Therefore, we have the following combinations:

- Pleasant/Unpleasant vs Active/Passive
- Pleasant/Unpleasant vs Strong/Weak
- Good/Bad vs Active/Passive
- Good/Bad vs Strong/Weak

Figure 4.5 shows the routine code to access the Wordnet and calculate MPL, TRI, EVA, POT using the two packages. These functions return the value of $MPL(w_i)$, $TRI(w_i,p_1,p_2)$, $EVA(w_i,p_1,p_2)$, $POT(w_i,a_1,a_2)$ where p_1=good, p_2=bad, a_1=strong, a_2=weak and w_i= emotion word.

We used ActivePerl to develop this code (see Appendix D for full code).

```
mpl (w1,w2){
  while(sense[i]){
        find the synonyms of the w1;
        push them in stack1;
        i++;
   }
   while(){
       increment mpl counter
       while(elements in stack1){
           if (stack1[i] = =w2){
              return mpl;
              exit;
           }
           else{
              find all synonyms of stack1[i];
              push in stack2 using a mirror_stack and the function optimize to assure
that                                                                          the
words found are different every time;
              i++;
           }

   empty stack1;
   increment mpl counter

       while(elements in stack2){
          if (stack2[i] = =w2){
             return mpl;
             exit;
          }
          else{
              find all synonyms of stack2[i];
              push in stack1 using a mirror_stack and the function optimize to assure
that                                                                          the
words found are different every time;
               i++;
          }
   empty stack2;

      }
   }
}

tri(word,axis1, axis2){
   tri=mpl(word,axis1)-mpl(word, axis2);
   tri_norm=tri/mpl(axis1, axis2);
   return tri_norm;
}

main{
   while(adj.txt ! EOF){
      eva1=tri (adj.txt[i],"good","bad");
      eva2=tri (adj.txt[i],"active","passive");
      eva3=tri (adj.txt[i],"strong","weak");
      eva4=tri (adj.txt[i],"pleasurable","abhorrent");
      print in a outfile (tri.txt) : eva1,eva2,eva3,eva4;
   }
}
```

Figure 4.5: MPL routine

The results of the routine provide us with quantitative values of EVA and POT. Figure 4.6 shows an example of search process in the Wordnet. In this example, ‘weak’ has 10 senses, i.e., 10 entries in a current dictionary. Each one has its own synonyms, because each sense represents a different meaning of the word. It’s is possible that one sense doesn’t have more synonyms than the word itself. Moreover, the word’s definition is also given.

```
The adj weak has 10 senses (first 5 from tagged texts)

1. (15) weak -- (having little physical or spiritual strength; "a weak radio signal"; "a weak link")
2. (4) watery, washy, weak -- (overly diluted; thin and insipid; "washy coffee"; "watery milk"; "weak tea")
3. (3) powerless, weak -- (lacking power)
4. (1) unaccented, light, weak -- (used of vowels or syllables; pronounced with little or no stress; "a syllable that ends in a short vowel is a light syllable"; "a weak stress on the second syllable")
5. (1) fallible, frail, imperfect, weak -- (having the attributes of man as opposed to e.g. divine beings; "I'm only human"; "frail humanity")
6. forceless, unforceful, weak -- (lacking force; feeble; "a forceless argument")
7. decrepit, debile, feeble, infirm, sapless, weak, weakly -- (lacking physical strength or vitality; "a feeble old woman"; "her body looked sapless")
8. weak -- (used of verbs having standard (or regular) inflection)
9. weak -- (lacking physical strength or vigor)
10. effeminate, weak -- (characterized by excessive softness or self-indulgence; "an effeminate civilization")
```

Figure 4.6: Search results in Wordnet

4.2.3 Results and conclusions

We classified 140 English emotional words. These words were extracted from the video recordings using the text reference and the database table (see Appendix B for final list of adjectives).

We found MPL(good,bad)=4 {good, sound, heavy, big, bad}. This finding was similar to Kamps et al. The result for other set are: MPL(strong, weak)=6, MPL(active, passive)=12 and MPL(pleasant, unpleasant)=8. Having observed this metric is it possible to assume that MPL gives a value that fulfills the Euclidean distance definition. It is a non-negative value and is null if and only if $w_1 = w_2$. Moreover, $MPL(w_i,w_j)$ also satisfies the properties below:

i) $MPL(w_i,w_j) = MPL(w_i,w_j)$,
ii) $MPL(w_i,w_j) + MPL(w_j,w_k) \geq MPL(w_i,w_k)$

This fact makes the words classification and their plotting in the space easier. We obtained the EVA and POT results in a text file as the output of the TRI routine. We imported this data to Microsoft Excel in order to managed and plot the results. We plotted the words in 1D and 2D. To evaluate these results we have to take account of the meaning of the function MPL and TRI. For example, even though the adjectives ‘good’ and ‘bad’ have opposite meaning, they are closely related by the synonyms relation.

There exists a 5-long sequence <good, sound, heavy, big, bad>, so MPL(good, bad)=4. Therefore, any word that is related to the adjective 'good' is also related to the adjective 'bad'.
In the calculation process we found two problems:

- Around 100 words were not listed in Wordnet. We used a Thesaurus to find substitute words.
- The word "pleasant" and "unpleasant" were actually not listed in Wordnet, we substitute them using "pleasurable" and "abhorrent".

Therefore, we calculated the following equations:

1. Eva1=TRI($w_{i,}$ good, bad)
2. Eva2=TRI(w_i, active , passive)
3. Eva3=TRI(w_i, strong, weak)
4. Eva4=TRI (w_i, pleasant, unpleasant)

Where w_i is the i^{th} word in the emotion words list.

Figure 4.7 shows the EVA value that depicted word relatedness from "good" to "bad". Figure 4.8 shows the EVA value that depicted word relatedness from "pleasant" to "unpleasant". Figure 4.9 shows the POT value that depicted word relatedness from "strong" to "weak". Figure 4.10 shows the POT value that depicted word relatedness from "active" to "passive". To create 2D emotion space, we depicted the emotion words based on its correlation of (EVA, POT). For example: sad (x,y), excited (x,y) and calm (x,y) where x is the EVA value and POT the y one. Figure 4.11 shows the list of emotion words on eight octants for pleasant-unpleasant and passive-active. Figure 4.12 shows the list of emotion words on eight octants for good-bad and passive –active. For others charts see Appendix C.
When we plotted our data in octants, we noticed that we had 9 octants, that is due to the fact that there are words with a neutral value for both EVA and POT, meaning that they have (0,0) as coordinates. For example, the word "full" has null value for EVA(full, pleasant, unpleasant) and also null value for POT(active, passive), so its coordinates in this 2D space are (0,0).We rejected these words because we considered that they should be classified into one octant, so the coordinates' value is an error. For example "great" must be excluded; because at least the EVA value should be positive, because it conveys a pleasant expression.

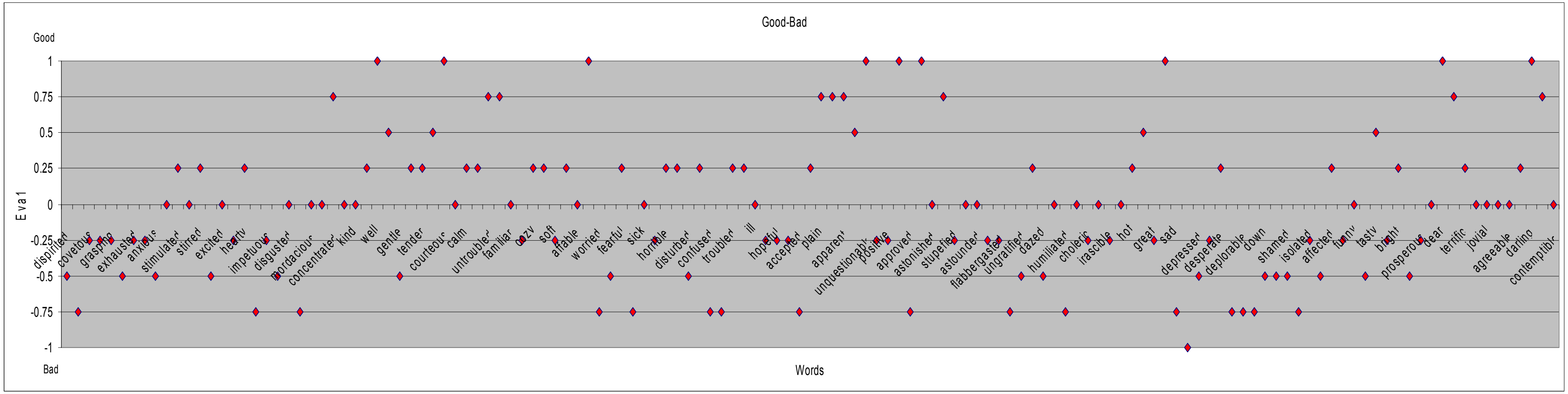


Figure 4.7: EVA related to 'good' and 'bad'

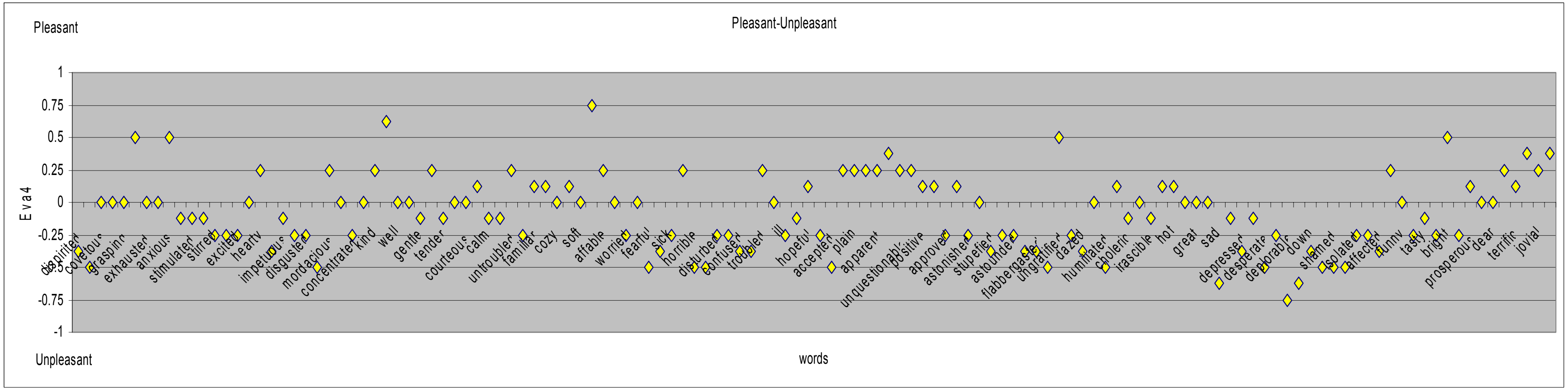


Figure 4.8: EVA related to 'pleasant' and 'unpleasant'

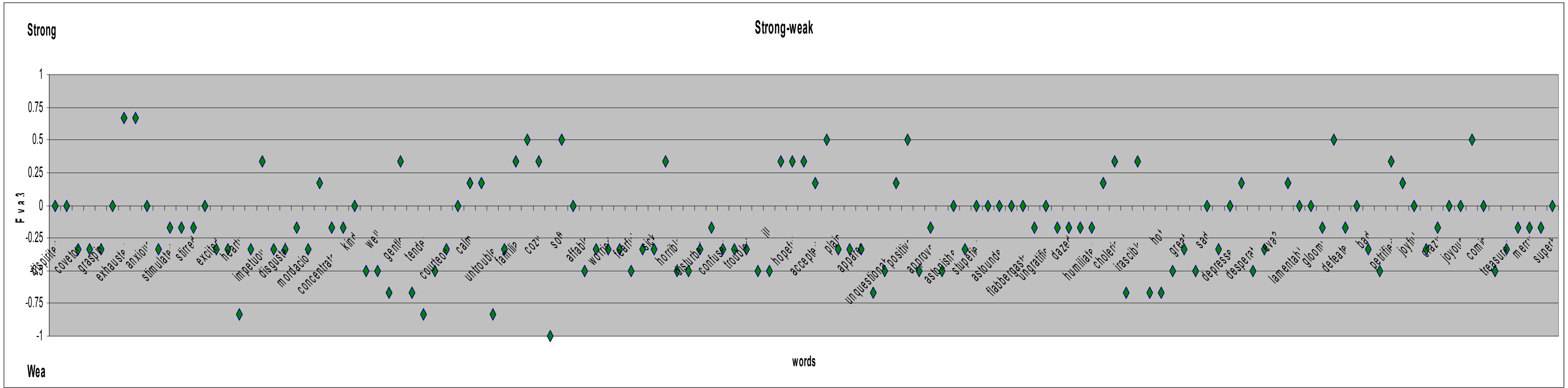


Figure 4.9: POT related to 'strong' and 'weak'

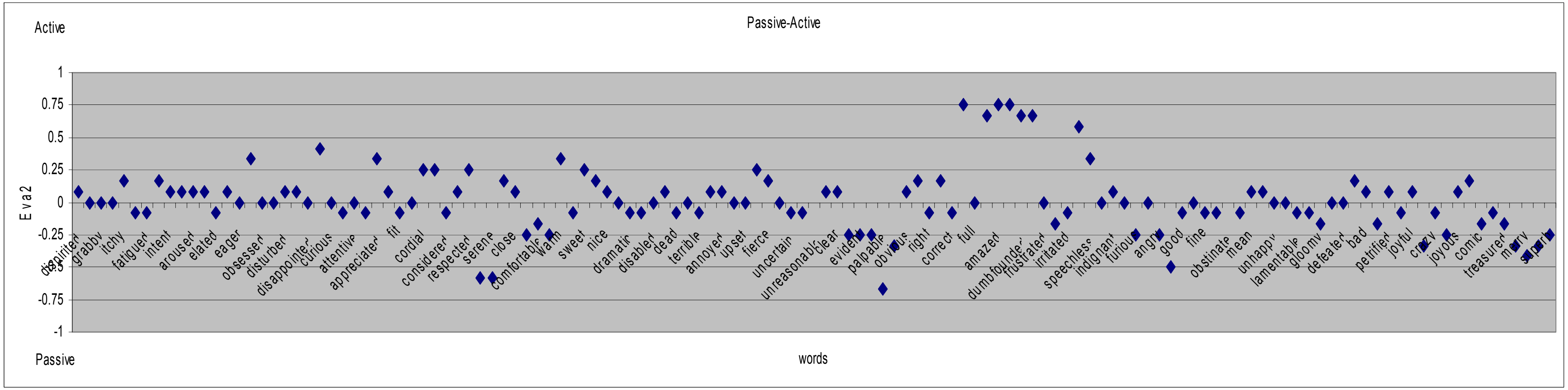


Figure 4.10: POT related to 'active' and 'passive'

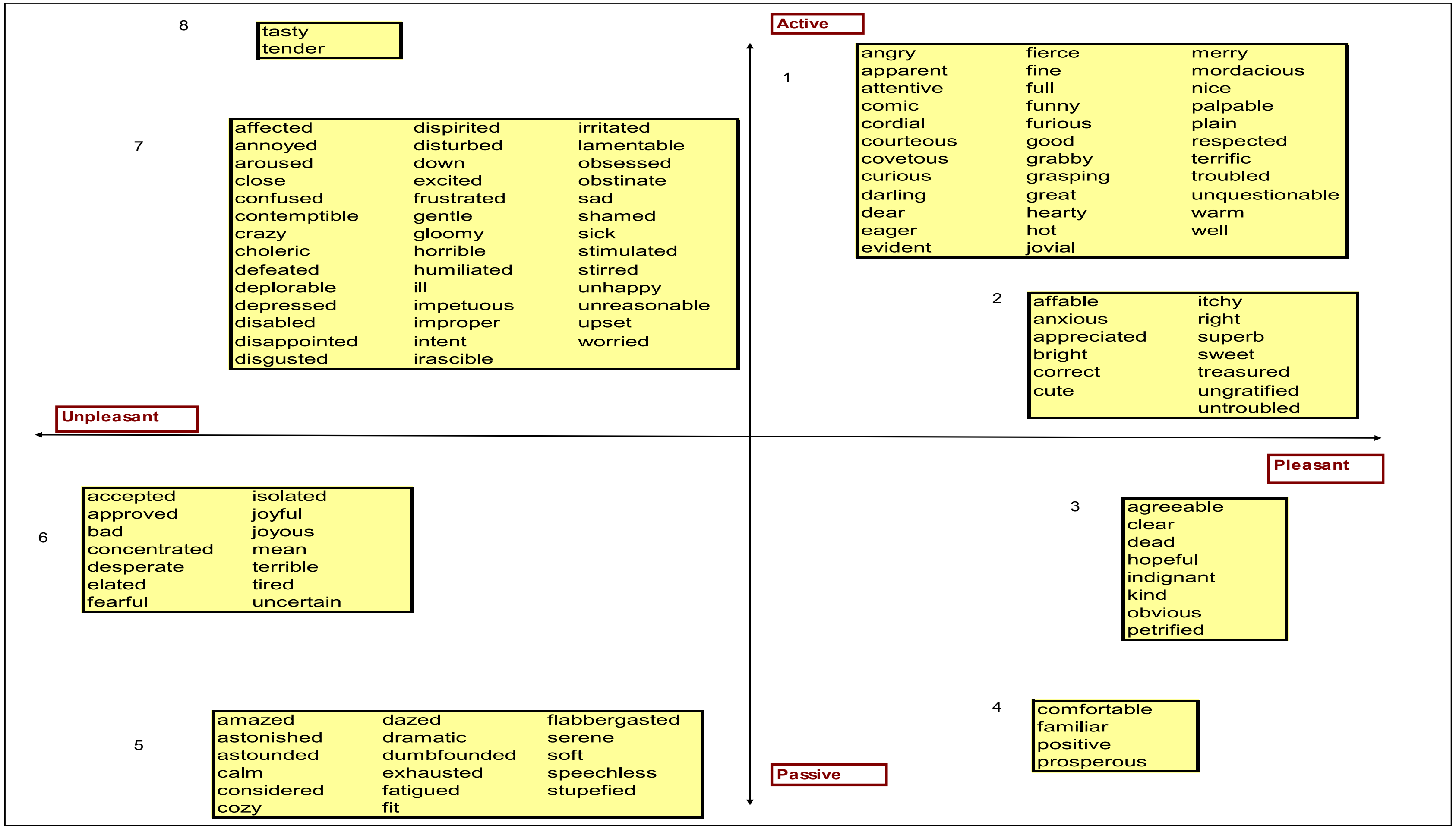


Figure 4.11: Classification in octants related to Pleasure-Activation

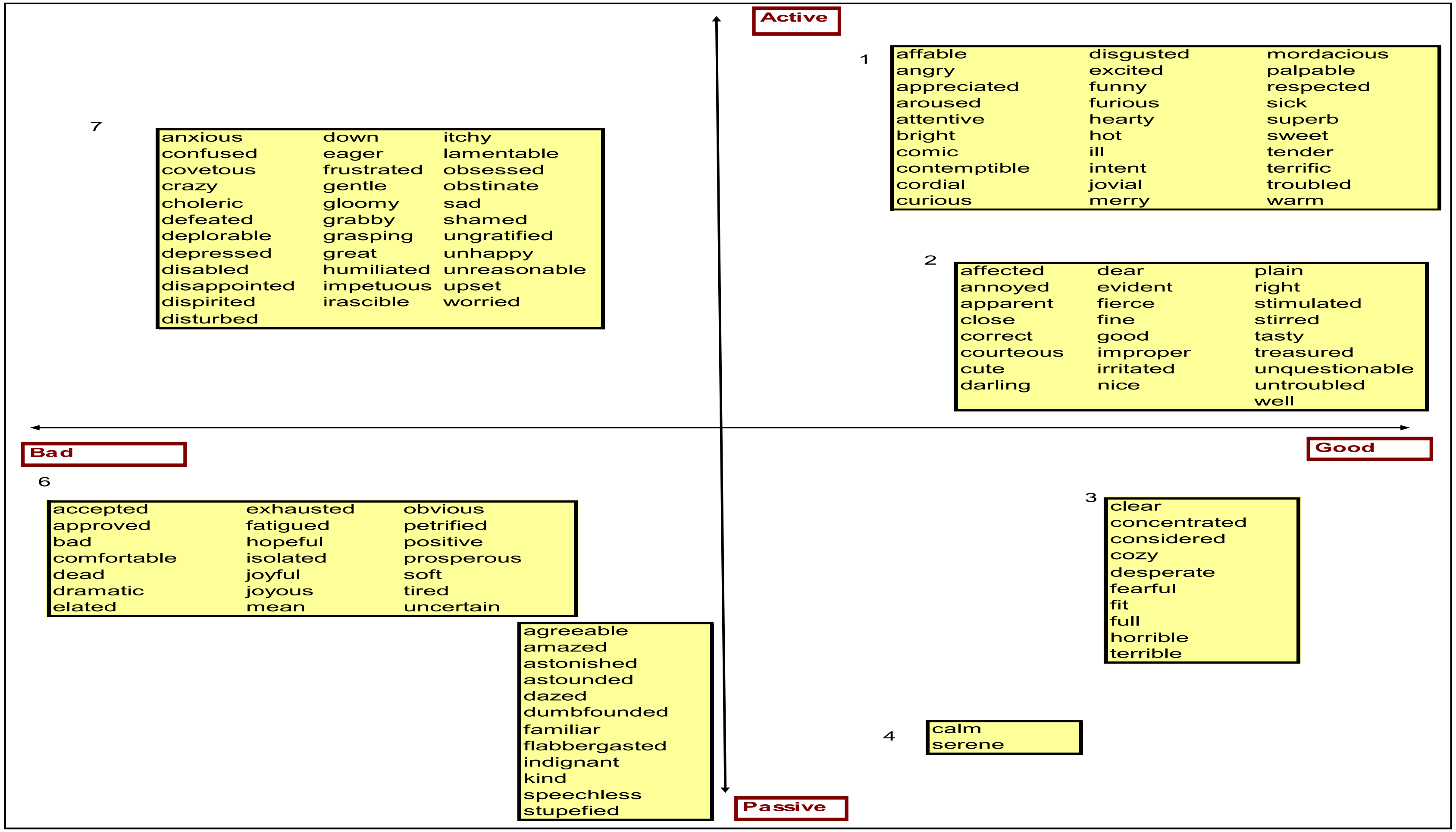


Figure 4.12: Classification in octants related to Goodness-Activation

We found EVA values for some words like “joyful” and “angry” and the POT value for some words like “sad” and “dramatic” were resulted not as we expected. EVA(joyful, good, bad) results negative value and EVA(angry, good, bad) results positive value. POT(sad, active, passive) results positive and POT(dramatic, active, passive) results negative. The idea of MPL suggests that we can use the distance to the word ‘good’ as a measure of ‘goodness’. But it doesn’t claim that the values obtained are a precise scale for measuring degrees of ‘goodness’. We expected a weak relation between the words used to express a positive opinion and their distance to words like ’good’. Table 4.1 shows the percentage of the correct classification versus the incorrect one. In the first part of the table the decision if a word is correct classified or not is based in our subjective judgment. For example, we expected that words like ‘indignant’ or ‘ungratified’ are placed in the pleasant hemisphere, on the contrary, they has a negative x coordinate (EVA value). Certainly, these results are not objective at all, so in the second and third parts of the table they are compared respectively with the previous experiments that Desmet and Russell carried out. But these experiments are also dependent of the people experience or psychological studies. Definitely, when people listen or read one word create an image in their mind classifying if the word inspires pleasure or on the contrary it tends to the idea of pain or unhappiness. It is not possible to conclude that these percentages are strictly consistent.

Table 4.1: Percentages of correct and incorrect classification

1. All emotion words	Number of words	Correct (%)	Incorrect (%)
EVA(w_i , good, bad)	140	72.4%	27.6%
EVA(w_i, pleasant, unpleasant)	140	81.3%	18.7%
POT(w_i , strong, weak)	140	54,5%	45,5%
POT(w_i , active, passive)	140	42,5%	57,5%

2. Emotion words used by Desmet	Number of words	Correct (%)	Incorrect (%)
EVA(w_i,pleasant, unpleasant)	21	71,4%	28,6%
POT(w_i , active, passive)	21	33,3%	66,7%
2D space (Octants)	21	33,3%	66,7%

3. Emotion words used by Russell	Number of words	Correct (%)	Incorrect (%)
EVA(w_i,pleasant, unpleasant)	22	31,8%	68.2%
POT(w_i , active, passive)	22	40,9%	59,1%
2D space (Octants)	22	18,2%	81,8%

The Wordnet structure explained before is a cause that could explain that a word that conveys 'pleasure' like 'joyful', is closer to the concept of 'unpleasure', i.e., MPL(joyful,pleasant)>MPL(joyful, unpleasant). As figure 4.6 shows, each word in Wordnet has different meanings that are used in order to find all the synonyms words has. When the search of a new set of synonyms is performed, the initial meaning of the word is lost. When a string of words is observed we expect look a degradation of the pleasure or activation through the plotting space; but it is not always the effect we see in the charts. Russell explained with his Cirmcumplex of Emotions how the level of activation or pleasure is modified through the octants. It leads a gradual change in the facial features. For example, 'astonished' placed in octant 8 (high activation) is identified by eyes wide open and the mouth as well; looking next octant (number 1) 'euphoric' represents also a high level of activation, the eyes less opened and the lips' contour begin to raise. Finally, in the second octant 'happy' is distinguished by the lips raised at all.

To conclude, the problem is not the Wordnet structure but the idea to use the definition of MPL to measure the distance between emotional words. Although MPL can be applied to the adjectives category in Wordnet, it is unsuitable for determining the semantic orientation of adjectives. The fact that the pairs of adjectives used to measure subjective meaning are directly related by the antonymy relation (such as good and bad) destroys the bipolarity of the concepts we want to study.
Looking at these results we looked for a different technique trying to find more consistent way to perform the 2D-space classification.

4.3 Multidimensional scaling experiment

The Multidimensional Scaling (MDS) is an explorative technique of data that allows us to obtain a representation of n-objects in a k-dimensional space, using information relative to "similarity" (or "dissimilarity) between each couple of objects. Generally it is used to know the similarities (distances) between objects in a space of 2D or 3D. This procedure not organizes the elements in exact way, but finds the configuration that approximates the observed distances in the best way. It uses several iterations that shift the objects to a space of selected dimension minimizing an error criterion.
Below there is an example:
δ_{ij} are the (dis)similarities (distances) between each couple of the n points $x_1,\ldots\ldots,x_n$. The set of the δ_{ij} are included in the data matrix Δ.

$$\Delta = \begin{bmatrix} 0 & & & & \\ \delta_{21} & . & & & \\ . & . & . & & \\ . & & . & . & \\ \delta_{n1} & . & . & \delta_{n,n-1} & 0 \end{bmatrix}$$

Let us call d_{ij} the distances between their images $y_1,\ldots\ldots,y_n$ in the k-dimensional space.

$$d_{ij} = \left\| y_i - y_j \right\|$$

The coordinates of y_i in the space of images (k-dimensional) are: $y_{11},y_{12},\ldots\ldots,y_{1k}$. They are the components of the C matrix:

$$C = \begin{bmatrix} y_{11} & . & . & . & y_{1k} \\ . & & & & . \\ . & & & & . \\ . & & & & . \\ y_{n1} & . & . & . & y_{nk} \end{bmatrix}$$

Now search for the configuration of image points y1,…………,yn that gives to the n(n-1)/2 distances dij a value that is as near as possible to the original distances δij. Usually it is not possible to find a configuration for which dij= δij for all i different from j. To find a convenient configuration among all possibilities, it is necessary to fix an error criterion, often called Stress function.

$$Stress^2 = \frac{\sum_{i<j} (d_{ij} - \delta_{ij})^2}{\sum_{i<j} \delta_{ij}^2}$$

This criterion only considers the distances among the points. It is normalized in such a way that its minimum will be invariant to scale changes. A very good configuration of the $y_1,\ldots\ldots,y_n$ is the one that minimizes the Stress, and it can be find with standard procedures of numerical analysis. Figure 4.13 shows an example to perform MDS from 3 to 2 dimensions.

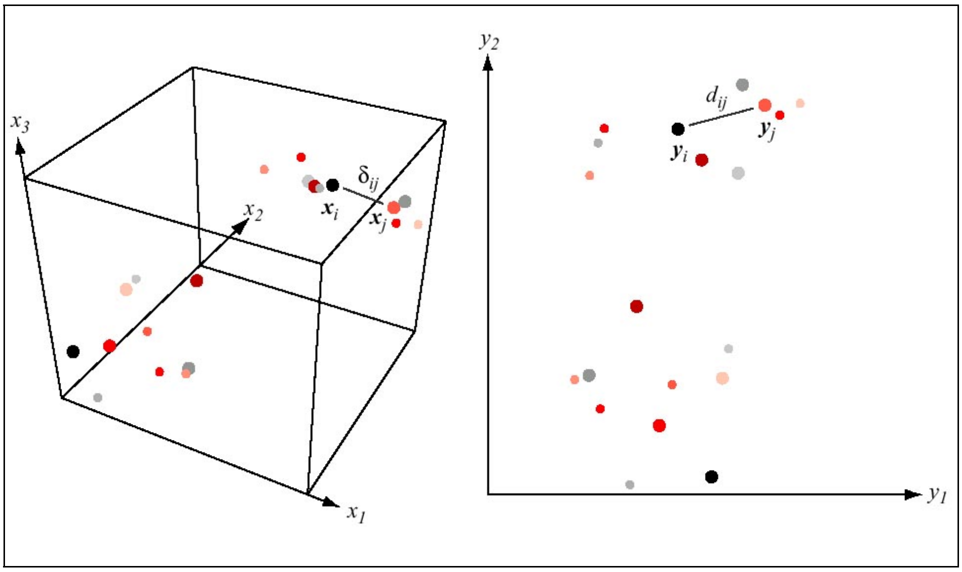


Figure 4.13: Graphic example of MDS

The initial configuration of $y_1,\ldots\ldots,y_n$ can be chosen by chance, or in a more convenient way to reduce the time of computation. Several MDS methods exist, but we use the one called Metric MDS. The distances d_{ij} in the k-dimensional space are connected to the dissimilarities d_{ij} thanks to a linear relation: $d_{ij}=a + b\delta_{ij} + e_{ij}$, and they are Euclidean distances. Data used is often dissimilarities and can be elements of any nature. For each couple of objects we have a measure of their (dis)similarity. The set of these measures forms the D matrix that must be complete and symmetric ($d_{ij}\approx\delta_{ij}$).

4.3.1 Method

As we explain in the previous experiment, the similarly called MPL used by Kamps measure the number of Synsets there is between the two given words. In our previous method we used EVA, a three parameter function to consider the relatedness with two defined words that we called axis words such as ‘pleasant’, ‘unpleasant’, ‘active’ and ‘passive’. We classified the emotion words in a 2D-space using the axis words to define the coordinates’ axes of our plotting. Analysing results, we noticed that some words weren’t correctly classified. We only took into account the relatedness or distance of the analysed word with the axis words, but not with all the words in the space. For this reason we decided to use a new method to plot the words. As starting point we use the MPL definition, but this time we consider this distance with all the 140 words we had collected. We apply the MDS method explained previously to plot all the calculated distances in a 2D-space.

4.3.1.1 Material

Obviously, we use the same list of emotion words used in the EVA experiment (see Appendix B) and the Perl routines to calculate MPL, so we will compare these results with the previous ones. We have the data in Excel sheets, so we decide to use XLSTAT as software for MDS plotting. This analytical and statistical solution for Microsoft Excels offers also the MDS function. The aim of this method is to build a mapping of a series of individuals from a proximities matrix (similarities or dissimilarities) between these individuals. In the ideal case where we have a matrix giving the distances between some points on a surface, the MDS would be able to rebuild exactly the map of the points (within about a symmetry and/or rotation). To build an optimal representation, the MDS algorithm minimizes a criterion called “Stress”.

4.3.2 Development and Data Analysis

Firstly, we run the MPL routine, obtaining the distances between all 140 words using the following main code (the mpl subroutine is the same used in the EVA experiment.)

```
main {
 while (adj.txt ! EOF){
   while (adj2.txt ! EOF){
             mpl=mpl(adj.txt[i],adj2.txt[j]);
             print in a OUTFILE (mpl_allwords.txt): mpl
             j++;
       }
      i++;
  }
 }
```

Figure 4.14: Main code used in MDS routines

We constructed a matrix 140x140 with all the data obtained. Figure 4.15 shows an example with 14 words. As explained before, $MPL(w_i,w_j)=MPL(w_j,w_i)$, that is why the matrix is symmetric. Moreover, the principal diagonal is all zeros, owing that $MPL(w_i,w_i)=0$.
The input to MDS is a square, symmetric 1-mode matrix indicating relationships among a set of items.
A simplified view of the MDS algorithm is as follows:

1) Assign points to arbitrary coordinates in p-dimensional space.
2) Compute Euclidean distances among all pairs of points, to form the C matrix.
3) Compare the C matrix with the input matrix by evaluating the stress function. The smaller the value, the greater the correspondence between the two.
4) Adjust coordinates of each point in the direction that best maximally stress.
5) Repeat steps 2 through 4 until stress won't get any lower.

It is possible to modify the number of iterations we want the model compute, in order to minimize the stress.

	annoyed	angry	bad	disgusted	fearful	good	joyful	sad	strong	weak	pleasurable	abhorrent	passive	active
annoyed	0	7	6	8	5	5	12	6	6	7	9	7	10	9
angry	7	0	6	8	7	6	11	7	4	8	8	9	8	5
bad	6	6	0	7	5	4	9	2	3	5	7	5	7	8
disgusted	8	8	7	0	6	7	11	8	6	8	9	7	10	9
fearful	5	7	5	6	0	4	8	5	4	7	8	4	8	9
good	5	6	4	7	4	0	11	5	2	5	6	6	7	6
joyful	12	11	9	11	8	11	0	10	10	10	13	11	12	13
sad	6	7	2	8	5	5	10	0	5	5	9	4	9	8
strong	6	4	3	6	4	2	10	5	0	6	4	6	7	5
weak	7	8	5	8	7	5	10	5	6	0	6	6	7	8
pleasurable	9	8	7	9	8	6	13	9	4	6	0	8	11	7
abhorrent	7	9	5	7	4	6	11	4	6	6	8	0	10	10
passive	10	8	7	10	8	7	12	9	7	7	11	10	0	12
active	9	5	8	9	9	6	13	8	5	8	7	10	12	0

Figure 4.15: Example of 14x14 MPL matrix

We ran XLSTAT and applied the MDS function to this matrix. First of all, it is necessary to compute the dissimilarity matrix. It is available from the describing data option in XLSTAT. Then we used the analysing data option where we found the MDS function. We choose the "absolute" model that in the final representation makes the distance as close as possible to the initial Euclidean distances.

Figure 4.16 shows the map we obtained. Also we got a table with the coordinates of the words in the 2D space, data that we add to the database.

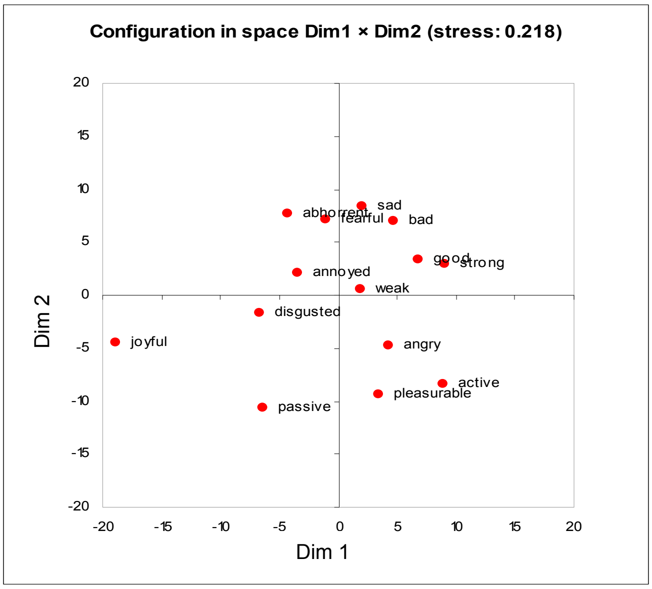


Figure 4.16: Example of MDS map obtained with 14x14 matrix

4.3.3 Results and conclusions

On account of the big amount of data, we analyzed a distribution with a small number of words. We will use the one shown in figures 4.15 and 4.16.

Looking at the distribution obtained, the coordinates' axes can be deduced. Dim 1 represents the activation ranged from passive to active and Dim 2 is the 'pleasure' axis range from 'pleasant' to 'unpleasant' (as explained substituted by their corresponding synonyms 'pleasurable' and 'abhorrent').Theoretically, there are two important things to realize about an MDS map. The first is that the axes are, in themselves, meaningless, but we would like to define them as arousal and pleasantness axes. Then, the analysis would be more consistent without considering the meaning of the axes. We would conclude if the words are well classified looking the set of words around each word. The second is that the orientation of the picture is arbitrary. It is another reason for not using our defined axes. All that matters in an MDS map is which point is close to which others.

Figure 4.17 shows the distances measured in the representation space, i.e., the Euclidian distances between words whose physic representations are coordinates' points.

	annoyed	angry	bad	disgusted	fearful	good	joyful	sad	strong	weak	pleasurable	abhorrent	passive	active
annoyed	0	12,720	10,303	6,738	4,837	11,124	15,223	8,706	13,560	5,910	14,777	6,781	11,775	15,515
angry	12,720	0	11,009	10,861	12,991	7,102	26,548	12,701	7,262	6,931	4,264	15,773	16,694	8,156
bad	10,303	11,009	0	14,468	6,345	4,190	25,174	2,795	5,909	7,662	15,114	7,634	20,867	18,262
disgusted	6,738	10,861	14,468	0	10,928	13,250	16,086	13,936	15,196	7,028	10,865	13,360	6,551	9,989
fearful	4,837	12,991	6,345	10,928	0	8,708	18,915	4,118	11,124	6,510	16,174	2,883	16,539	18,030
good	11,124	7,102	4,190	13,250	8,708	0	26,340	6,550	2,472	6,309	11,336	10,860	19,799	14,872
joyful	15,223	26,548	25,174	16,086	18,915	26,340	0	22,999	28,760	20,629	26,945	18,911	13,363	25,459
sad	8,706	12,701	2,795	13,936	4,118	6,550	22,999	0	8,577	7,834	16,553	4,875	20,032	19,245
strong	13,560	7,262	5,909	15,196	11,124	2,472	28,760	8,577	0	8,466	11,474	13,140	21,703	15,396
weak	5,910	6,931	7,662	7,028	6,510	6,309	20,629	7,834	8,466	0	9,692	9,393	13,569	11,640
pleasurabl	14,777	4,264	15,114	10,865	16,174	11,336	26,945	16,553	11,474	9,692	0	19,046	15,459	4,277
abhorrent	6,781	15,773	7,634	13,360	2,883	10,860	18,911	4,875	13,140	9,393	19,046	0	18,496	20,893
passive	11,775	16,694	20,867	6,551	16,539	19,799	13,363	20,032	21,703	13,569	15,459	18,496	0	12,866
active	15,515	8,156	18,262	9,989	18,030	14,872	25,459	19,245	15,396	11,640	4,277	20,893	12,866	0

Figure 4.17: Distances measured in the representation space

Normally, MDS is used to provide a visual representation of a complex set of relationships that can be scanned at a glance. In our study we expect find a 2D-space to classify words according to two dimensions described. However, the best possible configuration in two dimensions is poor and highly distorted representation. If so, this will be reflected in a high stress value. To solve it, we should increase the number of dimensions, but we would lose the aim of our classification.

As detailed before, the MDS model doesn't give the exact space configuration. If we try to plot N dimensions in a 2D-space, in fact we won't obtain the real image but the projection of the distribution in two dimensions.

Figure 4.18 shows the ideal distances calculated using the model (disparities). In this case of absolute model, the disparities are equal than the dissimilarities.

	annoyed	angry	bad	disgusted	fearful	good	joyful	sad	strong	weak	pleasurable	abhorrent	passive	active
annoyed	0	11,619	11,446	11,874	9,539	10,344	21,448	10,392	12,689	11,358	14,000	10,677	15,843	14,560
angry	11,619	0	12,166	12,728	12,884	11,045	21,656	12,923	10,296	12,728	12,689	14,799	14,765	9,327
bad	11,446	12,166	0	13,856	8,485	7,348	23,601	5,000	7,616	9,055	14,866	9,849	16,733	16,643
disgusted	11,874	12,728	13,856	0	11,489	13,638	19,157	13,601	14,213	12,961	13,675	11,446	15,297	14,318
fearful	9,539	12,884	8,485	11,489	0	8,367	21,424	8,775	9,592	11,225	15,264	8,062	16,673	17,117
good	10,344	11,045	7,348	13,638	8,367	0	25,199	9,434	4,690	9,487	12,923	11,533	16,852	14,387
joyful	21,448	21,656	23,601	19,157	21,424	25,199	0	22,450	26,058	21,471	22,091	21,213	18,628	22,000
sad	10,392	12,923	5,000	13,601	8,775	9,434	22,450	0	10,817	9,110	15,492	7,616	17,000	16,186
strong	12,689	10,296	7,616	14,213	9,592	4,690	26,058	10,817	0	11,314	12,767	13,077	18,385	14,387
weak	11,358	12,728	9,055	12,961	11,225	9,487	21,471	9,110	11,314	0	11,533	10,149	14,071	14,731
pleasurable	14,000	12,689	14,866	13,675	15,264	12,923	22,091	15,492	12,767	11,533	0	14,142	16,882	10,954
abhorrent	10,677	14,799	9,849	11,446	8,062	11,533	21,213	7,616	13,077	10,149	14,142	0	16,763	16,971
passive	15,843	14,765	16,733	15,297	16,673	16,852	18,628	17,000	18,385	14,071	16,882	16,763	0	18,028
active	14,560	9,327	16,643	14,318	17,117	14,387	22,000	16,186	14,387	14,731	10,954	16,971	18,028	0

Figure 4.18: Ideal distances

Figure 4.19 shows the residual distances, that is the subtraction of the distance measured minus the ideal distance. Obviously, if the number of dimension is increased, the residual distances decrease. To understand this point is better to see figure 4.20 that illustrates the Stress function.

	annoyed	angry	bad	disgusted	fearful	good	joyful	sad	strong	weak	pleasurable	abhorrent	passive	active
annoyed	0	1,101	-1,142	-5,136	-4,703	0,780	-6,224	-1,687	0,872	-5,448	0,777	-3,896	-4,068	0,954
angry	1,101	0	-1,157	-1,867	0,107	-3,943	4,892	-0,222	-3,034	-5,797	-8,425	0,974	1,929	-1,171
bad	-1,142	-1,157	0	0,612	-2,140	-3,159	1,573	-2,205	-1,707	-1,393	0,248	-2,215	4,134	1,618
disgusted	-5,136	-1,867	0,612	0	-0,561	-0,388	-3,071	0,334	0,983	-5,933	-2,810	1,914	-8,746	-4,329
fearful	-4,703	0,107	-2,140	-0,561	0	0,342	-2,509	-4,657	1,533	-4,715	0,910	-5,179	-0,135	0,913
good	0,780	-3,943	-3,159	-0,388	0,342	0	1,141	-2,884	-2,218	-3,177	-1,587	-0,672	2,947	0,484
joyful	-6,224	4,892	1,573	-3,071	-2,509	1,141	0	0,549	2,703	-0,842	4,855	-2,303	-5,264	3,459
sad	-1,687	-0,222	-2,205	0,334	-4,657	-2,884	0,549	0	-2,239	-1,277	1,061	-2,740	3,032	3,059
strong	0,872	-3,034	-1,707	0,983	1,533	-2,218	2,703	-2,239	0	-2,848	-1,293	0,063	3,318	1,008
weak	-5,448	-5,797	-1,393	-5,933	-4,715	-3,177	-0,842	-1,277	-2,848	0	-1,840	-0,756	-0,502	-3,090
pleasurable	0,777	-8,425	0,248	-2,810	0,910	-1,587	4,855	1,061	-1,293	-1,840	0	4,904	-1,422	-6,677
abhorrent	-3,896	0,974	-2,215	1,914	-5,179	-0,672	-2,303	-2,740	0,063	-0,756	4,904	0	1,733	3,922
passive	-4,068	1,929	4,134	-8,746	-0,135	2,947	-5,264	3,032	3,318	-0,502	-1,422	1,733	0	-5,162
active	0,954	-1,171	1,618	-4,329	0,913	0,484	3,459	3,059	1,008	-3,090	-6,677	3,922	-5,162	0

Figure 4.19: Residual distances

The degree of correspondence between the distances among points implied by MDS map and the input matrix is measured by the *stress* function. Thus, the smallest stress leads the best representation. The stress function used in our model is called *"Kruskal Stress -1"*. The distortions may be spread out over all pair wise relationships, or concentrated in just a few pairs. In general, however, longer distances tend to be more accurate than shorter distances, so larger patterns are still visible even when stress is high.

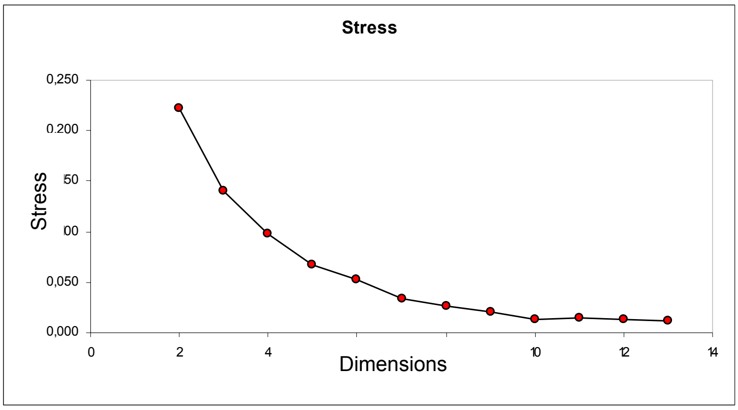


Figure 4.20: Stress function

There are two things to look for in interpreting an MDS picture: clusters and dimensions. Clusters are groups of items that are closer to each other than to other items. For instance, in figure 4.21 we select 'abhorrent', 'fearful', 'sad', 'annoyed' and 'disgusted' as a cluster. Thus, using this cluster we can analyze each word on it. When really tight, highly separated clusters occur in perceptual data, it may suggest that each cluster is a domain or sub-domain which should be analyzed individually. It is especially important to realize that any relationships observed within such a cluster, such as item *a* being slightly closer to item *b* than to *c* should not be trusted because the exact placement of items within a tight cluster has little effect on overall stress and so may be quite arbitrary. Consequently, it makes sense to extract the sub-matrix corresponding to a given cluster and re-run the MDS on the sub-matrix. Therefore, we decided to compute each word of the 140 with the basic and axis words, obtaining a 14x14 sub-matrix that can be compared with the EVA's results as shown in the example. But, having re-run it, we still observed inconsistent results. The following figure 4.21 shows this effect. The word "good" is not correctly classified due to it is placed near words like "bad", "sad" or "angry" that have contrary meaning.

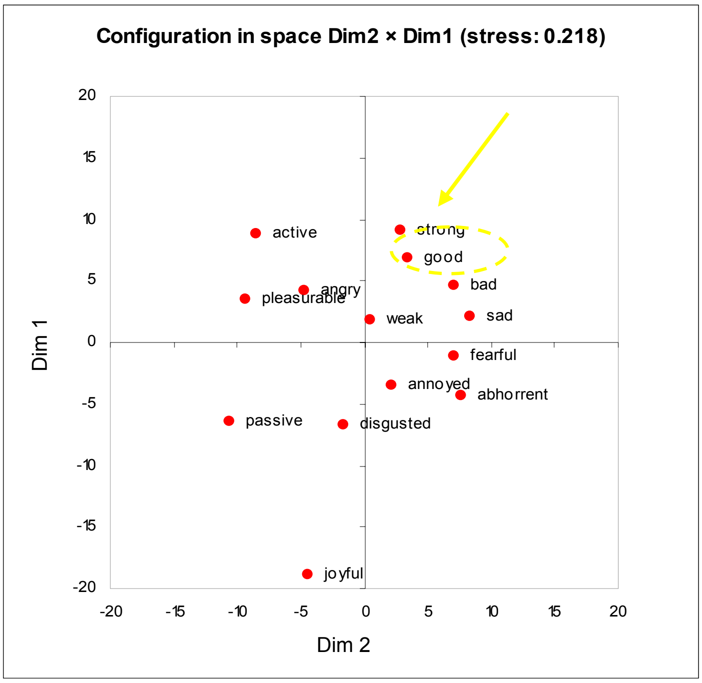


Figure 4.21: Error in classification

The implicit model of how similarity judgments are produced by the brain is that items, the words in our case, have attributes such as activation, potency, pleasure in varying degrees, and the similarity between items is a function of their similarity in scores across all attributes. This function is often conceived of as a weighted sum of the similarity across each attribute, where the weights reflect the importance or saliency of the attribute. It is important to realize that these substantive dimensions called attributes need not correspond in number or direction to the mathematical dimensions (axes) that define the vector space (MDS map). For example, the number of dimensions used by respondents to generate similarities may be much larger than the number of mathematical dimensions needed to reproduce the observed pattern. This is because the mathematical dimensions are necessarily orthogonal (perpendicular), and therefore maximally efficient. In contrast, the human dimensions, while cognitively distinct, may be highly correlated and therefore contain some redundant information.

Figure 4.22 shows the MDS analysis of the 140 adjectives including basic emotions (sad, joyful, angry, disgusted and fearful) and the axis words (good, bad, pleasant, unpleasant, strong, weak, active and passive).

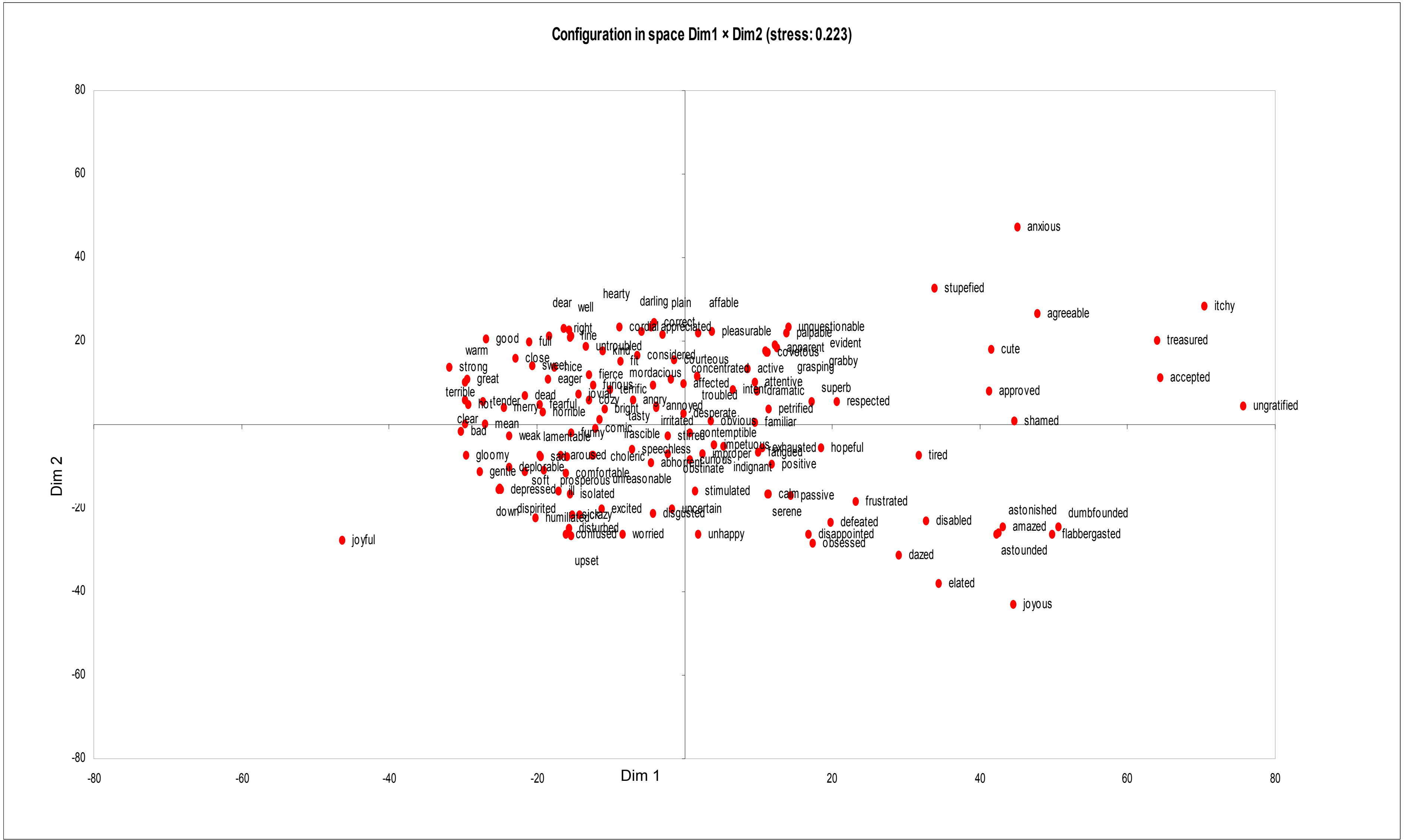


Figure 4.22: 140x140 MDS mapping

Due to being difficult analyzed this amount of data, we choose the most relevant words to make the evaluation easier. We reduced the number of words to 52 based on the words Russell and Desmet analyzed. Figure 4.23 the matrix with the MPL data between these 52 words. The yellow circles drawn indicate some clusters of words. We can conclude that these set of words are well classified due to the similarity of meaning between the words on it. Let's go to analyzed particularly each cluster. For example, cluster 1 represents a neutral excited state as octant 1 in Desmet or Russell classification with words as 'astonished'. On the contrary, cluster 3 indicates low activation, i.e., a calm state such as 'calm' and 'serene'. Cluster 4 and 5 characterise the unpleasant neutral cases as octant 6 in the previous experiments where words like 'sad', 'isolated' or 'dipirited' are placed. Cluster 6 represents the unpleasant excited category where obviously we find 'angry' or 'irritated'. In this classification, 'joyful' is correct placed because its closest word is 'elated' that also indicates pleasant excitation. Words like 'indignant' aren't correct classified, given that the closer words are 'familiar' and 'curious'.
In conclusion, best results are obtained if the number of words are decreased due to the number of dimensions avoided is smaller. It is also important to compute MDS with words that have similar attributes. For instance, in the 52x52 matrix all the words describe emotions or emotional situations. However, in the 140x140 matrix, words that people use in the speech to convey their emotion are included such as 'nice', 'good', 'dramatic' or 'funny'. Dividing the words to compute in two groups (one with words that express emotions and the other including words found in speech) the classification would improve.

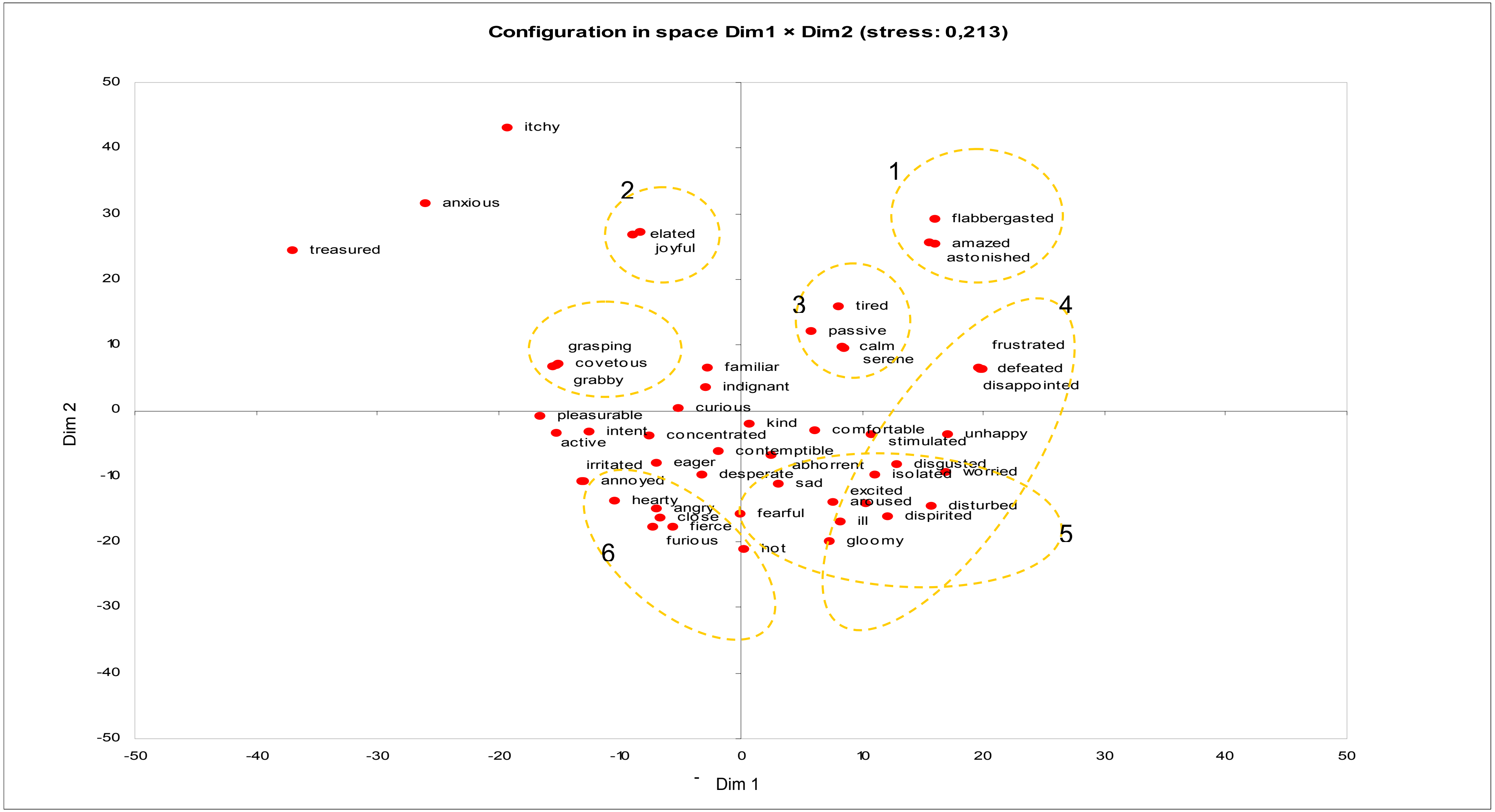


Figure 4.23 : 52x52 MDS mapping

Chapter 5: System design

This chapter describes the global system design of ASL. The purpose of this step is to work around the system implementation based in all the experiments done before. This system must be able to manipulate the data we had collected and receive new data to analyze it.

5.1 Requirements

Firstly, ASL has to be easily manageable not only because general public can use it but also it will be modified and extended in future work. Furthermore, we could use the results of this work to accomplish the restriction about the labelling process in FED as explained in chapter 1. The main requirements are:

- *Adaptability*: As a proof of concept, the techniques we use to implement the system can be improved and substituted by more sophisticated ones. Therefore, the system is set up modularly, so future improvements can be implemented quite easy.

- *Extendibility*: It is possible that certain additions will be made to our system. Additional modules to manage data and new techniques to analyse it could be implemented later. Obviously for this reason we need again a modular design. Dependencies between the different modules and their codes have to be minimized.

- *Accessibility to Wordnet*: The system must access easy to this database. The Perl scripts and its correspondent executable in the main system accomplish this task.

5.2 Global design

ASL receives a text as input and must be able to add emotion pictures ("smileys") on it automatically. Figure 5.1 shows the conceptual schema. Figure 5.2 shows the global design of this system.

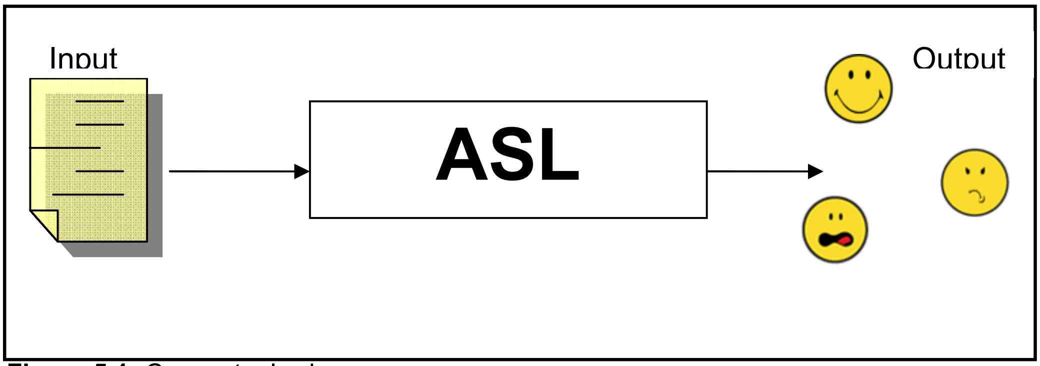


Figure 5.1: Conceptual schema

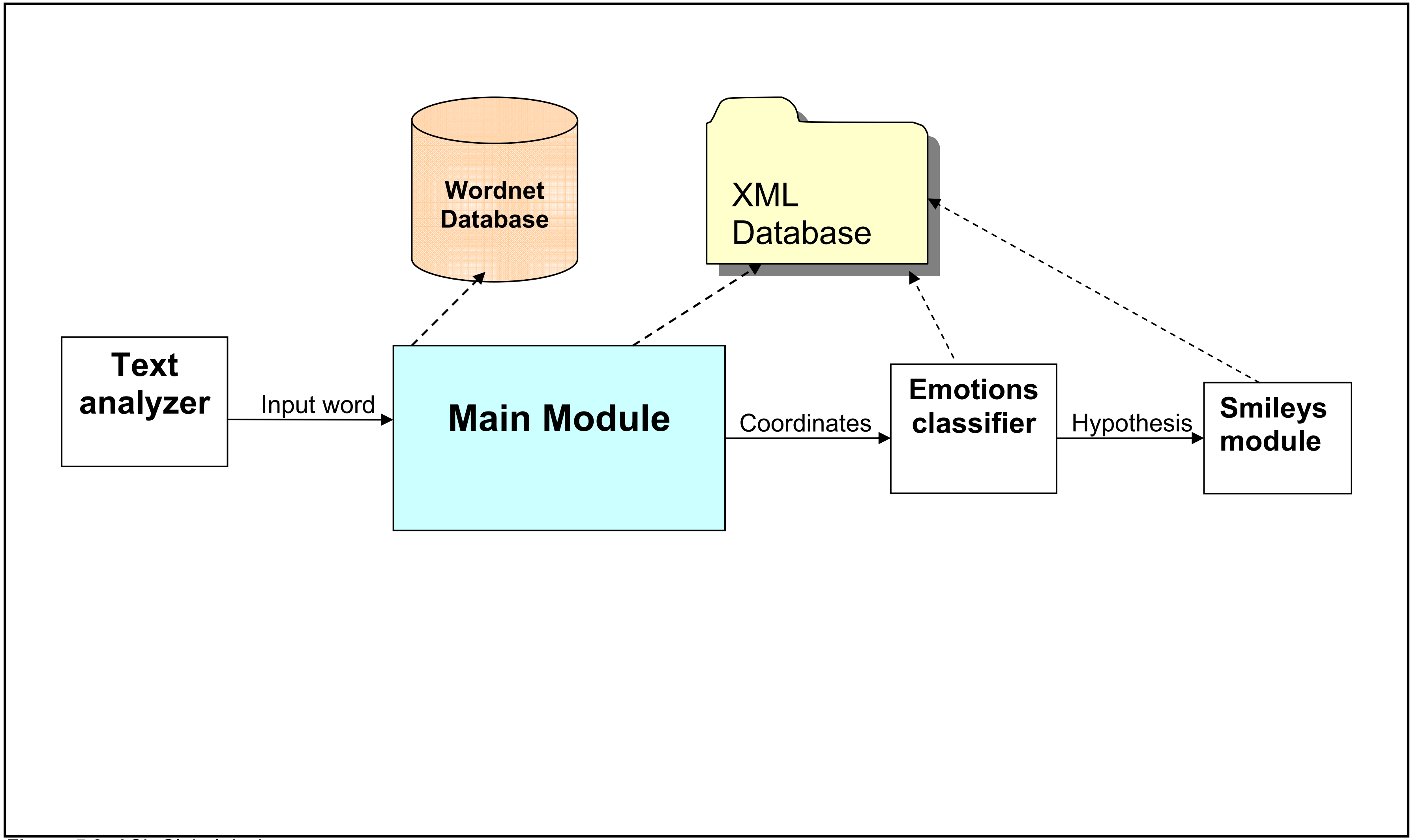


Figure 5.2: ASL Global design

The individual components are described in the following sections.

5.2.1 Text analyzer

Text analyzer checks the input text ASL receives. Firstly, this module read trough the whole text and has to decide which words have to be selected as emotional words. These words will be the input for the main module. This selection is based in different kinds of evaluations. On one hand, the morphologic analysis determines the grammatical category of each word, i.e., to know if a word is a verb, noun, adjective... On the other hand the syntactic resolves the word function within the sentence, for instance, the function of the adjectives is to complement the nouns. Moreover, it is important to make a stemming process to have an overview of all forms a word can appear in, such as verbs in past participle, third person, infinitive…In this first implementation, ASL is only capable to manage adjectives, so the text analyzer has only to choose the adjectives from the text. Finally, the system outputs the selected words. Figure 5.3 shows how text analyzer works. It receives the fragment and extracts the adjectives found that will be the input for the next module.

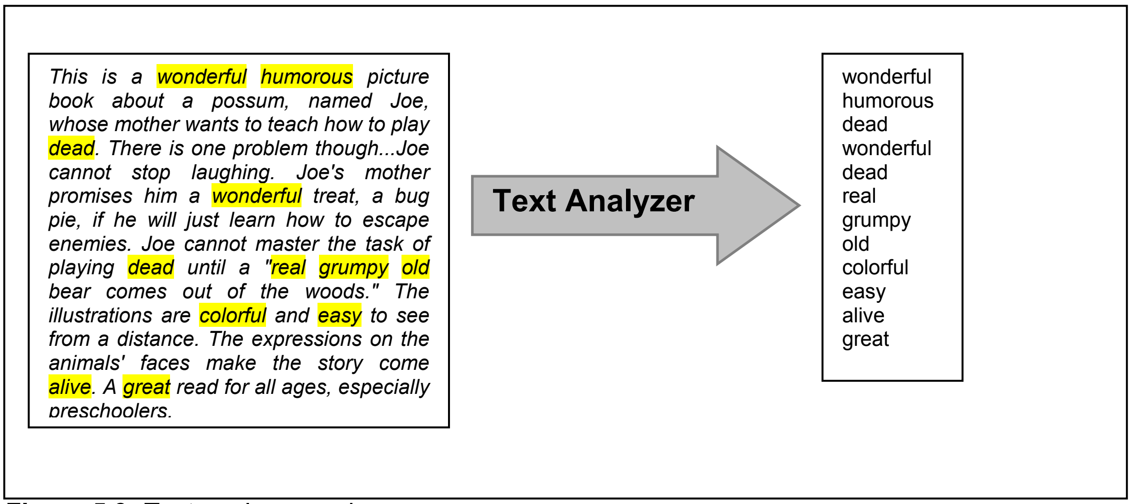


Figure 5.3: Text analyzer work

To design this system individually we will use the work of our colleague Chen, J. (Chen, J., 2005). Her developed system receives text with a single or multiple sentences and analyzes it to capture emotive information. To select the words from the input text this system use Natural Language Processing (NPL). NPL works as a parser, i.e., a computer routine that analyses the input sentence and extracts a meaning of the sentence as output. The system uses this parser to extract words or phrases that corresponds to one or more emotion types.

5.2.2 Main module

Visual Basic is used to implement the main module. We created a Windows application in order to make user interaction easier. Therefore, we can use this module as individual and also as an executable whose input is the text analyzer's output.

To be sure that EVA's results are as expected, in this first version of ASL user should introduce two inputs. One is, of course, the word should be analyzed and the other is a first hypothesis about how the user would classify this word, for example if it is pleasant or unpleasant, active or passive. Afterwards, in next versions this hypothesis should be avoided and ASL should be capable of calculate good results without the user's subjective help.
To begin the analysis, the system check if it's a new word or it exists in our XML data. If it exists, the output given is the data we have in the XML document. The hard work is when the input is a new word, then we have 2 techniques that the global system combines to make the hypothesis. This single system gives two kinds of coordinates to the emotion analyzer. The system works in both cases as follows:

1. EVA: (see chapter 4). The system call the MPL executable in order to calculate the distances below:
    - MPL(word, hypothesis_axis1)
    - MPL(word, contrary_axis1)

    - MPL(word, hypothesis_axis2)
    - MPL(word, contrary_axis2)

    Then, system compares each couple of MPL that is, making the following question:
    Is MPL(word, hypothesis_axis1) < MPL(word, contrary_axis1) ?
    If the answer is yes the system can continue with the EVA calculations. However if the answer is no, it means that the user hypothesis is not correct, so the system warns to the user if he/she wants to carry on with EVA or prefers change his/her initial hypothesis. Then, EVA is calculated based in its definition and the MPL values that the executable returns. So, we have EVA1 that represents the coordinate in the horizontal axis ranged from pleasant to unpleasant and EVA2 that represents the coordinate in the second axis that express activation, ranged from active to passive. The coordinate point that is defined as (EVA1,EVA2) is the output of the first technique.

2. MDS: (see chapter 4). The system calls the XLSTAT Tool as an executable. Creating a matrix 14x14 (word, 5 basic emotion words and 8 axis words) this analytic tool calculates the coordinates based in the dissimilarities between the words as explained in the previous chapter. Every time the input word is changed, the matrix is created as new one and therefore the results will be different. For this reason, MDS not only gives the coordinates for the word but also the coordinates of the other 13 words.

The output of the main system is on one hand the EVA coordinates and in the other hand MDS coordinates.
Moreover, we have also other options in the windows application. We can save the results in the XML files or look up the data we have already. The system can also show the charts with all the words classified or a new chart including the new input word.

5.2.3 Wordnet database

As we have explained in previous sections, Wordnet is a lexical database for the English language. We access this database to calculate some parameters that we need to conclude the correspondent hypothesis. It could be substituted by any database that keeps the same structure as Wordnet.

5.2.4 XML Database

5.2.4.1 XML

XML was created in order to use structured documents over the web. The only viable alternatives, HTML and SGML, are not practical for this purpose. HTML comes bound with a set of semantics and does not provide arbitrary structure. SGML provides arbitrary structure, but is too difficult to implement just for a web browser. Full SGML systems solve large, complex problems that justify their expense.
Users must be able to view XML documents as quickly and easily as HTML documents. XML is also useful to supply a wide variety of diverse applications: authoring, browsing, content analysis, etc. XML are easy to create, it must be possible to create XML documents in different ways: directly in a text editor, with simple shell and Perl scripts, etc...

XML documents should be human-legible and reasonably clear. If there isn't available an XML browser, it ought to be readable in a text editor and understand the content meaning.

5.2.4.2 Dataset

In ASL the Dataset is used to access XML Data. `DataSet` instance represents an entire database, including the ability to track changes made to individual data elements and to persist them to the underlying database when necessary. The `DataSet` can maintain its state while disconnected from the actual database. The DataSet can be used to build a data model without writing any SQL. It can also be used to persist the data model to an XML Schema or to read an existing XML Schema and dynamically build the data model. The DataSet can also read and write its data to XML.

5.2.4.3 Data

We stored all the data we have in XML files. We decide to use this language given that is accessible from all kinds of programming languages and applications. It is a flexible language and this documents .xml can be read and written from JAVA, Visual Basic, and also Microsoft Excel that are the languages we used in the global implementation.
If the input of the main module is a word that is already analyzed, to execute all the scripts is not necessary; you can resolve the hypothesis looking in the XML files. (See Appendix E for files). We have 4 types of documents .xml:

a) Words.xml: This file collects information about the 140 words we analyzed such as the stemming forms, the MPL with the basic emotions and MPL with the words we use like axes.

b) EVA.xml: This file collects information of the EVA coordinates to plot the 140 words in the 4 different 2D spaces we have defined such as activation-goodness, activation-pleasure, potency-goodness and potency-pleasure
c) MDSbasic_matrix.xml: This file collects the MDS coordinates for each word with the basic and axis words. We calculated a 14x14 matrix with every word and we ran the MDS obtaining this 2D- coordinates.
d) MDS_140matrix.xml: This files collects the MDS coordinates for all the words obtained from processing MDS with all the words we have,(140x140 matrix).
e) Smileys.xml: This file contains the smileys we will use to substitute the words in the text. The information this file gives is the label of the emoticon and the path where it is stored.

5.2.5 Emotions classifier

This module should calculate the distances between the word analyzed and the basic emotions using the coordinates it has as input. The output would be a hypothesis about the word's classification. To calculate the minimum distance, it has to take into account only the words within the same octant. Figure 5.4 shows an example where the word analyzed is "cheerful". The distance between sad and this word is smaller than the distance with joyful. But the final hypothesis should be joyful instead of sad which has the minimum distance. For this reason we only consider the distances between the words in the same octant.

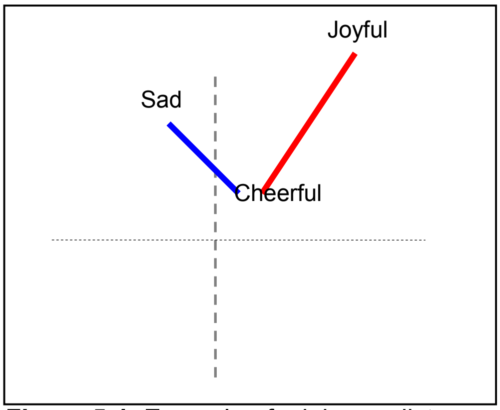


Figure 5.4: Example of minimum distance assignation

We can use the approach of Chen,J. (Chen, J., 2005). The system contains a database that stores emotion types and their corresponding smileys. The emotions are categorized by the minimum and maximum values of the 2 space dimensions. The system assigns the same smiley to emotion words whose coordinates are within these values. Table 5.1 shows the information for each emotion type stored in the database. X_{min}, X_{max}, Y_{min}, Y_{max} determine the range of x and y dimensions and the smiley is the correspondent facial expression for the emotion type.

Table 5.1: Facial expression table

Emotion type
X_{min}
Y_{min}
X_{max}
Y_{max}
Smiley

5.2.6 Smileys module

We also used JAVA to implement this module. Its role is to read the hypothesis, that is the input, and to assign a smiley. In order to do it, it only needs to look up in the XML file that contains the path of the smiley where they are stored. At the moment we decided only assign one of the basic emoticons like happy, sad, angry, disgusted or fearful.
The output of this system displays an appropriate facial expression to convey the input word.

Chapter 6: System implementation

This chapter describes the details of the first implementation of ASL. Section 6.1 structures the application. Next sections develop each sub-applications of the system.

6.1 ASL application

Figure 6.1 shows the welcome page to ASL application that contains menus to access the system facilities. The menus are divided in four categories:

1. MDS: Access to the MDS facilities, i.e., to look up the MDS data stored in the correspondent XML files or run the MDS executable for a new word.

2. EVA: Access the EVA facilities, that are, look up the EVA data stored, run the MPL executable for a new word.

3. Data: Allow the user to access the data stored. It is possible to read the XML files and add data to these files, look up some charts that will be displayed on the screen. The text analyzer facility is also accessible from the data menu.

4. Help: This menu provides the user with some text files with instructions explaining how to use all the ASL facilities.

Figure 6.1: Welcome page to ASL

6.1.1 EVA menu

The main function of this menu is to run the EVA executable in order to calculate the coordinates for a new word that is not stored in the ASL database. Execute this code is only feasible if the word exists in the Wordnet database, given that the executable requires access to Wordnet to be able to calculate MPL. Figure 6.2 shows the page where the user can call the Perl executable. The user introduces the word that he wants to analyze and if the adjective exists in ASL database, a new page is shown, figure 6.3 depicts it. On the contrary, the Perl code is executed obtaining the MPL distances to calculate EVA. As we explained in chapter 5 the user should introduce not only the word but also two hypotheses. These hypotheses along with the word are used as executable's parameters.

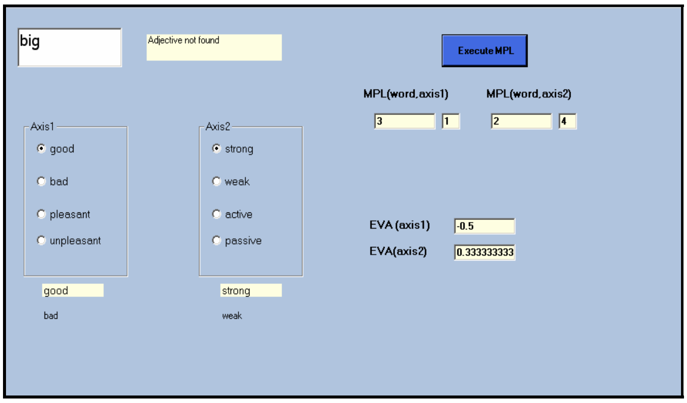


Figure 6.2: Execute MPL

The page will be shown if the adjective is found, allow us to read the "eva.xml" file that contains the EVA coordinates for all the 140 words. It is possible to select which one of the four 2D-spaces the user wants to work in. Depending on the value of the coordinates that appear in the XML database the application shows the corresponding smiley.

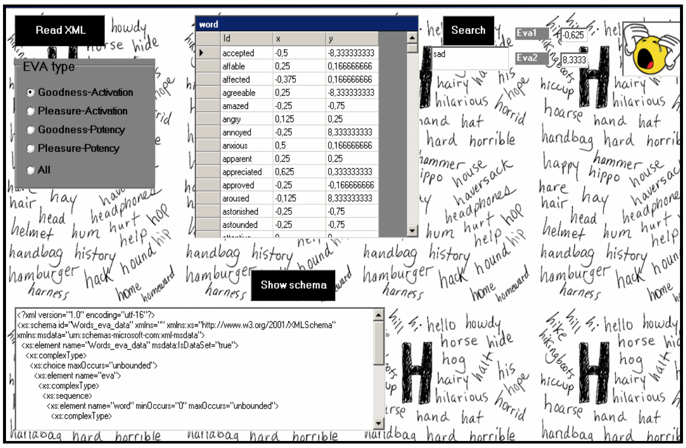


Figure 6.3: Word found in ASL database

6.1.2 Data menu

6.1.2.1 Reading XML files

Figure 6.4 shows the sub-application that reads the XML file. The data is given as a table and also a schema with the structure of the XML document is shown. The user can find a word and all its attributes navigating through the table. The application also gives the facility of searching a word and returns its attributes.

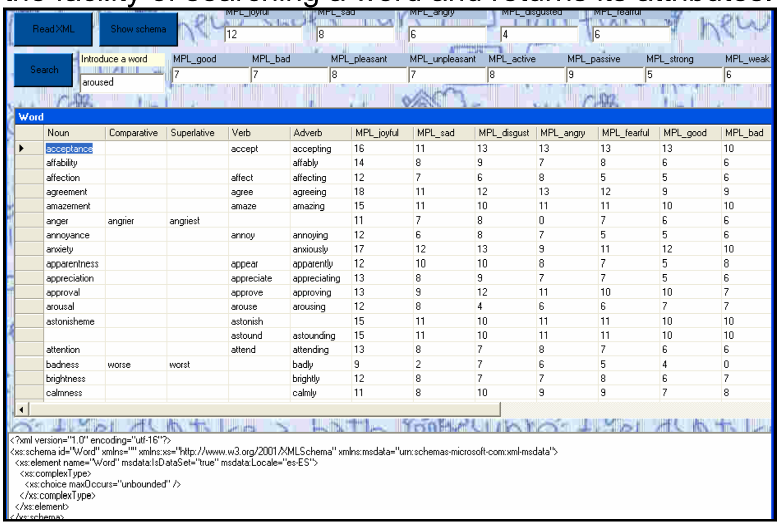


Figure 6.4: Reading XML files

6.1.2.2 Looking up charts

Figure 6.5 shows a screenshot of the application where it is possible to check some charts obtained as results from our experiments. The user can choose one of the four 2D-spaces obtained in EVA experiment, i.e., goodness-activation, pleasure-activation, goodness-potency or pleasure-potency. He/she also can check the MDS charts having used a matrix used the basic emotions words or the axis words explained in previous chapters.

In next versions of ASL, it would be possible to implement the facility to add the new word that user want to analyze to these charts. It will be an easy task due to the connection that exists between Visual Basic and Microsoft Excel where currently we process the data. It is also not difficult to read the coordinates from the XML files and process a chart in the application itself. Visual Basic contains a library that allows us to accomplish this task.

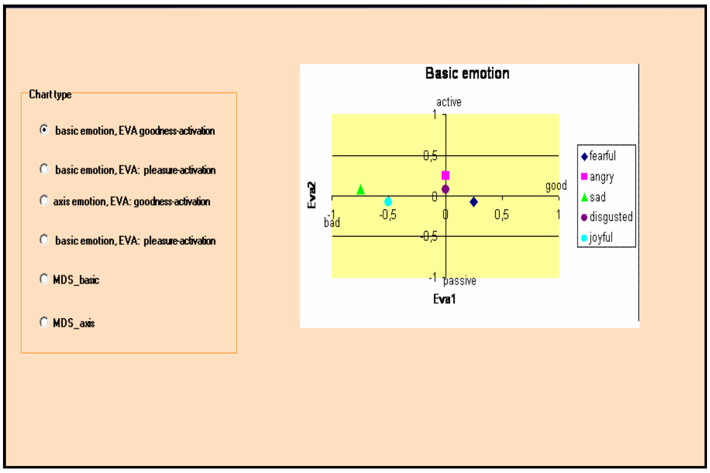


Figure 6.5: Looking up charts

6.1.2.3 Adding data to XML files

As mentioned before, the data collected in ASL is stored in a XML database. Figure 6.6 shows a screenshot of the main application that gives a new facility to the user. Using this sub-application the user can add new data to the XML files. Particularly, it is possible to append a new word and all its information to the "words.xml". The user is asked to fill all the parameters he/she knows. He/she can extract the *MPL data* from the MPL executable facility explained in section 1.1.1. The *word family* information should be known by the user, but sometimes is not possible to find all the requests. For the example depicted in the figure, 'bigness' as the noun and 'bigly' like the adverb should be also introduced, however the verb of the word 'big' doesn't exist. It is possible to avoid the unknown parameters and add them later.

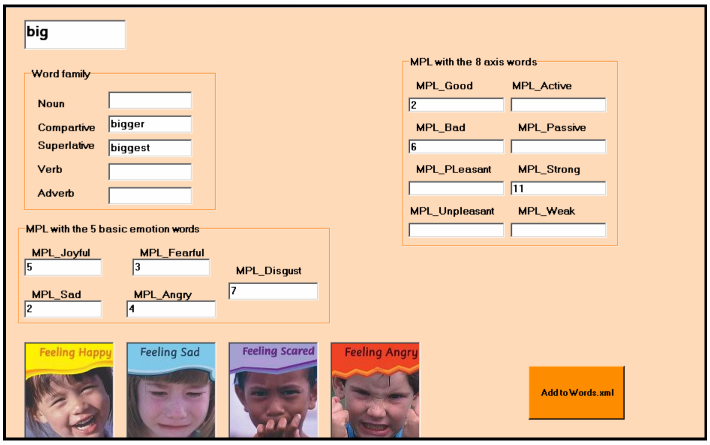


Figure 6.6: Adding data to XML files

6.1.2.4 Text analyzer

Figure 6.7 shows a screenshot of the text analyzer application. This module explained in chapter 5 should be implemented in Java as an individual sub-system. Due to the limitation of time, we implement a simple version of this module in our Visual Basic application. Its function is read a whole text extracting the adjectives we have in our database, but is not possible to find new adjectives that we haven't evaluated before. To solve this limitation we will use the work of our colleague Chen, J. (Chen, J., 2005).

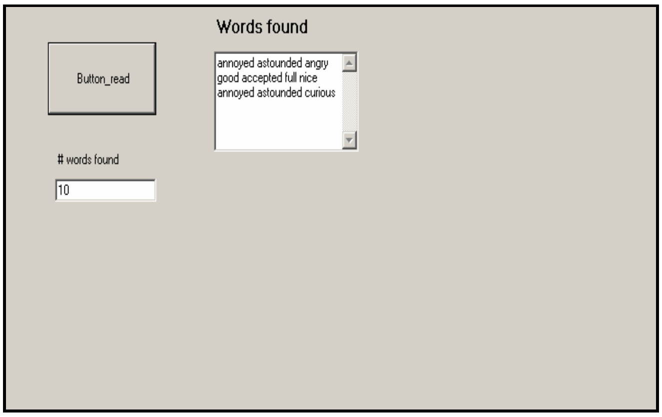


Figure 6.7: Text analyzer

Chapter 7: Conclusions and future work

Although having obtained the results from our experiments we extracted some conclusions, in this chapter we deduce the general conclusions of all the work around the design and implementation of ASL.

7.1 Design, implementation and evaluation conclusions

Our goal about automatically determine the character of the speech is accomplished. Exctracting human emotion from text is a difficult task to make it automatic. This work normally needs human manual annotations, but ASL associate automatically a facial expression to a text based in the lexical meaning of the words. Obviously, this labeling is partly inspired by psycholinguistic theories of human lexical memory, due to the fact that Wordnet is created by linguists. But it is more objective than experiments done before where the emotions or words were classified based on the subjective opinion of their participants. In our case, the meaning of the words is determined by its place in the Wordnet's structure.
ASL is a viable solution for our purpose; moreover it is scalable and adaptable being able to add improvements. As explained in chapter 5, the system is set modularly, so the modifications can be implemented quite easy.

However, we found some disadvantages in the ASL implementation. Firstly, Perl executable takes a long time to calculate MPL. Unless the value of MPL would be small, the executable takes several minutes to calculate this value only for one word. If we have a whole text to analyze the emotional character, the application has to wait for a long time to get the MPL of all the words. Similar effect happens with MDS when we run it from XLSTAT. If we input a matrix with high amount of data, the process is slowing down and Microsoft Excel could get hung up. A solution for this problem is to decrease the number of dimensions, i.e., input a smaller matrix makes the process faster. The results also improve given that we create clusters with similar attributes as we explained in chapter 4.

Having evaluated the two techniques used in chapter 4 to classify the words in a 2D-space, EVA and MDS is not trivial to decide the optimal one. Both are based on MPL distance and we can conclude that sometimes they don't fit at all with our subjective expectations.
Furthermore, we have some limitations working with Wordnet database. Although it contains around 150.000 words, 21.436 of them are adjectives; the user can introduce a word that doesn't exist in this database. To catch the error when a word is not found is not well implemented at this moment with the Lingua::Wordnet package. If you try to calculate MPL for a word not found using the Perl script, the executable goes into an infinite looping. We have the same problem when a word is found but doesn't have synsets to continue the search. Among of the set of adjectives there are only 18.563 synsets, so there is possible to find a word without synsets that convey the same meaning.
ASL is able to analyze the emotional character of an individual word and also read a whole text choosing the emotional words and analyze the emotions that they transmit.
One limitation is the fact that ASL can't realize the intention of the people when use emotional words. People use words for example ironically to explain the contrary of the feelings they have. The system can determine the emotional sense of a word, but if the word is used in other sense that is not the usual one, ASL can't detect it. For instance, if it is raining and someone says: *Nice* day! our system would analyze 'nice' and resolve it as a pleasant word. To improve ASL in this case, it is better to analyze all the words in whole text and conclude the character of the whole text as the emotion that appears more frequently, so we have to develop a good parser.

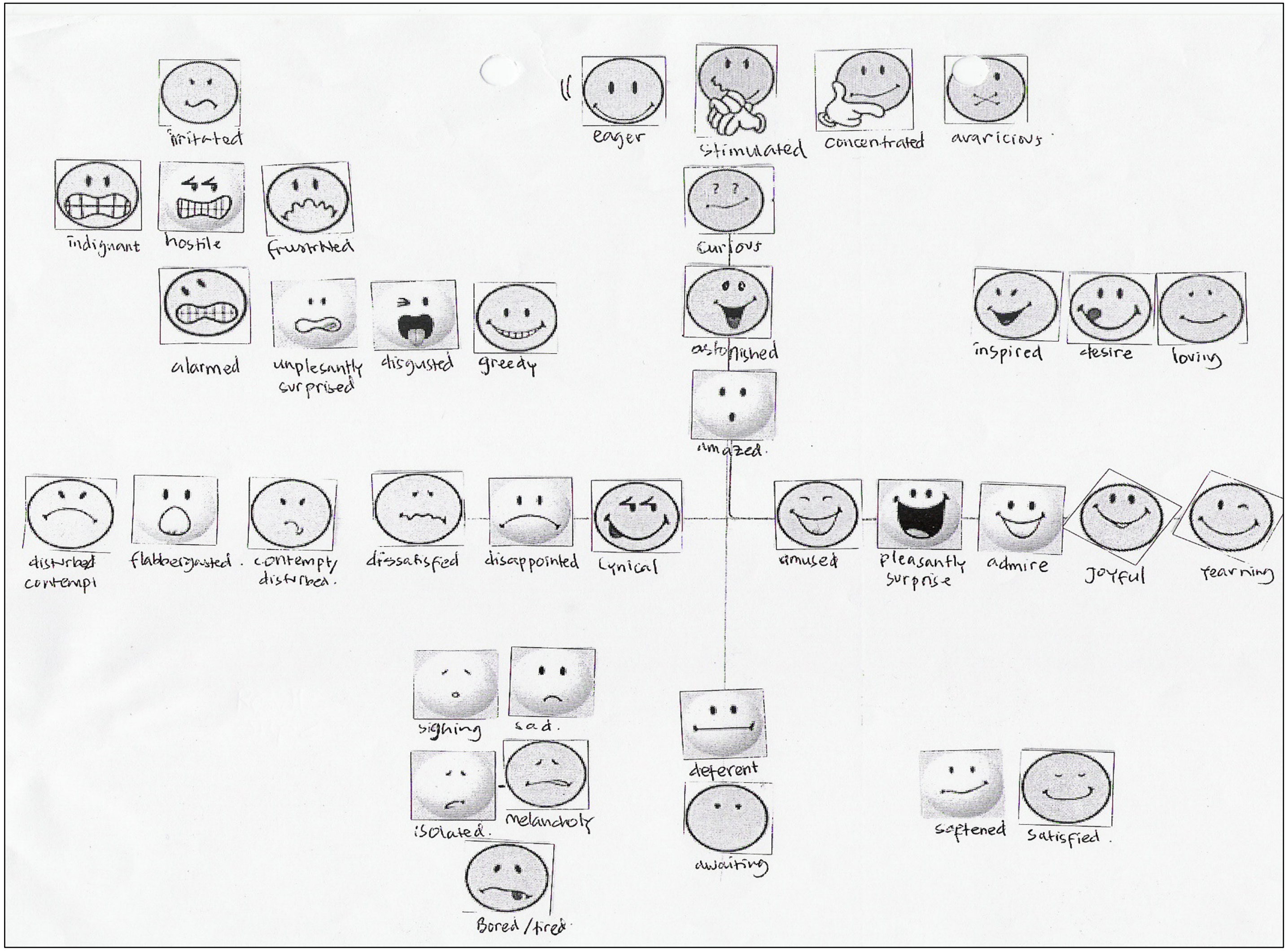
7.2 Future work

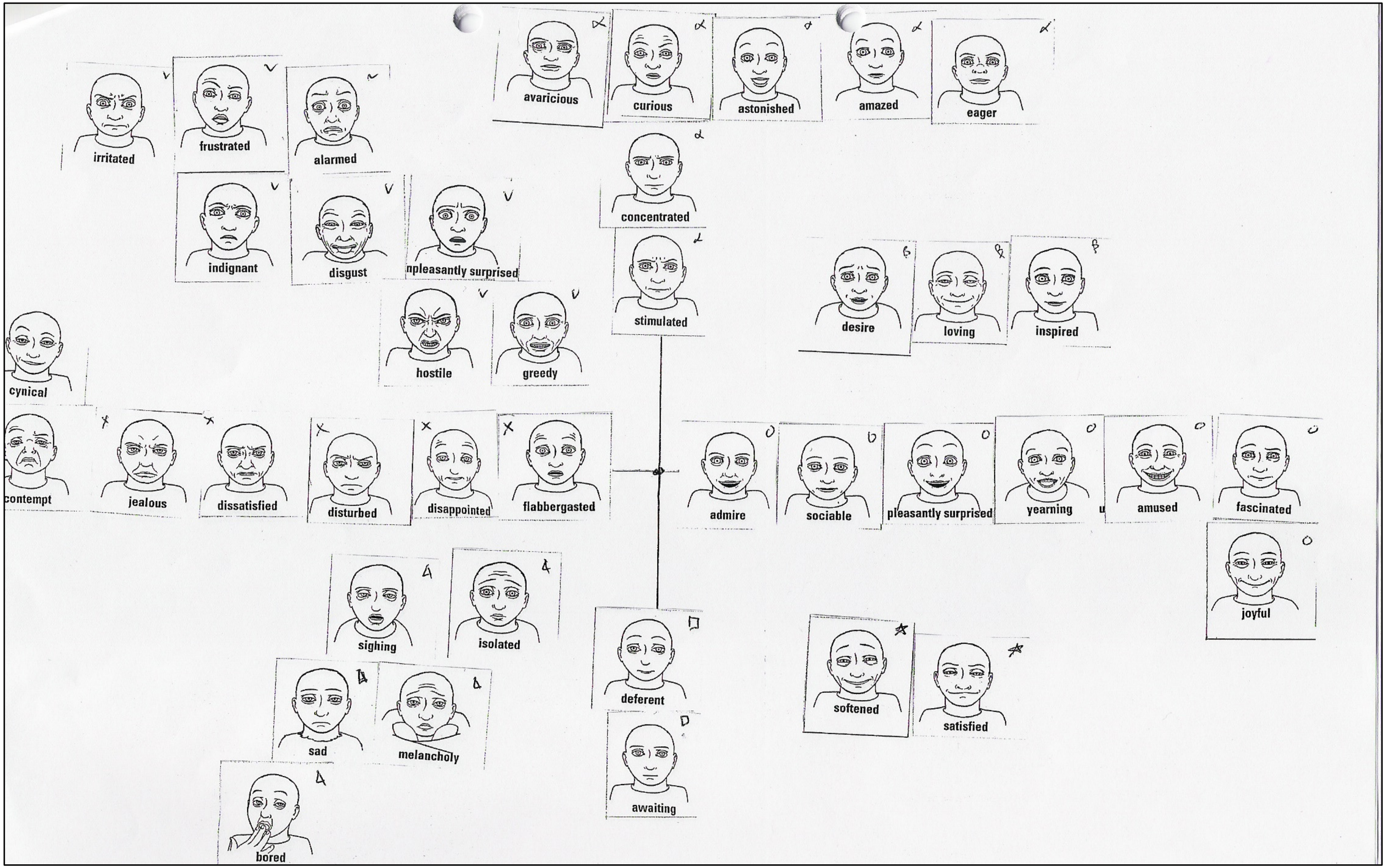
A large number of modifications could be done in order to improve ASL. This system is the first application able to recognize automatically the character of the speech, so future work is needed.
First of all, the database included in the system can be expanded. The developers of Wordnet update its data in each version of the database. Moreover, our XML database can be increased with new words and also with new data required by new implemented techniques. The number of smileys used to convey the emotional words found on the speech can be amplified. The first implementation of ASL only associates one of the 6 basic emotions: sad, happy, angry, fearful, disgusted and surprised to the words found in the text. In future versions a database with a large number of smileys can be added, thus the emotional words will be better conveyed.
New sophisticated techniques to classify the words in a 2D-space should be tested obtaining better results. Instead of classify a word as an emotional word is closer in terms of distance, it is also possible to use statistics and probabilistic methods. Having a database with data well classified, the system can studied the distribution of the set of emotions around the word that we want to classify. Furthermore, it is possible to calculate for each word the average of its classification results of all techniques and conclude the final classification; so the result will be more reliable.
It is also necessary work on the disadvantages explained in the previous section. The Perl scripts could be optimized, so the speed of the calculations will be improved.

Moreover, others tools to calculate MDS are available and capable to accelerate the process and avoid getting hung up.

Appendix A

Emotion Words Alias	Octant	Synonym
inspired	pleasant excited	enthusiastic, elate, exhilarate, spirit up, stimulated, excited, fire, devoted, eager, hearty, obsessed, passionate, arden, euphoria
desiring	pleasant excited	hangker, hunger, longing, pine, thirst
loving	pleasant excited	appreciate, cherish, prize
pleasantly surprise	pleasant average	appreciating, well, fit, lighthearted
fascinated	pleasant average	attracted to
amused	pleasant average	entertined, arrogance
admiring	pleasant average	treasure, value, adore, delight in
sociable	pleasant average	appetitive, close, familiar
yearning	pleasant average	guess, wish, lust
joyful (happy)	pleasant average	cheerful
satisfied	pleasant calm	relaxed, fulfilled, comfortable
softened	pleasant calm	cozy, intimate, smile, dreamy, cautious
awaiting	neutral calm	passive, anticipating
deferent	neutral calm	composed
bored	unpleasant calm	covetous, acquisitive, desirous, grabby, grasping, itchy, prehensile
sad	unpleasant calm	grief, pity, worried, regret
isolated	unpleasant calm	diilusioned, separate, suspicious
melancholy	unpleasant calm	gloomy, cheerless
sighing	unpleasant calm	dispirit, tired
dissapointed	unpleasant average	
contempt	unpleasant average	dissaproving-of, disagreement
jealous	unpleasant average	malice
dissatisfied	unpleasant average	aversive
disturbed	unpleasant average	irked
flbbergasted	unpleasant average	histerical, sorrow, doubtful
cynical	unpleasant average	grouchy, moody, grumpy
irritated	unpleasant excited	annoyed
disgusted	unpleasant excited	despise
indignant	unpleasant excited	anger, furious
unpleasantly surprised	unpleasant excited	puzzle, confuse, bewildered, fear, appalled, disbelief
frustrated	unpleasant excited	defeated, desperation
greedy	unpleasant excited	
alarmed	unpleasant excited	nervous, protest
hostile	unpleasant excited	ill, inimicable, inimical, unfriendly, attack, competitive, argumentative, opposed, warlike, fierce, cruel
curious	neutral excited	wonder
amazed	neutral excited	surprise
avaricous	neutral excited	longing, aroused
stimulated	neutral excited	provoke, quicken, energize, vitalize, motivated, move, innerve
concentrated	neutral excited	fixate, focus, settle
astonished	neutral excited	full surprised
eager	neutral excited	impatient, breathless, anxious, heated, hot, ambitious, intent
Based on Desmet 2004		


irritated
eager
stimulated
concentrated
avaricious
indignant
hostile
frustrated
curious
alarmed
unplesantly surprised
disgusted
greedy
astonished
inspired
desire
loving
amazed
disturbed contempi
flabbergasted
contempty disturbed
dissatisfied
disappointed
cynical
amused
pleasantly surprise
admire
joyful
yearning
sighing
sad
deferent
isolated
melancholy
awaiting
softened
satisfied
Bored / tired


avaricious
curious
astonished
amazed
eager
irritated
frustrated
alarmed
concentrated
indignant
disgust
npleasantly surprised
stimulated
desire
loving
inspired
hostile
greedy
cynical
contempt
jealous
dissatisfied
disturbed
disappointed
flabbergasted
admire
sociable
pleasantly surprised
yearning
amused
fascinated
joyful
sighing
isolated
deferent
softened
satisfied
sad
melancholy
awaiting
bored

Appendix B

Initial list	Used	Replaced by
accepted	x	
accessible		
acquisitive		covetous, grabby, grasping, itchy
admirable		fine
adorable		darling, cute
affable	x	
affected	x	
afraid		fearful, petrified
agitated		elated, excited, eager
agreeable	x	
agreed		agreeable
alarmed		fearful, petrified
amazed	x	
ambitious		anxiuos,hot,intent, eager
angry	x	
annoyed	x	
anxious	x	
appalled		confused
apparent	x	
appreciated	x	
approachable		
approved	x	
aroused	x	
astonished	x	
astounded	x	
attentive	x	
bad	x	
bening		gentle, good, kind, tender
bored		covetous, grabby, grasping, itchy
bright	x	
calm	x	
certain		positive
civil		affable,corteous
clear	x	
close	x	
coincident		
comfortable	x	
comic	x	
composed		calm
comprehensible		covetous, grabby, grasping, itchy
concentrated	x	
confused	x	
considered	x	
contemptible	x	
content		comfortable
cordial	x	
correct	x	

courteous	x	
covetous	x	
cozy	x	
crazy	x	
cultured		affable,corteous
curious	x	
cute	x	
cheerful		merry, joyful
choleric	x	
darling	x	
dazed	x	
dead	x	
dear	x	
defeated	x	
deferent		courteous
delicious		tasty
deplorable	x	
depressed	x	
desired		
desperate	x	
disabled	x	
disconcerted		annoyed, confused, disturbed
discontented		
disgusted	x	
dispirited	x	
displeased		annoyed
dissapointed	x	
dissatisfied		disappointed,unhappy,ungratified
disturbed	x	
disturbed	x	
doubtful		confused
down	x	
dramatic	x	
dumbfounded	x	
eager	x	
elated	x	
energetic		
enthusiastic		elated, excited, eager
euphoric		joyful,joyous
evident	x	
exasperated		irritated
excited	x	
exhausted	x	
exhilarate		elated, excited, eager
explicit		clear,plain
familiar	x	
fascinated		concentrated
fatigued	x	
fearful	x	
fed up		dissatisfied
felicitous		joyful,joyous

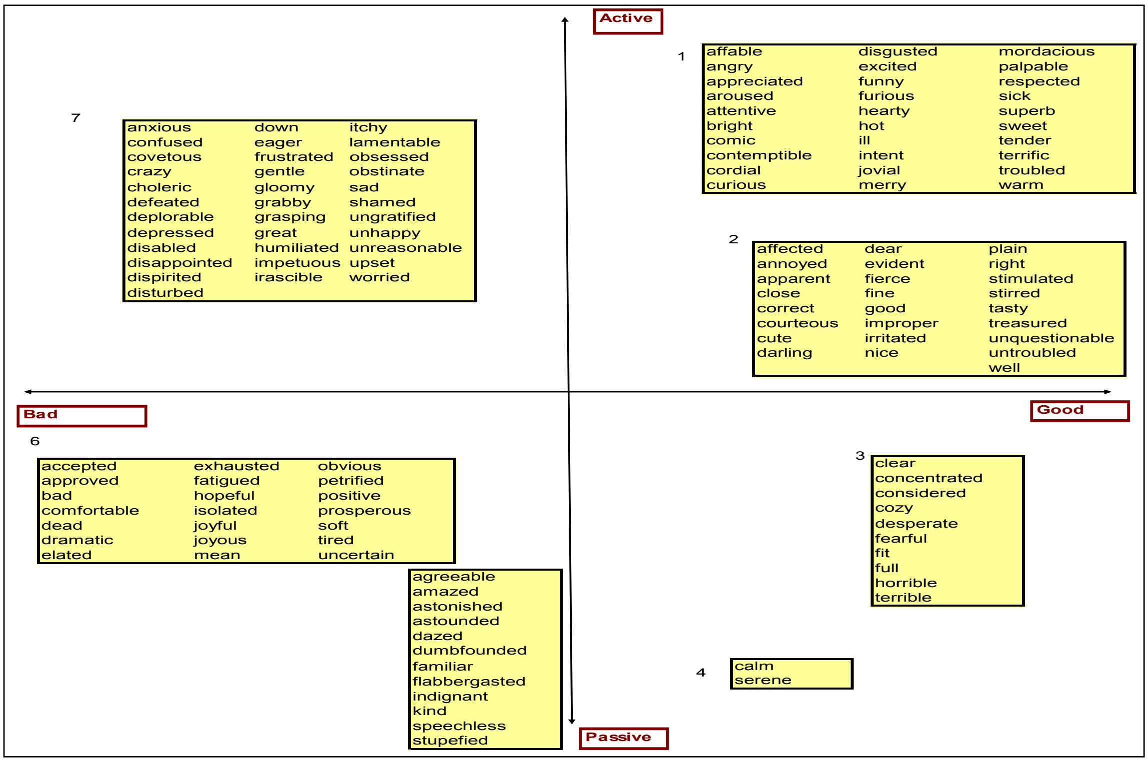
fierce	x	
fine	x	
fit	x	
fixate		concentrated
flabbergasted	x	
flustered		
focused		concentrated
friendly		affable,attentive,close, kind, cordial,familiar
frightened		fearful, petrified
frustrated	x	
full	x	
funny	x	
furious	x	
gentle	x	
glad		joyful,jovial
gloomy	x	
good	x	
grabby	x	
grasping	x	
gratified		joyful, jovial
great	x	
happy		joyful,joyous
hearty	x	
heated		anxiuos,hot,intent, eager
hilarious		funny
hopeful	x	
horrible	x	
horrified		afraid, petrified
hot	x	
humane		gentle, good, kind, tender
humiliated	x	
ill	x	
impatient		anxiuos,hot,intent, eager
impetuous	x	
impossible		improper,unreasonable
improper	x	
inadmisible		improper,unreasonable
incredulous		
indignant	x	
innerve		stimulated
insulted		
intent	x	
interested		curious
interrupted		
intolerable		improper,unreasonable
irascible	x	
irked		disturbed
ironic		mordacious
irritated	x	
isolated	x	
itchy	x	

jovial	x	
joyful	x	
joyous	x	
kind	x	
lamentable	x	
loveable		cute, sweet
mean	x	
melancholic		dispirited, down,sad, unhappy
merry	x	
mordacious	x	
motivated		stimulated
moved		stimulated
negative		
nice	x	
obsessed	x	
obstinate	x	
obvious	x	
pained		worried, upset, unhappy
palpable	x	
passionate		elated, excited, eager
petrified	x	
pissed off		
plain	x	
pleasant		pleasurable
pleasant		pleasurable
pleased		joyful,jovial
polite		affable,corteous
positive	x	
prosperous	x	
provoked		stimulated
provoked		
puzzled		confused
recognised		respected
relaxed		calm
respected	x	
right	x	
sad	x	
sarcastic		mordacious
satiric		mordacious
satisfied		positive
scared		fearful, petrified
serene	x	
settled		concentrated
shamed	x	
shocked		fearful, petrified
sick	x	
social		gentle, good, kind, tender
soft	x	
sorrowful		sad
speechless	x	
stimulated	x	

stirred	x	
stupefied	x	
successful		
suffer		sad
superb	x	
sure		clear, positive
surprised		astonished, astounded, dumbfounded, flabbergasted, stupefied
sweet	x	
tasty	x	
tender	x	
terrible	x	
terrific	x	
terrified		fearful, petrified
tired	x	
tormented		affected
tragic		sad
treasured	x	
troubled	x	
unaccepted		improper,unreasonable
uncertain	x	
understanding		kind
unfulfilled		dissatisfied
ungratified	x	
unhappy	x	
unpleasant		abhorrent,bad
unquestionable	x	
unreasonable	x	
unthinkable		improper,unreasonable
untroubled	x	
upset	x	
warm	x	
well	x	
worried	x	

Appendix C

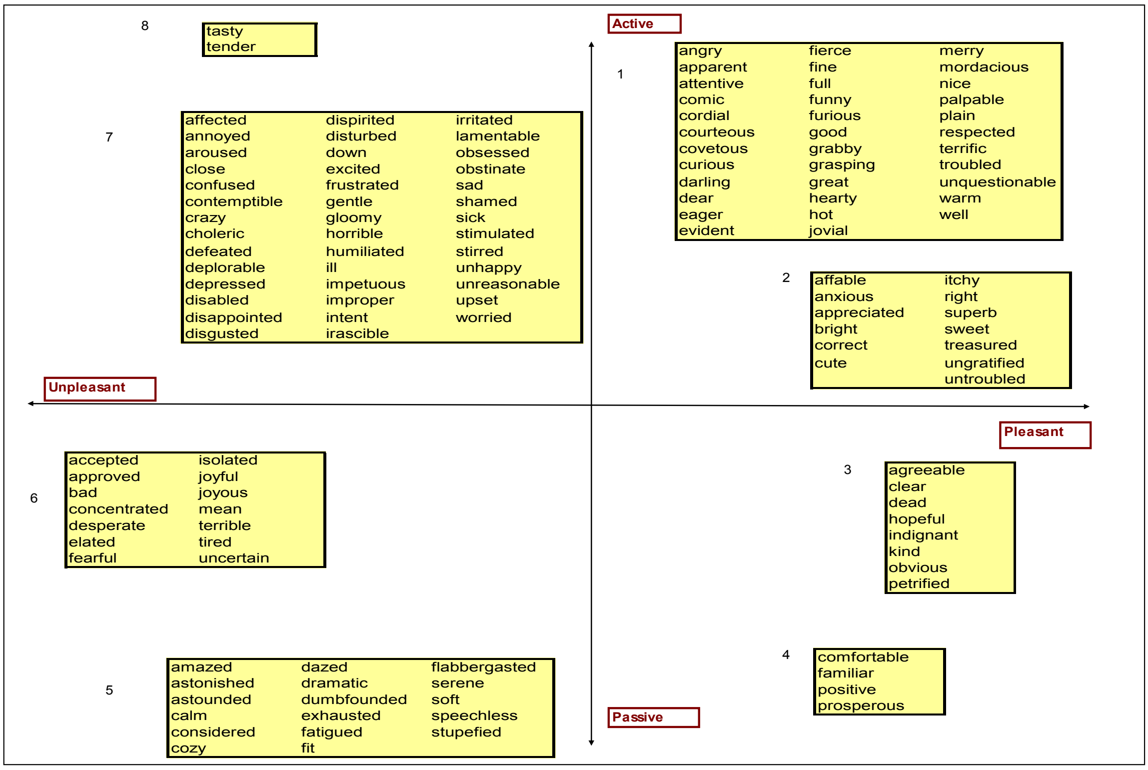
Goodness-Activation



octant 9

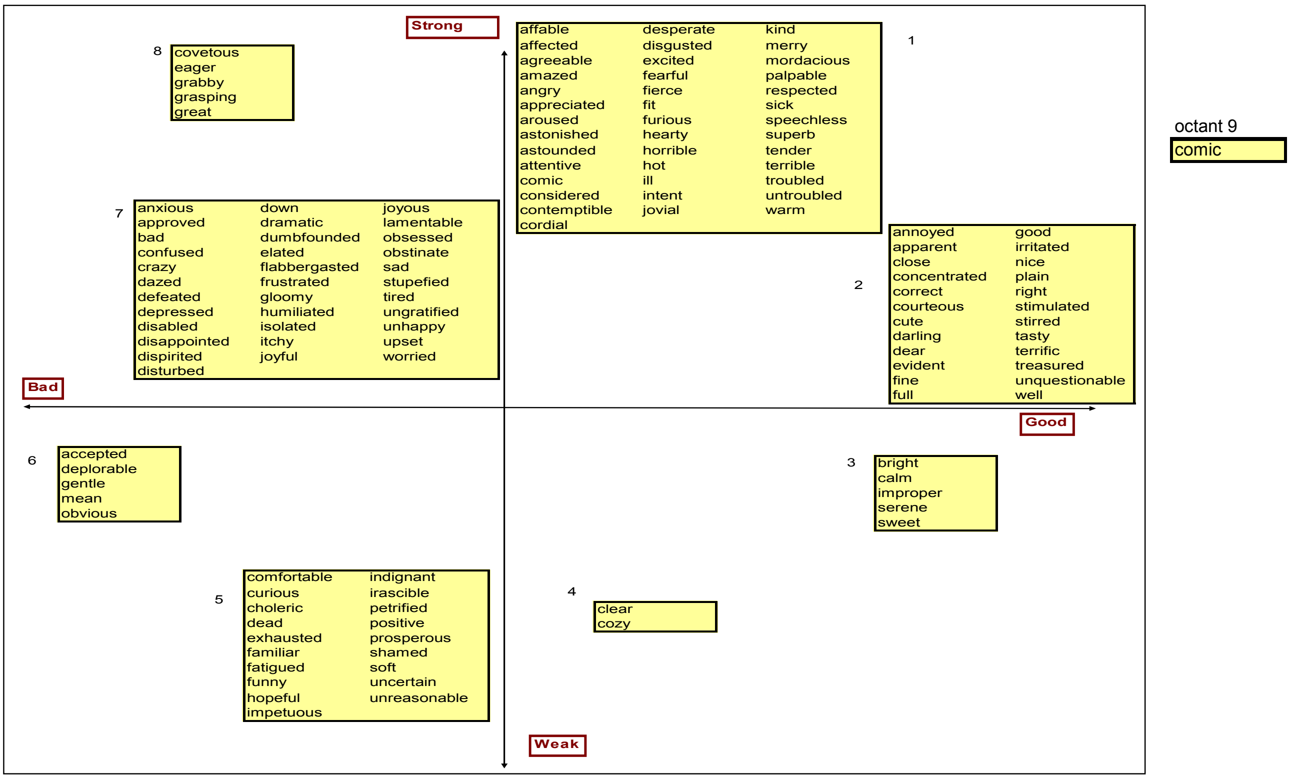
agreeable
astonished
amazed
astounded
kind
respected
superb

Pleasure-Activation

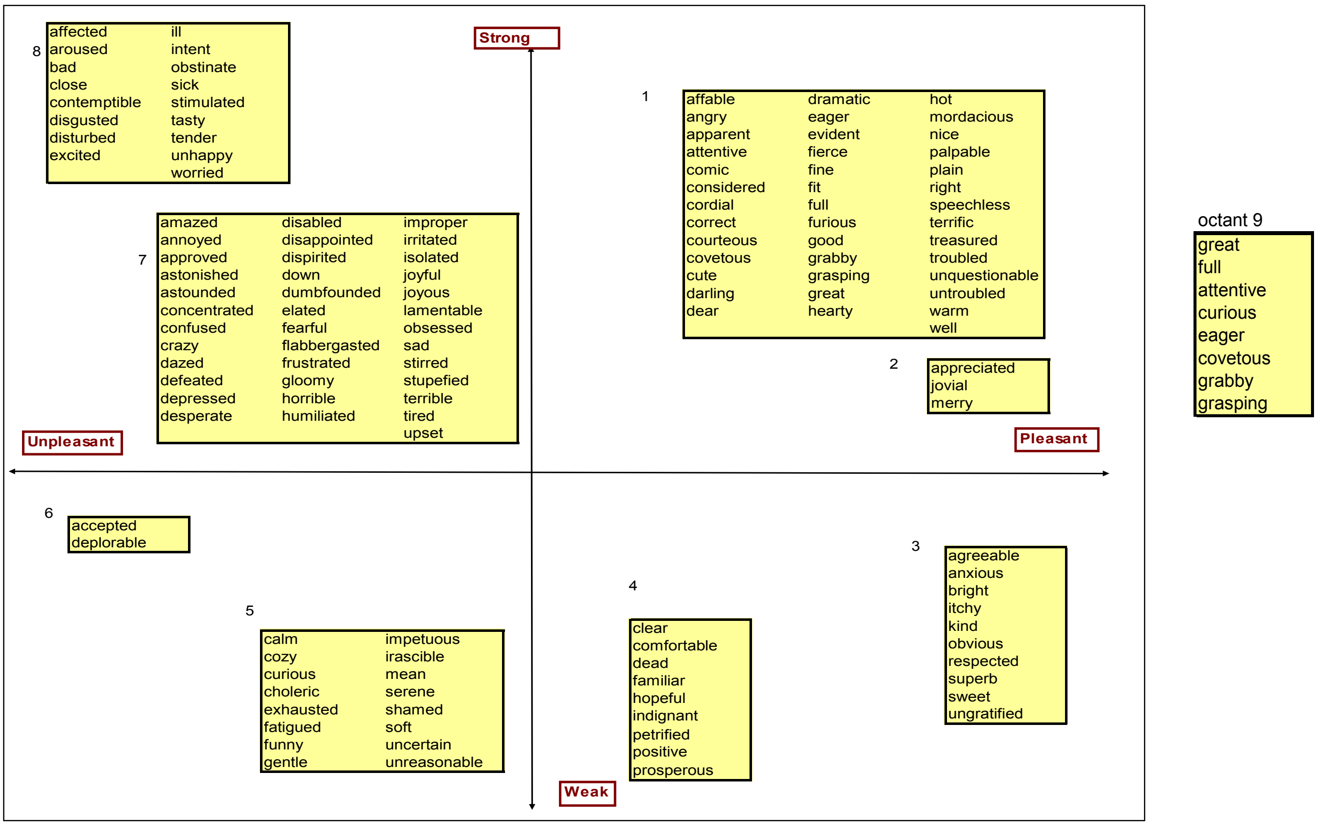


octant 9

curious
attentive
ill
contemptible



Pleasure-Potency



Appendix D

MPL routine (EVA experiment)

```
#!/usr/bin/perl -w
 use Lingua::Wordnet;
 use Lingua::Wordnet::Analysis;
#declarations
my $mpl=0;
my @stack1;
my @stack2;
my @mirror_stack;
my $element;
my $i=0;
my $j;
#my $h;
my $k;
my $sense=1;
my $wn = new Lingua::Wordnet;
my $ok=1;

sub optimize{
my ($w1,@mirror_stack1)=@_;
my $boolean_found=0; #0->false, 1->true
$i=0;
while ($i<@mirror_stack1 && $boolean_found==0){
 if($w1 eq $mirror_stack1[$i]){
           $boolean_found=1;
          }
  else{$i++;}
}
return $boolean_found;
}

#parameters: w1 and w2
my ($w1, $w2) = @ARGV;
unless ($w1 && $w2) {
       print "Usage: $0 word1 word2\n";
       exit;
}
#find all synonyms of w1 and push in stack1
        push(@mirror_stack,$w1);
       $wn->unlock();
       my $max = $wn->lookup_synset($w1,"a");
       for($sense=1; $sense<=$max; $sense++){
              my $synset = $wn->lookup_synset($w1,"a",$sense);
              $synset->write();
              $wn->close();
              my @words=$synset->words();
              my $lenght_words = @words;
              for($j=0;$j<$lenght_words;$j++){
                     my @split_array =split("%",$words[$j]);
                     unless($split_array[0] eq $w1){
                      push(@stack1,$split_array[0]);
                      push(@mirror_stack,$split_array[0]);
                     }
              }
       }

print "mpl: $mpl\nSTACK1: @stack1\n";
print "STACK_mirror: @mirror_stack\n";
while(){
       $mpl++;
       foreach $element1 (@stack1){
```

```
            if($element1 eq $w2){
                  print"result mpl: $mpl";
                  exit();
            }
            else{ $wn->unlock();
                  my $max = $wn->lookup_synset($element1,"a");
                  for($sense=1; $sense<=$max; $sense++){
                  my $synset = $wn->lookup_synset($element1,"a",$sense);
                        $synset->write();
                        $wn->close();
                        my @words=$synset->words();
                        my $lenght_words = @words;
                        for($j=0;$j<$lenght_words;$j++){
                              my @split_array =split("%",$words[$j]);
                    $ok=optimize($split_array[0],@mirror_stack);
                                    if($ok==0){
                                     push(@stack2,$split_array[0]);
                                     push(@mirror_stack,$split_array[0]);
                                    }
                        }
                  }
            }
      }
      print "mpl: $mpl\nSTACK2: @stack2\n";
      print "STACK_mirror: @mirror_stack\n";
      foreach $element (@stack1){
            pop(@stack1);
      }
      $mpl++;
      foreach $element2 (@stack2){
                  if($element2 eq $w2){
                        print"result mpl: $mpl";
                        exit();
                  }
                  else{
                        $wn->unlock();
                        my $max = $wn->lookup_synset($element2,"a");
                        for($sense=1; $sense<=$max; $sense++){
                  my $synset = $wn->lookup_synset($element2,"a",$sense);
                              $synset->write();
                              $wn->close();
                              my @words=$synset->words();
                              my $lenght_words = @words;
                              for($j=0;$j<$lenght_words;$j++){
                                    my @split_array =split("%",$words[$j]);
                        $ok=optimize($split_array[0],@mirror_stack);
                                    if($ok==0){
                                     push(@stack1,$split_array[0]);
                                     push(@mirror_stack,$split_array[0]);
                                    }
                              }
                        }
                  }
      }
      print "mpl: $mpl\nSTACK1: @stack2\n";
      foreach $element2 (@stack2){
            pop(@stack2);
      }
}
```

TRI routine (EVA experiment)

```
#!/usr/bin/perl -w
 use Lingua::Wordnet;
 use Lingua::Wordnet::Analysis;

my $wn = new Lingua::Wordnet;
my $eva1=0;
my $eva2=0;
my $eva4=0;
my $eva3=0;


sub optimize{
my ($w1,@mirror_stack1)=@_;
my $boolean_found=0; #0->false, 1->true
$i=0;
while ($i<@mirror_stack1 && $boolean_found==0){

 if($w1 eq $mirror_stack1[$i]){
           $boolean_found=1;
          }
  else{$i++;}
}
return $boolean_found;
}
sub mpl{

       #parameters: w1 and w2

       my ($w1, $w2)=@_;

       #unless ($w1 && $w2) {
              #print "Usage: $0 word1 word2\n";
              #exit;
       #}

       #find all synonyms of w1 and push in stack1

       #declarations
       my $element;
       my $k;
        my $sense=1;
       my @mirror_stack;
       my @stack1;
        my @stack2;
        my $j;
              $wn->unlock();
              my $max = $wn->lookup_synset($w1,"a");
              for($sense=1; $sense<=$max; $sense++){
                     my $synset = $wn->lookup_synset($w1,"a",$sense);
                     $synset->write();
                     $wn->close();

                     my @words=$synset->words();
                     my $lenght_words = @words;
                     for($j=0;$j<$lenght_words;$j++){
                            my @split_array =split("%",$words[$j]);
                            unless($split_array[0] eq $w1){
                             push(@stack1,$split_array[0]);
                             push(@mirror_stack,$split_array[0]);
                     }
                     }
              }
```

```
	my $mpl=0;
	while(){
		$mpl++;
		foreach $element1 (@stack1){
			if($element1 eq $w2){
				return $mpl;
			}
			else{
				$wn->unlock();
				my $max = $wn->lookup_synset($element1,"a");
				for($sense=1; $sense<=$max; $sense++){
			my $synset = $wn->lookup_synset($element1,"a",$sense);
					$synset->write();
					$wn->close();
					my @words=$synset->words();
					my $lenght_words = @words;
					for($j=0;$j<$lenght_words;$j++){
						my @split_array =split("%",$words[$j]);
				$ok=optimize($split_array[0],@mirror_stack);
						if($ok==0){
						  push(@stack2,$split_array[0]);
						  push(@mirror_stack,$split_array[0]);}
					}
				}
			}
		}
		foreach $element (@stack1){
			pop(@stack1);
		}
		$mpl++;
		foreach $element2 (@stack2){
				if($element2 eq $w2){
				return $mpl;
				}
				else{
				$wn->unlock();
					my $max = $wn->lookup_synset($element2,"a");
					for($sense=1; $sense<=$max; $sense++){
			my $synset = $wn->lookup_synset($element2,"a",$sense);
						$synset->write();
						$wn->close();
						my @words=$synset->words();
						my $lenght_words = @words;
						for($j=0;$j<$lenght_words;$j++){
						my @split_array =split("%",$words[$j]);
				$ok=optimize($split_array[0],@mirror_stack);
							if($ok==0){
							 push(@stack1,$split_array[0]);
							    push(@mirror_stack,$split_array[0]);
							 }
						}
					}
				}

		}
			foreach $element2 (@stack2){
			pop(@stack2);
		}
	}
	return $mpl;
}
sub tri_mpl{
```

```
my ($word,$axis1,$axis2)=@_;
my $es =mpl($word,$axis1);
print "es:$es\n";
my $es2 =mpl($word,$axis2);
print "es2:$es2\n";
#my $tri= mpl($word,$axis1)-mpl($word,$axis2);
my $tri=$es-$es2;
#my $mpl_norm=mpl($axis1,$axis2);
#mpl(good,bad)=4
my $mpl_norm=4;
my $tri_norm=$tri/$mpl_norm;

print "tri_norm: $tri_norm\n";
return $tri_norm;
}


open(INFILE, "adj.txt") or die "Can´t open adj.txt:$!";
#open(OUTFILE, ">>tri.txt") or die "Can´t open tri.txt:$!";

 while (my $line= <INFILE>){
  @word_line=split(/\n/,$line);
  print "line: $word_line[0]\n";
  my $adj = $word_line[0];

  open(OUTFILE, ">>tri.txt") or die "Can´t open tri.txt:$!";
  print OUTFILE "$adj\n";

  $eva1=tri_mpl($adj,"good","bad");
  print "eva1: $eva1\n";
  print OUTFILE "eva1: $eva1\n";

  #$eva2=tri_mpl($adj,"active","passive"); #mpl(passive, active)=12
  #print OUTFILE "eva2: $eva2\n";
  #print "eva2: $eva2\n";

  #$eva3=tri_mpl($adj,"strong","weak");  #mpl(strong,weak)=6
  #print "eva3: $eva3\n";
  #print OUTFILE "eva3: $eva3\n";


  #$eva4=tri_mpl($adj,"pleasurable","abhorrent");
  #print OUTFILE "eva4: $eva4\n";
  #print "eva4: $eva4\n";

   close OUTFILE;
 }
  close INFILE;
```

MPL routine (MDS experiment)

```
#!/usr/bin/perl -w
 use Lingua::Wordnet;
 use Lingua::Wordnet::Analysis;

#declarations
my $wn = new Lingua::Wordnet;
my $eva1=0;
my $eva2=0;
my $eva4=0;
my $eva3=0;

sub optimitzar{

my ($w1,@mirror_stack1)=@_;
my $boolean_found=0; #0->false, 1->true
$i=0;

while ($i<@mirror_stack1 && $boolean_found==0){

 if($w1 eq $mirror_stack1[$i]){
           $boolean_found=1;
          }
  else{$i++;}
}
return $boolean_found;
}
sub mpl{

       #posar els parametres de la funcio a w1 i w2

       my ($w1, $w2)=@_;

       #unless ($w1 && $w2) {
              #print "Usage: $0 word1 word2\n";
              #exit;
       #}

       #buscat TOTS els sinonims de w1 i posarlos al stack1

       #syns2stack($w1, @stack1);

       #declarations
       my $mpl=0;
       my $element;
       #my $i;
       my $k;
        my $sense=1;
       my @mirror_stack;
       my @stack1;
        my @stack2;
        my $j;
        my $element1;
        my $element2;

              $wn->unlock();
              my $max = $wn->lookup_synset($w1,"a");
              for($sense=1; $sense<=$max; $sense++){
                     my $synset = $wn->lookup_synset($w1,"a",$sense);
                     $synset->write();
                     $wn->close();
                     my @words=$synset->words();
                     my $lenght_words = @words;
```

```
                for($j=0;$j<$lenght_words;$j++){
                        my @split_array =split("%",$words[$j]);
                        unless($split_array[0] eq $w1){
                         push(@stack1,$split_array[0]);
                         push(@mirror_stack,$split_array[0]);
                }
                }
        }
        #optimize
print "mpl: $mpl\nSTACK1: @stack1\n";
print "mpl: $mpl\nSTACK_mirror: @mirror_stack\n";
my $mpl=0;
while(){
        $mpl++;
        foreach $element1 (@stack1){
                if($element1 eq $w2){
                        #print"result mpl: $mpl";
                        return $mpl;
                        #exit();
                }
                else{
                        $wn->unlock();
                        my $max = $wn->lookup_synset($element1,"a");
                        for($sense=1; $sense<=$max; $sense++){
                my $synset = $wn->lookup_synset($element1,"a",$sense);
                                $synset->write();
                                $wn->close();
                                my @words=$synset->words();
                                my $lenght_words = @words;
                                for($j=0;$j<$lenght_words;$j++){
                                        my @split_array =split("%",$words[$j]);
                        $ok=optimitzar($split_array[0],@mirror_stack);
                                        if($ok==0){
                                          push(@stack2,$split_array[0]);
                                          push(@mirror_stack,$split_array[0]);}
                                }
                        }
                }
        }
        foreach $element (@stack1){
                pop(@stack1);
        }
        $mpl++;
        foreach $element2 (@stack2){
                        if($element2 eq $w2){
                        return $mpl;
                        }
                        else{  $wn->unlock();
                                my $max = $wn->lookup_synset($element2,"a");
                                for($sense=1; $sense<=$max; $sense++){
                my $synset = $wn->lookup_synset($element2,"a",$sense);
                                        $synset->write();
                                        $wn->close();
                                        my @words=$synset->words();
                                        my $lenght_words = @words;
                                        for($j=0;$j<$lenght_words;$j++){
                                my @split_array =split("%",$words[$j]);
                        $ok=optimitzar($split_array[0],@mirror_stack);
                                                if($ok==0){
                                                 push(@stack1,$split_array[0]);
                                                 push(@mirror_stack,$split_array[0]);
                                                 }
                                        }
```

```
                                    }
                             }

              }
              print "mpl: $mpl\nSTACK1: @stack2\n";
              foreach $element2 (@stack2){
                     pop(@stack2);
              }
       }
       return $mpl;
}

open(INFILE, "adj_end.txt") or die "Can´t open adj.txt:$!";

 while (my $line= <INFILE>){
   open(INFILE2, "adj2.txt") or die "Can´t open adj2.txt:$!";
   while (my $line2=<INFILE2>){
       @word_line=split(/\n/,$line);
       print "line: $word_line[0]\n";
       my $adj = $word_line[0];
       @word_line2=split(/\n/,$line2);
       print "line2: $word_line2[0]\n";
       my $word = $word_line2[0];

       open(OUTFILE, ">>mpl_all.txt") or die "Can´t open mpl_all.txt:$!";

       if($adj ne $word){
              my $mpl=mpl($adj,$word);
              print OUTFILE "$adj,$word,mpl:$mpl\n";
              print "$adj,$word,mpl:$mpl\n";
       }
 }
   close INFILE2;
 }
  close INFILE;
  closeOUTFILE;
```

Appendix E


```
- <Words_eva_data>
  - <!--
    135 adjectives list
    -->
- <eva Id="Pleasure-Activation">
  <word Id="accepted" x="-0,5" y="-8,33333333333333E-02" />
  <word Id="affable" x="0,25" y="0,166666666666667" />
  <word Id="affected" x="-0,375" y="0,166666666666667" />
  <word Id="agreeable" x="0,25" y="-8,33333333333333E-02" />
  <word Id="amazed" x="-0,25" y="-0,75" />
  <word Id="angry" x="0,125" y="0,25" />
  <word Id="annoyed" x="-0,25" y="8,33333333333333E-02" />
  <word Id="anxious" x="0,5" y="0,166666666666667" />
  <word Id="apparent" x="0,25" y="0,25" />
  <word Id="appreciated" x="0,625" y="0,333333333333333" />
  <word Id="approved" x="-0,25" y="-0,166666666666667" />
  <word Id="aroused" x="-0,125" y="8,33333333333333E-02" />
  <word Id="astonished" x="-0,25" y="-0,75" />
  <word Id="astounded" x="-0,25" y="-0,75" />
  <word Id="attentive" x="0" y="0" />
  <word Id="bad" x="-0,25" y="-8,33333333333333E-02" />
  <word Id="bright" x="0,5" y="0,25" />
  <word Id="calm" x="-0,125" y="-0,583333333333333" />
  <word Id="choleric" x="-0,125" y="0" />
  <word Id="clear" x="0,25" y="-8,33333333333333E-02" />
  <word Id="close" x="-0,25" y="8,33333333333333E-02" />
  <word Id="comfortable" x="0,125" y="-0,166666666666667" />
  <word Id="comic" x="0" y="0,166666666666667" />
  <word Id="concentrated" x="-0,25" y="-8,33333333333333E-02" />
  <word Id="confused" x="-0,375" y="0" />
  <word Id="considered" x="0" y="-8,33333333333333E-02" />
  <word Id="contemptible" x="-0,375" y="0" />
  <word Id="cordial" x="0,25" y="0,25" />
  <word Id="correct" x="0,125" y="8,33333333333333E-02" />
  <word Id="courteous" x="0" y="8,33333333333333E-02" />
  <word Id="covetous" x="0" y="0" />
  <word Id="cozy" x="0" y="-0,25" />
  <word Id="crazy" x="-0,25" y="8,33333333333333E-02" />
  <word Id="curious" x="0" y="0" />
  <word Id="cute" x="0,25" y="0,166666666666667" />
  <word Id="darling" x="0" y="8,33333333333333E-02" />
  <word Id="dazed" x="-0,375" y="-0,583333333333333" />
  <word Id="dead" x="0,25" y="-8,33333333333333E-02" />
  <word Id="dear" x="0" y="8,33333333333333E-02" />
  <word Id="defeated" x="-0,5" y="0" />
  <word Id="deplorable" x="-0,75" y="0" />
  <word Id="depressed" x="-0,375" y="8,33333333333333E-02" />
  <word Id="desperate" x="-0,5" y="-8,33333333333333E-02" />
  <word Id="disabled" x="-0,375" y="0" />
  <word Id="disappointed" x="-0,5" y="0" />
  <word Id="disgusted" x="-0,25" y="8,33333333333333E-02" />
  <word Id="dispirited" x="-0,375" y="8,33333333333333E-02" />
  <word Id="disturbed" x="-0,25" y="8,33333333333333E-02" />
  <word Id="down" x="-0,375" y="8,33333333333333E-02" />
  <word Id="dramatic" x="0" y="-8,33333333333333E-02" />
  <word Id="dumbfounded" x="-0,375" y="-0,666666666666667" />
  <word Id="eager" x="0" y="0" />
  <word Id="elated" x="-0,25" y="-8,33333333333333E-02" />
  <word Id="evident" x="0,25" y="0,25" />
  <word Id="excited" x="-0,25" y="8,33333333333333E-02" />
  <word Id="exhausted" x="0" y="-8,33333333333333E-02" />
  <word Id="familiar" x="0,125" y="-0,25" />
  <word Id="fatigued" x="0" y="-8,33333333333333E-02" />
  <word Id="fearful" x="-0,5" y="-8,33333333333333E-02" />
  <word Id="fierce" x="0" y="0,166666666666667" />
  <word Id="fine" x="0" y="8,33333333333333E-02" />
  <word Id="fit" x="0" y="-8,33333333333333E-02" />
  <word Id="flabbergasted" x="-0,375" y="-0,666666666666667" />
  <word Id="frustrated" x="-0,5" y="0" />
  <word Id="full" x="0" y="0" />
  <word Id="funny" x="0" y="8,33333333333333E-02" />
  <word Id="furious" x="0" y="-0,25" />
  <word Id="gentle" x="-0,125" y="0" />
  <word Id="gloomy" x="-0,5" y="0,166666666666667" />
  <word Id="good" x="0" y="8,33333333333333E-02" />
  <word Id="grabby" x="0" y="0" />
```

```
<word Id="grasping" x="0" y="0" />
<word Id="great" x="0" y="0" />
<word Id="hearty" x="0,25" y="0,333333333333333" />
<word Id="hopeful" x="0,125" y="-8,33333333333333E-02" />
<word Id="horrible" x="-0,5" y="0" />
<word Id="hot" x="0,125" y="0,5" />
<word Id="humiliated" x="-0,5" y="0" />
<word Id="ill" x="-0,25" y="0" />
<word Id="impetuous" x="-0,125" y="0" />
<word Id="improper" x="-0,125" y="8,33333333333333E-02" />
<word Id="indignant" x="0,125" y="-8,33333333333333E-02" />
<word Id="intent" x="-0,125" y="8,33333333333333E-02" />
<word Id="irascible" x="-0,125" y="0" />
<word Id="irritated" x="-0,25" y="8,33333333333333E-02" />
<word Id="isolated" x="-0,25" y="-0,166666666666667" />
<word Id="itchy" x="0,5" y="0,166666666666667" />
<word Id="jovial" x="0,25" y="0,333333333333333" />
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