Analysis of Physical Parameters of Emotional Human Speeches Employing Principal Component Analysis

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Abstract:

Human speeches can be recognized from their paralinguistic and linguistic point of view. The development of artificial-intelligence machines required the ability of the system to recognize the emotional of the speakers. The emotional condition of the speakers (sadness, happiness and anger) could be identified from the speeches intonation differences characterized by their different physical parameter such as: pitch, duration, intensity and formants. These physical parameters extracted from recorded human speeches in different emotional condition. In order to analyze their emotional condition from their physical parameters we employed Principal Component Analysis (PCA) to see the distribution of these parameters to indicate different emotional condition. PCA is the statistical method to see data distribution. The results of PCA1 vs. PCA2 distribution indicate unique characteristic emotional components for every emotional condition. Our method successfully differentiates the emotional condition base on human speeches.

Key words: Emotion, Human Speeches, and Principal Component Analysis.

1. Introduction

Voice or speech is the most common media in human's communication. It delivers communicator's information to communicant. There is additional information on face-to-face communications that communicant can get by seeing the gestures and mimics of the communicator, i.e. emotions. Maybe, that's the reason why videophone technology introduced. If the communicant is a machine, could it get this additional information to? Some research had been conduct to get emotional information from the gestures and mimics, but it applied for the certain socio-cultural only. There are differential gestures or mimics to express same emotions in every socio-cultural.

Linguistic is not the only information can be drawn from speech. There's also paralinguistic, which can be acquired by processing man's speech signal to get its physical parameters.

2. Emotional Speech

Amran Halim (1984) stated that intonation has the function of:

- Grammatical: it defines the meaning of a sentence.
- Emotional: it indicates or marking the emotion.

In the relation to intonation, Dimitrios Ververidis (2003) stated that intonation is the element of paralinguistic, which sometimes takes importance rules in communication. It occurred on the differentiation in emotional signal, i.e. pitch, which indicates the number of vibrations, quality, duration and rhymes of the voice, that is for coding and decoding information. Intonation could inform sex, age, physical and emotional condition, i.e. sad, angry and happy, and personality of the speaker or communicator.

In order to recognize the emotional speech, Moriyama (2002) stated that the process of human's emotional speech recognition including the recognition for every emotion, i.e. sadness, happiness, anger, etc. conducted different extraction and analyzing. To analyze human's emotional speech, the understanding of speech characterization called subjective quality is needed. Subjective quality involving physical parameters, which had mathematical values and units, will make analyzing process a lot easier.

3. Speech Analysis

The information of a speech can be analyzed in many different ways. The researcher had classified some approximating level to describe it, i.e.: level of acoustic, level of phonetic, level of phonology, level of morphology, level of syntactic and level of semantic (I Made Joni, 2003). In this paper, level of morphology, level of syntactic and level of semantic are neglected concerning on emotional speech analysis, which related to physical parameters such as fundamental frequency (F0), phoneme's duration and intensity of voice.

Intonation or prosody as the acoustical aspect of the speech is taking the main role, using phonemes, on identifying every acoustical segment. Every phoneme produced by the movement of vocal tract during articulation, which influencing the speeches spectral of spectrum dynamics (so called Formant). Phoneme can be long or short, hard of soft and had varies of patterns of pitch. Intonation has domain of interpretation beyond phonetic. In particular, intonation relates to duration and fundamental frequency (F0) of the row of speeches. The pronouncing of a word, which may vary in intonation, effects on its identity.

Emphasizing a phoneme by giving the pressured on it among the others is the main function of prosody. This pressured phoneme characterized by its longer duration, more intension and/or had F0 pattern which make it stood out among the other phonemes.

4. Hypothesis

There are three components considered the most important parameters in the intonation's sentence. Which are pitch, phoneme's duration and voice's intensity.

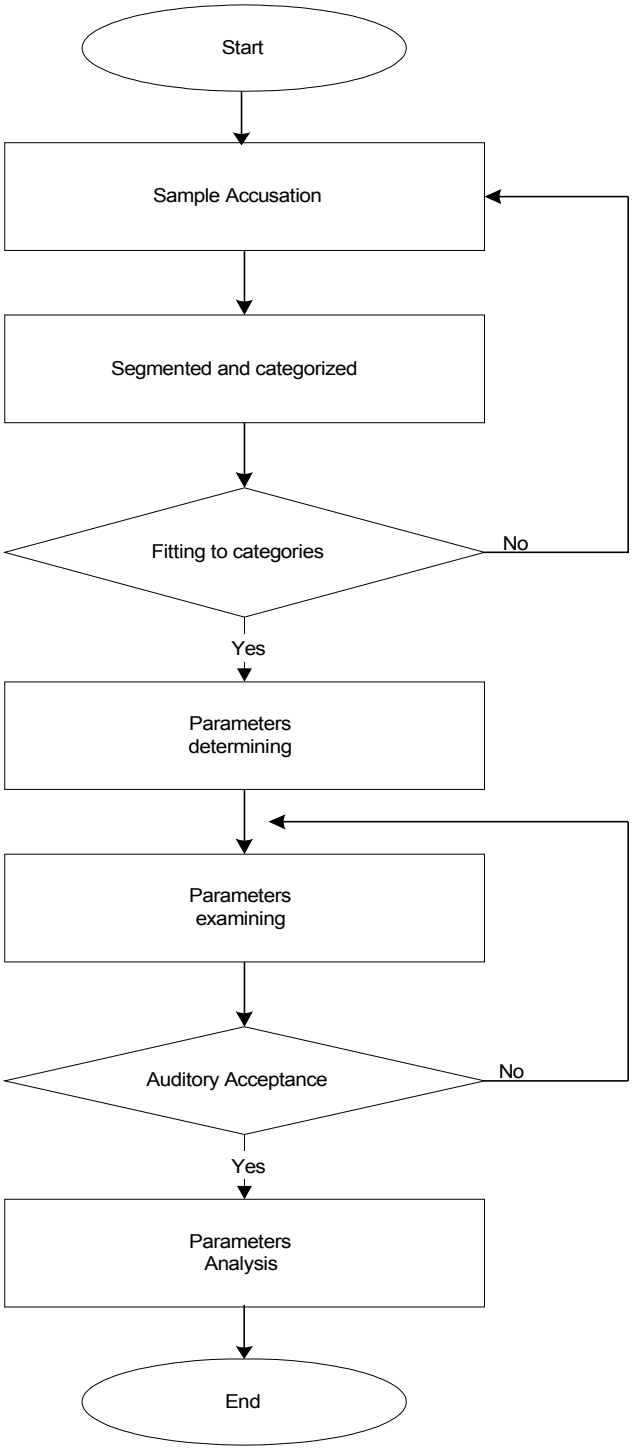
Pitch defines as the amount of vibration or the wave produces by the source of the sound. More vibrations mean higher tone. It could reflect the emotional condition such as, fear, sadness, passions, anger, sincerity, etc. It could emphasize the effects of words spoken. Some research clarifies that pitch is used to reveal self-identity, emotional condition and to influence other peoples (Addington, 1968).

Based on that, we presume if there was some unique information so we can acknowledge the emotional condition of the speaker right away. To establish this hypothesis we search for physical values or physical parameter in the spoken sentences. And we design the research flowchart as follows in Picture 1.

5. Sample Accusation

We took speeches sample of Indonesia Language from the dialogues of movies as acting mode of the speeches and from digitally recorded dialogues of volunteer as natural and normal mode of the speeches. Acting mode define as the acting emotion of speeches and natural mode define as the real emotion of speeches which were taken when the volunteer having some specific emotion (anger, sadness or happiness). While normal

mode define as no-emotional speech. The normal mode of speeches was taking from rephrasing dialogues of acting and natural mode of speeches taking in soundproof room.



Picture 1
Research's flowchart

6. Physical Parameters Analysis Method

The obtaining physical parameters analyzed using PCA method. This method employed to inquire distribution of speech's signals and the dominants parameters in emotional speeches. The PCA method reduces a lot of variables to some variables but still could inform the whole variables. The processes steps are:

1. Putting data in matrices *m* x *n*, whereas *n* is the columns of parameters and *m* is the rows of speeches. There are 8 physical parameters as variables in this matrices, so we had the matrix B as:

$$B = \begin{bmatrix} B_{(1,1)} B_{(1,2)} B_{(1,3)} \; . \; . \; . \; B_{(1,8)} \\ B_{(2,1)} B_{(2,2)} B_{(2,3)} \; . \; . \; . \; B_{(2,8)} \\ B_{(3,1)} B_{(3,2)} B_{(3,3)} \; . \; . \; . \; B_{(3,8)} \\ . \\ . \\ . \\ B_{(m,1)} B_{(m,2)} B_{(m,3)} \; . \; . \; . \; B_{(m,8)} \end{bmatrix} \qquad 6.1.$$

2. Eliminating means of each column by its matrices component. For the average of column 1,

$$\bar{x}_{(m,1)} = \frac{\sum_{i=1}^{n} B_{(m,1)}}{n} \qquad 6.2.$$

we have:

$$C_{(m,1)} = \bar{x}_{(m,1)} - B_{(m,1)} \qquad 6.3.$$

Thus,

$$C = \begin{bmatrix} C_{(1,1)} C_{(1,2)} C_{(1,3)} \; . \; . \; . \; C_{(1,8)} \\ C_{(2,1)} C_{(2,2)} C_{(2,3)} \; . \; . \; . \; C_{(2,8)} \\ C_{(3,1)} C_{(3,2)} C_{(3,3)} \; . \; . \; . \; C_{(3,8)} \\ . \\ . \\ . \\ C_{(m,1)} C_{(m,2)} C_{(m,3)} \; . \; . \; . \; C_{(m,8)} \end{bmatrix} \qquad 6.4.$$

3. Obtaining covariant P.

   $P = C' * C$ 6.5.

4. Obtaining Eigen values and vectors of P.

   a. Eigen values: $|P - \lambda I| = 0$ 6.6.

   b. Eigen vectors: $|P - \lambda I|x = 0$ 6.7.

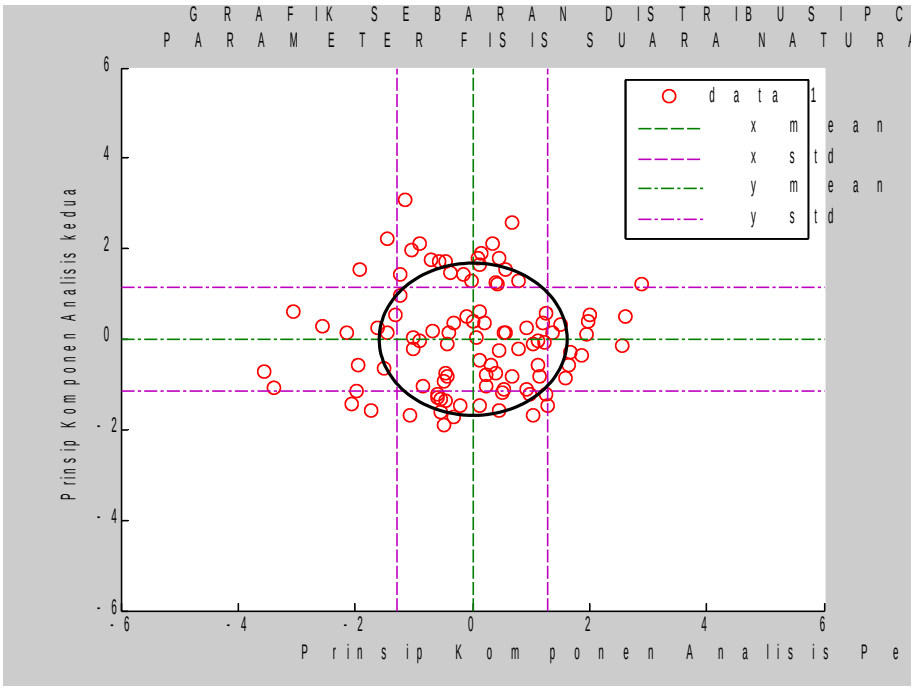
5. Obtaining new variables

   $PCA = H * L(:,i)$ 6.8.

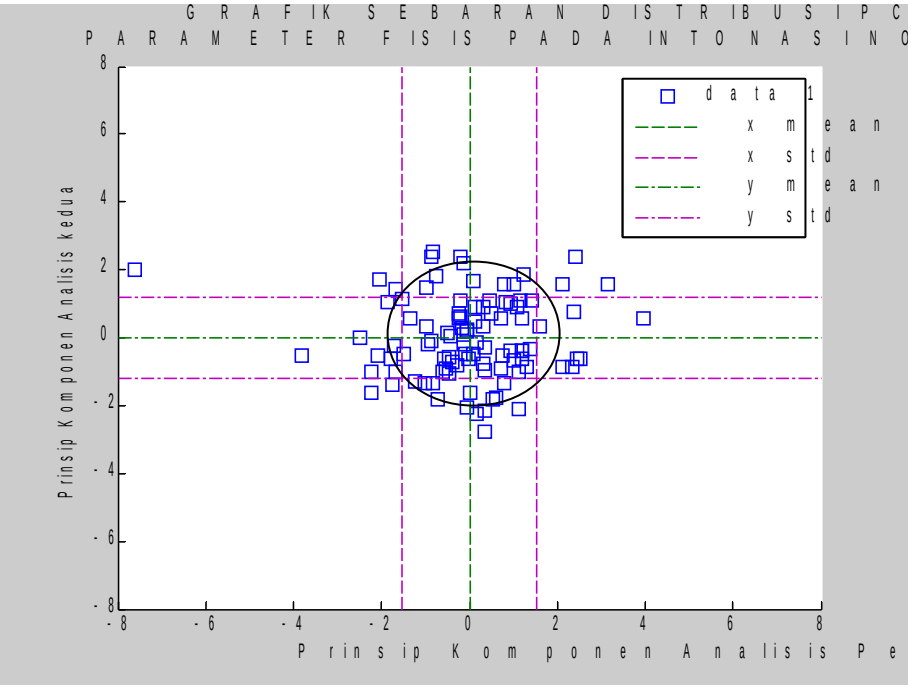
   For H: standardized matrices

   L (:,i): vector of Eigen values for each column.

The whole processes obtained physical parameters distribution for each categorized emotional speech as shown in Picture 2 and Picture 3.



Picture 2.
Physical parameters distribution for natural mode of anger of woman speeches



Picture 3.
Physical parameters distribution for natural mode of anger of man speeches

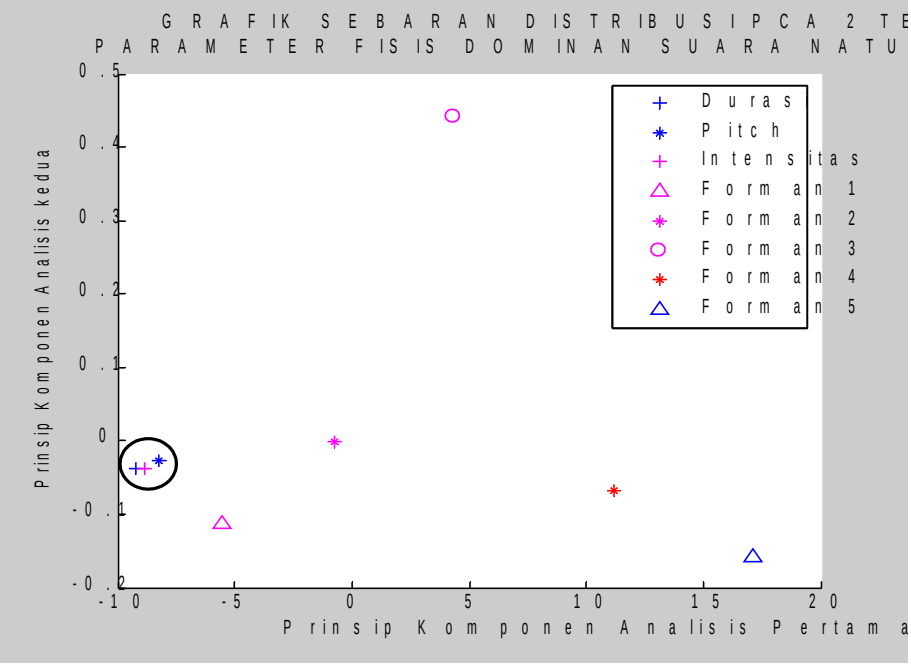
From the graphs of PCA2 vs. PCA1 for each categorized emotional speech we could obtain its means and standard deviation as shown in Table 1.

Table 1.
Physical parameters distribution

Categorized Emotion		Woman				Man			
		Mean		Standard Deviation		Mean		Standard Deviation	
		x (PCA1)	y (PCA2)	x (PCA1)	y (PCA2)	x (PCA1)	y (PCA2)	x (PCA1)	y (PCA2)
Sad	Natural	8.82E-15	1.16E-15	1.640	1.306	-4.48E-15	3.01E-15	1.587	1.255
	Acting	-1.52E-15	-2.85E-15	1.689	1.185	-3.76E-15	-3.19E-15	1.837	1.237
	Normal	1.57E-15	2.25E-14	1.544	1.415	-6.82E-16	6.40E-15	1.757	1.170
Anger	Natural	2.30E-14	-3.37E-15	1.273	1.159	5.79E-15	-5.10E-15	1.385	1.212
	Acting	6.07E-15	7.66E-16	1.575	1.302	-1.61E-14	-6.12E-15	1.395	1.266
	Normal	5.52E-15	-4.70E-15	1.649	1.197	1.20E-14	-9.77E-15	1.516	1.200
Happy	Natural	1.77E-12	1.62E-14	1.347	1.248	4.92E-13	4.70E-12	1.338	1.222
	Acting	7.23E-13	3.05E-14	1.679	1.220	4.05E-13	-2.23E-15	1.715	1.234
	Normal	-6.07E-15	-3.29E-15	1.527	1.207	2.32E-15	2.30E-15	1.759	1.241

To obtain the dominants parameters, we inverted the whole data that produced graphs of PCA2 vs. PCA1 which in serial of speeches to serial of parameters. Then, we had new graph of PCA2 vs. PCA1. One of these graphs is shown in Picture 4. We could see that pitch, duration and intensity were distributed at the same region. And it turned

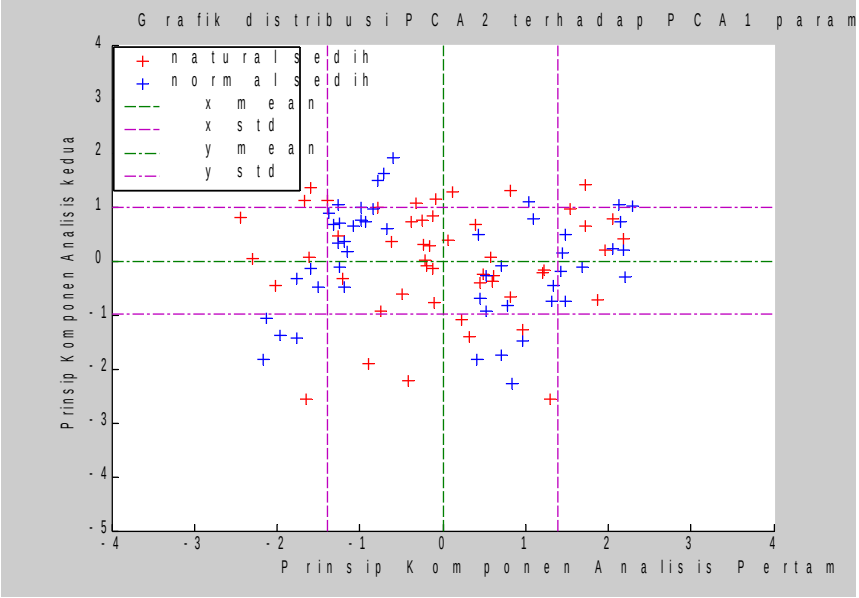
out to all new inverted graphs that these 3 parameters always share the same region. It indicates that the value of these 3 parameters from the inquired speeches share the same uniform and unique features. Thus, we concluded these 3 parameters are the dominant parameters that we did not use 5 others for further analysis.



Picture 4.
The distribution of dominant physical parameters for natural mode of anger of man speeches

7. Comparison of Physical Parameters Distribution

Since there are 3 dominant physical parameters, the emotional analysis used these parameters only by comparing the dominant physical parameters of natural mode to acting mode and normal mode. Picture 5 is shown the comparison of natural mode to normal mode. We could see the comparing distribution has different distribution pattern. And it appeared that all natural modes are differed from acting modes or normal modes. But, sometimes it's not easy to see these unique distribution patterns. Therefore, we used back-propagation Artificial Neural Network (ANN) programming from MatLab®'s toolbox to recognize the dominant physical parameters distribution pattern of natural modes out of acting modes or normal modes.



Picture 5.
The comparison of physical parameters distribution of natural mode of sad of woman speeches to its normal mode

The dominant physical parameters dataset for each natural mode are used for ANN program to recognize the distribution pattern as its related emotion. This task called learning process of ANN. According to several learning processes, we founded out that the best learning method was *traingda* (gradient descent adaptive) since it had the minimum mean square error (MSE) at 0.04 and number of epoch/iteration at 100 for the network architecture of [20 10 1]. So, we built the ANN program that had 2 hidden layers: 20 neurons and 10 neuron each, and 1 neuron at output layer. At output layer, we define minus 1 (-1) as sad, zero (0) as anger and one (1) as happy. So, if the output has different value out of –1 to 1, it is not the natural emotion of sad, anger or happy. Thus, we proceeded to learning process of ANN.

Afterward, we tested it out with the others data to see whether it could recognize them related to the right emotion. We prepared 15 testing data for each sex category or 10 data for each natural emotion (see Table 2). The testing results, Table 2, show that they had maximum error of 0.2705 or minimum accuracy of 99.7295% to recognize the emotional speech based on its dominant physical parameters.

Table 2.
ANN's testing results

Woman Emotional Speeches		Man Emotional Speeches	
Related Emotion Data	**Error**	**Related Emotion Data**	**Error**
Sad	0.0385	Sad	0.0268
Sad	0.0057	Sad	0.0769
Sad	0.0056	Sad	0.0439
Sad	0.0629	Sad	0.1004
Sad	0.0375	Sad	0.0494
Anger	0.0749	Anger	0.0999
Anger	0.0629	Anger	0.1206
Anger	0.0843	Anger	0.1402
Anger	0.0856	Anger	0.0983
Anger	0.0562	Anger	0.1356
Happy	0.0233	Happy	0.1937
Happy	0.0362	Happy	0.2522
Happy	0.0422	Happy	0.2705
Happy	0.0065	Happy	0.1852
Happy	0.0055	Happy	0.1793

8. Conclusions

1. Emotional condition of a speaker can be identified from his speeches physical parameters.
2. There are 3 dominant physical parameters of emotional speech, i.e. pitch, duration and intensity.
3. PCA exhibit the distribution of dominant physical parameters has different distribution pattern for each emotional condition.
4. Artificial Neural Network programming may be built for emotional recognition based on speeches (dominant) physical parameters, which is confirmed the existence of distribution pattern for each emotional condition.

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