A Sample Reduction and ANN Based Classification of Temporomandibular Joint Sounds

Uğur Taşkıran[1], Saadetdin Herdem[2], Mehmet Çunkaş[3], Filiz Aykent[4], Tuba Yılmaz Savas[4], H. Erdinç Koçer[3]
[1]Dept.of Electrical and Electronics Engineering, Faculty of Technology, Selcuk University, Konya, Turkey.
utaskiran@selcuk.edu.tr
[2]Dept.of Electrical and Electronics Engineering, Faculty of Engineering, Selcuk University, Konya, Turkey.
[3]Dept.of Electrical and Electronics Engineering, Faculty of Technology, Selcuk University, Konya, Turkey.
[4]Faculty of Dentistry, Department of Prosthodontics, Selcuk University,42079 Kampus, Konya,Turkey

***Abstract*— In this study, a portable sound recording equipment along with the user interface software is developed for Temporomandibular Joint (TMJ) sound classification. TMJ is simply known as jaw bone joint and problems arising from problematic joints known as Temporomandibular Disorder (TMD). TMD is a frequent disorder, it is so common that more than two third of population have some kind and level of TMD. TMJ sound listening one of the diagnose methods by the clinic dentists. In the study mentioned TMJ sounds are collected by portable equipment. After collection of data, some signal processing and data reduction based on sample reduction is realized. After obtaining relatively low point of data, ANN based classification of the sound waves are realized. Classification success rate is 78.9%.**

***Index Terms*—TMJ, TMD, sound classification, sample reduction, ANN based classification**

I. Introduction

Temporomandibular Joint (TMJ) which allows proper jaw movements, is the joint between the condyle of the mandibula and mandibular fossa of the temporal bone. Between these two bones there is an aticular disc. This means that joint has ability to make very complex movements. Any health problem arising from the TMJ is called Temporomandibular Disorder (TMD).

Researches show that TMD is very common problem among the general population. TMD is so common that 75% of the population is diagnosed to have some kind of TMD and at least 33% of the population shows one or more symptoms of the TMD [1]. Studies show that TMD is even more common among the Turkish population [2]. Pain is the main symptom of the TMD, but generally it appears that it is not directly emanating from the joint. Migraine like headaches, earaches, even strains in the eyes can be misinterpreted but can be arising from TMD. This type aches are called reflecting aches. Addition to these, loss of the movement of jaw, deviations and deflections and sound and pain during the opening and closing of the jaw and jaw locks can be among the symptoms of the disorder.

Many studies on classification of the TMJ sounds are published in the literature. Widmalm at all published several paper about the subject. First they tried to classify the clicking and crepitation, and in the other one of their studies they used Reduced Interference Distribution (RID) and defined and classified five different sound types [3], [4]. Similar studies based on Widmalm's research include amplitude and wave spectrum, and classification based on pattern recognition methods are also made by his colleagues and Widmalm [5] [6] [10].

Many different researchers and academician including Ghodsi at all [7] and Akan at all [8] [9], have used different techniques of classification including spectrum based techniques, time-frequency analysis, discrete evolutionary transform. Some of the studies like the research of Took at all have focused on differentiating sound from left and right joints based kurtosis and click sounds [11] [12].

Similar studies are realized not only for TMJ but different joints especially concentrating knee joints [13]

The listened sounds of the joint are used by the dentists frequently to diagnose the disease. Clinical consultation includes the listening of the TMJ sound during the opening and closing of the jaw. TMD related sounds are classified like crepitating, clicking and/or popping clicking. These sound classifications generally depends of the dentist's experience on the subject and sometimes misinterpretations occur especially in noisy clinical environments. Magnetic Resonance (MR) methods can be chosen for definitive diagnose but MR is costly and may not be readily available all the time. The object of the study indeed about designing a portable, less costly equipment which can be set up and used in very short time.

In this study, a portable sound recording equipment along with the user interface software is developed. Some classification of the sound waves based on ANN are realized. The advanced phase of the study is planned to include developing on-line diagnose results.

II. Material and Method

Study is done in many phases. The phases are background research and bureaucratic preparation for voluntary subjects, design and realization of the equipment, Design and realization of the recording software and its user interface, Collection of data with cooperation of Selcuk University, Faculty of Dentistry. In this point, it is important to note that collected data is not only used in this study but can also be used for many different type of future research project. The last phase is the classification of the collected data by means of a computer software.

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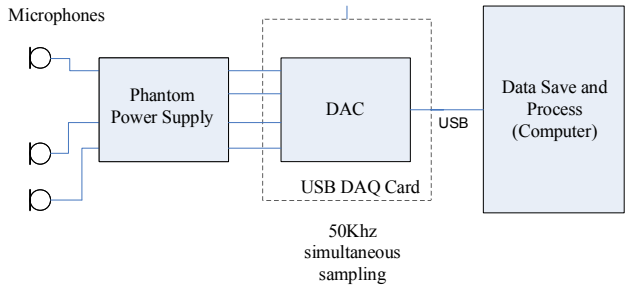


Fig. 1. Block Diagram of the Data Collection Equipment

A diagram of the data collection equipment is given in the Fig. 1. There are three high quality microphones, for two of which are for right and left TMJ sound recording and one which is for environment noise recording. Microphones are suggested to have at least 3KHz bandwidth by the literature studies. In this study microphones are Earthworks M23 having a bandwidth from 9Hz to 23KHz

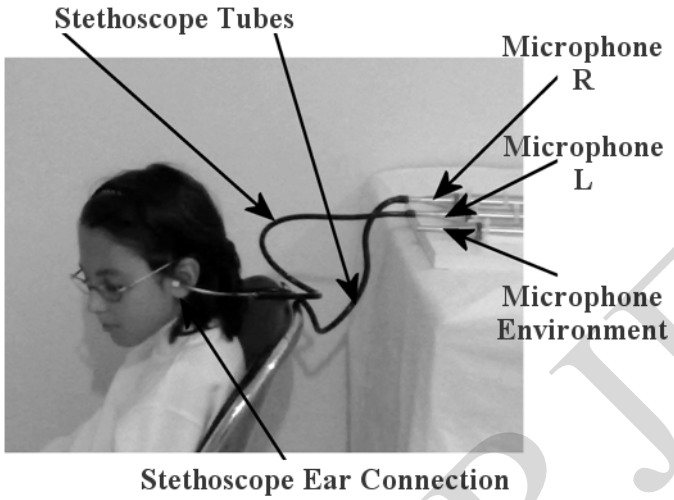


Fig. 2. Data Collection Setup

Sound collection is implemented by ordinary stethoscope to pick the TMJ sounds directly from ear channel as the literature suggested. The set up is not different from a dentist listening equipment of a patient. Only difference is instead of a dentist's ear, high quality microphones are used to pick the sound data. Typical connection setup for patient side can be seen in the Fig. 2. Microphones are power supplied by a phantom supply and data is transferred to USB connected DAC card. As a data conversion equipment National Instrument NI USB-9234 DAQ equipment is used. NI USB-9234 is a 4 channel data collection equipment. NI USB-9234 can sample 4 channel data simultaneously at 51200Hz in 24 bits of resolution. Only three channels are used, one is to collect right TMJ data, one is to collect left TMJ data and one is for environment noise data. All three different data set and simultaneous sampling is chosen to make correlation analysis and to develop noise reduction algorithms for future use.

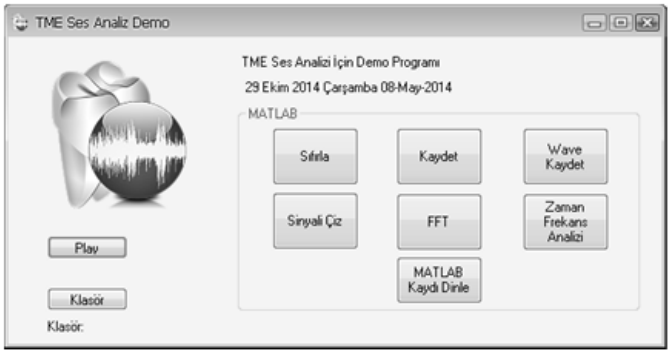


Fig. 3. User interface of the developed software

A computer software is developed in Visual C# and MATLAB for storing and simple online analysis of the data. Online analysis enables to check the over noisy or incorrectly recorded data. In the case of problematic data, recording can be redone in minutes. All the setup including laptop computer can easily be stored on a small suitcase having size of a typical small sized desktop computer. Consequently, equipment can be carried from clinic to clinic easily and can be setup in five minutes to collect data. User interface of the developed software is given in Fig. 3. Note that user interface is in Turkish. Software can be used to initialize the setup, to store the data, to store data in wave format, to draw the signal, to draw the DFT of the signal, to draw time-frequency analysis graph, to listen to recorded data and to choose the store folder.

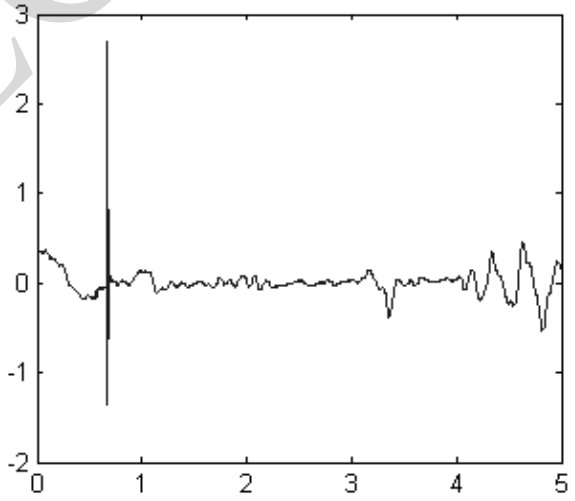


Fig. 4. A typical click sound wave of the TMJ. (Voltages vs. Seconds)

After development of the recording equipment and software the equipment is started to use both patient and healthy people's data. Data collection and clinical consultation of both healthy persons and patients are realized in Selcuk University Dentistry Faculty. All patient's clinical and computer data are stored carefully. Expert dentists of the Faculty consult the subjects about their condition. Around 150 data belonging to

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50 different subject including healthy subjects are cautiously collected.

After the collection of data the first phase of analysis is done by carefully comparing patient data and observing the recorded data and classifications are cleared according the dentists' consultation.

In this study only patients having click sound in their TMJ movements are considered. A typical click test subject's recorded sound wave is shown in Figure 4. Chosen 19 data includes healthy and click sound patients. Twelve of the data belongs to healthy subjects and seven of the data belongs to patients. Chosen data types are listed in TABLE I. Here Date and Time Stamps are used as data name, Legend for joint types are R for right TMJ and L for left TMJ. Legend for type are H for healthy and C for click sound data.

TABLE I. CHOSEN DATA NAMES AND TYPES (LEGEND FOR NAME; DATE AND TIME STAMP, R:RIGHT, L: LEFT, H: HEALTHY, C: CLICK)

Data Number	Data (Date and Time Stamp)	Joint	Type
1	23-Dec-2013-162306.mat	R	H
2	23-Dec-2011-162437.mat	L	H
3	23-Dec-2011-160635.mat	R	H
4	06-Jan-2012-163436.mat	L	H
5	06-Jan-2012-165823.mat	R	H
6	06-Mar-2014-130754.mat	L	H
7	08-May-2014-181536.mat	R	H
8	12-Dec-2013-204012.mat	L	H
9	12-Dec-2013-203148.mat	R	H
10	16-Dec-2013-153739.mat	L	H
11	16-Dec-2013-160501.mat	R	H
12	08-May-2014-181349.mat	L	H
13	06-Jan-2012-163211.mat	L	C
14	10-Apr-2014-110037.mat	L	C
15	06-Mar-2014-131156.mat	L	C
16	08-May-2014-181745.mat	L	C
17	26-Sep-2011-121110.mat	L	C
18	12-Dec-2013-204221.mat	L	C
19	16-Dec-2013-160114.mat	L	C

In first trial 50 Hz notch filter is used to filter the line noise. Some high frequency components are filtered out for sample reduction. Then, the data is tried to classify by using Artificial Neural Networks (ANN). This was some kind of time domain classification process resulting low success rate. Because of low success rate of time domain analysis, data is then chosen to be analyzed in frequency domain. Every raw data consists of 51200 samples of 5 seconds data, resulting total of 256000, 24 bit data points. This data first to 5 seconds of 10000 samples resulting 50000 samples by means of a down sampling FIR low pass filter limiting the bandwidth to less than 5KHz. Then Discreet Fourier Transform (DFT) is applied to transfer the data into frequency domain. Then ANN classification is employed for correct categorization. After applying many different sample reduction rates, the data samples are reduced down to 100 points per data.

III. RESULTS AND DISCUSSION

Discussion topics include noise reduction and classification algorithms of the signals collected by the designed instruments. The collection of data gathering consumes large amount of time and still requires many more signal data to be collected for more healthy classification results. This phase of the study only includes click sound classification. The data is first tried to be classified in time domain resulting low success rate. After that data is transformed by using DFT algorithm and data reduction algorithms are applied and ANN are used for classification resulting an acceptable classification rates. Results are presented TABLE II. and TABLE III.

Among the chosen 19 data set, 3 data sets are eliminated by the ANN training software. Randomly 14 data sets are chosen among the surviving 16 data set. Chosen data sets are used for training of the ANN. Remaining 2 is chosen for test purposes. For this phase of the research 7 trainings are realized. Total of 14 classification are made. Classification results are presented in TABLE II.

TABLE II. RESULTS OF ANN TRAINING

Trial Number	Data Number	Real Data Type	Classification	Data Number	Real Data Type	Classification
1	3	H	H	15	C	H
2	2	H	H	10	H	H
3	2	H	H	15	C	C
4	3	H	C	11	H	H
5	7	H	C	18	C	C
6	6	H	H	18	C	C
7	8	H	C	10	H	H

TABLE III. ANN CLASSIFICATION RESULTS

	Classification Results		
Number of Data	*Real Classification*	*ANN Results*	
		Healthy	*Click*
10	Healthy	8	2
4	Click	1	3
Total Number of Correct Classification is 11 out of 14 available valid data			

According to this, 8 out of 10 healthy data and 3 out of 4 click data are classified correctly. Concluding from these results, classification is 78.9% successful. This classification can be considered successful bearing in mind that data collections are realized in real clinical environment just after

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the clinical consultation by the dentist. On the other hand, some presented results in the literature claims more successful rates. The reason for this ANN classification algorithms require many more data than number of data presented here.

There are many ways to increase the classification success rate. First approach is to increase the number data to use in classification algorithms. This can be achieved two means. One is to continue to gather the data cooperating with the Faculty of Dentistry. The other one is the increasing the number clean data by using correlation analysis and advanced noise reduction techniques. In case of failure in increasing number of data available, it is possible to use statistical classification and hybrid classification techniques

IV. Conclusion

TMD is one of the common disorder in the area of dentistry. More than two third of the population have this problem with or without knowing that they were suffering from TMD. Many times symptoms are confusing and may be misinterpreted by the physicians. One of the diagnose method of the TMD is to listen the sound of the TMJ movement during the opening and closing the jaw. The paper presents a helping instrument for the clinical dentist for diagnosing the problem. The study also shows that data collected by the instrument can be used to classify the problematic and non-problematic TMJ. By using the methods of Fourier transform, sample reduction and ANN networks classification can be made by using the data collected by the instrument. The results demonstrate that the presented method although is simple enough to realize quickly it can give fairly good result of 78.9% success ratio. The classification algorithms used here can be developed further to increase classification success rate.

Acknowledgment

This work is supported by Selçuk University Scientific Research Coordination (BAP) (BAP Project Number: 10101007).

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