INITIAL ASSESSMENT OF FACIAL NERVE PARALYSIS BASED ON MOTION ANALYSIS USING OPTICAL FLOW METHOD

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UNIVERSITI MALAYSIA PERLIS

2015

Initial Assessment of Facial Nerve Paralysis based on Motion Analysis using Optical Flow Method

by

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A thesis submitted in fulfillment of the requirements for the degree of Master of Science in Mechatronic Engineering

School of Mechatronic Engineering

UNIVERSITI MALAYSIA PERLIS

2015

ACKNOWLEDGEMENTS

Alhamdulillah, all praises to Allah S.W.T for His blessing and guidance for me to finish this project and thesis successfully. The thesis has been realized by the combined work and skills of many people. Firstly, I would like to express my very great appreciation to my supervisor, Associate Professor, Ir. Dr. Kenneth Sundaraj for his valuable and constructive suggestions during the planning and development of this research work. His willingness to give his time so generously has been very much appreciated. His patient guidance, enthusiastic encouragement and useful critiques in publication and research work are very priceless. I would like to give special thanks to Universiti Malaysia Pahang (UMP) for funding me through fellowship scheme SLAB/SLAI. I am also indebted to all members of AI-Rehab Research Group, Universiti Malaysia Perlis (UniMAP) for the constant encouragement, support and friendship during my research. I would also like to thank Dr. Amirozi Ahmad, otolaryngologist from Hospital Tunku Fauziah (HTF) and his staffs for their cooperation in providing guidance and support during data collection and validation process. Many friends have helped me stay sane through difficult years. I greatly value their friendship and deeply appreciated their belief in me. Big thanks go to my parents and family for their endless advice, love and prayers. Finally, thanks to my dear husband, Muhammad Akmal Maksum, for his continued and unfailing love, support and understanding me all over the research works. You were always around at times I thought that it is impossible to continue. To my son, Muhammad Safiy Atheef, u are always my strength. Lastly, my thanks and appreciation goes to all these people and others who were directly or indirectly involved in this research. Without them, this research work would never have been completed.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AFA	Automated Facial Analysis
AU	Action Units
AVI	Audio Video Interleave
FNF	Facial Nerve Paralysis
HB	House Brackmann
HBGS	House Brackmann Grading System
KLT	Kanade-Lucas-Tomasi
LBP	Local Binary Pattern
MREC	Medical Research and Ethics Committee
SRA	Maximum Static Response Array
OP	Optical Flow
RAD	Resistor-Average-Distance
RBF	Radial Basis Function
SLFS	Stennert-Limberg-Frentrup Scale

Penilaian Awal Kelumpuhan Saraf Muka Berdasarkan Analisis Pergerakan Menggunakan Kaedah Aliran Optik

ABSTRAK

Pesakit yang mengalami lumpuh saraf muka menghadapi masalah fungsi, kosmetik, dan psikologi yang serius dengan keupayaan untuk berkomunikasi secara lisan dan bukan lisan terjejas. Rehabilitasi untuk kelumpuhan muka bermula dengan penilaian klinikal yang teliti dalam menilai tahap lumpuh. Secara umumnya, untuk penilaian ketidakfungsian saraf muka pada muka pesakit dalam aplikasi klinikal setiap hari, sistem pemerhatian yang subjektif oleh pakar klinikal telah digunakan. Penilaian subjektif terhadap fungsi saraf muka ini dicapai dengan membuat kesimpulan melalui pemerhatian kepada pergerakan muka yang tidak dipaksa. Kaedah-kaedah ini biasanya menghasilkan satu nilai dimana hipotesisnya sepadan dengan tahap kelumpuhan muka. Setakat ini, tiada kaedah penilaian secara subjektif yang boleh menghasilkan maklumat kuantitatif mengenai fungsi saraf muka dengan tepat. Kajian sebelum ini telah mencadangkan pelbagai kaedah bagi memperolehi data objektif untuk mengukur dan menentukan tahap kelumpuhan muka. Walau bagaimanapun, tiada kaedah kuantitatif yang mengikut piawaian bagi penerangan fungsi saraf muka secara objektif. Mengakui kepentingan penilaian muka ini, kajian ini dijalankan untuk membangunkan penilaian awal yang boleh mengkelaskan subjek kepada normal dan pesakit berdasarkan analisis pergerakan muka menggunakan algoritma aliran optik serta mengkategorikan pesakit kepada enam peringkat mengikut sistem House-Brackmann (HB). Sebelum penilaian awal dibangunkan, dua eksperimen telah dijalankan untuk mencari parameter yang terbaik dan juga ukuran terbaik untuk menilai kelumpuhan muka. Jarak dan luas kawasan telah dipilih sebagai dua parameter yang disiasat dalam kajian ini . Beberapa analisis matematik dan statistik telah dijalankan untuk menentukan ukuran yang terbaik daripada parameter-parameter ini. Keputusan menunjukkan bahawa jarak adalah parameter yang terbaik dan nilai pada bingkai awal senaman adalah pengukuran yang paling penting dalam mengesan perubahan pergerakan muka. Tesis ini juga membentangkan penilaian awal muka yang mengandungi markah individu untuk setiap senaman yang terlibat dalam kajian ini dan juga menggredkan tahap lumpuh untuk setiap pesakit sepadan dengan sistem HB. Kajian ini telah mendapat keputusan yang memuaskan yang telah disahkan oleh pakar perubatan dalam Otorinolaringologi. Penilaian awal muka ini memainkan peranan penting dalam permulaan sistem penilaian akhir untuk kelumpuhan muka dan membangunkan program rehabilitasi yang lebih baik untuk pesakit.

Initial Assessment of Facial Nerve Paralysis Based on Motion Analysis using Optical Flow Method

ABSTRACT

Patients with facial nerve paralysis suffer serious functional, cosmetic and psychological problems with impaired ability to communicate both verbally and non-verbally. Rehabilitation for facial paralysis begins with a thorough clinical evaluation in accessing the degree of paralysis. Generally, for assessment of facial nerve dysfunction on patient's face in daily clinical application, observation-based subjective grading systems by clinicians is been employed. Subjective assessments of facial nerve function are accomplished by inferring nerve function through the observation of voluntary facial movement. These methods usually yield a single value which hypothetically corresponds to the severity of facial paralysis. To date, there are no subjective assessment methods that can reliably produce quantitative information regarding facial nerve function. Previous works have proposed a wide range of methods to obtain objective data to quantify and determine the severity of facial paralysis. However, there is no standardized quantitative method for objective description of facial nerve function. Acknowledging the importance of this facial assessment, this research was conducted to develop an initial assessment method that can classify normal and patient subjects based on facial motion analysis using Optical Flow algorithm as well as categorizing the severity of patient into six levels according to House-Brackmann (HB) system. Prior to initial assessment method been developed, two experiments were conducted to find the best parameter and best measurement for assessing facial paralysis. Distance and area were selected as two measurement parameters which were investigated in this research. A number of mathematical and statistical analyses were performed to determine the best measurement of these parameters. The results indicate that the distance is the best parameter and the value of initial exercise frame is the most important measurement in tracking the changes of facial movement. This thesis also presents the initial facial assessment method which contains the individual scores for each exercise involved in this research and also grading the paralysis for each patient corresponds to HB system. This research showed satisfactory results which was validated by a medical professional in Otorhinolaryngology. This initial facial assessment method may play a pivotal role in initiation of final assessment system for facial paralysis and develop better rehabilitation program for patients.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Facial nerve incorporates about 7,000 individual nerve fibers. Each fiber brings the electrical impulses to a specific facial muscle. All information through the fibers of this nerve permits us to make any facial expression such as laugh, cry, smile, and frown. Human express the emotions such as sadness, surprise, happiness, excitement and confusion through facial expressions. For example, a smile can be interpreted as the sign of happiness while frowning shows some disagreement and sadness. Facial nerve paralysis will take place when some of the individual nerve fibers are disrupted. Besides, the movement of facial muscles starts spasming or twitching if these fibers are irritated. Figure 1.1 shows some of the facial muscles that are responsible for the facial expressions.

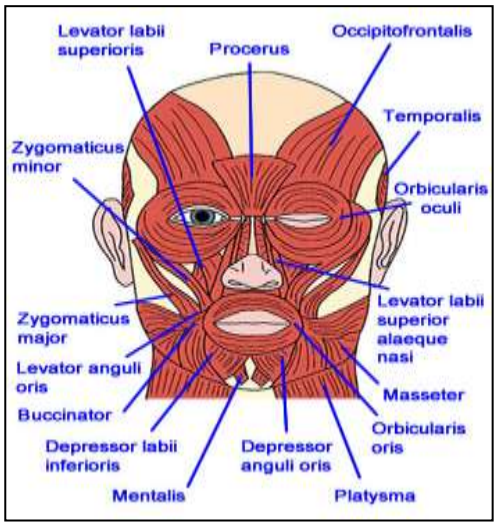

Figure 1.1: Head and facial muscles (Knysh B., 2015).

Facial nerve paralysis (FNP) is a common problem which involves the paralysis of any structure innervated by the facial nerve. Literature shows that the prevalent cause of this paralysis is Bell's palsy, named after Sir Charles Bell (1774-1842). Bell's palsy is an idiopathic disease category, reporting approximately 50% of the cases (Brach & VanSwearingen, 1999; Singhi & Jain, 2003).

The other possible causes of facial paralysis are due to birth, trauma, neurologic syndromes, infection, metabolic, neoplastic, toxic and iatrogenic (Benecke, 2002). Patients with these paralyses suffer serious functional, cosmetic and psychological problems with impaired ability to communicate both verbally and non-verbally. Numbness can occur on the affected side of the face although no actual sensory loss occurs (Singhi, 2003). Besides, they will be unable to close the eye on the affected side, which can lead to irritation and corneal ulceration. Because of that, the eye should be lubricated with artificial tears until facial paralysis ends (Piercy, 2005). However, the most dramatic impact of the paralysis is its psychological effect where the patients may have low confidence and fear when interacting with others.

A thorough medical history of patients and physical examination are the earliest steps in making a facial diagnosis. Clinicians examine whether the forehead is involved in motor defect or not. This is commonly accomplished by assessing how well a patient can raise his or her eyebrows. The results from this action help in determining which part the lesion is in whether in the upper motor neuron or lower motor neuron of facial nerve component. Rehabilitation is suggested by doctors after patient's treatment, depending on their condition. It is to regain the function of facial nerves and improve both the strength and flexibility of the nerves. The failure in rehabilitation procedures may lead to the continued weakness and inability to function of facial nerves.

The availability of facial rehabilitation is limited, and most individuals with facial movement disorders have been told to await (spontaneous) recovery or told no effective intervention exists. Consequently, individuals with this paralysis will deal with physical, psychological, and social disability daily. The rehabilitation for facial paralysis begins with a thorough clinical evaluation in accessing the degree of paralysis. It is important to measure the facial disability from onset to the various stages of recovery and also to detect changes over time or after treatment. In the past few decades, several internationally accepted systems have been proposed by different researchers, yet most of the existing systems are subjective. This subjective evaluation refers to various facial nerve grading systems, of which the most widely used is the House-Brackmann (HB) system (Dellanoy & Ward, 2010; Dulguerov, Wang, Perneger, Marchal, & Lehmann, 2003). The facial nerve evaluation will vary over many clinicians and it will results in inaccurate assessment of paralysis.

There is no standardized system yet for facial nerve evaluation which has been accepted for world-wide used. Thus, an objective standardized method, which is easy to perform, low cost and fast, and simple can be a useful clinical tool to detect the level of paralysis in patients with facial palsy and monitor their improvement or performance during and after the rehabilitation procedures. In this study, an initial facial assessment method is proposed to assist clinicians in assessing the facial nerve function. Comparisons have been made between two measurement parameters to determine which one is better to be implemented in the assessment system.

1.2 Problem Statement

The problems that motivate this study are the limitation of standard facial nerve assessment, subjective clinical assessment by clinicians or physiotherapist, and the requirement of printed scores during evaluation of facial nerve function.

A. Limitation of Standard Facial Nerve Assessment

There are many grading systems such as House-Brackmann (HB), Yanagihara and Sunnybrook system and also assessment methods available to evaluate the facial nerve function. However, no standardized system is used by clinicians because the previous systems have not achieved the requirement to be an ideal system for assessing facial paralysis. Mostly, all the assessment methods are based on the HB system. So, an initial assessment method which can give an objective measurement for both sides of the face, simple, easy to use, and based on the HB system is an ideal assessment method to evaluate the facial nerve function.

B. Subjective Clinical Assessment by Clinicians

No objective assessment of patient's nerve functions in real life application is clinically available. The results vary depending on the clinicians' observation and the evaluation is not standardized (Meier-Gallati, Scriba, & Fisch, 1998). Sometimes, the person who is still in a paralyzed state is treated as normal because the evaluation is only based on the clinicians' naked eyes. An objective assessment which provides quantitative measurement can reduce the time for grading the paralysis and make it

reliable to all the patients, even with different clinicians or physiotherapists' assessment (Murty, Diver, Kelly, & O'Donoghue, 1994). Even though the patient is still in the same level of HB scores, the clinicians are able to see how much their patients have improved in performance of rehabilitation based on the objective measurement.

C. Requirement of Printed Scores during Evaluation of Facial Nerve Function

The clinicians and doctors have to refer to the printed scores on sheets of paper and make their subjective evaluation based on the patients' movements (Isono, Murata, Tanaka, Kawamoto, & Azuma, 1996; He Soraghan, O'Reilly, & Xing, 2009). Apart from referring to the scores, some of them need to compare the snapshots taken during the rehabilitation program to evaluate the performance of patients. The initial objective assessment will assist the clinicians in detecting the level of paralysis and record the performance of patients. It will help clinicians to acknowledge the patients' improvement during rehabilitation program.

1.3 Objectives of Research

The main objective of this project is to develop an initial facial assessment for facial nerve paralysis based on motion analysis using Optical Flow (OF) method. The sub-objectives of this research include:

1. To explore and identify all possible facial muscles which are involved in the desired rehabilitation facial exercises.
2. To determine potential landmarks on the face based on muscle movement and medical professional's recommendation

3. To track the landmarks over the time (in the image frames) successfully by applying optical flow algorithm.
4. To investigate the most suitable measurement parameter based on motion analysis to be implemented in the initial assessment of facial nerve function.
5. To validate the performance of the initial facial assessment system, which is able to differentiate between normal and patient subjects, detect the level of paralysis with the HB system and compare the results with a clinician's evaluation.

1.4 Scope of Research

The scope of this research is to develop an initial facial nerve assessment to evaluate the facial nerve function. This research will analyze two parameters which are possible to evaluate the facial nerve function, which is distance and area. The proposed assessment method will be able to differentiate between normal and patient subjects, determine which side of face that is paralyzed and also able to predict the level of paralysis based on the HB scoring system. The data for this research are normal data (healthy subjects) and patient data (Bell's palsy patients from Hospital Tunku Fauziah (HTF). Bell's palsy is the common cause of facial paralysis which is reported in HTF. This assessment method will be validated by appropriate medical professionals from HTF.

1.5 Thesis Outline

In Chapter 1, the general idea of this research which is to develop an initial facial nerve assessment for facial paralysis has been briefly presented. The problem statement, research's objectives and scope are explained in this chapter. Theoretical studies and relevant literature are presented in Chapter 2. The physiology study on facial nerve and facial paralysis are explained thoroughly in this chapter. Previous works done on facial assessment method for facial paralysis is also discussed in this chapter. Chapter 3 focuses on the research methodology which is to develop an initial facial assessment for facial paralysis. The process of data acquisition, landmark placement, tracking the landmarks on the face, and the scores of the facial nerve function based on the exercise done by the subjects are discussed in detailed in this chapter. Results and discussion will be presented in Chapter 4. The results from the experiment are analyzed and explained in this chapter. Validation of the results by a medical professional from the Otorhinolaryngology department of HTF is also presented. Overall conclusion is summarized in Chapter 5. Contributions of the research are highlighted along with the challenges experienced during the research period. Finally, suggestions for future work are given at the end of this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents the overview of facial nerve and the type of facial nerve paralysis. The incidence and prevalence, causes, symptoms, and effects to patients who have facial nerve paralysis are discussed in this chapter. The literature on facial nerve assessment methods is also discussed.

2.2 Facial Nerve

The facial nerve consists of a motor and also a sensory part, which being frequently described as the nervus intermedius (*pars intermedii of Wrisberg*). Anatomy of the facial nerve is shown in Figure 2.1. The nerve contains 10,000 fibers out of which 7,000 are myelinated motor fibers (Feghali, Joseph, Fayad Y., & Murphy M., 2013). Most of the motor fibers travel to the extratemporal portion of the facial nerve and innervate the muscle of the face, scalp, and auricle, the buccinators and platysma, the stapedius, the stylohyoideus, and posterior belly of the digastricus (Kecskes, 2012).

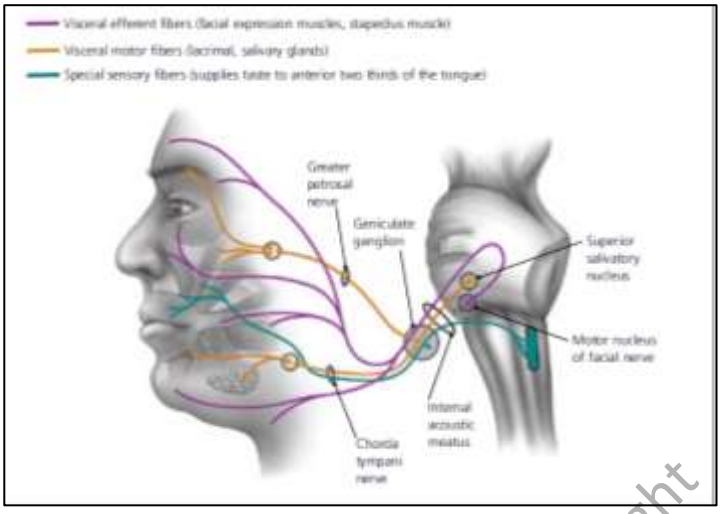

Figure 2.1: Anatomy of facial nerve (Tiemstra & Khatkhate, 2007).

The main function of the facial nerve is to express the voluntary behavior and spontaneous emotions via innervating 23 facial muscles on each side of the face. The facial muscles are inserted directly into the skin and the contraction of these muscles will cause the skin to move. Signals from the complex array of the nerves to the various muscles instruct the muscles to move in combinations and also as individually (Kecskes, 2012).

2.3 Facial Paralysis

Facial paralysis is the loss or impairment of motor function of facial muscles due to damage of the facial nerve (Cranial nerve VII), brainstem nuclei of the facial nerve, and/or the neuromuscular system innvervated by this nerve. The degree of paralysis is from minor weakness to complete paralysis depends on the site and extent of the lesion (Dunwald, 2010).

Facial paralysis or facial nerve palsy is a serious problem, for both the afflicted patient and the physician attempting to make a proper diagnosis (Benecke, 2002). Facial