AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Computer and Systems Engineering Department

Development of Feature Extraction Engine of Visual Information used in LGN-based Visual Prosthesis

A Thesis submitted in partial fulfillment of the requirements of the degree of
Master of Science in Electrical Engineering
(Computer and Systems Engineering)
By

Eng. Hossam El-Din Hesham Mohamed Abolfotuh
Bachelor of Science in Electrical Engineering
(Computer and Systems Engineering)
Faculty of Engineering, Ain Shams University, 2011
Supervised By

Prof. Dr. Hani M. K. Mahdi
Professor of Computer Systems
Computer and Systems Engineering Department
Faculty of Engineering, Ain Shams University

Dr. Bassem Abdullah
Assistant Professor
Computer and Systems Engineering Department
Faculty of Engineering, Ain Shams University

Cairo - 2017

AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Computer and Systems Engineering Department

Development of Feature Extraction Engine of Visual Information used in LGN-based Visual Prosthesis

By

Eng. Hossam El-Din Hesham Mohamed Abolfotuh
Master of Science in Electrical Engineering
(Computer and Systems Engineering)
Faculty of Engineering, Ain Shams University, 2017

Examiners' Committee

Name and Affiliation	**Signature**
Prof. Dr. Aliaa A. A. Youssif Dean of Faculty of Computers and Information, Helwan University	…….
Prof. Dr. Hazem M. Abbas Computer and Systems Engineering Department, Faculty of Engineering, Ain Shams University	…….
Prof. Dr. Hani M. K. Mahdi Computer and Systems Engineering Department, Faculty of Engineering, Ain Shams University	…….

Statement

This thesis is submitted as a partial fulfillment of Master of Science in Electrical Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

Eng. Hossam El-Din Hesham Mohamed Abolfotuh

Signature

……...…….

Researcher Data

Name: Hossam El-Din Hesham Mohamed Abolfotuh

Date of birth: January 7, 1990

Place of birth: Cairo, Egypt

Last academic degree: Bachelor of Science

Field of specialization: Electrical Engineering (Computer and Systems Engineering)

University issued the degree: Ain Shams

Date of issued degree: July 2011

Current job: Functional Safety Engineer in Ejad

Abstract

Restoring vision to the blind has been a challenge for long time. But today, it is no longer impossible thanks to Visual Prostheses. A visual prosthesis is a new hope to provide cure for the blind who suffers from damage in the eye or in the early stages of the visual pathway. Its main idea is to substitute the damaged organs of the visual pathway with an artificial system that mimic its functionality. Then, integrate it with the first intact organ in the pathway. The development of this system faced different challenges on the past decades. The main challenges were the unclear functionality of some organs in the visual pathway, technology limitations on the stimulating electrodes, and the small number of stimulating electrodes which limit the output quality of visual prostheses systems.

The main contribution in this research is the definition of an Image Processing Model to be followed in any visual prostheses system. This model defines the required image processing to highlight the main features in any visual input and remove the less important features. This will help to make use of the limited number of electrodes. Another role of this model is that it defines the functionality of the visual organs deep till the Lateral Geniculate Nuclease (LGN), which is the target of visual prostheses in this research. Another contribution is the development of a Features Extraction technique for dynamic scenes. Results of the new developed technique showed better perception and performance in comparison with another four state-of-the-art techniques. Finally, an Image Processing Toolbox was developed to handle the entire image processing functionality needed in visual prostheses. It was used to develop our new technique. This developed toolbox could be the starting point for future researches in visual prosthesis.

Thesis Summary

First, an Image Processing Model is defined to be the guideline in any image processing functionality for visual prostheses. Then, this model is used to develop a Dynamic Features Extraction technique. The technique was targeting Thalamic Visual Prostheses to stimulate the Lateral Geniculate Nuclease (LGN). The technique extracts the moving foreground objects and added the static or relatively slow changing background objects, then simulates the visual organs ahead of the LGN in the visual pathway. Finally, the thesis shows the components of the developed Image Processing Toolbox to gather all the needed functions for Image Processing in visual prostheses. The toolbox was tested throughout the study of Thalamic Visual Prostheses on rats. Moreover, a survey about image processing for visual prostheses researches that could be used in the future is documented.

The thesis is organized as follows: Chapter 1, is an introduction to the work presented in this thesis. Chapter 2 explains the biological and theoretical background of topics involved in the thesis' work. Chapter 3 introduces the Image Processing Model and the Dynamic Feature Extraction technique that was developed based on this model. Chapter 4 explains the Image Processing Toolbox and its case studies. Finally, Chapter 5 summarizes the conclusion for the thesis' work, and the planed future work.

Keywords: Visual Prostheses, Lateral Geniculate Nuclease (LGN), Image Processing, Feature Extraction, Background Subtraction, Visual Simulation, Toolbox.

Publications List

The list of publications from the work in this thesis:

1. Amr Jawwad, **Hossam H. Abolfotuh**, Bassem Abdullah, Hani M. K. Mahdi, and Seif Eldawlatly, "A Kalman-based Encoder for Electrical Stimulation Modulation in a Thalamic Network Model". In Bioinformatics and Bioengineering (BIBE), IEEE 15th International Conference on (pp. 1-5). Belgrade, Serbia, 2015.

2. **Hossam H. Abolfotuh**, Amr Jawwad, Bassem Abdullah, Hani M. K. Mahdi, and Seif Eldawlatly, "Moving Object Detection and Background Enhancement for Thalamic Visual Prostheses," In the 38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC 2016), Orlando, FL, USA, 2016.

3. Amr Jawwad, **Hossam H. Abolfotuh**, Bassem Abdullah, Hani M. K. Mahdi, and Seif Eldawlatly, "Tuning Electrical Stimulation for Thalamic Visual Prosthesis: An Autoencoder-based Approach," In the 38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC 2016), Orlando, FL, USA, 2016.

4. **Hossam H. Abolfotuh**, Amr Jawwad, Bassem Abdullah, Hani M. K. Mahdi, and Seif Eldawlatly, "BNEL_VP: An Image Processing Toolbox for Visual Prostheses," To appear in the Proceedings 8th International IEEE EMBS Conference on Neural Engineering (NER 2017), Shanghai, China 2017.

5. Amr Jawwad, **Hossam H. Abolfotuh**, Bassem Abdullah, Hani M. K. Mahdi, and Seif Eldawlatly, “Modulating Lateral Geniculate Nucleus Neuronal Firing for Visual Prostheses: A Kalman Filter-based Strategy,” In IEEE Transactions on Neural Systems and Rehabilitation Engineering (2017).