DEVELOPMENT OF CONDUCTIVE POLYMER BASED TACTILE SENSORS FOR WEARABLE BIO-MEDICAL DEVICES

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Degree of Master of Science

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University of Moratuwa

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Thesis submitted in partial fulfillment of the requirements for the degree

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DECLARATION

I declare that this is my own work and this dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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The above candidate has carried out research for the MSc thesis under my supervision.

Signature of the Supervisor(s): Date:

Prof. Y.W.R. Amarasinghe

Prof. D.V. Dao

Prof. A. Mitani

Abstract

Tactile sensors are devices which acquire data from the physical world through sense of touch. These acquired data may be related to either, surface roughness, texture, force, or any other tactile parameter. Even though, tactile sensor systems are identified as a feasible method to acquire force feedback in robotics and automation systems, due to the requirement of physical interaction between the sensor and application, development of tactile sensors does not come to the spotlight during the past decades. Rather, researchers were more focused on developing non-contact sensors for various sensing modalities when comparing with the tactile sensors. Currently, importance of tactile sensors has come to the spotlight, as development of robotics, automation and biomedical applications are limited due to lack of tactile feedback. Also, many application areas are identified, where tactile sensors can be incorporated such as robotics, industrial automation, biomedical imaging, biomedical robotics, etc.

With the recent advancements of the medical industry, wearable devices are used to support in controlling long-term or repetitive diseases or a disease that comes with time (i.e. chronic diseases) such as heart related diseases, diabetes and asthma by providing information on vital signs. Those vital signs can be heart rate, blood pressure, temperature in the body, blood oxygen level, etc. Other than that wearable biomedical devices are capable of producing smart and intelligent patient monitoring required for several diseases that capable of providing real-time feedback and assist in clinical based decision making. Tactile sensors are useful in measuring and monitoring point based and an area based force/pressure values in biomedical industry.

Under this research, a novel tactile sensor has been developed using a conductive polymer-based sensing element. The incorporated sensing element is manufactured by polymer compression moulding, where the compound is based on silicone rubber and has enhancements by silica and carbon black, with Silane-69 as the coupling agent. Characteristics of the sensing element have been observed using its sensitivity and range.

For the force scaling purpose and point based force/pressure measuring, a novel 3D printed cylindrical arch spring structure was developed for this highly customizable tactile sensor by adopting commonly available ABSplus material in 3D printing technology. By considering critical dimensions of the structure, finite element analysis was carried out to achieve nearly optimized results. A special electrical routing arrangement was also designed to reduce the routing complexities. A microcontroller based signal conditioning circuit was introduced to the system for the purpose of acquiring data. The concept was further improved to use as a tactile sensor array and hence a 3-DoF tactile sensor with a 3D printed square type spring system was also developed in this research.

Under this research, a flexible conductive polymer based sensor that consists of a flexible electrodes sewn on a garment using conductive yarns, also developed. The flexible tactile sensor has been incorporated into a knee brace and tested for its performances of monitoring forces generated at the patella of the knee. The developed sensor attached knee brace is capable of differentiating human activities and posses.

***Keywords*- wearables, conductive polymer, tactile sensor, spring structures, 3D printing, knee brace**

DEDICATION

To the three pillars of my life,

loving wife,

my parents,

and my teachers...

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LIST OF ABBREVIATIONS

Abbreviation	Description
ADC	Analogue to Digital Converter
BAN	Body Area Network
CNC	Computer Numerical Control
DAQ	Data Acquisition
FSR	Force Sensitive Resistors
EDAX	Energy-Dispersive X-ray
FEA	Finite Element Analysis
GUI	Graphical User Interface
LabVIEW	Laboratory Virtual Instrument Engineering Workbench
MEMS	Micro Electro Mechanical Systems
PLA	Polylactic Acid
RTV	Room Temperature Vulcanizing
SEM	Scanning Electron Microscope
USB	Universal Serial Bus
USD	United State Dollars
VISA	Virtual Instrument Software Architecture

LIST OF APPENDICES