

## CONTENTS

<i>Certificate</i>	<i>iii</i>
<i>Declaration by the Candidate</i>	<i>iv</i>
<i>Copyright Transfer Certificate</i>	<i>v</i>
<i>Acknowledgements</i>	<i>vi</i>
<i>Contents</i>	<i>ix</i>
<i>List of Figures</i>	<i>xiii</i>
<i>List of Tables</i>	<i>xvii</i>
<i>LIST of Abbreviations</i>	<i>xix</i>
<i>Preface</i>	<i>xxiv</i>
<b>1 INTRODUCTION.....</b>	<b>1</b>
1.1 Challenges in Gait Analysis.....	3
1.2 Challenges in Ankle-Foot Prostheses .....	4
1.3 Objectives of the Thesis.....	4
1.4 Contribution of the Thesis.....	5
1.5 Organization of the Thesis.....	6
<b>2 THEORETICAL BACKGROUND.....</b>	<b>7</b>
2.1 Gait Analysis and Gait Phase Detection Techniques.....	7
2.2 Usefulness of Gait Analysis.....	17
2.3 Lower Limb Prosthetic Devices.....	18
2.4 Machine Learning Techniques.....	33
2.5 Performance Metrics for Machine Learning Classification.....	37
2.6 Conclusion.....	38

### **3 HUMAN LOCOMOTION CLASSIFICATION FOR DIFFERENT TERRAINS USING MACHINE LEARNING TECHNIQUES.....39**

3.1 Introduction .....	40
3.2 Implementation of Machine Learning Techniques for Gait Analysis .....	43
3.3 Materials and Methods .....	44
3.3.1 Data Collection.....	44
3.3.2 Data Analysis.....	46
3.3.3 Machine Learning-Based Predictive Model.....	46
3.3.4 Feature Selection.....	47
3.4 Results and Discussion.....	49
3.5 Conclusion.....	59

### **4 FSR AND IMU SENSORS-BASED HUMAN GAIT PHASE DETECTION AND ITS CORRELATION WITH EMG SIGNAL FOR DIFFERENT TERRAIN WALK.....61**

4.1 Introduction .....	63
4.2 Materials and Methods.....	67
4.2.1 Sensor Module.....	67
4.2.2 Signal Conditioning.....	68
4.2.3 Heuristic Rules and Zero-Crossing Algorithm-based Gait Phase Detection....	70
4.2.3.1 Gait phase detection using FSR sensors.....	70
4.2.3.2 Gait phase detection using IMU sensors.....	72
4.2.4 Gait Sub-phase Detection using Fuzzy Logic Implementation in Arduino.....	74
4.2.4.1 Fuzzy logic for gait phase detection.....	74
4.2.4.2 Adaptive Neuro-Fuzzy Inference Systems.....	75

4.2.5 Wireless Sensor Network.....	76
4.3 Results and Discussion.....	77
4.3.1 Gait Phase Detection using FSR Sensors.....	78
4.3.2 Gait Phase Detection using IMU Sensors.....	80
4.3.3 Synchronization of FSR, IMU, and EMG Sensors Data.....	82
4.3.4 Gait Phase Detection using Fuzzy Logic Implemented in Arduino IDE.....	85
4.4 Conclusion.....	88
<b>5 CLASSIFICATION OF HUMAN FOOT MOVEMENTS FOR ANKLE-FOOT PROSTHESIS CONTROL USING MACHINE LEARNING AND FUZZY LOGIC TECHNIQUES .....</b>	<b>89</b>
5.1 Introduction.....	91
5.2 Material and Methods.....	94
5.2.1 Human Lower-Limb Motion.....	94
5.2.2 Data Acquisition.....	96
5.2.3 Machine Learning Approaches for Movement Classification.....	104
5.2.4 Ankle-Foot Prosthesis Control in Sagittal Plane.....	106
5.3 Results and Discussion.....	107
5.3.1 Raspberry Pi based Classification.....	107
5.3.2 Arduino Nano 33 BLE based Classification.....	112
5.3.2.1 TinyML based prediction.....	112
5.3.2.2 Fuzzy logic-based prediction.....	114
5.4 Conclusion.....	118
<b>6 DESIGN AND ANALYSIS OF MAGNETORHEOLOGICAL DAMPER-BASED ANKLE-FOOT PROSTHESIS PROTOTYPE.....</b>	<b>119</b>

6.1 Introduction .....	120
6.2 Material and Methods.....	121
6.2.1 Ankle-Foot Prosthesis Models.....	122
6.2.2 Magnetorheological Damper: Application in Lower-Limb Prosthesis.....	124
6.2.3 MR Damper Specifications.....	125
6.2.4 MR Damper Controller.....	126
6.2.5 Prototype Working.....	130
6.3 Results and Discussion.....	132
6.3.1 Prosthetic Foot Analysis.....	132
6.3.2 Leaf Spring Analysis.....	134
6.3.3 A Summary of Amputation and Prosthesis Design .....	135
6.4 Conclusion.....	136
<b>7 CONCLUSIONS AND FUTURE SCOPE .....</b>	<b>137</b>
7.1 Conclusions .....	137
7.2 Future Work .....	139
<b>APPENDIX A GUI for Gait Analysis</b>	<b>141</b>
<b>APPENDIX B Printed Circuit Boards</b>	<b>142</b>
<b>APPENDIX C Ethical Clearance Certificate</b>	<b>144</b>
<b>APPENDIX D Consent Statement of Amputee</b>	<b>145</b>
<b>BIBLIOGRAPHY .....</b>	<b>147</b>
<b>LIST OF PUBLICATIONS .....</b>	<b>159</b>