**Title Page**

* Title of Dissertation
* Your Name
* University Name
* Department
* Date

**Abstract**

* Summary of Objectives, Methods, Results, and Conclusion

**Acknowledgments**

**Table of Contents**

**List of Figures**

**List of Tables**

**Abbreviations and Symbols**

**Chapter 1: Introduction**

The Electrocardiogram (ECG) is a vital tool in modern medicine, offering a non-invasive and direct method for monitoring the electrical activity of the heart. By recording the heart’s electrical signals through electrodes placed on the skin, the ECG provides essential insights into the rhythmic patterns and conditions affecting the heart’s function. This capability makes the ECG indispensable for diagnosing various cardiac abnormalities, such as arrhythmia’s, heart disease, and myocardial infarction.

An ECG signal represents the sum of electrical potentials generated by the heart muscle during each cardiac cycle. The signal is characterized by a series of waves and complexes, most notably the p wave, QRS complex, and T wave, each corresponding to specific phases of the hearts electrical cycle. The P wave indicates atrial depolarization, the QRS complex represents the ventricular depolarization, and the T wave is associates with ventricular repolarization. Analysing these components allows healthcare professionals to assess the timing of cardiac events, the presence of abnormal rhythms, and the heath of the heart muscle.

Monitoring ECG signals is crucial for several reasons:

* **Early detection**: Continuous of periodic ECG monitoring can help detect early signs of heart disease, even before symptoms appear.
* **Diagnosis**: ECG readings are essential for diagnosing various cardiac conditions, including arrhythmia’s, ischemic heart disease, and congenital heart defects.
* **Treatment monitoring**: For patients undergoing treatment for heart conditions, ECG monitoring provides valuable feedback on the effectiveness if interventions, such as medications, pacemaker function, and recovery after cardiac procedures.
* **Prognosis**: ECG findings can inform prognosis, helping predict the likelihood of cardiac events such as sudden cardiac death or recurrence of heart attacks.

**Figure 1** below shows the typical waveform of a beat within an ECG signal.

A diagram of a graph

Description automatically generated

Despite its importance, the accuracy of ECG monitoring can be compromised by various sources of noise that can significantly affect the quality of the signal. There are 4 major sources of noise in ECG signals, these are 1) Baseline Wander (BW), 2) Powerline Interference (PL), 3) Muscle Artefact (MA) and 4) **Electrode Motion (EM)** [1]. BW and PL have a relatively unique frequency content and thus are easily removed by simple digital filters [2] (Eg notch, low pass). MA and EM noise are more challenging to remove as they can have a wide frequency content that overlaps with that of the ECG signal, specifically the PQRST complex. Adaptive filters are primarily used for these type of noise sources, however these require a reference noise signal which needs to be estimated, providing a potential source of error.

Electrode motion noise in ECG signals refers to the interference caused by the movement of electrodes attached to the skin. When electrodes move, even slightly, they can pick up additional electrical activity not related to the heart's electrical signals. This extra activity is seen as noise in the ECG signal, which can distort the true reading. It's particularly problematic during physical activity or if the electrode doesn't adhere well to the skin. This noise appears as irregular spikes or a fuzzy baseline in the ECG trace, making it challenging to accurately interpret the heart's electrical activity. Managing electrode motion noise is crucial for ensuring reliable ECG readings, especially in scenarios requiring patient movement or long-term monitoring.

EM is difficult to remove from an ECG signal for several reasons. Firstly, the signal attenuated by electrode motion can be very similar to the ECG signal itself, this similarity can make it difficult to remove with digital filters which use both time and frequency domain characteristics to separate the two signals. The variability of EM noise also adds to the difficulty to remove the noise, this comes from the wide range of movements a subject can undergo such as running, walking, jumping or any other form of activity. Each activity will return a different characteristic shape of noise. Electrode placement can also vary the shape of the noise signal. Finally, individual differences such as skin type, amount of hair and other factors influencing the electrode-skin contact will affect the amount of EM noise added during movement, it is important that algorithms can deal with this problem effectively.

* Problem Statement
* Objectives
* Scope of Study
* Structure of the Dissertation

**Chapter 2: Literature Review**

* Overview of ECG Signal Processing
* Electrode Motion Artifacts
* Existing Methods for Noise Removal
* Machine Learning in Biomedical Signal Processing
* Gaps in the Literature

**Chapter 3: Methodology**

* Data Collection
  + Source of ECG Data
  + Preprocessing
* Noise Modeling
  + Types of Motion Artifacts
  + Simulation of Noisy Signals
* Machine Learning Techniques
  + Supervised Learning
  + Unsupervised Learning
  + Deep Learning Models
* Model Training and Validation
  + Training Procedures
  + Evaluation Metrics

**Chapter 4: Implementation**

* Software and Tools Used
* Implementation Details
* Workflow
* Challenges and Solutions

**Chapter 5: Results and Discussion**

* Performance of Machine Learning Models
* Comparison with Existing Methods
* Analysis of Results
* Implications and Applications

**Chapter 6: Conclusion**

* Summary of Findings
* Contributions to the Field
* Limitations of the Study
* Future Work

**References**

**Appendices**

* Additional Data
* Code Listings
* Supplementary Material