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شكر و تقدير

إن الحمد لله نحمده ونستعينه ونستهديه ونستغفره،ونعوذ بالله من شرور أنفسنا ومن سيئات أعمالنا،

من يهده الله فهو المهتدي، ومن يضلل فلا هادي له،

وإن أصدق الحديث كلام الله، وخير الهدي هدي محمد ﷺ،

وإن شر الأمور محدثاتها، وإن كل محدثة بدعة، وكل بدعة ضلالة، وكل ضلالة في النار.

والصلاة والسلام علىالمبعوث رحمة للعالمين، محمد رسول الله صلى الله عليه وآله وصحبه أجمعين والتابعين لهم بإحسان إلى يوم الدين .

احمد الله تعالى في إتمام مشروعي هذا

و أتقدم بجزيل الشكر وخالص الامتنان إلى أساتذتي الأفاضل الذين ساهموا بدور كبير في إخراج هذا العمل المتواضع و الذين اخص بالذكر منهم الأستاذ المؤطر 'هيمة عبد القادر'و الأستاذ 'مجوري عبد القادر' نعم الأستاذ – ***علمنا التواضع قبل العلم***- و أستاذي الذي للأسف لم يدرسني أكاديميا خالي'عبد الحق' –***رحمه الله***- ولكن درسني الشجاعة و العطاء

و الامتنان أيضا موصول لزملاء الدراسة الدين كانوا عونا لي وأنيسا في سنوات الدراسة هذه و بالخصوص زميل المشروع 'بن عون إبراهيم' الذي كان عند حسن الضن بتفانيه في عمله وأداءه لمهامه كما ينبغي

و أسأل الله أن ينفع بي و بهذا العمل الإسلام و العباد

الإهداء

اهدي ثمرة جهدي هذه الى

إلى من أُفضلها على نفسي، ولم لا؛ فلقد ضحت من أجلي

ولم تدَّخر جُهدًا في سبيل إسعادي على الدَّوام

(أُمي الحبيبة).

إلى صاحب السيرة العطرة، والفكر المُستنير؛

فلقد كان له الفضل الأوَّل في بلوغي التعليم العالي

(والدي الحبيب)، أطال الله في عُمره.

إلى أخي وأخواتي الذين أُجلُّهم وأحترمهم..

وسليمان الصغير نوارة الحوش-***حفظه الله*** -

إلى أصدقائي ومعارفي الذين هم بمثابة العائلة الثانية..

سبحانك اللهم وبحمدك اشهد ان لا اله الا انت استغفرك واتوب اليك

الملخص

يتمحور البحث حول تطوير وتحسين نموذج لتصنيف إشارات القلب الكهربائية (ECG) ، بهدف تحسين دقة وموثوقية التشخيص الطبي لأمراض القلب المختلفة. يتناول البحث تحليل البيانات المستخلصة من إشارات ECG ومعالجتها باستخدام نماذج تعليم الالة ، مع التركيز على تحقيق نتائج دقيقة في تصنيف الأنماط القلبية المختلفة. تم العمل على مجموعة بيانات MIT-BIH للاضطرابات القلبية لتدريب وتقييم النموذج، مع الاهتمام بتحسين الأداء العام للنموذج لضمان قدرته على العمل في بيئات طبية حقيقية.
يتضمن البحث جمع بيانات إشارات القلب من مصادر معتمدة، ومعالجتها، وتطوير نموذج تعلم الي باستخدام مكتبات مثل TensorFlow لتصنيف هذه الإشارات. سيتم تقييم أداء النموذج بدقة، وتطوير نظام لنقل النتائج بشكل آمن وسريع عبر البريد الإلكتروني. أظهرت نتائج البحث فعالية عالية في تحليل بيانات إشارات القلب الكهربائية (ECG) باستخدام النموذج المطوّر، حيث تجاوزت دقة التصنيف 90% لجميع الفئات المدروسة .يكتسب هذا البحث أهمية كبيرة في مجال الطب نظراً للحاجة الملحة إلى أنظمة تشخيص أكثر دقة وسرعة. يمكن للجهاز المبتكر أن يقلل من احتمالية التشخيصات الخاطئة ويوفر وسيلة موثوقة للأطباء لاتخاذ قرارات علاجية أكثر دقة.

Summary

The research focuses on the development and improvement of a model for classifying (ECG) signals, with the aim of enhancing the accuracy and reliability of medical diagnosis for various heart diseases. The study involves analyzing data extracted from ECG signals and processing it using machine learning models, with an emphasis on achieving precise results in classifying different cardiac patterns. The model was trained and evaluated on the MIT-BIH arrhythmia dataset, with attention to improving the model's overall performance to ensure its capability to operate in real medical environments. The research includes collecting heart signal data from reliable sources, processing it, and developing a machine learning model using libraries like TensorFlow to classify these signals. The model's performance will be accurately evaluated, and a system will be developed to transfer the results securely and swiftly via email.
The research results have shown high effectiveness in analyzing ECG data using the developed model, with classification accuracy exceeding 90% for all studied categories. This research is of great importance in the medical field due to the urgent need for more accurate and faster diagnostic systems. The innovative device can reduce the likelihood of incorrect diagnoses and provide a reliable means for doctors to make more precise therapeutic decisions.

Sommaire

La recherche porte sur le développement et l'amélioration d'un modèle de classification des signaux (ECG) en utilisant des techniques d'apprentissage automatique, dans le but d'améliorer la précision et la fiabilité du diagnostic médical des différentes maladies cardiaques. L'étude traite de l'analyse des données extraites des signaux ECG et de leur traitement en utilisant des modèles d'apprentissage automatique, avec un accent particulier sur l'obtention de résultats précis dans la classification des différents rythmes cardiaques. Le modèle a été entraîné et évalué sur un ensemble de données MIT-BIH des arythmies cardiaques, en mettant l'accent sur l'amélioration de la performance globale du modèle pour garantir sa capacité à fonctionner dans des environnements médicaux réels.. La recherche vise à fournir des solutions efficaces et rapides qui contribuent à améliorer la qualité des soins de santé et à réduire les erreurs de diagnostic, offrant ainsi une meilleure prise en charge des patients. La recherche comprend la collecte de données de signaux cardiaques à partir de sources fiables, leur traitement, et le développement d'un modèle d'apprentissage automatique en utilisant des bibliothèques comme TensorFlow pour classifier ces signaux. La performance du modèle sera évaluée avec précision, et un système sera développé pour transférer les résultats de manière sécurisée et rapide par e-mail. Les résultats de la recherche ont montré une grande efficacité dans l'analyse des données ECG en utilisant le modèle développé, avec une précision de classification dépassant 90% pour toutes les catégories étudiées. Cette recherche est d'une grande importance dans le domaine médical en raison de la nécessité urgente de systèmes de diagnostic plus précis et rapides. Le dispositif innovant peut réduire la probabilité de diagnostics erronés et fournir un moyen fiable pour les médecins de prendre des décisions thérapeutiques plus précises.

Table of contents

Table of contents

List of Figures

Chapter I

Chapter II

Chapter III

List of Tables

General Introduction

Biomedical instrumentation is a significant branch of biomedical engineering, focusing on the manufacturing of devices that contribute to medical diagnosis and treatment of diseases related to specific parts of the human body.

Cardiovascular diseases pose a major challenge in public health, as the heart plays a central role in the cardiovascular system and can be affected by various conditions.

Techniques for examining cardiac function allow the study of physiological parameters such as heart pressure, blood flow, and blood viscosity in the cardiovascular system using physiological and electrical signals.

Heart rate serves as a quantitative indicator of cardiac activity, typically measured in beats per minute (BPM), with variations influenced by age and level of physical activity.

In cases of cardiac rhythm disorders, known as arrhythmias, heart rate may deviate from the normal range, indicating either tachycardia or bradycardia.

Elevated or reduced heart rates at rest are significant risk factors for cardiovascular and vascular diseases. In this context, electrical signals from the heart are essential for precise analysis of disorders, aiding in immediate detection.

New technologies in the medical field require objective evaluation of information, with advancements in electronics and computing leading to the development of more efficient medical devices.

One such device is the electrocardiograph (ECG), which detects electrical voltage fluctuations, amplifies them, and records them electrically as electrocardiograms (ECGs). These signals can be recorded and stored for later detailed analysis to assist in diagnosing heart disorders.

Telemedicine is defined as the transmission of electronic medical data from one location to another with the aim of improving patient healthcare and enhancing medical education, as well as providing efficient healthcare services.

Telemedicine is utilized by doctors and specialists in several medical fields such as dermatology, oncology, radiology, surgery, cardiology, psychiatry, and home care.

The main objective is to facilitate continuous communication between the patient and the doctor and to develop a remote transmission service of ECG data via smartphones for remote patient monitoring, thereby contributing to providing accurate and effective medical diagnostic data.

Our work is divided into three parts:

In the first chapter, we provide medical information about the cardiovascular system and electrocardiography, making it easier to understand the origins of ECG signals.

In the second chapter, we review the stages of implementing an electronic circuit for detecting cardiac activity.

Finally, in the last chapter, we present the simulation and implementation process to connect the Arduinouno to an ECG sensor and display the data and diagnosis online for the device, allowing doctors to easily monitor patients' health status from anywhere in the world.

CHAPTER I

General Informations On The Cardiovascular System And The Electrocardiogram

1 Introduction

The first chapter of this manuscript is dedicated to the medical aspect, which includes a general description of the cardiovascular system and the anatomy of the heart.

The function of the cardiovascular system is based on the electrical activity of the heart. The study will focus on the concept of the ECG signal with its waves, as well as ECG technology and the different derivations that allow the collection of the ECG signal.

2 Cardiovascular System

The cardiovascular system is an essential part of the human body, responsible for pumping and distributing blood to ensure oxygen and nutrients reach the cells and harmful waste is removed. The heart is composed of muscle tissue specialized for pumping and consists of four main parts: the right atrium, left atrium, right ventricle, and left ventricle.

It works to pump blood regularly to the blood vessels. Blood vessels transport blood to and from the heart, including arteries that carry oxygen-rich blood and veins that carry oxygen-depleted blood. The function of the heart and blood pressure regulation is controlled by a regulatory system that includes the nervous system and hormones.

2.1 Internal Anatomy

The internal anatomy of the heart reveals intricate structural details including the atria, ventricles, and heart valves. The heart consists of four chambers: the right atrium, left atrium, right ventricle, and left ventricle. Oxygenated blood enters the right atrium from the superior vena cava (upper part of the heart), then passes into the right ventricle through the tricuspid valve.

From the right ventricle, oxygenated blood is pumped into the pulmonary arteries, which carry it to the lungs to become oxygenated.From the left atrium, oxygenated blood enters the left ventricle from the lungs through the mitral valve. From the left ventricle, oxygenated blood is pumped into the body through the aortic valve and the aorta, which carries blood to all parts of the body.

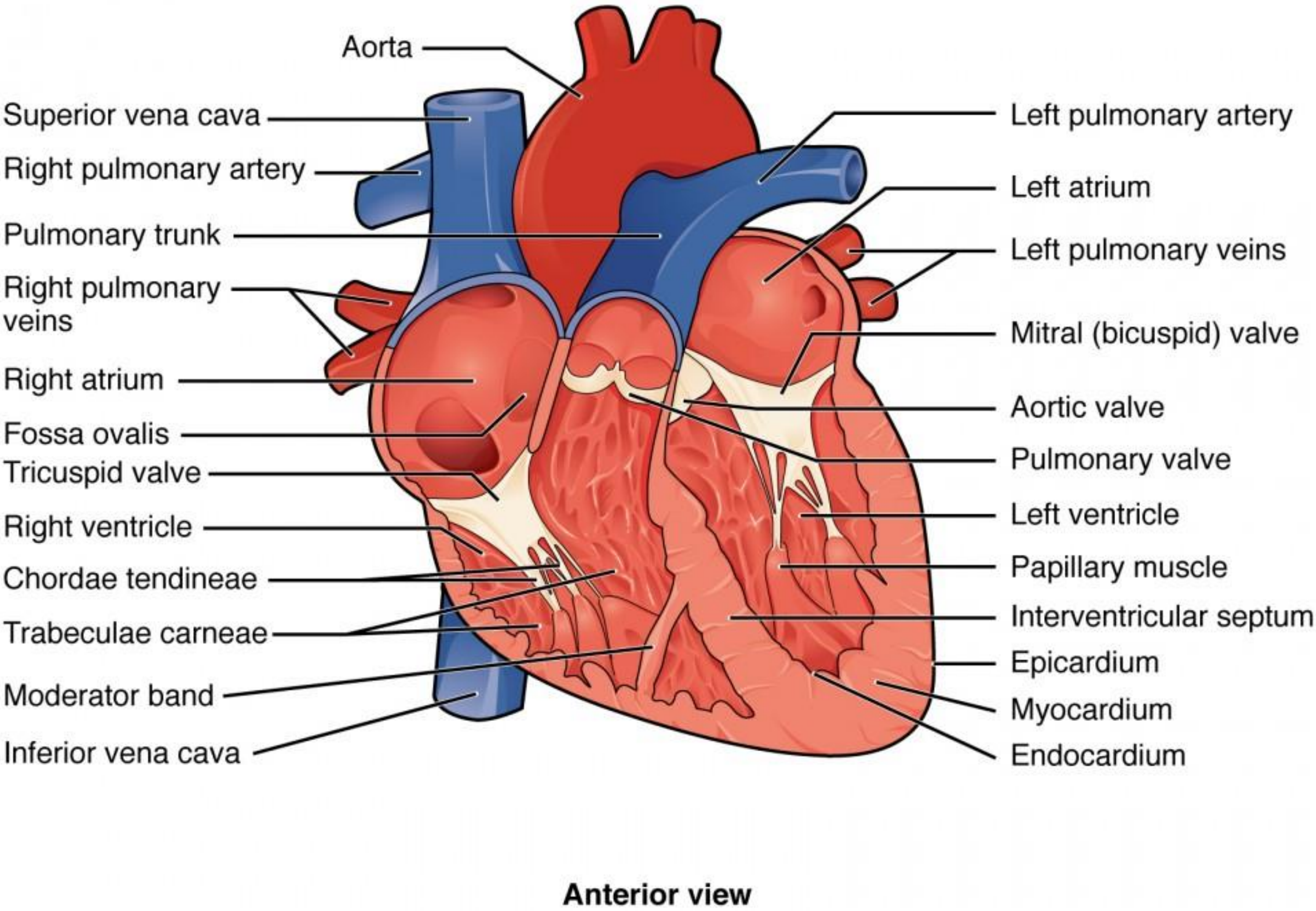


Figure I.1 : Internal anatomy**[1]**

2.2 External Anatomy

The external anatomy of the heart shows its shape and position within the chest. The heart islocated in the middle part of the chest, surrounded by the thoracic cage and situated behind the sternum. The heart consists of two main sections: the upper part or the dome, and the lower part or the base. The upper part is also known as the atria, while the lower part connects to large blood vessels such as the pulmonary trunk and the aorta.

The large pulmonary vessels and the pulmonary trunk appear on the front and upper part of the heart, while the pulmonary veins connect to the back and lower part of the heart.

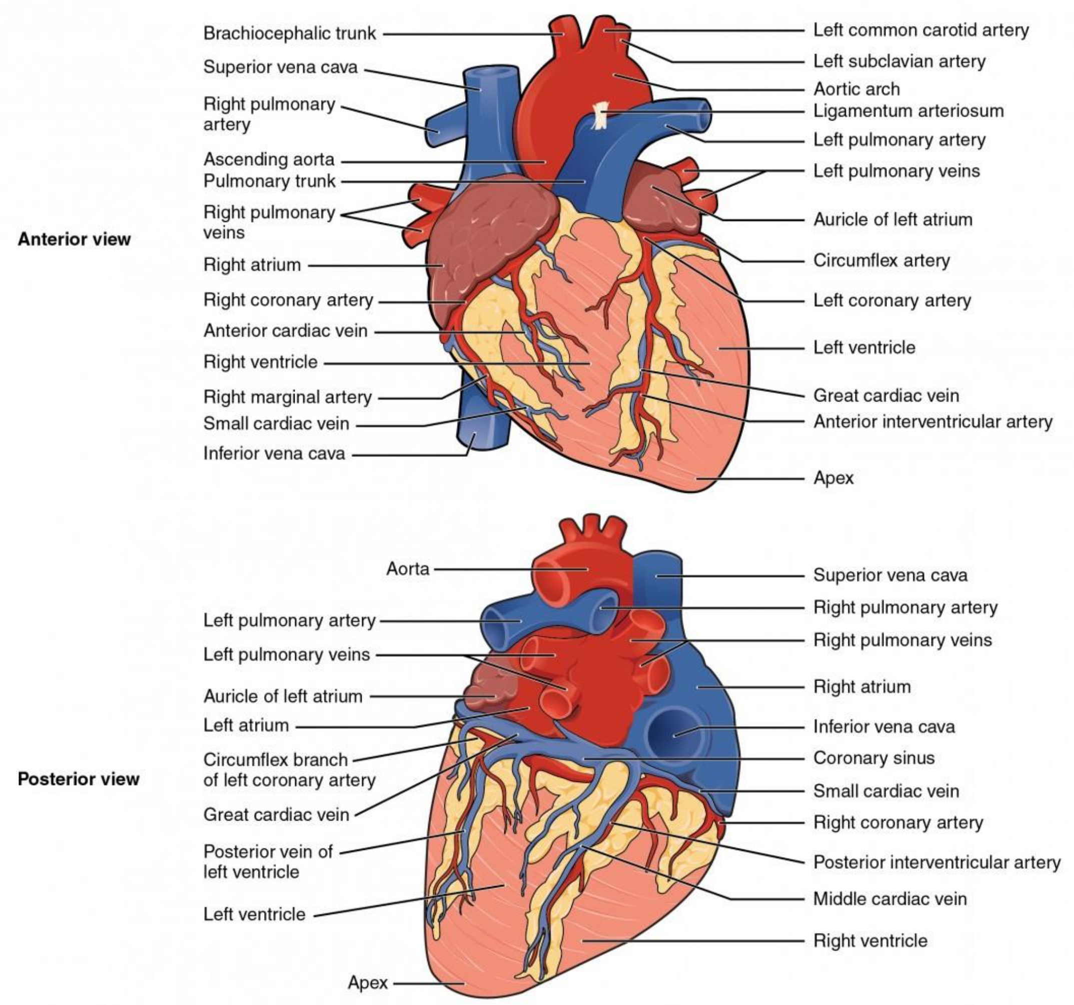


Figure I.2 : External anatomy**[1]**

2.3 Blood Circulation

The circulatory system begins in the heart, where oxygenated blood is pumped from the right ventricle to the pulmonary arteries, directing it to the lungs to replenish oxygen and expel carbon dioxide. From the lungs, oxygenated blood returns to the heart through the pulmonary veins to the left atrium, then the heart pumps this oxygenated blood to the body through the left ventricle and the systemic aorta. Blood travels through the arteries to various organs and tissues in the body, delivering oxygen and essential nutrients for their function.

The deoxygenated blood, along with cellular waste and carbon dioxide, is collected in the veins and returns to the heart to be pumped again in a new circulatory cycle.

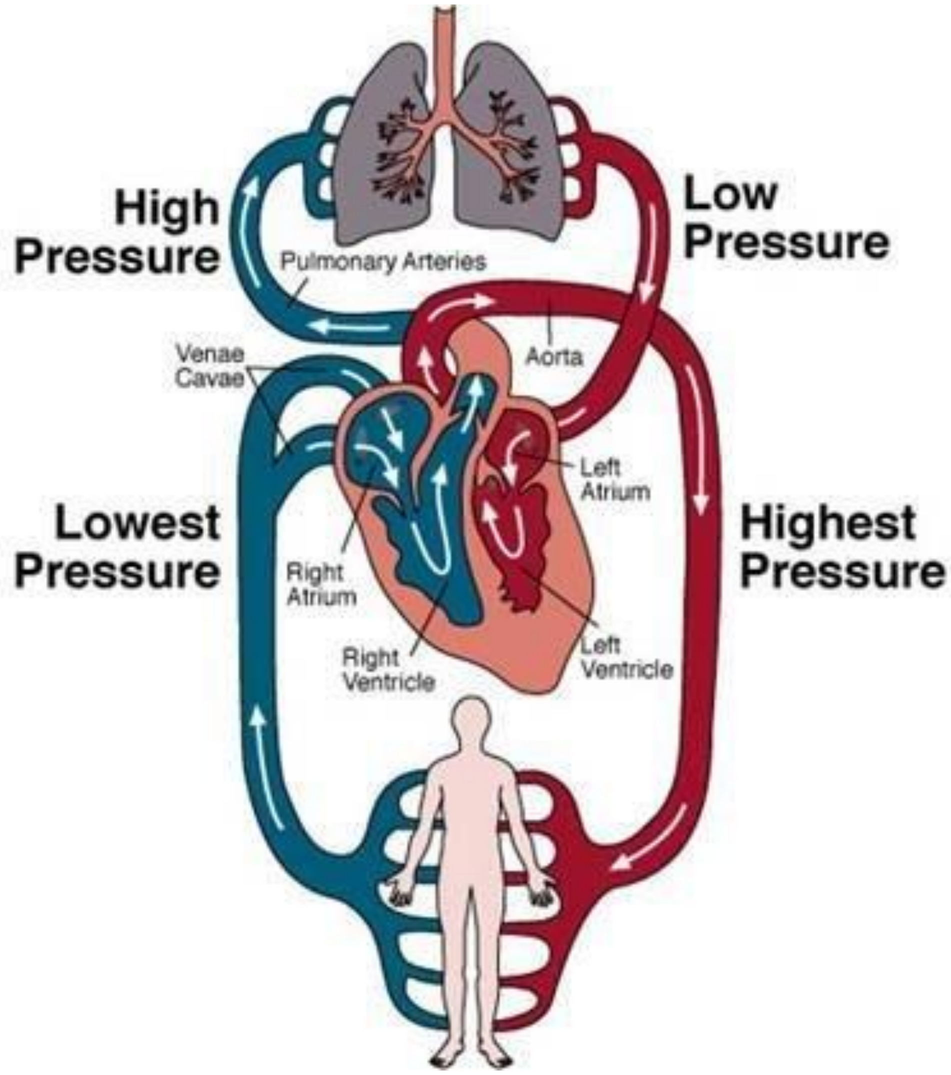


Figure I.3 : blood circulation**[2]**

2.4 Function Of The Atria And Ventricles

:The atria and ventricles are the main chambers of the heart, each with different functions

1.Atria:

-The atria are the upper chambers of the heart.

-Located above the ventricles, they receive blood from the blood vessels.

-Their primary function is to receive blood and direct it to the ventricles for pumping it to the rest of the body.

The atria muscles gently and smoothly pump blood into the ventricles.-

2.Ventricles:

The ventricles are the lower chambers of the heart.-

-The right ventricle is located below the right atrium, while the left ventricle is below the left atrium.

The main function of the ventricles is to pump blood to the body.-

-The right ventricle pumps blood to the lungs to be oxygenated, while the left ventricle pumps oxygenated blood to the rest of the body.

2.5 The Mechanical Activity Of The Heart

The mechanical activity of the heart involves several processes occurring in each cardiac cycle, including:
1.Atrial Contraction: The cardiac cycle begins with the contraction of the atria, where the atrial muscles contract to push blood into the ventricles.
2.Ventricular Contraction: Once the ventricles are filled with blood from the atria, the ventricles contract forcefully to pump blood into the arteries and blood vessels throughout the body.
3.Cardiac Contraction: Cardiac contraction occurs when the atria and ventricles contract simultaneously, aiding in the efficient pumping of blood to the body.
4.Cardiac Relaxation: After cardiac contraction, the heart must relax to allow for the entry of fresh blood from the atria.

2.6 The Electrical Activity Of The Heart

The electrical activity of the heart refers to the chronological sequence of electrical signals that travel through the heart tissues and stimulate the contraction of the cardiac muscle.

This activity begins with the generation of an electrical signal in the sinoatrial node (SA node) in the right atrium of the heart. Subsequently, the signal travels to the atrioventricular node (AV node), where it delays for a few moments to allow the atria to eject blood into the ventricles before it moves to the bundle of His and then to the Purkinje fibers, which propagate through the ventricles and cause their contraction.

This electrical activity contributes to regulating the heart's rhythm and ensuring its regular and efficient contraction.

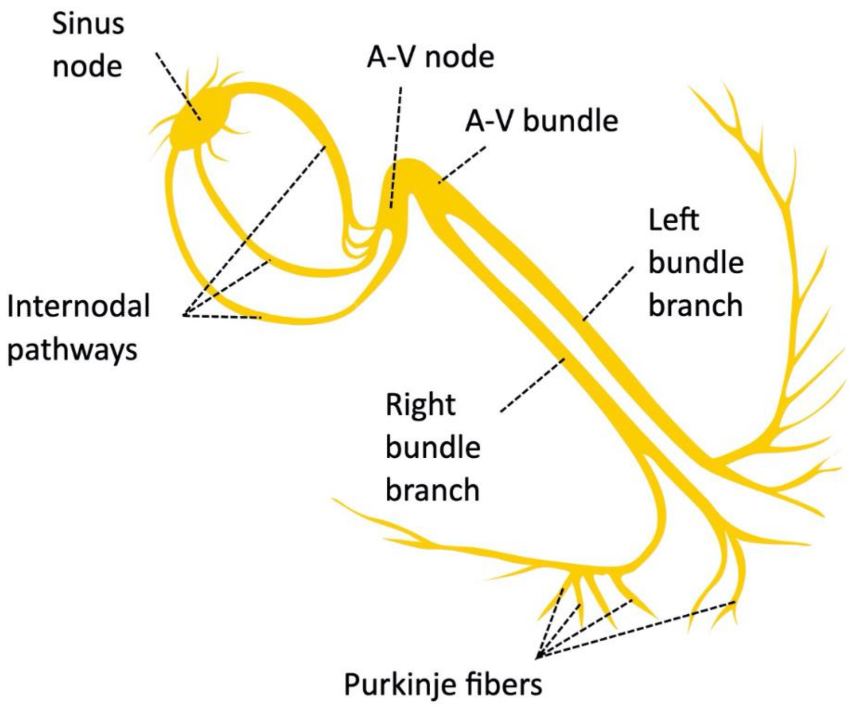


Figure I.4 : The Electrical Activity Of The Heart**[3]**

2.7 Cardiac Cycle

The cardiac cycle encompasses the entire process of the human heart from one heartbeat to the next. It includes two main phases:

- Diastole is: the relaxation phase during which the heart fills with blood.
- Systole follows diastole and involves the contraction of the heart muscle to pump blood out.

After emptying, the heart relaxes to receive blood returning from the body and lungs.

The cardiac cycle involves:

- Electrical events: depolarization/repolarization.
- Mechanical events: contraction (systole)/relaxation (diastole).
- Hemodynamic events: changes in pressure and volume.

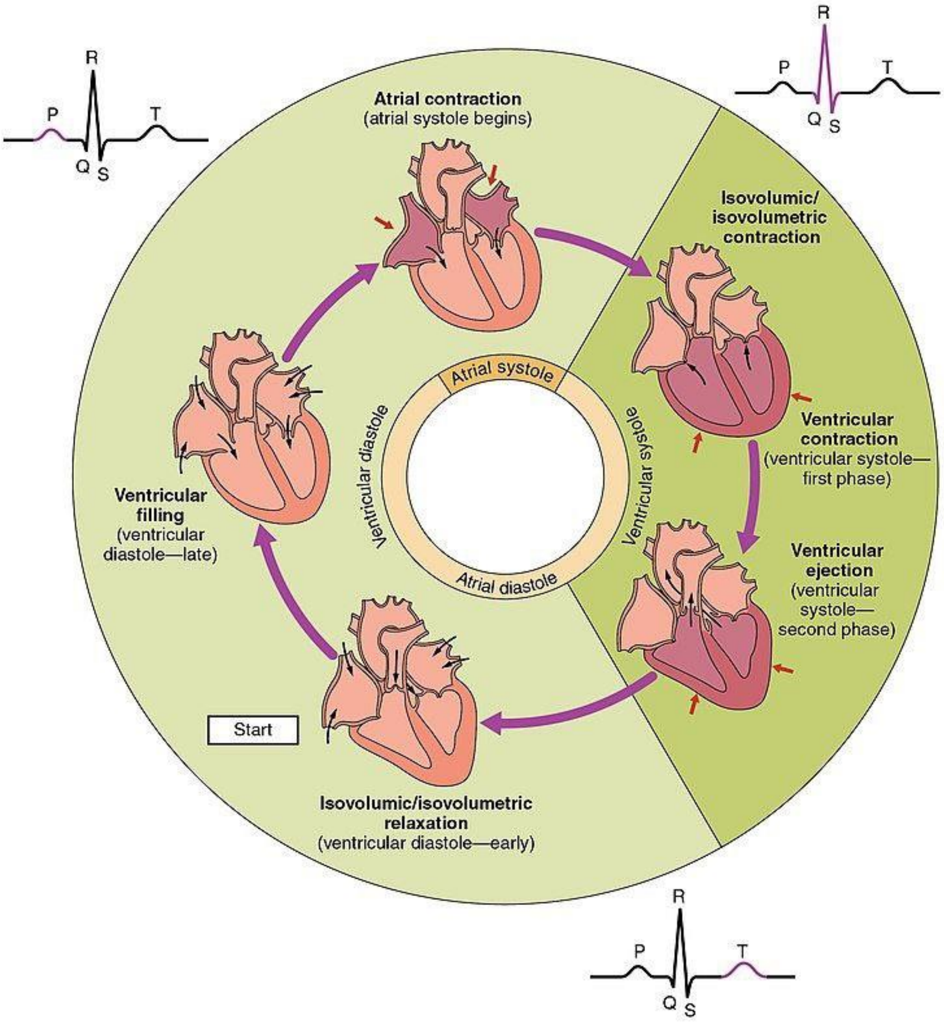


Figure I.5: Cardiac Cycle **[4]**

2.8 Cardiac Action Potential

Cardiac action potential consists of four distinct phases (Figure I.6 a).

- phase 0: upstroke occurs due to rapid transient influx of Na+. Later, Na+ channels are inactivated, combined with a transient efflux of K+.

- phase 2: also known as the plateau phase, the efflux of K+ and the influx of Ca2+ are counterbalanced. At the end of the plateau, sustained repolarization occurs due to K+ efflux via the delayed rectifier K+ channels exceeding Ca2+ influx;
- phase 3: of the action potential.
- phase 4: resting potential in myocytes is maintained.

In the clinical setting, the QT interval is measured from the beginning of the QRS complex to the end of the T wave (Figure I.6 b).

The QRS complex of the electrocardiogram corresponds to the action potential depolarization, while the T wave is associated with ventricular repolarization. Torsades de pointes is associated with the twisting of the QRS complex around the isoelectric line on the electrocardiogram.

Since QT interval depends to a large degree on the heart rate, it is typically reported as QTc, a value normalized for a heart rate of 60 bpm. Bazzett's formula21 is frequently used to introduce the heart rate correction. For reasons that are as yet unknown, QTc in adult females is about 20 ms longer than that in males. The normal limits of QTc in adults are 430 ms in males and 450 ms in females.13 An increase of up to 20 ms is considered borderline, while longer QTc values correspond to prolonged QT interval.

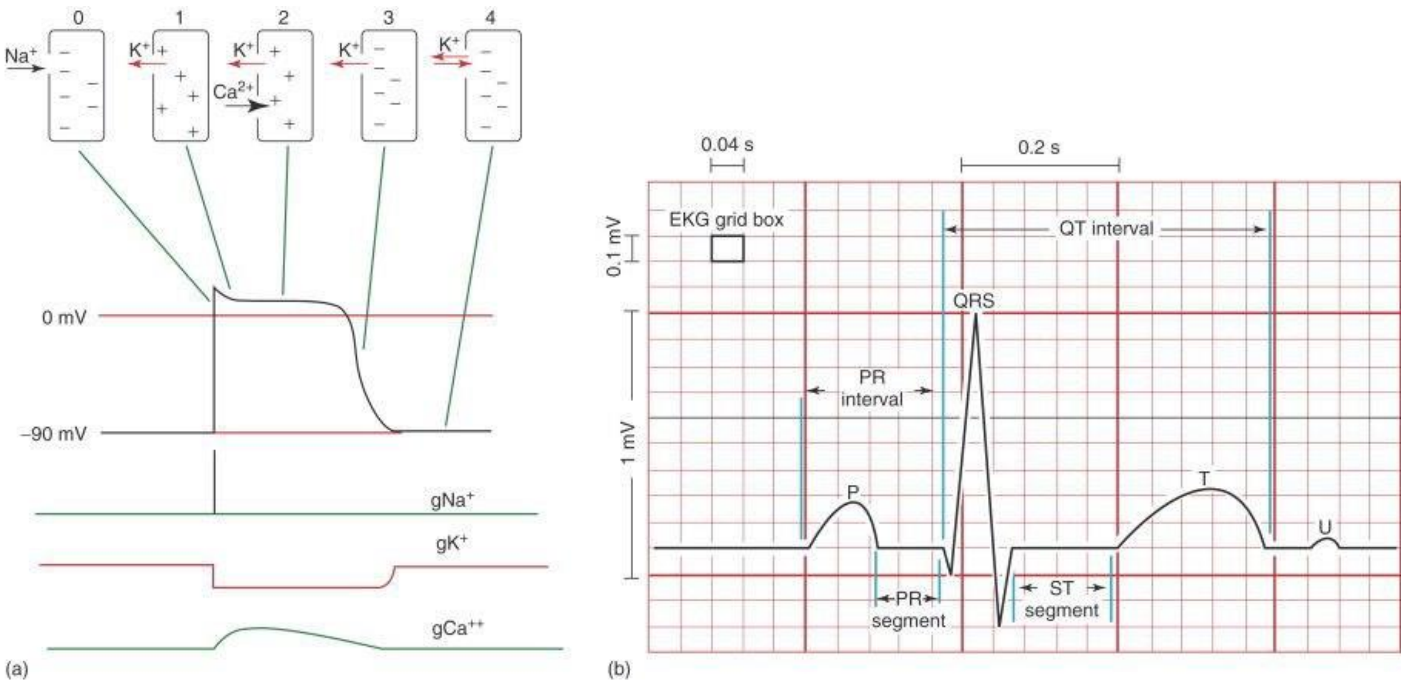


Figure I.6: ECG of Heart in normal sinus rhythm **[5]**

3 Electrocardiography

Is the process of producing an electrocardiogram (ECG or EKG), a recording of the heart's electrical activity through repeated cardiac cycles. It is an electrogram of the heart which is a graph of voltage versus time of the electrical activity of the heart using electrodes placed on the skin. These electrodes detect the small electrical changes that are a consequence of cardiac muscle depolarization followed by repolarization during each cardiac cycle (heartbeat). Changes in the normal ECG pattern occur in numerous cardiac abnormalities, including:

*Cardiac rhythm disturbances (such as atrial fibrillationand ventricular tachycardia).
*Inadequate coronary artery blood flow (such as myocardial ischemia and myocardial infarction).
*Electrolyte disturbances,such as hybokalemia.

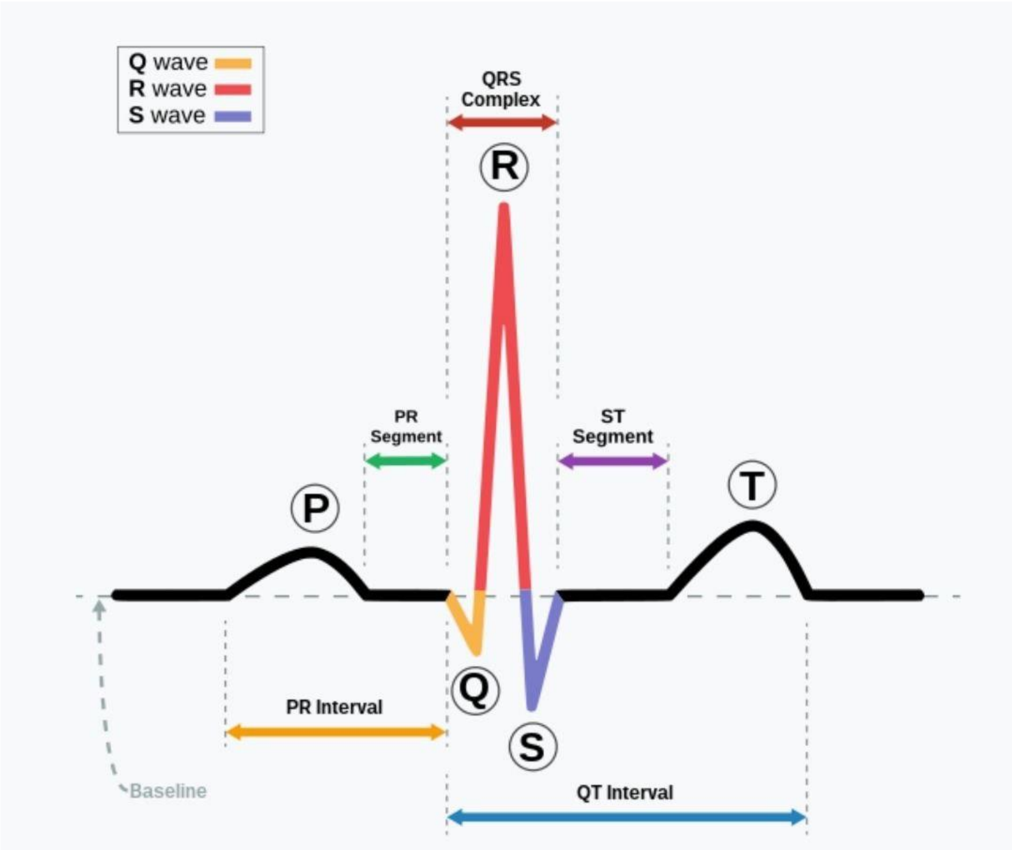


Figure I.7: ECG of Heart in normal sinus rhythm **[6]**

3.1 ECG Waves and Intervals

ECG interpretation includes an assessment of the morphology (appearance) of the waves and intervals on the ECG curve.Therefore, ECG interpretation requires a structured assessment of the waves and intervals.Before discussing each component in detail, a brief overview of the waves and intervals is given.

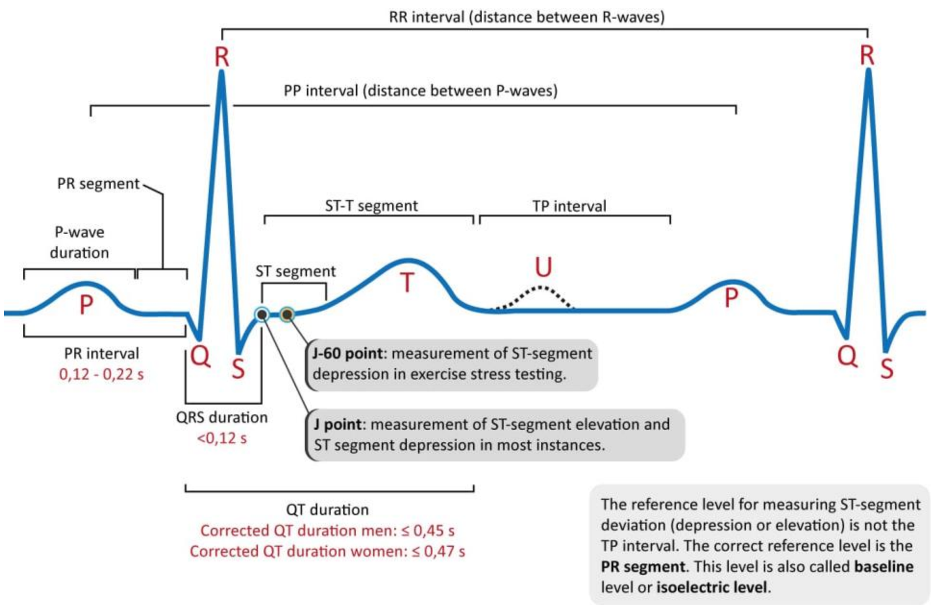


Figure I.8: Characteristics of the normal ECG**[7]**

The P-wave, PR interval and PR segment

ECG interpretation traditionally starts with an assessment of the P-wave.**[7]**

- The **P-wave**:reflects atrial depolarization (activation).

- The **PR interval**: the distance between the onset of the P-wave to the onset of the QRS complex.The PR interval is assessed in order to determine whether impulse conduction from the atria to the ventricles is normal.**[7]**

- the **PR segment**: Is the flat line between the end of the P-wave and the onset of the QRS complex , and it reflects the slow impulse conduction through the atrioventricularnode.The PR segment serves as the baseline (also referred to as the reference line or isoelectric line) of the ECG curve.The amplitude of any deflection/wave is measured by using the PR segment as the baseline.Refer to Figure I.8.**[7]**

The QRS complex

It represents the depolarization (activation) of the ventricles. It is always referred to as the “QRS complex” although it may not always display all three waves.Since the electrical vector generated by the left ventricle is many times larger than the vector generated by the right ventricle, the QRS complex is actually a reflection of left ventricular depolarization.**[7]**
QRS duration is the time interval from the onset to the end of the QRS complex.A short QRS complex is desirable as it proves that the ventricles are depolarized rapidly, which in turn implies that the conduction system functions properly.Wide (also referred to as broad) QRS complexes indicate that ventricular depolarization is slow, which may be due to dysfunction in the conduction system.**[7]**

The J point and the ST segment

-The **ST segment**: corresponds to the plateau phase (phase 2) of the action potential.The ST segment must always be studied carefully since it is altered in a wide range of conditions.Many of these conditions cause rather characteristic ST segment changes.The ST segment is of particular interest in the setting of acute myocardial ischemia because ischemia causes deviation of the ST segment (ST segment deviation).There are two types of ST segment devation.**[7]**

ST segment depression implies that the ST segment is displaced, such that it is below the level of the PR segment.ST segment elevation implies that the ST segment is displaced, such that it is above the level of the PR segment.The magnitude of depression/elevation is measured as the height difference (in millimeters) between the J point and the PR segment.

-The **J point**: is the point where the ST segment starts.If the baseline (PR segment) is difficult to discern, the TP interval may be used as the reference level.**[7]**

The T-wave
The **T-wave**: reflects the rapid repolarization of contractile cells (phase 3) and T-wave changes occur in a wide range of conditions.T-wave changes are frequently misunderstood in clinical practice, which the discussion below will attempt to cure.
The transition from the ST segment to the T-wave should be smooth (and not abrupt).The normal T-wave is slightly asymmetric, with a steeper downward slope.**[7]**

The U-wave

The **U-wave**: is seen occasionally.It is a positive wave occurring after the T-wave.Its amplitude is generally one-fourth of the T-wave’s amplitude.The U-wave is most frequently seen in leads V2–V4.Individuals with prominent T-waves, as well as those with slow heart rates, display U-waves more often.The genesis of the U-wave remains elusive.**[7]**

QT interval (duration) and QTc interval

-QT duration reflects the total duration of ventricular depolarization and repolarization.It is measured from the onset of the QRS complex to the end of the T-wave.The QT duration is inversely related to heart rate;i.e.

-the **QT interval** increases at slower heart rates and decreases at higher heart rates.Therefore to determine whether the QT interval is within normal limits, it is necessary to adjust for the heart rate.The heart rate-adjusted QT interval is referred to as the corrected QT interval (QTc interval).A long QTc interval increases the risk of ventricular arrhythmias.**[7]**

4 Télémédecine

Telemedicine encompasses various telecommunications technologies used for exchanging medical information, including telecommunication, data, and information technologies. Its applications in healthcare aim to facilitate the transfer of medical information to enhance the quality of care.
This facilitates swift medical exchanges among healthcare professionals, benefiting patients regardless of their geographical location. This is particularly crucial for patients discharged from the hospital post-surgery, as certain complications may arise, including the recurrence of heart issues during routine activities. Therefore, continuous ECG monitoring in such patients post-treatment aids in diagnosing heart conditions and implementing necessary precautions.

4.1 TLM's most Important application

- **Teleconsultation**: Remote medical consultation that enables communication between the doctor and the patient through digital means such as phone or email.
- **Remote psychotherapy**: Distance psychological therapy involving communication between the patient and therapist via digital means to assist the patient in addressing their psychological disorders.
- **Remote imaging**: Technology that allows for diagnostic or treatment examinations to be conducted remotely using digital technology.
- **Telepathology**: Remote diagnosis of diseases by examining tissues and cells via the internet or wired networks.
- **Remote skin treatment (Teledermatology):** Treatment of skin diseases remotely using high-resolution images and sending results to specialist doctors for diagnosis and treatment.
- **Remote home medical care**: Remote home medical care including monitoring the patient's vital signs and sending data to doctors for follow-up and intervention as needed.
- **Remote patient monitoring**: Remote monitoring of the patient's condition to transfer information about patient care from their home to doctors for follow-up and intervention.

- **Patient care in emergencies:** Patient care in emergencies by communicating with specialist doctors to provide advice and guidance for immediate treatment.
- **Patient care at the first level of health care**: Patient care at the first level of medical care for remote diagnosis and treatment through a specialized doctor.
- **Specialized counseling system**: Specialized counseling system enabling communication between specialist doctors, general practitioners, and patients to provide medical advice.
- **Remote surgery**: Conducting surgeries remotely using robotic technology and digital networks.
- **Telemedicine in pediatrics**: Use of technology to provide medical care to children, including psychological therapy and medical consultations.

4.2 Benefits of Telemedcine

Lower Costs: Patients can reach doctors and clinic professionals through video chat on mobile phones; there is no need to travel to the clinic. This saves both time and money while increasing their overall experience.

Enhance PreventiveCare: Patients can enable preventive care easily through telemedicine. They can access emergency care that drastically improves their health outcomes. For patients with limited access to care, telemedicine can bridge the gap between the two.

Improve Access to Care: For underserved patients residing in rural areas, telemedicine is a boon that provides them unlimited access to care. In addition, people with disabilities can also get access to care from their homes**.**

Reduce the Spread of Infections: Since the advent of the COVID-19 pandemic, clinics and hospitals have had to shut their doors to patients. Patients with infections often sit close to each other at doctors' clinics. Through telemedicine, patients can avoid spreading infections and keep themselves safe from exposure.

Provide Convenience: The most crucial benefit of telemedicine is its convenience to patients and clinics alike. Patients can schedule consultations between work and household chores. This can improve patient satisfaction manifold and improve retention for clinics.

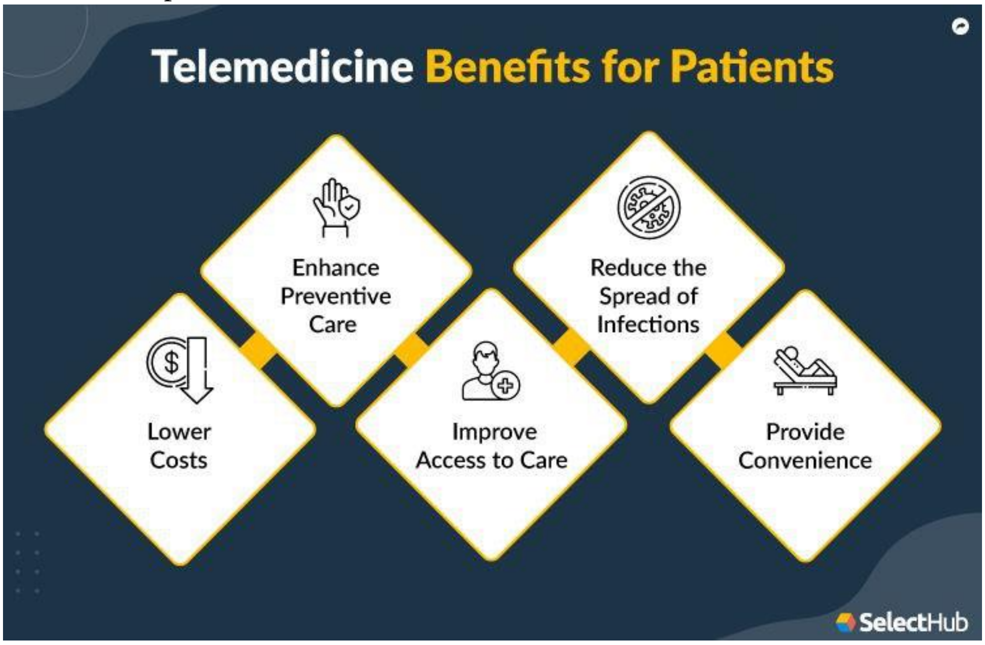


Figure I.9Telemedcine Benefits For Patients**[8]**

5 Conclusion

At the end of Chapter 1, we learned about the importance of the heart's electrical system and its role in regulating heartbeats, as well as how electrical signals are transmitted to cause its contractions. We also explored the anatomy of the heart, both internally and externally, along with its electrical and mechanical activities, in addition to understanding the cardiac cycle. Regarding cardiac monitoring, we learned how to record the heart's electrical activity to diagnose various heart problems, as well as the concept of Cardiac Action Potential.

finally, we discussed the use of telemedicine in providing remote healthcare, allowing doctors to communicate with patients and deliver medical services without the need for face-to-face interaction, thereby enhancing healthcare and improving access to it, and enhancing the overall efficiency of healthcare delivery.

Our aim with this study is to attempt to develop a device that measures and diagnoses a patient's condition remotely.

CHAPTER II

Conception and realization of the ECG Device

1 Introduction

The need for an electronic circuit capable of capturing the ECG signal and implementing a computer program to extract additional parameters such as heart rate through digital signal processing operations. To this end, we provide a general description of the different phases of electronic acquisition, processing, and visualization that allow the measurement of the ECG signal.

The main goal of our project is to read the heart signal and try to classify and diagnose it using artificial intelligence, which is a technological revolution, as it will play the role of a physician's assistant by giving him the diagnosis and at the same time an assistant to the patient so that he does not have to go to the doctor every time in order to save time and effort, especially during attacks of illness, and the device is considered a condition monitor remote .

2 General structure of the system

:The system (Figure II.1) that we are going to create is made up of four main parts
Displaying results on a phone.the electrodes, the AD8232 sensor, the arduino uno board, and

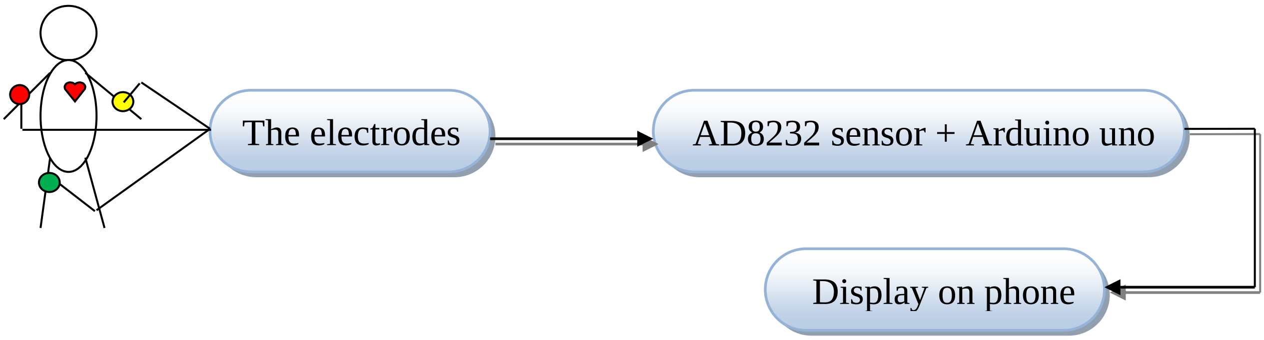


Figure II.1: Schematic diagram of the transmission chain

3 ECG Detection

The process involves measuring physiological signals generated by humans during the machine-patient interaction and within living, conductive tissues, using specialized biomedical sensors.
The sensor used for acquiring the ECG signal is an electrode, whose primary function is to convert physical quantities into output signals.

4 Definition of ECG Electrodes

ECG electrodes are essential components of the electrocardiogram, a non-invasive test that records the electrical activity of the heart over a specific period.
These electrodes play a crucial role in translating the heart's electrical impulses into a visual representation on the ECG monitor, enabling healthcare professionals to diagnose various cardiac conditions.**[9]**

4.1 The electrophysiological basis of the ECG electrodes

The movement of charged particles generates an electrical current.In electrocardiology, the charged particles are represented by intracellular and extracellular ions (Na+, K+, Ca2+).These ions flow across cell membranes (so that the cell can de- and repolarize) and between cells via gap junctions (so that the depolarization can spread between the cells).
Electrical potential differences arise as the electrical impulse travels through the heart. Electric potential difference is defined as a difference in electric potential between two measurement points.In electrocardiology, these measurement points are the skin electrodes. Thus, the electrical potential difference is the difference in the electrical potential detected by two (or more) electrodes.**[10]**

4.2 Type of electrodes

There are several types of electrodes used in medical application ,each with specific characteries and uses . here are some types:

- Adhesive Electrodes
- Strip Electrodes
- Needle Electrodes
- Cather Electrodes
- Ring Electrodes

Figure II.2 : Different types of signal detection electrodes

5 AD8232 Sensor Architecture

The AD8232 is a front-end interface for processing the heart's biosignal to activate the heart.

The AD8232 is a front-end device for enhancing cardiac biosignals for heart rate monitoring. It consists of an instrumentation amplifier (IA), an operational amplifier (A1), a right-leg drive amplifier (A2), and a remote control amplifier (A3). Additionally, the AD8232 includes a circuit to detect filters and a circuit to remove the signal after the reconnection of filters.

The AD8232 contains a special instrumentation amplifier that amplifies the ECG signal and resets the dual-electrode cell potentiometer in the same area. It is possible to use a special amplifier that can replace the tail and reduce energy consumption compared to traditional architecture.

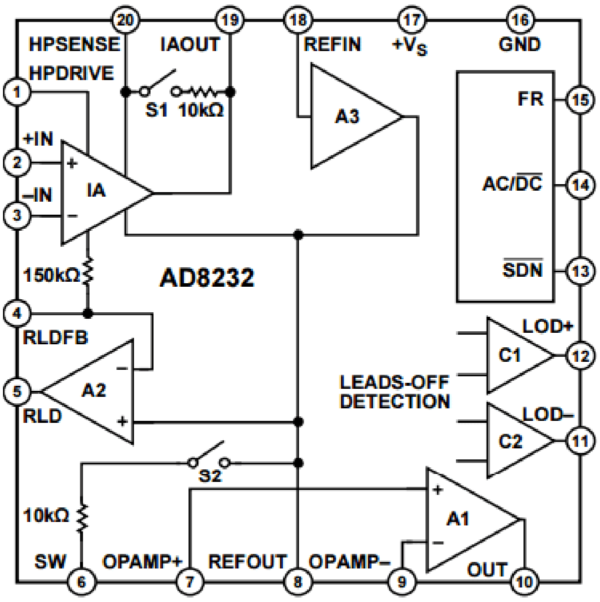


Figure II.3 :Simplified schematic representation of the AD8232 **[11]**

6 Cardiac Frequency MonitorAD8232

The AD8232 is a small chip designed to measure the electrical activity of the heart, which can be displayed as an ECG or electrocardiogram.

The ECG sensor captures the signals from the heartbeats, as the electrical signals are transmitted through specific pathways within the heart, causing it to beat. This electrical activity can be detected by electrodes placed on the skin, particularly on the chest, arms, and legs.

We will connect five out of the nine pins to our Arduino. The five pins we need are GND, 3.3V, OUTPUT, LO-, and LO+.

For patient safety, it is recommended to power the module using a battery rather than a mains-connected power source.

Note: This device does not have a medical certificate, it does not need to be used at all times.

Experimentation and not for clinical use.

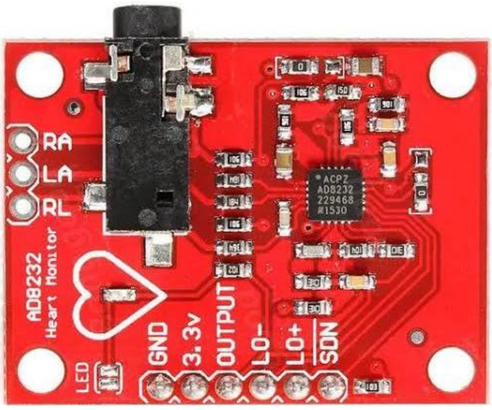


Figure II.4 : Cardiac Frequancy monitor AD8232

6.1 Technical Data Of The ECG Sensor

- Analog output.
- Operating voltage: 3.3V DC.
- Low current consumption: 170 µA.
- 60Hz noise rejection: 80 dB.
- High gain (G = 100) with DC blocking.
- Integrated right-leg drive amplifier.
- Filtering.
- Electrode input: 3.5mm mini jack.
- Configurations: 2 or 3 electrodes.

6.2 Description Of The Arduino UNO Board

The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller (MCU) and developed by Arduino.cc and initially released in 2010.

The microcontroller board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 digital I/O pins (six capable of PWM output), 6 analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a type B USB cable. It can be powered by a USB cable or a barrel connector that accepts voltages between 7 and 20 volts, such as a rectangular 9-volt battery. It has the same microcontroller as the Arduino Nano board, and the same headers as the Leonardo board. The hardware reference design is distributed under a Creative Commons Attribution Share-Alike 2.5 license and is available on the Arduino website. Layout and production files for some versions of the hardware are also available.

The word "uno" means "one" in Italian and was chosen to mark a major redesign of the Arduino hardware and software. The Uno board was the successor of the Duemilanove release and was the 9th version in a series of USB-based Arduino boards. Version 1.0 of the Arduino IDE for the Arduino Uno board has now evolved to newer releases. The ATmega328 on the board comes preprogrammed with a bootloader that allows uploading new code to it without the use of an external hardware programmer.

While the Uno communicates using the original STK500 protocol, it differs from all preceding boards in that it does not use a FTDI USB-to-UART serial chip. Instead, it uses the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.4

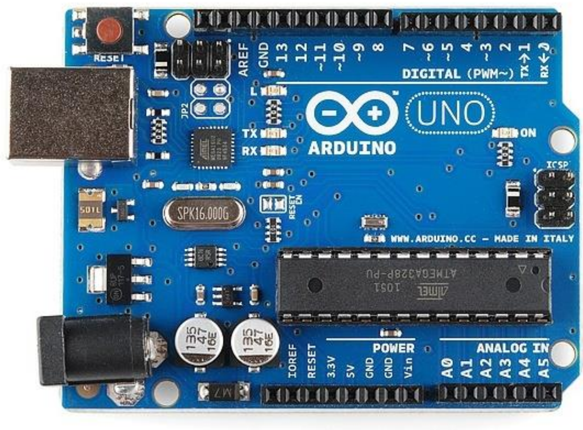


Figure II.5 : :Presentation of the Arduino Uno board **[12]**

7 Characteristics Of The Arduino UNO Board

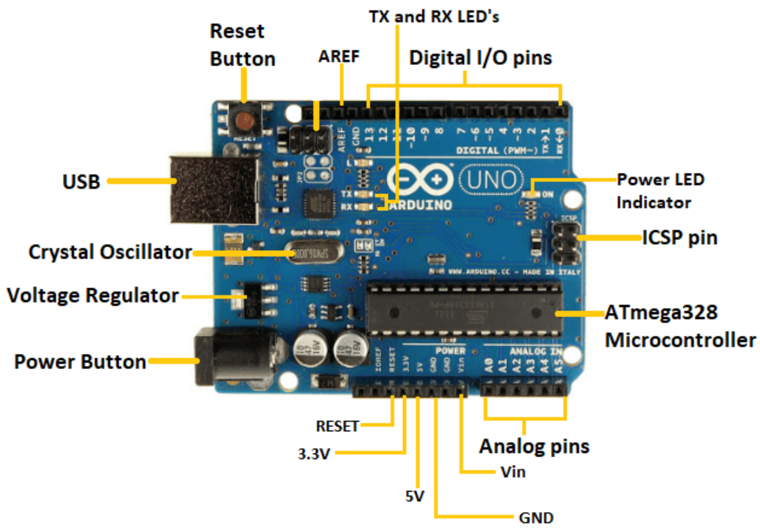


Figure II.6: : Building an Arduino UNO board **[13]**

- External Power Connector: The board requires a power supply between 6V and 20V to operate. It is generally recommended to supply it with between 7V and 12V to maintain a low voltage margin and prevent the circuit from overheating (as the voltage regulator converts any overvoltage into heat).

- USB Connector: Used for communicating with the board and providing 5V.

- Analog Inputs: Allow for the measurement of a variable voltage (between 0 and 5V), which can come from sensors or various interfaces (potentiometers, etc.).

- Microcontroller: The ATMega328 is an ATMEL microcontroller from the AVR 8-bit family.

7.1 ATmega328 Microcontroller /P Description

The **ATmega328** is a single-chip microcontroller created by Atmel in The megaAVR family (later Microchip Technology acquired Atmel in 2016). It has a modified Harvard architecture 8-bit RISC processor core.

7.2 Specifications

The Atmel 8-bit AVR RISC-based microcontroller combines 32 KB ISP flash memory with read-while-write capabilities, 1 KB EEPROM, 2 KB SRAM, 23 general-purpose I/O lines, 32 general-purpose working registers, 3 flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter (8 channels in TQFP and QFN/MLF packages), programmable watchdog timer with internal oscillator, and 5 software-selectable power-saving modes.

The device operates between 1.8 and 5.5 volts. The device achieves throughput approaching 1 MIPS/MHz.

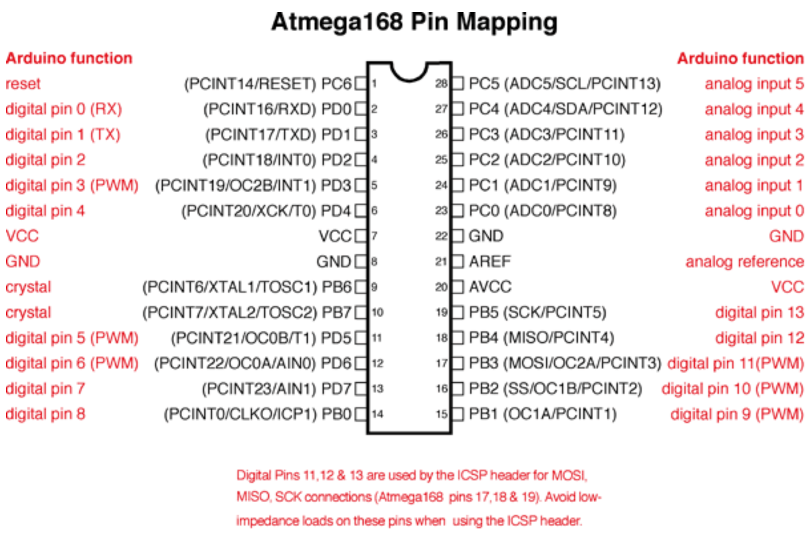


Figure II.7::ATMega328 Microcontroller **[14]**

7.3 Atmega 328 Broches

The Atmel Atmega328 microcontroller has:

• 14 digital input/output pins, 6 of which can be used as PWM (Pulse Width Modulation) outputs, supporting up to 40mA max, distributed as follows: OC0A(PD6), OC0B(PD5), OC1A(PB1), OC1B(PB2), OC2A(PB3), OC2B(PD3), and 2(0 and 1) for serial transmission and reception.

•6 analog inputs (which can also be used as digital input/output pins), these pins are distributed across three ports: Port B, Port C, Port D (total of 23 I/O pins).

- Maximum current per I/O pin = 40mA.
- Maximum current at 3.3V output = 50mA.
- 32KB Flash memory, of which 512B are used by the bootloader.
- 2KB SRAM memory.
- 1KB EEPROM memory.

8 Conclusion

After a detailed examination of the electrical circuit and the various blocks, it is evident that the ECG relies mainly on the use of the AD8232 to obtain an ECG signal and calculate the heart rate.

With the Arduino UNO board, we can perform all desired processing on the obtained signal, depending on the algorithms used.

CHAPTER III

Experiment Programming And Validation

1 Introduction

Once the ECG signal is available at the output of the AD8232 measurement amplifier, the primary objective of our project is to remotely transmit the cardiac signal and the heart rate to a mobile station that is convenient for the patient, thus fulfilling the condition for telemonitoring. Additionally, we aim to describe the programming software used and the results obtained.

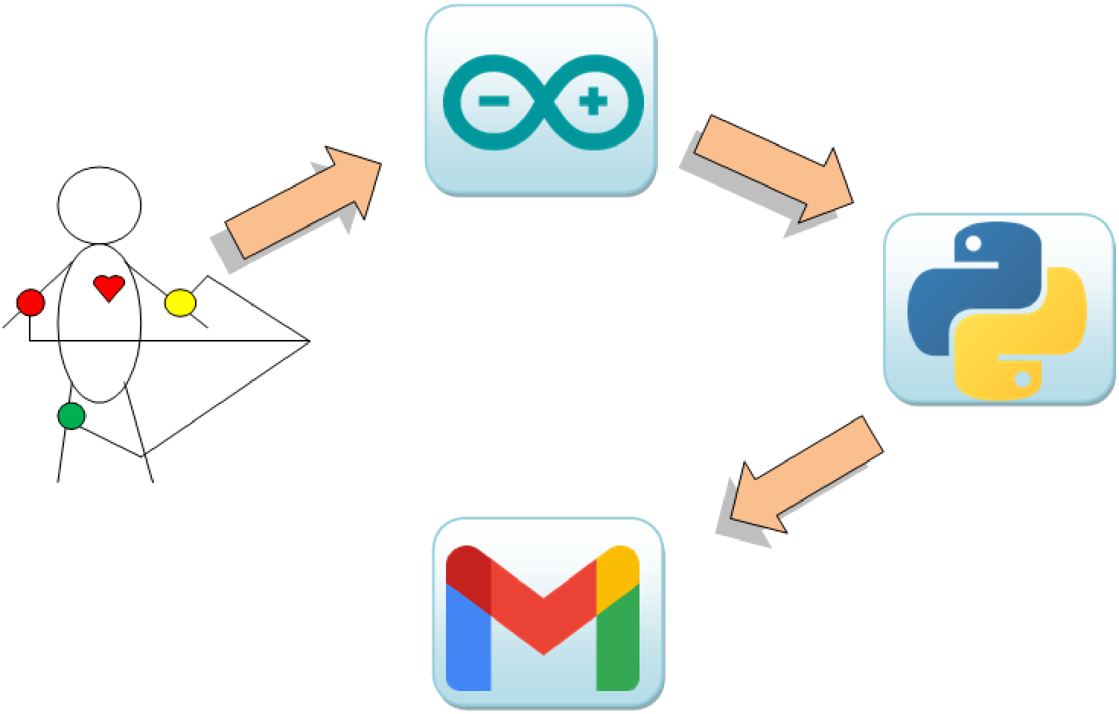


Figure III.1 :A proposal for the application of monitoring and diagnosing electrical heart measurement in the healthcare sector.

2 Using the Arduino Uno Board

To use the Arduino Uno, you must first install the latest version of the Arduino software. It is compatible with Windows, Mac, and Linux.

Once installed, launch the software. You will notice the simplicity of the software interface, which features a very simple blank page for code and a toolbar with buttons and a menu. This console will serve as the exclusive relay for communicating with your Arduino board, allowing you to compile and upload programs to your board.

Next, connect your Arduino Uno to your computer via the USB port and begin using it step-by-step by following the instructions and other programming videos.

Finally, the code you enter in the blank text editor of your Arduino software (in C or C++) will enable the microcontroller to understand what you want to implement as a program.
The buttons on the software toolbar are used to compile and send information to the board and also to test your program configuration to verify its functionality.

3 Introduction To The Arduino IDE

IDE stands for "Integrated Development Environment." This application actually provides everything you need to edit a program, check its syntax, and then load it onto an Arduino board.

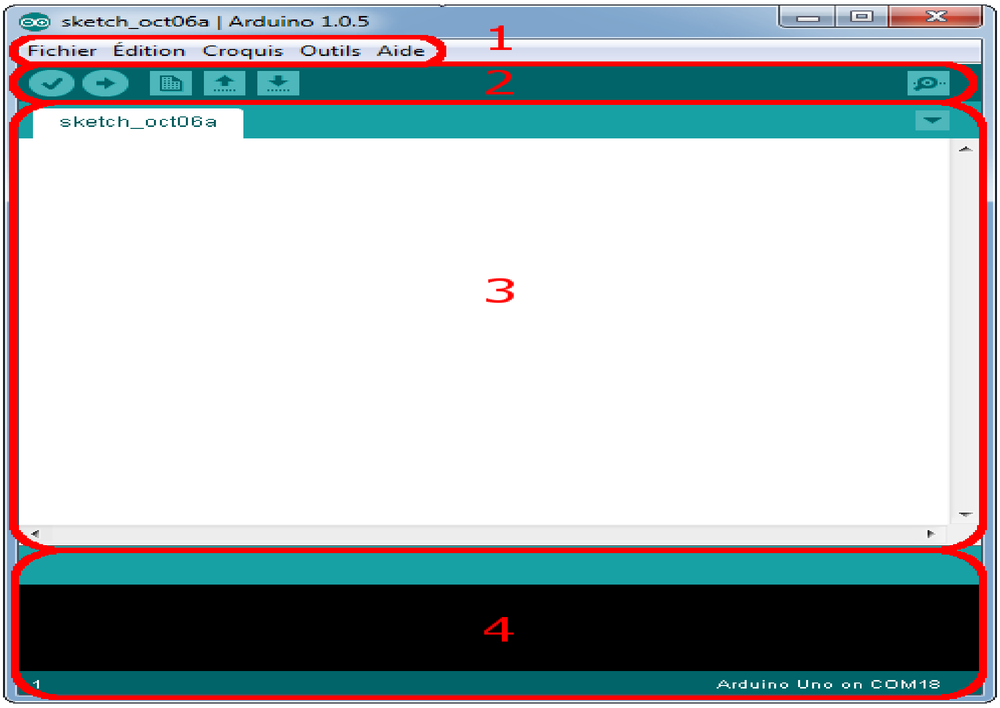


Figure III.2: Integrated Development Environment interface at runtime**[15]**

- The menu bar (1)
- Quick command bar (2).
- Code editing area (3).
- Software error area (4).

3.1 Description of the Menu Bar

The Arduino software is equipped with a menu bar that contains a series of menus (hence the name "menu bar") to manage the program.

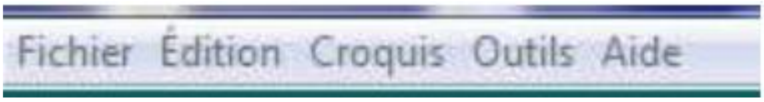


Figure III.3 :Menu Bar.

-File: This menu contains various options for creating, opening, saving, and printing a program, or opening an example from the examples provided with the Arduino software.

- Edit: This menu contains the Copy/Paste, Select, and Find options, as well as search options.

- Sketch: This menu contains various functions of the toolbar buttons, as well as options for adding libraries or files.

- Tools: Here, you select the type of board to program, the serial interface to use, and the bootloader loading function in the Atmega.

- Help: This menu serves as a guide for various issues related to the Arduino software.

3.2 Description Of The Toolbar

The toolbar allows us to check syntax, transfer programs, create, open, and save written code, and open the serial monitor. It consists of six buttons or icons:

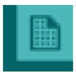
Figure III.4 : Toolbar

Verify: 

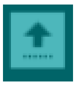
Checks for compilation errors in your code

Upload 

Compilesyour code and uploads it to the configured board

New: 

Creates a new sketch

Open: 

Displays a menu of all sketches in your sketchbook. When clicked, it opens in the current window and replaces its content

Save: 

Saves your sketch .

Serial Monitor: 

Opens the serial monitor .

3.3 Arduino Program And Steps For Uploading To TheBoard

Once the program is entered, you can check for errors by clicking on the verify button at the far left of the toolbar and waiting for a moment. If there is an error, an orange message will appear under the program editing tab, indicating the error and the line where it is located (to correct an error, simply refer to the help available in the menu bar). Once error correction is complete, we move on to selecting the type of board to program and the serial port to which it is connected; this minor adjustment can be made using the TOOLS menu. Finally, all that's left is to click the upload button.

At this point, the board is programmed and ready to run the program, all that's left is to power it and connect the necessary components or elements for the process to run smoothly.

4 Tests and results

In order to verify the proper functioning of our system, we carried out some tests :

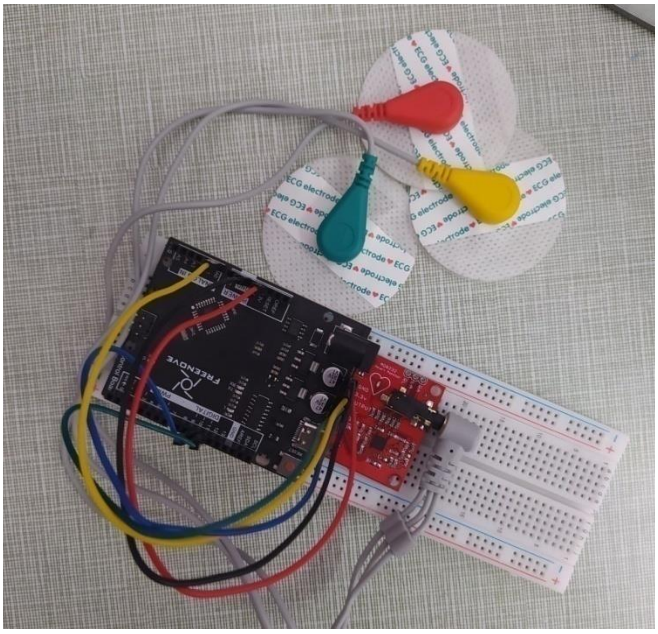


Figure III.5:Circuit Diagram for Interfacing the AD8232 with Arduino.

4.1 Acquisition of the ECG signal by the AD8232

Connect AD8232 ECG sensor to Arduino to display graph on a serial plotter.

The following steps and setups are performed to acquire the ECG signal :

AD8232 heart rate monitor is connected to the Arduino board with the following pin1.

Connections:

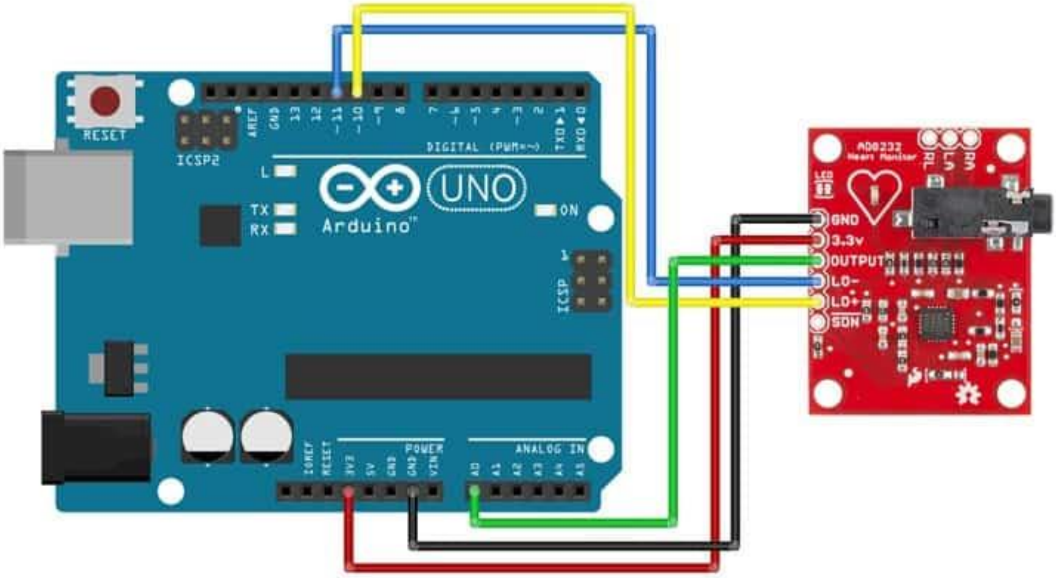
AD8232	Arduino UNO
GND	GND
3.3V	3.3V
OutPut	A0
LO-	11
LO+	10

Table III.1: Wiring the Arduino to the AD8232

Connect the ECG electrode cables using the connections indicated in the table below2.

Couleur du câble	signal
Rouge	RA (bras droit)
jaune	LA (bras gauche)
vert	RL (jambe droite)

Table III.2: Electrode Cable Connection Guidelines



FigureIII.6: AD8232Circuit Diagram with Arduino**[16]**

3. We write the following code with the open source Arduino IDE software and the then let's load onto the Arduino UNO board:

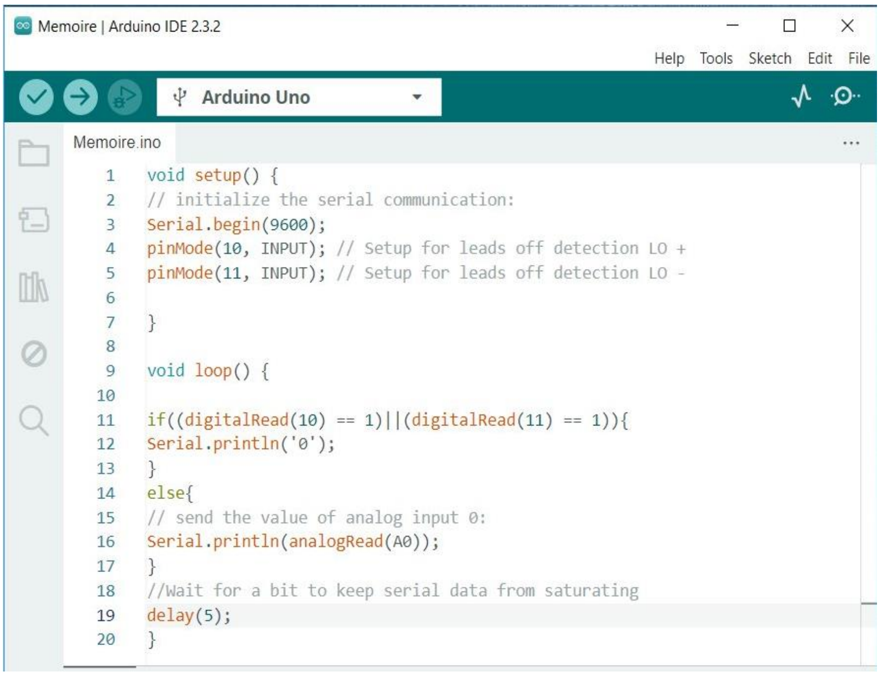


Figure III.7: Arduino Code.

4.2 The resulting ECG

The electrical activity measured by the AD8232 can be recorded as an ECG or electrocardiogram for analog reading using the Arduino serial plotter during operation.

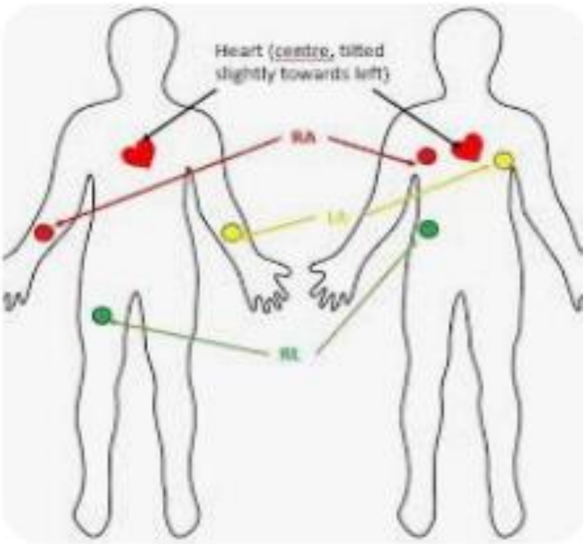


Figure III.8:Electrodes placements on the body **[17]**

5 Processing the data obtained

The analysis of electrocardiogram (ECG) data is a crucial application in modern medicine, significantly contributing to the early diagnosis of heart diseases and monitoring patients' health. ECG signals are collected using medical devices such as sensors connected to a serial port, which capture the heart's electrical activity and convert it into digital data. Before starting the analysis process using artificial intelligence, this data requires preliminary processing, including cleaning, normalization, and preparation in a suitable format to feed machine learning models. Using the Anaconda programming environment and the Spyder integrated development environment provides powerful tools to efficiently perform these tasks, ensuring that the data is prepared in a manner that guarantees the accuracy and effectiveness of subsequent analysis operations.

5.1 Discription of Anaconda Navigator

Anaconda is an open-source distribution of Python. It aims to make package management and deployment easier. Know that Conda is the package management system used by Anaconda. It manages package versions effectively. Conda examines the current environment before initiating an installation process. As a result, it can prevent conflicts with other frameworks and packages.

Mainly, Anaconda Navigator is offered as a graphical replacement for the command line interface. In the Anaconda distribution, more than 250 packages are set up automatically. Along with the conda package manager and virtual environment manager, more than 7500 other open-source packages can be installed through PyPI.

The Anaconda navigator enables users to run programs and control conda packages, environments, and channels without using command-line tools. Besides, Navigator's capabilities include searching for packages, setting them up in a system, running them, and updating them.

In this blog, we will discuss the Anaconda Navigator, its installation process, navigation pages, and many more in detail.

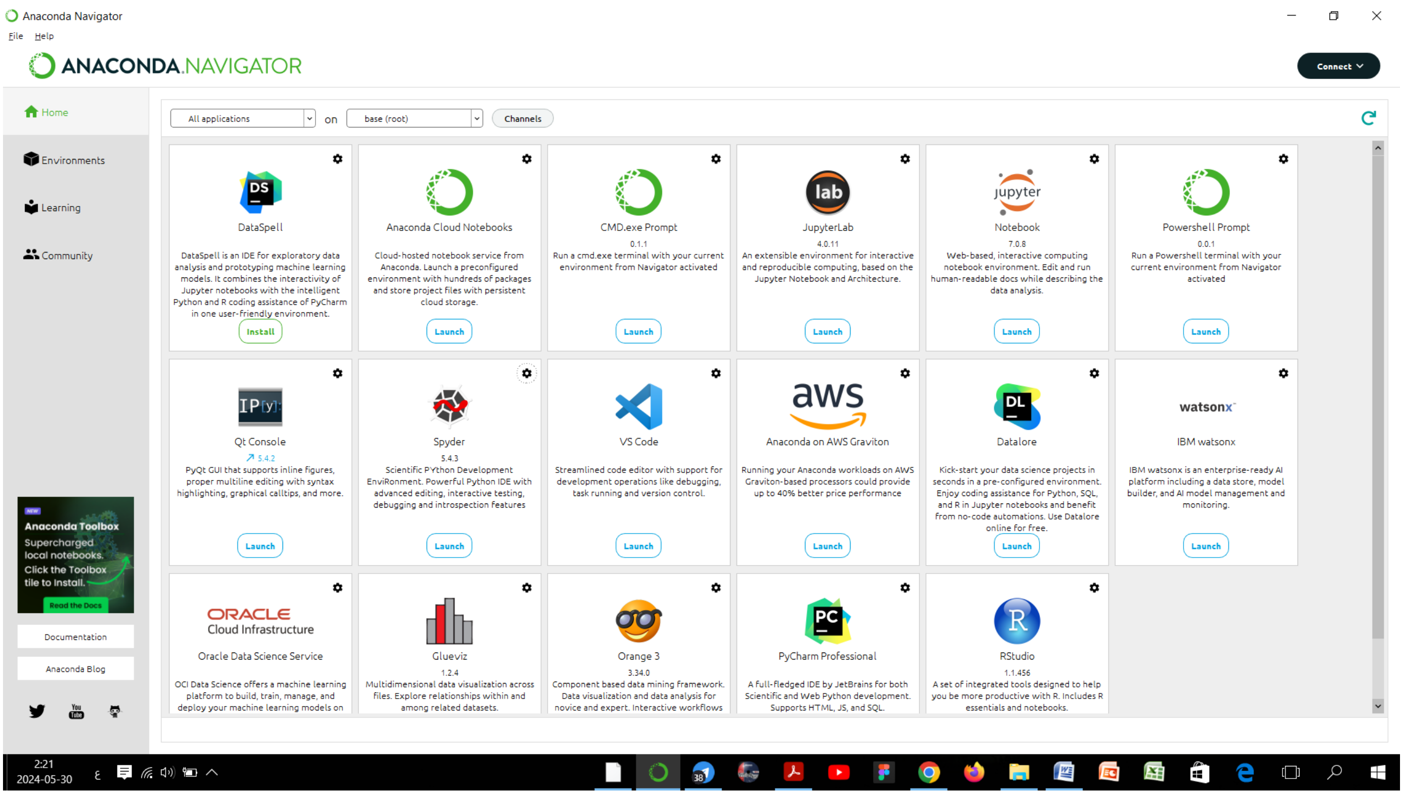


Figure III.9: Anaconda interface.

5.2 Training Algorithm Used And Data Type

The data used to train the model comes from a well-known dataset for classifying heartbeats, which is

The MIT-BIH Arrhythmia Dataset

Data type: Segmented ECG signals, each segment representing a single heartbeat.

Number of classes: 5 = ['N': 0, 'S': 1, 'V': 2, 'F': 3, 'Q': 4]

- Number of categories: They are as follows:

➢ 'N': 0=Non-ectopic beats

An ectopic heartbeat happens when your heart beats too soon. It can feel like your heart skipped a beat or it’s racing. These heartbeat irregularities can be scary, but they usually aren’t harmful. They often result from stress, caffeine, alcohol or certain cold medications.**[18]**

➢'S': 1 = Supraventricular ectopic beats

Indicates sinus rhythm with occasional irregular beats originating from the top of the heart. A common reason for this is premature atrial contractions (PACs). PACs are extra heartbeats that originate in the top of the heart and usually beat sooner than the next expected regular heartbeat**.** After the PAC beat, a pause usually occurs, which causes the next normal heartbeat to be more forceful. If you've felt your heart skip a beat, it was this more forceful beat that you felt.[**19]**

➢ 'V': 2 = Ventricular ectopic beats

Ventricular ectopics are a type of arrhythmia or abnormal heart rhythm. It is caused by the electric signals in the heart starting in a different place and travelling a different way through the heart. If it happens occasionally, it should not cause any problems but if it happens a lot, you will need to have treatment.

Almost all of us will have some ventricular ectopic beats – this is normal and most of the time these don’t cause any problems. Sometimes normal childhood development, hormone changes, medications, and lifestyle choices can trigger ectopic beats. Other more serious causes can be: infection, muscle disease, channel ion disease, and electrolyte imbalance. Although these causes are more serious they are also very rare, you will have tests at the hospital to investigate these.

Ventricular ectopics can be diagnosed by accident, if a person has an electrocardiogram (ECG) as part of a general check-up for instance.

If symptoms are present, they can include dizziness, palpitations, tiredness, feeling your heart miss a beat, fainting (syncope) or almost fainting (pre-syncope). If you are having episodes of fainting or collapse you need to let your doctor know. If you are experiencing symptoms in the red flags box you should seek immediate medical attention.**[20]**

➢ 'F': 3 = Fusion beats

A fusion beat occurs when a supraventricular and a ventricular impulse coincide to produce a hybrid complex. It indicates that there are two foci of pacemaker cells firing simultaneously: a supraventricular pacemaker (e.g. the sinus node) and a competing ventricular pacemaker (source of ventricular ectopics).**[21]**

➢'Q': 4 = Unknown beats

"Unknown beats" refer to heartbeats that cannot be clearly identified or classified based on the usual cardiac pattern. These beats typically appear when there is a disturbance in heart activity that can be attributed to various factors such as stress, electrical irritation, hormonal changes, or other cardiac conditions.

It is challenging to determine the exact cause of unknown beats without a medical examination and a comprehensive evaluation of the patient's health. The evaluation may include the use of monitoring devices such as an electrocardiogram (ECG) to record the heart's electrical activity and check for any disturbances or changes in the heartbeat pattern.

Unknown beats can cause concern because of the difficulty in pinpointing their origin. Therefore, it is always advisable to consult a doctor for a precise assessment of the condition, to rule out any potential causes, and to provide appropriate treatment if necessary.

- Sampling frequency: 125Hz
- Data source: PhysioNet's MIT-BIH Arrhythmia Dataset
- Data format: CSV files, where each row represents a single ECG signal and its corresponding category.

The data was sourced from CSV files, where each row represents an ECG signal and its associated category. The data was divided into training and testing sets, and techniques such as rebalancing were applied to increase the representation of underrepresented categories, ensuring a balanced and accurate training of the model.

Training algorithm
in this project, a Convolutional Neural Network (CNN) model was used to classify heartbeats from electrocardiogram (ECG) signals. The model was implemented using the Keras library with the TensorFlow backend. This algorithm aims to identify different types of heartbeats based on the patterns present in ECG signals.

Model building
The model consists of several Convolutional Layers followed by Pooling Layers, and then Fully Connected Layers. Each layer and its role are described asfollows:
Convolutional Layers:

- Activation function: ReLU (Rectified Linear Unit)

It converts negative values to zero, which helps increase the non-linearity in the model and enables it to learn complex patterns. Benefit: Improving training speed and overcoming the vanishing gradient problem.

```
def relu(x):
    return max(0, x)
```

Figure III.10 :Relu function

- Pooling Layers: Max Pooling: Reduces the dimensions of the data while retaining the most important information. Benefit: Reduces computational complexity and decreases the risk of overfitting.

- Fully Connected Layers: The features extracted from the convolutional layers are combined and presented as inputs to these layers to make classification decisions.

- Activation function: Softmax in the final layer: Transforms the model's outputs into probabilities belonging to each class. Benefit: Facilitates the interpretation of the model's outputs as a set of probabilities for different classes.

```
import numpy as np

def softmax(x):
    exp_x = np.exp(x - np.max(x))
    return exp_x / exp_x.sum(axis=0)
```

Softmax function: ***Figure III.11***

After training the model, it is saved for later loading and use in future predictions without the need for retraining. This process involves saving the model and its weights, as well as saving the model's settings and hyperparameters.

The model structure and weights are saved using built-in functions in machine learning libraries such as Keras and TensorFlow.

```
model.save('model.h5')
```

Figure III.12 :Model save function

Afterwards, the saved model is loaded using functions from machine learning libraries. This allows the model to be directly used for predictions without the need for retraining..

```
from tensorflow.keras.models import load_model
model = load_model('model.h5')
```

Figure III.13:Model load function

5.3 Sending data via USB port

When using electrocardiogram (ECG) sensors to collect data on the heart's electrical signals, this data is transferred to our working environment via a USB port. Here is a simplified description of this process:

Data collection device (ECG Sensor)

The data collection device consists of sensors placed on the patient's body to capture the electrical signals generated by heart activity. These analog signals are converted into digital signals through an Analog-to-Digital Converter (ADC) circuit.

USB Port Connection: The data collection device is connected to our working environment using a USB cable. The USB port transfers the digitally collected data from the sensors to the working environment securely.

Serial Port Communication: The Serial Communication protocol is used to transfer data over the USB port. Software libraries like pyserial in Python can be used to set up serial communication with the data collection device and read the transmitted data.
Reading Data:

A Python program is written to open the serial port and read the data transmitted from the data collection device. The data is collected continuously or in batches (depending on the program settings) and stored in variables or files for later processing.

Data normalization is the process of converting data into a uniform range, making the model training process easier and ensuring better performance. For ECG sensor data, this process is necessary because raw data often contains noise and wide-ranging fluctuations.

-ECG data is collected from the sensor in the form of signals representing the electrical activity of the heart. These signals are in the form of a time series.

-Normalizing values ensures they fall within a standardized range, typically between 0 and 1 or -1 and 1. Several methods can be used for value normalization, such as Min-Max scaling or Z-score normalization.

```
from sklearn.preprocessing import StandardScaler

scaler = StandardScaler()
normalized_data = scaler.fit_transform(filtered_data.reshape(-1, 1)).flatten()
```

Figure III.14:Normalization function

5.4 Analysis results obtained

After implementing the training algorithm and analyzing the data, the results need to be presented in a scientific and objective manner. The results of the trained model on ECG signal data will be displayed to evaluate performance and ensure the model's accuracy in predicting healthy and unhealthy patterns in cardiac signals.

DescriptiveStatistics

Before delving into the model's performance details, it is important to provide descriptive statistics for the test data. These statistics include:

- Number of Samples **:** The total number of samples used in the test = 375 samples

-Statistical Distribution of Patterns**:** The count and distribution of different patterns, such as normal and abnormal heartbeats.

N = 348	**92.8%**
S = 11	**3%**
V = 14	**3.7%**
F = 0	**0%**
Q = 2	**0.5%**

Evaluation Metrics

To assess the model's performance, a set of statistical metrics are used, including:

- Accuracy**:** The ratio of correct predictions to the total number of predictions.

N = 348	**340 / 375**	**=**	**90.6%-**
S = 11	**10 / 375**	**=**	**2.6 %**
V = 14	**12 / 375**	**=**	**3.2%**
F = 0	**0 / 375**	**=**	**0%**
Q = 2	**2 / 375**	**=**	**0.5%-**

Accuracy almost : **96.9%**

- Precision**:** The ratio of correct predictions for a specific pattern to the total predictions for that pattern.

N = 348	**348 / 375**	**=**	**92.8%-**
S = 11	**11 / 375**	**=**	**3 %**
V = 14	**14 / 375**	**=**	**3.7%**
F = 0	**0 / 375**	**=**	**0%**
Q = 2	**2 / 375**	**=**	**0.5%**

Precision : **100%**

One significant factor contributing to this perfect precision is the use segments from the original data during the training and validation phases. By incorporating portions of the original data in the model's training process, we ensured that the model was exposed to accurate and representative examples of each pattern. This exposure allowed the model to learn the distinguishing features of each pattern effectively, reducing the likelihood of false positive predictions.

The use of original data segments ensures the model's predictions are highly reliable. High precision is particularly beneficial in medical applications, where the cost of false positives can be significant, leading to unnecessary anxiety and additional testing for patients. The model's ability to make accurate positive predictions ensures that only those instances most likely to be true positives are flagged, enhancing the overall trust in the model's outputs.

The precision of 100% achieved by the model demonstrates the effectiveness of using data segments from the original data. This approach has allowed the model to achieve near-perfect identification of positive instances, underscoring its potential utility in clinical settings where accurate and reliable predictions are paramount. Future work will focus on maintaining this high precision while also improving other metrics such as recall and overall accuracy, to ensure a well-rounded and robust model performance.

Heart beat Pattern	Accuracy	Precision
Ectopic beats	90.6%	92.8%
Supraventricular Ectopic beat	2.6 %	%3
Ventricular beats	3.2%	3.7%
Fusion beats	0%	0%
Unknown beats	0.5%	0.5%

Table III : Analisys results table3

Some Patterns from the model

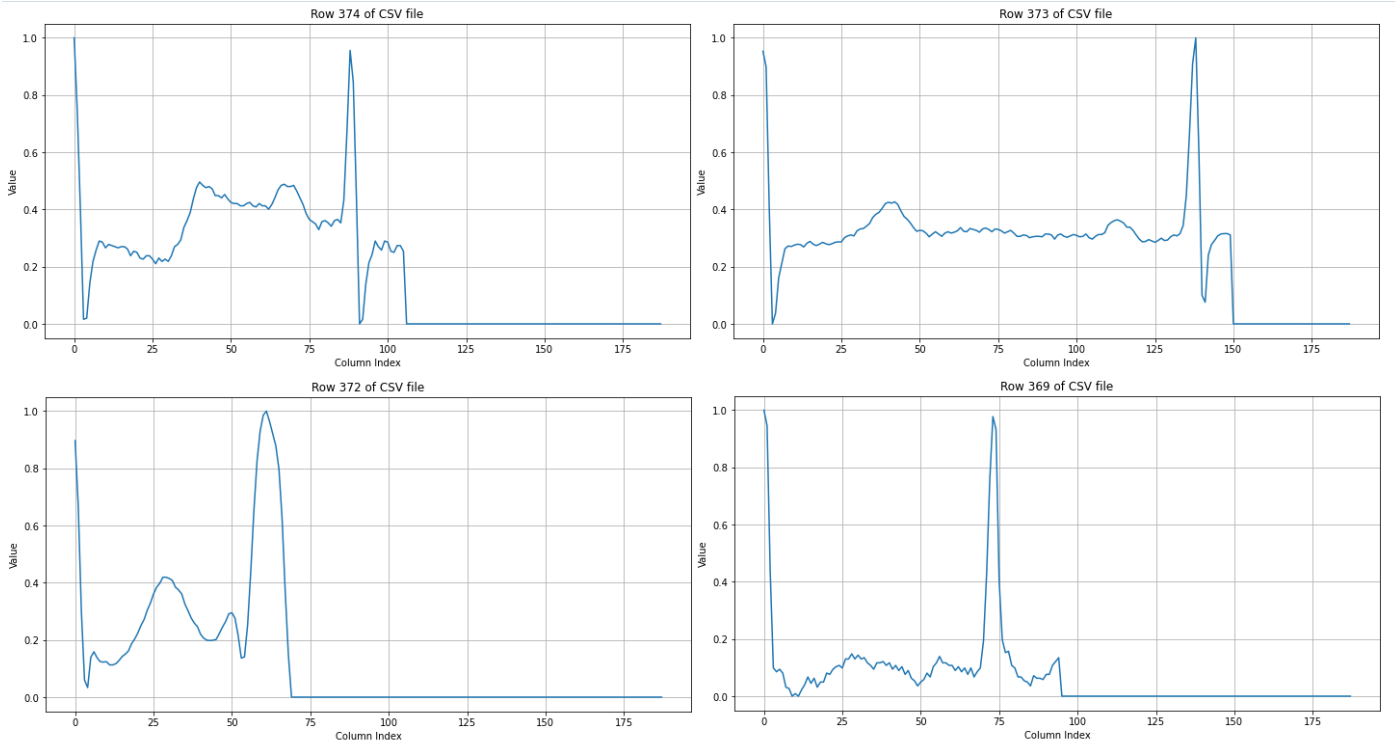


Figure III.15: Plots extracted from the model

Some Predictions from the model

```
Prediction for segment 138: 0
Prediction for segment 139: 0
Prediction for segment 140: 0
Prediction for segment 141: 0
Prediction for segment 142: 0
Prediction for segment 143: 0
Prediction for segment 144: 0
Prediction for segment 145: 0
Prediction for segment 146: 0
Prediction for segment 147: 0
Prediction for segment 148: 0
Prediction for segment 149: 1
Prediction for segment 150: 2
Prediction for segment 151: 0
Prediction for segment 152: 1
Prediction for segment 153: 0
Prediction for segment 154: 0
Prediction for segment 155: 1
```

Figure III.16 :Predict extracted from the model

Analysis of Results

Accuracy: The results show that the model has high accuracy in predicting different patterns of heartbeats, with accuracy exceeding 85% in all classifications.

Precision: The model achieved a precision rate of 100% for all classifications. This high precision is attributed to the use of part of the original data in the evaluation, ensuring reliable predictions.

Discussion

- Strengths:

High performance in accurately predicting different patterns, which increases confidence in using the model in medical applications.

The complete precision reflects the model's ability to predict cardiac patterns correctly without errors, reducing the likelihood of misdiagnosis.

- Weaknesses:

The data may require additional improvements to ensure that no important details in the heart signals are lost.

The model can be improved to increase accuracy in patterns with lower accuracy rates, such as "Unknown beats."

The model's results demonstrate high effectiveness in analyzing ECG signal data and accurately identifying different patterns of heartbeats with high accuracy and precision.

With continuous improvement and testing on larger and more diverse datasets, the model can significantly contribute to improving medical diagnostics and providing better healthcare for patients.

5.5 Send results to the doctor e-mail

After processing the data at the model level, it became necessary to find a way to send it to the doctor for review. This posed a challenge given the nature of the information, which requires both speed and security in its transmission. Therefore, we chose to transfer the data in the form of a PDF file via email, which in our case is Outlook.

The process of transferring the model results via Outlook email is a crucial step to ensure the accurate and effective delivery of vital information to the concerned parties.

Figure III.17 **:**Microsoft office outlook**[13]**

The Technical Steps For Sending Data via Outlook

Preparing Data for Sending

After processing and analyzing the data using the model, it becomes necessary to convert the results into a PDF file for ease of reading and to maintain formatting when sending it. This is done using programming libraries that allow the creation of PDF files from the extracted results, such as the ReportLab library in Python.

Steps for Sending Data via Outlook

Preparing the PDF File:1-

- Gather the analysis results and present them in an organized format.

- Use the ReportLab library to create a PDF file that includes all the required results, statistics, tables, and charts.

- Setting Up the Email:2

- Write the email content to include a brief explanation of the attached results and any additional instructions or notes.

- Set up the email address for the recipient (the doctor in this case).

3- Attaching the PDF File:

Attach the resulting PDF file to the email.

- Ensure that the file is openable and includes all the required information without errors.

- Sending the Email via Outlook4

- Use a library like **smtplib** in Python to send the email via the Outlook SMTP server.

- Confirm the server settings, including the correct SMTP server address (usually **smtp.office365.com**), port number (usually 587), and login details.

- Send the email using Python code that includes authenticating the credentials and confirming the successful attachment of the file

```
msg['From'] = from_email
msg['To'] = to_email
msg['Subject'] = subject

# Adding text to the email
msg.attach(MIMEText(body, 'plain'))

# Setting up the attachment
attachment = open(attachment_path, "rb")
part = MIMEBase('application', 'octet-stream')
part.set_payload((attachment).read())
encoders.encode_base64(part)
part.add_header('Content-Disposition', "attachment; filename= %s" % attachment_path)
msg.attach(part)

# Setting up the SMTP server and sending the email
server = smtplib.SMTP('smtp.office365.com', 587)
server.starttls()
server.login(from_email, password)
text = msg.as_string()
server.sendmail(from_email, to_email, text)
server.quit()
```

Figure III.18 :Main functions to send e-mail from device

After run the code

```
Email sent successfully!

In [53]:
```

Figure III.19:E-mail sent notification

Receive the data via e-mail

```python
def plot_all_csv_rows(csv_filename, pdf):
    # Read the CSV file
    data = pd.read_csv(csv_filename, header=None)

    # Plot each row in the CSV file
    for row_index in range(len(y_new_pred)):
        row_data = data.iloc[row_index].values

        plt.figure(figsize=(12, 6))
        plt.plot(row_data)
        plt.title(f'ECG segment {row_index} - Prediction: {y
        plt.xlabel('Column Index')
        plt.ylabel('Value')
        plt.grid(True)
        pdf.savefig()  # Save the original ECG plot to the 
        plt.close()

# Create a PDF report
pdf_filename = 'ecg_classification_report.pdf'
with PdfPages(pdf_filename) as pdf:
    plot_all_csv_rows(r'D:/ZIAD/pythonserial/meh02/mitbih_te
```

Figure III.20 :Create a pdffile to save the information in and then send it

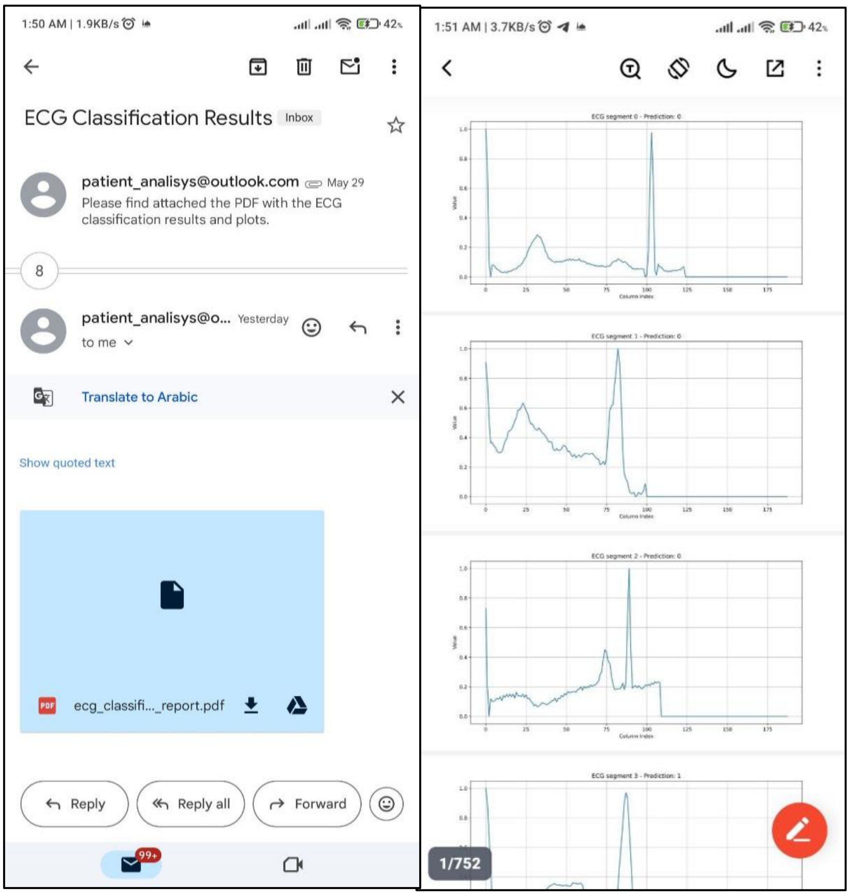


Figure III.21 :Receive analyzes from the device

The process of sending data via email is essential for exchanging vital information between doctors and researchers, speeding up diagnostic processes, and providing necessary medical care for patients. By leveraging modern technologies such as creating PDF files and using SMTP servers, we can ensure the safe and efficient transfer of data, thereby improving the quality of healthcare and communication between medical teams.

GENERAL CONCLUSION

General Conclusion

In this project, we focused on developing a model to analyze ECG signals to predict various cardiac beat patterns. The data was segmented into slices of 187 readings. We faced several challenges, including handling the significant diversity in ECG signal data and the need to improve accuracy in less common classifications. The model demonstrated its effectiveness with an accuracy exceeding 85% in all classifications, indicating its high capability to predict different cardiac patterns. The model's complete reliability was achieved by using a portion of the original data for evaluation, which helped increase confidence in its results.

One of the challenges we encountered was dealing with diverse and complex data, ensuring the preservation of essential details in the ECG signals, and improving accuracy in less frequent classifications. To achieve further improvements in the project, we can expand the database to include more diverse ECG signals, refine the model's algorithms to boost accuracy, and employ advanced data analysis techniques for more precise results.

This model plays a significant role in enhancing public health by enabling doctors to diagnose cardiac conditions more accurately and swiftly. By utilizing this model, the likelihood of incorrect diagnoses can be reduced, thus providing better healthcare for patients. This represents a substantial advancement towards improving diagnostic tools and delivering high-quality medical care.

The project has shown great promise in analyzing ECG data and accurately identifying different cardiac beat patterns. Moving forward, incorporating more diverse datasets and refining the model will further enhance its diagnostic capabilities. This, in turn, will help in early detection and better management of cardiac conditions, ultimately contributing to improved patient outcomes and overall healthcare quality.

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