الجمهورية الجزائرية الديمقراطية الشعبية

Ministry of Higher Education and Scientific Research

UNIVERSITY YAHIA FARES OF MEDEA

FACULTY OF TECHNOLOGY

Department of Electrical Engineering

Master's Thesis

Field: Electronics

Speciality: Embedded Electronics Systems

Topic

Smart System for Patient Identification, Triage, and Prioritization in Medical Emergencies

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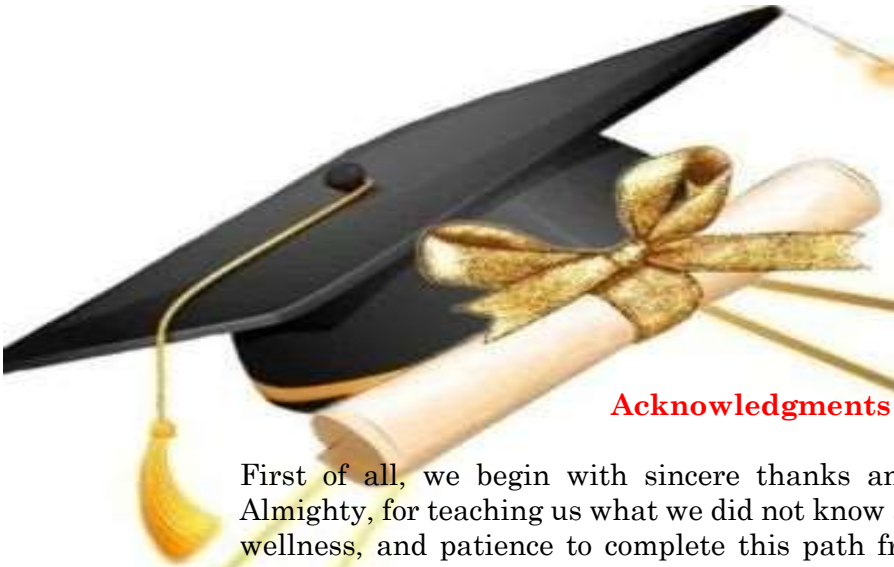
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Class 2024

Work conducted at the Laboratory of Advanced Electronic System (LSEA) of Medea University, ALGERIA



Acknowledgments

First of all, we begin with sincere thanks and gratitude to Allah, the Almighty, for teaching us what we did not know and granting us the health, wellness, and patience to complete this path from beginning to end. The completion of this work would not have been possible without the support, patience, and encouragement of some very special people.

We would like to take this opportunity to express our gratitude to those who helped us in a thousand and one ways with their love and great prayers, starting first with our beloved parents, for their patience and hard work day and night to provide us with a good life. Our precious mothers stayed up and raised us with the best education to become who we are today. Thank you, dad, and thank you, mom.

We are deeply grateful to our honorable Professor Bouhedda Mounir, who supported us with all his invaluable help throughout the completion of this work and chose us from among many others to be our supervisor. We would also like to thank Mr. Zouadi Okba, a PhD student at Yahya Fares University of Medea, for his assistance in the completion of this work. Our sincere thanks also extend to the members of the committee: The President Mr. Bailiche Amine and the Examiner Dr. Benyezza Hamza. We are deeply and warmly thankful to them.

We would also like to express our deep and warm thanks to Dr. Jameela for her explanations in the medical field and for patiently addressing our many questions and doubts.

Our gratitude goes out to all those who supported us, even if with a passing word, and to all friends and loved ones.

Thanks to everyone





Dedication

To my dear father
Mr. RABIA Ali
You gave your life for us and for your children
to grow up with the best
upbringing, and you strived to give us your health
and money to live happily
and prosperously, I dedicate my success and
success to you, me
beloved heartthrob.
To my dear mother,
FARHAT Fatiha
You, the source of tenderness, the paradise of basil, the
one who finds safety
in your arms, I dedicate this work to you,
which is the fruit
of your great efforts, your watchfulness over
our illness and your
great sacrifices, may God protect you for us.
To my dear sisters
Jasmine, Amira and Nour Al-Huda
To my dear brother
Bilal, I love you above the love of lovers.
And a testimony to my brotherly affection and deep respect.
I wish you much happiness and success.
To my grandparents and the rest of the
family, I greet you each according to your
place in my heart
As an expression of my gratitude
and sincere love
I dedicate this work to everyone
who loves me
To my beloved friend Fatma YAHIAOUI,
a sister whom my mother did not give birth to,
and to my companion in this journey,
Amira Lamia ELMOHRI,
may God protect you both.
And to the rest of my friends and those I love,
thank you.



OUASSILA

Dedication

To my dear father
Mr. Benissa ELMOHRI
Dear father, you gave us your health and
money and made the greatest efforts for us,
as you worked hard
to ensure that we, your children, live a
comfortable and
wonderful life.
To my dear mother
Latifa BENCHEDI
O Paradise of the Merciful, the address of safety,
you who was recommended to me by the Merciful,
you gave us from your health and yourself,
watched over us and fought fatigue for us,
we love you,
most precious, I dedicate this work to you,
and I pray that God will keep you and my father.
To my dear sisters
Radia, Djamila, Marioma Malika
To my dear brothers
Jamal and Abdul Rahman
I love you, the best brothers, may
God sustain you for me and me
for you.
And a testimony to my brotherly affection
and deep respect.
I wish you a lot of happiness and the rest
of the family, I greet
you each according to his position and status in my heart.
As an expression of my gratitude and sincere love
I dedicate this work to everyone who loves me
To my friends
Madina, Khadija, Safia. Zola, Chaima,
Fatma Madjber and
Fatma Yahiaoui and Maroua
To my companion in this journey,
OUASSILA RABIA,
may God protect you.
And to the rest of my friends and those
I love, thank you.



AMIRA LAMIA

العنوان: نظام الذكي لتحديد هوية المرضى وفرزهم وتحديد أولوياتهم في حالات الطوارئ الطبية

ملخص-يهدف هذا المشروع إلى تطوير نظام ذكي لتصنيف المرضى وتحديد أولوياتهم في أقسام الطوارئ. يعتمد مشروعنا على خوارزميات متقدمة في الذكاء الاصطناعي، حيث يتم تصنيف المرضى بناءً على قاعدة بيانات تحتوي على مؤشرات مختلفة لكل مريض. في النهاية، نحدد مستوى خطورة حالته الصحية. يتم تطوير هذا النظام في بيئة برمجية مرئيةNode RED، مع الاعتماد على لغة البرمجة بايثون لتنفيذه.

الكلمات المفتاحية: الذكاء الاصطناعي، التصنيف، الطوارئ، Node-RED، الترتيب بالأولويات.

Title: Smart System for Patient Identification, Triage, and Prioritization in Medical Emergencies

Abstract: This project aims to develop an intelligent system for classifying patients and determining their priorities in emergency departments. Our project relies on advanced artificial intelligence algorithms, where patients are classified based on a datasetcontaining different indicators for each patient. Finally, we determine the level of severity of his or her health condition. This system is developed in the Node RED visual programming environment using the Python programming for the implementation.

Keywords : Artificial Intelligence, Classification, Emergency, Node-RED, Prioritization.

Titre : Système intelligent d'identification, de triage et de hiérarchisation des patients en cas d'urgence médicale

Résumé – Ce projet vise à développer un système intelligent permettant de classer les patients et de déterminer leurs priorités aux urgences. Notre projet s'appuie sur des algorithmes avancés d'intelligence artificielle, où les patients sont classés sur la base d'une base de données contenant différents indicateurs pour chaque patient. Enfin, nous déterminons le niveau de gravité de son état de santé. Ce système est développé dans l'environnement de programmation visuelle Node RED, en utilisant le langage de programmation Python pour l'implémentation.

Mots-clés : Classification, Intelligence artificielle, Priorisation, Node-RED, Urgence.

Table of Contents

Abstract……/

List of figures ……/

List of tables…… /

List of abbreviation……/

General introduction *1*

Chapter I: Emergency department **2**

I.1 Introduction 2

I.2 Different conditions that occur in the ED 2

I.3 Vital Signs 3

I.3.a ECG *3*

I.3.b Blood oxygen saturation *6*

I.3.c Blood pressure (BP) *7*

I.3.d Temperature *8*

I.4 Clinical indicators 9

I.4.a Loc (Loss of Consciousness) *10*

I.4.b Rest *10*

I.4.c Chest Pain *11*

I.4.d Shortness of Breath *11*

I.4.e Palpitations *12*

I.5 Patient Identification 12

I.6 Prioritizing patients 13

I.7 Triage 14

I.8 State of the art 15

I.9 Conclusion 17

Chapter II: Hardware and software tools **18**

II.1 Introduction 18

II.2 Artificial Intelligence 18

II.2.a Machine learning *18*

II.2.b Deep learning *22*

II.2.c Difference between ML and DL *22*

II.3 Positive impact of AI on society and healthcare 23

II.4 Developing AI in Python and other languages 24

II.5 AI ML methods 25

II.5.a Random Forest *25*

II.5.b Logistic Regression *29*

II.5.c Artificial Neural Networks *32*
II.5.d Support Vector Machine (SVM) *37*
II.6 Comparison of RF, ANN, LR, and SVM 40
II.7 Performance measures of the four models 41
II.8 Development tool (Node-RED) 42
II.8.a What is Node-RED *42*
II.8.b Editor Node-Red *43*
II.8.c Advantages of Node-RED *43*
II.8.d Uses of Node Red *44*
II.9 Conclusion 44
Chapter III: Deploying the Smart Prioritization System 45
III.1 Introduction 45
III.2 Specifications 45
III.3 Classification based on AI 49
III.3.a Algorithms Summary *49*
III.3.b ANN model *51*
III.3.c SVM *54*
III.3.d LR Classifier *57*
III.3.e RF classifier *59*
III.3.f Comparison between the four classifiers *61*
III.4 Node-RED 63
III.4.a Supervision interface *63*
III.4.b Starting the Node-red *63*
III.4.c Programming with Node-Red *65*
III.5 Test 66
III.6 Conclusion 70
General conclusion 70
References 71

List of figures

Number	Title of the figure	The page
I.1	Electrocardiogram Wave	**4**
I.2	Oxygen saturation meter	**6**
I.3	Range of SPO2	**7**
I.4	Blood pressure measurement	**7**
I.5	Five main blood pressure ranges	**8**
I.6	Body Temperature Conditions	**9**
I.7	Some clinical indications	**12**
II.1	AI Architecture	**18**
II.2	Types of Machine Learning	**19**
II.3	Types of Supervised Learning	**20**
II.4	Types of Unsupervised Learning	**21**
II.5	Bagging and boosting	**26**
II.6	Example of a Rondam forest	**28**
II.7	Type of logistic Regression	**29**
II.8	Example of a logistic regression	**32**
II.9	Artificial neural networks Layer	**35**
II.10	Example of an ANN	**37**
II.11	Support Vector Machines	**38**
II.12	Example of a SVM	**39**
II.13	Confusion matrix	**41**
II.14	Editor Node red	**43**
III.1	Scheme of the Specification	**45**
III.2	Flowchart of four algorithms	**50**
III.3	Load the Excel file	**51**
III.4	Model extract features and target variable	**51**
III.5	Split the data into training and testing sets	**51**
III.6	Creating the neural network model	**51**
III.7	Model is clustered	**52**
III.8	Model performance is evaluated	**52**
III.9	ANN confusion matrix 1	**53**
III.10	ANN confusion matrix 2	**53**
III.11	ANN confusion matrix 3	**54**
III.12	SVM model is built using a linear kernel	**54**
III.13	Train the model using the training data	**54**
III.14	Confusion Matrix	**55**
III.15	SVM confusion matrix 1	**56**
III.16	SVM Confusion matrix 2	**56**
III.17	SVM Confusion matrix 3	**56**
III.18	Data is scaled	**56**
III.19	Grid search is then configured	**57**
III.20	LR confusion matrix **1**	**58**
III.21	LR Confusion matrix **2**	**58**

III.22	LR Confusion matrix **3**	**58**
III.23	Initialize the Random Forest classifier	**58**
III.24	Initialize the RF classifier with the best parameters	**59**
III.25	RF confusion matrix 1	**60**
III.26	RF confusion matrix 2	**60**
III.27	RF confusion matrix 3	**60**
III.28	Confusion matrix for the four classifiers	**61**
III.29	Accuracy	**62**
III.30	Time classification	**62**
III.31	Running Node-Red	**63**
III.32	Programming environment Node-Red	**64**
III.33	Install Nodes	**64**
III.34	System Flow the Node-Red	**65**
III.35	Node data	**65**
III.36	Node in python	**66**
III.37	Patient Data Integration and Classification Flow	**66**
III.38	Test patient 1	**67**
III.39	Test patient 2	**67**
III.40	Test patient 3	**67**
III.41	Test patient 4	**67**
III.42	Test patient 5	**68**

List of tables

Number	Title of the table	The page
I.1	ECG Waves	**4**
I.2	ECG Intervals	**5**
I.3	State normal and abnormal heartbeats	**6**
I.4	State normal and abnormal Oxygen	**6**
II.1	Difference ML and DL	**22**
II.2	Comparison of RF, ANN, LR, and SVM	**40**
III.1	Extract of Dataset	**46**
III.2	Example from the database	**48**
III.3	Test results for female teachers ANN	**53**
III.4	Test results for female teachers SVM	**55**
III.5	Test results for female teachers LR	**57**
III.6	Test results for female teachers RF	**59**
III.7	Patient classifications	**68**

List of abbreviation

Symbol	Significations
ANN	Artificial neural networks
AI	Artificial Intelligent
BH	Hemoglobin high
BL	Hemoglobin law
ChP	Chest Pain
CI	Clinical indicators
CM	Confusion Matrix
DL	Deep Learning
ECG	Electrocardiogram
ED	Emergency Department
loc	Loss of Consciousness
LR	Logistic Regression
ML	Machine Learning
Palp	Palpitations
RF	Random Forest
ShBr	Shortness of Breath
SPO2	Blood Oxygen Saturation
SVM	Support Vector Machines
VS	Vital Signs

General introduction

General introduction

The imperative to enhance healthcare systems, particularly in hospitals and emergency departments, is indisputable, especially in the wake of recent crises such as the coronavirus pandemic and the earthquake in Turkey. A minimal difference in service or wait times within healthcare systems can significantly impact patient outcomes, often determining the line between life and death. This raises a critical question: Is triaging patients in an emergency department based on the order of arrival truly effective? Even though triage nurses may expedite treatment for patients in critical condition upon arrival, this method alone is insufficient.

Extensive research in emergency department patient triage has explored the use of artificial intelligence (AI) and big data analytics. This body of work has concentrated on developing classification models to identify and categorize emergency cases by urgency, thus allowing medical teams to prioritize and allocate resources more effectively. AI technologies analyze clinical data to quickly provide accurate diagnoses and effective treatments. Some studies emphasize guiding emergency treatments, while others aim to improve chronic disease management and enhance patient experience by reducing waiting times and elevating the quality of care[1].

Given these advancements, the possibility of creating a smart system that can efficiently sort, classify, and prioritize patients in the emergency department to alleviate the burden on medical staff and ensure swift, precise classification becomes apparent.

Our objective is to develop such a smart system, leveraging a comprehensive dataset of vital and clinical indicators (CI) to assess patients' conditions rapidly and accurately. Effective triage in the emergency department relies on specific methodologies to prioritize care. We utilized various AI algorithm, implemented using the Python programming language, along with the IBM Node-RED platform for Human-Machine Interface (HMI) setup.

This thesis is organized into three chapters. The first chapter provides an overview of the emergency department. The second chapter discusses the software and technical solutions employed. The third chapter details our developed system. Finally, we conclude with general insights and future perspectives.

Chapter I
Emergency department

Chapter I: Emergency department

I.1 Introduction

The hospital's Emergency Department (ED) is a vital center dedicated to providing immediate and essential care to patients facing medical emergencies or acute medical conditions. It serves as the front line for a variety of emergencies. The primary function of the ED is to provide immediate patient care and make initial assessments of the patient's condition. This is done by determining the severity of the condition and taking the necessary actions to help stabilize the patient's condition.

The hospital has a specialized team of doctors and nurses who work tirelessly 24/7 to meet emergency medical needs. It is important that the emergency department is well-equipped with medical equipment and modern technology to ensure effective care. Dealing with emergencies in an organized and efficient manner requires organizing staff and prioritizing by severity.

It also involves directing patients to different medical departments in the hospital based on their medical needs after their emergency is stabilized. In general, the emergency department plays a vital role in the healthcare system, as it contributes to saving lives and providing the necessary care for patients in times of urgent need.

This chapter shows the most important indicators that are taken into account to evaluate patients, and what actions are taken after determining the patient's condition in the emergency department. Some existing solutions are also presented, compared to our contribution in this project.

I.2 Different conditions that occur in the ED

The emergencies that people may face vary depending on the circumstances and situations, and involve several aspects of physical and mental health. Here are some common conditions that can require medical intervention in the emergency department [2]

- **Injuries and fractures:** Car accidents, falls, sports injuries, and work accidents may cause fractures or injuries that require immediate care.
- **Cardiovascular diseases:** Chest pain, symptoms of cardiac arrest, and high blood pressure can be emergencies that require immediate evaluation.
- **Respiratory issues:** such as severe asthma, gas poisoning, and acute shortness

of breath.

- **Surgical emergencies:** such as an inflamed appendix, infections, and brain tumours.
- **Poisoning and burns:** Food or chemical poisoning, and major burns can be emergencies.
- **Psychiatric conditions:** such as hallucinations, suicide, and emotional outbursts.
- **Pregnant women's conditions**: Problems during pregnancy such as bleeding or strong contractions.
- **Ophthalmological conditions:** Eye injuries, acute vision loss, and ocular pain.
- **Diabetic emergencies:** such as high or low blood sugar.
- **Aggression and weapon injuries:** Shooting incidents or injuries with firearms.

These are just a few examples, and emergencies can vary depending on individual circumstances and the person's medical environment. It is essential to act quickly and effectively to provide the necessary care in such cases.

The two main functions of the ED, needed to identify the patient's condition, will be explored: Measured and unmeasured health indicators (vital signs and CI), and the identification of that patient between medical records.

I.3 Vital Signs

Vital signs (VS)are measurements that reflect the health status and vital functions of the body, these indicators are measured in the ED to assess the severity of the condition and make quick decisions about necessary care. Here are some key VS[3].

I.3.a ECG

ECG is an electrical signal that reflects the activity of the heart over a specific time and is analyzed by doctors specialized in this field to assess the electrical activity of the heart and diagnose any possible disorders to guide treatment and make the necessary medical decisions [4].

The electrocardiogram (ECG) is made up of a series of waves, and each wave is assigned a letter of the alphabet (**Figure I.1**). On this basis, the sequence of waves representing a single cardiac cycle is labeled sequentially as follows: P, Q, R, S, T and U, each wave is explained in a table **(Table I.1).**

During ECG analysis, the temporal Relationship between different Waves is estimated by measuring the distances between them on the time axis. These temporal distances are called ECG intervals. These intervals provide important information about heart activity and function**.** Each interval is explained in **Table I.2.**

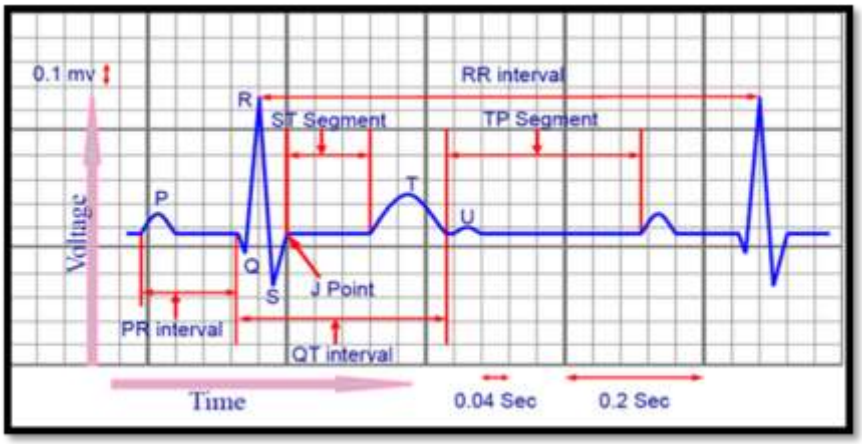


Figure I.1: Electrocardiogram Wave [5]

Table I.1: ECG Waves [3]

Name of Waves	Representation
P wave	This wave represents the depolarization of the atria from the sinoatrial node to the atrioventricular node. It can be positive or negative and has a duration of approximately 90 milliseconds. It usually precedes the QRS complex, but is often difficult to observe on the ECG, especially in noisy conditions.
QRS complex	Represents the ventricular depolarization that precedes the mechanical effect of contraction. It has the largest amplitude on the ECG and consists of three consecutive waves following the P wave: An initial Q wave with negative polarity, a positive R wave in the normal ECG, and finally a negative S wave. The normal duration of the QRS complex is between 85 and 95 milliseconds.
T wave	This wave reflects the repolarization of the ventricles. It can be positive, negative, or biphasic. In general, the wave follows the complex QRS and retraces to an isopolarized line (except in certain pathological conditions). Its amplitude is less than that of the complex QRS complex [6].
U wave	Represents the complete termination of the heartbeat and is often invisible on an ECG. However, sometimes, the U wave may appear as a small secondary wave after the T wave. If the U wave is noticeable, it may be a sign of hypokalemia or hypercalcemia. High calcium may lead to an increased risk of kidney stones and weak bones.

Table I.2: ECG Intervals[3]

Name of interval	Representation
PR interval	The PR interval, which lasts between 0.14 and 0.2 seconds, is measured between the beginning of the P wave and the beginning of the QRS complex and represents the time interval between atrial and atrioventricular node depolarization. This delay represents the time it takes for the electrical impulse to propagate from the sinus node to the ventricles. It is used to detect arrhythmias and assess heart rate variability. The PR interval, which lasts between 0.14 and 0.2 seconds, is measured between the beginning of the P wave and the beginning of the QRS complex and represents the time interval between atrial and atrioventricular node depolarization. This delay represents the time it takes for the electrical impulse to propagate from the sinus node to the ventricles. It is used to detect arrhythmias and assess heart rate variability.
ST segment	Also known as the duration of full ventricular impulse, this segment corresponds to the period of time during which the ventricles remain in active depolarization. It is defined as the time between the end of the S wave and the beginning of the T wave
PQ interval	The time interval between the onset of atrial depolarization and the onset of ventricular depolarization. This time reflects the propagation of the electrical impulse from the sinus node to the ventricles The PQ interval is measured from the beginning of the P wave to the beginning of the QRS complex.
QT interval	This interval represents the duration of ventricular contraction, the time from the beginning of ventricular excitation to the end of ventricular relaxation. It is calculated from the beginning of the QRS complex to the end of the T wave.

- **Comparison of normal and abnormal heartbeats**.

In Table I.3., a comparison is made between normal and abnormal heartbeats, focusing on the differences in speed, pattern and strength, highlighting the common patterns of each type and their impact on heart health[6].

Table I.3: State normal and abnormal heartbeats

Normal heartbeat	Dangerous heartbeats
• Moderate speed, pattern and strength. • The pulse rate is usually between 60 to 100 beats per minute. • The pulse is regular and coordinated, with regular intervals between each beat. • Normal pulse strength is moderate to strong	• Can vary greatly in speed, pattern, and strength. • This includes fast or slow, irregular, and irregular heartbeats. • Heartbeats can be sudden and unexplained, indicating heart issues that require immediate medical attention. • Excessively strong or very weak heartbeats can indicate serious health conditions such as shock or heart failure

I.3.b Blood oxygen saturation

The oxygen saturation index (SpO_2) is a measure of the amount of saturated oxygen in the blood, expressed as a percentage. It reflects the ability of the hemoglobin in the blood to absorb oxygen and transport it to the body's tissues[7]. Most devices measure this indicator in the finger or earlobe as shown in **Figure I.2.**



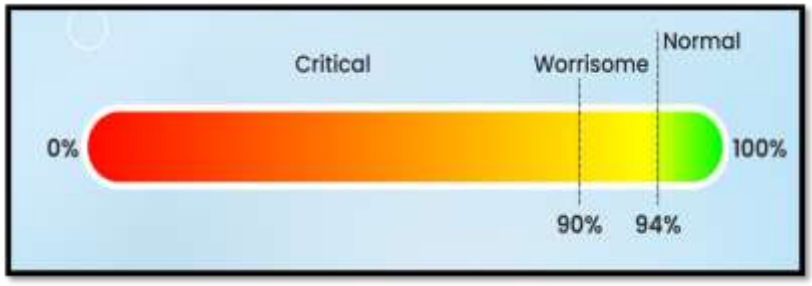
Figure I .2: Oxygen saturation meter [8]

The differences between normal and critical oxygen saturation are explained by **Table I.4**

Table I.4. State normal and abnormal Oxygen[7]

Normal	Critical
• A normal SpO2 level is between 95% and 100%. • In this range, oxygen saturation is considered good and shows that the blood is carrying sufficient amounts of oxygen to the tissues.	• A sharp drop in SpO2 level may indicate breathing or circulation issues. • SpO2 levels below 90% are considered abnormal and require immediate attention.

When the oxygen saturation level is low, it is usually a sign of interference with oxygen transport in the body and may require immediate medical intervention. There are many reasons that can lead to a low SpO2 level, including breathing issues, heart disease, or even high altitude in mountainous areas, as shown in the following (**FigreI.3**).



FigureI.3: Range of SPO2 [8]

I.3.c Blood pressure (BP)

Blood pressure is measuring the force exerted by blood on the walls of arteries during a heartbeat, recorded in millimeters of mercury (mmHg). It includes two values: systolic and diastolic pressure. A typical reading is shown as a fraction, such as 120/80 mmHg, where 120 represents the systolic pressure and 80 represents the diastolic pressure. Systolic pressure, the higher number, indicates the pressure in the arteries when the heart contracts to pump blood, while diastolic pressure, the lower number, shows the pressure when the heart is at rest between beats. An inflatable cuff is used to measure blood pressure by wrapping it around the arm and inflating it to record the reading through an automated process[9](**Figure I.4.)**.

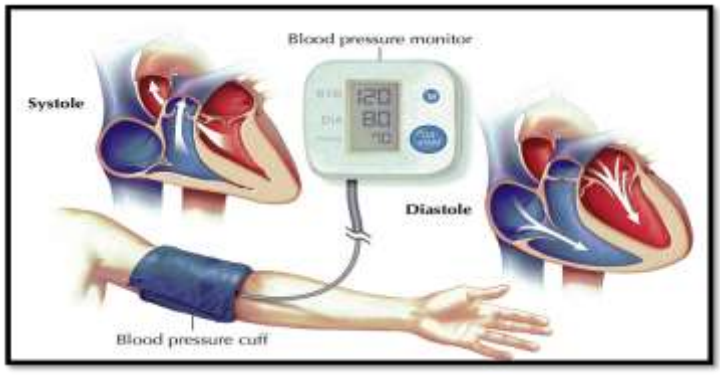


Figure I.4: Blood pressure measurement [10]

- **Systolic Pressure:**

Systolic pressure is the peak arterial pressure during heart contraction when the left ventricle pumps blood into the arteries. It is the upper value in a blood pressure reading.

Normal: Between 90 to 120 mm Hg.

Serious condition: A systolic pressure over 180 mm Hg requires immediate medical attention.

- **Diastolic Pressure:**

Diastolic pressure is the lowest arterial pressure between heartbeats when the heart is resting and filling with blood. It is the lower value in a blood pressure reading.

Normal: Between 60 to 80 mm Hg.

Serious condition: A diastolic pressure over 120 mm Hg requires immediate medical attention.

An ideal blood pressure reading is generally 120/80 mm Hg. Deviations from this, either high or low, can signal health problems that need medical evaluation and treatment. Blood pressure spans various ranges, as depicted in **Figure I.5.**

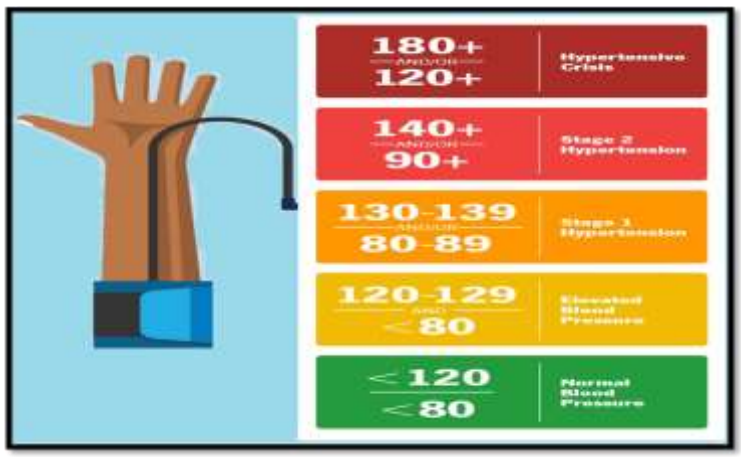


Figure I.5: Five main blood pressure ranges[11]

I.3.d Temperature

Body temperature is usually measured using a thermometer (such as the temperature of your mouth, armpit, or ear) or using electronic devices such as a digital thermometer, and is usually expressed in units of degrees Celsius (°C) or Fahrenheit (°F). It is important to monitor your body temperature and respond if it is unusually high or low as shown in **Figure I.6**, especially if you have serious illnesses or medical conditions [12] .

- **Normal state**

The average body temperature in adults is usually between 36.5 and 37.5 degrees Celsius (97.7 - 99.5 Fahrenheit). Exact values can be slightly variable depending on the method of measurement and time of day.

- **Dangerous temperatures**

This depends on the health context and individual factors. In general, body temperature of 38°C (100.4°F) or higher in adults is usually considered a sign of fever. If your body temperature reaches levels above 39°C (102.2°F), this may be a high fever and requires immediate medical attention.

For children, dangerous temperatures may be slightly different. Generally, a body temperature of 38 C (100.4 F) or higher in children is usually considered a sign of fever. High temperatures in children should be carefully monitored and talk to a doctor if they persist for a long time or are accompanied by other symptoms.

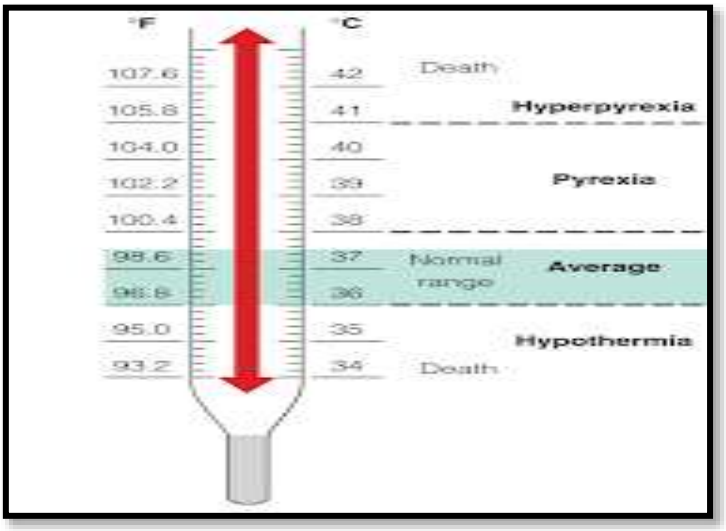


Figure I.6: Body Temperature Conditions[13]

I.4 Clinical indicators

In addition to VS, clinical signs (non-measured) are also used in the emergency room to assess the patient's condition and make quick decisions about treatment. Some common clinical signs are shown in **Figure I .7**

I.4.a Loc (Loss of Consciousness)

A blackout or temporary loss of consciousness is a condition characterized by a person losing consciousness for a temporary period of time, and is a medical condition that needs immediate attention. The causes of loss of consciousness can be varied and include:

- **Lack of blood flow to the brain:** Loss of consciousness can be the result of
- severely low blood pressure, which reduces blood flow to the brain.
- **Temporary circulatory arrest:** A disorder in the cardiovascular system can cause a temporary cessation of blood flow to the brain.
- **Low blood sugar (diabetes):** Low blood sugar to alarming levels can cause loss of consciousness.
- **Cardiac or respiratory infection:** Some acute illnesses such as carditis or bronchitis may lead to loss of consciousness.
- **Epilepsy:** Epileptic seizures can cause temporary loss of consciousness.

Cases of loss of consciousness need prompt and appropriate evaluation to determine the possible cause and provide the necessary medical attention. In emergencies, medical attention can include providing oxygen, identifying and fixing any blood pressure or diabetes disorders, and providing appropriate treatment for other diseases that may cause loss of consciousness.

I.4.b Rest

In the emergency department, when the term "comfort" is mentioned, it is associated with providing immediate and necessary medical care to patients with emergency conditions. Providing comfort is an important part of treatment in this context and includes several aspects, including:

Physical rest: The patient is given the opportunity to rest and relax by providing a quiet and comfortable environment. A comfortable bed may be provided, as well as assistance in finding a comfortable resting position.

Psychological comfort: The patient is given emotional and moral support through supportive words and a sense of security and confidence in the medical care they are receiving.

Relief from additional symptoms: Comfort may play a role in alleviating symptoms associated with a medical emergency, such as pain, nausea, headache, and fatigue.

Rest is an essential part of the treatment strategy in the emergency department, aiming to provide the necessary support for the patient to optimize their condition and aid in recovery.

I.4.c Chest Pain

Chest pain regardless of severity, may indicate a new health issue. This pain may radiate to other areas such as the arms, neck, or jaw. The pain varies from sharp to dull, and may be accompanied by a feeling of tightness or pressure. The pain can last for a short or long time and may increase during activity or decrease during rest. It is advisable to seek medical help immediately if a heart attack or other serious health issue is suspected. [14]

Causes of chest pain include:

- Problem with your lack of blood in your heart.
- lung disease.
- sudden feeling of fear.

I.4.d Shortness of Breath

The term "ShBr" stands for "shortness of breath" and is used in a medical context to describe a condition in which it is difficult for a person to breathe normally or feel unable to get enough air. Shortness of breath is a common symptom of many medical conditions and can be from various sources,[15] including:

- Respiratory issues.
- Heart conditions.
- Upper respiratory infections.
- vascular diseases.
- Gastrointestinal diseases.
- Psychiatric illnesses.

Shortness of breath is a medical symptom that requires immediate medical evaluation, especially if it is accompanied by other symptoms such as chest pain, nausea, or dizziness. A person experiencing difficulty breathing should seek immediate medical attention to determine the cause of the condition and take the necessary actions.

I.4.e Palpitations

Heart palpitations is a feeling as if your heart is beating irregularly, racing or pounding, and may be felt in areas such as the chest, throat or neck. Heart palpitations can occur at any time, even while resting or doing normal daily activities. Although it can be sudden, it's usually not dangerous or harmful. However, in some cases, it may be associated with a heart rhythm.

disorder that requires medical attention. It affects more women than men and can affect anyone regardless of gender. Symptoms may appear at different stages of life such as during adolescence or during pregnancy. [16]

Causes of heart palpitations:

- Fever.
- Anemia.
- Emotions, such as anxiety, stress, fear, and panic.
- Low levels of sugar, or oxygen.
- Alcohol.

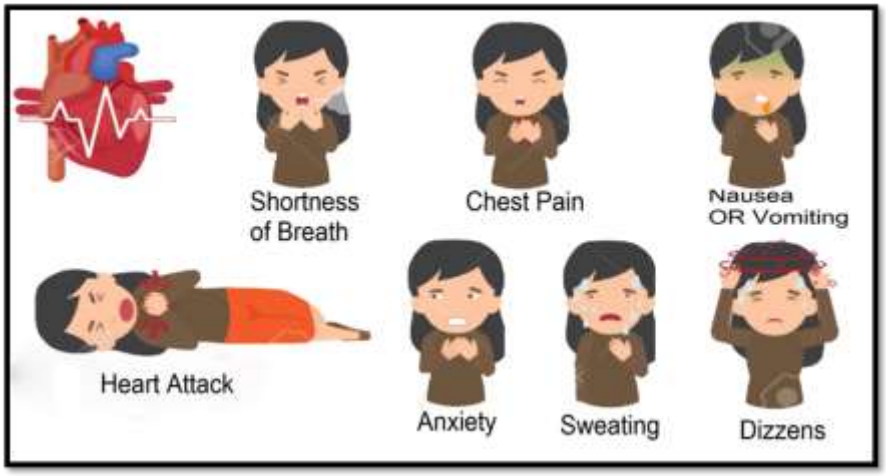


Figure I .7: Some clinical indications[17]

I.5 Patient Identification

Patient identification is the process of confirming the true identity of each patient who is dealt with in medical services. The ECRI PSO Institute has come up with multiple strategies to correctly identify a patient using technology and involving the patient and family members, and encouraged the adoption of this report's recommendations for all healthcare organizations to provide safe patient care [18]. Some of the common methods used for patient identification throughout the year

include:

- **Presentation of official documents:** Official identities such as a national ID, passport, or government-issued ID card are used to identify the patient.
- **Name and date of birth identification:** Identification using the patient's name and date of birth is used as the primary means of identity verification.
- **Biometric Fingerprint:** Fingerprint technologies are used for patient identification, where a fingerprint is recorded and compared with stored data to confirm the identity.
- **Facial Recognition:** Facial recognition can be used to identify a patient by taking a picture of their face and comparing it with the images stored in the database.
- **Unique national number:** In some countries, the unique national number assigned to each citizen is used as a means of patient identification in health services.
- **Smart card identification:** Smart cards such as electronic health cards can be used to identify the patient and save time in entering information.

These methods are widely used in various countries to ensure accurate and secure patient identification, facilitating the delivery of necessary medical care and improving the patient experience.

I.6 Prioritizing patients

In the emergency department, prioritization is vital to ensure effective and efficient healthcare delivery. Prioritization in this context means identifying cases that require immediate medical care and arranging treatment based on the severity of the medical emergency and the patient's condition[19]. The prioritization process depends on several factors, including:

- **Assessment of the medical condition:** The patient's condition is carefully assessed to determine the degree of emergency, based on symptoms and VS such as blood pressure, heart rate, breathing and consciousness
- **Determine the severity of:** The patient's condition based on the medical assessment and the use of any specific emergency management assessment tools such as the NEWS triage algorithm or others.
- **Past medical factors:** Patients past medical history is considered, including chronic diseases, previous surgeries, and prescribed medications.

- **General health status:** General health status is considered, as certain conditions or medical syndromes can affect prioritization.
- **Available resources:** The department's ability to provide the necessary care, including available physicians, nurses, medical equipment, and medical beds.
- **Documentation and communication:** Ensure that decisions made regarding patient prioritization are documented and communicated effectively with medical teams, patients and their relatives.

The prioritization process aims to direct patients to care based on their medical condition and available safeguards, contributing to effective treatment and optimal treatment outcomes. Patients should be continuously monitored and priorities should be reassessed if their health status changes or additional information becomes available.

I.7 Triage

In the past, ED triage relied mainly on quick assessments and clinical evaluation by doctors and nurses. Traditional methods of triage involved relying on direct symptoms and information provided by the patient, as well as simple tests such as blood pressure and heart rate. It also relied on the judgment of medical staff in identifying emergencies and prioritizing treatment.

In comparison, nowadays, the triage process has been greatly improved with advances in technology and medical science. Sophisticated information systems and optical analysis techniques are used to accelerate and optimize the assessment and triage process. In addition, comprehensive assessment methods are used to more accurately assess a patient's condition, allowing for more effective prioritization.

Artificial intelligence and machine learning ML techniques have been implemented in some systems to further analyze medical data, enabling them to make accurate recommendations for emergency identification and prioritization. Modern triage also relies on recognized scientific criteria and standardized metrics to assess cases and determine the degree of emergency, increasing the accuracy and efficiency of the process [20]

There are several models used for the triage process in the emergency department, of which there are four main ones:

- **Manchester Triage System:** This is one of the most popular models used cases according to five levels of emergency: Red Emergency (urgent), Orange Emergency (urgent), Yellow Emergency (delayed), Green Emergency (non-urgent), and Blue Emergency (nonurgent) [21].
- **Emergency Severity Index (ESI):** The ESI is a common tool used to assess the degree of emergency for patients in the emergency department. The model is based on categorizing cases into five levels, assessing symptoms, health status, and the patient's need for immediate treatment [22].
- **Canadian Triage and Acuity Scale (CTAS):** The CTAS is commonly used in Canada to assess patients in the emergency department. It is based on categorizing cases into five levels according to a set of criteria that includes symptoms, medical history, and environmental factors [23]
- **Sunderland Triage Model:** This model is based on categorizing cases into three main levels: Emergency, Urgent, and Non-Emergency. Cases are assessed based on symptoms, VS , and patient history [24].

These models are used to determine the degree of urgency of each case and appropriately direct care accordingly. It also helps to effectively direct resources and optimize the patient experience in the emergency department[20].

I.8 State of the art

In recent years, the world has witnessed a number of developments in the field of health, especially in the emergency department, as artificial intelligence has played a key role in these changes. Where international universities and centers competed globally to solve these changes, and among these universities and centers we mention:

- **United States of America**

which is an important center for most research, where Stanford University has developed a new model to accelerate clinical data science in hospitals, while Harvard University has developed innovative predictive models used to set priorities in health care[25], while the Massachusetts Institute of Technology (MIT) has witnessed great activity in developing artificial intelligence applications

in using ML techniques to prioritize and analyze big data[26]

These technologies help identify cases that need immediate medical care, thereby reducing waiting times and improving the effectiveness of treatment. In addition, AI can be used to better direct medical resources and prioritize healthcare delivery, improving the quality of care and increasing the effectiveness of the treatments provided.

- **China**

China has conducted several researches in several universities, including Tsinghua University, which has conducted several researches in the field of medical data analysis and artificial intelligence applications in health care delivery as well as patient triage in the ED Peking University[27], where this university has participated in several researches on the use of artificial intelligence in patient triage and emergency health care delivery, as well as identifying emergency cases more accurately[28].

The system analyzes data quickly and efficiently, allowing for the identification of cases that need immediate medical care such as critical or emergency cases. It can also identify individuals who can wait longer without jeopardizing their health, By using this system, ED management can be improved and medical resources can be directed more effectively, thus improving the quality of healthcare provided to patients in emergencies.

- **Europe**

Europe has recently witnessed a prominent activity in the field of research and development in various fields of medicine and health care, where the University of Oxford has conducted several studies on categorizing patients and directing them to emergency treatment[29], And a future study applies AI-based sorting [29].

The system relies on analyzing patients' medical records and personal data using AI techniques, allowing it to determine each patient's degree of emergency and prioritize treatment accurately and efficiently. Based on this categorization, patients are directed for immediate treatment or waiting according to their urgent need for treatment.

The system improves ED management, reduces waiting times and improves the patient experience, as well as helping to use medical resources more efficiently and direct them to cases that require immediate attention.

- Despite the various studies carried out by most universities and international centers, they still face several issues and obstacles to the implementation of these studies, including the following These studies require huge and significant costs, whether in terms of the cost of developing software and technologies or in terms of costs associated with improving infrastructure and training staff and others,and studies and applications in the field of health care may face legal and regulatory challenges, including compliance with privacy and health security standards and data protection laws, as well as the lack of patient data in some special cases, such as accidents and health crises and the possibility of errors.

To address these challenges and potential obstacles, we have developed a smart system designed to efficiently sort patients using a datasetof clinical and vital indicators. This smart system categorizes patients' health status at various levels within the emergency department, ensuring privacy is maintained. Additionally, the system is cost-effective and easy to implement, requiring minimal effort to integrate into existing workflows.

I.9 Conclusion

In this chapter, an in-depth exploration of the ED and the variety of cases it handles was provided. Key vital and CI considered in patient treatment were discussed, emphasizing that patient identification, triage, and prioritization are crucial aspects of ED operations.

As the volume of patients and injuries continues to rise, it is imperative that processes and programs within the ED are continually enhanced. Such improvements are essential to ensure better emergency medical response capabilities and improved patient care outcomes in the future. By integrating advanced technologies and refining existing methodologies, these growing demands can be met more effectively.

Chapter II
Hardware and software tools

Chapter II: Hardware and software tools

II.1 Introduction

In this chapter, the focus will be on exploring some popular algorithms in data analysis, as well as presenting the theoretical and software solutions needed for the project. Additionally, guidance will be provided on utilizing the Node-RED platform, which has been integrated as an essential component of the project to effectively achieve the objectives.

II.2 Artificial Intelligence

Artificial Intelligence (AI) is a branch of computer science concerned with creating technological systems that behave in a way that resembles human intelligence.

It focuses on developing algorithms and models that enable computers to learn and make predictions or decisions based on data.

AI encompasses different techniques such as ML, DL, Natural language processing, neural networks, computer vision[30].

However, ML and DL will be covered in a simpler way, as they are both essential parts of AI as shown in the **Figure II.1**.

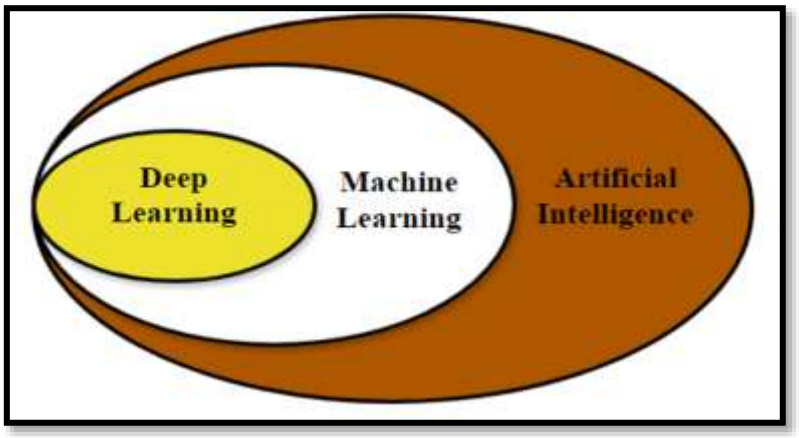


Figure II.1: AI Architecture

II.2.a Machine learning

ML is a basic branch of artificial intelligence and relies on the idea that systems can learn from patterns and recognize data automatically instead of relying on

fixed programming rules, as it aims to develop models capable of learning from data and making accurate decisions accordingly, enabling them to adapt to changes in data or changes in the environment, for the success of this process requires sufficient quality data, and provides several applications such as classification, prediction, analysis and others, where we rely on the use of effective algorithms and models. ML has contributed to the development of many fields to provide them with smart solutions that suit them[31].

ML is divided into several branches, including supervised learning, unsupervised learning, reinforcement learning and semi-supervised learning (**Figure II.2**).

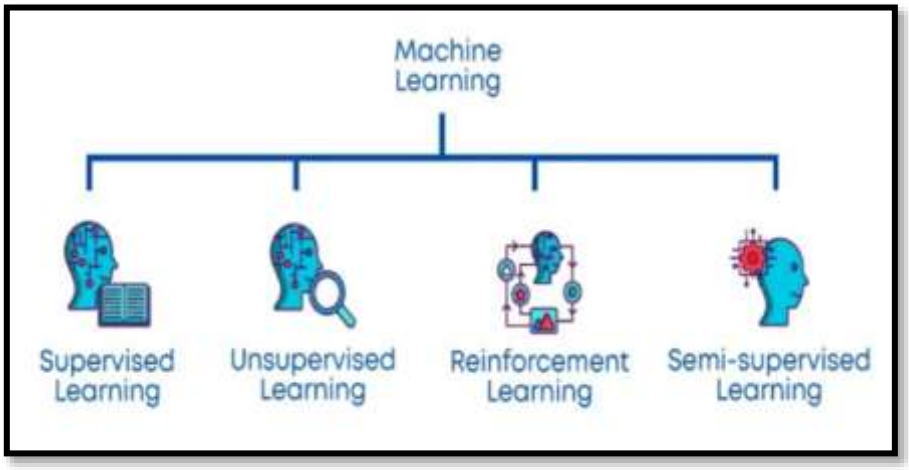


Figure II.2: Types of Machine Learning [30]

- **Supervised Learning**

In SL, algorithms are provided with a specific set of desired outcomes to learn from. This is typically done using a labelled dataset, which consists of paired inputs (X) and corresponding outputs (Y). Through training on this dataset, the algorithm discerns patterns between inputs and outputs. The dependent variable (Y), also known as the target, represents what the algorithm aims to predict or classify. The independent variables (X) are the features used to make these predictions. SL can be broadly classified into two main types based on the nature of the target variable (Y) (**Figure II.3**).

- **Classification:** This involves categorizing observations into distinct classes or categories. In classification tasks, the target variable (Y) is a categorical variable. For instance, it could involve classifying emails as spam or not spam, identifying whether a transaction is fraudulent or legitimate, or predicting whether a patient has a particular disease.
- **Regression:** is tasks focus on predicting continuous numerical values. Here, the target variable (Y) is continuous, and the goal is to estimate its value based on the input features. Examples of regression tasks include predicting house prices based on features like location, size, and amenities, forecasting sales figures based on historical data, or estimating the temperature based on weather variables**.**

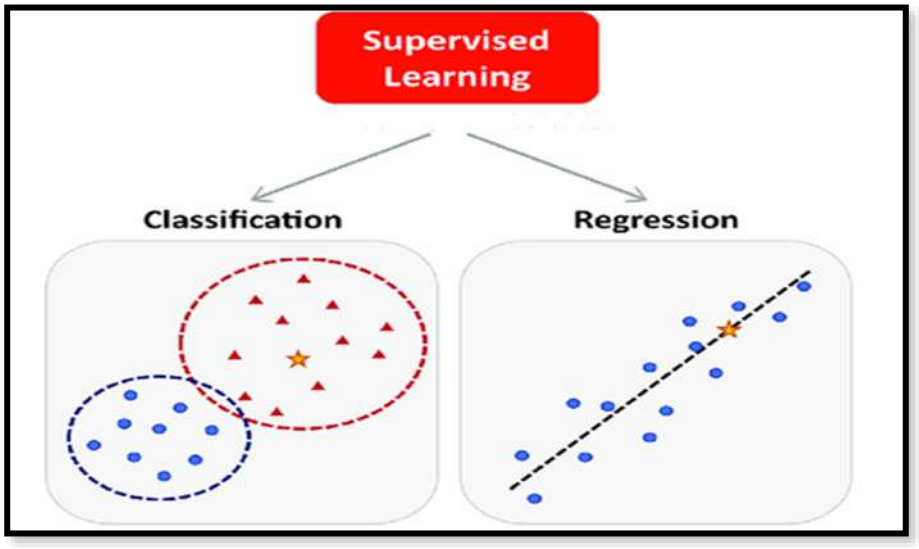


Figure II.3: Types of Supervised Learning[32]

Both classification and regression are fundamental concepts in supervised learning, each suited to different types of predictive tasks.

- **Unsupervised Learning**

In unsupervised learning, the model is trained on an unlabeled dataset, and the model has to discover patterns and structure in the data on its own. This includes tasks like clustering, where the model groups similar data points together. There are two main types of unsupervised learning as shown in **Figure II.4**.

- **Dimensionality reduction:** It aims to reduce the number of variables (features) in the data while maintaining the variance between observations. This helps to simplify the analysis and reduce redundant data that may lead to noise in the analysis.
- **Clustering**: It aims to group observations into *clusters* where the observations within each cluster are similar while being different from the other clusters. This is used to understand the internal structure of the data and the relationships between them.

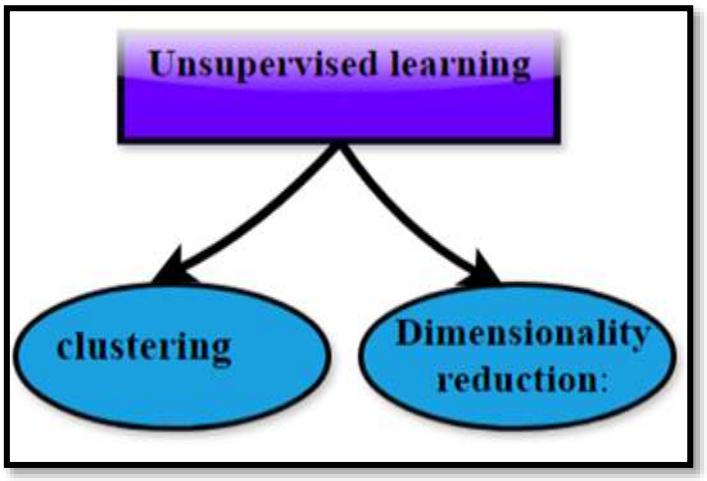


Figure II.4: Types of Unsupervised Learning

- **Semi-Supervised Learning**

Semi-supervised learning uses a small amount of labeled data and a large amount of unlabeled data to train the model. Its goal is to learn a function that can accurately predict the output variable based on the input variables, similar to supervised learning. However, the algorithm is trained on a dataset that contains both labeled and unlabeled data [31]

- **Reinforcement Learning**

Reinforcement learning aims to make decisions that maximize rewards in certain situations. Unlike supervised learning, a reinforcement agent learns from experience and the feedback it gets after each action. This method is used in automated systems that need to make continuous decisions without human

guidance, relying on algorithms that learn from the results of their actions to achieve the best results [33].

II.2.b Deep learning

DL is a branch of ML that draws inspiration from the structure and operations of the human brain, particularly artificial neural networks ANN. Its core objective is to enable computers to undertake tasks that humans naturally excel at. Through DL, computer systems can be trained to execute classification tasks across various data formats like images, text, and audio. Essentially, it entails emulating elements of human brain functioning to develop more effective and intuitive learning algorithms[30], [31], [34].

II.2.c Difference between ML and DL

The **table II.1** presents the major differences between the ML and the DL

Table II.1: Difference ML and DL [34]

Aspect	ML	DL
Data	Structured data.	Unstructured data
Training Data Size	Works better with smaller datasets	Works with big data for better performance.
Interpretability	Easier to interpret and explain results.	Complex models can be less interpretable.
Training Time	Faster training with smaller models.	Longer training due to deeper architectures.

As we have a structured and not really big data, ML is adopted in this project. In besides, it is best suited for creating learning models capable of handling a wide range of tasks and data.

II.3 Positive impact of AI on society and healthcare

AI is used to improve the quality of human life by reducing errors, increasing accuracy, and advancing diverse sectors such as health, education, marketing, climate science, drug discovery, and medical equipment. It also enhances efficiency, reduces waste, promotes innovation in various industries, contributes to economic growth and development, accelerates scientific research, improves data analysis and processing, and enriches our understanding of complex phenomena. These are just a few applications of how AI can improve our lives and the world around us[35].

AI has a prominent role in improving the quality of health care and has become able to develop care systems and improve the level of its services. For instance, AI is used to diagnose diseases by analyzing medical images, such as diagnosing skin diseases by analyzing skin images and identifying strange spots and others. It can also contribute to analyzing clinical data to direct the patient to treatment more accurately. Additionally, it is used to help monitor critical cases to predict them and contribute to making quick and accurate treatment decisions. It can also assist in categorizing patients in the emergency department, predicting their health condition, and determining the severity of their situation based on their vital and clinical data.

In these ways, AI contributes to improving health services, personalized healthcare, and improving patient outcomes to enhance their hospital experience[36].

On the other hand, the ED is the center of the hospital and the most important place that the health sector must pay attention to, as it has a prominent role in receiving patients in emergency and critical situations. In recent years, the world has witnessed an increase in research and studies related to the application of AI in this department. For example, a study published in “the Journal of Emergency Medicine in 2019[37] used a ML model to predict the readmission of patients to the hospital after receiving care in the ED. This study found that this model predicts with acceptable accuracy. Another study published in “the International Journal

of Medical Informatics in 2020"[38] focused on the automated patient triage system based on several ML algorithms and found that this system helps improve resource allocation and reduce the time required to receive patients. These studies reflect the developments that occur in the ED to be improved.

II.4 Developing AI in Python and other languages

The use of Python has become effective and popular today, but despite this, the door remains open to other programming languages Such as Java and C++, but the use of Python still has many benefits, as it provides powerful libraries that facilitate and help in building and training models, including "TensorFlow", "Keras", "PyTorch" and "Scikit-learn" In addition, the Python language is widely used in data analysis, prediction, intelligent analysis, and developing ML models using its libraries such as "Pandas", "NumPy" and "Matplotlib"

Although Python is an important choice in the field of AI, there are many other languages that can be successfully used to develop AI applications and projects, depending on the needs of the project and the developer's preferences[39], [40]. When a new patient is presented with data, the model determines whether the patient is at high or low risk of stroke based on the available clinical data. As represented in the following **Figure II.8.**

Python is known for its many powerful and diverse libraries that provide APIs for a variety of tasks and applications. Among the most popular libraries are:

- **NumPy:** A powerful library for scientific computing and digital data manipulation, allowing users to perform advanced mathematical operations and manipulate data efficiently.
- **Pandas:** Provides tools for analyzing data and working with data organized in tables (Data Frame), making it easy to clean, analyze, and explore data.
- **Matplotlib**: Used to draw graphs and charts, helping to visualize and understand data better.

- **Scikit-learn**: Provides a wide range of ML and statistical learning algorithms, making it easy to implement predictive models and evaluate their performance.
- **TensorFlow and PyTorch**: Libraries for ML and DL, providing tools for building and training artificial neural models.
- **Keras**: A high-level interface for building neural models using TensorFlow or Theano, which is easy to use and widely used in DL applications. These are just some of the popular libraries that can be used with Python, and there are many other libraries that provide various functionalities for many fields.
- **seaborn:** A library for plotting statistical data using Python [39], [41]

II.5 AI ML methods

Algorithms are the backbone of artificial intelligence and ML, used to analyze data, learn patterns, and make decisions based on available information. Algorithms vary according to the different purposes they serve, and each has advantages and disadvantages depending on the type of data and the issue to be solved. In this context, we will learn about four popular algorithms that are widely used in multiple fields: (RF), (LR), (ANN), and (SVM).

II.5.a Random Forest

- **Definition**

A RF is a ML model that creates a set of multiple decision trees that are trained on a subset of the dataset to arrive at a single, more accurate prediction or result.

Our dataset is divided into several randomly generated subsets of samples. We combine all the model results to get the final prediction that gives us the final result. In this way, we build a robust model from several not necessarily robust models.

One of the most important features of the RF algorithm is its ability to handle datasets that contain both continuous variables, as in the case of regression, and categorical variables, as in the case of classification. A combination of models is

used to make predictions rather than relying on a single model. The ensemble relies on two types of methods (**Figure II. 5**).

- **Bagging**: creates a heterogeneous training subset from the training data sample with replacement and the final output is based on a majority vote.
- **Boosting**: It merges weak learners into strong learners by creating sequential models so that the final model has the highest accuracy.[42]

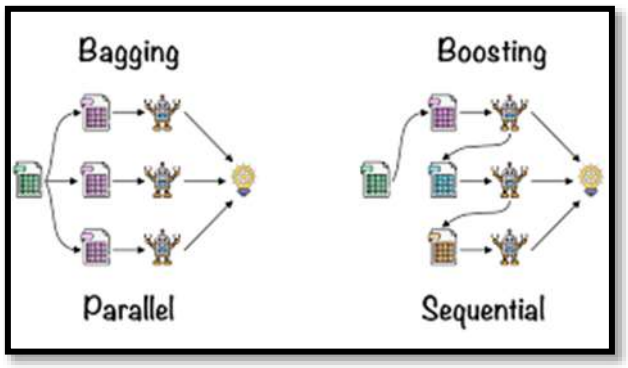


Figure II.5: Bagging and Boosting

- **RF training process**

RF setup involves splitting the information into training information and testing information, selecting random attributes, or a subset, from the entire dataset and setting up the subtrees using bootstrap testing (taken from the first information with replacement. Row sampling is the name given to this method). To increase diversity, choose random features for each tree to increase diversity. Each model is set up independently. The training generates results for each model. The final output is determined by combining the results for all models by performing a voting procedure and selecting the most predictable result among the models. The implementation is evaluated based on test data and measurements, such as accuracy and error rate.

- **Classification and prediction**

Classification and prediction systems are central to the RF approach. In classification, the model shapes information into clear categories, and in predictive

screening, the model is used to predict attributes with available values. For example, the model can be used to categorize patients and non-patients in light of health records, or to predict the price of a stock in the cash market in light of the stock's past supply and various factors. For each case, the model performs information processing, structured investigation, informed guidance, and implementation, working to understand the attributes and increase the accuracy of future predictions.

- **Features of RF**

It has many features that give it the ability to classify and predict effectively. These features include its robustness to diversity and variability, its ability to minimize noise and parallelism for speed making the whole process faster and more efficient to efficiently handle large databases, and efficiently display the effect of features. RF software is easy to use and understand, and the generated forests can be saved for future use on other data. This makes it a popular way to analyze data in a wide range of applications.

- **Optimizing RF performance**

RF performance is tuned in a variety of ways:

- Determining the appropriate number of trees and the depth of each tree .
- Normalizing excessive data to increase speed, as it affects the fit of trees and data, and detecting overlaps .
- Adapting to unbalanced data by using resampling to create a balanced dataset and using various criteria to boost performance and avoid bias.
- Employ feature engineering techniques to extract key information from the data and use feature engineering techniques to extract important information from the data and improve model assimilation.

- **Warnings and challenges for users of RF**

Delays in data processing because it calculates data for each decision tree separately and may cause over-reliance on random data. Bias and variability can

arise, as the model can be more complex or less complex than required, affecting the accuracy of the clustering. Moreover, it's really hard to know how the model follows the decisions between now and then, requiring additional work to analyze the results appropriately. Since RFs process larger datasets, they require more resources to store that information.

As a general rule, using random trees requires carefully setting their boundaries and successfully dealing with missing information and disturbances to achieve the best ranking and execution of predictions.[42], [43]

- **Example**

Develop a classification model based on patients' clinical data to determine the risk of heart attack. The data includes variables such as age, gender, VS, and medical history. The RF algorithm builds several different Decision Trees and combines their results by voting to determine the final classification. When a new patient is presented with data, the model categorizes the patient as either high or low risk for a heart attack based on the available clinical information. As represented in the following **Figure II.6.**

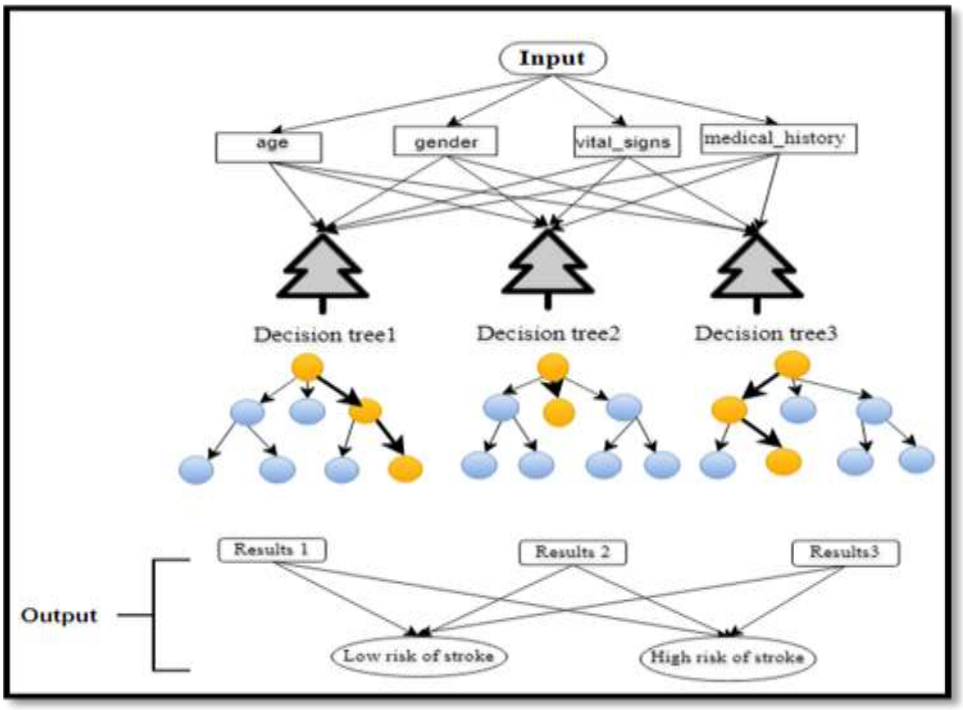


Figure II.6: Example of a Rondam forest

II.5.b Logistic Regression

LR is a statistical approach used to assess the existence of a relationship between a dependent variable and one or more independent variables. It is presented as a predictive model that allows predicting the outcome of the dependent variable based on two (A or B) or more independent variables and is more appropriate when dealing with binary data. Binary data means that the dependent variable is inherently dichotomous [44]There are three types of LR (**Figure II.7)**. Binary LR: Used to predict the association between two variables, where the dependent variable is inherently paired (1 or 0), meaning the outcome can be yes/no, pass/fail, and so on.

Multinomial LR: In this type, you have a categorical dependent variable with at least two unordered outcomes, meaning there is a possibility of two or more outcomes.

Ordinal LR : Indicates that the dependent variable has a significant order where the variable can be sorted into two or more categories, for example, compatible/partial/different or poor/great/moderate.

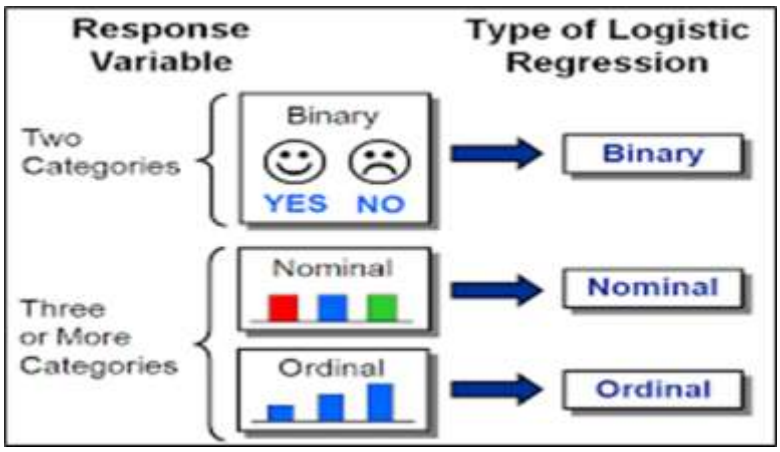


Figure II.7: Type of logistic Regression

- **LR Analysis**

The LR analysis process involves several important steps:

- **Data collection:** The analysis begins by collecting data that is relevant to the issue you want to solve. Data should be collected on the dependent variable

(the variable we want to predict, such as success/failure) and the independent variables (the factors we believe affect the dependent variable).

- **Cleaning the data:** After data is collected, it must be cleaned to ensure the accuracy of the analysis. This includes addressing missing data, checking for extreme deviations or abnormal values, and converting the data into the appropriate format for analysis.
- **Splitting the data:** After the data is cleaned, it is usually divided into two groups « a training set » and « a testing set ». The training set is used to develop the logistic model, while the test set is used to evaluate the performance of the model.
- **Building the model:** The data in the training set is used to build the logistic model. This involves identifying important independent variables, and implementing the model using LR.
- **Model evaluation:** After the model is built, its performance is evaluated using the test set. This involves using performance metrics such as accuracy, validity rate, and ROC curve to evaluate how well the model predicts data for which it has not been trained.
- **Analyze and interpret results:** Model results are analyzed and interpreted to understand the relationship between the independent variables and the dependent variable. The results can also be used to make decisions or guide policies.
- **Model refinement (selection of variables)**: If there is a need, improvements can be made to the model such as adding new variables or removing inefficient variables.[44], [45]

▪ **Applications of LR**

LR has become popular in many fields, used in medicine to identify risk factors for a patient's condition and predict serious and chronic diseases such as diabetes and cancer, helping medical professionals to make wise choices regarding patient care

and improving patient outcomes, in aerospace to predict the weather, in banking to predict the likelihood of a loan applicant defaulting on a loan, and in organizations to minimize expenses.

In weather forecasting, in banking to predict the likelihood of a loan applicant defaulting on a loan or not, and in organizations in minimizing expenses and losses in marketing, the model can be used to predict whether a target group of customers will buy a new product or not. It helps researchers make informed decisions based on statistical data collected through the analysis of medical information, knowledge of shopper behavior, probability assessment, predictions, and dissection of social information.

- **Challenges and issues**

  - LR should not be used if the number of observations is less than the number of attributes, as this will lead to overfitting.
  - It is difficult to obtain complex relationships in LR .
  - Difficulty in interpreting model results. It is best to improve data quality, improve logistic models, provide robust interpretations of results, and look for new ways to analyze data.
  - Data skew: The issue of data imbalance between different categories can be solved by using weighting techniques or adjusting performance measures.[46]

- **Example**

We use a LR algorithm to develop a classification model based on patients' clinical data to determine the risk of stroke. The data includes variables such as age, gender, VS, and medical history. The model learns the relationship between these variables and the likelihood of stroke. When a new patient is presented with data, the model determines whether the patient is at high or low risk of stroke based on the available clinical data. As represented in the following **Figure II.8.**



Figure II.8: Example of a logistic regression

II.5.c Artificial Neural Networks

▪ **Definition**

ANN contain artificial neurons called modules. These units are arranged in a series of layers that together make up the entire ANN in the system. A single layer can contain only dozens of units or millions of units, depending on the model and the patterns hidden in the data. Typically, an ANN has an input layer and an output layer as well as hidden layers. The input layer receives data from the outside world that the neural network needs to analyze or recognize. This data then passes through one or more hidden layers that convert the inputs into data of value to the output layer. Finally, the output layer provides an output in the form of the ANN's response to the input data[47].

▪ **Types of ANN**

- **Progressive neural network:** A PNN is one of the basic ANN. In this network, the data or inputs provided travel in one direction. It enters the ANN through the input layer and exits through the output layer while there may or may not be hidden layers.
- **Convolutional neural network:** A convolutional neural network has some similarities to a feed-forward neural network, and contains one or more convolutional layers that use a convolutional process on the input and then pass the result obtained in the form of output to the next layer.CNNs have

applications in speech and image processing and are particularly useful in computer vision.

- **A modular neural network:** A modular neural network contains a set of different neural networks that work independently to obtain outputs without any interaction between them. Each of the different neural networks performs a different subtask by having a unique input compared to the others. The advantage of this modular neural network is that it breaks down a large, complex calculation into smaller components, thereby reducing its complexity while still obtaining the desired output.
- **Radial basis function neural network**: Radial basis functions are those that take into account the distance between a point and the center. It consists of two layers. In the first layer, the inputs to all radial basis functions are set in the hidden layer and then the output layer calculates the output in the next step. They are commonly used to model data representing any trend or basis function.
- **Recurrent neural network:** A recurrent neural network memorizes the output of a layer and feeds that output back into the inputs to better predict the outcome of the layer. The first layer of a recurrent neural network is very similar to a feed-forward neural network, and the recurrent neural network begins once the output of the first layer has been computed. After this layer, each unit remembers some of the information from the previous step so that it can act as a memory cell in performing calculations[48].

▪ **Artificial neurons**

Artificial neurons, or "artificial nerves," are the basic building blocks of ANN. They represent an artificial resemblance to neurons in the human brain. Artificial neurons receive internal and external signals, process them, and send signals to other units within the network. The operation of artificial neurons depends on several elements, including weight, input, and transmitter function. When an artificial neuron receives signals from inputs, a net signal is calculated based on the weight associated with each input, and a transfer function is applied to this net signal. If the net signal exceeds a specific threshold, the neuron is activated and sends the signal to the other units in the network. Using this process, data is

represented and analyzed in ANN, and artificial neurons can learn and adapt to the data presented to them through a process of training and adjusting the weight and correlations between the units[49]

▪ **ANN Layers**

ANN consist of multiple layers As in the **Figure II.9**, which can be explained as follows:

- **Input Layer:**

  - This is the first layer of the network and receives the input data.

  - Each unit in this layer represents a variable in the input data.

- **Hidden Layers:**

  - Multi-layer ANN usually consists of hidden layers.

  - These layers process and transform the input data in a way that allows

  -The model to learn and acquire useful representations of the data.

- **Output Layer:**

  - This is the last layer in the network and generates the final results.

  - Each node in this layer represents a value from the output data associated

  With the issue to be solved.

As the complexity of the problem increases, so does the number of layers in the network. Each module, connected through adjustable links, responds to incoming signals based on its assigned weight and threshold. This organizational structure enables the network to acquire sophisticated representations of data and flexibly address diverse challenges[49], [50]

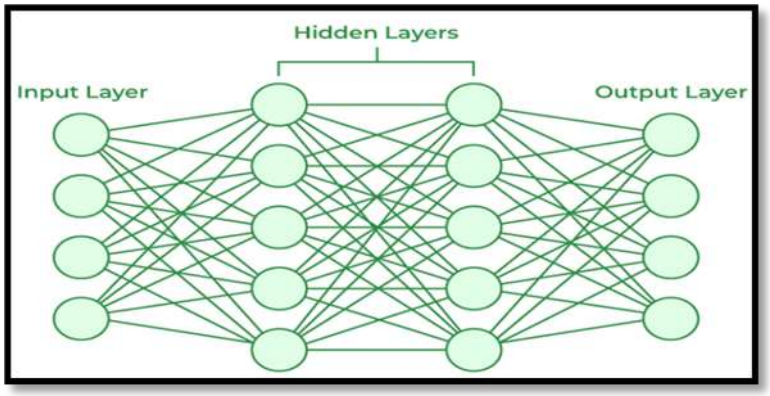


Figure II.9: Artificial neural networks Layer[51]

- **ANN training**

The process of training ANN requires leveraging data and selecting appropriate algorithms to modify the weight of associations between units within the network, and this process plays a crucial role in improving the quality and performance of the final model. The main steps include:

- ***Data preparation:*** The data is divided into training, validation, and test sets, and is balanced and varied.
- ***Determine the network structure:*** Choose an appropriate neural network structure, including the number of layers and units in each layer
- ***Training process:*** Feeding data to the network and optimizing the weight and correlations between units based on the differences between predicted and actual results.
- ***Verification and testing:*** Using a verification set to evaluate the performance of the model and a test set to evaluate its performance on new data.

The training phase greatly affects the quality of the final model, and if the network is well trained with balance[47].

- **Applications and areas of use of ANN**

ANN are heavily used in social media. For example, let's take Facebook's "People You May Know" feature which suggests people you may know in real life so you

can send them friend requests. Well, this magical effect is achieved using artificial neural networks that analyze your profile, your interests, your current friends and also their friends, and many other factors to calculate the people you are likely to know. Another popular application of ML in social media is facial recognition. This is done by finding about 100 reference points on a person's face and then matching them with those already available in the datasetusing convolutional neural networks [51]

Marketing and sales: When you log in to e-commerce sites like Amazon, they will recommend your products for purchase based on your previous browsing history. This uses ANN to determine a customer's likes, dislikes, past shopping history, etc. and then tailor marketing campaigns accordingly.

Healthcare: ANNs are used in oncology to train model that can recognize cancerous tissue at the microscopic level with the same accuracy as trained doctors. Many rare diseases may manifest in physical characteristics and can be recognized in their early stages using facial analysis on patient images. The full implementation of ANNs in the healthcare environment can only enhance the diagnostic capabilities of medical experts and ultimately lead to an overall improvement in the quality of medical care worldwide[47].

- **Example**

An artificial neural network (ANN) model is used to develop a classification model based on patients' clinical data to determine the risk of stroke. The data includes variables such as age, gender, VS, and medical history. The model learns the complex patterns between these variables and the likelihood of stroke through a network of artificial neurons. When presented with new patient data, the model categorizes the patient as either high or low risk for stroke based on the available clinical information. As represented in the following **Figure II.10.**

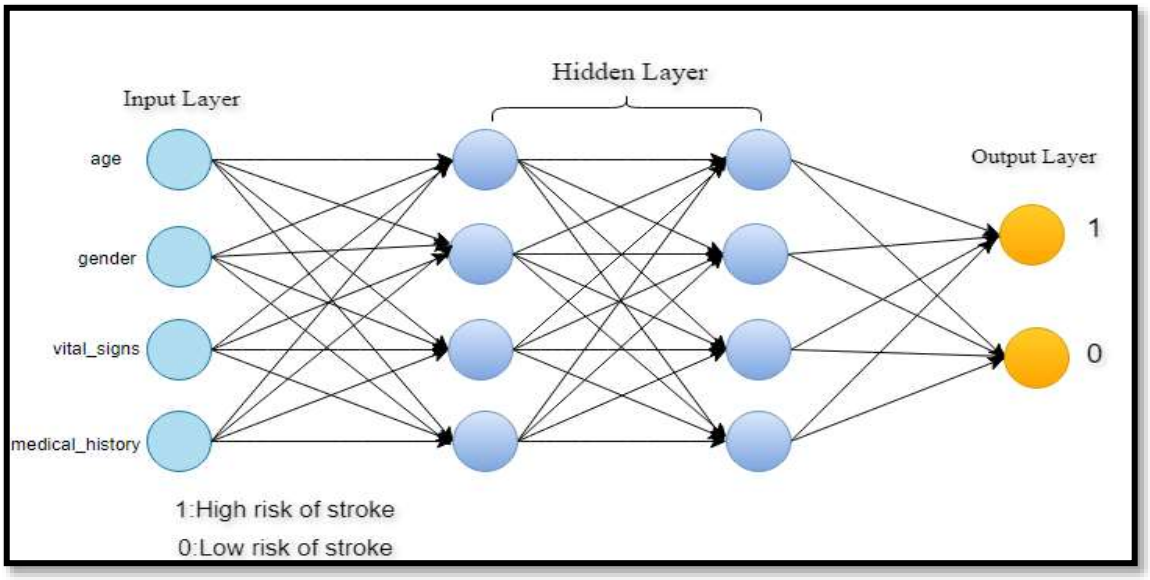


Figure II.10: Artificial Example of a ANN

II.5.d Support Vector Machine (SVM)

- **Definition**

SVM are mathematical model used in ML for object classification. They offer advantages over neural networks, especially in text or image classification, as they can be trained more quickly and achieve satisfactory results even with limited training data.

They are based on the idea of finding a surface that separates the different classes in the data with the largest possible margin.[52]

SVM model determines the maximum margin between the two classes so that the gap between them is as large as possible in the following way:

- **Maximum Margin Determination:** SVM starts by determining the maximum margin between the two classes by finding a hyperplane that serves as the line separating the points belonging to each class. The margin is the distance between this hyperplane and the closest point of each class as shown in the **Figure II.10**.

- **Figure Building the hyperplane:** The separating surface is chosen so that it is perpendicular to the maximum margin and as far away as possible from the

nearest points of each class. This ensures that the gap between the two classes is as large as possible.

- **Select Kernel and Transform (optional):** In some cases, data transformations by kernels may be used to characterize data in a higher-dimensional space if they are not linearly separable in the original space.

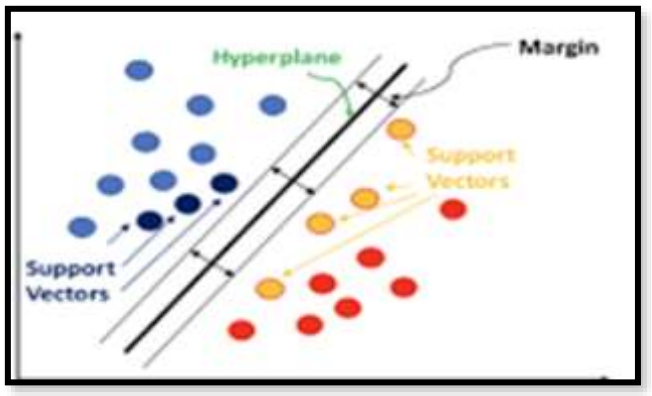


Figure II.11. Support Vector Machines[52]

▪ **Types of SVM**

There are three main types of (SVMs) depending on the type of issue and data:

- **Linear SVM:** Used to separate data using straight lines or planes in a high-dimensional space. These models provide simple and fast computations with the ability to effectively classify even with large datasets. However, they may not be suitable for non-linear data.
- **Nonlinear SVM models:** Used to provide data separation using non-linear levels in a high-dimensional space. They rely on kernel functions to define these levels, such as polynomials, etc.
- **Support vector regression (SVR):** Used when continuous prediction is the goal without the need for classification. Support vector regression is used to minimize the distance between the predicted output and the actual output.

- **Non-Linear Separable Data**

While it's apparent that the two datasets are visually distinct, they cannot be effectively separated using a straightforward linear hyperplane. However, one approach to still leverage SVM is by introducing an additional dimension, creating separation in a higher-dimensional space via a hyperplane. Yet, this method can pose significant challenges in terms of complexity, both computationally and conceptually. In many instances, it can unnecessarily complicate the algorithm and lead to computational inefficiencies. Therefore, we won't delve further into this alternative within the scope of this article.[52]

- **Kernel Trick for Support Vector Classification work**

The kernel trick in SVMs enables classification of non-linear datasets by computing relationships between data points in the original space using kernel functions. This avoids explicit mapping to higher dimensions. Mercer's Theorem allows us to optimize without knowing the exact mapping, as long as we can compute inner products between data points. Kernel functions like the Gaussian or spectrum kernel satisfy Mercer's Theorem, simplifying the process for handling non-linear data[53].**Example**

The (SVM) model is used to develop a classification model based on patients' clinical data to determine the risk of stroke. The data includes variables such as age, gender, VS, and medical history. The model learns to separate these variables from the likelihood of stroke by creating optimal decision boundaries. When presented with new patient data, the model categorizes the patient as either high or low risk for stroke based on the available clinical information **(Figure II.10).**

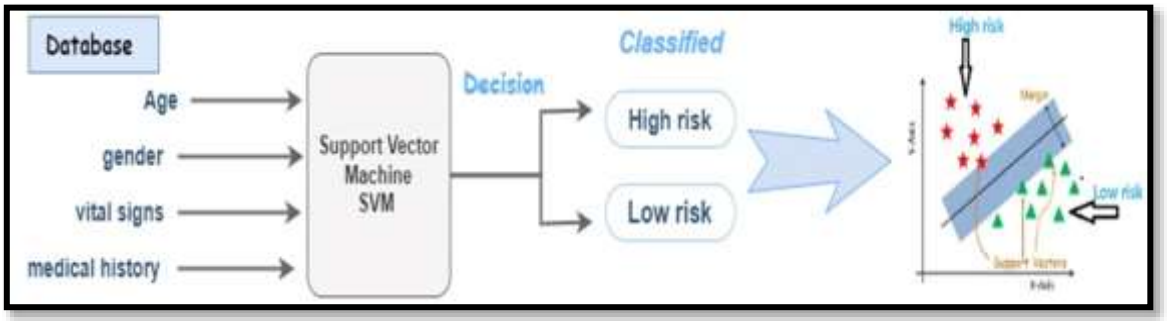


Figure II.12: Artificial Example of an SVM

II.6 Comparison of RF, ANN, LR, and SVM

This comparison aims to shed light on the main differences between these four models

Table II.2: Comparison of RF, ANN, LR, and SVM[47], [54]

	RF	LR	ANN	SVM
Purpose and applications	Used for classification and prediction by generating random decision trees and aggregating their classifications to make a final decision[42]	Used for classification by calculating probabilities, usually for predicting binary classification using explanatory variables	Used for ML, classification, and prediction, they consist of layers of artificial nodes and use DL algorithms.	Used for classification and prediction by finding a separating surface that separates categories of data by the largest possible distance.
Data manipulation	Depend on specific independent variables.	Depend on specific independent variables.	Can handle a variety of data, including unstructured data such as images and text.	Depend on specific independent variables.
Model complexity	Simple models that are easy to understand.	Simple models that are easy to understand.	complex models that require specifying a large number of parameters and extensive training	Simple models that are easy to understand.
The main principle of operation	Aggregate multiple decisions from decision trees to arrive at a final decision.	Uses a probability model to predict the classification of samples.	Relies on artificial nodes and DL processes to gain knowledge from data	Builds a separating surface between data categories so that the margin between them is as large as possible

II.7 Performance measures of the four models

The evaluation of the presentation of the previous four models is based on the use of the accompanying components[55]

- ***Accuracy:*** Given by Equation II.1, It measures the number of classifications the model gets out of the total number of predictions; it is the percentage of correct predictions.

$$\boldsymbol{Accuracy = \frac{TP}{TP+FP}} \quad \textbf{(II.1)}$$

TP: is the number of True Positives.

FP: is the number of false positives (False Positives).

The accuracy value is between 0 and 1, where 1 means that all results that are categorized as positive by the model are actually positive, while a value of 0 means that there are no true positives that are correctly categorized.

- ***Confusion Matrix CM*:** is a tool used to evaluate the performance of a classification model in ML. The CM is usually displayed as a table containing the actual results versus the predictions made by the model.
  The CM is used to understand the performance of the model in typically consists of four main components (**Figure II.11)**:

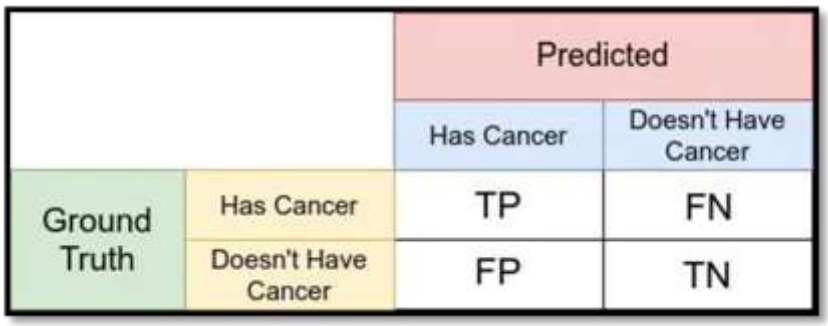


Figure II.13: Confusion Matrix [55]

True Positives (TP): The number of instances that are correctly categorized as positives.

True Negatives (TN): The number of cases that were correctly categorized as negatives.

False Positives (FP): The number of cases that were misclassified as positives.

False Negatives (FN): The number of cases that were misclassified as negatives.

- ***Error Rate:*** is a metric used to estimate the accuracy of a classification model in ML. It is the percentage of misclassified cases out of the total number of cases in the test set. It represents the fraction of predictions that are wrong relative to the actual cases.

The error rate is calculated using the formula (II.2).

$$\boldsymbol{Error\ Rate = 1 - Accuracy} \qquad \textbf{(II.2)}$$

The error rate provides a general idea of the model's efficiency in correctly categorizing cases. The lower the error rate value, the better the model is at correctly predicting outcomes.[55]

II.8 Development tool (Node-RED)

II.8.a What is Node-RED

Node-RED is an open-source software environment developed by IBM to make it easy to connect different devices, services, and interfaces via visual information flow. It is based on the Node.js environment and enables easy creation of Internet of Things (IoT) applications and system integration using a drag-and-drop interface. Node-RED provides a graphical user interface that enables users to create and edit flows consisting of nodes that represent data points, services, and devices, and connect these nodes with virtual wires to form data and process flows without the need to write complex code [56]

II.8.b Editor Node-Red

Figure II.12 contains the Node-RED editor, which includes installed nodes on the left, with more available online. In the center, it displays the flows representing our implementation. At the top, it shows all tasks running on the device or processor. On the right, there is an information and debugging window.

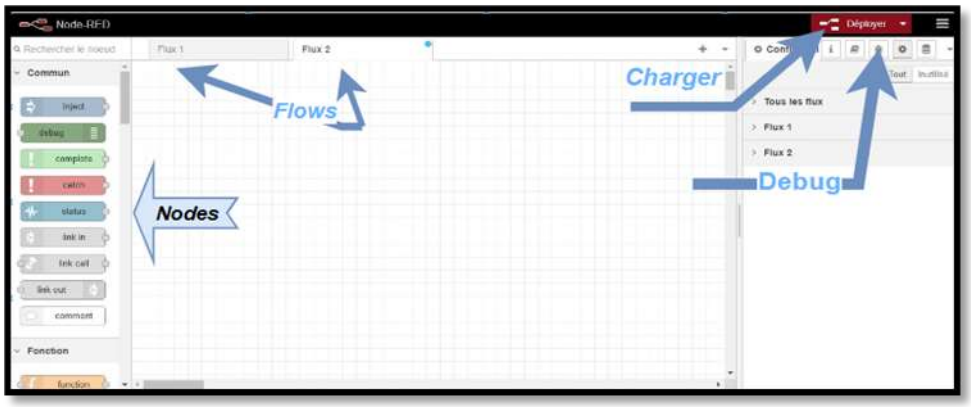


Figure II.14: Editor Node Red

Nodes include input nodes, processing nodes and output nodes,

- **Input Nodes:** are used to insert data into the flow. They have a gray box on the right side to connect to other nodes for sending data.
- **Processing Nodes**: are used to process data. They have one or more input nodes and one or more output nodes. These nodes are used to convert data types, write custom code, and trigger messages.
- **Output Nodes:** are used to send data to the outside world or to other services like Twitter. They feature a gray box on the left side to connect to input nodes or functions.

II.8.c Advantages of Node-RED

- **Ease of Use:** The visual flow-based interface is user-friendly and accessible even to those with minimal programming experience. Users can build applications by connecting pre-built nodes.
- **Flexibility:** Node-RED supports a wide range of devices, APIs, and services, allowing for seamless integration and automation.
- **Active Community:** A vibrant and active community contributes to a rich ecosystem of nodes and plugins, which extend Node-RED's capabilities.

- **Scalability:** It can run on small devices like the Raspberry Pi as well as on large cloud servers, making it suitable for various scales of applications.
- **Rapid Prototyping:** Allows for quick development and iteration of prototypes and applications, facilitating faster innovation and deployment

II.8.d Uses of Node Red

- Internet of Things (IoT): Connects devices for data collection, processing, and automation.
- System Integration: Integrates various systems and services like databases, APIs, and messaging systems.
- Data Analysis: Facilitates real-time data processing and analysis by connecting data sources and analytics services.
- Alerting and Notifications: Monitors conditions and sends alerts via email, SMS, or other messaging platforms when specific conditions are met[56].

II.9 Conclusion

Using recent advances in artificial intelligence and ML techniques, we can revolutionize healthcare. The Python programming language and its various libraries give us the tools to effectively analyze medical data and build accurate predictive models. Through the use of smart technologies, we can optimize healthcare processes, speed up diagnosis and improve treatment outcomes, thereby enhancing public health and saving lives. Success in this field requires close collaboration between scientists, medical professionals, and programmers to develop effective solutions that enhance the quality of health services and contribute to building a healthier future for all.

Chapter III

Deploying the Smart Prioritization System

Chapter III: Deploying the Smart Prioritization System

III.1 Introduction

This chapter will delve into the practical implementation of both hardware and software solutions within a smart system designed to classify and prioritize patients in the ED using AI algoritm. We'll provide an overview of the specifications, software, and hardware solutions employed in the project, accompanied by a thorough explanation of how the developed models function to achieve accurate classification and prioritization. Additionally, it will be highlighted that the implementation will take place within the Node-RED platform.

III.2 Specifications

Our project is developed around an intelligent electronic system to triage patients in emergency departments based on medical criteria. It is necessary to use a dataset to train this intelligent system. There are methods available to steer the implementation of this system, ensuring optimal performance tailored to the needs of the emergency department. (**Figure III.1**).

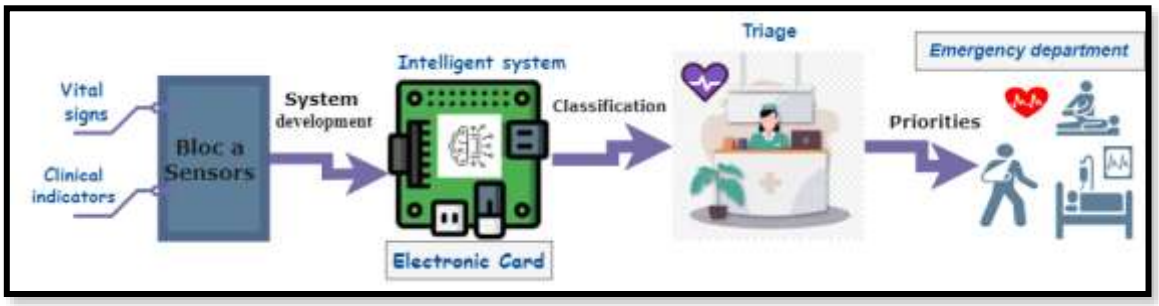


Figure III.1: Scheme of the Specification

In our system, several inputs are received from the sensors

- **QRS**
- **Pap**
- **Rest**
- **ECGR**

- **SPO2**
- **HB**
- **P_P**
- **ST**
- **LB**
- **ChP**
- **ShBr**
- **Peaks**

To make an intelligent decision that categorizes patients into five categories **("Risk";"Urgent"; "Sick ";"Cold State;" Normal")**، Our goal with this system is to prioritize patients according to the severity of their condition.

This process consists of using data about the patients (number of patients and their VS and CI). In our case, a dataset was created from the Physionet library [3], a health and bioinformatics library that contains many databases and biomedical signals.

A dataset of 571 patients' cases is used to synthesize the intelligent model.

In this stage, the data is displayed and divided into input and output, where the input represents the patients' parameters and the output represents the severity of their health condition, as in the **Table III.1**

Table III.1: Dataset examples

1	ECGR	Spo2	HB	HL	ChP	Palp	ShBr	Rest	Peaks	QRS	P_P	ST	class	
2	77	97	23	12	0	0	0	0	67	0.06	0	1	Sick	0
3	77	80	15	10	0	1	1	0	67	0.06	0	1	Urgent	1
4	66	80	15	10	1	1	1	1	67	0.06	0	1	risk	2
5	66	80	23	12	0	1	0	1	67	0.06	0	1	Urgent	1
6	55	97	15	10	0	0	0	0	54	0.5	0	0	Cold State	4
7	55	92	12	8	0	0	1	0	77	0.047	0	1	Sick	0
8	44	97	23	12	0	0	0	1	64	0.169	0	0	Cold State	4
9	44	92	23	12	1	0	1	0	64	0.169	0	0	Urgent	1
10	33	97	12	8	0	0	0	0	60	0.10	0	1	Normal	3
11	33	97	12	10	0	1	1	1	60	0.10	0	1	Cold State	4
12	22	92	12	8	0	0	0	1	110	0.10	0	1	Sick	0
13	22	97	12	8	0	0	0	1	110	0.10	0	1	Normal	3

- **Inputs**

ECG Records: Many different ECG contexts help doctors in diagnosis and treatment and have been changed to suit us to be entered into the sensors:

- Sleep apnea records is represented by (**77**).
- Long-term ST records is represented by (**66**).
- Arrhythmia records is represented by (**55**).
- Heart failure records is represented by (**44**).
- Normal ECG is represented by (**33**).
- normal ECG with heart rate 110 is represented by (**22**).

SpO_2: The level of oxygen saturation in the blood (%), a low level of which may cause breathing issues and worsen the patient's condition.

HB: high blood pressure (systolic).

HL: low blood pressure (diastolic).

ChP: Chest pain, which may be an indication of a heart attack or may indicate that the patient is having chest issues and may be a risk factor, is represented by a binary value, where 1 means the patient is in pain and 0 means the patient is not in pain

Palp: Palpitations (binary, no:'0' or yes:'1'). Palpitations may indicate that the patient has a heart condition

ShBr: Shortness of breath may indicate that the patient has lung and respiratory issues '0' indicates that the patient is not short of breath and '1' indicates that the patient is short of breath

rest: Same as rest, rest is important for correct diagnosis of the patient. 1 indicates that the patient is at rest and 0 indicates that the patient is not at rest.

Peaks: The number of peaks in the ECG.

QRS: The QRS complex is the part of the ECG that represents the period of contraction of the ventricles and is a key indicator of the heart's electrical activity. The duration of the QRS complex is measured in seconds or milliseconds

P_P: The P wave is the wave that represents the contraction of the atria. The presence or absence of the P wave is recorded as a binary indicator (0 or 1).

ST: The portion of the ECG that follows the QRS complex and extends to the beginning of the T wave. important for diagnosing conditions such as cardiac ischemia or myocardial infarction.

Peaks: The number of peaks in an electrocardiogram (ECG) that represent the electrical activity of the heart during the heartbeat cycle.

- **Output**

The director contains five categories that represent the risk levels for each health condition, through which we can show the health status of each patient

Sick (0): Indicates a health condition that requires regular medical follow-up but is not an emergency.

Urgent (1): Indicates an emergency condition that requires immediate intervention, such as acute ischemic heart disease or a heart attack.

Risk (2): Indicates a high-risk condition that requires intensive monitoring and urgent treatment to prevent the condition from developing into an emergency.

Cold state (3): Indicates a condition that requires medical intervention but is not critical and can be managed in non-urgent ways.

Normal (4): Indicates a normal health condition with no cardiac abnormalities that require medical intervention.

- **Example:**

Below we explain an example from the dataset**(Table III.2).**

Table III.2: Example from the dataset

1	ECGR	Spo2	HB	HL	ChP	Palp	ShBr	Rest	Peaks	QRS	P_P	ST	class	
2	77	97	23	12	0	0	0	0	67	0.06	0	1	Sick	0

This data shows a set of medical measurements for a person, arranged in a row with a set of values for each measurement. Let's explain each column and its meaning:

- **ECGR** The ECG value, here 77 means the patient has sleep apnea
- **Spo2** Blood oxygen saturation, here 97%.
- **HB** Indicates systolic blood pressure, this value is 23 mHg.
- **HL** Indicates diastolic blood pressure, this value is 12 mHg.
- **ChP** If the patient has chest pain, 0 means no pain.
- **Palp** If the patient has palpitations, 0 means no palpitations.

- **ShBr** If the patient is experiencing shortness of breath, 0 means none.
- **Rest** Can be related to the state of rest, here 0, may mean the patient is not at rest.
- **Peaks** Number of peaks in the electrocardiogram, here 67.
- **QRS** The duration of the QRS complex in the ECG, here 0.06 seconds, which is the amount of time it takes for an electrical impulse to travel through the ventricles.
- **P_P** at 0 No P wave.
- **ST** at 1An ST segment is present, which may indicate a heart issue such as ischemia.
- **Class** A description of the patient's condition, here “Sick” means sick.

Based on this data, a person can be understood to have a health issue that is categorized as “sick” even though their oxygen saturation and Hemoglobin are high, and this may be related to sleep apnea.

III.3 Classification based on AI

To optimize the classification task, four different AI algoritm are used. It is crucial to understand and execute each step of the process accurately. These models were implemented using Visual Studio Code and Python version 3.10.11 on a Lenovo ThinkPad computer with the following specifications:

- Processor: Intel(R) Core (TM) i5-6300U
- RAM: 8 GB.
- ROM: 255 GB.
- Operating System: Windows 10 Professional.

III.3.a Algorithms Summary

The flowchart in Figure III.2 provides a summary of the used four intelligent models.

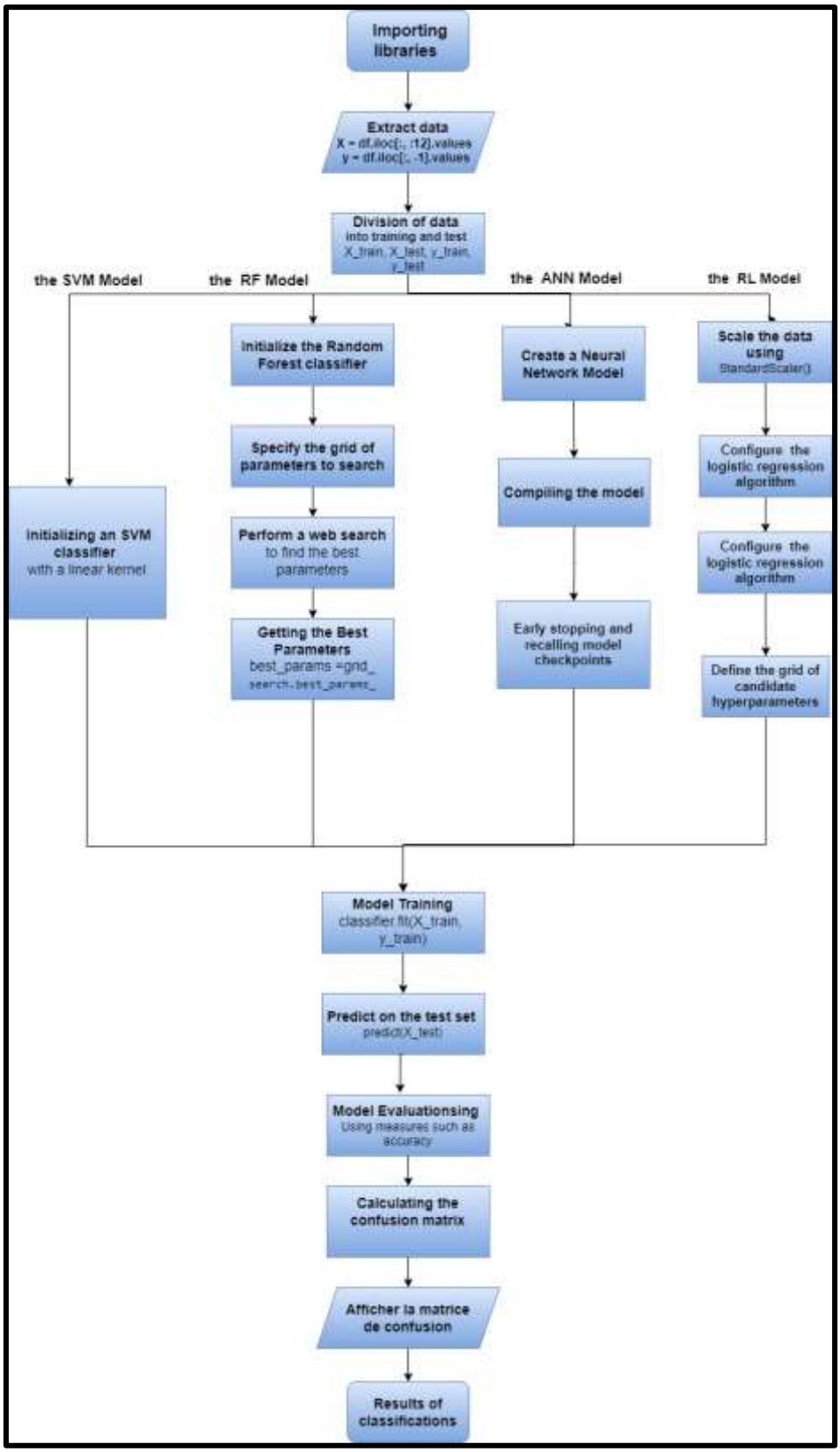


Figure III. 2: Flowchart of four intelligent models

III.3.b ANN model

In the ANN model, several libraries are imported that are necessary to perform various tasks such as data processing (Pandas), data segmentation (Scikit-learn), and neural network building and training (TensorFlow and Keras).

- The Excel file containing patient data is read using the Pandas library and loaded into a DataFrame **Figure III .3.**

```
df = pd.read_excel('C:\\Users\\IT DOCTOR\\Desktop\\PFE\\GGGGGGGGGGGGGGGGGGGG\\database1 (1).xlsx', header=0)
```

Figure III .3: Load the Excel file

- The feature matrix (X) is then defined, where the first 12 columns are used as the feature matrix and the last column is the target variable (y) **Figure III .4.**

```
X = df.iloc[:, :12].values
y = df.iloc[:, -1].values
```

Figure III .4: Model extract features and target variable

- Then it's time to split the data into training (80%) and test (20%) sets using the " train_test_split" function. **Figure III .5**

```
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=42)
```

Figure III .5: Split the data into training and testing sets

- The neural network model is created using the Keras library. The model has two layers: **Figure III .6**
  - Input layer (12 units)
  - Output layer (5 units for multiple classifications)

```
model = Sequential()
model.add(Dense(60, input_dim=12, activation='tanh'))
model.add(Dense(5, activation='softmax'))
```

Figure III .6: Creating the neural network model

- The model is clustered using the "sparse_categorical_crossentropy" loss function and the "adam" optimization model with accuracy as the performance criterion and an early stopping strategy is set up for the case of model performance degradation, as well as saving the best model. The model is ready to be trained in **Figure III .7**

```
model.compile(loss='sparse_categorical_crossentropy', optimizer='adam', metrics=['accuracy'])
```

Figure III.7: model is clustered

- Train the model using the training data and evaluate the performance on the test data. Then load the saved model and use it for prediction on the test set.

- Model performance is evaluated by calculating accuracy using" accuracy_score ". To evaluate its performance more precisely, we calculate and display the CM in **Figure III .8.**

```
accuracy = accuracy_score(y_test, y_pred)
print("Accuracy:", accuracy)
```

Figure III .8: Model performance is evaluated

▪ Tests

Testing is done by changing the parameters epochs, test size, and to evaluate the performance of the model and assess its effectiveness **Table III.3.**

epochs are essential for evaluating and optimizing the model's performance.

The result is compared based on accuracy and matrix de confusion and time learning; time classification.

Epochs: an epoch refers to one complete pass through the entire training dataset. During each epoch, the model learns from the data, updates its weights, and improves its ability to make predictions.

Time learning: the duration an model takes to learn patterns from the training data. The learning time varies from one model to another based on the complexity of the model and the size of the data used.

Classification time: is the duration an model takes to classify new data after it has been trained. This time is important as it reflects the speed of the model in handling new data in real-time or practical applications**.**

Table III.3: Test results for female teachers ANN

Test_ Size	epochs	**Accuracy**	Learning Time(s)	Classification Time(ns)	Memory capacity (MB)
20%	100	**0.77**	21	39200	377.84
	1000	**0.95**	125	50700	378.46
	5000	**0.92**	200	19900	377
30%	100	**0.72**	25	17900	376
	1000	**0.92**	135	44700	376.94
	5000	**0.90**	239.1	25000	378
40%	100	**0.74**	24	25800	375
	1000	**0.91**	163	27700	376
	5000	**0.93**	270	33100	374

- **Results**

the best accuracy values and confusion matrices were recorded based on the proportion of data used for testing. The best accuracy for each dataset size was then compared, and the optimal CM among the three obtained was identified. Upon comparing the confusion matrices in **Figures III.9, III.110**, and **III.11** with the accuracy values, we observed that the accuracy is highest when 80% of the data is used for training and 20% for testing, with the process, repeated approximately 1000 times. This approach increases the accuracy to 95%, reducing the error rate to 5%. Additionally, the learning time was 125s, and the classification time was 50700 ns.

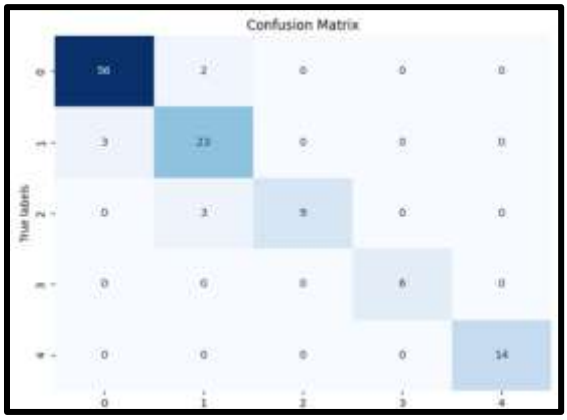


Figure III .9 : ANN confusion matrix 1

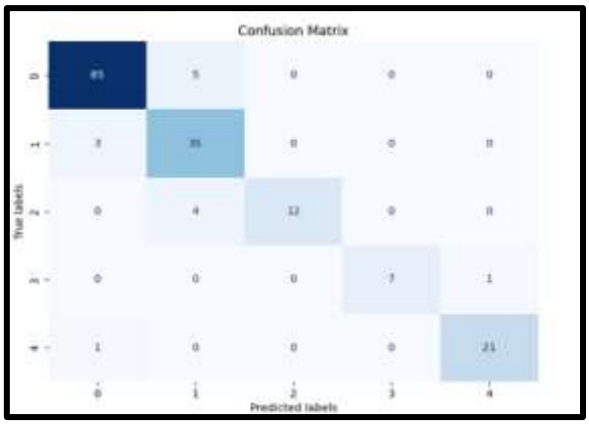


Figure III .10 : ANN confusion matrix 2

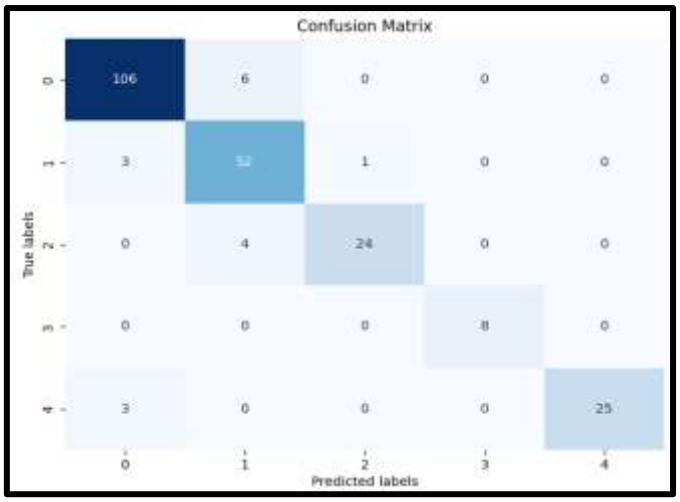


Figure III .11 : ANN confusion matrix 3

III.3.c SVM

- The SVM model is based on the "tensorflow" library, which provides powerful tools for building and training deep models that are similar to ANN starting with file import, data segmentation, and feature selection.

- The SVM model is built using a linear kernel and specifying (random_state=50) is a setting that ensures that the random processes within the model give the same results every time the code is run, making it easy to iterate and debug.

  Figure III .12

```
classifier = svm.SVC(kernel='linear',random_state=50)
```

Figure III.12: The SVM model is built using a linear kernel

↳ Train the model using the training data and then use the trained model to predict the labels on the test set **Figure III .13**

```
classifier.fit(X_train, y_train)
y_pred = classifier.predict(X_test)
```

Figure III .13: Train the model using the training data

↳ The CM is calculated using "confusion_matrix" an analytical tool that displays the overall performance of the model by displaying correct and incorrect classifications Figure **III .14.**

```
conf_matrix = confusion_matrix(y_test, y_pred)
```

Figure III.14: Confusion Matrix

- **Tests**

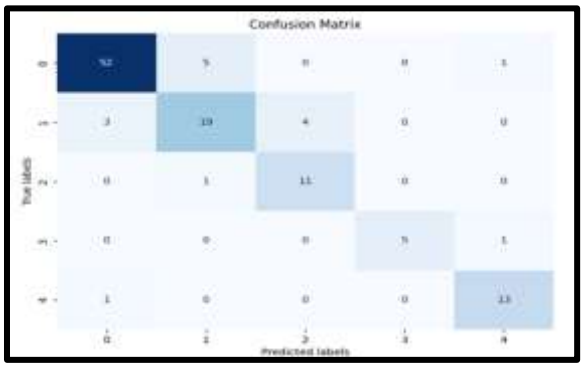
Kernel and Random_state (Repeat trainingSvm) parameters that by changing them we can evaluate and test the model Table III.2.

Table III.4: Test results for female teachers SVM

Test_ Size	Kernel type	Random_ state (Repeat training**Svm**)	**Accuracy**	Learning Time(s)	Classification Time(ns)	Memory capacity (MB)
20%	Poly	0	**0.52**	0.95	8200	166.55
	Linear	50	**0.88**	3.22	8300	186.55
	rbf	100	**0.52**	1.00	12100	166.09
30%	Poly	0	**0.52**	1.12	9700	166.01
	Linear	50	**0.86**	1.13	10600	165.59
	Rbf	100	**0.52**	1.04	20800	166.14
40%	Poly	0	**0.52**	1.02	11500	166.5
	Linear	50	**0.87**	1	7900	165.8
	rbf	100	**0.53**	1.01	12900	166.17

- **Results**

After the test, several values of the best accuracy and best CM were assigned from the table according to the proportion of data submitted for the test. Then, the best accuracy for each size is compared, and the optimal CM from the three obtained is selected. After comparing the values of the confusion matrices in **Figures III.15, III.16**, and **III.17** along with the accuracy values, it is observed that accuracy is high when 80% of the data is used for training and the rest for testing the model. Setting the random state for training to 50, the accuracy reaches 88% with good CM values. The learning time is 3.22s, and the classification time is 8200ns, showing a slight increase in memory capacity. However, the primary concern remains on accuracy and the CM. memory capacity



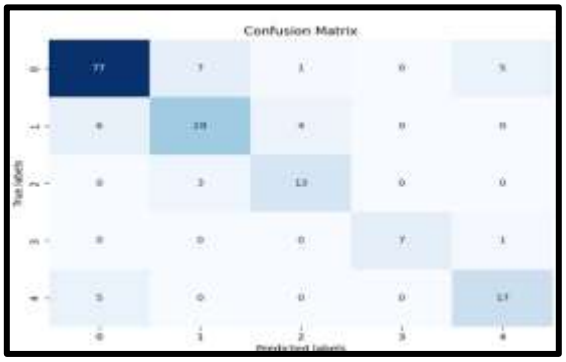


Figure III .15 : SVM confusion matrix 1 **Figure III .16 :** confusion matrix 2

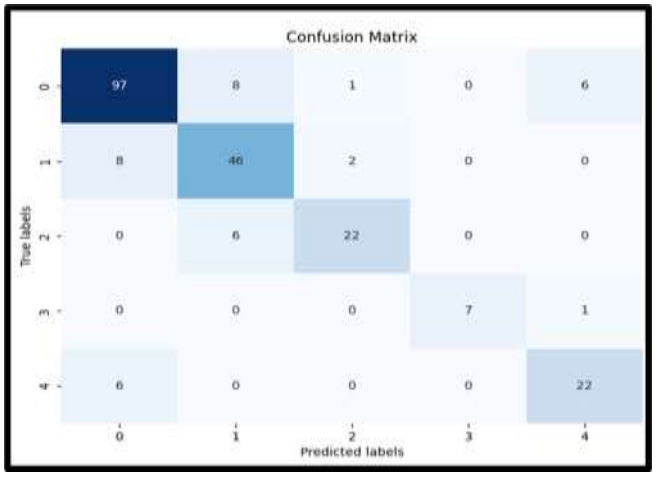


Figure III .17 : SVM confusion matrix 3

III.3.d LR Classifier

- The LR model is based on the "LR" library, which provides powerful tools for building and training deep models that are similar to ANN starting with file import, data segmentation, and feature selection.
- The data is scaled using the "StandardScaler ()" function to scale the data to the same size **Figure III .18.**

```
scaler = StandardScaler()
```

Figure III.18: Data is scaled.

- Initialize the LR model and select the candidate hyperparameter grid, which in turn searches for the best parameters for the logistic model

The grid search is then configured with "GridSearchCV" and the model is ready for training with "x_train_scaled, y_train" After training, prediction is performed on the test set to evaluate the accuracy **Figure III .19**.

```
grid_search = GridSearchCV(estimator=logistic_classifier, param_grid=param_grid, cv=5, scoring='accuracy')
```

Figure III .19: Grid search is then configure

- **Tests**

_Max_iter: defines the maximum number of iterations to ensure the convergence of the model.

_Coefficient C: controls the simplicity or complexity of the model, where a small value means a simpler model and a large value means a more complex model.

By changing these parameters, we can evaluate and test the model **Table III.5**

Table III.5: Test results for female teachers LR

Test_ Size	Max_iter	C Punishment power	Accuracy	Learning Time(s)	Classification Time(ns)	Memory capacity (MB)
20%	100	(-2,2,4)	**0.89**	1.65	25000	137.67
	1000	(-3,3,7)	**0.90**	2.328	32000	137.48
	2000	(-6,6,9)	**0.88**	3.36	22400	137.65
30%	100	(-2,2,4)	**0.88**	1.76	32800	136.9
	1000	(-3,3,7)	**0.89**	2.16	32900	137.38

	2000	(-6,6,9)	**0.91**	2.87	34300	137.14
40%	100	(-2,2,4)	**0.85**	1.37	36400	137.29
	1000	(-3,3,7)	**0.89**	1.72	23700	137.46
	2000	(-6,6,9)	**0.88**	3.08	28000	137.3

- **Results**

After comparing the best accuracy and the best CM in **Figure III .20, III .21, and III .22** according to the ratio of data provided for testing from the table, it was observed that the accuracy was high when 80% of the data was used for training and the rest for testing, along with 1000 iterations and the addition of a penalty power for model identification ranging from (-3, 3, 7). It was noted that the accuracy was high, reaching 90%, the CM values were good, and it did not require much memory capacity and time learning 2.328s and classification time 32000ns despite the large number of iterations and the power factor. The main focus remained on accuracy and CM, which showed the effectiveness of the model.

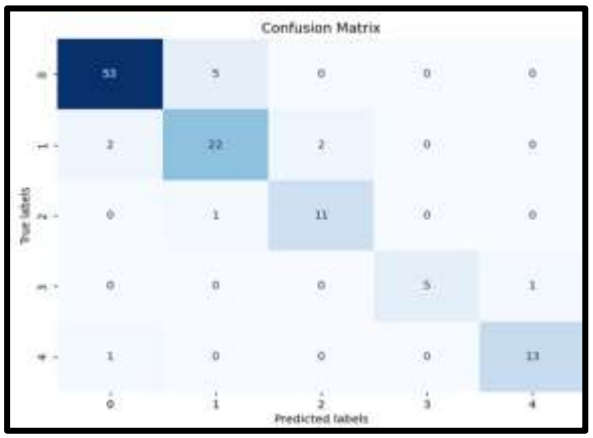


Figure III .20: LR confusion matrix **1**

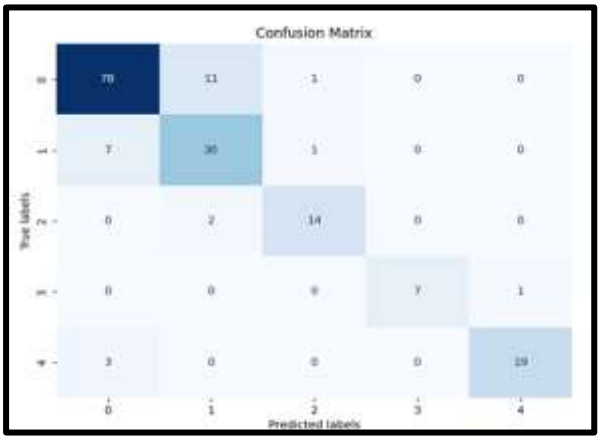


Figure III .21 :LR confusion matrix **2**

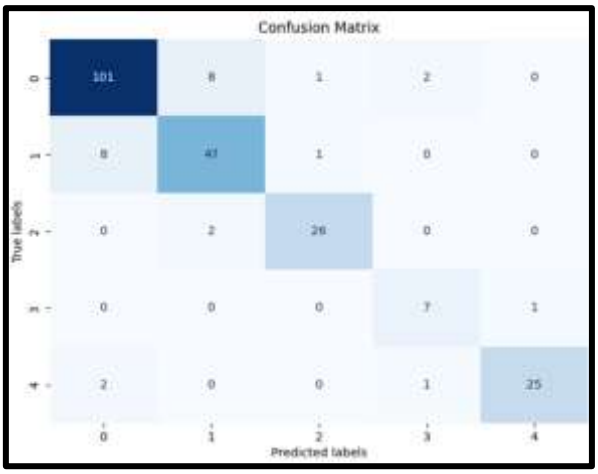


Figure III .22: confusion matrix **3**

III.3.e RF classifier

- The RF model is based on the "RandomForestClassifier" library, which provides powerful tools for building and training deep models that are similar to ANN starting with file import, data segmentation, and feature selection.

- Initialize the RF classifier, and specify the sub-parameter grid to search for the best combination **Figure III .23**

```
rf_classifier = RandomForestClassifier()
```

Figure III .23: Initialize the Random Forest classifier

- We perform a grid search using "GridSearchCV ()" where the RF classifier takes the parameter grid, CV value, and performance metric as inputs.
- Find the best parameters and initialize it with the best parameters obtained. Here the model is ready to be trained with "x_train, y_train" **Figure III .24.**

```
rf_classifier = RandomForestClassifier(**best_params)
```

Figure III .24: Initialize the RF classifier with the best parameters

- **Tests**

Adjusting the parameters `n_estimators', `min_samples_leaf', and `max_depth' allows for careful selection, and optimization of these parameters is crucial for optimal model performance and generalization. **Table III.6.**

_n_estimators: Number of trees in the model, increases stability but may increase memory consumption and training time.

_min_samples_leaf: Minimum number of samples required in each leaf node, reduces overfitting by limiting unnecessary splits.

_max_depth: Maximum depth of each tree, affects the model's ability to capture data complexities and may increase overfitting risk.

Table III.6: Test results for female teachers RF

Test_ Size	n_ Estimators	min_ samples _leaf	max_ Depth	**Accuracy**	Learning Time(s)	Classification Time (ns)	Memory capacity (MB)
20%	50	1	None	**0.70**	2.59	29600	145.04
	100	5	10	**0.75**	5.97	28200	143.21
	200	10	20	**0.66**	8.02	24800	143.39
30%	50	1	None	**0.70**	2.59	10000	144.7
	100	5	10	**0.71**	4.35	14800	143.21
	200	10	20	**0.69**	6.36	22900	143.1
40%	50	1	None	**0.68**	2.53	30600	144.65
	100	5	10	**0.70**	4.11	18300	142.8
	200	10	20	**0.63**	6.63	21200	142.76

- **Results**

After comparing the best accuracy and best CM Figures **III .25, III .26, and III .27** according to the proportion of data provided for testing from the table, it was noticed that the accuracy is high when choosing 80% for training and the rest for testing. Additionally, identifying 100 trees containing five leaves with a depth of 10 results in an accuracy of 75% compared to the rest, and time learning of 5.97s, and a classification time of 28200ns.The values of the CM are good, and the error rate is low. The main focus remains on the accuracy and CM, which demonstrates the effectiveness of the model.

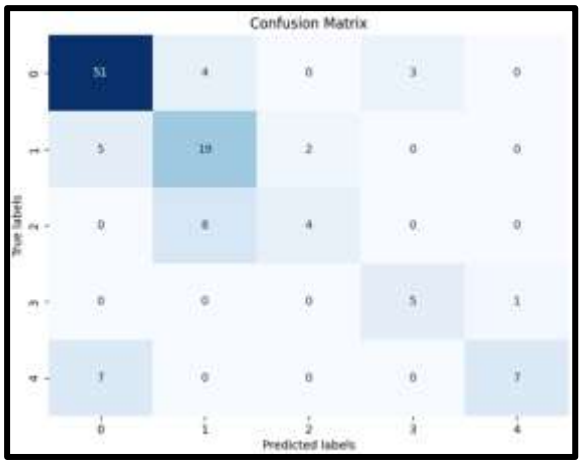


Figure III .25 : RF confusion matrix 1

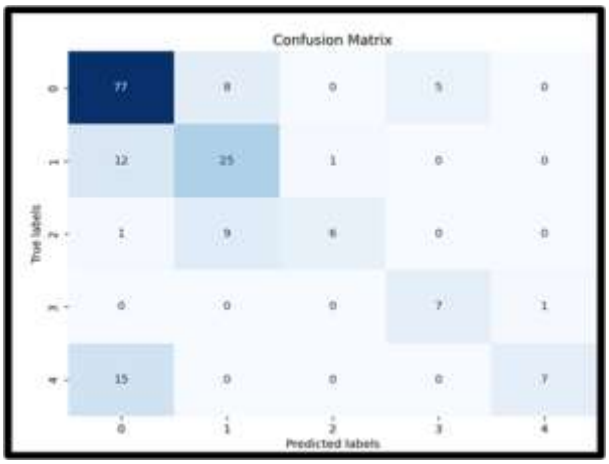


Figure III .26 : RF confusion matrix 2

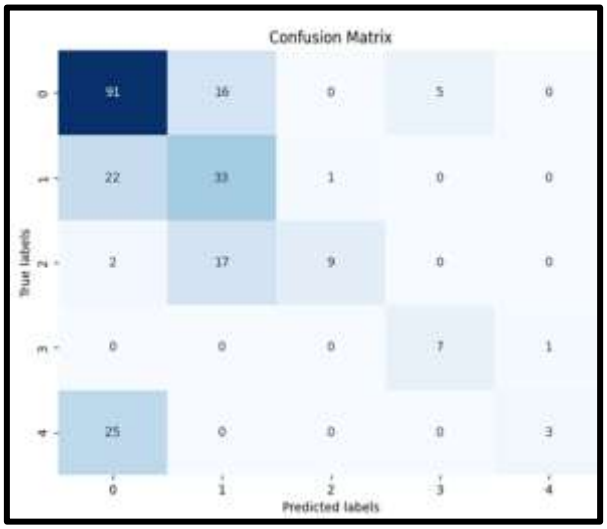


Figure III .27: RF confusion matrix 3

III.3.f Comparison between the four classifiers

After testing the four models by changing the parameters for each of them, the best accuracy and best CM were chosen for each model to be compared between them to determine the best model to rely on in classification.

- **Comparison of the CM**

In this section, the CMs of four models are compared, as depicted in **Figure III .28** By analyzing these matrices, valuable insights are gained into the reliability of their accuracy in classification tasks.

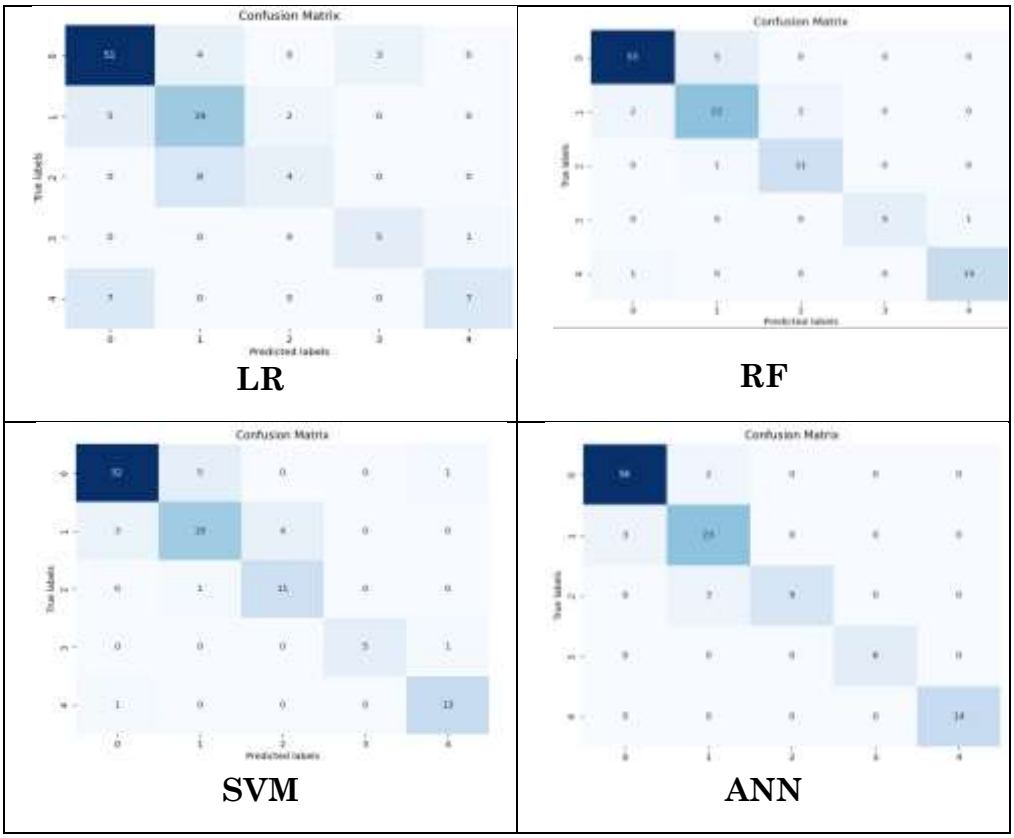


Figure III .28: Confusion matrix for the four classifiers

- **Comparison for accuracy**

The performance of the four models is compared in **Figure III. 29.** By considering the accuracy, the performance of each model in classification tasks can be evaluated.



Figure III .29: Accuracy

- **Execution time comparison**

The performance of four different AI models is compared in terms of time taken to classification. This is shown in **Figure III.30**

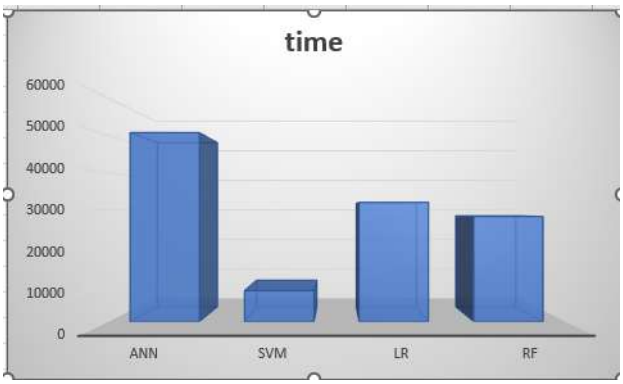


Figure III .30: Classification time

- **Discussion**

When comparing the accuracy in **Figure III.28** and the CM in **Figure III.29,** it is clear that the ANN model shows the highest accuracy and a very low error rate. The CM also emphasizes its exceptional performance. In addition, most of the models show low learning and classification times, which means that they miss some patient cases. Therefore, our decision to choose this model is mainly based on its accuracy and CM which means it does not misclassify the patient's condition.

Accuracy is critical for categorizing patients in the ED due to the varying severity of their health conditions. Hence, this model is the perfect choice for this task, due to its high level of accuracy.

III.4 Node-RED

III.4.a Supervision interface

In our project, we rely on a web application interface that can be accessed through a browser. This solution brings together all the components used in the project. Through Node-RED, we were able to facilitate the project thanks to a set of predefined and configurable blocks, which simplifies visual programming.

Workflows consist of a combination of connected nodes, including input nodes, processing nodes, and output nodes. The supervisory interface is created using Node-RED's dashboard, allowing us to visualize the collected data via various graphical elements.

III.4.b Starting the Node-red

Getting started with Red Node is accessing the programming interface via a browser. Preferably on a PC.

First opening the Command Prompt terminal window, we launch it by typing the following command: `node-red'. A message will appear confirming that it is running and will provide the URL to access it via a browser, which is clearly shown in **Figure III .31**.

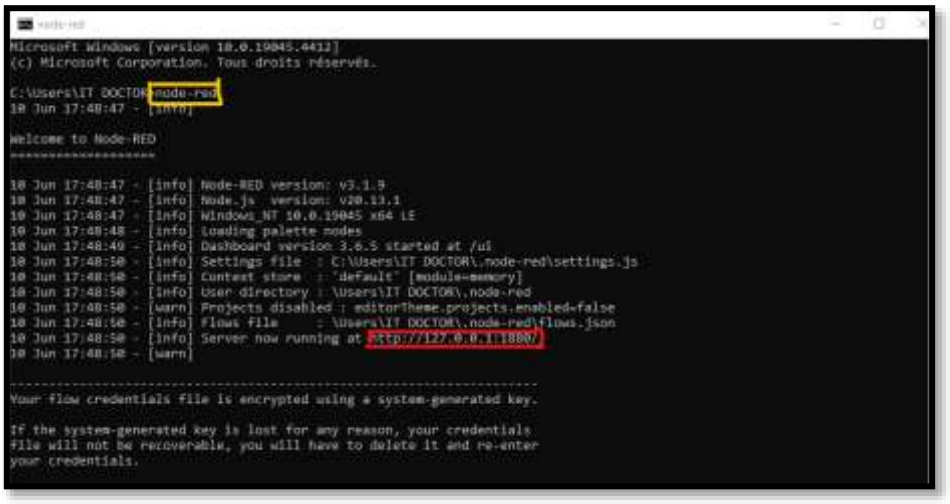


Figure III .31: Running Node-Red

Then we open the browser and type the following address: ***/http://127.0.0.1:1880/,*** The browser will load the Node-RED User interface, allowing us to start using it (**Figure III .32**).

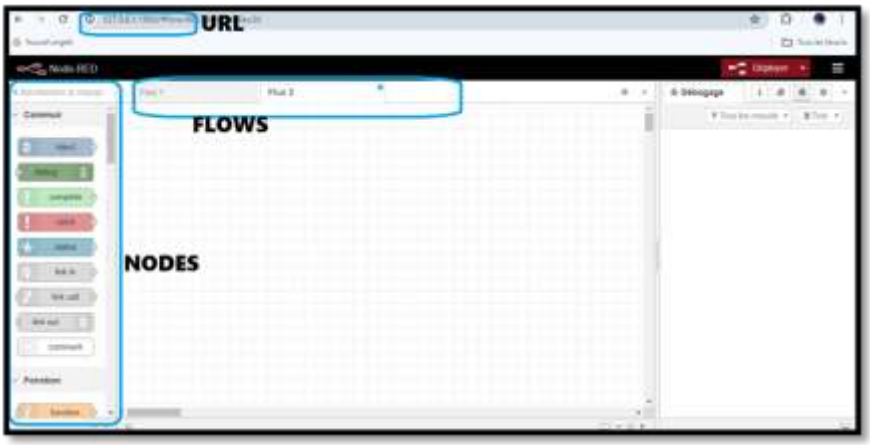


Figure III .32: Programming environment Node-Red

After executing the previous commands, we can install new nodes. **Figure III .33** illustrates how to install nodes.

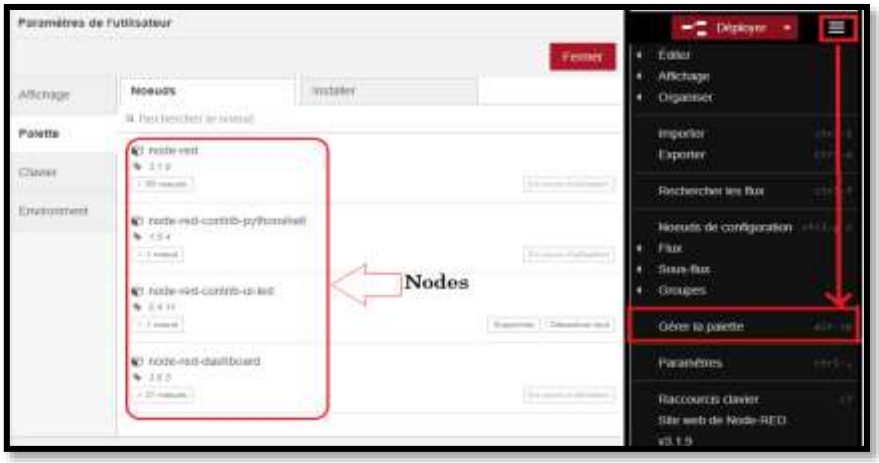


Figure III .33: Install Nodes

III.4.c Programming with Node-Red

The program stored on the hard disk is used for loading and use within the NODE RED environment. Our workflow consists of three blocks (**Figure III.34**)

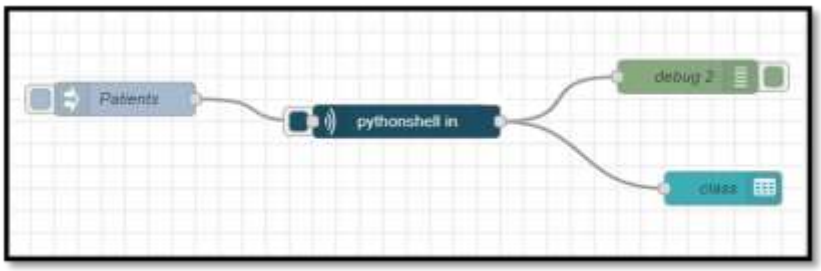


Figure III.34: System flow in the Node-Red

Data transmission: The Send Data block is usually used to send data that is input from sensors, but in our case, we don't have sensors. Therefore, we input the data in vector form. **(Figure III.35).**

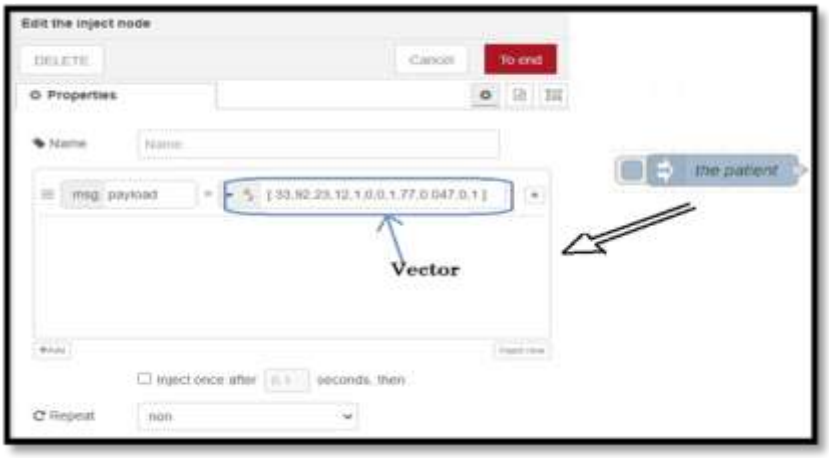


Figure III.35: node data

Processing data: Data processing: Upon receiving the data from the first set, it is processed using a node programmed in Python. This processing involves categorizing the patients (**Figure III.36**).

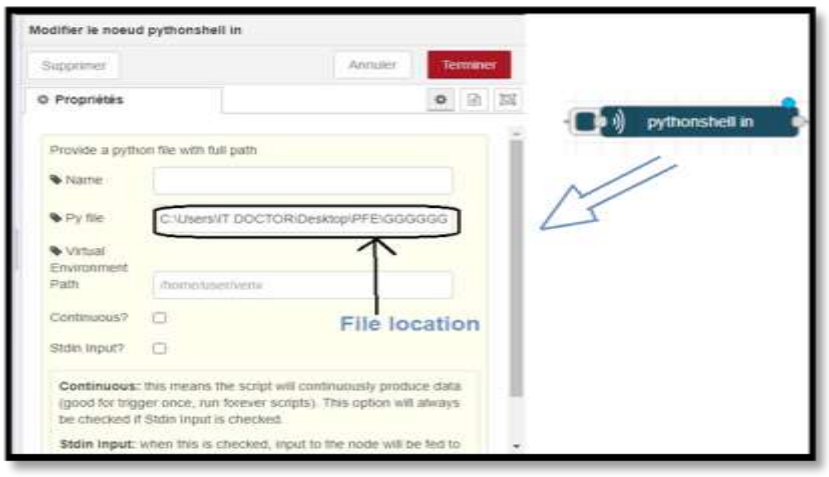


Figure III.36: node in Python

Display of results: After processing the data and getting the results, which are usually displayed by another node, the patient's classification is displayed.

III.5 Test

In this example, the data of 5 patients is entered (one at a time). Upon receiving the data from the injection nodes, the patients are categorized using a Python programmed node. To display the input data in IHM's gauge, 12-gauge nodes are added for each indicator **Figure 37**.

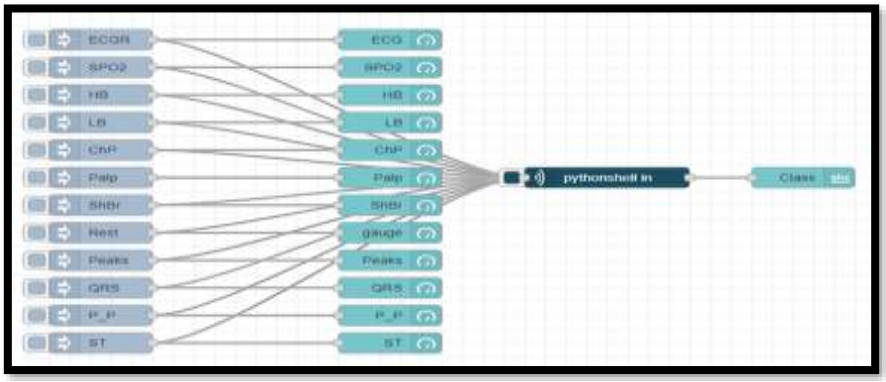
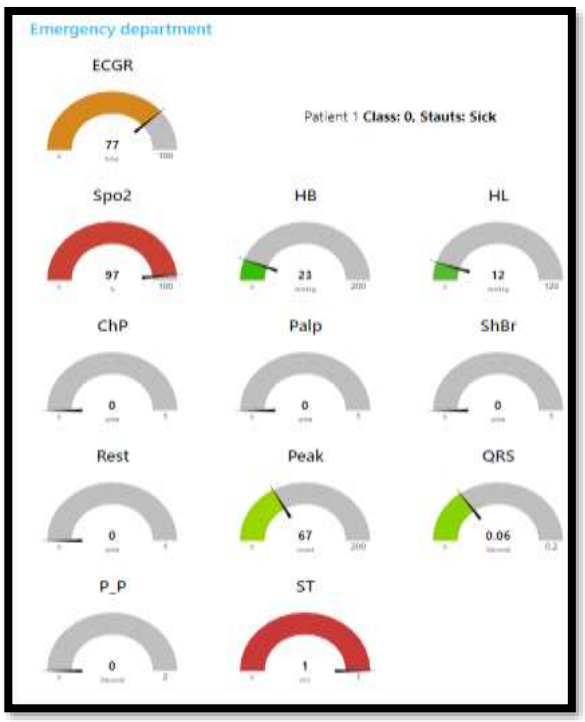


Figure III.37: Patient Data Integration and Classification Flow

The Node-RED Dashboard UI is then used to display the patient categorization by health status as shown in the following figures **III.37,III.38, III.39, III.40 and III.37**



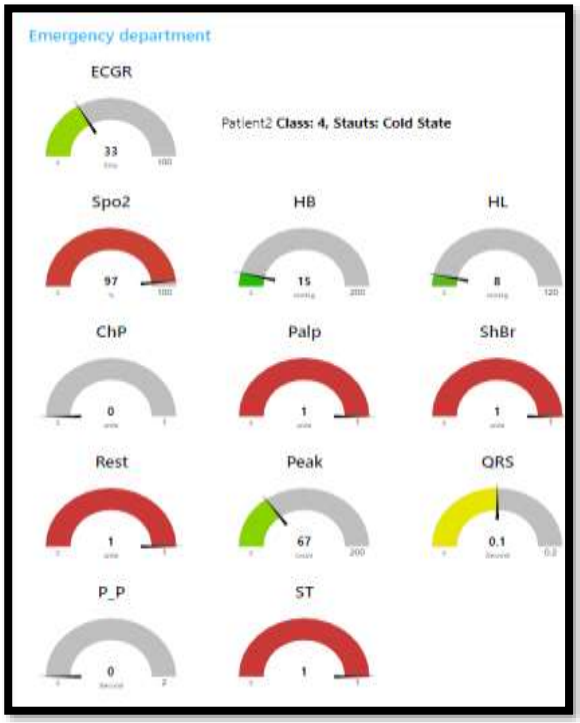
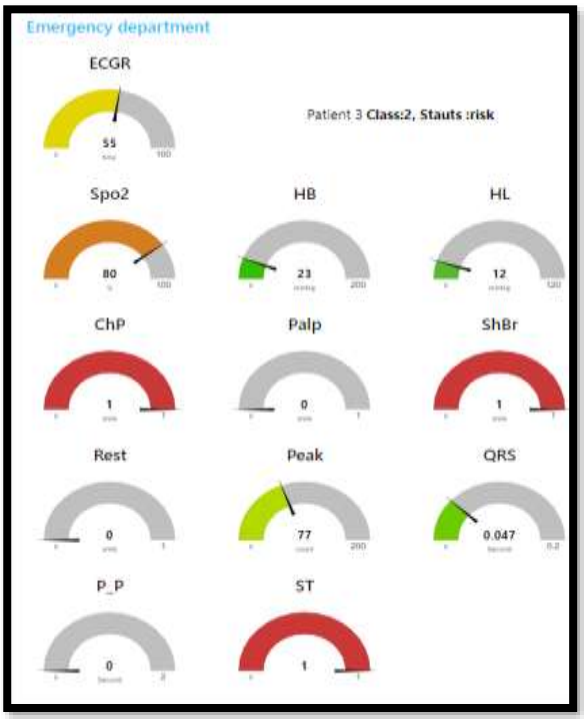


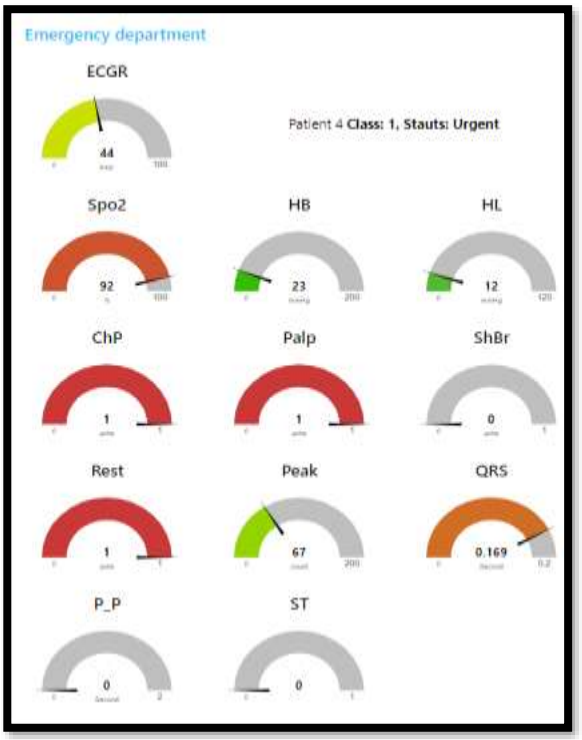
Figure III.37: Test patient1

Figure III.38: Test patient2

Figure III.39: Test patient **3**

Figure III.40: Test patient **4**





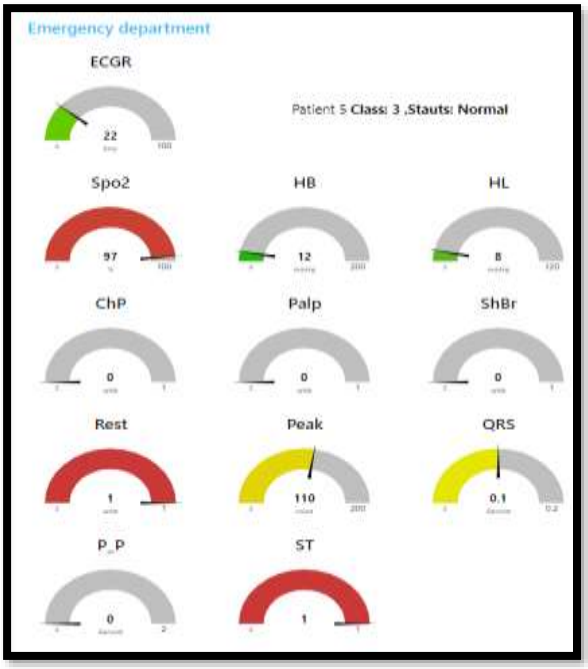


Figure III.41: Test patient **5**

The patients were then displayed in the following **Table III.7**

Table III.7: Patient classifications

Emergency department

patient	Class
Patient 1	Class 0, status: Sick
Patient 2	Class 4, status: cold state
Patient 3	Class 2, status: risk
Patient 4	Class 1, status: Urgent
Patient 5	Class 3, status: Normal

III.6 Conclusion

In this chapter, the details of implementing an artificial intelligence system for classifying and prioritizing patients in the ED were presented. The datasetwas explained to facilitate the process. Then, the performance of four ML Models was examined to determine the most reliable model for the system. Several parameters, such as the number of trees in the RF model, the size of the training data, and the learning rate for ANN, were used to optimize the models' performance. The best accuracy of each model was compared to achieve the best results, with a particular focus on accuracy and the CM as key indicators. Ultimately, the artificial neural network classifier was selected for prioritizing patients in the ED due to its highly effective performance, achieving exceptional accuracy and efficiency in patient classification, this system was then Development using Node-RED to manage and visualize the data and results.

General conclusion

General conclusion

In this thesis, an intelligent system for triaging and prioritizing patients in emergency departments was developed using artificial intelligence algorithm. An overview of emergency department cases and the importance of triage and prioritization was first provided. Various artificial intelligence models, including artificial neural networks, support vector machines, logistic regression, and random forests, were explored, highlighting their characteristics and the key Python libraries employed. Previous studies demonstrating the potential benefits of enhancing emergency department healthcare services, such as improved patient organization, prioritization of critical cases, enhanced patient experience, and reduced mortality rates, were also examined.

Through rigorous testing and evaluation, the artificial neural network model emerged as the most reliable and accurate classifier for patient prioritization in the emergency department setting. Extensive parameter tuning, including the number of epochs, training data size, and learning rate, was performed to optimize the model's performance. The selected neural network classifier achieved exceptional accuracy, with a low error rate and effective patient classification, as evidenced by the confusion matrix analysis.

The developed system was subsequently Development using the Node-RED platform, facilitating data management, processing, and visualization through a user-friendly web interface. The integration of the intelligent prioritization system into the emergency department workflow has the potential to streamline operations, enhance patient care, and improve overall efficiency.

Future research in the field of embedded systems and electronics should focus on developing dedicated hardware solutions to further enhance the performance and real-time capabilities of the intelligent prioritization system. By leveraging specialized hardware architectures and optimized embedded systems, the system could potentially achieve faster processing times, reduced power consumption, and improved reliability. Additionally, the integration of advanced sensors and medical devices could provide more comprehensive and accurate patient data, further refining the classification process.

Furthermore, the development of embedded systems with secure communication protocols and robust data protection mechanisms would be crucial for ensuring the privacy and integrity of sensitive patient information. Collaborative efforts between researchers in artificial intelligence, embedded systems, and healthcare could lead to innovative solutions that seamlessly integrate intelligent prioritization algoritm with embedded hardware platforms, ultimately enhancing patient care and resource management in emergency departments.

In the rapidly evolving field of healthcare technology, the application of artificial intelligence and embedded systems holds immense promise for improving patient outcomes and healthcare delivery. The intelligent prioritization system developed in this thesis represents a significant step towards leveraging advanced technologies to address critical challenges in emergency department operations, paving the way for future research and development in the realm of embedded systems and electronics.

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