الجمهورية الجزائرية الديمقراطية الشعبية

MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH

UNIVERSITY YAHIA FARES OF MEDEA

FACULTY OF TECHNOLOGY

Department of Electrical Engineering



Final Year Project

Dissertation Submitted in Partial Fulfillment of the Requirements for the Master Degree

In Automatic and Systems

Option: Automatic and Systems

TITLE

Application of 3D Vision System for Trajectory Planning: Application to Mobile Robots

Proposed and directed by:

- Mr. Sofiane TCHOKETCH KEBIR
- Mr. Mohamed MAAZOUZ

Prepared and presented by:

Mr. Abderrahmane FERRAH

DEDICATION

This thesis is dedicated to:

The sake of Allah, my Creator and my Master.

My great teacher and messenger, Mohammed (May Allah bless and grant him), who taught us the purpose of life,

My great parents, who never stop giving of themselves in countless ways,

My dearest wife, who leads me through the valley of darkness with light of hope and support,

My beloved child: Mohamed redha

For all my teachers from primary to graduation

To all my family, the symbol of love and giving, my friends who encourage and support me, all the people in my life who touch my heart.

FERRAH abderrahmane

ACKNOWLEDGMENTS

First of all, we thank Almighty God for giving me courage, patience and strength during all these years of study.

Many people have helped me along the way. Their guidance, good humor, advice and inspiration sustained me through the months of work. First of all, I'd like to thank all of them.

Furthermore, I would like to express my gratitude to my supervisor Mr. Sofiane TCHOKETCH KEBIR for proposing this challenging project for their advice and support during the realization of this project

I wish to thank the laboratory and department for placing its infrastructure and material at my disposal.

I'm also grateful to the library staff for all the assistance they offered us when we were looking for documentation

I'm indebted to my family and polish friends for all their supports throughout the period of my study.

Last but not least, I would like to thank all people who helped me in one way or another to make the realization of this project in reality.

ملخص

هدفنا في هذه المذكرة هو تطبيق أنظمة التمثيل البصري ثلاثي الأبعاد لتخطيط مسار روبوت متحرك من خلال اكتشاف وتفادي العقبات .ويقوم الروبوت أولا على عنصر الكاميرا " كينكت" ,اردوينو, اردوينو وايفاي شيلد للاتصال بين الروبوت والكمبيوتر،وثانيا على اردوينو موتور شيلد يعتمد على الموديلL293D لتغذية المحركات مما يضمن الحركة للروبوت.

ننهي عملنا من خلال تطبيق عملي يوضح الأداء.

كلمات البحث: روبوت متحرك, كاميرا " كينكت"، اردوينو، اردوينو وايفاي شيلد ، اردوينو موتور شيلد

ABSTRACT

Our goal in this master thesis is to apply 3D visualization systems to plan a moving robot path by detecting and avoiding obstacles.

First the robot based on the RGB D camera, Arduino and Arduino wifi Shield for communication between Robot and computer, and second on Arduino Motor Shield Based on L293D model to power ON the motors, thus ensuring the movement of the robot.

We finish our work through a practical application that demonstrates performance.

Keywords: *Mobile Robot, RGB D Camera, Arduino, Arduino wifi Shield, Arduino Motor Shield*

RESUME

Notre objectif dans cette mémoire est d'appliquer des systèmes de visualisation 3D pour planifier un chemin de robot mobile en détectant et en évitant les obstacles.

D'abord, le robot basé sur la caméra Kinect RVB D, Arduino et Arduino Shield WiFi pour la communication entre le Robot et l'ordinateurs .Ensuite Arduino Shield Moteur Basé sur le modèle L293D pour alimenter les moteurs, assurant ainsi le mouvement du robot.

Nous finissons notre travail à travers une application pratique qui démontre la performance.

Mots-clés : *Robot Mobile, Caméra RVB-D, Arduino, Arduino Shield WiFi. Arduino Shield Moteur*

LIST OF ABBREVIATIONS

AI	Artificial Intelligence
RIA	Robot Institute of America
JIRA	Japanese Industrial Robot Association
AMR	Autonomous mobile robot
AGV	Autonomous guided vehicle
RUR	Rossum's Universal Robots
SRI	Stanford Research Institute
GPS	Global Positioning System
DOF	According to degree of freedom
MGC	Motion and Gesture Control
GUI	Graphical user interface
DC	Direct current
AC	Alternative current
SMPS	Switched-mode power supply
HMI	Human Machine Interface
PACS	Picture archiving and communications system
ASL	American Sign Language
HMM	Hidden Markov Model
2D	Two Dimensions
3D	Three Dimensions
DIP	Digital Image Processing
TV	Television
DPI	Dots per inch
PIXEL	Picture element
VOXEL	Volume element
KB	kilo bytes
JPEG	Joint Photographic Experts Group
TIFF	Tagged Image File Format
DNG	Digital Negative Format
PNG	Portable Network Graphics
GIF	Graphics Interchange Format
BMP	Bitmap

PSD	Photoshop Document
CAD	Computer Aided Design
MRI	Magnetic resonance imaging
CAT	Computer-assisted tomography
KLT	Karhunen-Loeve Transform
NCUT	Normalized Cut
MCL	Markov Clustering
HAC	Hierarchical Ascending Classification
ISODATA	Iterative Self-Organizing Data Analysis Technique Algorithm
FCM	Fuzzy c-means
MATLAB	MATrix LABoratory
IDE	Integrated development environment
MAH	Milliampere hour
PWM	Pulse Width Modulation
ICSP	In-Circuit Serial Programming
USB	Universal Serial Bus
SRAM	Static Random Access Memory
EEPROM	Electrically Erasable Programmable Read-Only Memory
WIFI	Wireless Fidelity
IP	Internet Protocol
TCP	Transmission Control Protocol
SD	Secure Digital
SPI	Serial Peripheral Interface
WEP	Wired Equivalent Privacy
WPA	Wireless Protected Access
PCB	Printed circuit board
EMF	Electromotive force
RGB-D	Red Green Blue Depth
SXGA	Super Extended Graphics Array
VGA	Video Graphics Array
NUI	Natural User Interface

TABLE OF CONTENTS

LIST OF ABBREVIATION……..I
TABLE OF CONTENTS…….III
LIST OF TABLES…….. VIII
LISTE OF EQUATIONS.....VIII
LIST OF FIGURES…….. IX
GENERAL INTRODUCTION……...XII

CHAPTER I: ROBOTIC GENERALITIES.....1

I.1. Introduction ……2
I.2. Introduction to Robotics…….2
I.3. Definitions……3
I.3.1. Definition 1…….3
I.3.2. Definition 2……3
I.3.3. Robot definition by Robot Institute of America (RIA)……3
I.3.4. Robot definition by Japanese Industrial Robot Association (JIRA)……..3
I.3.5. Definition of Mobile Robots……..3
I.4. Robots History ……4
I.4.1. First achievements Before IXth century (between myth and reality)……4
I.4.2. The first automated systems (Clocks and fountains) IXth - XIIIth Century……4
I.4.3. The first Automated systems (Clocks and fountains) XIIIth - XVIIth Century……4
I.4.4. The first programmable logic controllers (Clocks and fountains) IXth-XVIIthCentury……5
I.4.5. The XVIIIth century automated systems are simulate the human movement……5
I.4.6. The XIXth century automated systems for Industrial use……5
I.4.7. Robotics concept in the XXth Century……5
I.4.8. The XXth Century robots……5
I.4.9. 1960-80: First mobile robots……6
I.4.10. Since 2000: Exploration……6
I.4.11. Since 2000: Democratization of robots ……6
I.5. Robot components ……6
I.5.1. Effectors……6
I.5.2. Sensors……6
I.5.3. Other Components……7
I.6. Robots classification……8
I.7. Robots technology……8
I.8. Robots type……8
I.8.1. Manipulator Robots……8

I.8.2. Mobile Robots……10
I.9. Fields of Application……17
I.9.1. Nuclear Industry……17
I.9.2. Civil Security……18
I.9.3. Chemical……18
I.9.4. Mine……18
I.9.5. Agricultural……19
I.9.6. Cleaning……19
I.9.7. Space……19
I.9.8. Industry……20
I.9.9. Underwater……20
I.9.10. Military……20
I.10. Conclusion……21

CHAPTER II: ROBOT MOTION AND GESTURE CONTROL……22

II.1. Introduction ……23
II.2. Introduction to Motion……23
II.3. Motion definition……24
II.3.1. Motion Examples……24
II.4. Motion types……24
II.4.1. Uniform motion……24
II.4.2. Non uniform motion……24
II.5. Motion classifications……24
II.5.1. Translator motion……25
II.5.2. Rotator motion……25
II.5.3. Vibrator motion……25
II.6. Introduction to Gesture Control……25
II.7. Gestures definition……26
II.8. Gestures types……26
II.8.1. Hand and arm gestures……26
II.8.2. Head and face gestures……27
II.8.3. Body gestures……27
II.9. How to Recognize Gestures!……29
II.10. Gesture Recognition System……29
II.11. Vision-based Gesture Recognition……30
II.11.1. Pre-processing……30
II.11.2. Segmentation……30
II.11.3. Feature extraction……30

II.12. Gestures and Communication system……..…….....30
II.13. Application areas for Gesture Control Technology……...…….…31
II.13.1. Entertainment field…….…… ……..…....30
II.13.2. Consumer electronics field……...……..……30
II.13.3. Automotive field…….……..……31
II.13.4. Healthcare field…….…….……..32
II.13.5. Education field.…… ……..…….....……...32
II.13.6. Simulation field…….…….....……..……32
II.14. Gesture Interaction advantages…….……32
II.15. Gesture Interaction disadvantages……32
II.16. Sign signal transmission Channel……..……33
II.17. Hidden Markov Model (HMM)…….33
II.18. Hand recovery……...……....……..33
II.19. Machine sign language recognition……...…..…….33
II.20. Conclusion…… ……...……34

CHAPTER III: DIGITAL IMAGE PROCESSING, SEGMENTATION & 3D RECONSTRUCTION……..…… ……...….35

III.1. Introduction ……..……...……. ……...…36
III.2. Introduction to digital image processing…… …..……..…..…..36
III.3. Images definition……...……...……37
III.4. Image types…… ….....……...……..37
III.4.1. Analog image……..……..……..……37
III.4.2. Digital Image……...…… ….....…..…..……...…37
III.5. Digital image characteristics……..…...…. ……..…..…..…38
III.5.1. Image size……...……...……...…38
III.5.2. Image resolutions…… …..……...……41
III.6. Image color coding…… ……..…. …..……...…….42
III.7. Image weigh…… ……..…….. ……42
III.7.1. How to calculate a 640x480 image in true color…….....…….43
III.8. Image histogram……...…….……....….43
III.8.1. Histogram types……..…….……....….44
III.9. Image contour and texture……...……...……...….44
III.10. Image brightness…… ……..……..……...….44
III.11. Image contrast……..…. ……..…… ……..….45
III.12. Image quantification……...……...…. …..…..……45
III.13. Image thresholding……...…..……...……..……45
III.14. Image noise…… ……..……..……... ….45

III.15. Image formats……46
III.16. Image types……46
III.16.1. Binary images……46
III.16.2. Grayscale images……47
III.16.3. Color images……47
III.16.4. Indexed Images……48
III.16.5. Raster Images……48
III.16.6. Vector images……48
III.17. Some application domains of digital image processing……49
III.17.1. Medicaldomain……49
III.17.2. Agriculture domain……49
III.17.3. Industrydomain……49
III.17.4. Law enforcementdomain……49
III.18. Segmentation……50
III.18.1. Definition……50
III.18.2. Color image segmentation……50
III.18.3. Color image segmentation strategies……51
III.18.4. Different approaches to segmentation……53
III.19. Introduction to 3D vision systems……60
III.19.1. Vision by computer……60
III.19.2. Classification of Vision by Computer Systems……60
III.19.3. 3D reconstruction……61
III.19.4. 3D reconstruction techniques……61
III.20. Stereoscopic vision……62
III.21. Conclusion……63

CHAPTER VI: TRAJECTORY PLANNING AND ROBOT CONTROL, IMPLIMENTATION & RESULTS……64

IV.1. Introduction……65
IV.2. Connecting and mounting the mobile robot……65
IV.2.1. Power Supply……65
IV.2.2. Arduino UNO……66
IV.2.3. Arduinowifi Shield……67
IV.2.4. Arduino Motor Shield Based on L293D……68
IV.2.5. DC motors……70
IV.2.6. Robot……73
IV.2.7. Xtion pro live RGB and Depth Sensor……74
IV.3. MATLAB Software……77

IV.3.1. MATLAB language……..……..…...77
IV.3.2. MATLAB working environment……..……...……..……77
IV.3.3. Handle Graphics…….……..…….…..……78
IV.3.4. MATLAB mathematical function library……..…..……..……78
IV.3.5. MATLAB Application Program Interface (API)……...……...……..78
IV.4. IDE Arduino Software……..…...……..78
IV.4.1. Arduino Program Development…….……78
IV.4.2. Structure of an Arduino Sketch…….……...……79
IV.4.3. Parts of the IDE main screen. …….……...…..……79
IV.4.4. Arduino Specific Functions……79
IV.5. Mobile robot programming steps…….……...…….80
IV.5.1. Using Matlab Software……..82
IV.5.2. Using IDE Software……..……...……87
IV.6. Discussion and perspective of test results……...……..…….87
IV.6.1. First test……..……..……..……..89
IV.6.2. Second test……...……..……..…….91
IV.6.3. Third test……...……..……..94
IV.6.4. Fourth test……...……..…..…….96
IV.6.5. Fifth test……..……..……..99
IV.7. Conclusion…….……...…..……102

GENERAL CONCLUSION……..……...……...……..…..……...XIII

BIBLIOGRAPHY……..……XVI

LIST OF TABLES

Table.3.1. Image color coding……..……..…..……..…….42
Table.3.2. How to calculate a 640x480 image in True color……..…….43
Table.3.3. Advantages and Disadvantages of segmentation techniques……..……..……..…..……57
Table.4.1. Xtion PRO LIVE sensor characteristics…… …...……75

LIST OF EQUATIONS

3.1. Euclidean distance ……..……..……39
3.2. City block distance ……...……....…...…… 39
3.3. Chessboard distance ……...……...……. 39
4.1. First angle calculation……..……..……..…..……..84
4.2. Second angle calculation…….……...…….84
4.3. Third angle calculation……..……..…….84
4.4. Distance calculation…….....……...……86

LIST OF FIGURES

Figure.1.1. Fountains of Al-Jazari……4
Figure.1.2. Robot System……7
Figure.1.3. Manipulator Robot……9
Figure.1.4. Mobile robots…… 10
Figure.1.5. Robot security organs……12
Figure.1.6. Service robot……14
Figure.1.7. Unicycle robot…… 15
Figure.1.8. Tricycle robot……16
Figure.1.9. Car Robot…… 16
Figure.1.10. Omni-directional robot……18
Figure.1.11. Nuclear Industry robot……18
Figure.1.12. Monitoring of street passers robot……18
Figure.1.13. Emergency assistance robot…… 19
Figure.1.14. Picking fruits and vines processing robot……19
Figure.1.15. Exploration robot……20
Figure.1.16. Conveying and monitoring robot……20
Figure.1.17. Monitoring and ammunition manipulation robot……21
Figure.2.1. Ballsmotion……23
Figure.2.2. Five senses…… 25
Figure.2.3. Body gestures……27
Figure.2.4. Hand and arm gestures……27
Figure.2.5. Head and face gestures……28
Figure.2.6. Hand gesture……28
Figure.2.7. Gesture recognition system……30
Figure.2.8. System architecture……31
Figure.2.9. Sign signal transmission channel……33
Figure.3.1. Image definition……37
Figure.3.2. Image size……38
Figure.3.3. Image pixel……39
Figure.3.4.4 and 8 connected components……40
Figure.3.5. Image resolution…… .41
Figure.3.6. Image histogram……43
Figure.3.7. Image brightness……44
Figure.3.8. Thresholding of an image…… 45
Figure.3.9. Binary image……46
Figure.3.10. Grayscale image……47

Figure.3.11. Color images……47
Figure.3.12. Indexed images……48
Figure.3.13. Vector image……49
Figure.3.14.RGB image processing steps……51
Figure.3.15. Scalar strategy……51
Figure.3.16. Marginal strategy……52
Figure.3.17. Vector strategy……52
Figure.3.18. Spatial analysis and pixels classification……54
Figure.3.19. Regions dividing and merging……54
Figure.3.20. Region growing and merging……55
Figure.3.21.ISODATA……59
Figure.3.22.K-Means clustering……60
Figure.4.1. Connecting and mounting the mobile robot……65
Figure.4.2. Power Supply……66
Figure.4.3. Arduino UNO……66
Figure.4.4.wifi Shield……67
Figure.4.5. Motors Shield……69
Figure.4.6. H-bridge……69
Figure.4.7. Dc motors……70
Figure.4.8. Moving part and body of the Motor……71
Figure.4.9.*emf* and rotation sense……71
Figure.4.10.H bridge……73
Figure.4.11. Parts of the Robot Base Chassis……73
Figure.4.12. Assembled parts of the robot……74
Figure.4.13. Xtion pro live RGB and Depth Sensor……75
Figure.4.14.RGB and Depth image……76
Figure.4.15.IDE main screen……79
Figure.4.16.flow chart of the proposed method……81
Figure.4.17. Image acquisition with 4 and 3 obstacles……82
Figure.4.18. binary image with 4 obstacles……83
Figure.4.19. binary inflated image with 4 obstacles……83
Figure.4.20. binary inflated image with 3 obstacles……83
Figure.IV.21. first path generated by PRM algorithm……84
Figure.IV.22. second path generated by PRM algorithm……84
Figure.4.23. Initial position……85
Figure.4.24. The robot rotation……85
Figure.4.25. The robot reaches the desired point……86

Figure. 4.26. The robot reaches the desired point and continue to the second link then back to the initial position of orientation……..……...……..86
Figure.4.27.MATLAB GUI Interface…… ...……...…..…… 88
Figure.4.28. First acquisition ……...……..……...89
Figure.4.29. Binary and inflated image…….……..…...…… 89
Figure.4.30. Obstacles detection and robot removing……..……..…… 90
Figure.4.31. Robot removed from image……...……..…..……...……90
Figure.4.32. Path generation…….……...……...… 91
Figure.4.33. Second acquisition…….....…….…...…….…… 91
Figure.4.34. Binary and inflated image……...……..…….. 92
Figure.4.35. Obstacles detection and robot removing……...……..……...…….. 92
Figure.4.36. Robot removed from image……...……...…….…..93
Figure.4.37. Path generation…….…..……...……..93
Figure.4.38. Third acquisition …….……..……...94
Figure.4.39. Binary and inflated image…….…….…….....…… 94
Figure.4.40. Obstacles detection and robot removing……...…..…… 95
Figure.4.41. Robot removed from image……...……..…..……...……95
Figure.4.42. Path generation…….……...……...96
Figure.4.43. Fourth acquisition ……...……..……...96
Figure.4.44. Binary and inflated image……..……..……...…… 97
Figure.4.45. Obstacles detection and robot removing…..……..…… 97
Figure.4.46. Robot removed from image……...……...……..……98
Figure.4.47. Path generation……....…….……...…… 98
Figure.4.48. Fifth acquisition ……..……..……... 99
Figure.4.49. Binary and inflated image…….……..…..……...…… 99
Figure.4.50. Obstacles detection and robot removing…….…..…… 100
Figure.4.51. Robot removed from image……...…….……..…..……100
Figure.4.52. Path generation…….……..……...…… 101

GENERAL INTRODUCTION

Robotics can help the man in difficult, repetitive or painful tasks. Moreover, it constitutes the dream of substituting the machine for the man in these tasks.

Robotics has two main points of interest: manipulative robotics (industrial robotics) and mobile robotics. One of the major problems of mobile robotics is trajectory planning. Around this path planning problem, many studies have been carried out in order to develop general methods to guide robots.

The robot path planning problem is a very challenging problem in robotics.

The main goal of this problem is to construct a collision-free path from a starting position to an end or destination position. However, this navigation problem includes several difficult phases that need to be overcome, such as obstacle avoidance, position identification, and so forth. This problem can be broken in to several subtasks. A reliable navigation algorithm must be able to:

1. Identify the current location of the robot.
2. Avoid any collisions.
3. Determine a path to the object.

For this reason, mobile robot navigation problem is a challenging problem, and a number of studies have been attempted, resulting in a significant number of solutions.

This thesis is organized into four major chapters:

The first, discusses historical reviews of the robots, generalities about robots, historical reviews presentation and definitions on it, the different types of robots and their Fields of applications. The second, deals with motion and gesture control: presentation and definitions. The different types of MGC and their Fields of applications. The Third expose Image processing technics, segmentation and 3D reconstruction. Presentation and definitions on it, the different types of Image processing, segmentation and 3D reconstruction and their applications. The Fourth explains the methods used to program the robot; we have used two software, and seven hardware’s for this reason. Also we present the last steps of adaptation between the different parts previously developed, performances and tests obtained with the applications that we realized.

Finally, we will conclude with a conclusion that summarizes our work, as well as perspectives that can be considered to make improvements to the future.

CHAPTER I

ROBOTIC GENERALITIES

I.1. Introduction

Technology is perhaps the greatest agent of change in the modern world. The world is witnessing a constant development of technologies this includes all technical fields and in particular the field of automation.The popular imagination has long foreseen a world where robots take over all manner of everyday tasks.Advances in robotics technology are making human-machine collaboration a daily reality.

Better and cheaper sensors make a robot more able to understand and respond to its environment, robot bodies are becoming more adaptive and flexible, the designers taking inspiration from the extraordinary flexibility and dexterity of complex biological structures, such as the human hand.

Robots are becoming more connected, benefiting from the computing revolution by being able to access instructions and information remotely, rather than having to be programmed as a fully autonomous unit.

In this chapter we will talk about robotics: presentation and definitions the different types of robots and their Fieldsof applications.

I.2. Introduction to Robotics

Robotics is a modern technology and it is one of the most exciting fields of scientific research, even todaymost processesare automated by robots.

Robotics is the science that interested in robots. Infactit is a multi-disciplinary fieldsspanning many disciplines such asmathematics,electronics,mechanics,computer science,automatic and systems, ArtificialIntelligence (AI),neuroscience,cybernetics,physics,and biology... etc.

Robotics is used in manyindustries such as automotive, medicine, appliances andothers.

The most complex machines can be assembled using robotics. Robots can be fixed or mobile depending on the application. FixedRobots are generally used in factories, hospitals, agriculture…etc.However mobile robots are generallyused in dangerous environments like nuclear, military and mineclearance…etc.

I.3.Definitions

I.3.1.Definition 1

- ❖ According to:

- ➢ ***Oxford American Dictionary***

- A robot is a machine able of carrying out a complex series ofactions automatically.

- ➢ ***Merriam-Webster Dictionary***

- A robot is amachine that looks and acts like a human being.
- A robot is a device that automatically performs repetitive tasks.

I.3.2.Definition 2

- ❖ A robot is a poly-articulated mechanical system, drivenby actuators and controlled by a calculator, whichis intended to perform a wide variety of tasks.
- ❖ A robot is a mechatronic device (combining mechanical, electronic and computer science) automatically performing various tasks.
- ❖ It is an intelligent machine that requires autonomy ofmovement.

I.3.3.Robot definition by Robot Institute of America (RIA)

RIA presents its definition of a robot as:

- ❖ A programmable multifunctionalmanipulator designed to move materials, parts, tools, orspecialized devices through various programmed functions.[1]

I.3.4.Robot definition by Japanese Industrial Robot Association (JIRA)

- ❖ JIRAs chiefly concerned with industrial robots, but hascreated a robot classification system.[1]
- ➢ Manipulators (Manual, Sequential, Programmable)
- ➢ Numerically Controlled
- ➢ Adaptive
- ➢ Smart
- ➢ Intelligent Mechatronic system

I.3.5.Definition of Mobile Robots

1. An automatic machine, Capable to move aroundin its environment and is not fixed to

one physical location.Mobile robots can be"autonomous" (AMR – autonomousmobile robot) which means, they are able of navigatingon an uncontrolled environment without the need for physical or electro-mechanical guidance devices.Alternatively mobile robots can work automatically or canbe controlled by a computer or an operator.

2. It is an autonomous vehicle able to move in any given environment.

I.4.Robots History

I.4.1. First achievements Before IXth century (betweenmyth and reality)

- In Egypt, articulated jaw of an Anubis mask,Amon'sarm moves to designate the new pharaoh.[2]
- Ctesibios and Heron of Alexandria. Hydraulic orpneumatic systems as fountains with animated figuresand birds singing.
- In China, the equatorial armillary spheres (assembly of rings or globes depicting celestial movements) fromGuoShouchang

I.4.2.The first automated systems (Clocks and fountains)IXth - XIIIth Century

- 809, Sultan HarounAl-Rachid offer the Charlemagne,the first mechanical automated system (clock).(See Figure.1.1. below)
- At the end of 12th century, the fountains of Al-Jazarifor the comfort of the man. (system that can reminds usof the flush of our bathroom).[2]

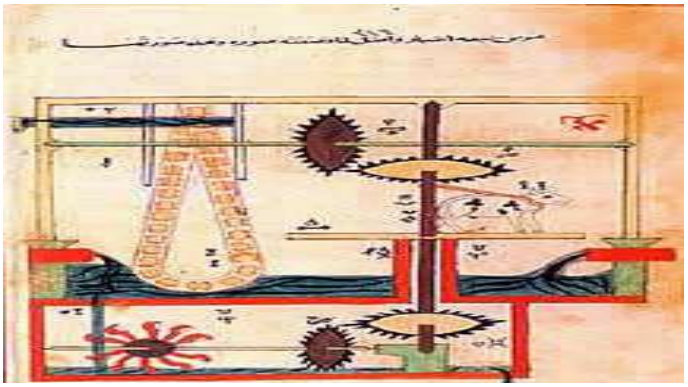


Figure.1.1. Fountains of Al-Jazari

I.4.3.The first Automated systems (Clocks and fountains)XIIIth - XVIIth Century

- 13th-15th: Automated mechanical and hydraulicsystems ... etc.

- In 1350, a mechanical rooster was erected on Strasbourg Cathedral, was flapping its wings and singing everydays at noon.
- 1496-1499: The clock tower, Venice.
- 1452-1519 Leonardo da Vinci, developsa lion articulated. [2]

I.4.4.The first programmable logic controllers (Clocks andfountains) IXth - XVIIth Century

- 1576-1626 Salomon of Caus,hydraulic mechanismsand the first programmable machine.
- 1642 Pascal invents Pascaline,first calculator.

I.4.5.TheXVIIIth century automated systems are simulatethe human movement

- A PLC programming system.
- 1721-1790 Pierre Jacquet-Droz, a writer, a draftsmanand a tympanon player (simplified piano).[2]

I.4.6.TheXIXth century automated systems for Industrialuse

- 1709-1782 Jacques de Vaucanson, appoint inspector of silk manufactures,he has the idea of using its pincylinder to program looms. This is the first useful of anautomated system.
- 1805 Joseph-Marie Jacquard,punch card programming.
- Charles Babbage1943, adapts the idea for calculators.In the first computer, the Mark I, used by the US Navyto calculate the trajectory of the shells.
- 1890 Thomas Edison, a doll speaks through a phonograph.
- 1898 Nikola Tesla, wireless controlled boat.[2]

I.4.7. Robotics concept in the XXth Century

- 1921 Karel Capek (writer Czech Republic, 1890-1938)invents the word ”Robot” (Robota, work forced, painfultask, servitude).The piece RUR, the Robots Universals ofrossum describes the revolt of robots!.
- 1941 Isaac Asimov, invents the term «Robotics” and predicts the increase of industrial robotics. He reframes therobots as a machine serving man and not dangerous.[2]

I.4.8.TheXXth Century robots

- 1947 first teleoperated electrical manipulator

- 1954 first programmable robot.
- 1961 appearance of a robot on a General Motors assembly line.
- 1963 use of vision to control a robot.[2]

I.4.9.1960-80: First mobile robots

- 1960-64: Opening of the Artificial Intelligence laboratories,Stanford Research Institute (SRI),Stanford University, and University ofEdinburgh.
- Late 60's: Implementation of"Shakey" first mobileRobot, integrating, perception, planning and execution.
- 1977: First French mobile robot HILARE AT LAAS.
- 1980-1990: Important development of Artificial Intelligence and robotics: new robots are constantly appearing.
- 1992: Establishment of the annual competition on mobile robotics.
- 1995: Establishment of the Robo-Cup
- 1997:firstextraplanar mobile robot on Mars.
- 1999:Launch of Aibo.[2]

I.4.10.Since 2000: Exploration

- 2003: Project "MarsExploration Rover" (Spirit and Opportunity).
- 2009:"Mars Science Laboratory" project succeeding the Rover project, planned shipment of Curiosity late2011.[2]

I.4.11.Since 2000: Democratization of robots

- Use ofdrones in real situation (Iraq ...).
- 2006: the Aibo project is no longer profitable enough,end of production.
- 2009: Nao robot used at Robocup-Soccer[2]

I.5.Robot components

I.5.1.Effectors

The robots are equipped with effectors allowing them to act in the environment:

I.5.2.Sensors

Robots are equipped with sensors allowing them to perceive the environment in which they evolve

❖ **Proprioceptive**

Measure the state of robot itself (position sensor (GPS), speed sensor, load sensor and batteries).

❖ **Exteroceptive**

Provideinformation on the state of the environment (temperature sensor, telemeter, compass and heat detector.

I.5.3.Other Components

Many other components can be present, depending on the type of robot considered: (See Figure.1.2. below)

- Storage devices (store programs, information about the environment ...).
- Communicationinterfaces (screen, WIFI ...etc).
- Power supply unit (battery, solar panels ...etc).

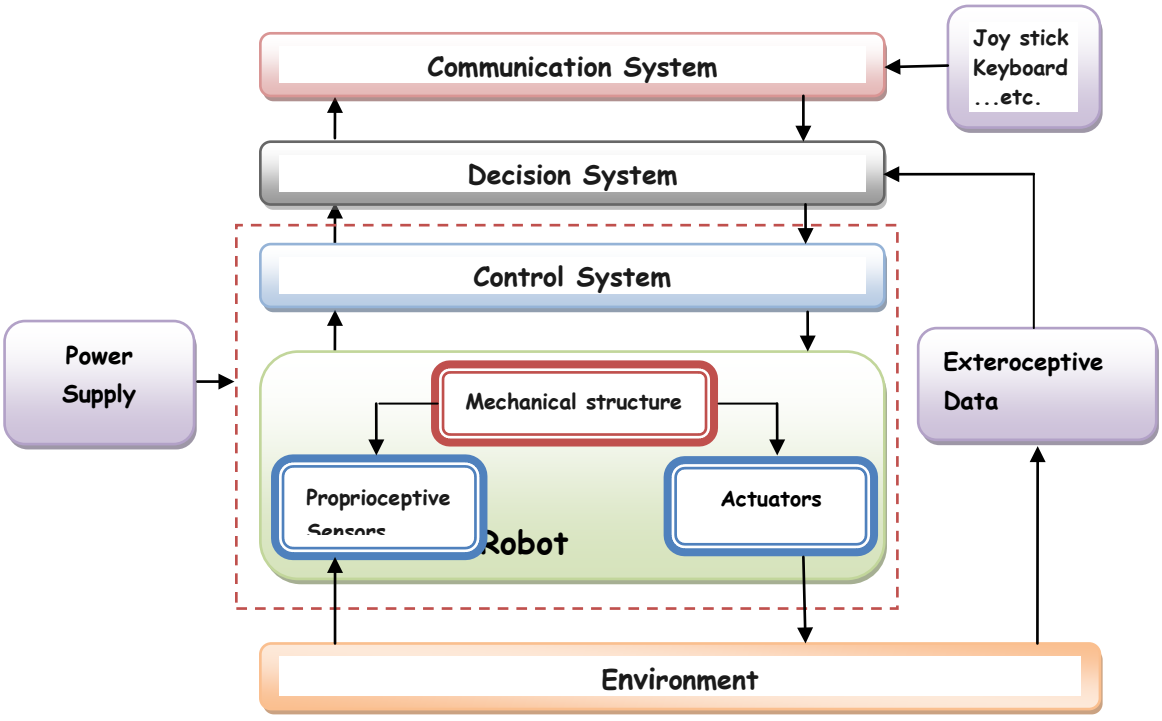


Figure.1.2. Robot System

I.6.Robots classification

There are various ways of classifying for robots

- Fixed or mobile.
- Serial or parallel.
- According to the degree of freedom (DOF).
- Rigid or flexible.
- Control,Point-to-point, autonomy and “intelligence”.

I.7.Robots technology

- Robot is a sophisticated and expensive equipment
- Main components: mechanical components, actuators,transmission devices, sensors, electronics and computers.
- Actuators are electric, pneumatic or hydraulic.
- Transmission device needed/required to transfer motion
- Sensors are required for feedback control alsopermitthe robot to: touch and feel, see and learn
- Specialised sensors for welding, painting, assembly and other industrial operations. [3]

I.8.Robots type

The two major families of robots are:

- Manipulator Robots.
- Mobile Robots.

I.8.1.Manipulator Robots

Manipulators are composed of an assembly of links and joints. Links are defined as the rigidsections that make up the mechanism, and joints are defined as the connection between two links.The device that attached to the manipulator which interacts with its environment to performtasks is called the end-effector.(See Figure.1.3. below).[4]



Figure.1.3. Manipulator Robot

I.8.1.1.Manipulator Robots classification

Manipulators can be classified according to a variety of criteria. The following criteria are:

- **By Motion Characteristics**
  - **Planar manipulator:**

A manipulator is called a planar manipulator if all the links move in planes parallel to one another.

- **Spherical manipulator:**

A manipulator is called a spherical manipulator if all the links perform spherical motions about a common stationary point.

- **Spatial manipulator:**

A manipulator is called a spatial manipulator if at least one of the links of the mechanism possesses a general spatial motion.

- **By Kinematic Structure**
  - **Open-loop manipulator (or serial robot):**

A manipulator is called an open-loop manipulator if its links form an open-loop chain.

- **Parallelmanipulator :**

A manipulator is called a parallel manipulator if it is made up of a closed-loop chain.

- **Hybrid manipulator:**

A manipulator is called a hybrid manipulator if it consists of open loop and closed loop chains at the same time.

I.8.1.2.Manipulator Robots types

Manipulator robots come in many forms these forms are divided into five major categories:

- Cylindrical robots
- Straight robots
- Spherical robots
- Articulated robots
- SCARA robots

I.8.2.Mobile Robots

A mobile robot is the one that can move in its environment independently, robot must be able to navigate in any environments;we are interested in studying wheeled robots, which are the main type of mobile robots.(See Figure.1.4. below).[4]



Figure.1.4. Mobile robot

I.8.2.1.Mobile robots classification

The classification of mobile robots is done according to several criteria (degree of autonomy, the system of locomotion and energy used ...).

I.8.2.2.Mobile Robots architecture

The architecture of mobile robots consists of three essential parts:

- The mechanical structure and motricity.
- The security organs.
- The information processing system and task management.

I.8.2.2.1. Mechanical structure and motricity

There are four types of mechanical structures that provide traction:

1. Wheeled robots.
2. Crawler Robots.
3. Walking robots.
4. Crawling robots.

I.8.2.2.1.1.Wheeled robots

Wheel mobility is the most common applied mechanical structure,this technical method ensures by the arrangement and the dimensions of wheels

I.8.2.2.1.2. Crawler robots

The use of caterpillars has the advantage of good ground adhesion and obstacle clearance capability, the use is geared towards employment on uneven ground or poor quality in adhesion

I.8.2.2.1.3.Walking robots

Walking robots are intended to perform various tasks whose access to the site is difficult.Locomotion is controlled in terms of joint coordinates. The different technical studies are getting closer to the march of animals and especially that of insects

I.8.2.2.1.4. Crawling robots

Crawling is a locomotion solution for a tunnel-like environment thatleads to making spindlystructures.

The system consists of a set of modules each having several mobilities; and the techniques used are derived from animal movement methods.

I.8.2.2.2.Security organs

It is dangerous to leave the mobile robot completely free,so it is mandatory to equipped it with organs guaranteeing security like brakes and sensors.(See Figure.1.5. below).

Two types of sensors are used:

- Proximetric sensors provide pre-collision detection (ultrasound, microwave, infrared).

- Contact sensors detect a collision or shock with the environment (electrical contact, variable resistance, optical fiber ...etc).

To guaranteeing security we have to know the system state (working or at rest)

Organizing the security of a mobile robot is represented on the following diagram:

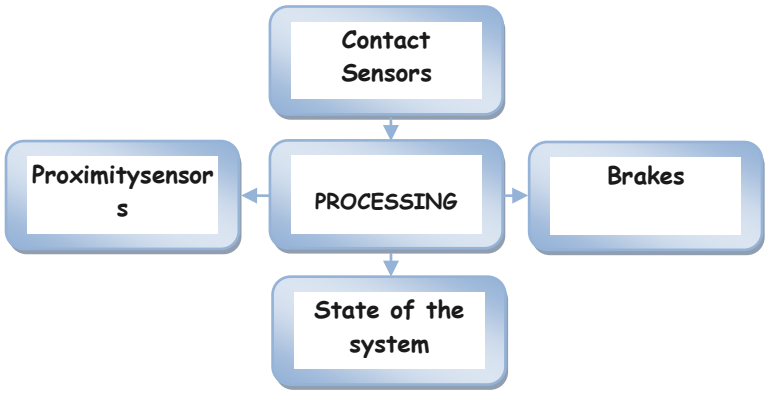


Figure.1.5. Robotsecurity organs

I.8.2.2.3.Data processing and task management

All the data processing and task management are controlled withmain computer module that allows the mobile robot to move and activate the various organs.

I.8.2.3.Mobile Robot parts

Getting straight to the point for a robot to be mobile (which can move), it should have some basic systems as mentioned below:

- **Locomotion System**

This system defines how the robot moves. Using this systemyou can make your robot move forward, backward, right, left and climb Up/down.

To accomplish this we need devices which convert electrical energy into mechanical energy. These devices are called actuators and the most popular actuator is the DC Motor.

- **Power Supply System**

We need a power supply to operate a robot. It acts as a food to the robot.For robotic applications (in fact most major applications), we need DC supply (usually 5V, 9V, 12V, sometimes goes as high as 18V, 24V, 36V, etc).

The power source should also be able to supply sufficient current to drive all the loads connected to it directly or indirectly.

❖ **Actuator System**

Actuators are devices which bring about the locomotionof the robot. There are many actuators used like DC Motors, Stepper Motors, Servo Motors, etc.

The way they are connected together, their circuit diagram, their location, orientation, position, etc.

❖ **Sensor System**

In order to interact the robot with the physical world, we need to introduce sensors (which can measure physical parameters like temperature, pressure, heat, radio waves, IR waves, etc). These sensor systems provide a feedback from the real world to the digital world (embedded electronics), which are processed and the robot takes the decision accordingly.

❖ **Signal Processing System**

Data coming from the sensors need to be processedto allow the robot for analyzes the situation and makes its decisions. Forthiswe introduce electronic components to process the signals.

These components can be any analog/digital device or even a microcontroller.

❖ **Control System**

This is the major governing system of the robot. Every electronic system presented in the robot is called control system (open-loop and closed-loop).

I.8.2.4.Mobile Robot advantage

The various advantages of mobile robots can be summarized as follows:

1. Increased production capacity
2. Replacement of the man in the performance of the arduous tasks or dangerous

I.8.2.5. Perception in Mobile Robots

The basic element of the perception system is the sensor that is intended to translate into usable data information representing features of the environment.

The means used for the perception of the environment are numerous. We quote:

- Global vision systems.
- Laser and ultrasound telemeter.
- Optical and infrared sensors.
- Touch sensors.

I.8.2.6.Mobile robot types

I.8.2.6.1.Explorers robots

They are intended to explore environments where the man cannot surrender.[5]

- Explore other planets like Mars.
- Exploration of wrecks or rubble: search for victims at the world trade center or during earthquakes.
- Demining of land.
- Exploration of radioactive zones: maintenance of reactors, storage pool

I.8.2.6.2.Service robots

They are meant to help the man for certain tasks:[2]

- Agricultural robots.
- Goods transport robots: docker robots.
- Household robots: vacuum cleaner, lawn mower
- Museum guide: city of space in Toulouse.
- Help for people: old people or people with disabilities.



Figure.1.6. Service robot

I.8.2.6.3.Playful and humanoid robots

- Qrio,Aibo.
- Mindstorm
- Asimo.
- Nao

I.8.2.7.Wheeled Mobile Robot types

There are several classes of wheeled robots determined primarily by the position and the number of wheels used.We will cite here the four main classes of wheeled mobile Rorots.

I.8.2.7.1.Unicycle robot

A unicycle robot is operated by two independent wheels;it may have freewheel to ensure itsstability.Its center of rolling is located on the axis connecting the two driving wheels;It is a non-holonomic robot. His command can be very simple; it is indeed quite easy to move it from one point to another by a sequence of simple rotations and straight lines.

- ✓ - non-holonomist
- ✓ + stable
- ✓ + rotation on oneself
- ✓ + low mechanical complexity

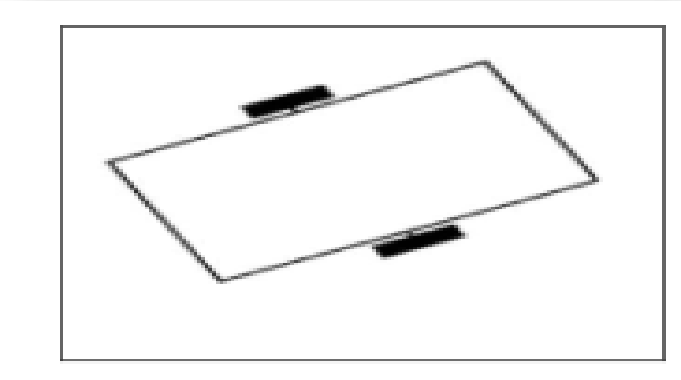


Figure.1.7. Unicycle robot

I.8.2.7.2. Tricycle robot

A tricycle robot consists of two fixed wheels placed on the same axis and a rolling center wheel placed on the longitudinal axis.The movement of the robot is given by the speed of the twofixed wheels and the orientation of the rolling wheel. His control is more complicated and generally impossible to perform simple rotations because of a limited turning radius of the rolling wheel.

- ✓-non-holonomist
- ✓ -unstable
- ✓ -no rotation on oneself
- ✓ + moderate mechanical complexity

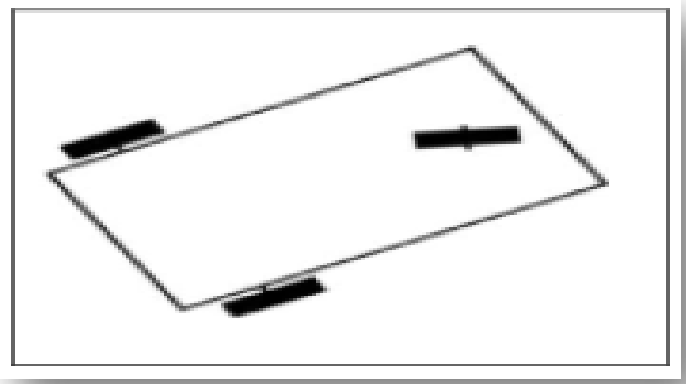


Figure.1.8. Tricycle robot

I.8.2.7.3.Car robot

A car robot is similar to the tricycle; it consists of two fixed wheels placed on the same axis and two rolling center wheels placed also on the same axis.The car robot is more stable because it has an additional point of support.All other properties of the car robot are identical to the tricycle robot.

- ✓- non-holonomist
- ✓+ stable
- ✓ - no rotation on oneself
- ✓+ moderate mechanical complexity

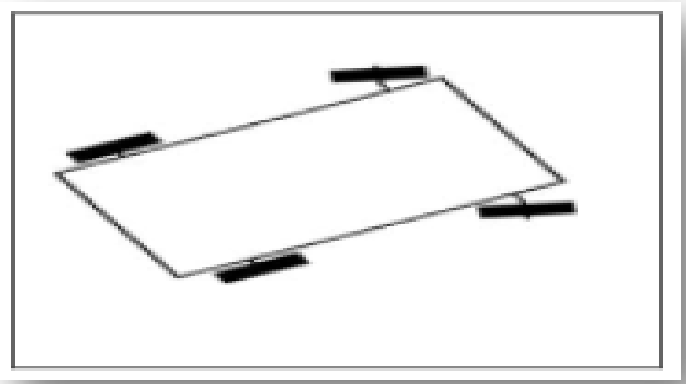


Figure.1.9. Car Robot

I.8.2.7.4.Omni-directional robot

An Omni-directional robot is a robot that can move freely in all directions. It is generally consists of three rolling offset wheels placed in equilateral triangle.

The great advantage of the Omni-directional robot is thatit'sholonomicbecauseit can move in all directions.But we have an inconvenient of a much greatermechanical complexity.

- ✓+ holonome
- ✓+ stable
- ✓ + rotation on oneself
- ✓- significant mechanical complexity

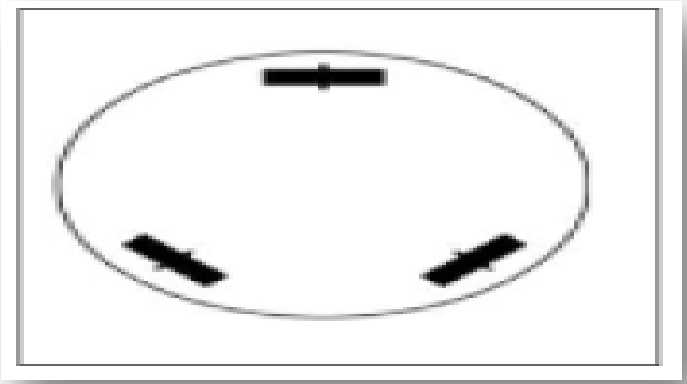


Figure.1.10. Omni-directional robot

I.9.Fields of Application

The fields of application of mobile robots is vast, we present some applications.[5]

I.9.1.Nuclear Industry

- ✓ Monitoring of sites.
- ✓ Handling of radioactive materials.
- ✓ Dismantling of power stations



Figure.1.11. Nuclear Industry robot

I.9.2.Civil Security

- ✓ Mine clearance
- ✓ Monitoring of street passers.
- ✓ Neutralization of terrorist activity
- ✓ Ammunition monitoring



Figure.1.12. Monitoring of street passers robot

I.9.3.Chemical

- ✓ Site monitoring
- ✓ Handling of toxic materials
- ✓ Health monitoring.

I.9.4.Mine

- ✓ Emergency assistance.



Figure.1.13. Emergency assistance robot

I.9.5.Agricultural

- ✓ Picking fruits.
- ✓ Treats, harvest, vines processing.



Figure.1.14. Picking fruitsand vines processing robot

I.9.6.Cleaning

- ✓ Ship's hull.
- ✓ Industrial cleaning

I.9.7.Space

- ✓ Exploration.



Figure.1.15. Exploration robot

I.9.8.Industry

- ✓ Conveying.
- ✓ Monitoring.



Figure.1.16. Conveying and monitoring robot

I.9.9.Underwater

- ✓ Laying of cables
- ✓ Search for modules
- ✓ Search for submerged ships.
- ✓ Seabed inspection

I.9.10.Military

- ✓ Monitoring.
- ✓ Explosive pose
- ✓ Ammunition manipulation.



Figure.1.17. Monitoring and ammunitionmanipulation robot

I.10.Conclusion

Through this chapter, we can say that in the context of robotics;robots play a great role inourlives. Today we find most robots working for people in industries, factories, warehouses, and laboratories.

Robots can do jobs better and faster than humans; robot can be built and assemble a carbutrobots cannot perform every job.

As the technology improves, there will be new ways to use robots which will bring new hopes and new potentials.

CHAPTER II

ROBOT MOTION AND GESTURE CONTROL

II.1. Introduction

A gesture is a motion of the body that contains information. There are plenty of gestures and they can differ a lot.

The gestures can be performed with objects such as pointing at something or manipulating an object, or without like waving or using sign language. Some may contain more information than others. In this chapter we will talk about motion and gesture control; presentation, definitions, different types and their Fields of applications.

II.2. Introduction to Motion

Upon observing surroundings, we can see many interactions taking place around us like a book falling, an Ear Drum vibrating, bus moving, nuclear reactions ...etc.

Everything on the universe moves, it can either be a small amount of movement or swift, but it leads to this change in position of an object is called Motion.

If an object is moving, we would be curious to know what are the things that happens which make a body Move, how long will a body Move and many other queries pop up.

An example which is mentioned below in figure.2.1.



Figure.2.1. Balls motion

An object tends to continue in its motion at a constant velocity until and unless an outside force acts on it.

The term velocity refers both to the speed and the direction in which an object is moving. It is easy to recognize an object in motion and an object at rest.

Rest is when the body doesn’t change its position with respect to the surroundings. (Motion and rest are relative terms).

II.3. Motion definition

Motion is a change in position of an object or else a process of moving or being moved. When the body changes its position with respect to its surrounding, the body said is in Motion

II.3.1. Motion Examples

- Football on ground
- Motion of Moon around Earth
- Rock falling off a cliff
- A Car moving on a Road to Trees on the roadside
- Person inside a moving Bus with respect to person outside the Bus
- Birds flying in the Sky are the examples of Motion

II.4.Motion types

There are two types of motion:

- **Uniform motion**
- **Non uniform motion**

II.4.1. Uniform motion

When equal distance is covered in equal interval of time, the motion is said to be in uniform motion. The bodies moving with constant speed or velocity have uniform motion or increase at the Uniform rate.

II.4.2. Non uniform motion

When unequal distances are covered in equal interval of time, the Motion is said to be in non uniform motion. The bodies executing non uniform motion have varying speed or velocity.

II.5. Motion classifications

We can even classify Motion into three types:

- **Translator motion**
- **Rotator motion**
- **Vibratory motion**

II.5.1. Translator motion

In translator motion, the particle moves from one point in space to another. This motion may be along a straight line or along a curved path.

They can be classified as:

1. *Rectilinear Motion*: motion along a straight line is called rectilinear motion
2. *Curvilinear Motion* : motion along a curved path is called a curvilinear motion

II.5.2. Rotator motion

In rotator motion, particle of the body describes concentric circles about the axis of motion.

II.5.3. Vibrator motion

In vibratory Motion, the particles move to and fro about a fixed point.

II.6. Introduction to Gesture Control

Humans interact in the physical world by means of five senses. (See figure**.2.2.** below) However, gestures have been an important means of communication in the physical world from old times, even before the invention of any language.

For decades keyboards and mouse have been the main input devices for computers, however with the rising popularity of ubiquitous and ambient devices, (i.e. Play Stations) and equipment which allows users to grasp virtual objects.

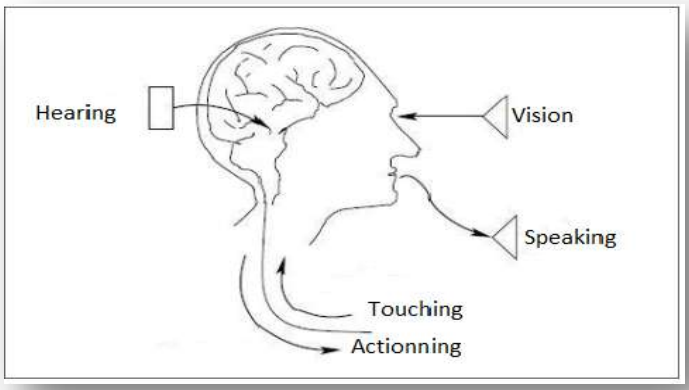


Figure.2.2. Five senses

For decades, keyboards and mouse have been the main input devices for computers. However, with the rising popularity of ubiquitous and ambient devices, (i.e. PlayStations), and

equipment which allows users to grasp virtual objects, hand or body gestures are becoming essential. Machines is taking control of every complex works, interactions with machines have become more important than ever.

Robots are classified into two types: Autonomous robots like Line sensing or edge sensing robots, and remote controlled robots like Gesture controlled Robots. The output and the functioning of machines will be more intuitive if they are communicated using human gestures. A gesture is a form of communication in a non-verbal manner by using visible body movements or actions conveying messages. The gesture can be captured using a camera, data gloves, and Bluetooth or infrared waves, Acoustic, Tactile, optical ...etc.

The embedded systems designed for specific control functions can be optimized to reduce the cost and the size of the device, and increase the reliability and performance.

Operating machines have become more flexible with the advent of smart phone and other modern technologies. Researchers have shown interest in gesture recognitions and have built several robots and devices that are controlled by human gestures.

II.7. Gestures definition

- A movement of your body (especially of your hands and arms) that shows or emphasizes an idea or a feeling
- Something said or done to show a particular feeling or attitude
- A movement usually of the body or limbs that expresses or emphasizes an idea, sentiment, or attitude.

II.8. Gestures types

Due to the increasing researches and development of new gesture control products different gesture functionalities have been explored.

- Gestures are often a language or a specific culture and they can be classified into the following types:

II.8.1. Hand and arm gestures

Recognition of hand poses and arm movements (sign languages). (See figure**.2.3.** below).



Figure.2.3. Hand and arm gestures

II.8.2. Head and face gestures

Some examples are: (See figure**.2.4.** below).

- Nodding or head shaking.
- Face recognition.
- Facial expression recognition and many others represent head and face gestures.

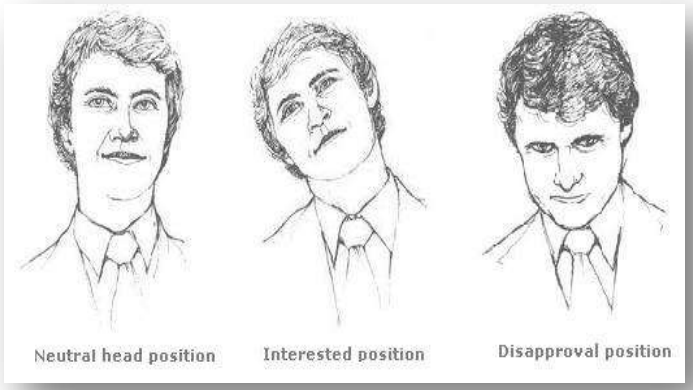


Figure.2.4. Head and face gestures

II.8.3. Body gestures

At the early development stages of gesture control technology, most of the research is based on hand gestures and head gestures. The researchers use special gloves or headsets with micro controllers to detect these gestures. As the technology moves on body gesture and finger point movement are introduced to the gesture controls for instance, Wii and Kinect can recognize a player's body gestures. (See figure**.2.5.** below).

A gesture is scientifically categorized into two distinctive categories: static and dynamic.
A waving hand means goodbye is an example of dynamic gesture and the stop sign is an example of static gesture.

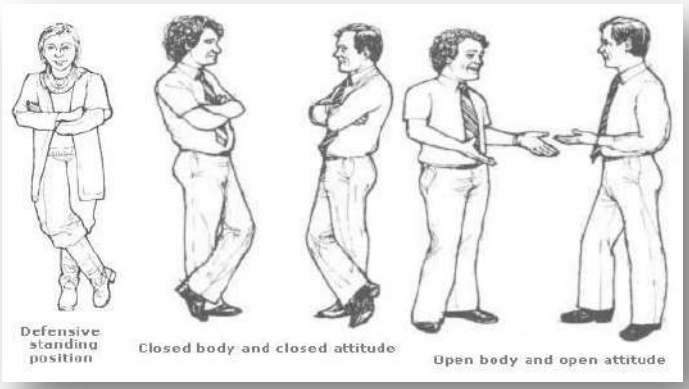


Figure.2.5. Body gestures

II.8.3.1. Static gesture

The information carried by the static gesture is expressed by a single posture.

II.8.3.2. Dynamic gesture

Unlike the static gesture, the information is expressed by two characteristics, which are the configuration of the hand and its position, which corresponds to a movement of the hand in time. It is the most difficult type to treat. (See figure**.2.6.** below). [6]

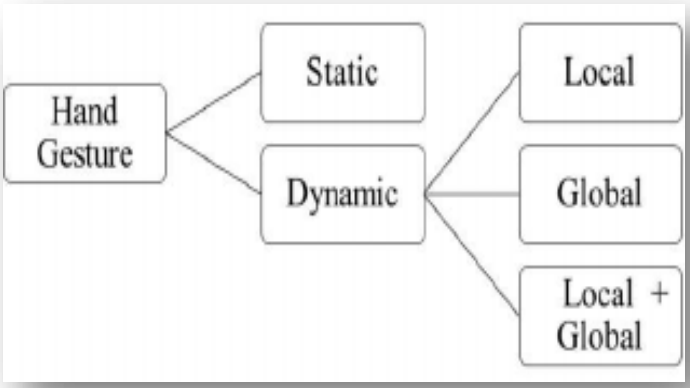


Figure.2.6. Hand gesture

According to their functions gestures are divided into three categories:

1. **Ergotic**

   Ergotic gestures to modify and transform the environment there's energy transfer in this action.

2. **Epistemic**

   Epistemic gestures to get knowledge from the environment for example the information received by the tactile sense.

3. **Semiotic**

   Semiotic gestures to transmit information to the environment and the semiotic function allow the gesture to be a way of expression; it can be used in addition to the speech.

   McNeil said that the action of speaking is often accompanied in our culture by movements of arms and hands; they anticipate the speech of a few milliseconds. [6]

II.9. How to Recognize Gestures!

Gestures can be recognized by using sensors. Accelerometer-based gesture recognition performs matching or modeling in time domain, there is no feature extraction stage.

The detected and recognized hand gestures are used as a command signals for controlling devices, some user interfaces, for example icon-based interface or motion-based interface are adjusted accordingly in order to support natural hand control. [6]

II.10. Gesture Recognition System (See Figure.2.7. below). [7]

The gesture recognition system is made of three primary components:

- An input device to collect the movements of the gesture
- A software system to classify those movements
- An output device to communicate the gesture.

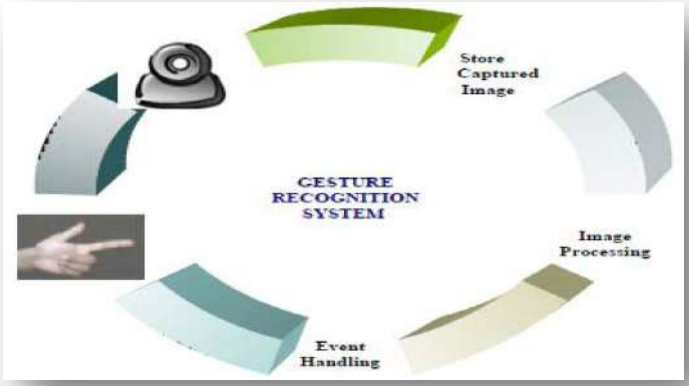


Figure.2.7. Gesture recognition system

II.11. Vision-based Gesture Recognition

Vision based gesture recognition is the one that consists from an image or a video sequence to recognize gestures or postures of a person for example this vision based system can use only one camera, or several in the goal of computing a 3D model of the scene.
Vision based gesture recognition is a multi-steps process that consists of:

II.11.1. Pre-processing

Before using the image for gesture recognition, it is necessary to apply some filters or other transformations in order to have an image that satisfies certain assumptions implied by future used methods.

II.11.2. Segmentation

This phase consists of extracting some points and regions from an image which are used for further processing.

II.11.3. Feature extraction

In this step the goal is to extract features like contours, fingertips ...etc; these features are used as characteristic patterns for the recognition algorithm.

II.12. Gestures and Communication system

Humans naturally use gesture to communicate. It has been demonstrated that young children can easily learn to communicate with gesture before they learn to talk. A gesture is

non verbal communication made with a part of the body we use gesture instead of or in combination with verbal communication. Using this process human can interface with the machine without any mechanical devices. Human movements are typically analyzed by segmenting them into shorter and understandable format. the movements may vary from one person to another it can be used as a command to control different devices of daily activities, mobility etc. (See figure.2.8. below). [8]

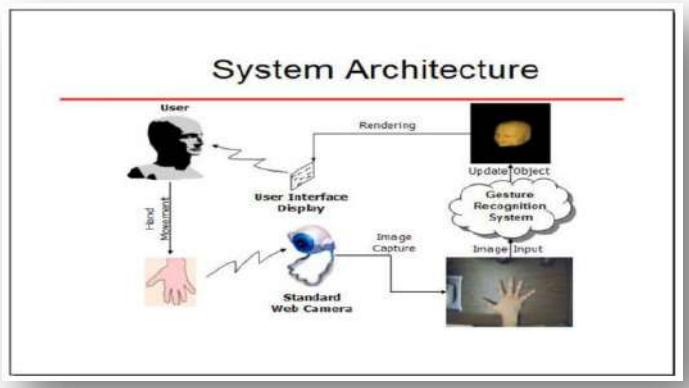


Figure.2.8. System architecture

II.13. Application areas for Gesture Control Technology

Gesture control technology has been used in many different areas including the entertainment field, electronics field, automotive field, healthcare field, education field and simulation field

II.13.1. Entertainment field

Gesture technology can provide more entertainment opportunities for any type of user; among them: dance, music, sport and playstation games.

II.13.2. Consumer electronics field

Gesture has been used extensively in consumer electronics, bringing dramatic changes in our daily life. Since the first iPhone released in 2007 and tablets.

II.13.3. Automotive field

In the automotive industry, many manufacturers believe that gesture control will be used to enhance dashboard controls and become the new interface between driver and car. For example, BMW presented a gesture-based car to the Consumer Tech Show of 2016.

II.13.4. Healthcare field

One of the widely interested areas for Leap motion is in the field of surgery where a hands-free experience will allow more flexibility of cross-sectional image viewing during a surgical procedure.

II.13.5. Education field

According to a 2011 Horizon Report, gesture based computer is one of the key trends in education technology and one of the most important technologies that engages and motivate learners through movement to facilitating the student performances.

II.13.6. Simulation field

Body gesture creates the simulation of human body activities in the screen. Physical simulation can improve the realism of the resulting gesture animation in several ways.

II.14. Gesture Interaction advantages

Gestural interactions tend to enrich Human-Machine communication with the following improvements:

- Natural, direct and effective interaction
- No need for designated input devices
- Has potential for high information bandwidth
- Low power requirement
- Simple circuitry it doesn’t require special hardware
- Devices can be controlled more comfortably

II.15. Gesture Interaction disadvantages

Some basic limitations of using such communication are given below:

- It has a limit distance in controlling devices.
- Line of sight communication as transmitters and receivers must be almost directly aligned to communicate.
- The data rate or speed of transmission is lower than a typical wired transmission

II.16. Sign signal transmission Channel

This Channel operates in both directions as a means of transmitting and receiving information. (See figure.2.9. below).

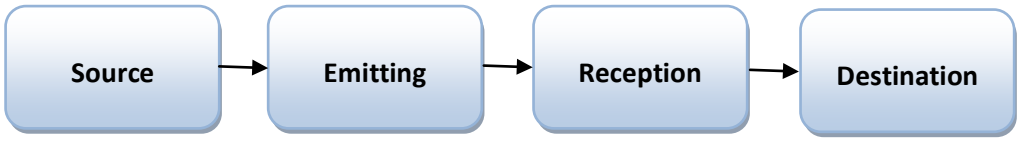


Figure.2.9. Sign signal transmission channel

II.17. Hidden Markov Model (HMM)

A Hidden Markov Model is a type of graphical model used to temporal data. Unlike traditional Markov Models HMMs assume that the data observed is not the actual state of the model but it is generated by the underlying hidden states.

HMMs have found a wide application in many different fields. They are known for their use in temporal pattern recognition and generation, such as speech recognition, handwriting recognition, and speech synthesis. [10]

II.18. Hand recovery

Computers are packaged with video cameras and the interest in human gesture recognition has grown. A wide variety of interfaces have been proposed using video driven gestures for mouse control, full body interactions, expression tracking, conducting music and electronic presentation.

The hands have been a point of focus for many gesture recognition systems. Tracking the natural hand in real time using camera imagery is difficult but successful systems have been demonstrated in controlled settings.

II.19. Machine sign language recognition

Attempts at machine sign language recognition have begun to appear in the literature over the last years. However, these systems have generally concentrated on isolated signs and small training and test sets. Tamura and Kawasaki demonstrate an early image processing system which recognizes 20 Japanese signs. Charayaphan and Marble demonstrated a feature

set that could distinguish between the 31 isolated ASL signs in their training set. Takahashi and Kishino discuss a data glove-based system that could recognize 34 of the 46 Japanese kana alphabet gestures using a joint angle and hand orientation coding technique. [11]

II.20. Conclusion

In this chapter we have introduced the use of a new means of communication in human-machine interactions that is "the gesture", which is a very expressive non-verbal communication medium, and which allows more natural interaction that completes the verbal channel, its benefits are demonstrated by the feasibility of such interaction in several areas: sign language, handwriting, augmented reality, virtual reality and machine control.

An overview of gestural control shows the importance as a new robot administration technology, the application of this new technology is based on different issues such as gesture recognition, complexity of the scene, acquisitions, and the nature of real-time processing.

CHAPTER III

DIGITAL IMAGE PROCESSING, SEGMENTATION & 3D RECONSTRUCTION

III. 1. Introduction

When we speak about a digital image processing, we mean that the set of techniques used to modify a digital image in order to improve its quality or to reduce its size (in terms of bits compression encoding) or to get information out of it.

Digital image processing is a new field of knowledge which has been quickly developed; and has four distinct fields of action: analysis, synthesis, coding and quality enhancement.

Image segmentation is an important and challenging process of image processing and used to partition an image into several parts/segments having similar features and properties. Among the basic applications of image segmentation or content based image retrieval we can mention: Medical imaging, object detection and recognition tasks, automatic traffic control systems and video surveillance …etc.

Obtaining three dimensional (3D) models of scenes from images has been a long lasting research topic in photogrammetry and computer vision. Many applications exist which require these models; in traditionally robotics and inspection applications accuracy was often the main concern; nowadays more and more interest comes from the multimedia and computer graphics communities. Today the evolution of computers permits to display complex 3D models and many computer games are located in large 3D worlds.

In this chapter, we will talk about image processing, segmentation, and 3D reconstruction: Presentation and definitions on it, the different types of Image processing, segmentation, 3d reconstruction and their applications.

III.2. Introduction to digital image processing

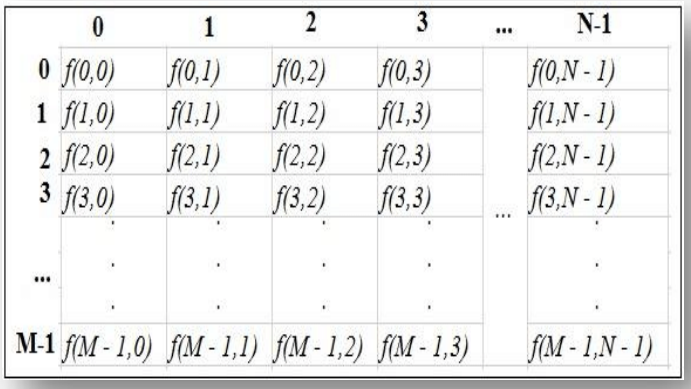
Pictures are the most common and convenient means of conveying or transmitting information. A picture is worth a thousand words and concisely conveys information about positions, sizes, and inter-relationships between objects they portray spatial information that we can recognize as objects.

Human beings are good at deriving information from images, because of our visual and mental abilities about 75% of the information received by human is in pictorial form.

Digital Image Processing (DIP) is a multi disciplinary science that borrows principles from diverse fields such as optics, surface physics, visual psychophysics, computer science and mathematics.

III.3. Images definition

An image is usually a function of two spatial variables, f [x y], which represents the brightness f at the Cartesian location [x y] it also may be graphed in three dimensions with brightness displayed on the z-axis. (See Figure.3.1. below) [12]



	0	1	2	3	...	N-1
0	f(0,0)	f(0,1)	f(0,2)	f(0,3)		f(0,N - 1)
1	f(1,0)	f(1,1)	f(1,2)	f(1,3)		f(1,N - 1)
2	f(2,0)	f(2,1)	f(2,2)	f(2,3)		f(2,N - 1)
3	f(3,0)	f(3,1)	f(3,2)	f(3,3)	...	f(3,N - 1)
...	.	.	.	.		.
	.	.	.	.		.
	.	.	.	.		.
M-1	f(M - 1,0)	f(M - 1,1)	f(M - 1,2)	f(M - 1,3)		f(M - 1,N - 1)

Figure.3.1. Image definition

III.4. Image types

There are two types of images analog and digital

III.4.1. Analog image

Analog images are the type of images that we as humans look at. They include such things as photographs, paintings, TV images, and all the medical images that recorded on film or displayed on various display devices like computer monitors.

What we see in an analog image, are various levels of brightness (or film density) and colors, it is generally continuous and not broken into many small individual pieces.

III.4.2. Digital Image

Digital images are recorded as many numbers and divided into a matrix or array of small picture elements or pixels. Each pixel is represented by a numerical value and the advantage of digital images is that they can be processed in many ways by computer systems. [13]

III.5. Digital image characteristics

- Its size expressed in pixels
- Its resolution which is expressed in pixels
- Its color coding
- His weight

III.5.1. Image size

The size of an image is expressed in pixels here is an image that has a definition of 400 pixels wide by 300 pixels high. (See Figure.3.2. below)



Figure.3.2. Image size

III.5.1.1. Pixel and Voxel definition

III.5.1.1.1. Image pixels

Pixel is an abbreviation of the term « picture element » and it is the smallest unit of a digital image or graphic that can be displayed and represented on a digital display device. A pixel is represented by a dot or square on a computer monitor display screen and the pixels are the basic building blocks of a digital image or display and are created using geometric coordinates.

Depending on the graphics card and display monitor the quantity of size, color and pixels combination varies and is measured in terms of the display resolution. (See Figure.3.3. below)

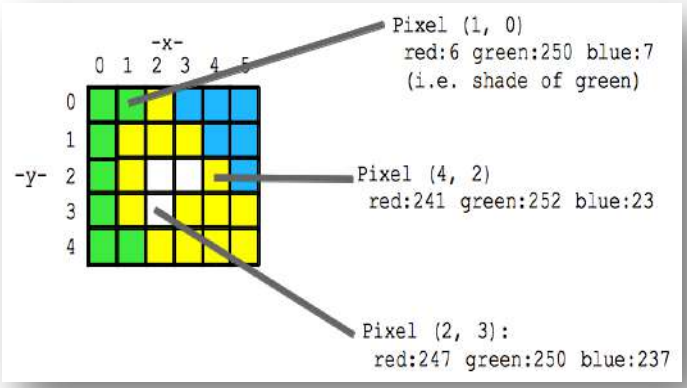


Figure.3.3. Image pixel

III.5.1.1.2. Image voxels

Voxel is an abbreviation of the term «volume element» and it is the smallest distinguishable box-shaped part of a three-dimensional space and a particular voxel will be identified by the x, y and z coordinates.

III.5.1.2. Distances between two pixels

The distance between two pixels in a digital image is a significant quantitative measure. The distance between points with coordinates $(i\ j)$ and $(h\ k)$ may be defined in several different ways.

- **Euclidean** distance is defined as:

$$\boldsymbol{ED}\ \ (\boldsymbol{i\ j}),(\boldsymbol{h\ k}) = \sqrt{(\boldsymbol{i}-\boldsymbol{h})^2 + (\boldsymbol{j}-\boldsymbol{k})^2} \qquad \textbf{(Eq. 3.1).}$$

- **City block** distance is defined as:

$$\boldsymbol{CD}\ \ (\boldsymbol{i\ j}),(\boldsymbol{h\ k}) = \boldsymbol{max}\left|(\boldsymbol{i}-\boldsymbol{h})\right| + \left|(\boldsymbol{j}-\boldsymbol{k})\right| \qquad \textbf{(Eq. 3.2).}$$

- **Chessboard** distance is defined as:

$$\boldsymbol{CD}\ \ (\boldsymbol{i\ j}),(\boldsymbol{h\ k}) = \boldsymbol{max}\{\left|(\boldsymbol{i}-\boldsymbol{h})\right| + \left|(\boldsymbol{j}-\boldsymbol{k})\right|\} \qquad \textbf{(Eq. 3.3).}$$

III.5.1.3. Pixels connectivity

In image processing pixel connectivity is the way in which pixels in 2-dimensional or voxels in 3-dimensional relate to their neighbors. A set of pixels in which each pixel is

connected to all other pixels is called a connected component. In general a connected component is a set of black pixels « ***P*** »

❖ **4-Connectivity when can we say that a given set of black pixels is 4- connected?**

First we have to define the concept of a 4-neighbor (also known as a direct-neighbor)

III.5.1.3.1. Definition of a 4-neighbor

A pixel « ***Q*** » is a 4-neighbor of a given pixel « ***P*** », if Q and P share the same edge.

❖ **8-Connectivity when can we say that a given set of black pixels is 8- connected?**

First, we have to define the concept of an 8-neighbor (also known as an indirect neighbor)

III.5.1.3.2. Definition of an 8-neighbor

A pixel « ***Q*** » is an 8-neighbor (or simply a neighbor) of a given pixel « ***P*** », if Q and P either share the same edge or a vertex.

The 8-neighbors of a given pixel P make up the Moore neighborhood of that pixel.

III.5.1.3.3. Definition of an 8-connected component

A set of black pixels « ***P*** » is an 8-connected component (or simply a connected component) if for every pair of pixels « P_i » and « P_j » in « ***P*** » there exists a sequence of pixels « P_i », ..., « P_j », such that: (See Figure.3.4. below)

A. All pixels in the sequence are in the set « P_i » are black.
B. Every 2 pixels that are adjacent in the sequence are 8-neighbors.

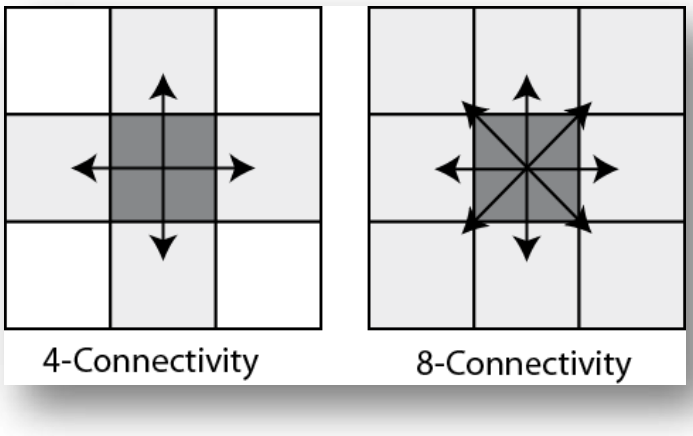


Figure.3.4. 4 and 8 connected components

III.5.2. Image resolutions

Image resolution refers to the collective information that represents the content within an image. Resolution is widely used in unison with pixels but is much more. Pixels are small square light meters, which capture the light at different levels of brightness ranging from 0 (black) to 255 (white).

Four types of resolution represent the collective information that creates a file. Spacial, Spectral and Tonal resolution represent a still image while the fourth, Temporal, allows for the moving image or video.

Resolution refers to the collected information within an image. Content collected by four types of Resolution; Spatial, Tonal, Spectral and Temporal. (See Figure.3.5. below)

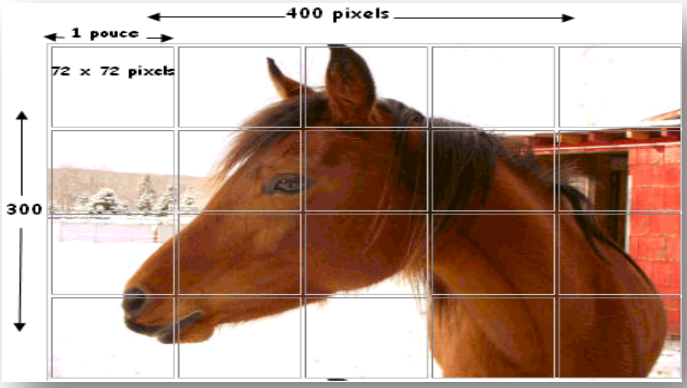


Figure.3.5. Image resolution

III.5.2.1. Spacial resolution

Spatial Resolution measure of how closely lines can be resolved in an image.

III.5.2.2. Tonal resolution

Tonal Resolution represents the gray levels or brightness levels within an image.

III.5.2.3. Spectral Resolution

Spectral Resolution defines wave length intervals within an image usually 3, Red, Green, and Blue (RGB).

III.5.2.4. Temporal Resolution

Temporal Resolution defines the refresh rate on the monitor and ensures the precision of a measurement with respect to time.

III.6. Image color coding

An image is represented by a two-dimensional array and each box being a pixel. To represent an image by a computer we need to create an array of pixels, each box of which contains a value and this value is stored in a box and encoded on a number of bits determining the color or intensity of the pixel, it is called depth of coding. Computerized images come in several color levels. (See Table.3.1. below) [12]

Table.3.1. Image color coding

Levels	**Colors**
1 bit	2 (black and white)
4 bits (2^4)	16 colors (16 gradients of gray from black to white or 16 different colors)
8 bits (2^8)	256 colors or shades of gray (256 gradients of gray ranging from black to white or 256 different colors)
16 bits (2^{16})	65,536 colors (16 gradients of gray ranging from black to white or 16 different colors)
24 bits (2^{24})	16 777 216 colors (this representation is used to represent an image by defining each component (RGB, for red, green and blue). Each pixel is represented by an integer comprising the three components, each coded on one byte, that is to say in total 24 bits)
30 bits (2^{30})	1 073 741 824 colors

III.7. Image weight

To know the weight (in bytes) of an image, it is necessary to count the number of pixels contained in the image, to calculate the number of squares in the table, you have to multiply its height by its width.

The weight of the image is then equal to its number of pixels that multiplies the weight of each of these elements.

III.7.1. How to calculate a 640x480 image in true color: [12]

- **Pixels number:** 640 x 480 = 307 200 pixels
- **Weight of each pixel:** 24 bits / 8 = 3 bytes (1 byte = 8 bits)
- **Image weight is also equal to:** 307 200 x 3 = 921 600 bytes / 1024 = 900 Kbyte

(To know the size in KB it is enough to divide by 1024).

In the table below we have some examples (considering that the image is not compressed):

Table.3.2. How to calculate a 640x480 image in True color

Definition of the image	Black and white (1 bit / pixel)	256 colors or shades of gray (8 bits / pixel)	65000 colors (16 bits / pixel)	True colors or real colors 16 000 000 colors (24 bits / pixel)
320x200	7.8 Ko	62.5 Ko	125 Ko	187.5 Ko
640x480	37.5 Ko	300 Ko	600 Ko	900 Ko
800x600	58.6 Ko	468.7 Ko	937.5 Ko	1.4 Mo
1024x768	96 Ko	768 Ko	1.5 Mo	2.3 Mo

III.8. Image histogram

A histogram is a graph; that shows frequency of anything. Usually histogram has bars that represent frequency of data occurring in the whole data set.

A histogram has two axes the x-axis and the y axis, the x-axis contains event whose frequency you have to count, the y-axis contains frequency. the different heights of bar shows different frequency of occurrence of data. (See Figure.3.6. below)

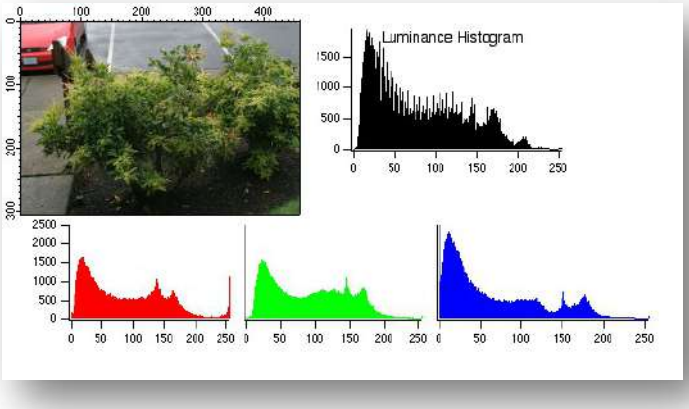


Figure.3.6. Image histogram

III.8.1. Histogram types

There are two types of histograms:

- **Normalization**

  The histogram normalization, or dynamic expansion, is an affine transformation of pixel grayscale that the image uses all the dynamics of the representation [12]

- **Equalization**

  The histogram equalization, is a transformation of the grayscale, whose principle is to balance as best as possible the distribution of the pixels in the dynamics [12]

III.9. Image contour and texture

The contours represent the boundary between the objects of the image or the boundary between two pixels whose gray levels represent a significant difference. Texture can be defined as an entity consisting of mutually related pixels and a group of pixels. Image Texture gives us information about the spatial arrangement of color or intensities in an image or a selected region of an image. An image texture is a set of metrics calculated in image processing designed to quantify the perceived texture of an image Definition

III.10. Image brightness

Brightness is a relative term. It depends on your visual perception. Since brightness is a relative term, so brightness can be defined as the amount of energy output by a source of light relative to the source we are comparing it to. In some cases we can easily say that the image is bright and in some cases it is not easy to perceive. (See Figure.3.7. below)

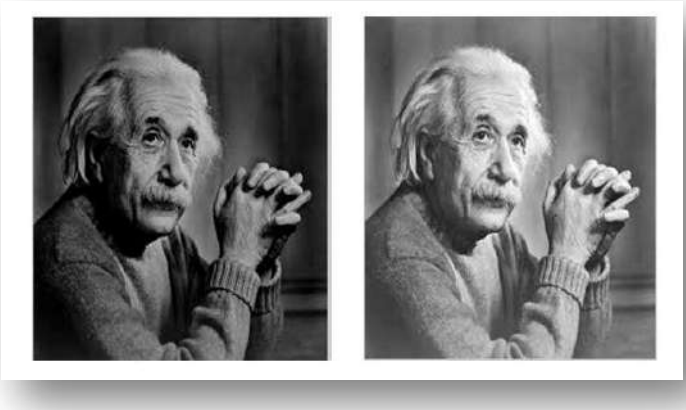


Figure.3.7. Image brightness

III.11. Image contrast

Contrast is the difference in luminance or color that makes an object (or its representation in an image or display) distinguishable. In visual perception of the real world contrast is determined by the difference in the color and brightness of the object, and other objects within the same field of view. The human visual system is more sensitive to contrast than absolute luminance, we can perceive the world similarly regardless of the huge changes in illumination over the day or from place to place. The maximum contrast of an image is the contrast ratio or dynamic range.

III.12. Image quantification

Transformation of amplitude with continuous values into amplitude which can take only a limited number of distinct values, for an image with 256 gray levels, each amplitude is coded on a byte

III.13. Image thresholding

Thresholding is a non-linear operation that converts a gray-scale image into a binary image where the two levels are assigned to pixels that are below or above the specified threshold value. (See Figure.3.8. below)



Figure.3.8. Thresholding of an image

III.14. Image noise

Noise is a random variation of image density, visible as a grain in film and pixel level variation in digital images.it is key image quality factor. Noise is present in all electronic systems and originates from a number of sources including electronic interference.

It appears as an irregular granular pattern in all images and degrades image information.

III.15. Image formats

An image format is a computer representation of the image, associated with information about how the image is encoded and possibly providing guidance on how to decode and manipulate it. An image format generally includes a header that contains image data (for example, image size in pixels) followed by image data. The structuring of the data is different for each image format.

III.16. Image types

There are sixth basic types of images:

- Binary images
- Grayscale images
- Color images
- Indexed images
- Raster images
- Vector images

III.16.1. Binary images

In binary image each pixel is just black or white and there are only two possible values for each pixel white for the edges, and black for the background. Images for which a binary representation may be suitable include text (printed or Handwritten), fingerprints, or architectural plans. (See Figure.3.9. below)

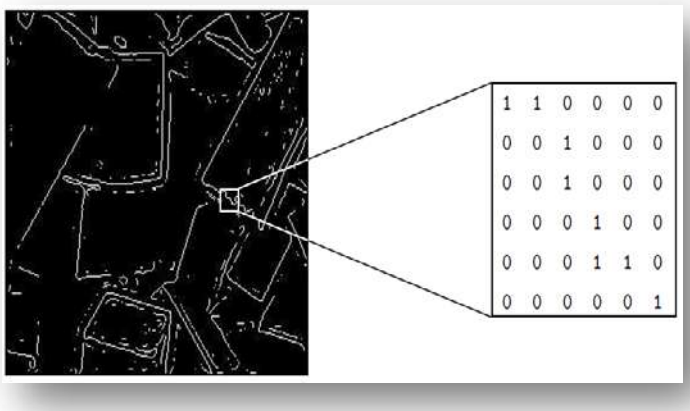


Figure.3.9. Binary image

III.16.2. Grayscale images

In grayscale images each pixel is a shade of grey, normally from 0 (black) to 255(white); this range means that each pixel can be represented by eight bits or exactly one byte.

This is a very natural range for image file handling. Other grayscale ranges are used, but generally, they are a power of 2. Such images arise in medicine (X-rays), images of printed works, and indeed 256 different grey levels are sufficient for the recognition of most natural objects.An example is the street scene. (See Figure.3.10. below)

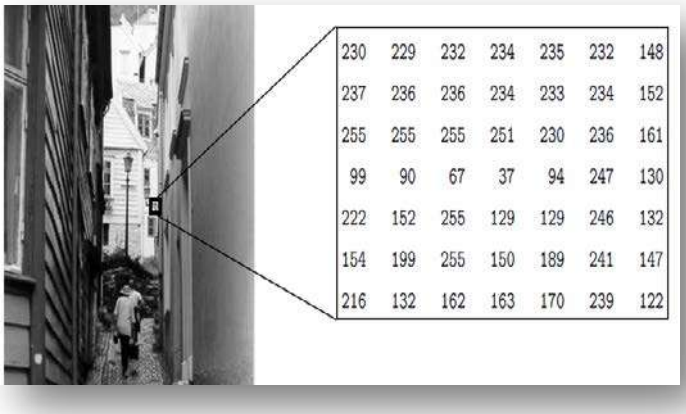


Figure.3.10. Grayscale image

III.16.3. Color images

Here each pixel has a particular color thatis being described by the amount of Red, Green and Blue in it. If each of these components has a range 0-255, this gives a total of 255^3 = 16777216 different possible colors in the image. This is enough colors for any image. Since the total number of bits required for each pixel is 24, such images are also called 24-bit color images. Such an image may be considered as consisting of a « stack » of three matrices; representing thered, green and blue values for each pixel. This means that for every pixel three values. (See Figure.3.11. below)

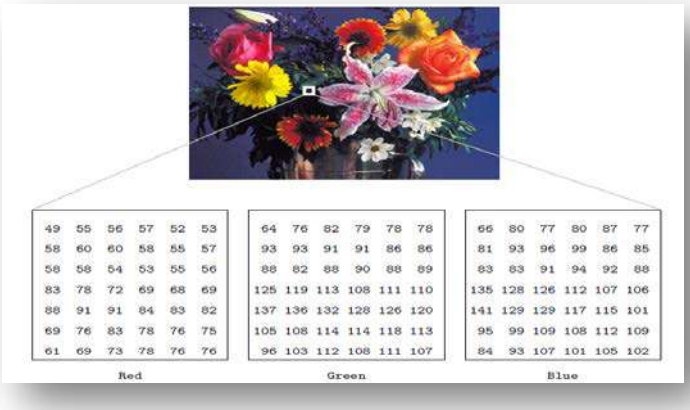


Figure.3.11. Color images

III.16.4. Indexed Images

An indexed image consists of a data matrix « ***x***» and a colormap matrix, « map ».

The data matrix « ***x*** » can be of class uint 8, uint 16, or double.

The colormap matrix« ***map*** » is an m-by-3 array of class double containing floating point values in the range [0 1]. Each row of map specifies the red, green, and blue components of a single color. An indexed image uses direct mapping of pixel values to colormap values. The color of each image pixel is determined by using the corresponding value of « ***x*** » as an index into a map. The value 1 points to the first row in a map, the value 2 points to the second row, and so on. (See Figure.3.12. below)

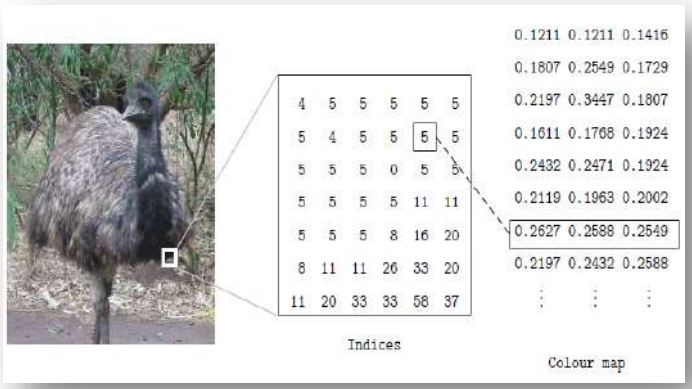


Figure.3.12. Indexed images

III.16.5. Raster Images

Raster images are created with pixel-based programs or captured with a camera or scanner. They are more common in general such as jpg, gif, png, and are widely used on the web.

III.16.6. Vector images

Vector graphics are created with vector software and are common for images that will be applied onto a physical product. Also used in CAD, engineering, and 3D graphics. (See Figure.3.13. below)

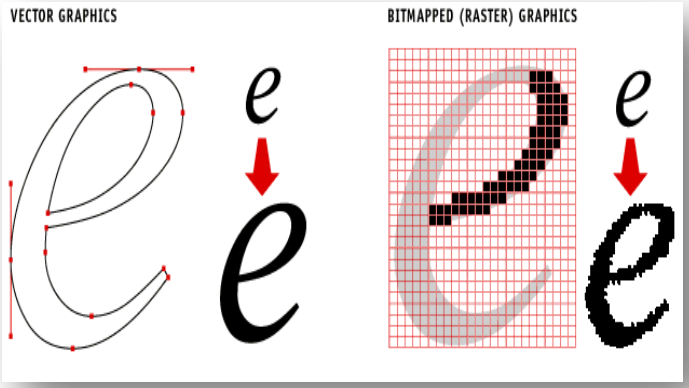


Figure.3.13. Vector image

III.17. Some application domains of digital image processing

Digital Image processing has an enormous range of applications; almost every area of science and technology can make use of image processing methods. Here is a short list just to give some indication of the range of image processing applications.

III.17.1. Medical domain

- Inspection and interpretation of images obtained from X-rays, MRI or CAT scans
- analysis of cell images, of chromosome karyotypes

III.17.2. Agriculture domain

- Satellite/aerial views of land, for example to determine how much land is being used for different purposes, or to investigate the suitability of different regions for different crops
- inspection of fruit and vegetables distinguishing good and fresh produce from old

III.17.3. Industry domain

- Automatic inspection of items on a production line
- inspection of paper samples

III.17.4. Law enforcement domain

- Fingerprint analysis
- sharpening or de-blurring of speed-camera images

III.18. Segmentation

III.18.1. Definition

The term image segmentation refers to dividing an image into multiple parts or the partition of an image into a set of regions that cover it. Segmentation has two objectives. The first objective is to decompose the image into parts for further analysis; the second objective of segmentation is to perform a change of representation.The goal of image segmentation is to cluster pixels into salient image regions, regions corresponding to individual surfaces, objects, or natural parts of objects.Segmentation could be used for object recognition, occlusion boundary estimation within motion or stereo systems, image compression, image editing, or image database.

III.18.2. Color image segmentation

Color image segmentation is an important task in image analysis and understanding. It is widely used in many image applications as a critical step. The primary purpose of segmentation is to divide an image into meaningful and spatially connected regions (such as object and background) on the basis of diverse properties. Existing segmentation approaches can predominantly be divided into the following four categories: region-based methods, feature-based methods, boundary-based methods, and model-based methods. Most existing image segmentation methods consider only the low-level features and it is difficult to obtain ideal segmentation results without high level visual features. Therefore, many researchers aim to build a bridge between low-level features and visual cognitive behaviors of human. Most segmentation methods integrated high-level knowledge, which are learning cognitive information from underlying features, and they obtain the corresponding label of elements and textons of image. Researchers aim to find high-level summary tags or labels to represent all the underlying features. With all these elements and textons, the segmentation can employ affinity computing to make decision of pixels labels of semantic objects and regions. This procedure employs knowledge-assisted multimedia analysis model to bridge the gap between semantics and low-level visual features. (See Figure.3.14. below) [16]

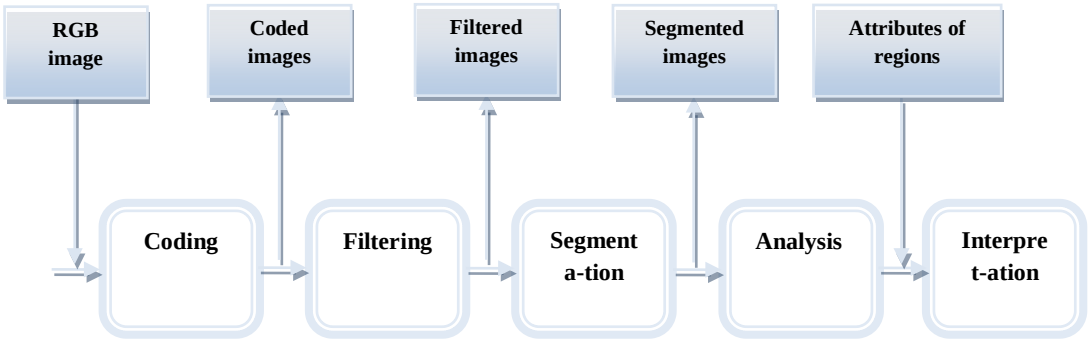


Figure.3.14. RGB image processing steps

III.18.3. Color image segmentation strategies

This section first presents the different strategies that can be adopted for processing color images (Multi-component). There are three possible strategies for segmenting Color Images.

- Scalar strategy
- Marginal strategy
- Vector strategy

III.18.3.1. Scalar strategy

It's about going from a color image to a monochrome image, which can be done by quantification or by the Karhunen-Loeve Transform (KLT). All monochrome segmentation methods are possible. (See Figure.3.15. below)

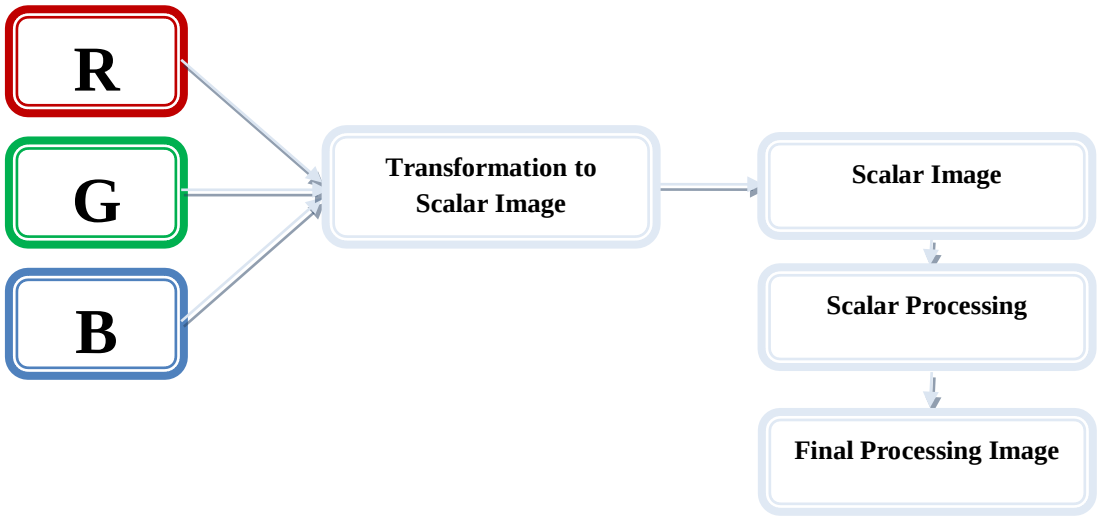


Figure.3.15. Scalar strategy

III.18.3.2. Marginal strategy

It consists in processing the component of images separately; and the three results are then merged. (See Figure.3.16. below)

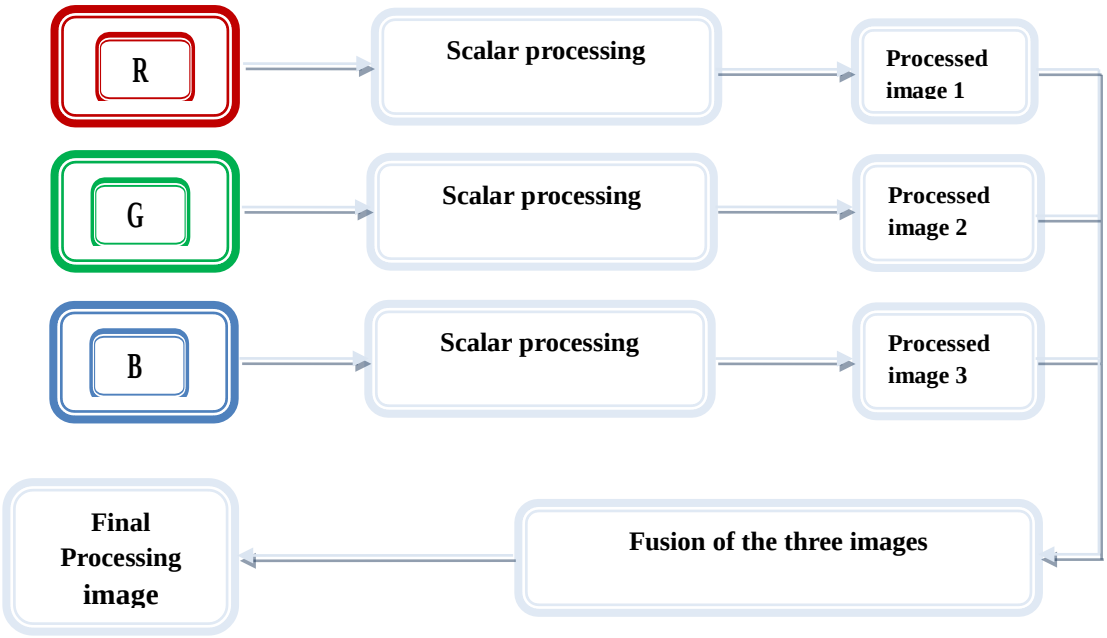


Figure.3.16. Marginal strategy

III.18.3.3. Vector strategy

It consists of processing each pixel as a vector in the chosen color space, the primitives are extracted taking into account all three components at once. (See Figure.3.17. below)

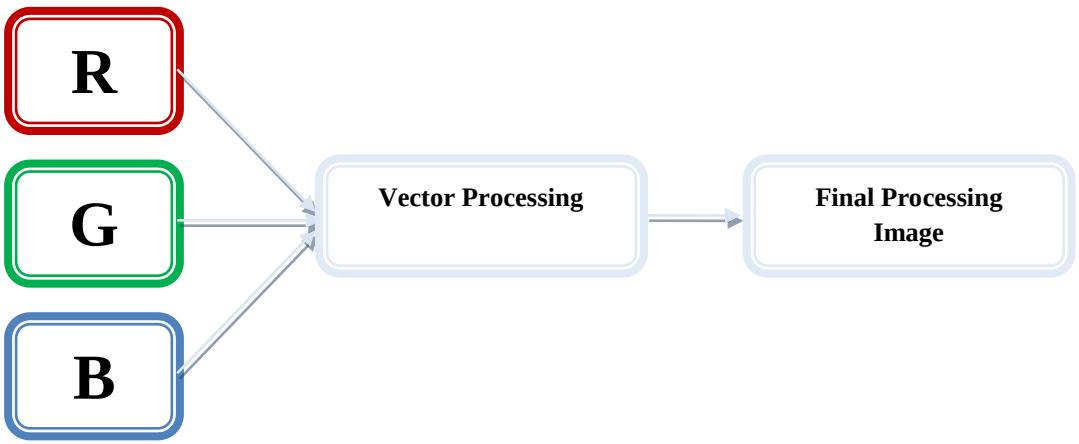


Figure.3.17. Vector strategy

III.18.4. Different approaches to segmentation

The problem of image segmentation can be solved by different approaches.

III.18.4.1. Approaches using graph theory

The approaches using graph theory consist in creating an image graph form and exploit the different properties of this theory to find the image different regions. The general idea is to model the pixels by the nodes of this graph and the characteristics (distance, similarity ...etc) connecting these pixels by arcs. Among the key methods involved in the minimal cutting method normalized graph (Normalized Cut NCUT), and flow method (Markov Clustering MCL). [12]

III.18.4.2. Approaches using Borders

Border approaches are among the most common methods in image segmentation.This type of approach consists of extracting primitives defined by discontinuity lines separating the regions that differ from each other only in their color levels or in their textures.Practically, it's about highlighting transition areas and detecting the different boundaries that separate regions in an image.Border approaches themselves can be classified into several categories. Derivative, surface and variational models can normally be distinguished.

III.18.4.3. Approaches using Regions

A region is defined as a homogeneous group of connected pixels with respect to a chosen property. There are several ways to define homogeneity of a region that are based on a particular objective in the segmentation process. For instance, it may be measured by color, gray levels, texture, motion and depth of layers…etc. Overlaps among regions are not permitted, thus, each pixel belongs only to a single region. Two neighboring regions should be merged if the new combined region is homogeneous. Consequently, each region is anticipated to be as large as possible under its certain characterization. Then, the total number of regions is reduced.

The segmentation method based regions can be divided into two large families according to whether the pixels are analyzed in the (spatial) image plane or in the color space. (See Figure.3.18. below)

- Color images segmentation methods using spatial analysis.
- Color image segmentation method using pixels classification.

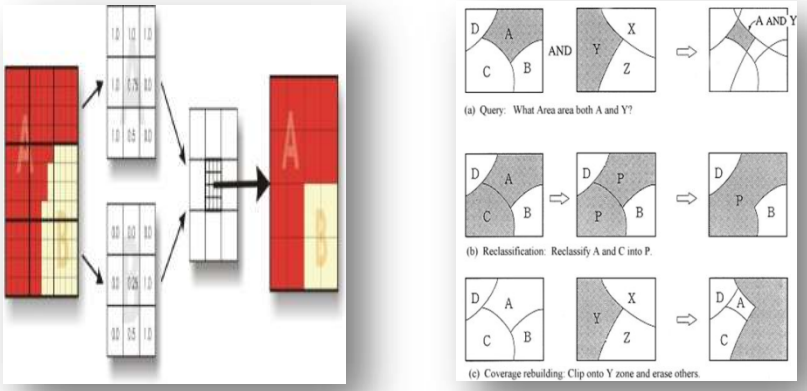


Figure.3.18. Spatial analysis and pixels classification

III.18.4.3.1. Color images segmentation methods using spatial analysis

This type of methods is based on the analysis of pixels directly in the image plane by browsing the image, in order to group the related pixels respecting the predicate used to build the regions.They mainly focus on the spatial interaction between the pixels, knowing that the decision of associating pixels to build regions is common for all methods.This decision is binary, so the predicate used is either true (1 logical) or false (0 logical).

We can distinguish 04 approaches:

- Segmentation using region dividing.
- Segmentation using region growing.
- Segmentation using region merging.
- Segmentation using region splitting and merging. (See Figures.3.19 and 3.20. below)

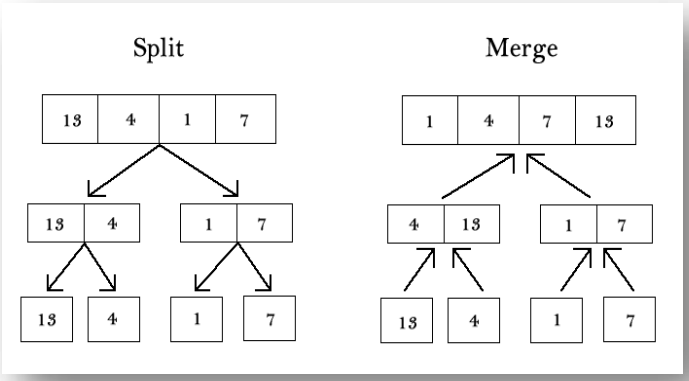


Figure.3.19. Regions dividing and merging

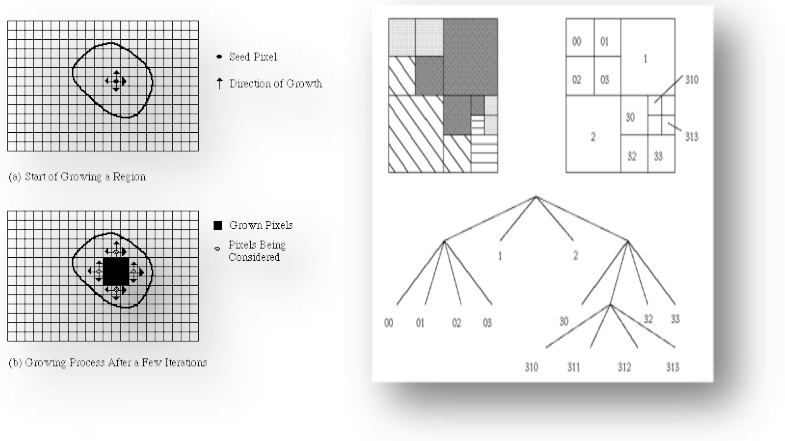


Figure.3.20. Region growing and merging

III.18.4.3.1.1. Segmentation using regions dividing

This segmentation method takes a region of an image and using the histograms of the characteristic values in that region, determines a threshold on a characteristic, in order to divide the region into sub-regions.

Segmentation using regions dividing steps:

- Choose a region in the image. This region is represented by a bit mask that limits the total area of the image that will be analyzed in one step.
- Calculate the histograms for all characteristics of the image portion that is contained in the region. Smooth the values in the histogram so as to eliminate small peaks, if necessary.
- Choose the best peak in the set of histograms. Generally the best peak corresponds to an isolated peak. When such a peak can't be found, the region is considered segmented.

III.18.4.3.1.2. Segmentation using region growing

These methods consist of growing each region around a starting pixel called a germ.

The regions are created one after the other following two phases:

- The initialization phase is the phase of choosing a new seed.
- The iterative phase in which the neighboring pixels are gathered to the germ according to a homogeneity criterion until convergence.

III.18.4.3.1.3. Segmentation using region merging

Merging must start from a uniform origin region. One method is to divide the image into 2x2 or 4x4 blocks and check each one, another is to divide the image into strips, and then subdivide the strips further. In the worst case, the origin will be a single pixel. Once a origin has been found, its neighbors are merged until no more neighboring regions conform to the uniformity criterion. At this point, the region is extracted from the image, and a further origin is used to merge with another region.

There are some drawbacks which must be noted with this approach.The process is inherently sequential, and if fine detail is required in the segmentation then the computing time will be long. Moreover, since in most cases the merging of two regions will change the value of the property being measured, the resulting area will depend on the search strategy employed among the neighbors, and the seed chosen.

III.18.4.3.1.4. Segmentation using region splitting and merging

These methods consist of iteratively cutting (dividing) the image until homogeneous blocks are obtained according to a given criterion; then group the neighboring blocks so that the resulting block respects a homogeneity criterion.These methods may use graph theory,Voronoï partitioning, quaternary tree data structure or pyramid approaches.

III.18.4.3.1.5. Advantages and Disadvantages of the Segmentation Techniques (See Table.3.3. below)

Table.3.3. Advantages and Disadvantages of segmentation techniques

Segmentation Technique	Advantages	Disadvantages
Regions dividing	-Guaranteed to produce coherent regions -Works from the inside out instead of the outside in which object a pixel belongs to is immediate	Cutting areas unfaithful to the original image
Region Growing	-Simple and fast - It allows the object segmentation complex topology - It preserves the shape of each region of the image	-The computation is consuming, no matter the time or power. -Noise or variation of intensity may result in holes or over segmentation. -This method may not distinguish the shading of the real images.
Region Merging	-The image could be split progressively according to our demanded resolution because the number of splitting level is determined by us -We could split the image using the criteria we decide, such as mean or variance of segment pixel value In addition, the merging criteria could be different to the splitting criteria	-This method depends on the merging criterion that can influence the final result segmentation -It can introduce the effect of sub segmentation
K-means	-K-means algorithm is easy to implement - Its time complexity is f(n), where n is the number of patterns. It is faster than the hierarchical clustering.	-The result is sensitive to the selection of the initial random centroids -We cannot show the clustering details as hierarchical clustering does.

III.18.4.3.2. Color image segmentation method using pixel classification

Pixel classification is a method that assigns each pixel in an image into classes, based on textural and intensity information. This can be useful especially for image types like brightfield, histochemical stains, or other non-fluorescent images, where often traditional intensity-based thresholding methods do not perform well. The researcher teaches the classifier to recognize which pixels belong in which class by marking a small number of pixels across a few images, which is used to build a classifier that can then be applied to a larger batch of images.

There are two types of classification

- **Unsupervised classification methods**

In unsupervised classification methods, processing is only done on the digital data of the image: there are no classes defined a priori from the beginning.

Once the segmentation is done, only then does the analyst seek to interpret, if possible in a useful way, the different classes found. Of course, the analyst is not totally absent from the segmentation process: he chooses certain parameters (number of classes, the distance between classes, statistical method ...). The interpretation of the classes obtained is often difficult, but the classifications supervised are ideal as pre-classification or when no almost no field information on the image. They often propose a partition of the image, created from a cut-off from the histograms, highlighting the cores to which we connect the more distant points thanks to a calculation of distance.The two most used statistical methods in classification unsupervised are the Hierarchical Ascending Classification (HAC) and the method mobile centers.

- **Supervised classification methods**

To perform a supervised classification, information about objects of the image that one seeks to reveal on the characteristics of homogeneous areas.The analyst, usually a specialist, determines the legend of the classification he wishes to obtain and selects in the image or on the histogram samples of pixels belonging to the different classes defined.These samples depend on the knowledge of the expert, the information he has on the image.It's up to the computer to analyze the digital data of these samples to determine the spectral signature of the different classesof objects, according to a method chosen by the analyst.

III.18.4.4. ISODATA (Iterative Self-Organizing Data Analysis Technique Algorithm)

The ISODATA (Iterative Self Organizing Data Analysis Technique) method is one of the classification based methods in image segmentation. It is an unsupervised classification algorithm; the objective of the ISODATA is to split non homogeneous regions into two subregions.

This method don't need to know the number of clusters, the algorithm splits and merges clusters.The User defines threshold values for parameters and computer runs algorithm through many iterations until the threshold is reached. (See Figure.3.21. below) [17]

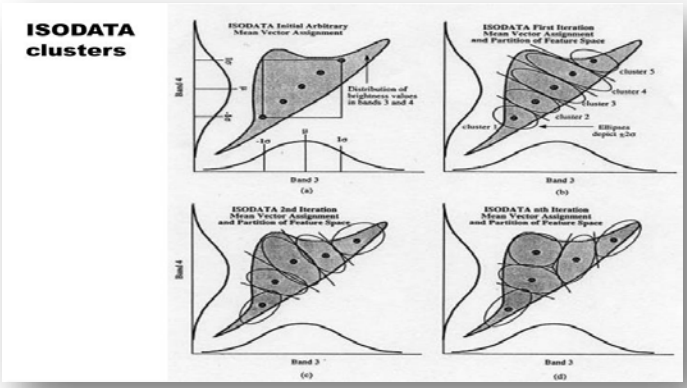


Figure.3.21. ISODATA

III.18.4.5. Methods that require knowledge of pixel class number

III.18.4.5.1. k-means mobile center methods

K-Means is one of the most popular "clustering" algorithms. K-means stores k centroids that it uses to define clusters. A point is considered to be in a particular cluster if it is closer to that cluster's centroid than any other centroid.

K-Means finds the best centroids by alternating between assigning data points to clusters based on the current centroids chosing centroids (points which are the center of a cluster) based on the current assignment of data points to clusters. (See Figure.3.22. below)

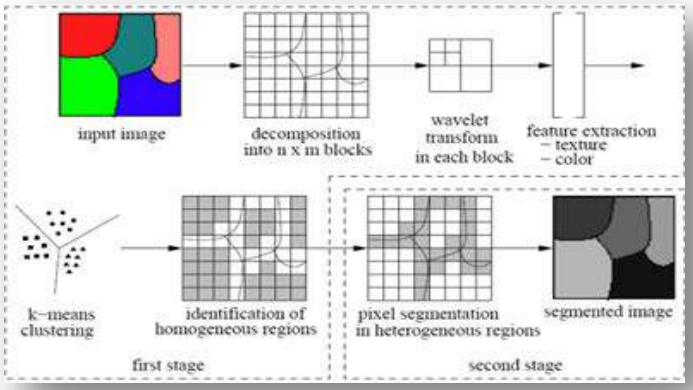


Figure.3.22. K-Means clustering

III.18.4.5.2. C-means fuzzy methods

Fuzzy c-means (FCM) is a method of clustering which allows one piece of data to belong to two or more clusters. This method is frequently used in pattern recognition.

III.19. Introduction to 3D vision systems

Computer vision is the base of all artificial vision systems and it is a process of information processing, the input of a vision system is constituted by an image sequence, the output is a description of the input in terms of objects and the relation ships between these objects.

III.19.1. Vision by computer

Computer vision is concerned with the automatic extraction, analysis, and understanding of useful information from a single image or a sequence of images. Computer vision's goal is not only to see but also process and provide useful results based on the observation. For example, a computer could create a 3-D image from a 2-D image; it involves the development of a theoretical and algorithmic basis to achieve automatic visual understanding.

III.19.2. Classification of Vision by Computer Systems

According to the nature of the scene observed we can determine the type of system.
There are two main types of systems:

III.19.2.1. Two-dimensional vision systems

These systems allow an acquisition of the image in 2D scene, they do not exploit the notion of depth and therefore only recognize flat and isolated objects, and these systems are used in space domains such as remote sensing and character recognition, industrial robotics ...etc.

III.19.2.2. Three-dimensional vision systems

These systems are able to identify objects from an image of a three-dimensional world, that's why they are used in robotics because they allow a robot to move in an unknown environment with obstacles

III.19.3. 3D reconstruction

The three-dimensional reconstruction of a set of points informs on the geometric structure of this same set.

III.19.3.1. Different approaches to three-dimensional reconstruction

III.19.3.1.1. Projective reconstruction

When the points are finished in a projective frame, such a reconstruction does not contain any critical information (absence of the notion of angle, length, parallelism…etc).

III.19.3.1.2. Affine reconstruction

When the points are defined in an affine landmark.Such a reconstruction contains affine information (ratio of length, parallelism)

III.19.4. 3D reconstruction techniques

We can list four categories of the reconstruction methods:

- Shape by spacecarving
- Reconstruction fromEpipolarGeometry
- Reconstruction from Contours
- Reconstruction from the camera movements

III.19.4.1. Shape by space carving

This method based on the calculation of a criterion of photo consistency necessary to even a constant and homogeneous light all around the object

III.19.4.2. Reconstruction from Epipolar Geometry

It is the most classical method since we already use the epipolar geometry to initialize the visual servoing and that we can estimate the position of the cameras

III.19.4.3. Reconstruction from Contours

To base the 3D reconstruction on the contours of an object seems to be difficult to feasible on a natural object of any form with very irregular contours

III.19.4.4. Reconstruction from the camera movements

This method has been extended to deal with other affine cameras such as weak perspective cameras and paraperspective cameras. Based on the same principal, algorithms have also been developed for 3D reconstruction with perspective cameras and scenes with non-rigid motions

III.20. Stereoscopic vision

Stereoscopic vision is also called space vision or plastic vision, is a characteristic, possessed by most persons of normal vision and is important for ability to conceive objects in three dimensional effects and to judge distances.

Stereoscopic vision is the basic prerequisite for photogrammetry and photo interpretation. Stereoscopy is defined as the science or art which deals with stereoscopic or other three dimensional effects and methods by which these effects are produced. The close objects are larger, brighter, and more detailed than a distant object, and that the close object obstructs the view of a distant object. Monocular vision means seeing with one eye. Binocular vision means using both eyes simultaneously. The degree of depth perception is called as “Stereoscopic acuity.” Normal Stereoscopic acuity is possible when images on retina have certain characteristics.

Two eyes must see two images, which are only slightly different in angle of view, orientation, color, brightness, shape, and size. Human eyes, fixed on the same object provide two points of observation which are required for parallax. A finger held with the arm stretched and

alternately viewed with left and the right eye appears to move sideways. Thus movement or displacement is the horizontal parallax. [12]

III.21. Conclusion

Digital image processing is a technology applying number of algorithms to process digital image. The outcome of the process can be either image or set of representative characteristics or properties of an original image.

The major aim of segmentation method is to provide the accuracy in segmented images.

In this chapter, we have reviewed current techniques for digital image processing, the segmentation of moving objects in an image sequence and 3D reconstruction. Emphasis has been given to those techniques for content-based functionalities.The most promising approach combines temporal and spatial segmentation.

CHAPTER IV

TRAJECTORY PLANNING AND ROBOT CONTROL, IMPLIMENTATION & RESULTS

IV.1. Introduction

This chapter explains the methods that we have used to program the robot; also describe the two software, and seven hardware's.

MATLAB software is used for obstacles detection, trajectory planning, segments and angles calculation. MATLAB will send a signal from the PC to the robot using the wifi network.

Arduino IDE software used for Shield wifi programming, arduino pins configuration and motor execution.

IV.2.Connecting and mounting the mobile robot

Our control system for mobile robot allows to controlling the direction of rotation and the running time of both DC motors. The detection of the obstacles is done by image acquisition, to provide a command to our robot. (See Figure.4.1.below)

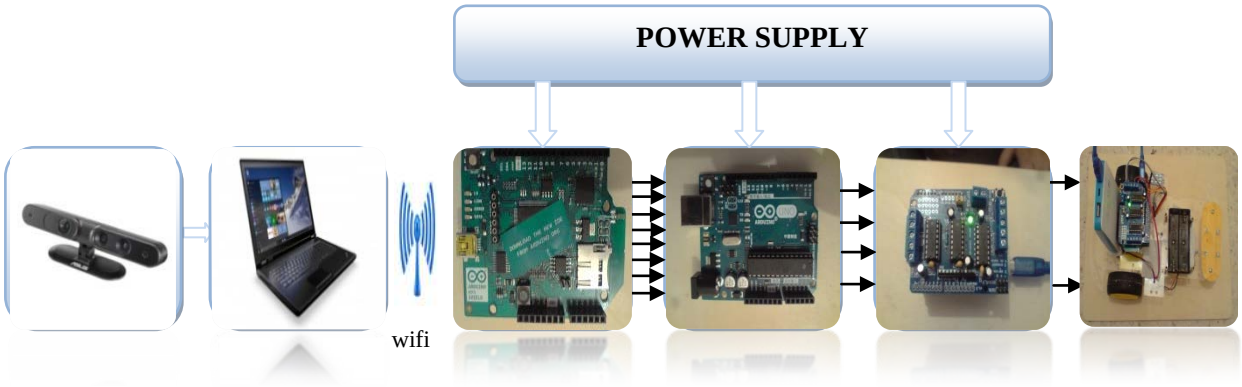


Figure.4.1. Connecting and mounting the mobile robot.

IV.2.1. Power Supply

Generally, every electronic circuit requires a stable source of Dc voltage for its use, this is provided by the power supply. This source is generally constituted of a transforming circuit, transfer the alternating voltage delivered by the power supply line 220 V_{ac}, 50Hz. After having transformed it to a lower voltage through the transformer, a diode bridge to rectify this voltage, while the filter provides the necessary filtering. The regulation is provided by a regulator of $5V_{dc}$ (78LS05). In our project, we have used 10000 mAh power bank and two batteries.(See Figure.4.2.below)

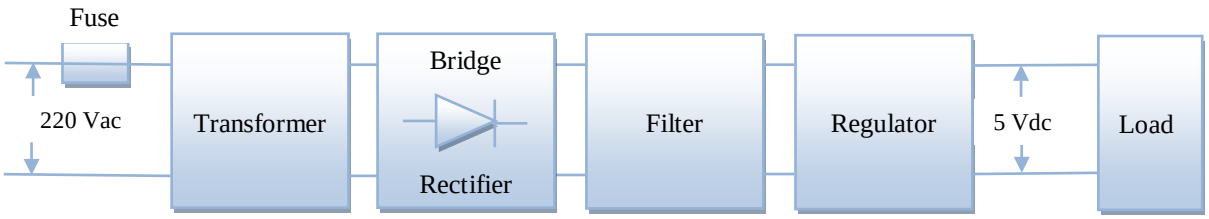


Figure.4.2. Power Supply

IV.2.2. Arduino UNO

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital Input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.

The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter. "Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically. (See Figure.4.3.below)[18]



Figure.4.3. Arduino UNO.

IV.2.2.1. Technical Specifications

- Microcontroller ATmega328.
- Operating Voltage 5V.
- Digital I/O Pins 14 (of which 6 provide PWM output).

- Analog Input Pins 6.
- DC Current per I/O Pin 40 mA.
- DC Current for 3.3V Pin 50 mA.
- Flash Memory 32 KB of which 0.5 KB used by
- Boot loader.
- SRAM 2 KB.
- EEPROM 1 KB.
- Clock Speed 16 MHz.

IV.2.3. Arduino wifi Shield

The Arduino wifi Shield allows an Arduino board to connect to the internet using the 802.11 wireless specifications (wifi). (See Figure.4.4.below)

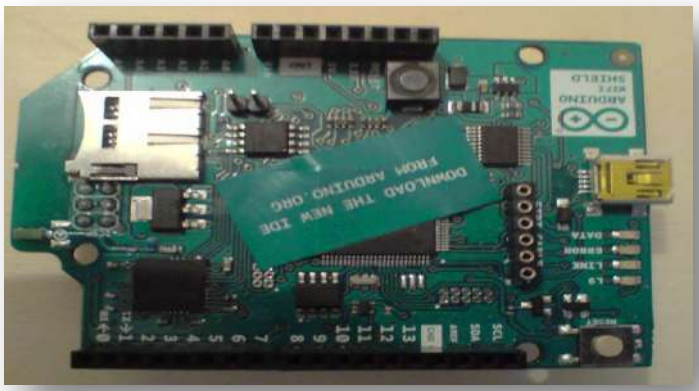


Figure.4.4. wifi Shield

It is based on the HDG104 Wireless LAN 802.11b/g System in-Package. An Atmega 32UC3 provides a network (IP) stack capable of both TCP and UDP. Use the wifi library to write sketches which connect to the internet using the shield. The wifi shield connects to an Arduino board using long wire-wrap headers which extend through the shield. This keeps the pin layout intact and allows another shield to be stacked on top.

The wifi Shield can connect to wireless networks which operate according to the 802.11b and 802.11g specifications. There is an onboard micro-SD card slot, which can be used to store files for serving over the network. It is compatible with the Arduino Uno and Mega. The onboard micro SD card reader is accessible through the SD Library. When working with this library, SS is on Pin 4.Arduino communicates with both the wifi shield's processor and SD card using the SPI bus (through the ICSP header).This is on digital pins 11, 12, and 13 on the

Uno and pins 50, 51, and 52 on the Mega. On both boards, pin 10 is used to select the HDG104 and pin 4 for the SD card. These pins cannot be used for general I/O. On the Mega, the hardware SS pin, 53, is not used to select either the HDG104 or the SD card, but it must be kept as an output or the SPI interface won't work. Digital pin 7 is used as a handshake pin between the wifi shield and the Arduino, and should not be used. [19]

- Requires an Arduino board (not included).
- Operating voltage 5V (supplied from the Arduino Board).
- Connection via: 802.11b/g networks.
- Encryption types: WEP and WPA2 Personal.
- Connection with Arduino on SPI port.
- On-board micro SD slot.
- ICSP headers.
- FTDI connection for serial debugging of wifi shield.
- Mini-USB for updating wifi shield firmware.

The shield contains a number of informational LEDs:

- L9 (yellow): this is tied to digital pin 9.
- LINK (green): indicates a connection to a network.
- ERROR (red): indicates when there is a communication error.
- DATA (blue): indicates data being transmitted / received.

IV.2.4. Arduino Motor Shield Based on L293D

This motor driver board is based on the L293D a monolithic integrated that has a feature to adopt high voltage, high current at four channel motor drivers designed to accept loads such as relays solenoids, DC Motors and Stepper Motors and switching power transistor.(See Figure.4.5.below).To simplify the use of two bridges, on each pair of channels is equipped with a validation input. A separate supply input is provided for the logic, allowing operation at a lower voltage and internal clamp diodes are included. These 4 H-bridges which provide up to 0.6 A per bridge (1.2A peak) at voltages from 4.5 V to 36 V. (See Figure.4.6.below) [20]

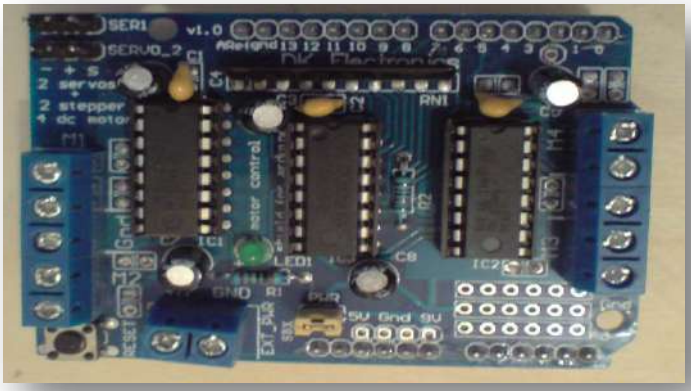


Figure.4.5. Motors Shield

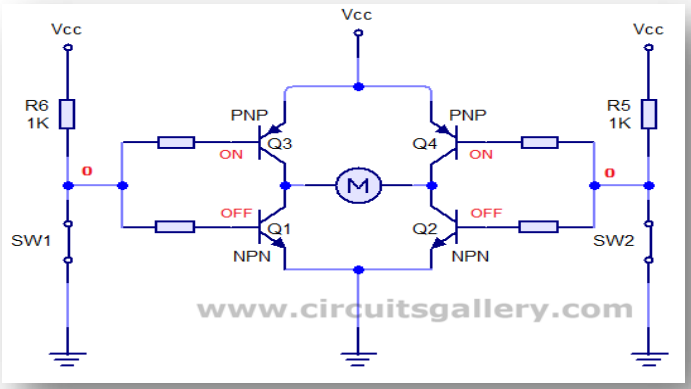


Figure.4.6. H-bridge

This shield has pull-down resistors to keep the motors disabled during power up. It also features a 2-pin terminal block to ensure separate logic and motor external power supplies. This expansion board is compatible with Arduino Mega, Diecimila, and Duemilanove. This motor driver shield is capable of driving:

- Four DC motors and two servos.
- Two DC motors, stepper motor, and two-way servo.
- Two stepper motors and servos.

IV.2.4.1. Specifications

- L293D motor driver chip.
- Four H-bridges.
- Terminal blocks for power supply and DC motors.
- Reset button.

- Big terminal block connectors (10-22 AWG).
- PCB Size: 69 x 53 mm.

IV.2.5. DC motors

DC Motors are widely used in a variety of application fields, from copiers and other office equipment, to remote-controlled equipment, medical equipment, vending machines, and game machines. The DC motors are used for all of the robotics projects.

An electric motor is a device for converting electrical energy into mechanical energy (usually a torque). This conversion is usually obtained through the generation of a magnetic field by means of a current flowing into one or more coils. (See Figure.4.7.below)

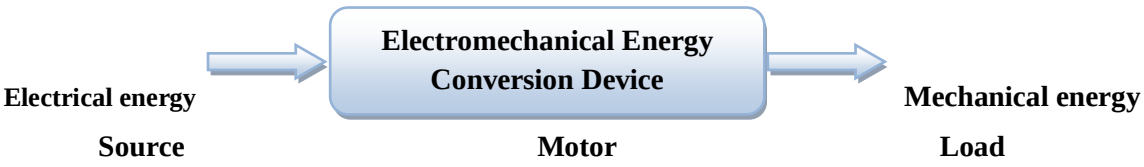


Figure.4.7. Dc motors.

The rotation is obtained by the attractive force between two magnetic fields:

- One field is located on the rotor (the moving part).
- The second magnetic field is located on the stator (the body of the motor).

Consider a coil in a magnetic field of flux density **B**. When the two ends of the coil are Connected across a DC voltage source, the current I flow through it. A force is exerted on the coil as a result of the interaction of magnetic field and electric current. The force on the two sides of the coil is such that the coil starts to move in the direction of the force. In an actual DC motor, several such coils are wound on the rotor, all of which experience force, resulting in the rotation. (See Figure.4.8.below)

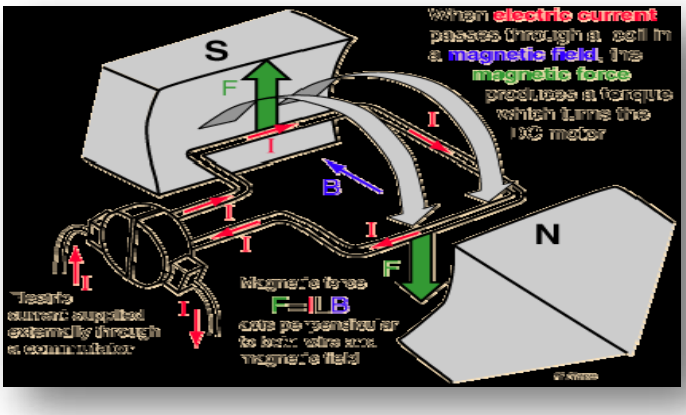


Figure.4.8. Moving part and body of the Motor.

The greater the current in the wire or the greater the magnetic field, the faster the wire moves because of the greater force created.

At the same time, this torque is being produced, the conductors are moving in a magnetic field. At different positions, the flux linked with it changes, which causes an *emf* to be induced $((e = d\varnothing / dt))$. This voltage is in opposition to the voltage that causes current flow through the conductor and is referred to as a *counter-voltage* or *back emf*. (See Figure.4.9.below) [21]



Figure.4.9.*emf* and rotation sense

IV.2.5.1. Construction

DC motors consist of one set of coils, called armature winding, inside another set of coils or a set of permanent magnets, called the stator. Applying a voltage to the coils produces a torque in the armature, resulting in motion.

IV.2.5.1.1. Stator

- The stator is the stationary outside part of a motor.
- The stator of a permanent magnet dc motor is composed of two or more permanent magnet pole pieces.
- The magnetic field can alternatively be created by an electromagnet. In this case, a DC coil (field winding) is wound around a magnetic material that forms part of the stator.

IV.2.5.1.2. Rotor

- The rotor is the inner part which rotates.
- The rotor is composed of windings (called armature windings) which are connected to the external circuit through a mechanical commutator.
- Both stator and rotor are made of ferromagnetic materials. The two are separated by air-gap.
-

IV.2.5.1.3. Winding

A winding is made up of series or parallel connection of coils.

- Armature winding: The winding through which the voltage is applied or induced.
- Field winding: The winding through which a current is passed to produce flux (for the electromagnet)
- Windings are usually made of copper.

IV.2.5.2. Supplying power to DC motors

The motor can be powered simply by an electromechanical relay or by a transistor associated with a freewheel diode. Most often, the motor needs to rotate in both directions of rotation; we use then a device named H Bridge. (See Figure.4.10.below)

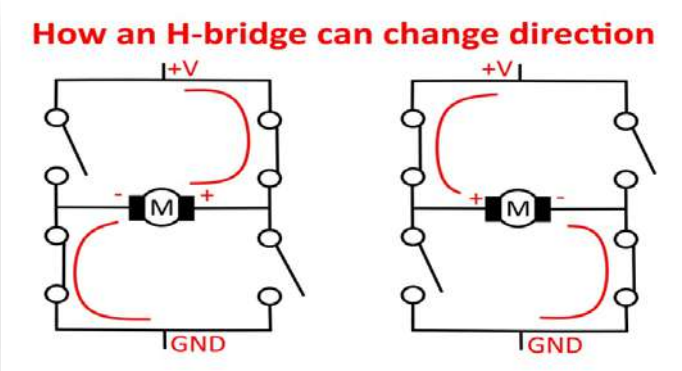


Figure.4.10. H-Bridge.

IV.2.6. RobotIV.4.11.2. (See Figure.4.12.below)

IV.2.6.1. Parts of the Robot Base Chassis (See Figure.4.11.below)

• Caster Wheel. This swivels around to allow robot movement in any direction.

• Encoder discs. These can be used with more complex software to measure the wheel rotation.

• Power Switch (optional): This may be difficult to push into place in the rectangular cutout in the chassis.

• Motor Mounting Brackets will hold the motors to the chassis.

• Assorted 3mm diameter machine screws and nuts.

•Wheels.

•DC Gear Reduction Motor.

• Battery pack for 4 AA size batteries (Suggest rechargeable).

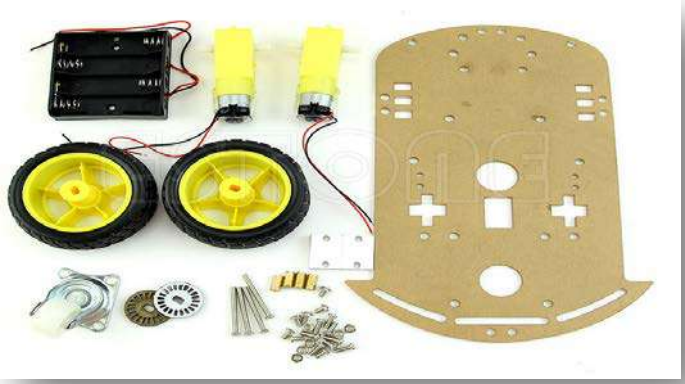
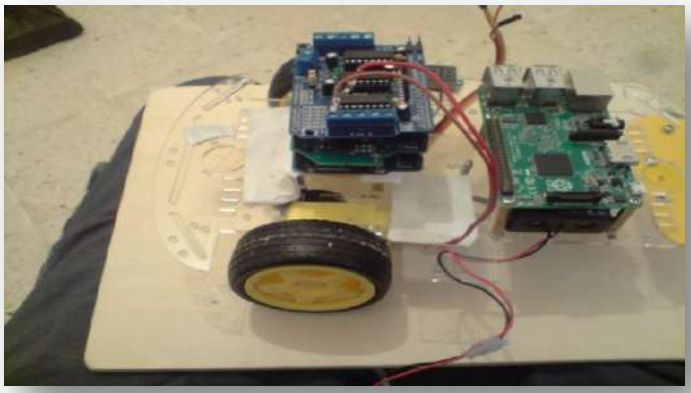


Figure.4.11. Parts of the Robot Base Chassis



IV.4.12.Assembled parts of the robot

IV.2.7. Xtion pro live RGB and Depth Sensor

RGB-D sensors combine RGB color information and depth information. Sensors that provide such data have existed for years, including the Swiss Ranger SR4000 and PMD Tech products .The per-pixel depth-sensing technology that is used in consumer RGB-D cameras was developed by PrimeSense. The PrimeSense sensor projects an infrared speckle pattern. The projected pattern is then captured by an infrared camera in the sensor, and compared part-by-part to reference patterns stored in the device. These patterns were captured previously at known depths. The sensor then estimates the per-pixel depth based on which reference patterns the projected pattern matches best the depth data provided by the infrared sensor is then correlated to a calibrated RGB camera. This yields an RGB image with a depth associated with each pixel. A popular unified representation of this data is a point cloud: a collection of points in three dimensional spaces, where each point can have additional features associated with it. With an RGB-D sensor, the color can be one such feature. Additionally, approximated surface normals are also often stored with each point in a point cloud. (See Figure.4.13.below)[22]



Figure.4.13. Xtion pro live RGB and Depth Sensor.

IV.2.7.1. Devices

Because consumer RGB-D sensors were created as NUI devices, they have certain characteristics that limit their utility for mapping applications. In particular, the field of view is much smaller than mapping-specialized sensors, and the depth resolution deteriorates notably with depth. Asus has an Xtion PRO version, which only provides depth data, and an Xtion PRO LIVE version, which provides depth, color, and audio (using a microphone array, like the Kinect).

IV.2.7.2. Technical specifications of the Xtion PRO LIVE sensor.

Table.4.1. Xtion PRO LIVE sensor characteristics**.**

Field of View	58° H, 45° V, 70° D
Depth Image Size	VGA (640x480) : 30 fps QVGA (320x240): 60 fps
Resolution	SXGA (1280*1024)
Interface	USB2.0

The core of the RGB-D image/video is the depth image, which is usually generated by a range sensor. Compared to a 2D intensity image, a range image is robust to the variations

in color, illumination, rotation angle, and scale RGB-D images/videos can facilitate a wide range of application areas, such as computer vision, robotics, construction and medical imaging. Since a lot of algorithms are proposed to solve the technological problems in these areas, an increasing number of RGB-D data sets have been created so as to verify the algorithms.

IV.2.7.3. Kinect hardware configuration

Generally, the basic version of Microsoft Kinect consists of an RGB camera, an infrared camera, an IR projector, a multi-array microphone and a motorized tilt.

The distance between objects and the camera is ranging from 1.2 meters to 3.5 meters here, RGB camera is able to provide the image with the resolution of 640 × 480 pixels at 30 Hz. This RGB camera also has option to produce higher resolution images (1280×1024 pixels), running at 10 Hz. The angular field of view is 62 degrees horizontally and 48.6◦ vertically. Kinect's 3D depth sensor (infrared camera and IR projector) can provide depth images with the resolution of 640 × 480 pixels at 30 Hz. The angular field of this sensor is slightly different with that of the RGB camera, which is 58.5 degrees horizontally and 46.6 degrees vertically. In the application such as NUI (Natural User Interface).

The multi-array microphone can be available for a live communication through acoustic source localization of Xbox 360. This microphone array actually consists of four microphones, and the channels of which can process up to 16-bit audio signals at a sample rate of 16 kHz. Following Microsoft, Asus launched Xtion Pro Live, which has more or less the same features with Kinect. In July 2014, Microsoft released the second generation Kinect. In general, the technology used for generating the depth map is based on analyzing the speckle patterns of Infrared laser light. (See Figure.4.14.below)

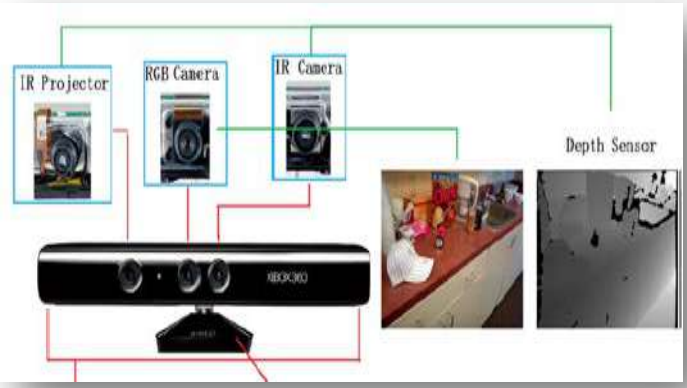


Figure.4.14. RGB and Depth image.

IV.3. MATLAB Software [23]

MATLAB is a high-level language and interactive environment for numerical computation, visualization, and programming. Using MATLAB, you can analyze data develop algorithms, and create models and applications. The language, tools, and built in math functions enable you to explore multiple approaches and reach a solution faster than with spreadsheets or traditional programming languages, such as C/C++ or Java. You can use MATLAB for a range of applications, including signal processing and communications, image and video processing, control systems, test and measurement, computational finance, and computational biology. More than a million engineers and scientists in industry and academia use MATLAB, the language of technical computing. Typical uses include:

- Math and computation.
- Algorithm development.
- Modeling, simulation, and prototyping.
- Data analysis, exploration, and visualization.
- Scientific and engineering graphics.
- Application development, including Graphical User Interface building

The MATLAB system consists of five main parts:

IV.3.1.MATLAB language

This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create complete large and complex application programs.

IV.3.2. MATLAB working environment

This is the set of tools and facilities that you work with as the MATLAB user or programmer. It includes facilities for managing the variables in your workspace and importing and exporting data. It also includes tools for developing, managing, debugging, and profiling M-files, MATLAB's applications.

IV.3.3. Handle Graphics

This is the MATLAB graphics system. It includes high-level commands for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics. It also includes low-level commands that allow you to fully customize the appearance of graphics as well as to build complete Graphical User Interfaces on your MATLAB applications.

IV.3.4. MATLAB mathematical function library

This is a vast collection of computational algorithms ranging from elementary functions like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix eigenvalues, Bessel functions, and fast Fourier transforms.

IV.3.5. MATLAB Application Program Interface (API)

This is a library that allows you to write C and FORTRAN programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

IV.4. IDE Arduino Software

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them. [24]

IV.4.1. Arduino Program Development

- ✓ Based on C++ without 80% of the instructions.
- ✓ A handful of new commands.
- ✓ Programs are called 'sketches.
- ✓ Sketches need two functions:
  - ❖ Void setup.
  - ❖ Void loop.
- ✓ Setup runs first and once.
- ✓ Loop runs over and over, until power is lost or a new sketch is loaded.

IV.4.2. Structure of an Arduino Sketch

• The first one is "setup ()".

Anything you put in this function will be executed by the Arduino just once when the program starts.

• The second one is "loop ()".

Once the Arduino finishes with the code in the setup function, it will move into the loop, and it will continue running it in a loop, again and again, until you reset it or cut off the power.

IV.4.3. Parts of the IDE main screen. (See Figure.4.15.below)



Figure.4.15. IDE main screen.

IV.4.4. Arduino Specific Functions

• Pin Mode (pin, mode)

- ❖ Configures a digital pin to read (input) or write (output) a digital value

• Digital Write (pin, value)

- ❖ Writes the digital value (HIGH or LOW) to a pin set for output

• Digital Read (pin)

- ❖ Reads a digital value (HIGH or LOW) on a pin set for input

• **Analog versions**

- ❖ Analog Read's range is 0 to 2^{10} (1024) (for Arduino Uno)
- ❖ The ARDUINO Due and the ARDUINO Zero have 12-bit ADC capabilities that can be accessed by changing their solution to 12. This will return values from analog Read between 0 and 2^{12} (4095).

• **Serial commands**

- ❖ print, write, delay

IV.5. Mobile robot programming steps

After the presentation of the two software's that we have used for the programming purpose of our mobile robot. We need to give a general description of the approach of this programming, and all that will be presented on the following flowchart. [25]

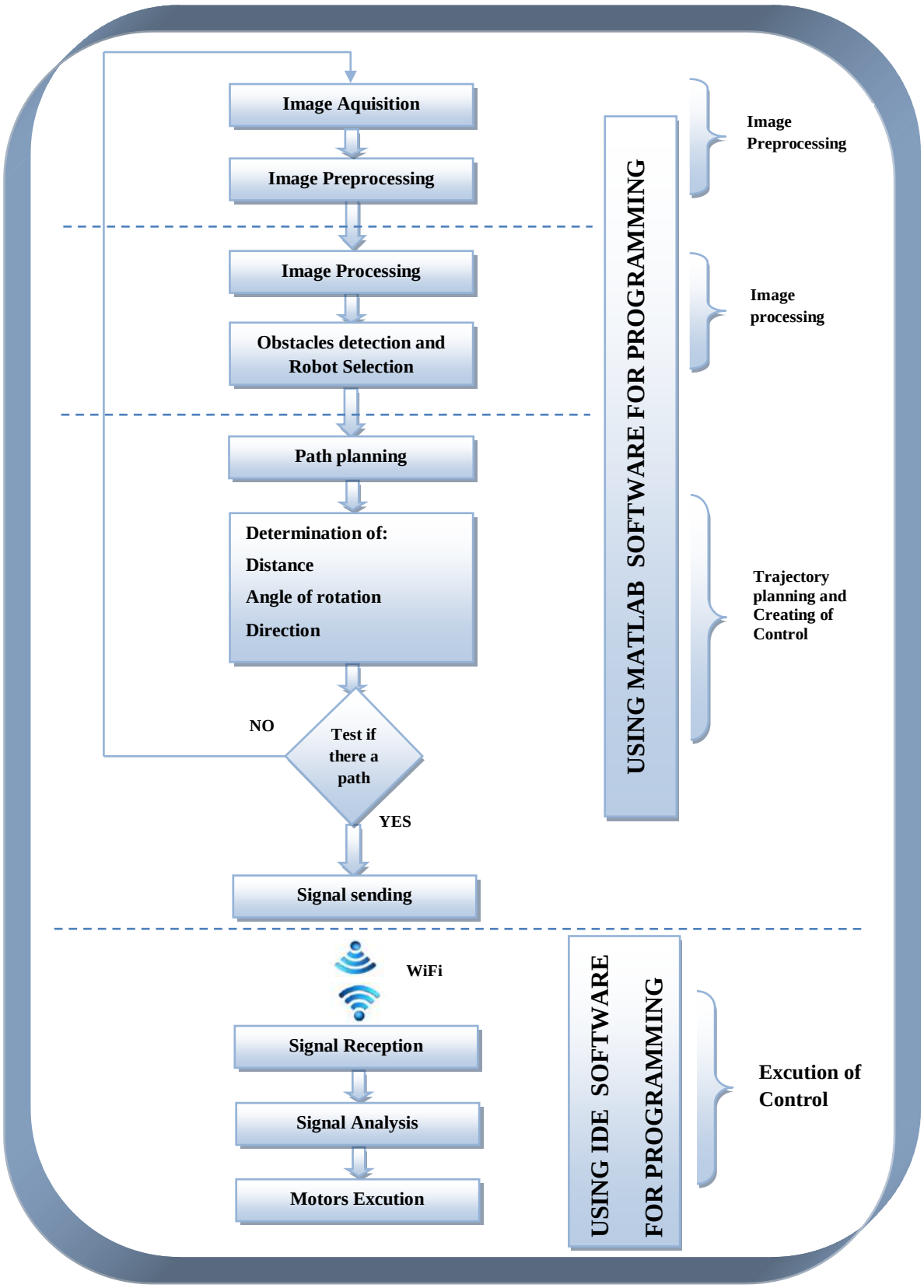


Figure.4.16.flow chart of the proposed method

IV.5.1. Using Matlab Software

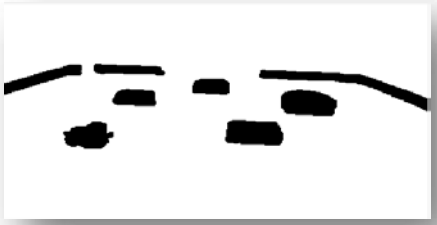
In our thesis we have used Matlab software for the first step of programming

IV.5.1.1. Image Preprocessing

In chapter II, we quoted the various tools for acquiring the gesture, and we chose the vision because it's one of the best ways of acquisition, but which imposes a more difficult treatment. We used an RGB D type vision sensor that provides Depth Image Size VGA (640x480)color images, with a frame rate of 30 frames / second, and a Field of View 58° H, 45° V, 70° D and Resolution of SXGA (1280*1024).At the end of this step we get an image as follows:



Original image with 4 obstacles



Black and white image with 4 obstacles



Original image with 3 obstacles.

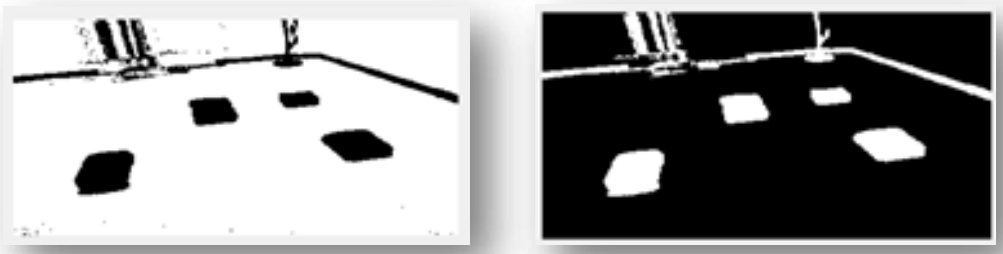


Black and white image with 3 obstacles.

Figure.4.17. Image acquisition with 4 and 3 obstacles

IV.5.1.2. Image processing

The second step based on Capture the image of the environment from RGB-D Camera and Convert it into a Binary format with ‘1’s as obstacles and ’0’s as a surrounding. Then remove robot from obstacles by omitting it from the image and the matrix; after that we have performed some morphological operations on the image to remove unwanted information.
Then inflate the image by the size of the robot so as to avoid the collision between it and obstacles. (See Figures.4.18, 4.19, 4.20 below)



Binary image **inversed binary image**

Figure.4.18. binary image with 4 obstacles

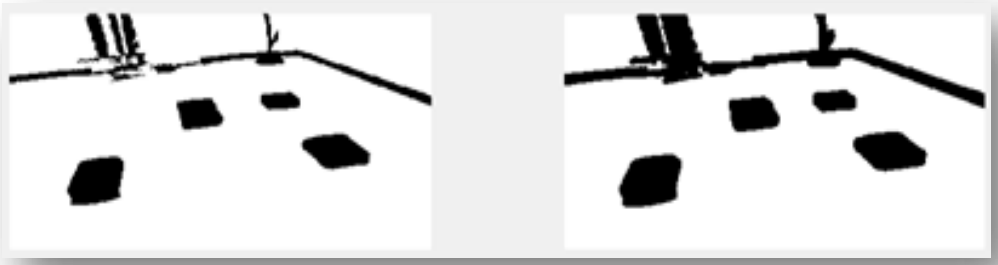


Figure.4.19. binary inflated image with 4 obstacles



Figure.4.20. binary inflated image with 3 obstacles

IV.5.1.3. Trajectory planning

The main goal of this dissertation is to construct a collision-free path from a starting position (Location of Robot) to an end or destination position. Using the Probabilistic Roadmap (PRM) we have computed an obstacle-free path between two locations on a given map path planner. PRM path planner constructs a roadmap in the free space of a given map using randomly sampled nodes in the free space and connecting them with each other. Once the roadmap has been constructed, you can query for a path from a given start location to a given end location on the map.PRM uses this binary occupancy grid representation to deduce free space. Furthermore, PRM does not take into account the robot dimension while computing an obstacle-free path on a map. Hence, we should inflate the map by the dimension of the robot, in order to allow computation of an obstacle-free path that accounts for the

robot's size and ensures collision avoidance for the actual robot. (See Figures.4.21, 4.22.below) [26]

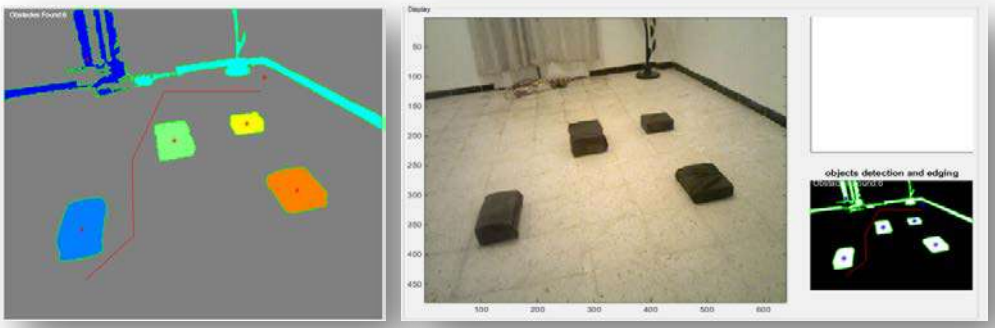


Figure.IV.21. first path generated by PRM algorithm

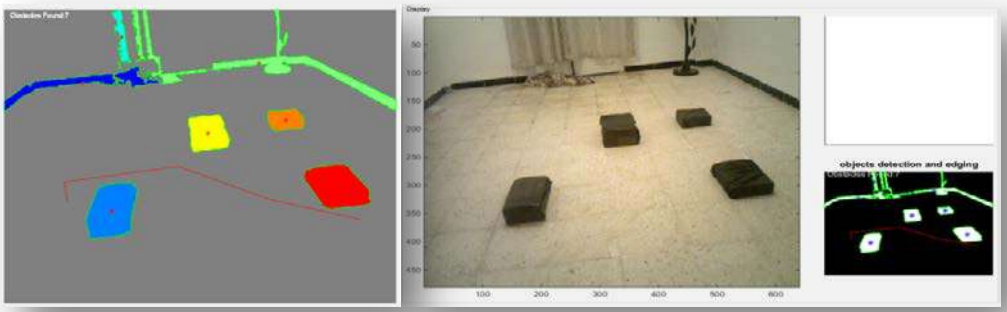


Figure.IV.22. Second path generated by PRM algorithm

IV.5.1.4.Creationof the control

In order to create a control, we have gone through the trajectory calculation from point A to point B, then the transmission of the control signal. In order to move the robot to the desired point, we need to calculate the angle between the robot and this point, then we calculated the distance between the axis and this point.

IV.5.1.4.1. Calculation of rotation angle [25]

We calculated the rotation angle of robot using the following method:

$$\alpha_i = arctan\left(\frac{\Delta y_i}{\Delta x_i}\right) \qquad \textbf{(Eq. 4.1).}$$

$$\alpha_{i+1} = arctan\left(\frac{\Delta y_{i+1}}{\Delta x_{i+1}}\right) \qquad \textbf{(Eq. 4.2).}$$

$$\alpha_{i+n} = arctan\left(\frac{\Delta y_{i+n}}{\Delta x_{i+n}}\right) \qquad \textbf{(Eq. 4.3).} \qquad \text{With i= 0, 1, 2, 3}$$

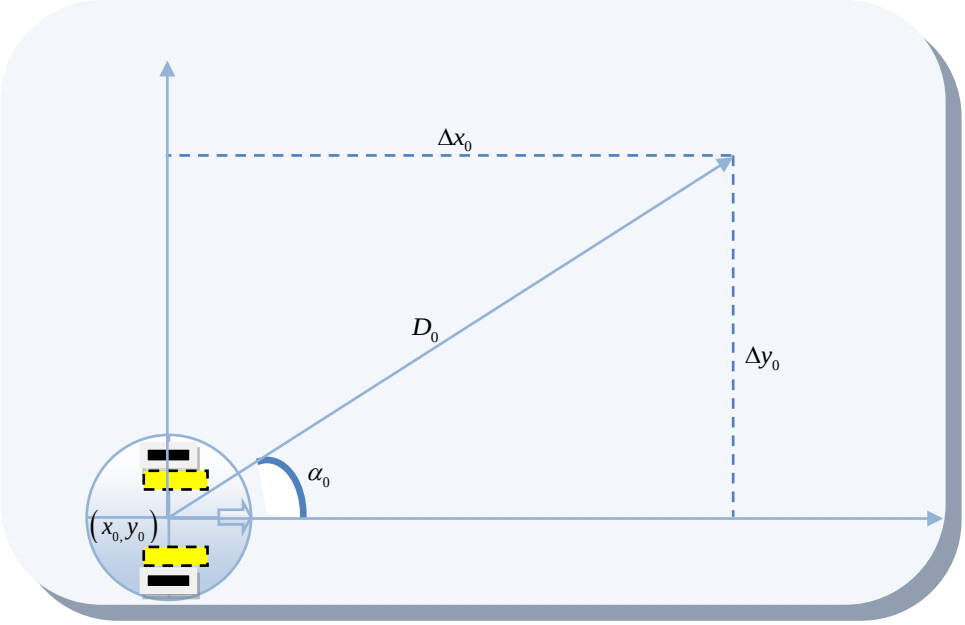


Figure.4.23. Initial position

We measured the time needed to make a single turn by the robot around itself, then, we calculate the corresponding time for this angle α.

IV.5.1.4.2. Determination of Direction

The choice of direction of rotation is made from the Angles:

$(\alpha_{i+n} = \alpha_{i+1} - \alpha_i)$

if $\alpha_{i+1} - \alpha_i > 0$ then turn the Robot left

If $\alpha_{i+1} - \alpha_i < 0$ then turns the Robot Right

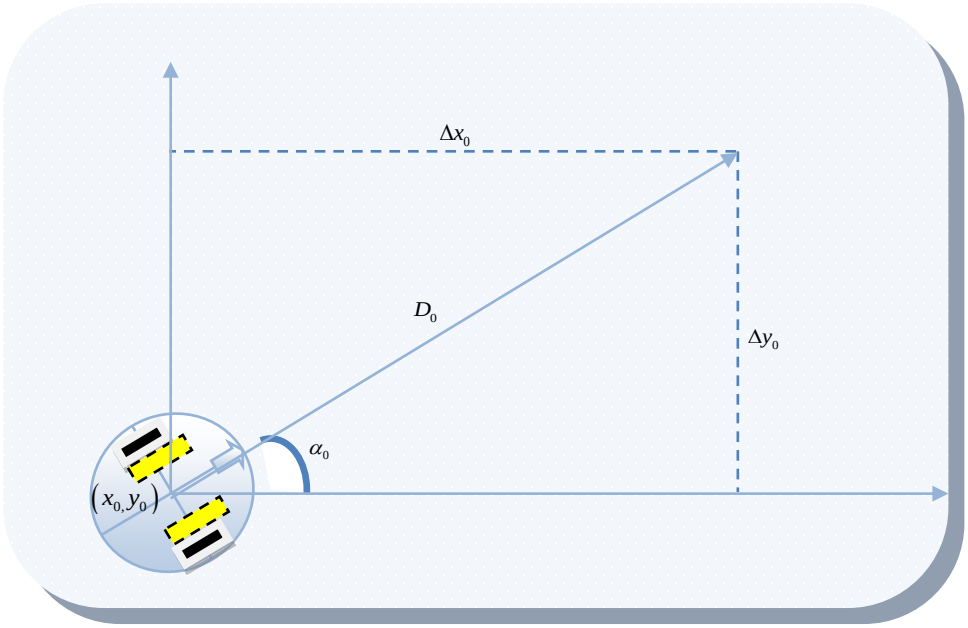


Figure.4.24. The robot rotation.

IV.5.1.4.3. Calculation of distance

In general the calculation of distance is made by the following formula:

$$d = \sqrt{\Delta x^2 + \Delta y^2} \qquad \textbf{(Eq. 4.4).}$$

But in our case with three dimentions the measurments will obtained from depth image that we have seen befor (Euclidean distance).

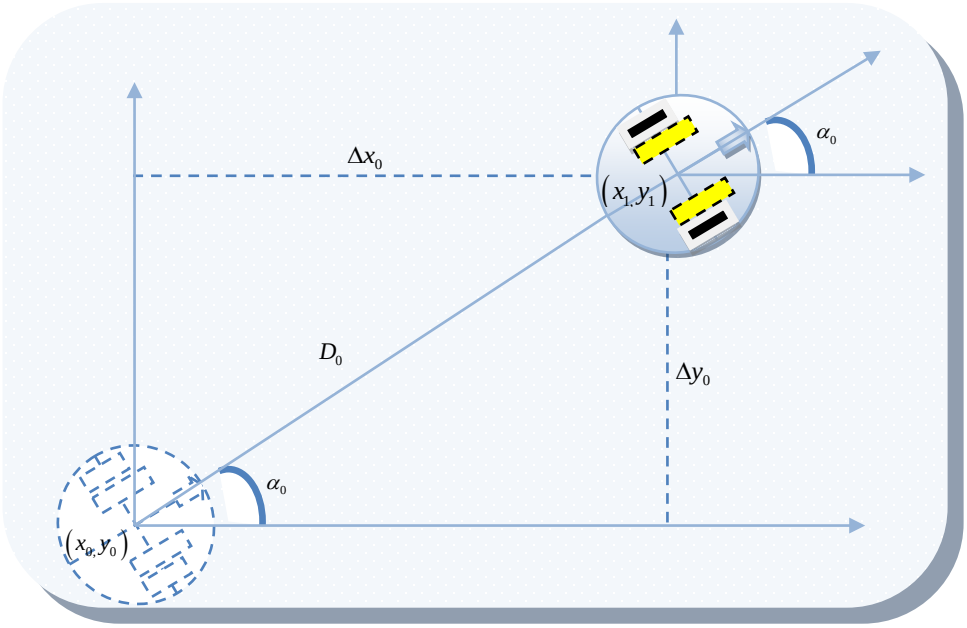


Figure.4.25. The robot reaches the desired point

We measured the time required to make One meter (1000mm) distance by the robot, then, we calculate the corresponding time for this distance D.

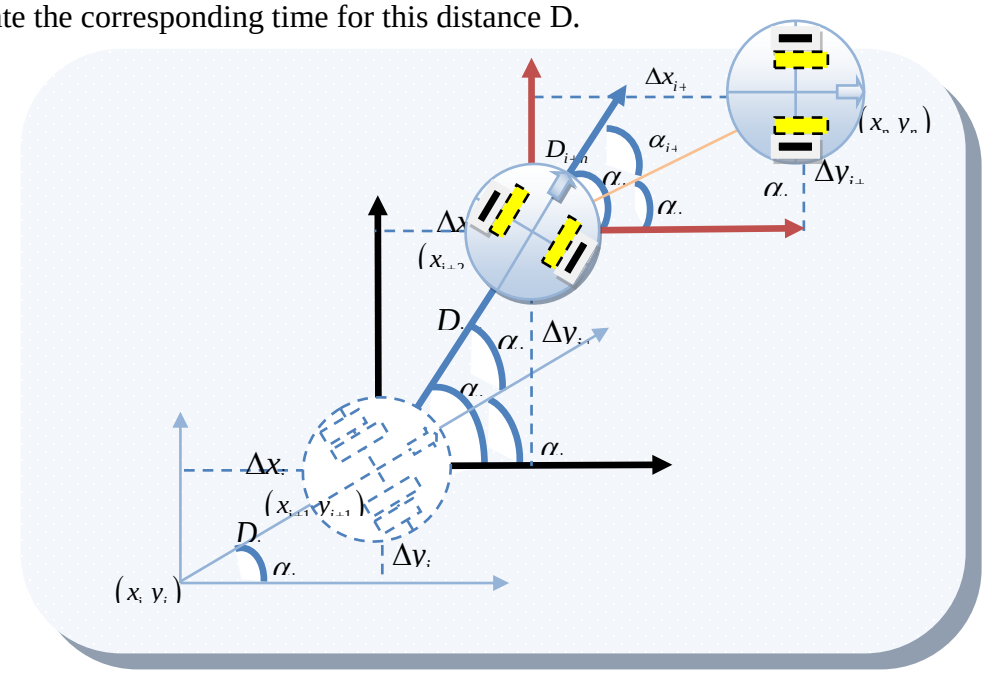


Figure. 4.26. The robot reaches the desired point and continue to the second link then back to the initial position of orientation.

At the end of this step, Matlab will send an execution signal to the robot (DC motors) through the wifi of our laptop, this signal has the following form: http: // IP address / Direction of rotation.

Signal 1	http://192.168.8.101/GET/ROBOT.LEFT:	The Robot will turn left.
Signal 2	http://192.168.8.101/GET/ROBOT.RIGHT:	The Robot will turn right.
Signal 3	http://192.168.8.101/GET/ROBOT.DIRECT:	The Robot will go direct.
Signal 4	http://192.168.8.101/GET/ROBOT.STOP:	The Robot will stop.

Matlab will control of our mobile robot in a reel time, by sending a signals containing IP address and direction of rotation.

The duration of each signal, is executed by matlab software.

IV.5.2. Using IDE Software

In our thesis we have used IDE software for the second step of programming (programming of Arduino Uno).

IV.5.2.1. Control execution

For the transmission of signals between the laptop (Matlab) and the Robot (Arduino Uno), we will use our Wifi Shield and our Arduino to create a simple Web server. Using the Wifi library, our mobile robot (Arduino Uno) will be able to answer an http request; after the reception of a signal (http) contains the IP address and the direction of rotation. Our Arduino Motor Shield will respond by power ON or OFF the motors for a defined duration. We have access to an 802.11b / g wireless network. For our case, we will need to change the network settings in the sketch to match our particular network. For networks using WPA / WPA2 Personal, we need the username and password. [25]

IV.6. Discussion and perspective of test results

To facilitate the use of this application we have created a simple interface using the MATLAB GUI. The interface contains processing panel, calibration panel and display panel. The Processing panel consists of four push buttons:

- Start/Stop acquisition.
- Start processing.
- Obstacles detection.
- Robot calibration and control.

The Calibration panel consists of three edit text windows:

- IP address.
- Time in second to perform one meter.
- Time in second to perform one tour 360°.

The Display panel consists of tow axes windows:

- Axes1 to display original image acquisition.
- Axes2 to display binary image and display trajectory.

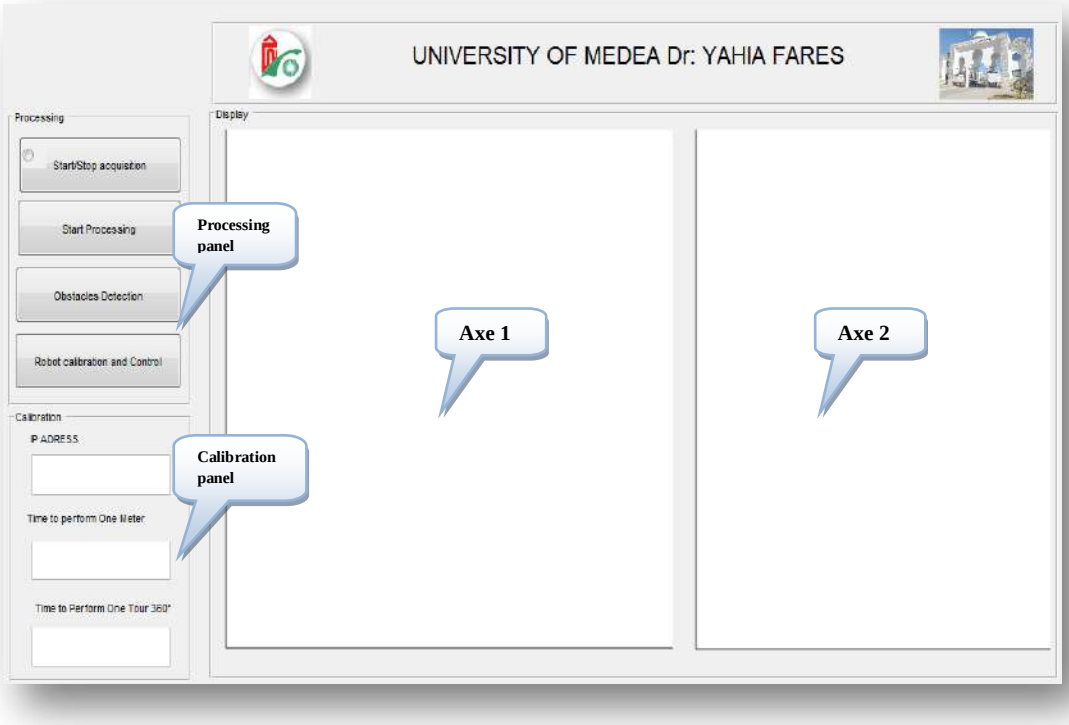


Figure.4.27. MATLAB GUI Interface.

IV.6.1. First test



Figure.4.28. First acquisition

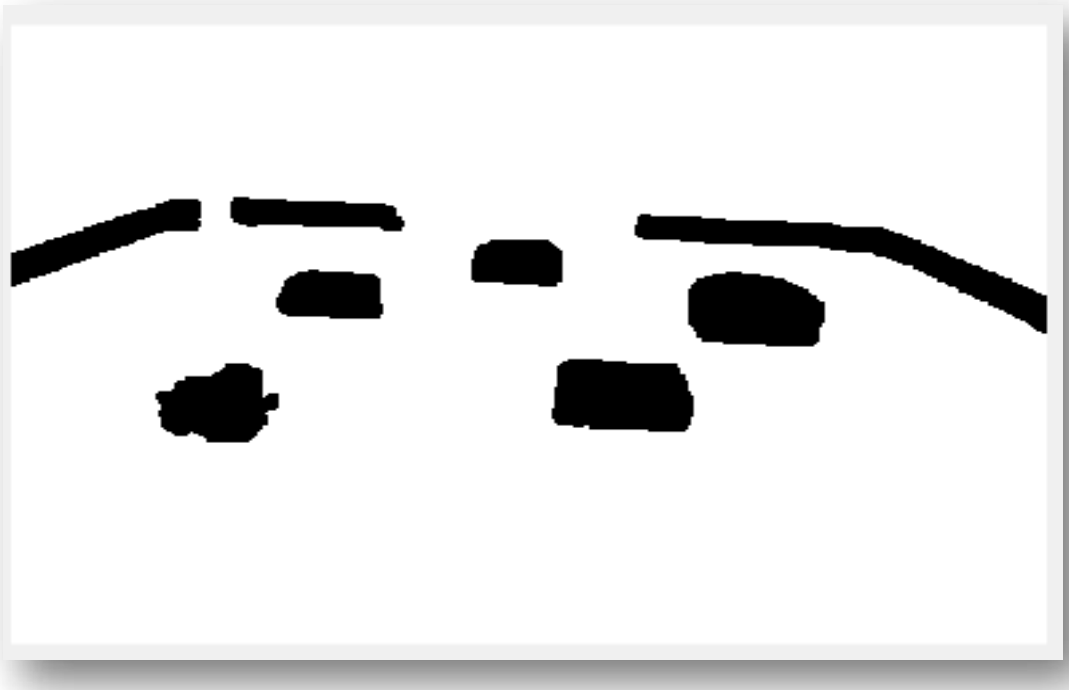


Figure.4.29. Binary and inflated image

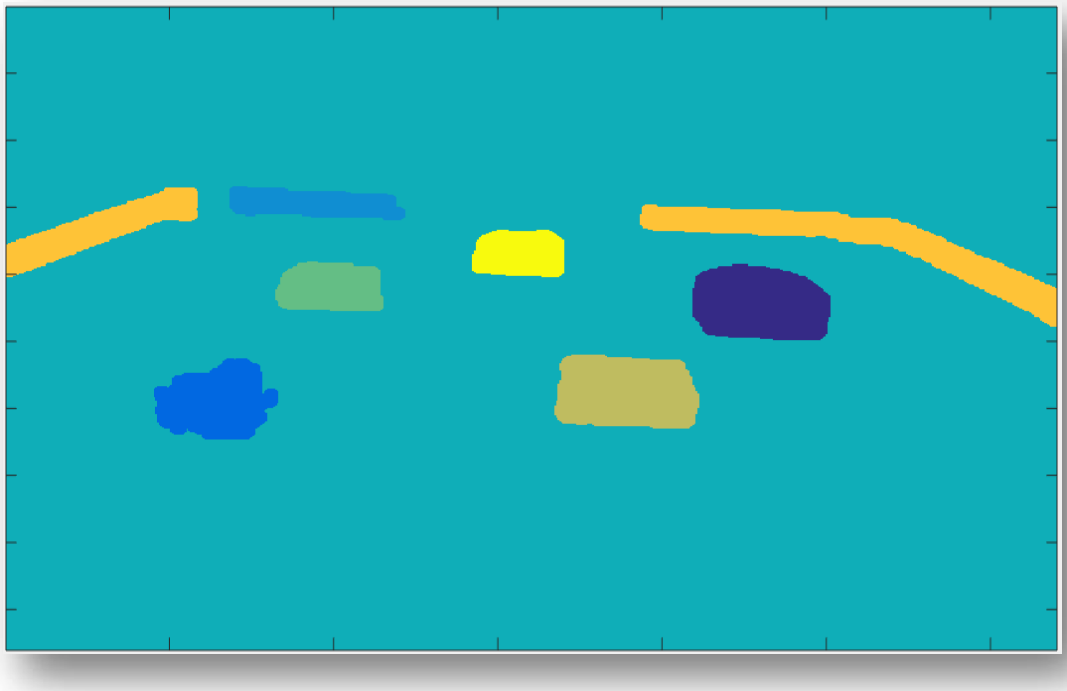


Figure.4.30. Obstacles detection and robot removing

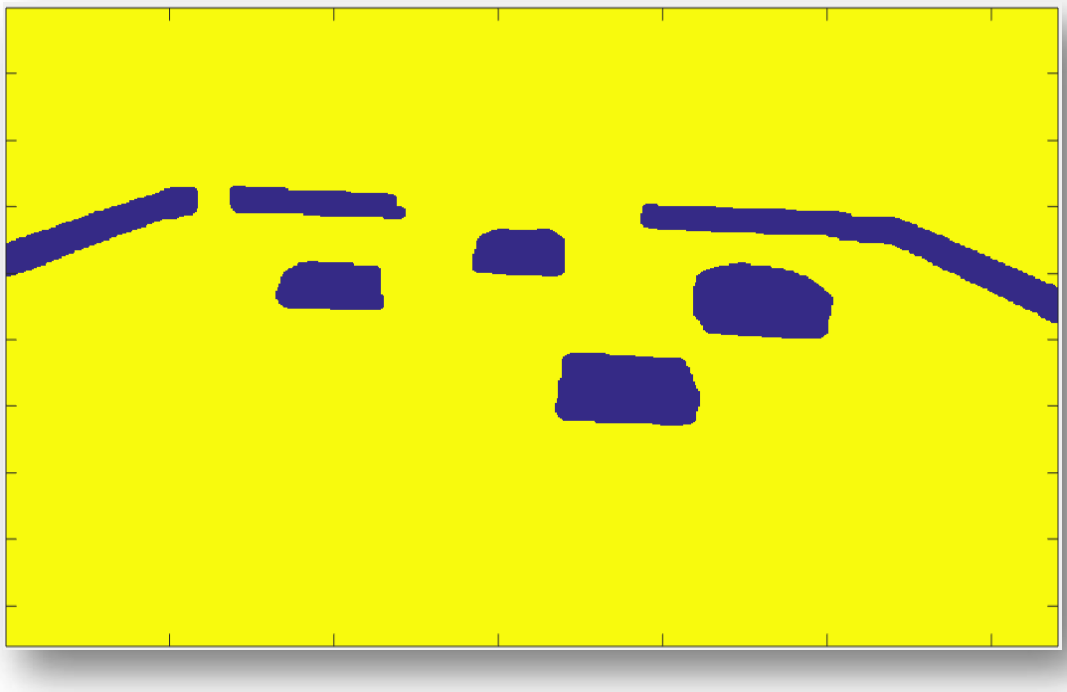


Figure.4.31. Robot removed from image

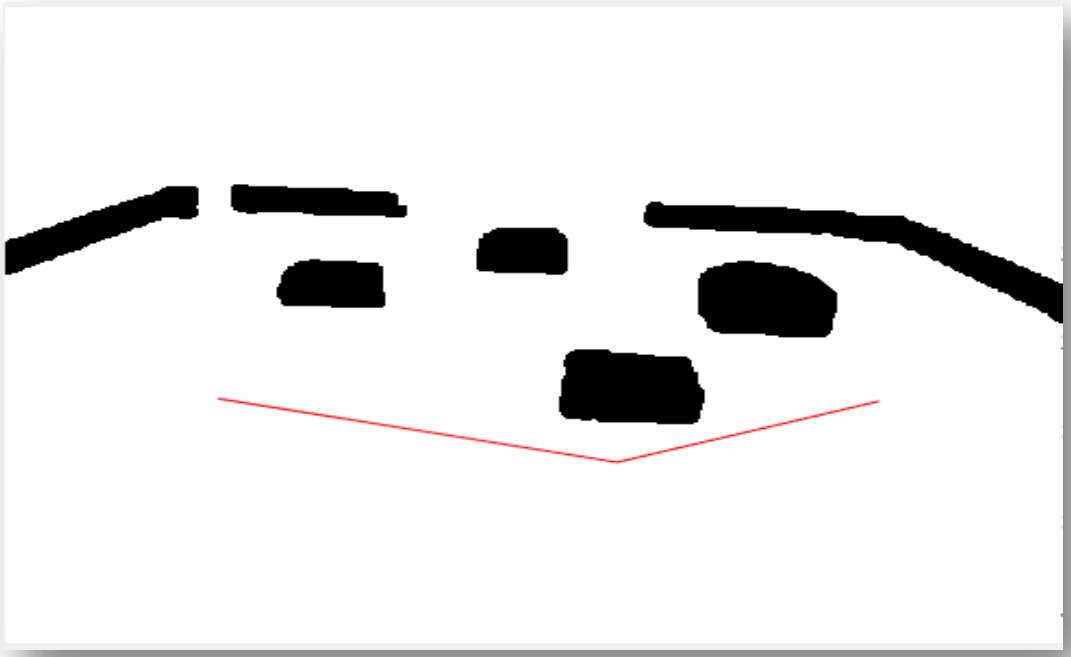


Figure.4.32. Path generation

IV.6.2. Second test



Figure.4.33. Second acquisition

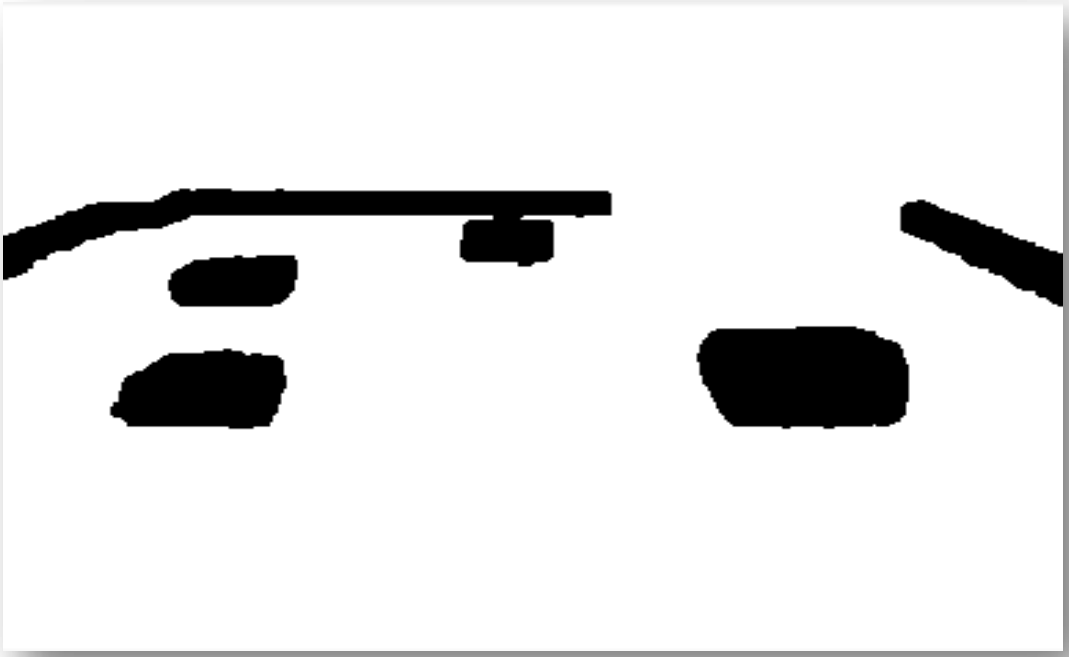


Figure.4.34. Binary and inflated image

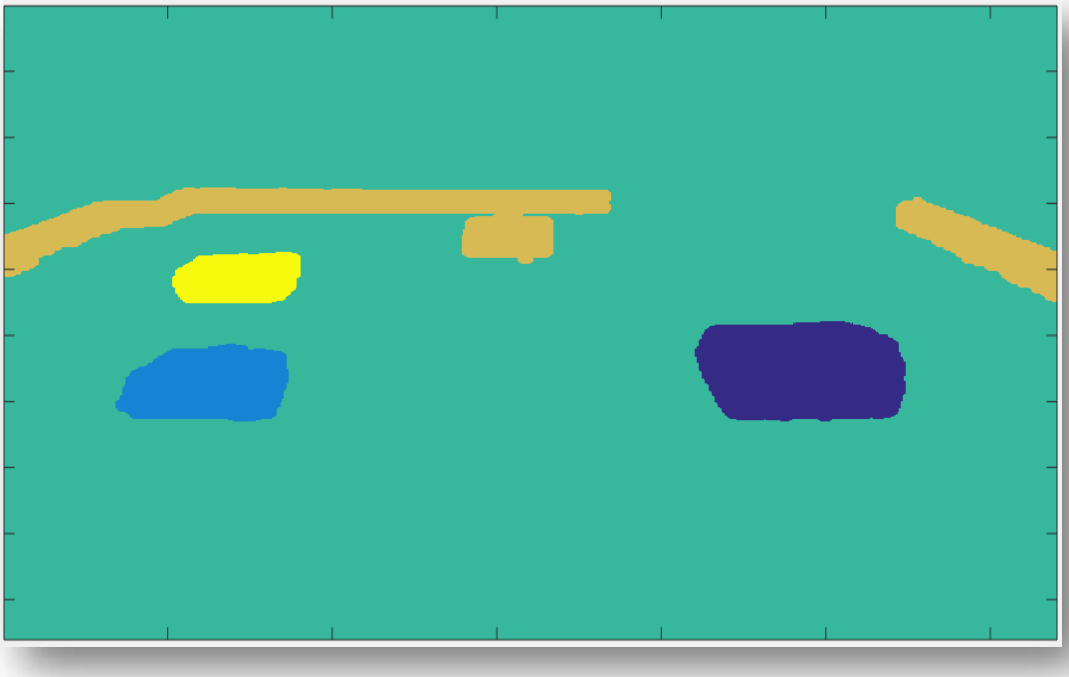


Figure.4.35. Obstacles detection and robot removing

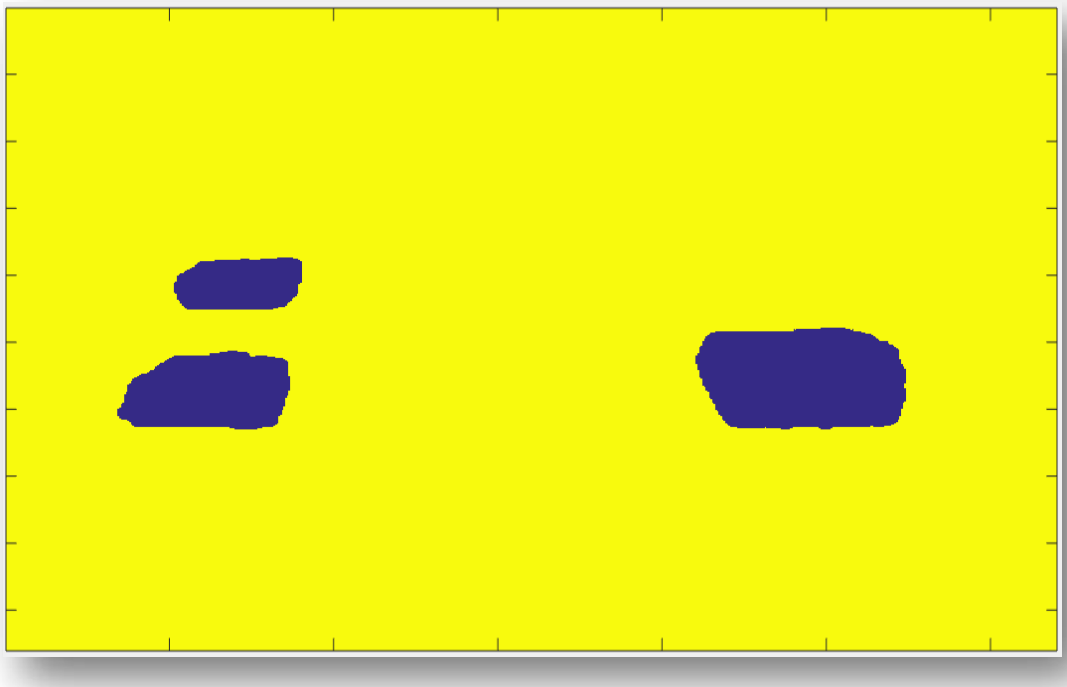


Figure.4.36. Robot removed from image

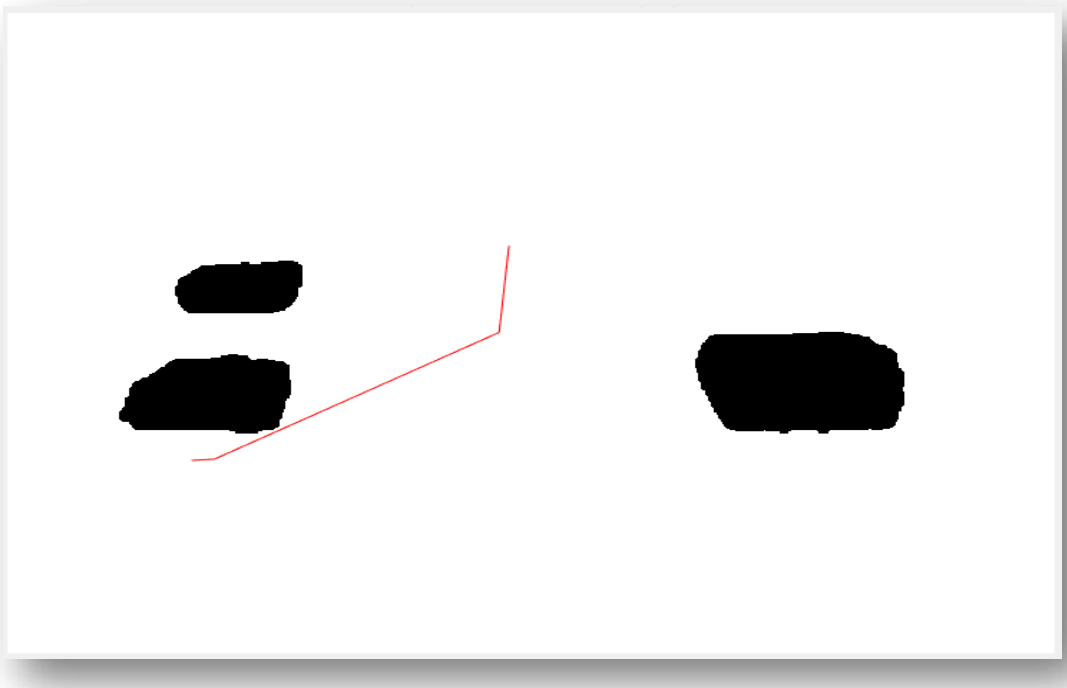


Figure.4.37. Path generation

IV.6.3. Third test



Figure.4.38. Third acquisition

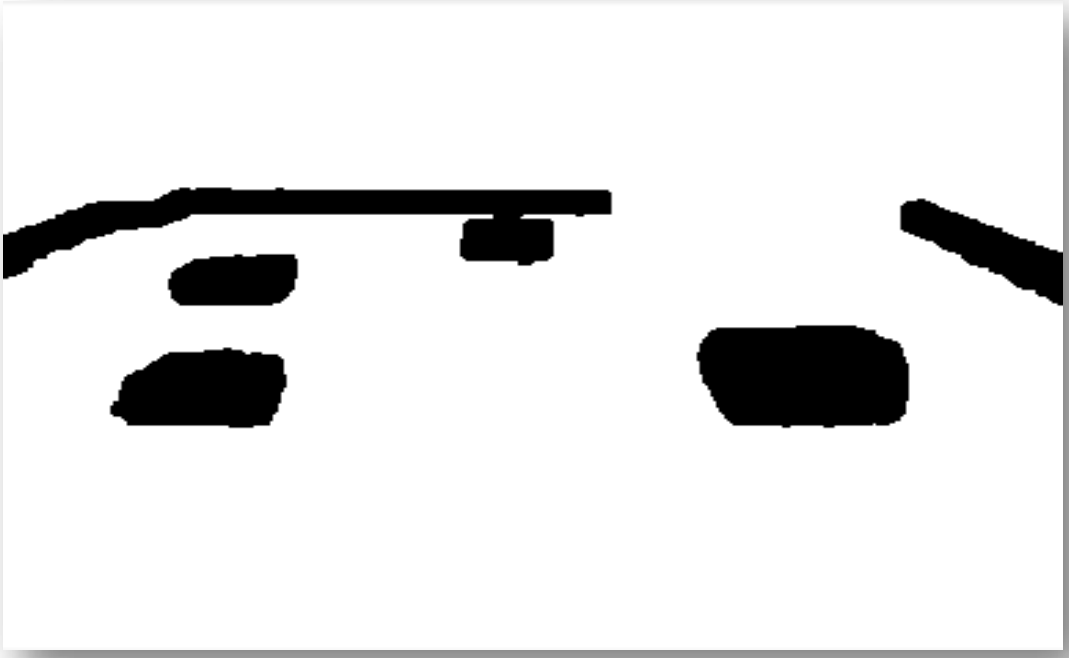


Figure.4.39. Binary and inflated image

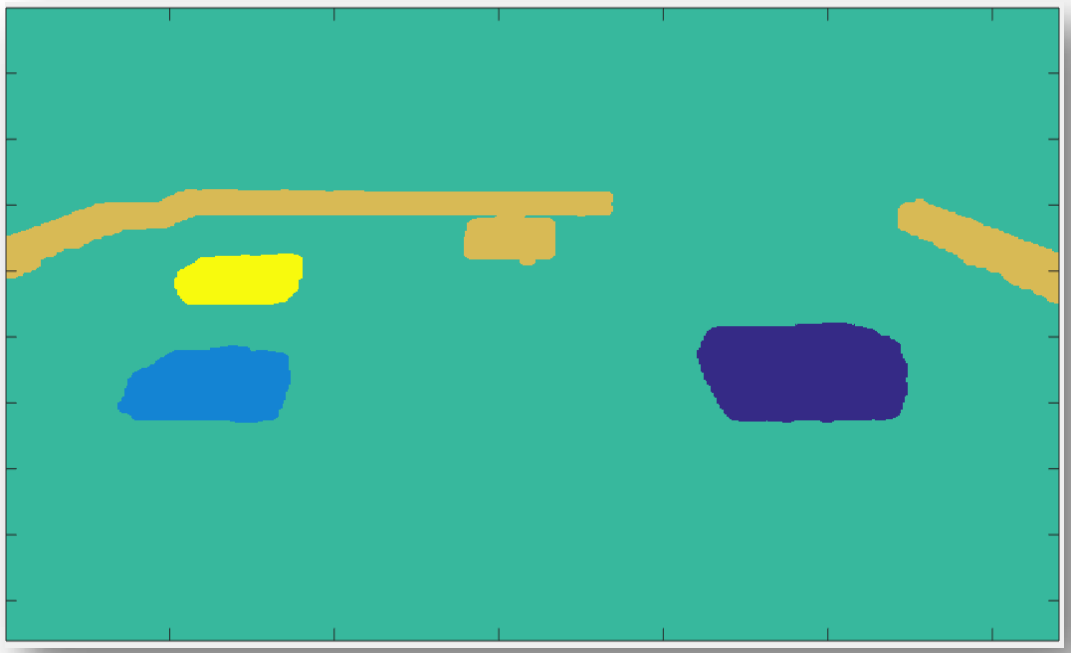


Figure.4.40. Obstacles detection and robot removing

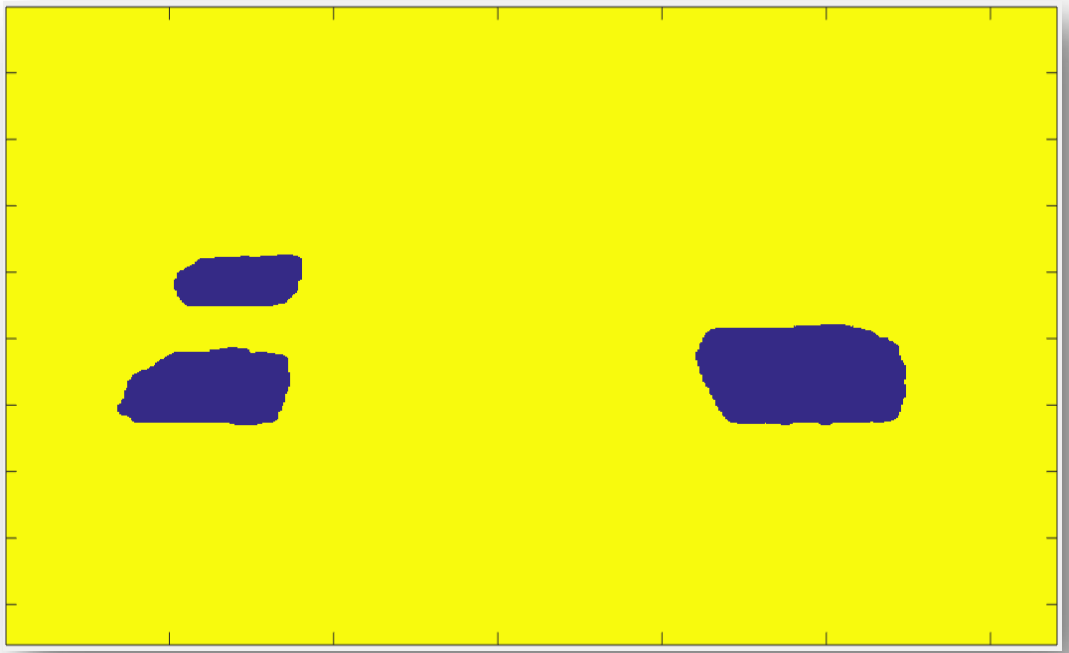


Figure.4.41. Robot removed from image

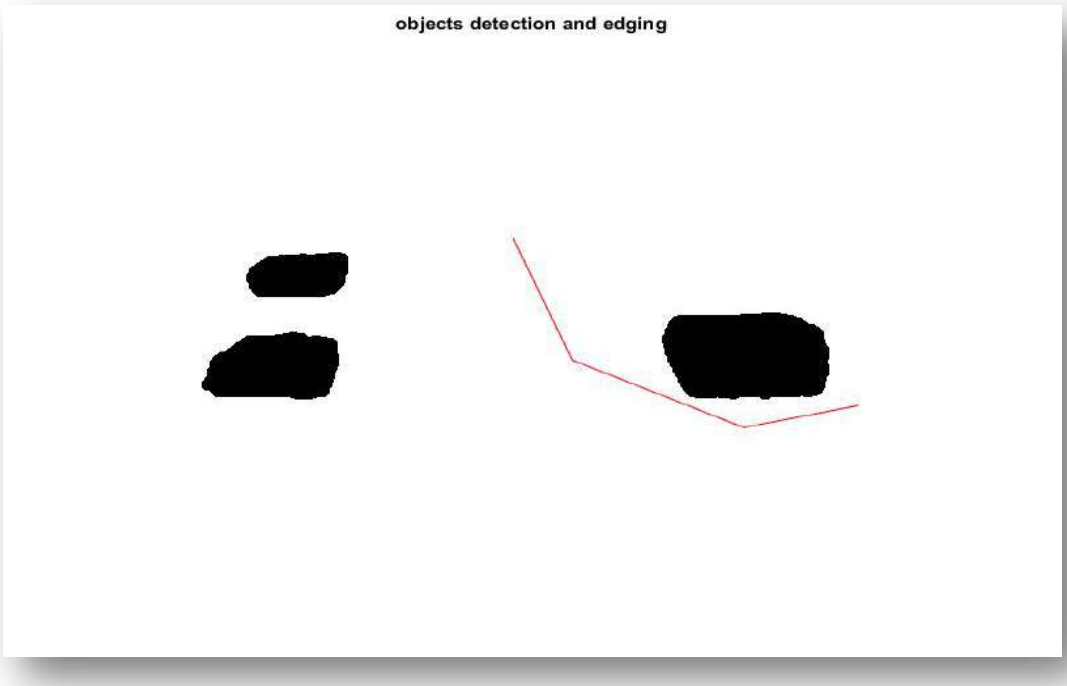


Figure.4.42. Path generation

IV.6.4. Fourth test



Figure.4.43. Fourth acquisition

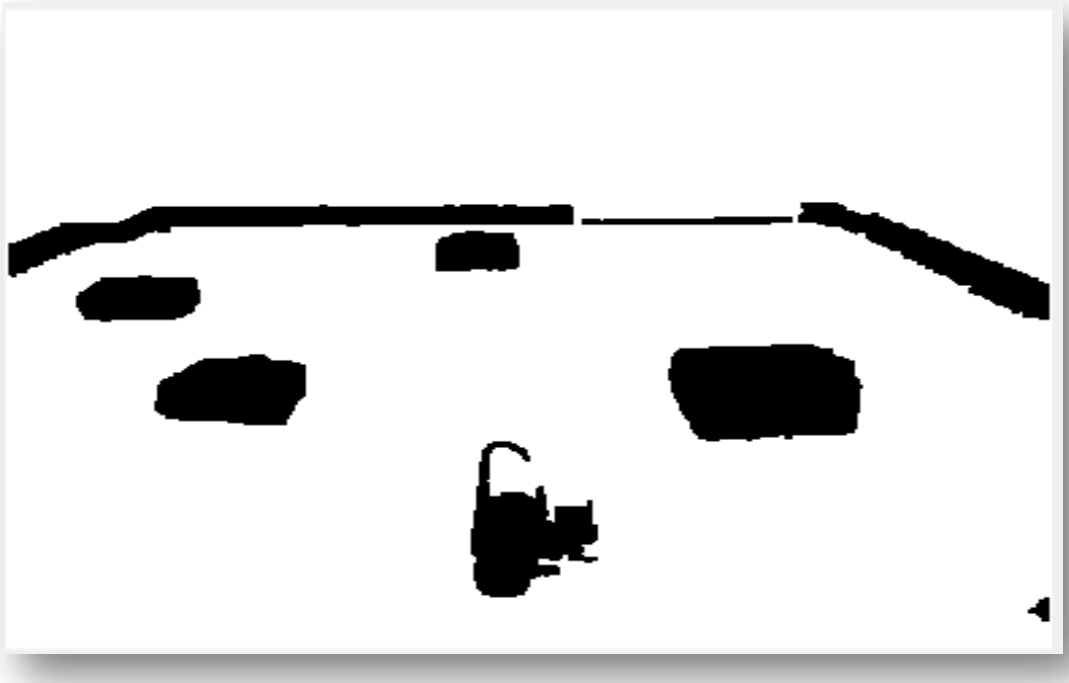


Figure.4.44. Binary and inflated image

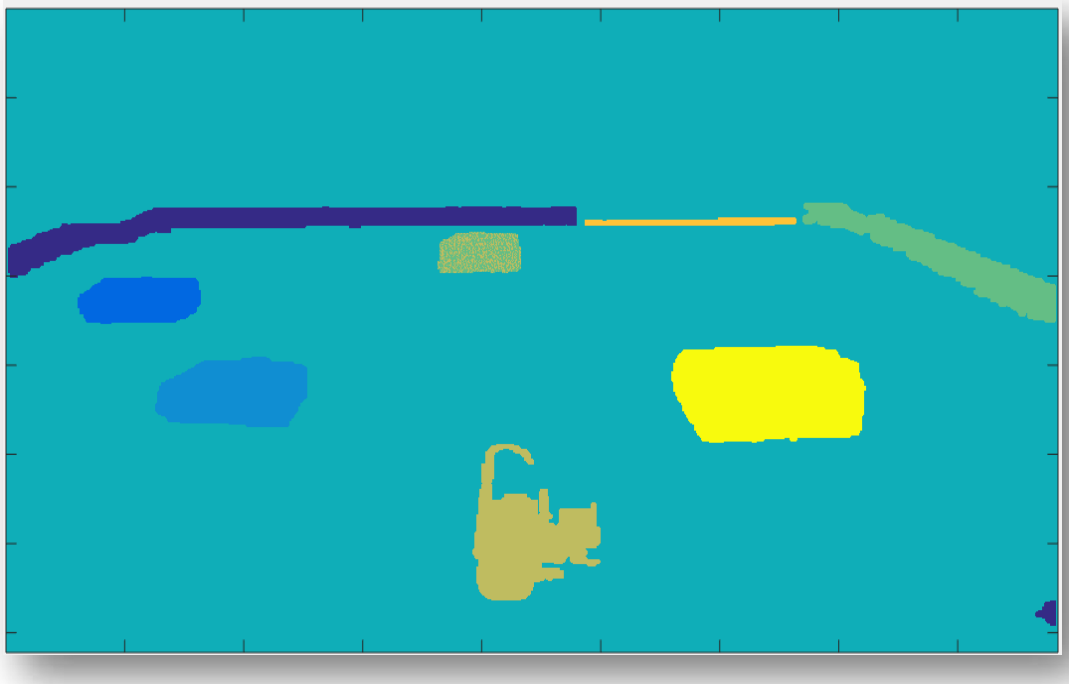


Figure.4.45. Obstacles detection and robot removing

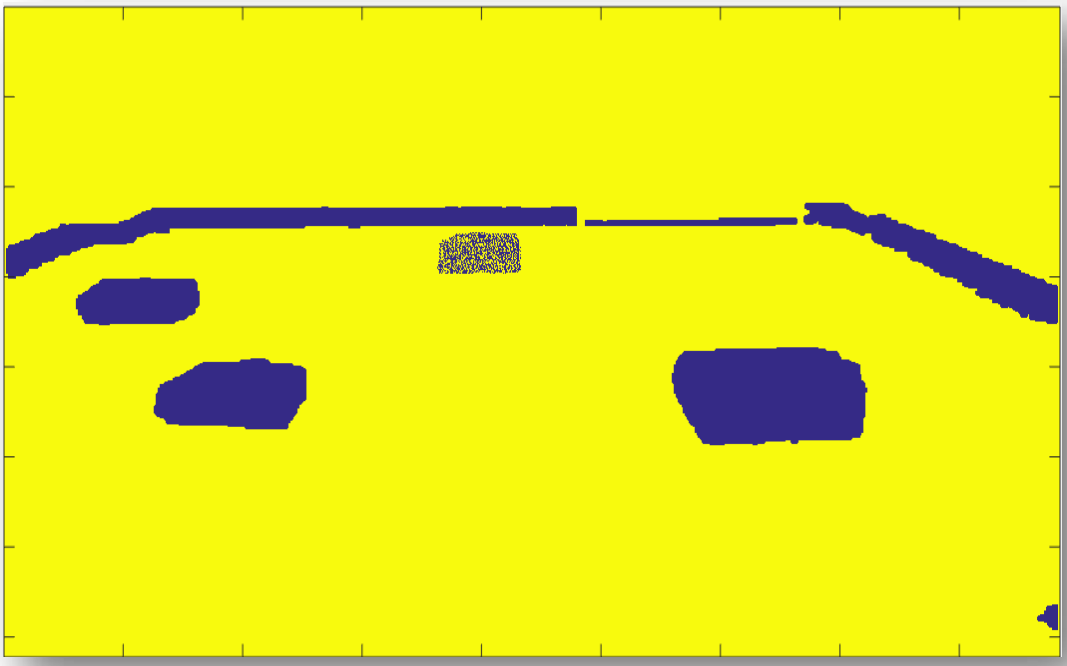


Figure.4.46. Robot removed from image

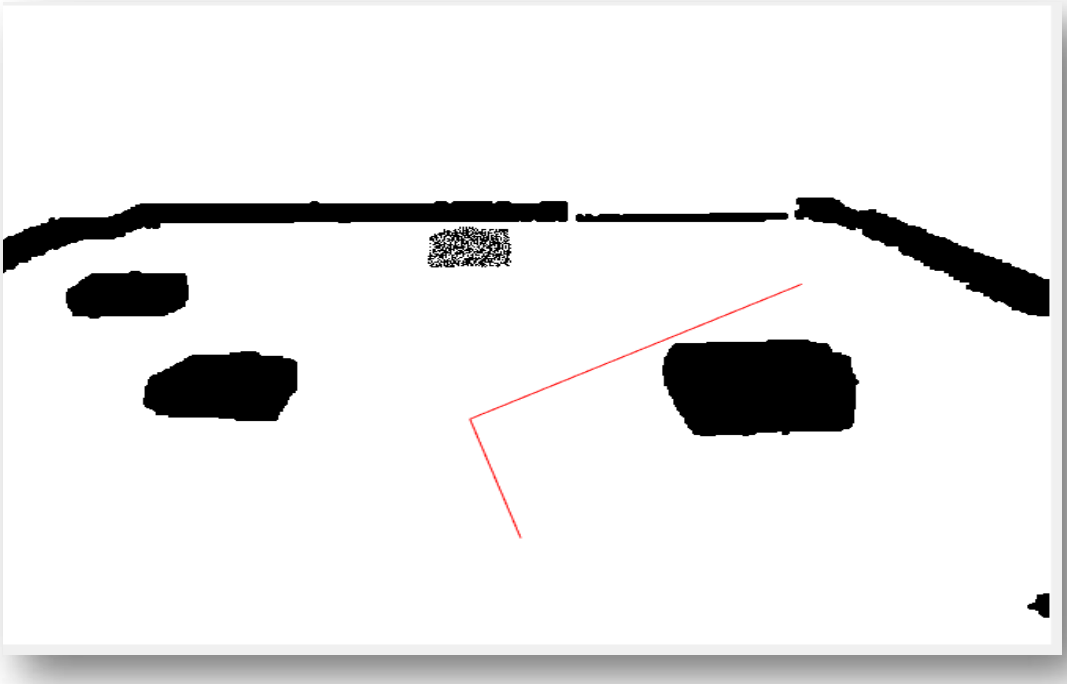


Figure.4.47. Path generation

IV.6.5. Fifth test



Figure.4.48. Fifth acquisition

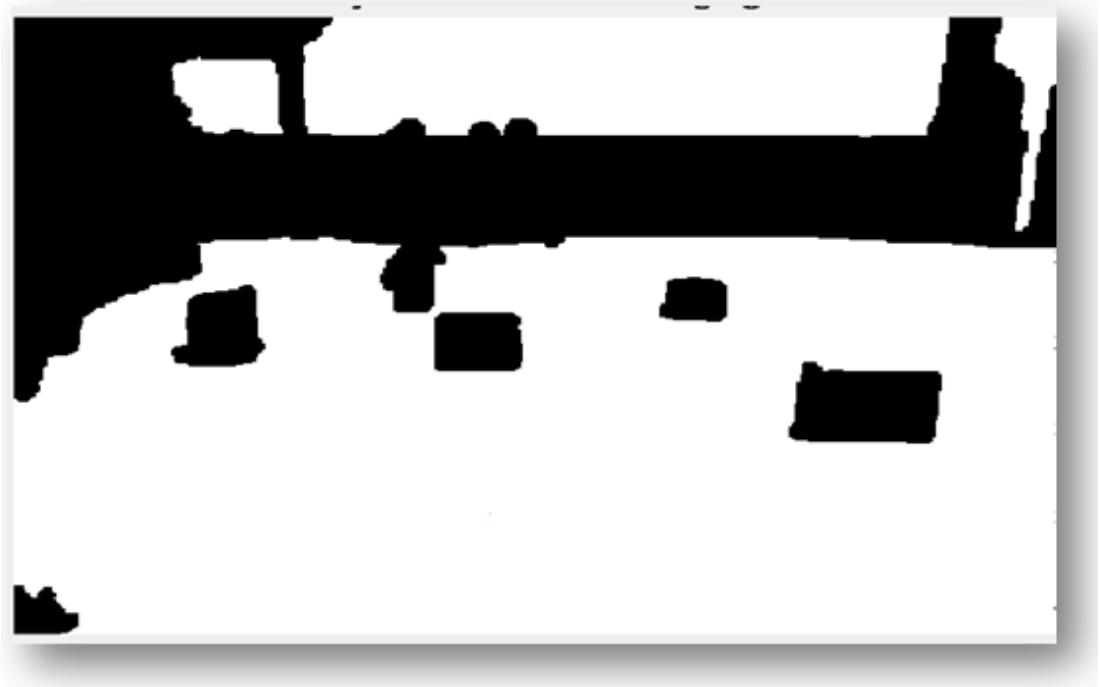


Figure.4.49. Binary and inflated image

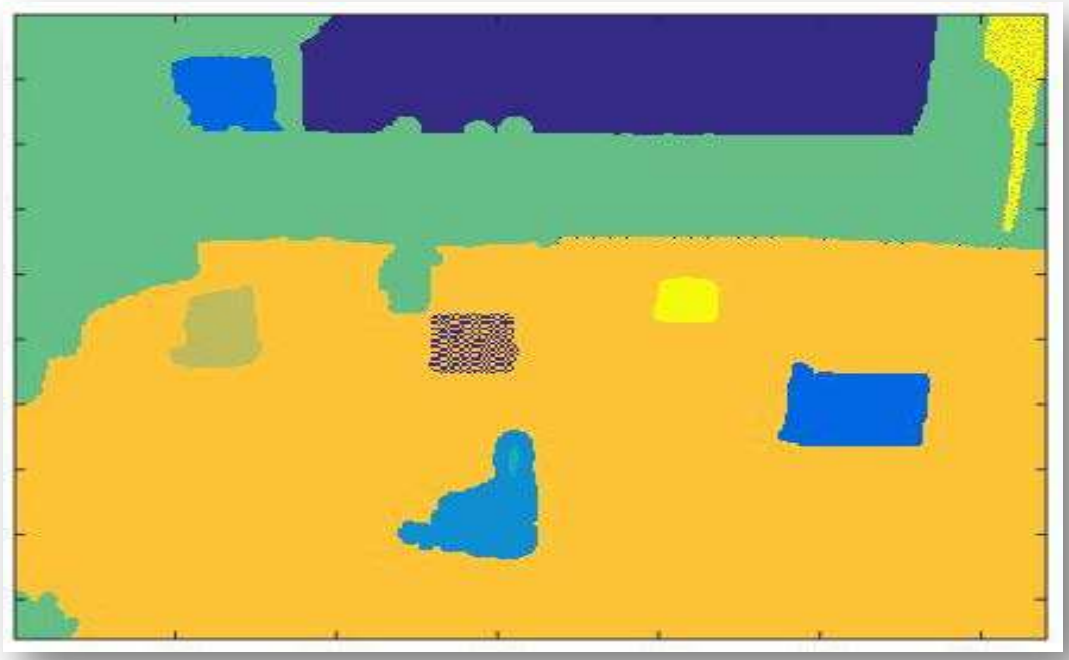


Figure.4.50. Obstacles detection and robot removing

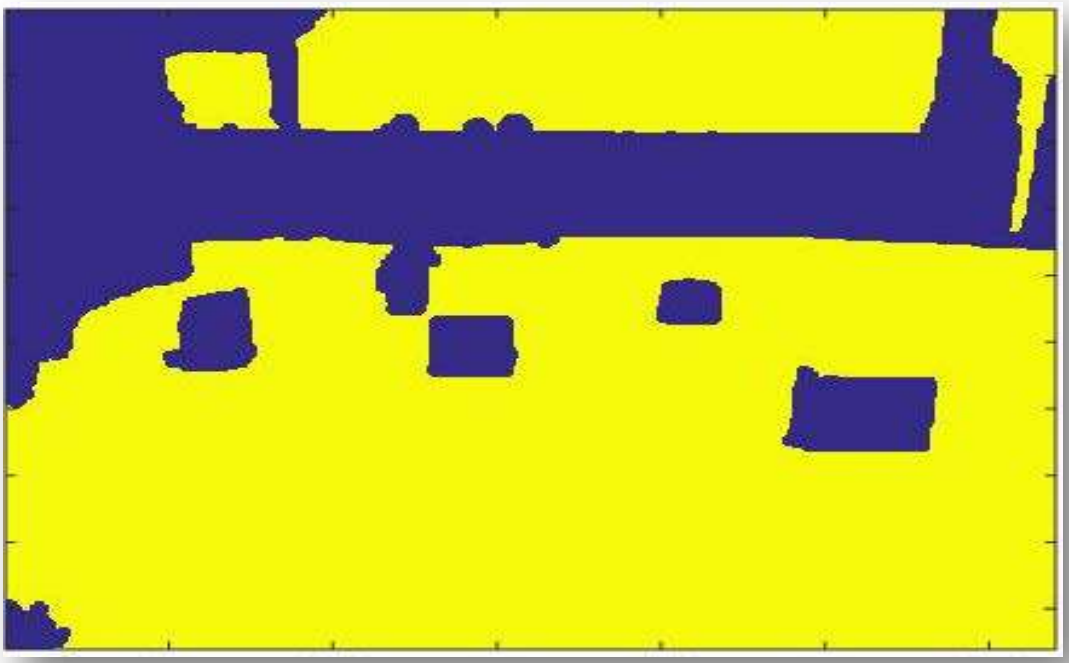


Figure.4.51. Robot removed from image

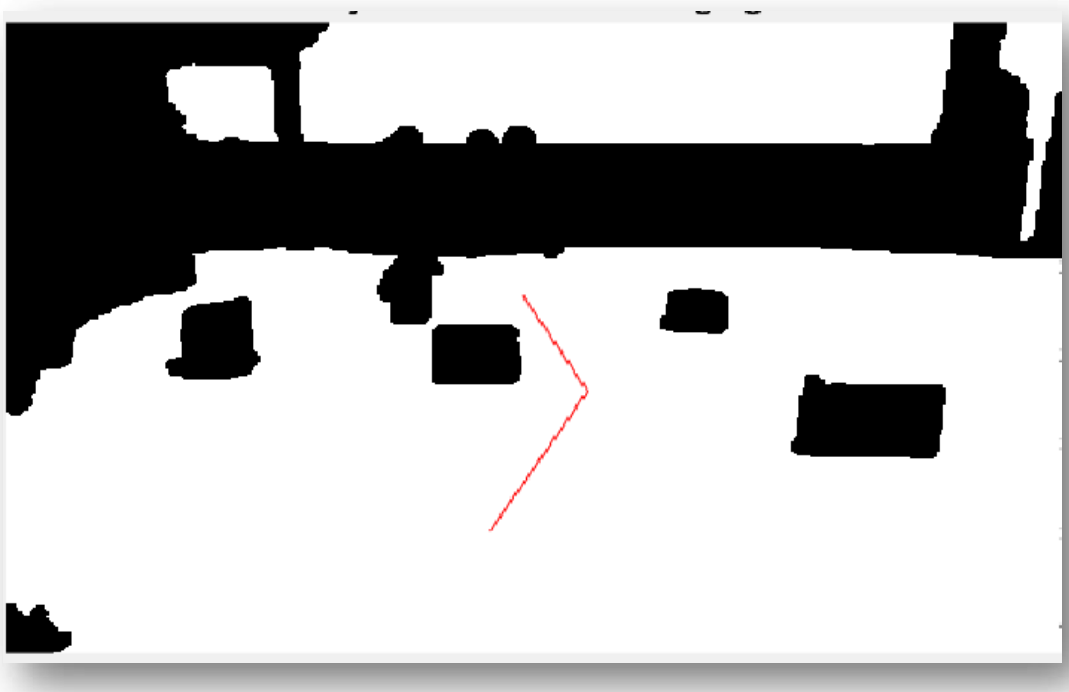


Figure.4.52. Path generation

According to the tests we have done, it is clear that our robot does the same trajectory that we gave; unfortunately, the robot did not follow the points given with precision and that because of robot mechanism and the control in an open loop.

All tests gave us the same results, so we can say that we have reached our goal of Trajectory Planning using 3D vision system to control of mobile robot.

IV.7. Conclusion

In this chapter, we have presented our work which consists of programming the trajectory to control of our mobile robot. We presented the methods of obstacles detection, path planning and calculation of our robot. We also saw how programmed the wifi shield to connect the robot with PC and control the robot. Finally, we conducted tests that allow us to validate our control system. From the results obtained, the robot follows the path obtained from the detection, but there is a lack of precision, this problem attributes to open-loop work and the mechanism of our robot. Due to the complexity of the two control cards, and the difficulty of communication with the wifi shield, it is obligatory to use the mechanical mechanism (2 DC motors only) of this robot and to make the various adaptations and control cards to build our mobile robot.

GENERAL CONCLUSION

The main goal of my work is the Application of 3D Vision Systems to construct a collision-free path from a starting position to an end or destination position, to control of a mobile robot type unicycle in a real time.

To carry out this work, we went through different steps:

We have used an RGB D camera that provides Depth Image Size VGA (640x480) and color images resolution of SXGA (1280x1024), after acquiring these images MATLAB will process them in order to get the scene, detect the obstacles and generate the trajectory for robot; our robot moves by 2 wheels and these two wheels are driven by two DC motors;

I used this type of motors for their power of rotation and displacement to the goal; for controlling these motors we have used an Arduino Motor Shield Based on L293D module, Arduino UNO board and the wifi shield.

We have used the Arduino UNO board for its particular characteristics, which helped us to facilitate the tasks and also for its simple programming; Arduino programming is very important. It has led us to better control the software side so that we can translate the path to executable instructions by the program; to permit the robot to track trajectory wirelessly by the wifi shield. Programming over Matlab is also important, so we learned a lot about this software.

This project allowed me to deal with practical problems and to check theoretical knowledge acquired throughout our training; in the world of robotics; results have shown that the mobile robot is able to reach the target destination successfully for different types of trajectories patterns and without the collision with obstacles

The analysis of the works presented in this thesis allows us to consider four axes concerning future research prospects:

- **Improved accuracy and speed of the robot.**
- **Control the robot with a closed loop.**
- **The use of stepper motors to have a high accuracy in the movement of the robot.**
- **Using better optical sensors to calculate the speed of the robot.**

BIBLIOGRAPHY

[1] http://www.bowlesphysics.com/images/Robotics_-_A_historical_perspective.pdf [Accessed MAY 2018].

[2] ftp://ftp-sop.inria.fr/members/David.Daney/cours/mgbm/robotique.pdf [Accessed MAY 2018].

[3] Ghosal, Ashitava. "ROBOTICS: ADVANCED CONCEPTS & ANALYSIS." (2014).

[4] Krogh, Bruce, and Charles Thorpe. "Integrated path planning and dynamic steering control for autonomous vehicles." *Robotics and Automation. Proceedings. 1986 IEEE International Conference on*. Vol. 3. IEEE, 1986.

[5] Belkhadria Khemisti, "control of a mobile robot by artificial neural networks",thesis for graduation from magister in electronics. Option: Robotics. El HadjLakhdar University

[6] BERRACHED Chahrazed « SYSTEM OF RECOGNITION OF Gestures of the Hand», ", THESE for obtaining the Master's degree in Computer Science Presented on June 22, 2014 sector: Information and Knowledge System University Abu BakrBelkaid- Tlemcen

[7] Hand Gesture Recognition System Swapnil D. Badgujar1 , Gourab Talukdar2 , Omkar Gondhalekar3 , Mrs. S.Y. Kulkarni4 1,2,3 Department of Computer, Engineering, Pune University, India 4 Assistant Prof., Department of Computer, Engineering, Pune University, India

[8] H.ABDELMOUMENE, «Study and realization of TeleGestServo, an Interface of Gestural Enslavement in Teleoperation ", USTO, LAERSI, Thesis of magister 2008-2009.

[9] Byrne, Andrew Patrick Joseph. "American Sign Language (ASL) literacy and ASL literature: A critical appraisal." (2013).

[10] Rabiner, Lawrence R. "A tutorial on hidden Markov models and selected applications in speech recognition." *Proceedings of the IEEE* 77.2 (1989): 257-286.

[11] Starner, Thad E. *Visual Recognition of American Sign Language Using Hidden Markov Models*. Massachusetts Inst Of Tech Cambridge Dept Of Brain And Cognitive Sciences, 1995.

[12] BENSALEM NABIL AND SKANDER MOHAMED "segmentation of RGB D images ",THESIS in order to graduate from MASTER in TELECOMMUNICATION SYSTEM. . University of MEDEA YAHIA FARES 2013/2014

[13] Kenneth, R. C. *Digital image processing*. Prentice Hall, 1996.

[14] https://www.webmarketing-com.com/2012/11/06/16580-quels-sont-les-9-formats-differents-pour-une-image [Accessed MAY 2018].

[15] Diehl, Norbert. "Object-oriented motion estimation and segmentation in image equences." *Signal processing: Image communication* 3.1 (1991): 23-56.

[16] Shi, Jianbo, and Jitendra Malik. "Normalized cuts and image segmentation." *IEEE Transactions on pattern analysis and machine intelligence* 22.8 (2000): 888-905.

[17] El-Zaart, A. "Images thresholding using ISODATA technique with gamma distribution." *Pattern Recognition and Image Analysis* 20.1 (2010): 29-41.

[18] Arduino, "Arduino". [Online]. Available at: https://www.arduino.cc/[Accessed MAY 2018].

[19] Arduino Wifi Shield [Online]. Available at:

https://upverter.com/datasheet/8e08f3810c309b008810c9207819977a95131e78.pdf [Accessed MAY 2018].

[20] http://www.alldatasheet.com/view.jsp?Searchword=L293d [Accessed MAY 2018].[21]Braga, Newton C., and N. C. Braga. *Mechatronics sourcebook*. Thomson/Delmar Learning, 2003.available at:

http://www.robotiksistem.com/dc_motor_properties.html[Accessed MAY 2018].

[22] Litomisky, Krystof. "Consumer rgb-d cameras and their applications." *Rapport technique, University of California* 20 (2012).available at:

http://alumni.cs.ucr.edu/~klitomis/files/RGBD-intro.pdf [Accessed MAY 2018].

[23] SHAOHAO CHEN research computing information service and technology Boston University available at:https://www.bu.edu/tech/files/2016/09/intro_matlab.pdf [Accessed MAY 2018].

[24] IDE Arduino software available at:
http://www.centropiaggio.unipi.it/sites/default/files/course/material/esercitazione_led_e_fotor.pdf
[Accessed MAY 2018].

[25] Mr. GUESMI Mohamed M. DOUAKH Abderrahim «THE GESTURAL CONTROL FOR A MOBILE ROBOT (ARDUINO) » Presented to obtain a Master's degree in Electrical Engineering Option: Automatic and Systems University Year 2015/2016

[26] Code for Robot Path Planning using Probabilistic Roadmap Rahul Kala Robotics and Artificial Intelligence Laboratory, Indian Institute of Information Technology, Allahabad Devghat, Jhalwa, Allahabad, INDIA available at:
http://rkala.in/codes/A%20star.zip [Accessed MAY 2018].