Capstone Design Project I

Using Image Processing Indoors for Localization and Optimal Path Determination

Supervised by Dr. Zahi Nakad

Elie Raad – 201604575

Rita Mahfoud – 201604745

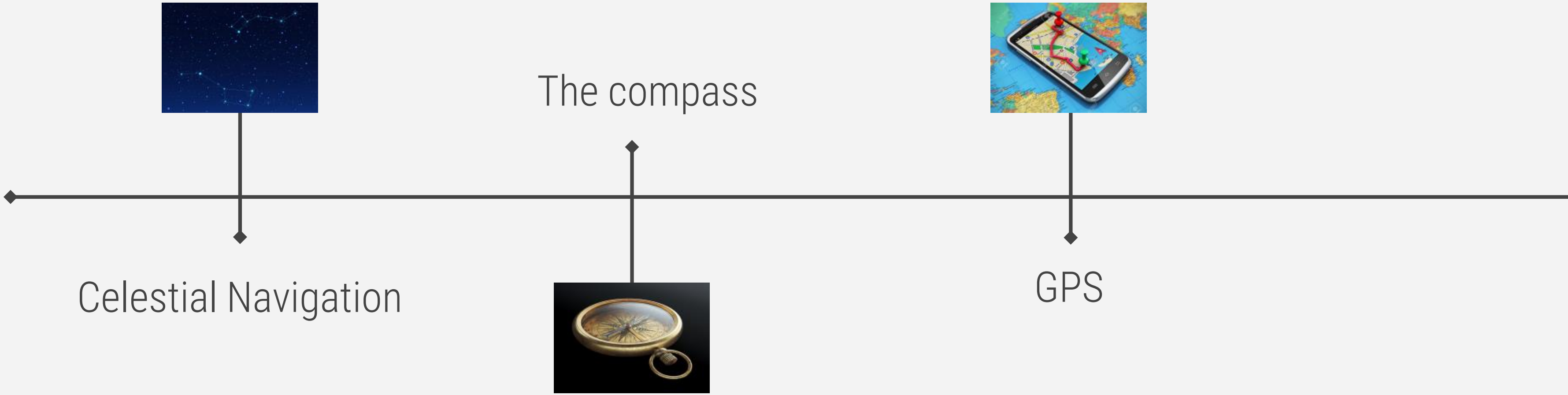
Mohamad Orabi – 201602807

Karim Abi Fadel – 201601579

Outline

I. Introduction

The issue of navigation goes back to more than thousands of years ago, and since then navigation techniques have considerably evolved.



What about indoor environments?

Indoor environments fail to meet most of the requirements for GPS to work.

The main concern of our project is indoor localization for assistance inside shops.

- Guiding blind people
- Autonomous cleaning
- Restocking of shelves
- Helping someone on a wheelchair

https://www.competition.org.za/news/2017/2/22/how-big-supermarket-chains-in-southern-africa-keep-out-small-suppliers

II. Constraints

Accuracy	• Resulting distance given in **meters**. • Margin of error of **+/- 50 centimeters**.
Time	• Initial detection with the path generation: **30 seconds** approximately. • Other intermediate detections and rerouting: around **10 seconds**.
Power	• The prototype is expected to work for a total time of **four hours**. • The prototype can be charged overnight.
Size	• The size of our prototype should be in the range of **25 cm x 25 cm** and height of **10 cm**.
Cost	• The total cost of the prototype shall not exceed **500$.**

II. Background

A. Outdoor vs indoor localization using GPS

- Most advanced technologies are heavily reliant on GPS for their operations in outdoor environments. This is due to the incredible accuracy 1-3 meters that it can provide outdoors. Enhancements to this system such as differential GPS increase its accuracy to 1-3 centimeters.

- The problem of indoor localization is growing more relevant as we continue to build huge structures such as shopping centers, malls, universities, parking structures, etc. However GPS fails in this area. Other technologies will be discussed in what follows.

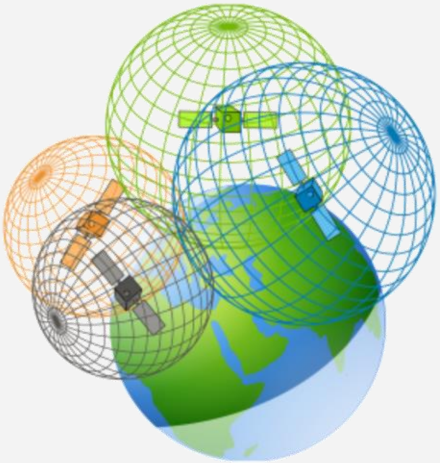
https://www.infsoft.com/blog/techniques-for-client-based-indoor-positioning

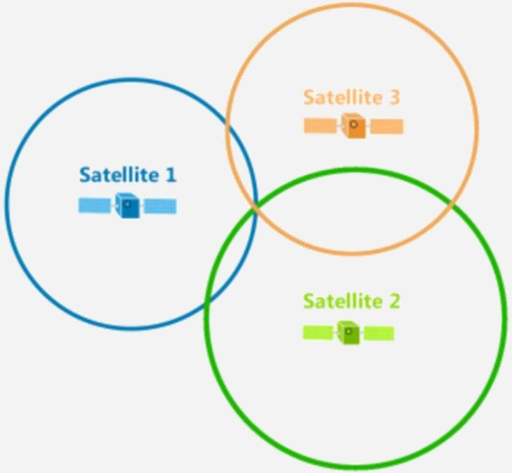
II. Background (cnt'd)

B. Behavior of GPS on indoor localization

First a basic explanation of how GPS works:

A GPS signal only contains information about the satellite itself, and a receiver then uses that information along with the distance traveled by the signal to determine its location. This is called Trilateration.





https://gisgeography.com/trilateration-triangulation-gps/

II. Background (cnt'd)

B. Behavior of GPS on indoor localization

- A GPS's positioning accuracy is dependent on how accurately a receiver can measure the **distance between it and the corresponding satellite** known as pseudo range.

- A main source of error for GPS signals is multipath, which is when replicas of the original line of sight (LOS) signal bounce off of reflecting surface and to the input of the antenna.

- Multipath is a common issue for GPS both indoors and outdoors, but while multiple methods have been developed to accurately track the LOS signal and mitigate the effects of multipath outdoors, in most cases the <u>LOS signal is not visible when the receiver is indoors</u>.

IV. Solutions and Expectations

A. Different ways of indoor localization

Radio solutions

- Rely on different wireless technology protocols as well as mathematical modelling over wireless communication devices.
- Utilized for human navigation because of the commonality of Wi-Fi-enabled handheld devices.
- Calculate the relative location of a device based on the received signal strength.
- Bluetooth technology can be used for indoor mapping solutions that are concerned with proximity.

IV. Solutions and Expectations

A. Different ways of indoor localization

Non-Radio solutions

- In the case that a wireless infrastructure is noisy, non-radio solutions are viable proposals that are more accurate.
- Magnetic positioning takes advantage of a building's unique geomagnetic fingerprint that is the result of Earth's distorted magnetic field due to the building's material.
- Non-radio visual positioning is possible using a camera by either matching live images with a pre-stored database of image-coordinates pairs or using fiducial markers that are decoded to engender the x, y and z coordinates of the camera.

IV. Solutions and Expectations

B. Applications of indoor localization

- Smartphone applications for proximity advertisement and guidance through shopping malls, museum tours, warehouses, hospitals and hotels.
- Applications with audible and haptic feedback for the visually impaired.
- Inanimate solutions include luggage tracking for airport logistics and robot navigation inside warehouses and shops.

IV. Solutions and Expectations

C. Use of indoor localization inside shops

In our project we opt for a **non-radio camera solution**, for the following reasons:

- Practicality
- Accuracy
- Low cost
- No Wi-Fi in supermarkets
- Most supermarkets are already equipped with labels that can serve as markers to be detected and analyzed via image processing

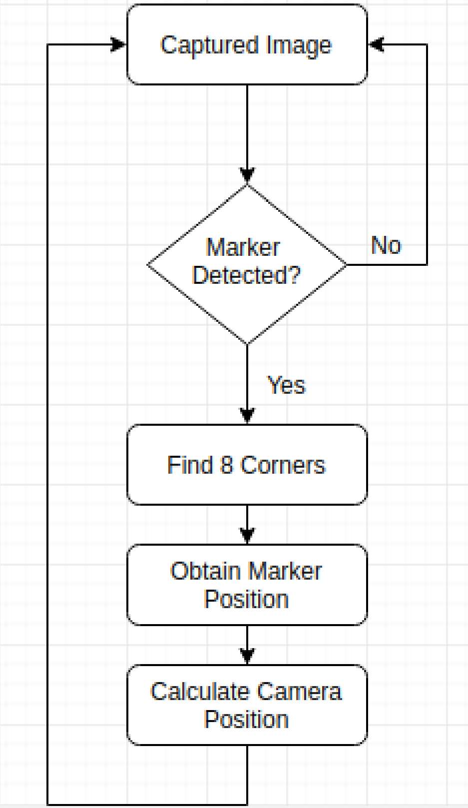
V. Our Design

Two main categories for vision-based positioning have been proposed and widely explored:

- Produce an output based on its surroundings.
- Use known markers placed inside the environment. ✓

The latter is perfect for our project since most grocery shops have already pre-installed signs to help customers find their needs.

Using a mathematical model of the camera and preinstalled marker with known features we can calculate the position of the rover in the real world.



Inspired by the signs used at "Spinneys" supermarket, the used markers will consist of a quadrilateral border and a predefined number.

1. Lens correction
2. Find focal length and projection center offset
3. Take out distortions
4. Calculating the camera position

Let C be the set of all corner edges of the marker:
$c = \{c0, \dots, c7\}$ such that $c0 = (x0, y0, 1) \dots .\ c7 = (x7, y7, 1)$.
Let m be the set of all object edges (i.e. in real world):
$m = \{m0, \dots, m7\}$ such that $m0 = (X0, Y0, 1) \dots m7 = (X7, Y7, 1)$.

These points can be described by the following transformation:

$$\mathbf{c = s * H * m = s * M * W * m}$$

s: scaling factor
M: intrinsic parameters

fx	0	cx
0	fy	cy
0	0	1

The unknown parameters are (fx, fy) camera focal lengths and (cx, xy) the optical centers expressed in pixels coordinates.

W physical transformation W = [R T]
T translation vector and R rotation matrix R = [Rx, Ry];

By detecting the marker, we can extract the smaller rectangle containing the number which will be used to estimate the desired output using optical character recognition.

A. Rover 5 Chassis

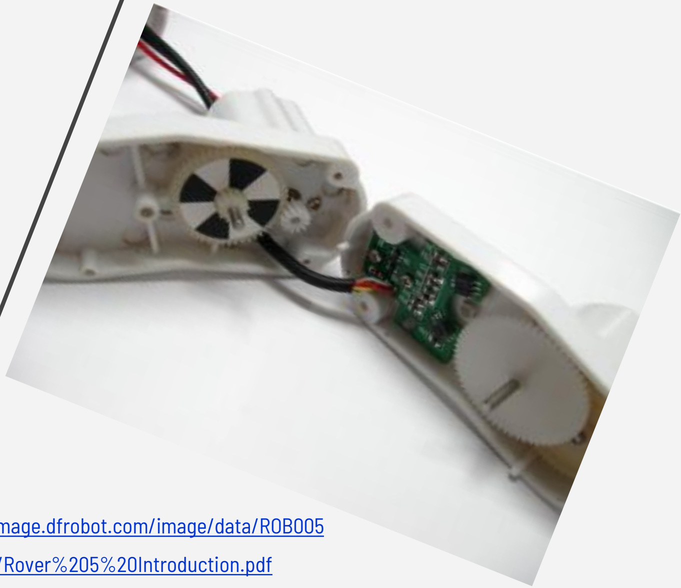
- Flexible
- Easy to use
- New breed of tracked robot chassis designed for students
- Includes four independent motors

http://image.dfrobot.com/image/data/ROB0055/Rover%205%20Introduction.pdf

B. Encoders

The rover chassis includes encoders for positioning.
They will be used to:

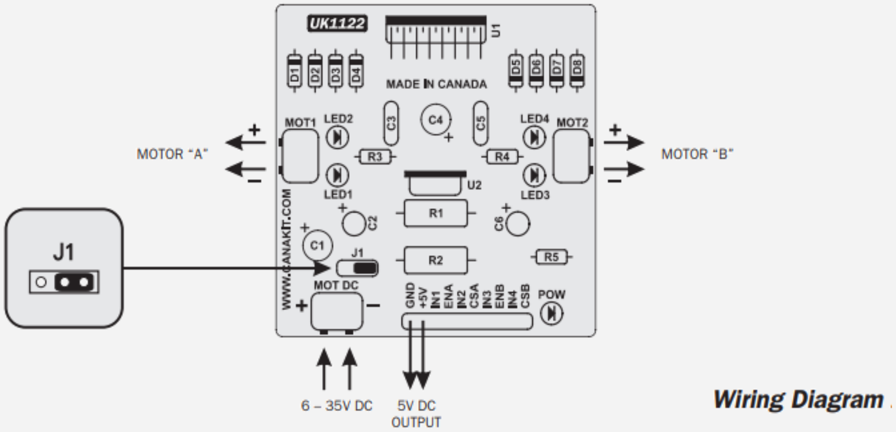
- Monitor the speed of the rover
- Determine the direction of the rover
- Reverse sense of direction



http://image.dfrobot.com/image/data/ROB0055/Rover%205%20Introduction.pdf

C. L298N Dual Motor Controller

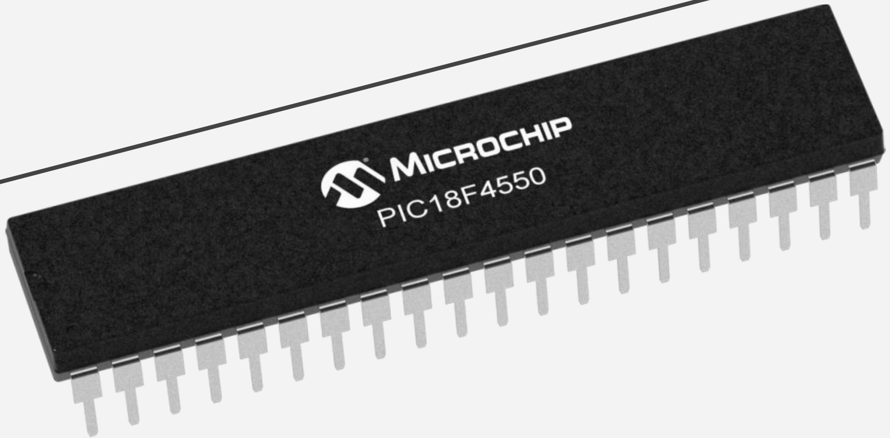
Our rover will be traveling on a 2D map of the environment. Therefore, a motor driver is needed to control our motors. The diagram above represent a dual motor driver based on the L928 Dual H-Bridge used to independently control two motors in both directions.



http://image.dfrobot.com/image/data/ROB0055/Rover%205%20Introduction.pdf

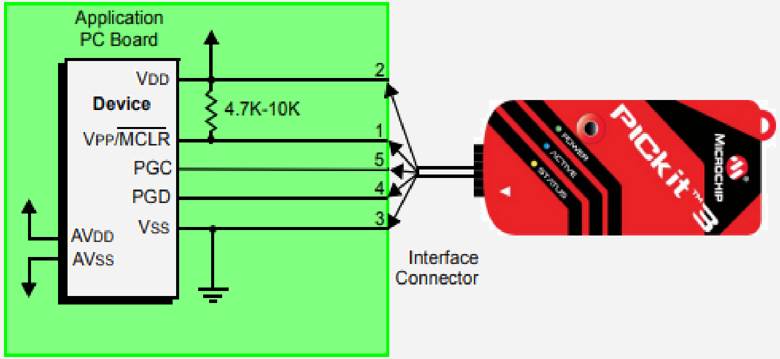
D. PIC18f4550

- Small
- Low power
- Low-cost
- Mechanism to control the motor driver in order to make our rover navigate through the environment.



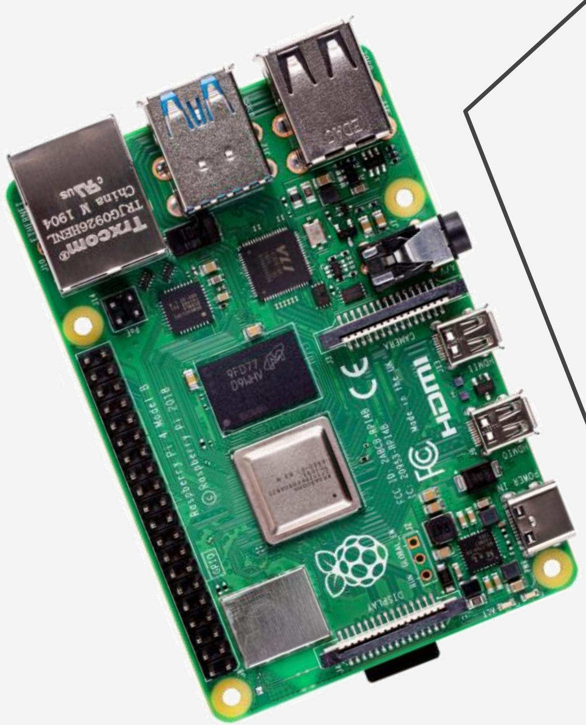
E. Pickit 3

The PICkit 3 is a tool for programming and debugging applications on hardware in real time which we will use to program the PIC18f4550 microcontroller.



http://j6k.undeci.de/pickit-3-circuit-diagram.html

F. Raspberry Pi

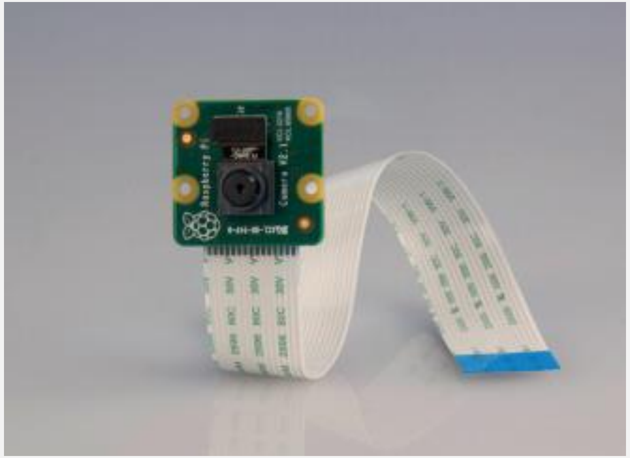


- Raspberry Pi 4 Model B is the latest product in the range of companion computers.
- Small-size.
- Low power.
- Low-cost processor.
- Provides desktop performance comparable to an entry-level x86 PC systems.

https://static.raspberrypi.org/files/product-briefs/Raspberry-Pi-4-Product-Brief.pdf

G. Raspberry Pi Camera Module

- Key component of our project
- High definition
- Ultra-small
- Lightweight
- Compatible with all versions of Raspberry Pi boards
- Maximum image transfer rate of 30 fps for 1080p images and 60 fps for 720p images.



https://cdn.sparkfun.com/datasheets/Dev/RaspberryPi/RPiCamMod2.pdf

VI. Conclusion

After doing the appropriate research, we have decided on the software and hardware to be used in our implementation making sure to choose the most suited components to meet our requirements while taking into consideration the constraints and limitations that arise with this project.

The next step is the actual implementation of the project using the components we decided on and hopefully reaching the desired outcomes: localization in indoor environments and generation of an optimal path with a decent level of accuracy.

VII. References

Thank You!

Any questions?