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Special Aspects of Mobile Autonomous Systems

REPORT

Autonomous Object Hunting

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1 Introduction

This research project has the objective to design a system that is able to navigate on its own in an unknown environment, search and identify an object[1] and build a map of the navigated route as well as a map of its surroundings. The system as a whole will consist of a mobile device, further named robot, and an auxiliary external computer. As the robot on its own only offers limited computing power, it will outsource computing intensive tasks to the external computer. Hence multiple processes on different platforms will be involved. To be able to operate in any arbitrary location, the system shall be independent of any additional hardware as for example networking devices. Besides it is desirable to design the system in such a manner, that supplementary software, which is not planned now, can be added easily by additional external computers. Figure 1 shows a potential connection between the robot, i.e. the symbol in the middle, and other devices via a wireless LAN[2].
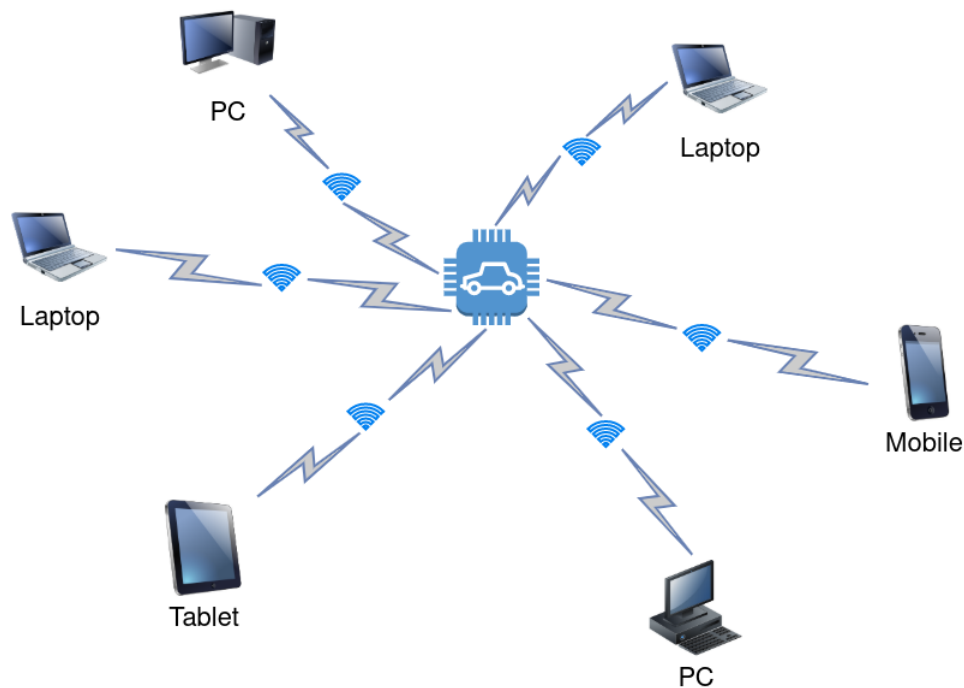

Figure 1: Display of possible connections

The robot will steer by controlling multiple motors, which will be attached to wheels. Furthermore it will be able to capture its surroundings and any obstacle near it by distance measurement sensors. They will be mounted around the robot in order to register surroundings in any direction. Additional sensors will keep track of the orientation in space and movements of the robot. The target object will be identified by processing data of a visual sensor, i.e. a camera attached to the robot.

The aim of the robot is to avoid collisions in any environment and find the target object. When the target object is found it shall stop navigating and indicate the successful identification of the object to the user.

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[1]The action of searching and identifying an object will further be referenced as object hunt.
[2]A LAN (local area network) is a computer network that interconnects computers within a limited area.

2 Hardware

The hardware of the device can be separated in two subsystems. On the one hand, the robot, which will navigate in the environment, on the other hand the external computer with a static location. This section only focuses on the hardware of the robot. The hardware of the external computer is not further described in this report as any arbitrary recent computer with a working WiFi interface can be used.

Following you will find a short description and the use case of each part used in the robot. All parts mentioned in this section will be combined to one mobile robotic system.

2.1 Chassis

The chassis forms the foundation of the robot. It consists out of two identical floors, arranged above each other. Drive motors, wheels, revolution sensors and the power unit are mounted on the first floor. Attached to the second floor are the processing unit, PCB board, ultra sonic sensors, smart movement sensor and the camera unit. Each floor has several holes in order to lay the cables from processing unit and PCB board properly.

2.2 Gear Motors

Every movement the robot as a unit can make, is realized through four direct current gear motors, each attached to a wheel. Since the processing unit can not operate the gear motors directly, dedicated motor drivers are needed in order to operate the gear motors properly. The L293DNE quadruple half-h drivers [1] are suited and each can operate two gear motors forwards as well as backwards.

2.3 Stepper Motor

The stepper motor is connected to an attachment for the camera module. A stepper motor with 5 V DC operating voltage, 64 steps per revolution and four phases is chosen. The stepper motor can be driven by a single L293DNE motor driver. This allows to turn the camera module theoretically by an arbitrary angle. However, attention should be paid to the cable, which connects the camera module to the processing unit. It is long enough to enable the camera module some free moving space. If it is stressed to much, the equipment can be damaged permanently.

2.4 Revolution Sensors

A brake plate is mounted to each gear motor. With this plates the revolution of the respecting motor can be measured. The plates offer a resolution of 20 counts per revolution, which is sufficient precise for this project. A TCST1103 [2] optical sensor attached to each brake plate allows to get notification of the status of the regarding brake plate. A resistor connected in series with the phototransistor output leads to a signal fluctuating between ground and the applied voltage, depending if the light of

the emitter can pass the brake plate or is blocked by it. An auxiliary circuit consisting o an operational amplifier is interposed and outputs a clean edge, if the fluctuating voltage surpasses a threshold value. This edge can be detected by e.g. a microcontroller. In combination with the wheel diameter the revolution measurement is used to calculate the distance traveled as well as the speed of the robot.

2.5 Ultra Sonic Sensors

In total four ultra sonic distance sensors are mounted on the robot. The HC-SR04 [3] model is used for all ultra sonic distance sensors. They allow the robot to measure the distance to obstacles in the front, in the back, to the left and to the right. As the HC-SR04 operate on 5 V, most likely a voltage divider has to be interposed between processing unit and each HC-SR04 module. The ultra sonic sensor information is crucial for the robot to navigate, as it is the only information it can receive about its surroundings.

2.6 Smart Movement Sensor

The smart movement sensor is used to get information about the orientation of the robot in space. This is needed in order to locate the robot with respect to the starting position of the hunt. Furthermore this sensor can be used to read acceleration data of the robot. The sensor communicates via an I^2C[3] interface.

2.7 Power Unit

For the robot to be mobile a rechargeable power source is needed. A portable power bank with a voltage of 5 V and Li-polymer battery cell is used. It provides a peak output current of 3 A, which is sufficient to allow simultaneous control of all attached motors and electronics. Furthermore it offers a capacity of 20000 mAh, to allow the robot exploration of spacious environments without recharging.

2.8 Processing Unit

The processing unit of the robot is one of the most important arts of this project. there are several specifications, which it needs to comply with in order to realize the objectives of this project. The specifications are the following:

1. Low power consumption

   As the robot is battery driven, the processing unit should consume as low power as possible to extend battery life.

2. Extensive and accessible GPIO interface

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[3]I^2C (Inter-Integrated Circuit) is a two wire, synchronous, serial computer bus invented by Phillips Semiconductor in 1982.

The sensors and actuators are connected directly or via auxiliary circuits to the processing unit. Therefore it is important to have sufficient GPIO pins for all planned hardware.

3. Ability to create a WiFi hotspot

   The robot needs to maintain its own WiFi network in order to operate in any location and be independent of additional hardware.

4. Supports TCP/IP[4]

   The connection to external computers needs to be bidirectional and reliable. TCP/IP satisfies these specifications and is a state of the art solution.

5. Supports I^{2}C

   I^{2}C is needed for communication with the smart movement sensor (see section 2.6).

6. Supports multithreading

   The robot needs the ability to perform various tasks simultaneously. therefore a CPU[5] with multiple cores is inevitable to archive the objectives of this project.

Taking all specifications into consideration, a Raspberry Pi 4 model B is considered to be used as the processing unit of the robot. It fulfills all mentioned specification, is less expensive than comparable products and offers a big community. Since the Raspberry pi 4 is available in different versions, differentiate in the available RAM, the version with 4 GB RAM is chosen. This enables potential for further additions.

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[4]TCP/IP, or the Transmission Control Protocol/Internet Protocol, is a suite of communication protocols used to interconnect network devices.

[5]Central Processing Unit

2.9 Combined Hardware

The resulting hardware, without the power supply, of the robot and its interconnections can be seen in figure 2.
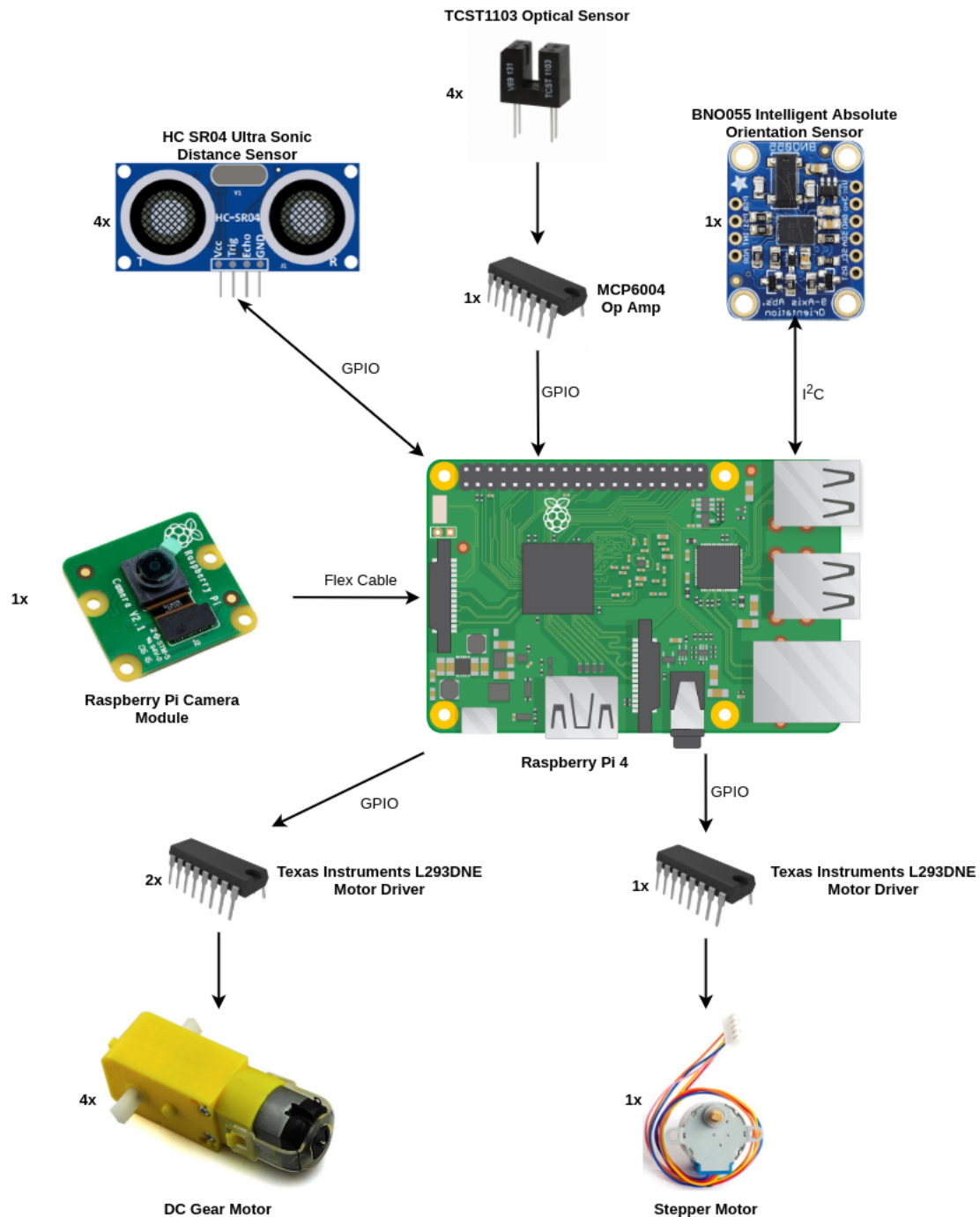

Figure 2: Combined hardware

2.10 PCB Board

The wiring of all components is expected to be rather complex. Since breadboard connections are prone to errors and can get unclear, if multiple connections are involved, a PCB board is designed

for the circuit. Furthermore each device will be connected by a dedicated connector in order to allow easy assembly and disassembly of the system as a whole as well as replacements of single devices.

At first a test circuit is designed for every part. In this manner the function of each sub circuit can be controlled and potential modifications can be realized easily. When each circuit is working as desired, the single sub circuits are combined in one system wide circuit and transferred to an electronic design automation software. In this project the education version of EAGLE [6] is used.

The circuit can be assigned to a two layer PCB board of the dimension 82 mm x 65 mm. It is designed to be easily plugged in on top of the 40 pin GPIO connector of the Raspberry Pi. The mounting holes have the same dimensions as the ones of the Raspberry Pi. Hence the same screws to install the Raspberry Pi, are used to attach the PCB board. All GPIO contacts are lead through to allow easy measurement of signals while the PCB board is installed on top of the Raspberry Pi. Figure 3 shows the populated PCB board.
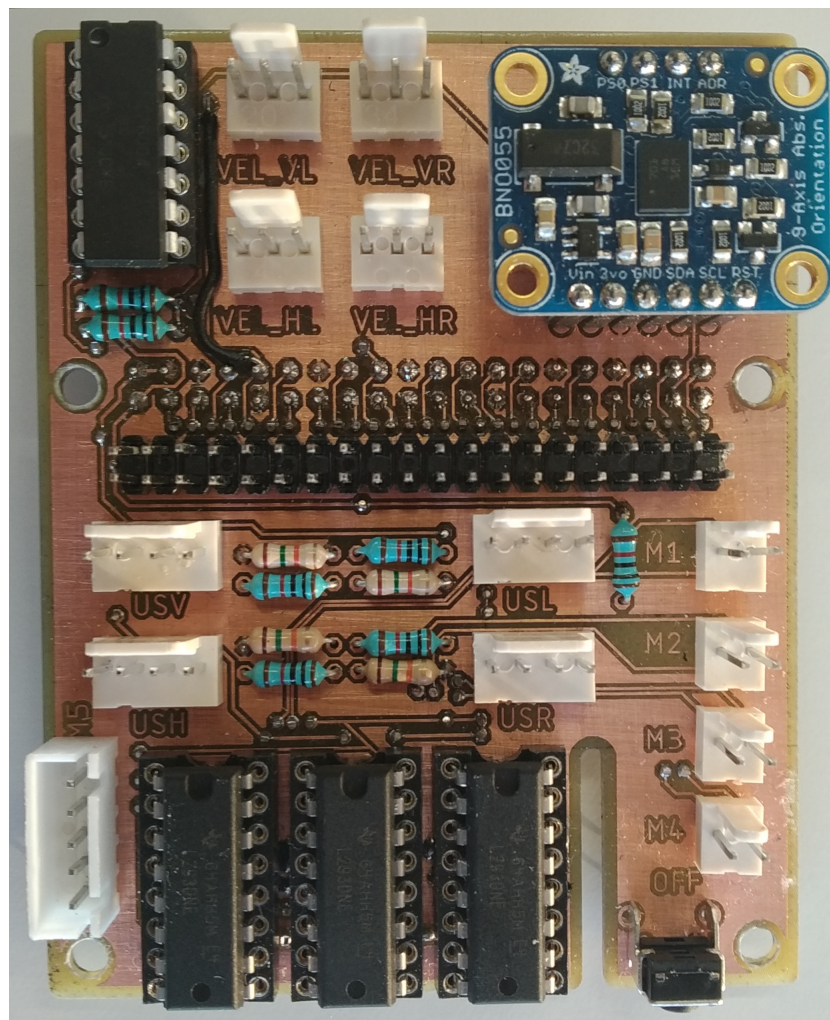

Figure 3: Populated PCB board

3 Internal Software

The in this section described processes are internal processes, i.e. running on the robot itself. In total there are three custom processes running on the robot. Figure 4 shows the structure of the developed software. This section focuses on the base and the navigation process. The image streaming process is referenced in section 4.
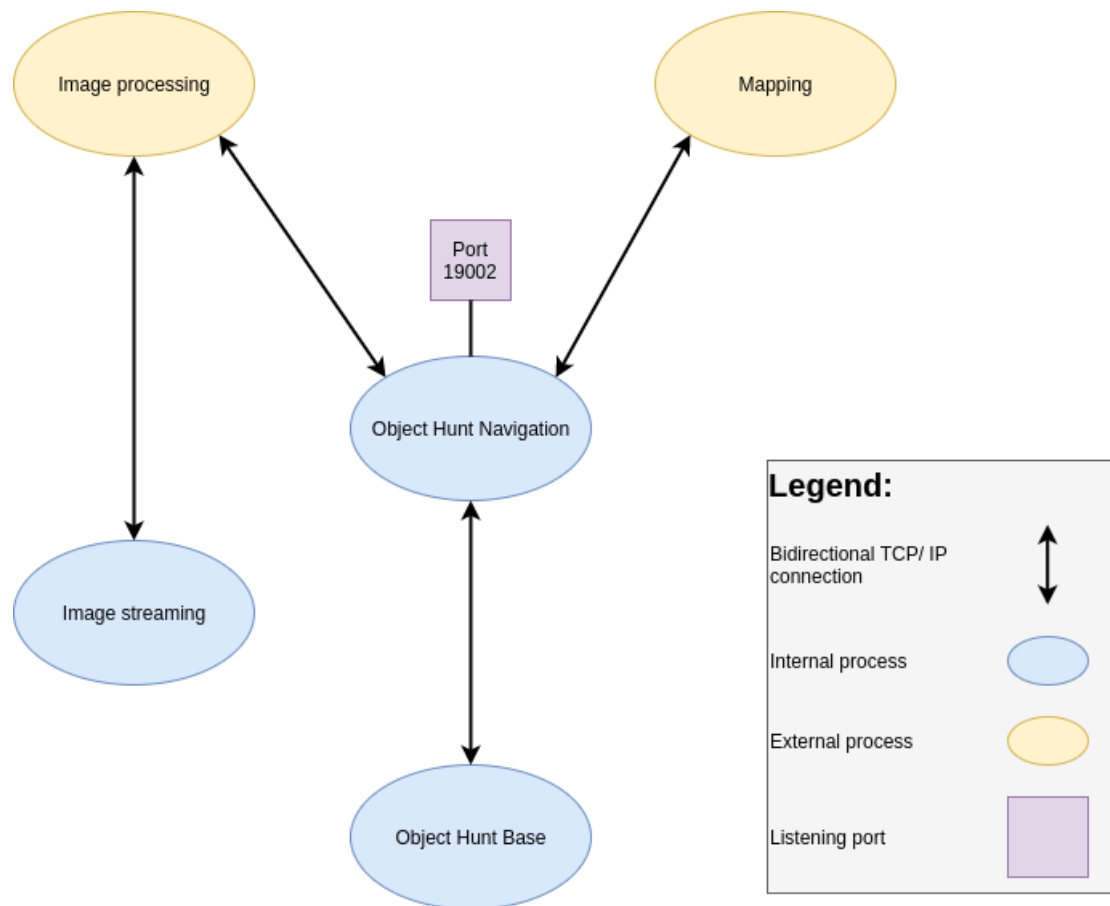

Figure 4: Software structure

3.1 Base Process

3.2 Navigation Process

4 Image Processing

5 References

References

[1] Texas Instruments Incorporated, "L293x Quadruple Half - H Drivers – Data Sheet" 2016 [Online]. Available: https://www.ti.com/lit/ds/symlink/l293d.pdf. [Accessed: 31.01.2020].

[2] Vishay Semiconductors, "Transmissive Optical Sensor with Phototransistor Output" 2011 [Online]. Available: https://www.vishay.com/docs/83764/tcst1103.pdf. [Accessed: 31.01.2020].

[3] Elec Freaks, "Ultrasonic Ranging Module HC - SR04" [Online]. Available: https://cdn.sparkfun.com/datasheets/Sensors/Proximity/HCSR04.pdf. [Accessed: 31.01.2020].

[4] Adafruit, "BNO055 Absolute Orientation Sensor" 2015 [Online]. Available: https://learn.adafruit.com/adafruit-bno055-absolute-orientation-sensor/overview. [Accessed: 31.01.2020].

[5] Raspberry Pi foundation, "Raspberry Pi 4 Model B" [Online]. Available: https://www.raspberrypi.org/products/raspberry-pi-4-model-b/. [Accessed: 31.01.2020].

[6] Autodesk, "EAGLE overview" [Online]. Available: https://www.autodesk.com/products/eagle/overview. [Accessed: 31.01.1020].