Wroclaw University of Technology

Faculty of Electronics,

Chair of Cybernetics and Robotics,

Intermediate Project

PUCK COLLECTOR

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Abstract:

The main aim of this project is to design and construct mobile robot called “Puck Collector”. Robot of this class should be able to operate in the ring. While working, robot should be able to find, sort and collect coloured pucks according to desired colour. It must also avoid collisions with opponent robot and be able to go back to the home base and leave correctly sorted pucks. Main result of this project is mobile robot of (2,0) class, equipped with two sorters, two closed magazines and one openable gate. Robot tracks its own position by odometry which allows to return to start position which is home base. Additional optical sensors give possibility to detect obstacles and react properly to situation around the robot.

1. **Introduction**

The main aim of this project is to design and construct mobile robot called “Puck Collector”. Puck Collector robot takes part in Robotic Challenge competition called “Puck Collect”. In this competition two autonomous mobile robots aim to collect colourful pucks randomly placed on arena. The arena is 250x250 cm square framed by 8 cm high board. Each robot starts from their base which are squares pained in red and blue. During match which is couple of minutes long, robots are moving and trying to bring packs of a given colour to their home bases.

Size of the robot is limited and its length and width could not be greater than 50 cm. Robot height is unlimited.

According to above specification main goals to accomplish during this project have been specified:

- To design and construct mobile platform with mechanics which allows to collect, sort and transport pucks;
- To choose and install sensors;
- To develop and test software operating basic robot modules (sensors, drives, sorter);
- To develop and test algorithm performing basic actions: navigating on the arena, avoiding collisions, collecting pucks, bringing pucks to the home base.

Additional goals:

- To develop advanced “winning” algorithm;
- To use camera and board with embedded Linux for acquisition and processing view of the arena to find pucks and the rival robot.

2. **Results**

Mechanical construction

Robot length and width is 49cm and it meets the imposed limitations. Its main structure is made of aluminium profiles. Thanks to this construction, the device is durable and light. Moreover, used materials are easily accessible in hardware stores and gives possibility for smooth processing.

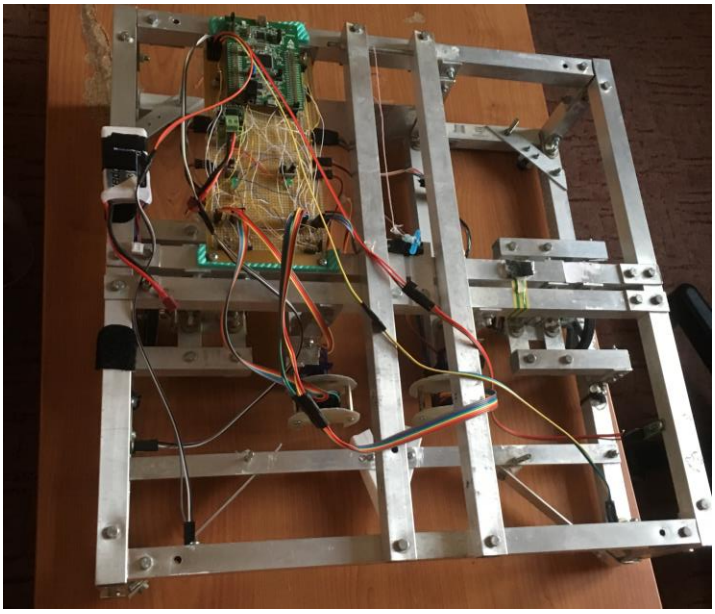


Figure 1 Mechanical construction

The robot can move thanks to two Pololu engines with encoders that have been applied. Motors are mounted on the middle of the robot which gives possibility to turn in a spot.

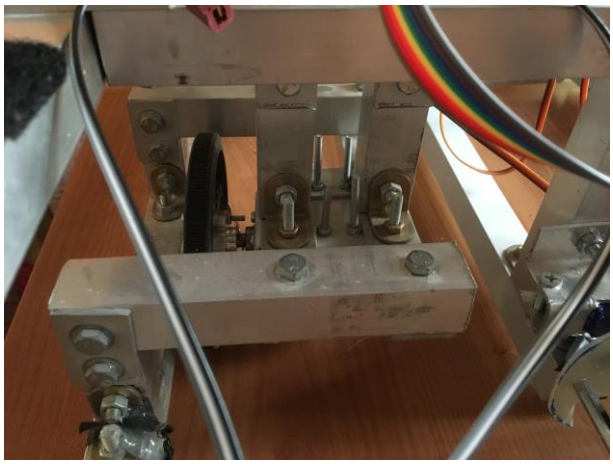


Figure 2 Engine mount

Main parameters of engine:

- Encoder resolution: 64 impulses per rotation
- Gear: 50:1
- For 6V supply:
  - 100 rotations per second;
  - Mean current: 250mA
  - Peak current: 2500mA
  - Torque: 6kg*cm
- For 12V supply:
  - 200 rotations per second;
  - Mean current: 300mA
  - Peak current: 5000mA
  - Torque: 12kg*cm

Wheel diameter: 90mm

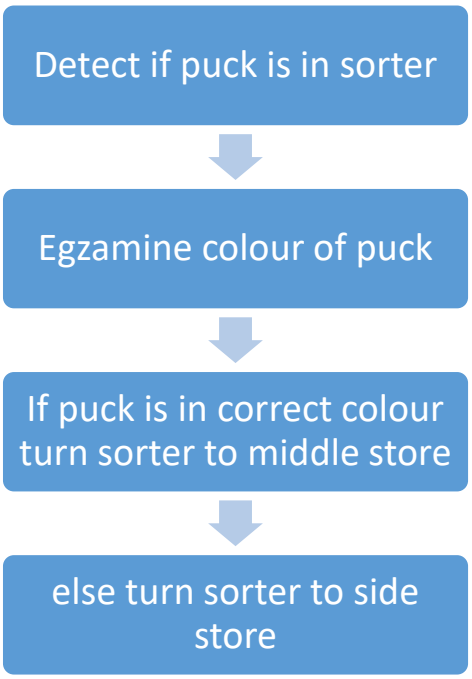
Parameters of installed engines provide possibility for lively movement of the robot and, if it is necessary, to ramming the opponent.

Sorter

Sorter is one of the most important modules in Puck Collector robot. The executive part is made of PCB laminate and metal spacers. Mechanism is driven by micro-servo *Tower Pro SG92-R*. Sorter is also equipped with two sensors: colour module sensor *TCS3200D* and reflection sensor *CNY70*.

Colour sensor allows to detect three colours: red, green, blue – in puck collector competition red and blue pucks are usually used. The main purpose of the reflection sensor is detection if puck is into the executive part of sorter – under colour sensor.

Algorithm of pucks sorting:



Robot is equipped with two sorters.

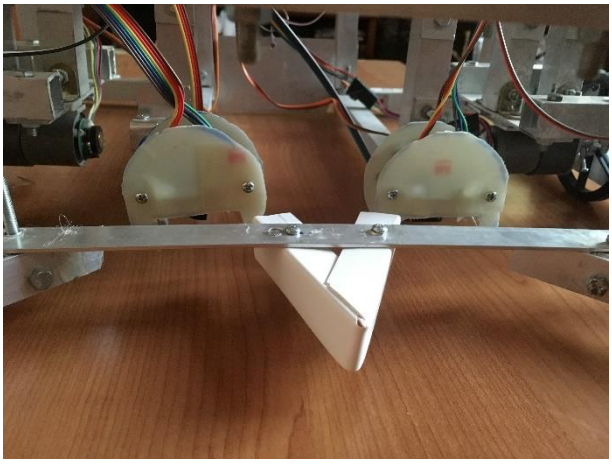


Figure 3 Robot Sorters

Puck stores

Robot contains three store places for pucks. They are in the rear part of the robot. Two of them which are placed on sides are designed to hold opponent pucks inside robot construction – they have no output. Middle store is designed to store valid pucks. It is ended by openable gate which allows to leave content of the store in the home base. The gate is lifted by micro-servo *Tower Pro SG92-R*.

Figure 4 Three puck stores and store gate

Obstacle sensors

When it comes to the obstacle detection, four Sharp Analog Distance sensors *GP2Y0A60SZLF* were used. Max range of those parts is 150cm which covers almost whole ring for puck collector competition. Two sensors are placed on the front of the robot. They detect obstacles on the way of robot. The others two are installed one the left side and right side of the device. They could be used to check if any obstacle or the border of the arena is next to the robot. This knowledge gives possibility to decide in which way robot should turn.

Electronics

The main board is made of universal PCB. On it is placed STM32F4Discovery with STM32F407VG MCU, engine drivers and power supply.

STM32F4Discovery is the brain of the robot. STM32F407VG is powerful microcontroller with ARM Cortex M4 Core. It is equipped with single precision FPU, DMA and expanded timers with hardware support for encoders what, with combination of maximal clocking up to 168MHz, makes this chip a good choice for robot controller usage.

To control engines, two channel Pololu engine driver module *TB6612FNG* was chosen. On the motherboard there are two such modules – one module for one engine. To increase performances, they are used in configuration with combined channels. This module allows to use four operating modes of engines: free move, active break, clockwise and counter-clockwise movement.

Main parameters of Pololu module *TB6612FNG:*

- VMot: 4,5 – 13,5V
- VCC: 2,7 – 5,5V
- Max current for channel: 3A
- Current for channel: 1A
- Current – combined channels: 2A

Using these modules in configuration with combined channels gives safety margin that protects construction against damage – in example situation when the engine is blocked.

Robot is supplied from 2C LiPo accumulator. On the main board there are three power supply circuits with linear stabilisers:

- 5V circuit for supply servomotors;
- 5V circuit for supply sensors required 5V supply;
- 3V3 circuit for supply Discovery board and sensors that requires 3V3 supply.

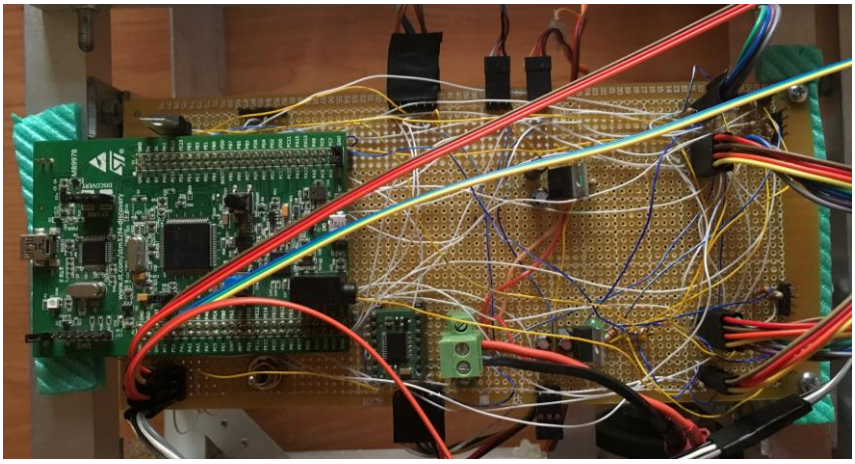


Figure 5 Robot main board

Code

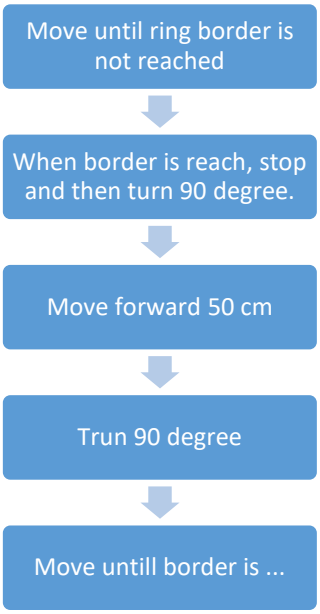
Program of the robot was written in C++ language. Code is divided into objects that are responsible for servicing of different task, such as: servicing sensor colour, engines control, servomotors control etc. Each module could be used separately in other mobile robot projects. More complicated modules, like sorter module, are constructed by composition of simpler ones. Furthermore, program allows to implement strategy executing list of commands like: move (desired distance in cm), turn (desired angle of turning), stop, open store gate. Execution of strategy could be interrupted by other components with higher priority, like collision avoidance module.

Navigation

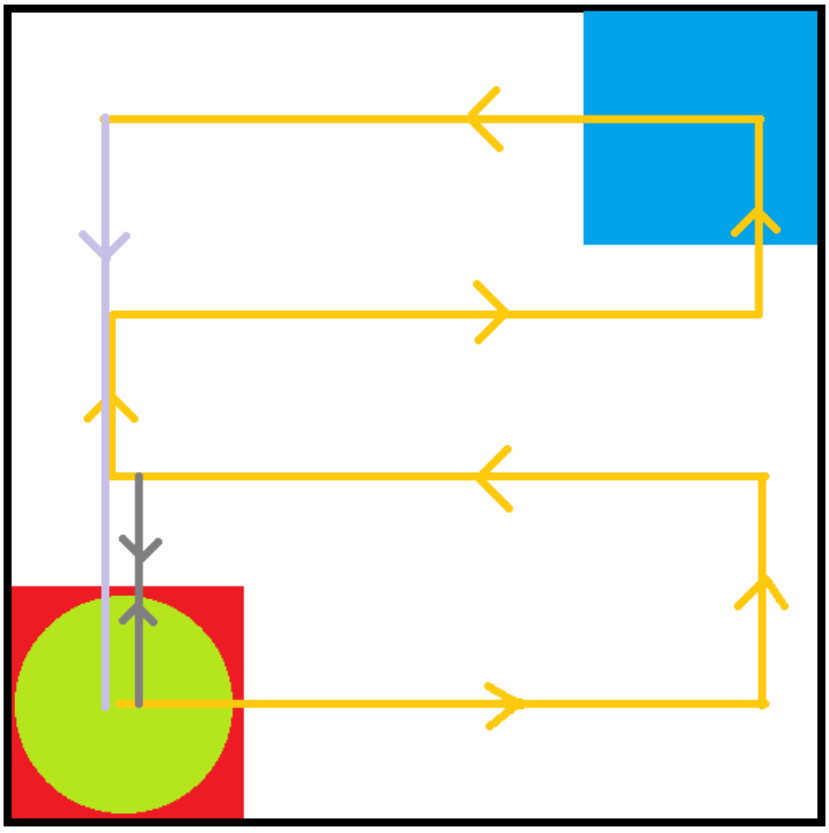
In current version robot only remembers its angular orientation with assumption that initial angle orientation is 0 degree. Global coordinates x,y are not computed. To describe translation movement only distance to overcame is used. Both, angular orientation and travelled distance are computed by odometry formulas for differential drive.

Algorithm

One of the assumed goals was to develop algorithm that allows to operate on the arena and test basic functions of the robot. Designed algorithm is called “Crazy harvester”. The main purpose of algorithm is to “scan” ring with avoiding of opponent robot. “Scan” movement could by described by simple diagram:



During scanning, robot should return to home base and leave collected valid pucks. In next step, it should continue scanning until whole arena is scanned. Then, robot should return to home base and leave other collected pucks. When robot detects opponent in its way, it should stop and wait until way becomes clean. That strategy protects against collisions and losing orientation in the ring.



Red square – home base;

Green circle – robot;

Orange line – path of scanning;

Grey line – path of returning to home base in the middle of scanning;

Light grey line – path of returning to home base when scanning is over.

This algorithm provides assurance of collecting a large number of pucks.

Used tools

System workbench for stm32 - The System Workbench toolchain, called SW4STM32, is a free multi-OS software development environment based on Eclipse, which supports the full range of STM32 microcontrollers and associated boards.

CubeMx - STM32CubeMX is a graphical tool that allows to configure STM32 microcontrollers very easily and generate the corresponding initialization C code through a step-by-step process. This software is licensed by ST license SLA0047.

Git **-** is a version control system (VCS) for tracking changes in computer files and coordinating work on those files among multiple people.

3. **Summary**

The main goals of project were accomplished. Built robot is able to navigate and perform moves in the ring, sort pucks, detect obstacles. User with little effort is able to implement many various strategies by combining developed libraries.

The main problem that occurred during realisation of this project was quickly increasing error of the odometry. After execution of some movement actions planed, the robot position was a little bit different than the real position. Calibrations and more precise measurements of construction constant values that are required for odometry formulas improved received results. Probably the extension of the robot platform by installation IMU sensor and implementation advanced sensor fusion algorithms would also improve accuracy of movement.
The second problem was straight line moving. For the same PWM singles for both motors, robot still turns to the left side. This problem was resolved by implementation of PI regulator, that, after calibration, compensates errors and keeps robot on the correct path.

4. **References**

- Rules for Puck Collect competition https://www.robotchallenge.org/fileadmin/user_upload/_temp_/RobotChallenge/Reglement/RC-PuckCollect.pdf
- Robot **Sarmatic** http://www.forbot.pl/forum/topics7/inny-puck-collect-sarmatic-vt7460.htm
- **Mobile Robotic Lecture – Odometry incremental navigation, dead-reckoning** http://kcir.pwr.edu.pl/~jjakubia/MobileRobotics/slides/mobrob_odometry.pdf
- **STM32F407 datasheet** http://www.st.com/content/ccc/resource/technical/document/datasheet/ef/92/76/6d/bb/c2/4f/f7/DM00037051.pdf/files/DM00037051.pdf/jcr:content/translations/en.DM00037051.pdf