Development of hardware platform for participation in RoboCup Junior Rescue Maze competition*

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Abstract. One of the current challenges of our time is the development of robotic systems for human rescue, capable of working autonomously in extreme situations. This challenge has not yet been fully solved and the RoboCup Junior Rescue competition offers an opportunity for young people to touch it. Based on the area of interest and capabilities, the choice fell on the category "Maze": the robot must be small, maneuverable and passable, while having on board all the necessary electronics for the correct operation of the algorithm. This category of competition in the Junior league looks the most realistic in our opinion, because the regulations do not contain specific instructions on how to solve the task at hand, opening up freedom of action. We have three years of experience in these competitions and would like to share our experiences with colleagues. This paper will focus on the electronics design and construction of small robots using RoboCup Junior Rescue Maze as an example.

Keywords: Robotics · Electronics · Rescue Maze.

1 Introduction. Past experience

Prior to development, an analysis of previous participation experience and that of fellow competitors in this competition category was carried out. The conclusion was that virtually all robotics systems, however different in design and electronic equipment, had one thing in common - moving through a maze by linking a map to landfill cells. This aspect imposes a certain instability - if for some reason the robot strays from the intended path, the chance of successfully mapping and navigating through the maze is greatly reduced. The popularity of this method for solving the problem posed by the rules is due to the relative ease of execution and low resource consumption in comparison with the method, which will be considered further in this work.

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With all the shortcomings of the "classic" solution in mind, it was decided to move to the next level of development: making a robot whose main sensor is a lidar and the map is processed on a single-board computer. In this way, navigation would not depend on the location of the robot inside the cell, stability would increase, and in the case of a stuck scenario, the robot would be able to orient itself on the walls around it and match its location to the map.

2 Construction

2.1 Design idea

The key sensor for odometry was the RPLidar A2-M7, which entailed additional design requirements. Two major challenges were identified during the development process: the need to hold the lidar horizontally for correct mapping and the small size of the large amount of bulky electronics on board.

To solve the first problem, it was decided to develop a suspension system that minimised the tilt of the robot body as it moved over obstacles on the range. This solution also increase the cross-country capability.

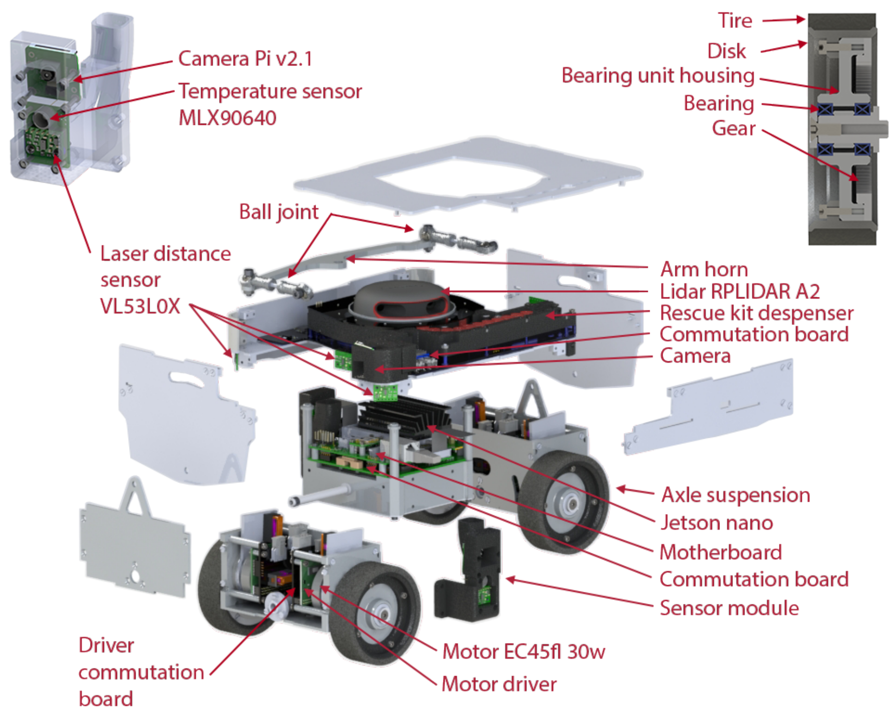

Fig. 1. Explosion-design diagram.

Justification for the choice of suspension. The long-travel independent suspension was selected. It is based on the Rocker-bogie suspension. This suspension is used in most Mars vehicles. This suspension design was chosen because: the suspension provides high obstacle-crossing efficiency due to the fact that each wheel of the robot bears an equal load, i.e. its weight is constantly redistributed between the wheels; the central electronics unit to which the lidar is attached tilts by half when the robot passes an obstacle.

Object	Variable	Quantity	unit
Constant			
Acceleration of free fall	g	9,8	m/s^2
Rated motor torque	M_motor	0,0549	Nm
Rated motor speed	V_speed	2910	rpm
Gear and belt drive efficiency	КПД	0,8	
Characteristics of the drive unit			
Gear ratio	n_ratio	10	
Rated torque of the drive unit	M_unit_t	0,4392	Nm
Rated speed of the drive unit	V_unit_rotation	291	rps
Driving characteristics			
Angle	α	30	degree
Velocity	v	1	m/s
Acceleration time	t	1	s
Acceleration	a	1	m/s^2
Weight and size characteristics			
Mass	m	3	kg
Total length of the robot	L_total	0,18	m
Wheel-to-edge clearance	l_w_t_e_cl	0,001	m
Diameter	D	0,075	m
Radius	R	0,0375	m
Center distance	L	0,103	m
approximate center of mass	l	0,0515	m
Wheel clearance	l_clearance	0,028	m
Required parameters of the node and wheel			
	k	0,577350269	
Static torque on 1 wheel	M_st	0,1378125	Nm
Dynamic torque on 1 wheel	M_dyn	0,028125	Nm
Torque on 1 wheel	M_wheel	0,1659375	Nm
Torque on the drive unit	M_unit	0,331875	Nm
Speed and torque reserve			
Linear velocity	V_linear	**1,14275**	m/s
Torque reserve ratio	K_torque	**1,32339**	>1

Fig. 2. Calculated the torque reserve for the robot, depending on the mass dimensions and motor characteristics.

Rescue kit dispenser system The rescue kit dispenser system has been designed so that the lidar placed in the centre. The rescue kits are pushed against the disc with a cut-out piston, which is held in place by a rubber band wrapped around the sleeve. The position of the disc is monitored using magnets in the disc and hall sensors on the top switching board (see Fig. 1).

2.2 Calculating the permeability of the robot

Before the modelled parts are ordered from the factory, the design must be checked for proper functioning by calculating the torque reserve and maximum speed. In this case there is a torque margin of 1.3 and a maximum speed of 1.14 m/s. Calculations were made in MS Excel table (see Fig. **??**).

3 Electronics

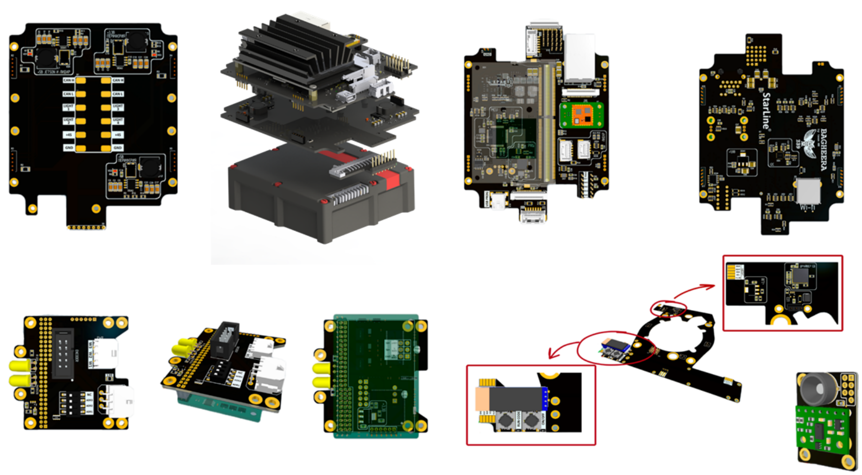

Fig. 3. Robot boards review.

3.1 List of main components. Development process

Altium Designer was chosen as the development tool for robot electronics, as it is one of the few CAD systems that provides the whole process of design and debugging of the device in a single software environment. At the same time the results of one design stage are transferred to the next stage, and changes made at any stage are displayed in all parts of the project. This allows you to track and synchronise your edits, and to monitor the integrity of your design. The result is a well-tuned and harmonised device prototype long before it is physically realised.

The robot's main computing device is an NVIDIA Jetson Nano single-board computer. It processes data from the lidar, gyroscope-accelerometer and cameras. The motherboard included with Jetson Nano does not fit in terms of size and number of connectors, so it was decided to design its own. The essential peripherals for communicating with the microcomputer, which must be on a self-developed motherboard, are an ethernet and USB port. These serve for SSH connection to the microcomputer. The self-developed board allows three connectors for MIPI cameras; most boards allow for one, or in rare cases, two MIPI cameras. Two ports are provided for lidar connection in two different ways, in case one fails. The motherboard also hosts the STM32F405RG microcontroller, which is responsible for controlling low-level peripherals: controlling the march motors, controlling the rescue kit delivery system, and reading the VL53L0X laser rangefinder and MLX90640 thermal imagers. It is connected to the NVIDIA Jetson Nano via SPI and UART. There is space for an MTi-3-T gyro accelerometer board with separate power supply and ESR protection

Power delivery arrangement. Work time calculations. Using formula 1, the peak power consumption was calculated for all 14 types of devices according to their numbers. Based on these calculations, with normal consumption, the battery capacity (3000 mAh) is sufficient to cover 0.5 hours of continuous operation.

$$P_(max) = \sum_{i=1}^{14} U_i \cdot I_i \cdot k_i = 85.17 Watt \quad (1)$$

Three LM14050 DC-DC converters for 5A are located on the power distribution board: to power a single board computer with cameras (14.8V $\rightarrow$ 5V), to power the lidar (14.8V $\rightarrow$ 5V), and to power the microcontroller and peripherals (14.8V $\rightarrow$ 3.3V). On top of the power distribution board locating the motherboard which is connected using PLS pins.

3.2 PCB arrangement. Commutation boards

In order to accommodate all the electronics and ensure reliable connections, a board kit was designed consisting of: a motherboard, a power distribution board, four motor driver circuit boards, a user interface board, an error display board, a battery adapter board, and two sensor module boards.

In order to reduce the space requirement, the main boards are stacked on top of each other and connected by means of PLS connectors. This solution also avoided a large amount of wiring.

3.3 Debugging and summarizing

The electronics design was heavily influenced by the presence of a single board computer: the cameras are connected via a MIPI CSI high-frequency interface which had to meet certain conditions in order to work. The Ethernet was a particular challenge. Overall, the amount of electronics and peripherals required for its operation doubled, while the space requirement decreased.

Working with a single-board computer was a challenge, since at the time of development no up-to-date documentation for its motherboard had been published, which made it difficult to develop one's own

4 Conclusions on the work done

The competition robot for the new season is considerably more complex than the developments of previous years. The development of the design with the suspension fitting into such a small size caused a lot of difficulties, it took us twice as much time as the development of the previous season's robot.

Fig. 4. Comparison of our robot that took part in 2019 (left) with the current development (right).

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