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doi:10.15199/48.2023.02.12

State of the Art on Development of a Prototype of Autonomous Moving Vehicle Model Controlled by Microcomputer

***Abstract**. The development of novel digital technologies and the fast development of electric drive systems for the transport industry leads to the necessity of creating novel educational equipment to train students in developing control algorithms, hardware, and software for controlling the movement of electric vehicles. One of the solutions is implementing a simple and cheap single-board computer for this task. This work deals with developing the prototype of a small-sized electric vehicle model based on the single-board computer Raspberry Pi to create a laboratory basis for teaching students to use novel technologies in controlling electromechanical equipment.*

Streszczenie.** Rozwój nowoczesnych technologii cyfrowych oraz szybki rozwój elektrycznych układów napędowych dla przemysłu transportowego powoduje konieczność tworzenia nowatorskich urządzeń edukacyjnych do szkolenia studentów w zakresie opracowywania algorytmów sterowania, sprzętu i oprogramowania do sterowania ruchem pojazdów elektrycznych. Jednym z rozwiązań jest wdrożenie do tego zadania prostego i taniego komputera jednopłytowego. Niniejsza praca dotyczy opracowania prototypu modelu małogabarytowego pojazdu elektrycznego w oparciu o komputer jednopłytkowy Raspberry Pi w celu stworzenia bazy laboratoryjnej do nauczania studentów wykorzystania nowatorskich technologii w sterowaniu urządzeniami elektromechanicznymi.* (Stan wiedzy na temat rozwoju prototypu autonomicznego modelu poruszającego się pojazdu sterowanego przez mikrokomputer***)

Keywords: Raspberry Pi, control system, education.
Słowa kluczowe: Raspberry PI, systemy sterowania, edukacja

Introduction

The growth of digital technologies determines the implementation of digital control algorithms in different areas of industry [1–7]. One of such areas is the development of control systems for electrical motors. The advantages of digital control systems are high processing speed, high precision, and flexibility, allowing one to implement different types of controllers using the same hardware. Another novel trend is the development of vehicles driven by electric motors. Digital control systems are widely used for this purpose. All these technologies are in focus nowadays [8–12]. Thus there is a necessity to create an educational equipment to teach students developing algorithms, hardware, and software for controlling the movement of autonomous electric vehicles. One of the possible solutions is the implementation of single-board computers for educational purposes. This work deals with developing the prototype of a small-sized self-driving vehicle based on the single-board computer Raspberry Pi.

Hardware

Typically, electric vehicles are driven by either DC or AC motors. As the simplest way is to create a DC-motor electric drive system, this paper will further deal with this choice to provide the basics of developing the digitally controlled electric drive systems for electric vehicles.

In this work it was used Maxon RE 13 DC motor with integrated Maxon MEnc 13 encoder, and Maxon GP 13 reduction gear [13], which is typical solution for electric plane models. Encoder outputs could be connected to Raspberry Pi GPIOs with an I2C interface to collect motor velocity data. This unit provides vast possibilities for creating different types of control system due to integrated encoder used to gain feedback signal, and reduction gear used for precise velicity control, which could be useful for students when studying principles of control systems development.

Recently it became prevalent to use single-board computers for educational tasks. Their advantages are small-size, low price, free software, and, in most cases, they have integrated software for easy connection to different peripheral devices, which could be used as a part of the control system. Conducted analysis showed that one of the best solutions for implementation in the educational process is using a Raspberry Pi single-board microcomputer [14].

The Raspberry Pi is a series of credit card-sized single-board computers developed by the Raspberry Pi Foundation and initially aimed to help promote the teaching of computer science basics in high-schools. Raspberry Pi has a wide range of hardware solutions to interact with the outside world. Thanks to its outstanding features, it has been successfully used in many digital maker projects, such as music machines, parent detectors, weather stationsj, tweeting birdhouses with infra-red cameras and many others [15–17].

Thanks to general purpose input-output (GPIO) pins, there is the possibility of attaching various sensors to process their information in Raspberry Pi and attaching actuators to create digital control or automatic systems. Another thing is the presence of a CSI connector for plugging a digital camera, which may be used to increase the possibilities of creating a device for a visual driving system when the car can move without human aid.

Based on conducted analysis of the Raspberry Pi possibilities for solving the task of creating a controlled electric car model, it was proposed the functional chart of the laboratory set-up (Fig. 1).

Additionally, this project used a five-megapixel fixed-focus Raspberry Camera module that supports 1080p30, 720p60, and VGA90 video modes, as well as stills capture. It attaches via a 15cm ribbon cable to the CSI port on the Raspberry Pi.

As a mechanical part, it was chosen a basement of an RC toy car, which is enough to reach the aim of developing driving control algorithms for electro-mobile (Fig. 2).

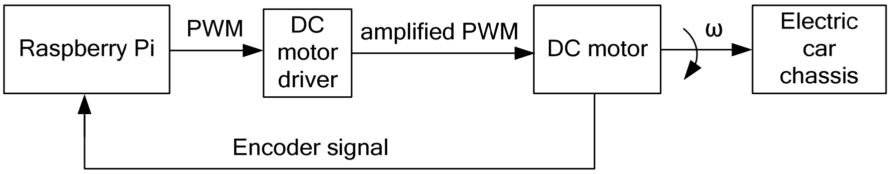

Fig. 1. Functional chart of the laboratory set-up

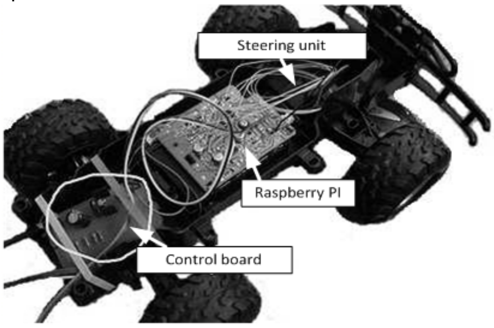

Fig. 2. The photo of the mechanical part with the installed Raspberry Pi-based control board

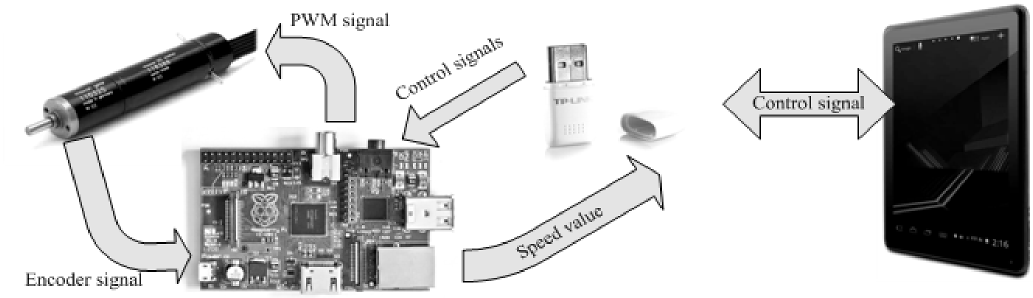

Fig. 3 Functional chart of developed control system

In order to implement distant manual control of the electro-mobile model, it was used Wi-Fi dongle, and also it was developed web-interface to control the Raspberry Pi-based program, which could be run from any device which has an Internet browser. Eventually, based on the above-described equipment, the available chart of control system for electric drive was developed to drive a small-sized RC car model, shown in Fig. 3.

Control unit software development

In order to synthesize different control algorithms, a specialized software was developed. Developing teaching equipment and software should provide vast possibilities for implementing different types of control algorithms. For the initial implementation it was chosen most commonly used control algorithms such as PID-control and Fuzzy-control [18]. The idea is that students have to compute parameters of control algorithms based on RC car and pathway features and implement them in an RC car control unit using developed software with the aim of their comparison. To solve this task, an appropriate algorithm was developed to control the movement and steering of the RC car (Fig. 4) and an algorithm for correcting the set-point for DC motor voltage signal depending on road conditions (Fig. 5). These algorithms were implemented using Python programming language built-in into the Raspbian operating system [19].

Another essential task is to implement autonomous RC car movement [20]. To solve this task, an image stream from the Raspberry camera was used. To recognize road curves, it was trained Neural Network (NN). In order to minimize CPU load, it was used low camera resolution (320x240px). All possible road conditions (such as left turn, right turn, straight road etc.) were collected in training data images.

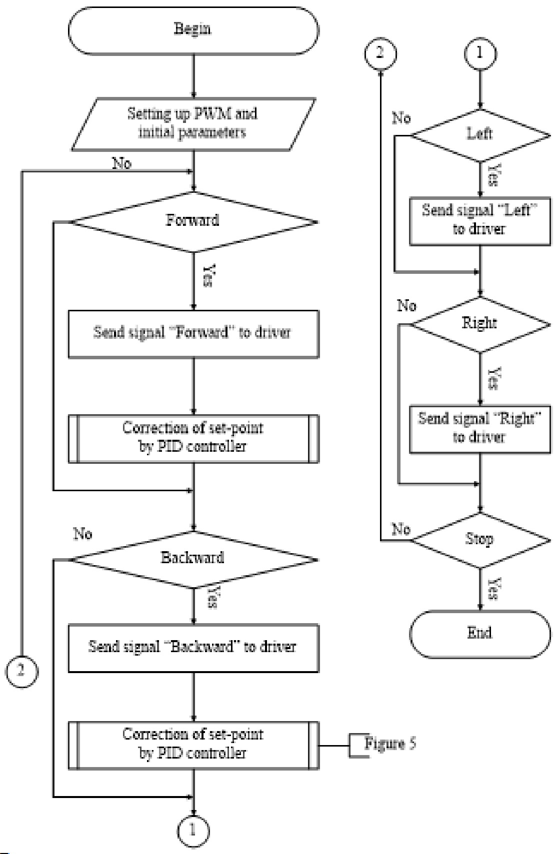

Fig. 4. Algorithm of RC car movement control

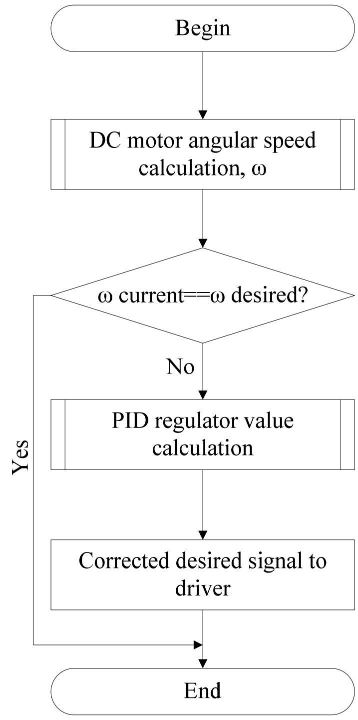

Fig. 5. Algorithm of recalculation of desired DC motor voltage

To train Neural Network, it was used the lower part of an image (as just this part contains an image of the road). Thus, in this project it was used NN with 38400 nodes in input layer (describing each pixel in input image), one hidden layer with 64 nodes and output layer with 4 nodes which corresponds to movement control instructions forward, backward, left and right (Fig. 6).

Basing on synthesized algorithms, it was developed related software using Python programming language.

As result, it was developed a prototype of a self-driving car whcih could be used to teach students to developing different principles of control algorithms for self-driving vehicles.

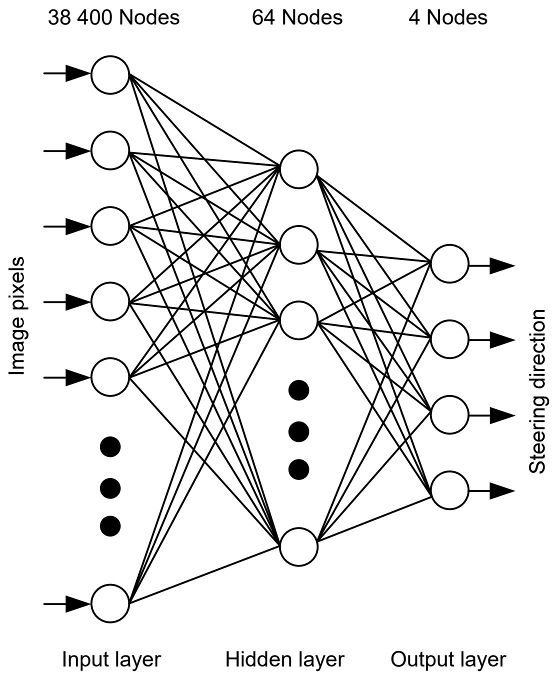

Fig. 6. Structure of implemented Neural Network

Autonomous vehicle tracking system

Another important task in developing autonomous vehicles control systems is possibility ot track their position online. For this purpose, it was used GPS signal receiving module GY-NEO6MV2 connected to Raspberry Pi, with related software submodule, alsor written with the use of Python programming language. Received coordinates via Wi-Fi connection are sent to host computer, and, with the use of CGI-scrypts, processed to represent tracking position at the developed web-interface (fig. 7).

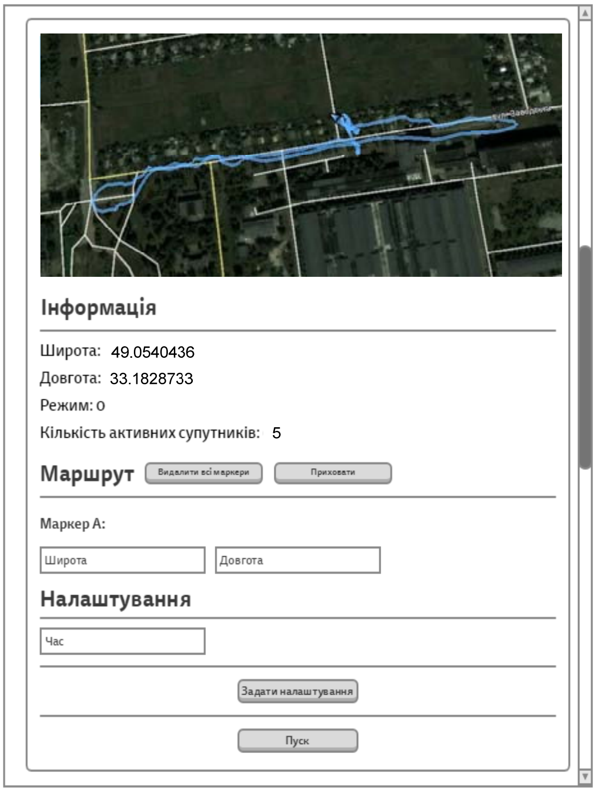

Fig. 7. Web-interface demonstrating work of tracking subsystem

Conclusions

This work describes a developed electric drive control system aimed to be used as laboratory equipment for studying the principles of development, creation, and investigation of DC-motor digital control systems. As the basis for this system, an electric drive of a small-sized RC car model was chosen. As the central part of hardware and software, the single-board computer Raspberry Pi was chosen with its built-in facilities. Such an approach allows students to study the principles of development and operation of the electric vehicles control systems from their very basics. Relatively low price for Raspberry Pi components makes it possible to widen the number of laboratory stands that can be created under current economic restrictions to provide students access to study up-to-date software solutions, electronics, and principles of control the electromechanical equipment. In this project it was employed Artificial Neural Network to adjust speed of control vehicle, but students are free to experiments with different types of control algorithms basing on developed equipment. Another important feature of developed solution is implementation of GPS-coordinate receiving module, which allow investigation of a fully autonomous moving of vehicle from the very remote distance.

The developed system allowed students to study principles of development and creation of electric drive control systems, investigate and compare the operation of different types of regulators used to control electric drive operation, develop software used in control system, and develop and investigate the operation of different algorithms used for image recognition.

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