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RASPBERRY PI BASED LAP COUNTER FOR AMATEUR CAR RACING[1]

Summary. This article presents the design of a lap counter and timer that can be used in amateur car racing. Main functions of this computer to count laps, measure lap time, vehicle speed and accelerations. The system uses a GPS module, accelerometer and magnetometer sensors.

Keywords: GPS, accelerometer, car computer, data logging, car racing, inertial sensors

LICZNIK OKRĄŻEŃ ZBUDOWANY ZA POMOCĄ PLATFORMY RASPBERRY PI PRZEZNACZONY DLA AMATORSKICH RAJDÓW SAMOCHODOWYCH

Streszczenie. W artykule opisano projekt licznika okrążeń przeznaczonego do użycia podczas amatorskich wyścigów samochodowych. Urządzenie pozwala także na pomiar czasu okrążenia oraz zapis parametrów trasy, takich jak kierunek jazdy i przeciążenia działające na samochód. W komputerze zastosowano odbiornik GPS oraz czujniki akcelerometryczny i magnetometryczny.

Słowa kluczowe: GPS, akcelerometr, komputer samochodowy, rejestracja danych, rajdy samochodowe, czujniki inercyjne

1. Introduction

In modern cars computers are not uncommon, most engines are controlled by a computer, and with the advancement of technology, more and more pieces of equipment and safety systems including ADAS solutions [1] have their own computational units. Lately a lot of

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research is performed to develop computer for autonomous car [2]. Computers for motor sport [3], however, are rather a niche solution. To reduce the weight the race vehicles often have many original elements removed. It is common to dismount dashboard and some elements of automatic control replacing them with manual control. The system mounted instead of original can provide additional information about the working parameters of the vehicle, as engine oil temperature, temperature of oil cooling the exhaust turbine. As the cars participating in the race are exposed to more extreme conditions of use, the data is often the necessary information for the driver, not to lead to overheating components, or to prevent another failure.

For the beginners the most important parameters to monitor during the race are accelerations and lap time. These can be acquired with accelerometer and magnetometer sensors [4] and GPS receiver and stored for future analysis. Possibility of analyzing the data collected from many different sensors connected to the computer installed in car supports rapid development of driving skills. It is possible to analyze data for improving racing line by increasing the speed at some sections of the race or changing the curve of the track.

One functionality of the computer installed in the race car is measurement of lap time. Since the low weight of the vehicle is one of the key elements in professional car races, systems for measuring the lap time are usually mounted outside the vehicles. The cost of such devices is excessive for the organizers and participants of amateur races. Although GPS is used mainly to navigate the driver [5, 6, 7] it can be also used for other purposes. Computer presented in this article has possibility to count laps and measure time of every lap using GPS signal.

Further parts of the paper are organized as follows. Chapter 2 describes the concept of the design with description of main elements of the system. Chapter 3 presents some important details of the design. Chapter 4 presents some basic tests that have been done and Chapter 5 summarizes the article.

2. Concept of computer for car sport

The concept of the car computer for amateur sport applications is based on the following requirements:

- low cost – affordable for car race adepts,
- laps counting,
- measuring of lap time,
- displaying current speed and direction,
- saving information to the file for future analyze.

There are software solutions available on the market with the functionality mentioned (RaceChrono, Motorlap, Harry's LapTimer and others [8]). This software can be installed on Android smartphone or tablet that integrates main computer, display and sensors in one device. The design proposed in the paper is based on the modular approach having the ability to assemble sensors in different locations in the car body that allows to achieve the best performance of every sensor.

2.1. Main module

Main part of the device is based on Raspberry PI [9] that is a platform developed mainly for teaching programming for students, pupils, even children. Because of high efficiency of the processor used, availability of a graphic processor and popular interfaces as HDMI, USB and Ethernet it can work with operating system based on the Linux kernel. The most popular operating system is Raspbian, which is adapted to the Raspberry PI distribution of Debian. Very important feature of Raspberry PI is the possibility to connect external electronic elements using serial ports (I2C, UART, SPI) or general purpose input output (GPIO) pins. There is also reach documentation available that supports development process.

Current state of the vehicle and information from sensors is presented on the graphic display. The main screen presents information about speed, direction and the time of last lap.

Due to the large amount of noise and voltage fluctuations in the car, the design of a stable power supply module was a very important part of the project. The main protection against interference is to use multiple capacitors, both ceramic and electrolytic, as close as possible to sensor modules, Raspberry PI platform and the display.

2.2. Sensors

In the proposed design a GPS sensor is used to determine current position of the car giving possibility to detect the lap ending point. Professional systems are usually based on laser detectors placed at the finishing line sometimes aided with radio modules to detect specific car in the situation when two or more cars cross the line almost simultaneously. Such systems require additional equipment mounted in all cars and at the finishing line. Solution described in this paper is not as precise as the professional equipment but allows end point detection with accuracy acceptable for amateur race drivers. GPS module also allows to calculate current speed of the car.

Accelerometer has been used to measure the acceleration of the car that provides very significant information for the driver – how the maximum tire grip is used. After analyzing the track and data from the accelerometer, it is possible to determine in which sections of the track the driver can accelerate without the loss of adhesion, or where the change of the trajectory is needed. Magnetometer has been used for determining the direction of movement.

3. Details of the design

Main part of the computer for the car is Raspberry PI B+ board. This version is based on the processor ARM1176JZF-S CPU working with 700 MHz clock frequency. There is 512 MB of RAM memory mounted on the board. Operating system and all software is stored on MicroSD flash card. Computer is equipped with monochrome LCD display with a resolution of 128x64. Display is based on the KS0108 controller that can be connected to the board with 8-bit parallel data bus and some control lines, all mapped on GPIO pins. In the design the module LSM303D has been used that is a combination of accelerometer and magnetometer in one package. Communication with the module is done using the I2C bus. GPS receiver based on the chipset MTK3339 has been used. It is connected to the Raspberry with serial port with transmission speed equal to 115200 bps. Its refresh rate is 10Hz. The block diagram of the computer for the car is presented in Fig 1.

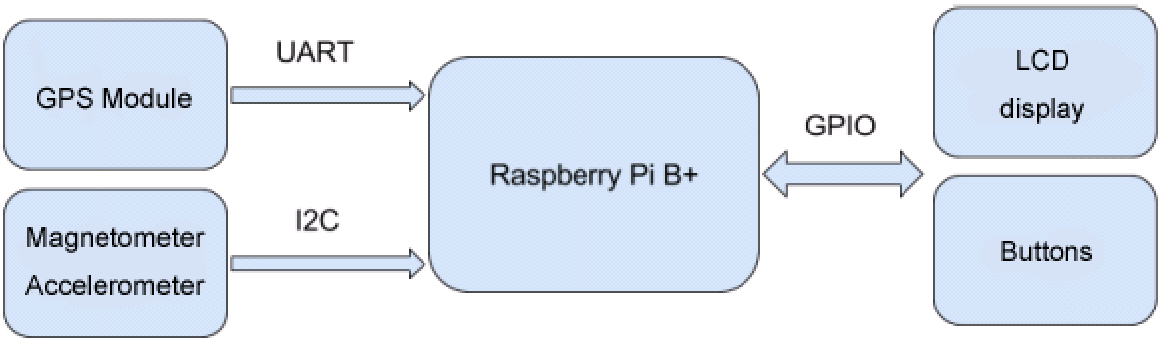

Fig. 1. The block diagram of the computer for car
Rys. 1. Schemat blokowy komputera samochodowego

Thanks to modular design elements of the system can be located in the car in places with lowest electromagnetic noise. It is important to locate the magnetometer as far as possible form engine and other element generating strong magnetic field. For GPS it is important to avoid obstacles like the plate from the car body.

Power supply voltage in the car drops while engine start that results in reset of the computer. To ensure that software will operate after every engine start the script has been written, It configures the gps module and starts the application.

Data from GPS is used to detect starting point of the lap and logged in file for future analysis. To set the starting point user should press key while standing on the start line. This will store position and direction information. To calculate distance d between two points basing on GPS coordinates the haversine formula is used. It is implemented with equations (1) – (4).

$$r_{earth} = 6378{,}137, \tag{1}$$
$$u = \sin^2\left(\frac{lat_{2rad} - lat_{1rad}}{2}\right) \tag{2}$$
$$v = \sin^2\left(\frac{lon_{2rad} - lon_{1rad}}{2}\right) \tag{3}$$
$$d = 2 * r_{earth} * asin(\sqrt{u + \cos(lat_{1\,rad}) * \cos(lat_{2\,rad}) * v}) \tag{4}$$

where:

$lat_{1\,rad}$, $lat_{2\,rad}$, lon_{1rad}, lon_{2rad} are coordinates of two points given in radians;

u, v are haversine functions on latitude and longitude separation respectively.

Data from accelerometer and magnetometer are used to determine direction of the car and the accelerations. Information is presented on LCD display and logged in the file.

4. Tests

Tests were performed to check the operation of the module GPS and magnetometer, as well as the algorithm of automatic lap metering. During the tests the problem with magnetometer has been observed, caused mainly by ignition coil and power lines of cockpit components such as radio or speakers. Tests performed during race show that, after choosing the best placement for GPS module lap counting works properly. Lap counter detects the finishing line with the accuracy about 5m that seems to be reasonable for amateur usage.

5. Conclusions

The proposed solution for a lap counter was tested during a real race and verified to work sufficiently well for driver need. Because of the available processing power, the discussed design can be further extended and improved. The first thing that should be improved is accuracy. Usage of active antenna should result in more accurate GPS positioning. Also faster receiver can be used to detect the finishing line of the lap with resolution better than 5m. Update rate of current receiver is equal to 10Hz, there are 50Hz modules available on the market.

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Omówienie

Artykuł przedstawia projekt komputera, który jest przeznaczony do wykorzystania podczas amatorskich wyścigów samochodowych. Dzięki użyciu odbiornika GPS możliwe jest ustalenie aktualnej pozycji samochodu, a w szczególności wyznaczenie momentu przejazdu przez linię końcową okrążenia. Zastosowanie akcelerometru i magnetometru pozwala na obliczenie bieżących przeciążeń i kierunku poruszania się pojazdu, co pomaga wyznaczyć najlepszą trajektorię pokonania toru z maksymalnym wykorzystaniem przyczepności opon. Komputer został zaprojektowany z zastosowaniem popularnej platformy sprzętowej Raspberry PI uzupełnionej o odbiornik GPS zbudowany na układzie MTK3339 i zintegrowany akcelerometr i magnetometr LSM303D. Jako interfejs użytkownika wykorzystano monochromatyczny wyświetlacz LCD ze sterownikiem KS0108. Schemat blokowy komputera przedstawiono na rys 1. Otrzymane z odbiornika GPS dane są przeliczane zgodnie ze wzorami (1) – (4) celem otrzymania informacji o przebytej odległości. Parametry jazdy są prezentowane na bieżąco na wyświetlaczu LCD, a także zapisywane do plików celem dalszej analizy. Komputer w podstawowej wersji spełnia wymagane funkcje i nadaje się do wykorzystania w amatorskich wyścigach. Dokładność detekcji linii końca okrążenia wynosi obecnie ok. 5 m. Zastosowanie nowocześniejszego odbiornika GPS o większej częstotliwości odczytu pozycji (50 Hz zamiast 10 Hz) pozwoli na dokładniejsze wyznaczanie tej linii. Dodatkową poprawę dokładności można uzyskać wtedy, gdy zastosuje się aktywną antenę GPS.

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