SMALL ANIMAL PHYSICAL ACTIVITY MONITORING SYSTEM

SUSTAV ZA NADZOR FIZIČKE AKTIVNOSTI MALIH ŽIVOTINJA

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Abstract

Gadgets are omnipresent in today's people's lives. Many of them do not have a needed and smart function, but are here to bring joy and happiness to people worldwide. Consumerism and hyper production has lowered the price of consumer and business electronics. The theme of this paper is to project and implement an automated system that monitors a pet's physical activity via popular Arduino mass produced development electronics. The system is monitoring the amount of physical activity and calculate average distance and speed the animal is doing daily. The principles and scheme of the assembly will be shown and described.

Keywords: IoT, Internet of things, Arduino, MATLAB, exercising wheel

Sažetak

Elektronički uređaji su sveprisutni u životu današnjeg društva. Mnogi od njih nemaju potrebu i pametnu funkciju, već postoje kako bi donijeli radost i veselje ljudima širom svijeta. Konzumerizam i hiper produkcija je snizila cijene potrošačke i poslovne elektronike. Tema ovog rada je projektiranje i implementacija automatiziranog sustava koji kontrolira ljubimčevu fizičku aktivnost pomoću popularne Arduino masovno proizvedene elektroničke pločice za razvoj. Sustav nadgleda količinu fizičke aktivnosti i računa prosječnu udaljenost i brzinu koju životinja radi dnevno. Principi i shema rada sklopa će biti prikazani i opisani.

Ključne riječi: IoT, Internet stvari, Arduino, MATLAB, rekreacijski kolut

1. Uvod

1. *Introduction*

A computer processor such as Intel i486 used to cost around the same as a small car. Nowadays a chip with similar power is the price of a chocolate bar [1].

The Internet of Things is a growing topic in the tech world, and more and more hardware projects include some connected objects. Such objects can be smart watches that connect to the web, cameras, energy monitoring devices, cars, robots, etc. Many industry giants such as Google, Samsung, and Apple are entering the market with connected objects. On the other hand, millions of people around the world use the Arduino platform to create hardware projects of their own design and functionality. Due to the ease of use, Arduino allows people without the background knowledge in computer programming and tech in general to create simple but amazing hardware projects [2].

Following the Arduino with its ease of use are cloud computing services. Many of industry giants such as Google and Microsoft provide excessive and straightforward support for Internet of Things projects on their cloud services. Arduino boards are great for usage in simple embedded solutions due to its simplicity and reliability in terms of programming code. Other solutions could be used in this project like Raspberry PI. Due to dependency of some kind of operating system on Raspberry PI, one is not as reliable. Adding more layers to any type of simple project increases the risk of system failure due to increased complexity.

2. Small animal physical activity monitoring system project

2. *Projekt sustava za nadzor fizičke aktivnosti malih životinja*

Unlike dogs, whose physical activity can be seen every day while they are out for a walk, there are some pets whose activity it is harder to observe. Some pets like hamsters, rats and hedgehogs are nocturnal animals and are active mostly at night and, due to their reverse biorhythm to humans, it is hard to observe their physical activity [3].

It is important to monitor the animal's activity because its decline may indicate that it is ill or in a poor physical condition [3].

The fact that all these animals enjoy spinning an exercise wheel, abridges the monitoring of physical activity and makes the system quite accurate [4].

The scope of this paper is description of a custom solution that monitors the animals daily physical activity. The system will be tested on an African pygmy hedgehog. The prototype of the monitoring system was made using Arduino Mega 2560 development board due to its fairly large amount of resources and memory on the microcontroller. Large resources are more helpful when prototyping such a device due to the ability that one does not have to pay attention on cleanness of the program code. The Arduino development board is also ideal in this circumstances due to its ease of obtainability and reasonable price [5] [6].

For the networking features the Arduino Ethernet shield was used which uses the Wiznet W5500 embedded Ethernet controller [7]. Server is hosted on a thingspeak.com cloud platform with MATLAB analytics support. MATLAB (matrix laboratory) is multi-paradigm numerical computing environment and a high level programming language for matrix manipulations, implementation of algorithms, plotting of functions and data manipulation. It is the calculation platform of choice currently used in the sciences and engineering and in many technical business areas [8].

3. System architecture

3. *Arhitektura sustava*

Due to its size, a hedgehog uses a larger wheel [4]. In this case a wheel with a radius of 0.14m is used. The radius of the wheel defines its circumference which is important due to measurements of the current speed of the wheel and overall distance. The formula for the circumference C of a circle is:
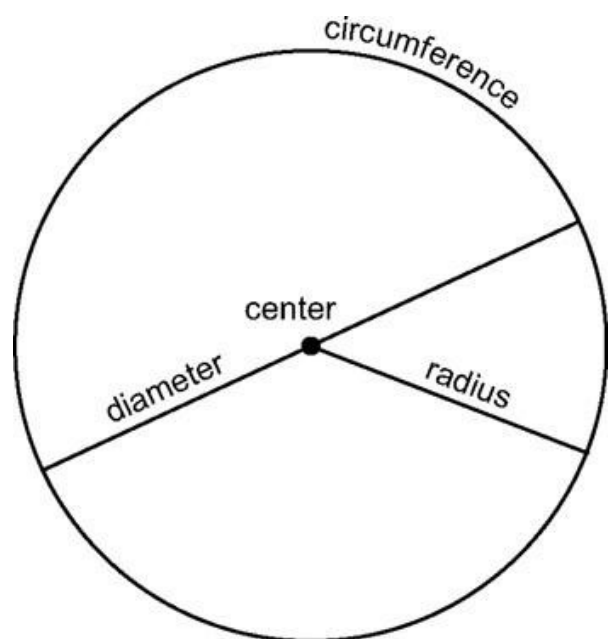
$$C = 2r\pi$$

Where r indicates the radius [9].

Figure 1: *Circle -This means that the exact circumference of the wheel can be calculated and is: C=0.87965m≈0.88m*

Slika 1: *Kružnica- Ovo znači da se točan opseg kotača može izračunati i on iznosi: C=0.87965m≈0.88m*

Now the circumference of the exercising wheel is known and is 0.88m. This means that the number of times that the exercising wheel has made a full circle has to be multiplied by circumference to get the overall distance. Hence, if the wheel is turned 3 times, the animal has passed 2.64 m. The idea is to fasten a sensor to the animals' wheel and count how many times it has turned the wheel and in what time span.

Many different approaches for measuring turns of the exercising wheel were taken into consideration.

An ultrasonic distance sensor could be used, but was impractical due to relatively big latency of the sensor and problems with high pitch sound that could be heard by some animals that were potential candidates for testing the device [10] [11]. Sharp GP2Y0A21YK infrared sensor was considered, but lacks precision on nearby objects. For Sharp infrared sensor to work properly, objects have to be in a distance range from 10 to 80 cm which is unacceptable for this application [12]. For the simplicity of the design the reed switch was used to measure the number of rotations of the wheel in a time period. The reed switch is a small and reliable device that turns on or off when a magnet is nearby. The reed switch is an electrical switch that consists of a pair of contacts on ferrous metal reeds in a hermetically sealed glass envelope. A magnetic field causes the reeds to come together, thus making a connection to electric circuit. The stiffness of the reeds causes them to separate, and opens the electric circuit [13].

Figure 2: *Reed switch*
Slika 2: *Reedov prekidač*

Arduino development board can be controlled using various programming languages such as Assembler, C, and C++. To make these components function, C language was used to write the programming code. Three libraries were used: SPI, Ethernet, and ThingSpeak. The SPI library allows Arduino components to communicate with SPI devices. SPI devices are Serial Peripheral Interfaces. The SPI protocol is a synchronous serial data protocol used by microcontrollers which can also be used for communication between two microcontrollers. The SPI library is used to listen to the reed switch and communicate with the Ethernet shield board [14]. The Ethernet library allows Arduino boards to connect to the internet with Arduino Ethernet Shield.

It can function as a server accepting incoming connections or as a client making outgoing ones. The library supports up to four concurrent connections as incoming ones, outgoing ones, or a combination of both. Ethernet shield uses the Wiznet W5500 embedded Ethernet controller which has an internal 32K buffer that allows the board to deal with an entire TCP and UDP protocol. The Wiznet W5500 implement TCP/IP Stack, 10/100 Ethernet MAC and PHY. Hardwired TCP/IP stack supports TCP, UDP, IPv4, ICMP, ARP, IGMP, and PPPoE. Using a Wiznet W5500 diminishes the need for utilizing complex socket program and handling of an Ethernet controller [15] [16].

The ThingSpeak library is used to connect to the ThingSpeak IoT Hub to write or read data. Due to the fact that ThingSpeak can only accept channel updates every 15 seconds, the data is sent every 20 seconds. Seconds are measured with Arduino internal clock which is not accurate, but it does not have to be due to correct measurement of time on the ThingSpeak server. The count on an Arduino board is generated from Timer 0 which is an 8-bit counter that is fed by the system clock and divided by 64 [17] [18].

The ThingSpeak cloud offers free data storage and analysis of time-stamped numeric or alphanumeric data which is stored in channels. Each user can open its own channel which can be private or public. It uses a MATLAB scientific calculation and high level programming through an interactive environment that allows for accurate resolution of complex calculation tasks more quickly than with traditional programming languages. MATLAB is also a high-level technical computing interactive environment for algorithm development, data visualization, data analysis and numerical calculations. MATLAB is suitable for solving problems of technical calculation using optimized algorithms that for the end user are easy to use commands. It is possible to use MATLAB in a wide range of applications including mathematical calculus, algebra, statistics, econometrics, quality control, time series, processing of signals and images, communications, design of control systems, test and measurement systems, modeling and financial analysis, computational biology, etc. [19].
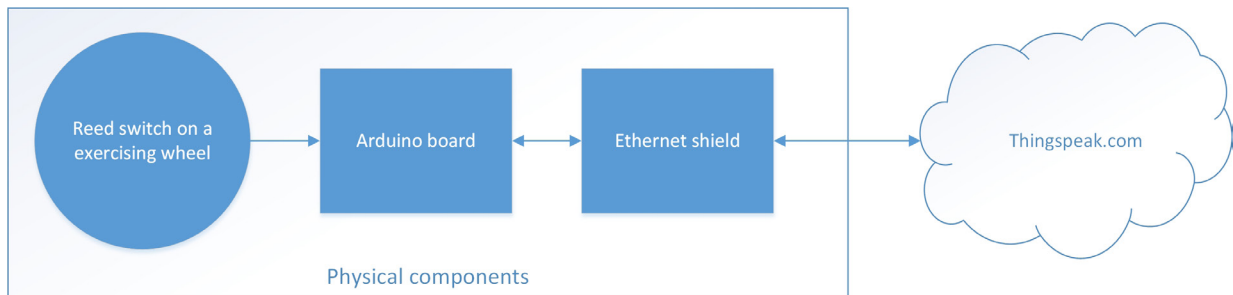
Figure 3: *Architecture of the project*

Slika 3: *Arhitektura projekta*

3.1   Client side

3.1   *Klijentska strana*

The Arduino MEGA 2560 is the brain of the client part due to the fact that the whole client application is carried out by it. Client application automatically gets an IP address from a DHCP server, thus one has to be provided on a network. It uses an algorithm that automatically generates its own mac address using a random function. Mac is then stored in an EPROM of the Athmel MEGA 2560 microcontroller, which is used later every time the device is turned on. That approach eliminates the possibility that two clients have the same MAC address within a single subnet of a computer network. Correspondingly, client for the ThingSpeak cloud has to be initialized. After the client is initialized, device that sends the request to the cloud has to use an API key to do so [18]. The device has to read triggered pin by the reed switch and collect data in a given time. The input from a reed switch has to be delayed due to the problem with the sensitivity of a reed switch when triggered with a week magnetic field. After enough time has passed, the collected data in terms of number of turns of the exercising wheel is sent to the cloud. The server is set to collect data no more often than 15 seconds; thus a time of 20 seconds was used to be on the safe side. Sending data to the ThingSpeak cloud is very trivial due to the fact that complete library was provided for communication and protocol used for sending and receiving data. The Arduino can be connected to a classic power socket using any power adapter that outputs between 7 and 12 volts and gives more than 300 mA of current due to Wiznet W5500 and ATMEGA2560 combined consumption [15] [20].

The Arduino Ethernet shield can also provide electricity through PoE (Power over Ethernet) device [7]. The device would be practical to use on a large scale experiment due to the ease of installation using only Ethernet cables. It passes electrical power along with data on Ethernet cabling. This allows a single cable to provide both data connection and electrical power to devices. Arduino Ethernet shield acts also as a PoE extractor, which means that it powers the whole Arduino unit including sensors. For that particular use case, a PoE injector has to be added on a network where devices are connected. PoE injector doesn't have to be also a switch. It can function separately as only PoE injector, but the downside of this is the power and extra cables that have to be added.
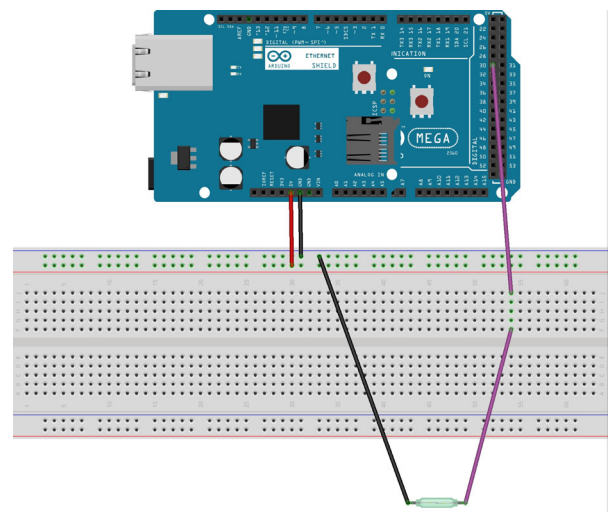

Figure 4: *Arduino schema*

Slika 4: *Arduino shema*

3.2   Server side

3.2   *Poslužiteljska strana*

The IoT Hub used for this project is ThingSpeak. ThingSpeak offers free data storage and analysis of time-stamped numeric or alphanumeric data which is stored in channels. Each user can open its own channel which can be private or public. Each channel can show infinite number of projections of the data collected from one or more embedded client devices which are sending data to the channel. As mentioned before, a MATLAB is used in all of the calculations on a server side which eases a process of computing due to MATLABs great flexibility and ease of use. With MATLAB a graphical representations of the input data can be easily created in real time.

Few graphs were created to show the power of the MATLAB tool. All graphs use the same input data in terms of number of revolutions of the exercising wheal in a given time period. The first graph (Figure 5) shows the number of revolutions of the exercising wheel in a time period which is basic graph due to the fact that it shows raw data collected from the client side.

Graph on figure 6 shows average speed in m/s of the exercising wheel in a time period. The average speed is calculated with a given formula:

$$v= s/t$$

In a formula v indicates velocity, s indicates distance and t indicates the period of time elapsed to cover that distance [21].
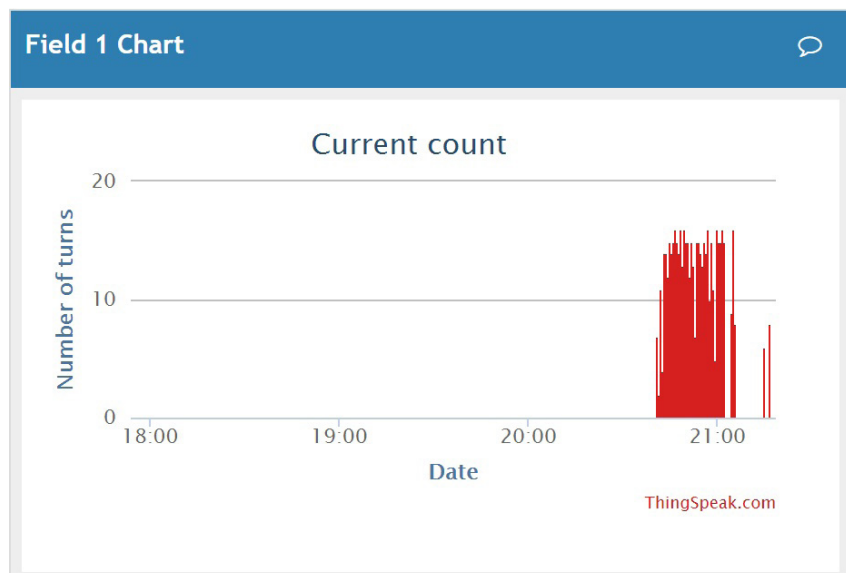

Figure 5: *Number of revolutions in a time period*

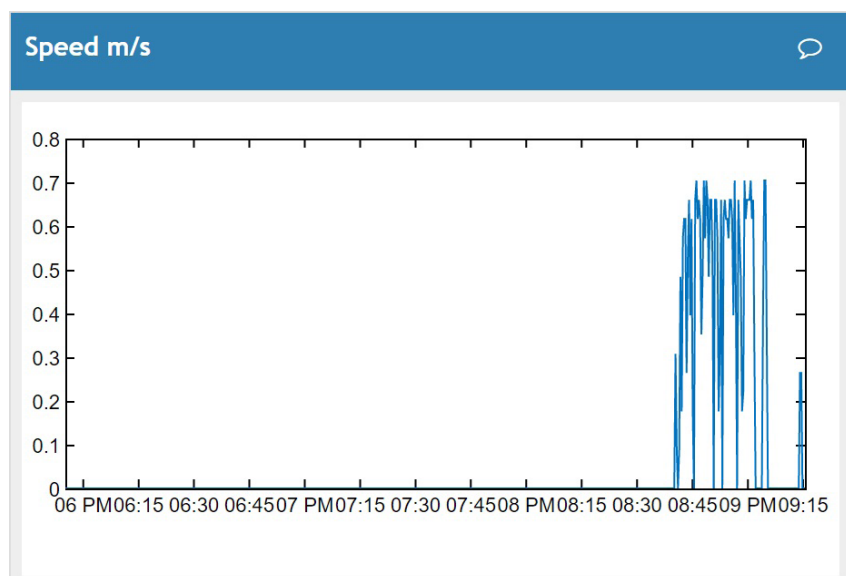**Slika 5:** *Broj okretaja u vremenskom periodu*

Figure 6: *Average speed in m/s in a time period*

Slika 6: *Prosječna brzina u m/s u vremenskom periodu*

The distance is calculated with the formula:

$$s=2r\pi n$$

Where n indicates the number of revolutions in a time period. Average speed can also be converted in km/h with conversion of meters to kilometers and conversion of seconds to hours. The average speed in km/h is show on figure 7.

To overview overall physical activity of the animal, summarization of the data by day was needed.

The summarization by day fundamentally gets the data for each separate day and summarizes all the revolutions of a spinning wheel in a day and multiplies it by circumference of the exercising wheal. The data retrieval for the day does not start at midnight, it starts at noon due to the animals' reverse biorhythm. It is active from evening to morning, and because of that, a simple summarization from midnight to midnight would not be correct. Essentially, the time period for one day is the second half of the previous day and the first half of the following day. The graph as a product of summarization can be seen in figure 8.
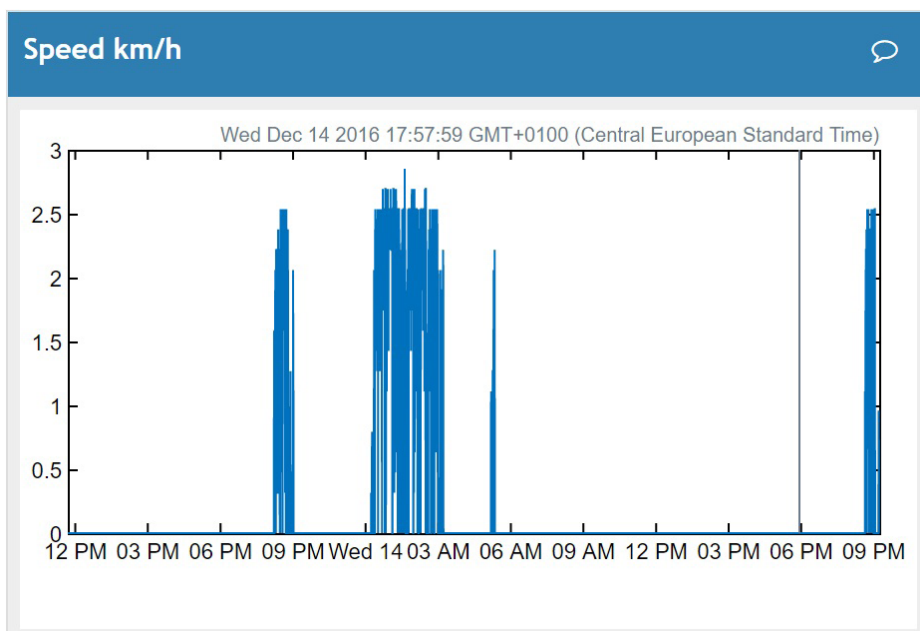

Figure 7: *Average speed in km/h in a time period*

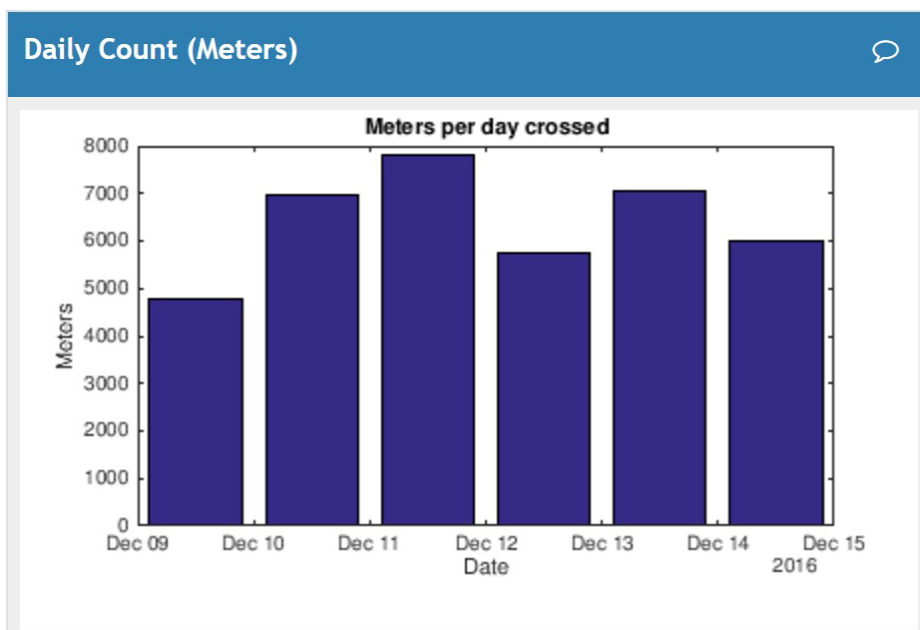***Slika 7:*** *Prosječna brzina u km/h u vremenskom periodu*

Figure 8:*Average speed in km/h in a time period*

Slika 8:*Duljina puta u metrima po danu*

4. Conclusion
4. *Zaključak*

Within this paper, an automated system to monitor a pet's physical activity was created. Due to ThingSpeak clouds ability to store, analyze and visualize the accumulated data, it has proved to be a very useful and powerful tool. The MATLAB eases the process of computing and manipulating data on the ThingSpeak cloud.

Due to the modularity of Adruino, additional sensors can easily be added to this system. For example, a thermometer could monitor the temperature of the room in which the animal is placed. This data could be used to analyze how the temperature affects the animals' activities. Also a scale sensor could be added to further monitor animal's intake of food with which an intake calorie can be calculated. With intake calorie, calories burned per meter for traveled distance can be calculated. With all these measurements, the overall health and physical condition of an animal can be monitored with all its fluctuations of mass and activity over the seasons.

This project has shown that the data collected from the animal can be analyzed and visualized in an easy way for the owner to interpret. Also, data can be stored for later retrieval for analyzation of the overall progress of the animal throughout the year and all its seasons.

5. REFERENCE
5. *REFRENCES*

[1] H. C. Adrian McEwen, Designing the Internet of Things, John Wiley and Sons, Ltd., 2014.

[2.] M. Schwartz, Internet od Things with the Arduino Yun, Packt Publishing, 2014.

[3.] H. HL, Hedgehogs, Vet Clin North Am Small Anim Pract, 1994.

[4.] Y. R. Johanna H. Meijer, "Wheel running in the wild," Proceedings Of The Royal Society B, vol. 281, no. 1786, 2014.

[5.] Arduino, "Arduino MEGA 2560," 9 12 2016. [Online]. Available: https://www.arduino.cc/en/Main/ ArduinoBoardMega2560.

[6.] "Arduino bord specs comparison," Arduino, 9 12 2016. [Online]. Available: https://www.arduino.cc/en/Products/ Compare.

[7.] Arduino, "Arduino Ethernet Shield," Arduino, 9 12 2016. [Online]. Available: https://www.arduino.cc/en/Main/ ArduinoEthernetShield.

[8.] J. Braselton, DATA ANALYSIS with MATLAB, CreateSpace Independent Publishing Platform, 2016.

[9.] S. D. S. University, Perimeter, Area and Circumference, San Diego: Addison-Wesley, 2004.

[10.] L. S. University, "How Well Do Dogs and Other Animals Hear?," Louisiana State University, 03 06 2003. [Online]. Available: http://www.lsu.edu/deafness/ HearingRange.html. [Accessed 12 12 2016].

[11.] I. Studio, "Ultrasonic ranging module HC-SR04 datasheet," 03 11 2010. [Online]. Available: http://www.electroschematics. com/wp-content/uploads/2013/07/HC-SR04-datasheet-version-2.pdf. [Accessed 12 12 2016].

[12.] Sharp, "GP2Y0A21YK datasheet," 2005. [Online]. Available: http://www.sharpsma. com/webfm_send/1208. [Accessed 14 12 2016].

[13.] V. Gurevich, Electric Relays: Principles and Applications, CRC Press, 2005.

[14.] Arduino, "SPI library," Arduino, [Online]. Available: https://www.arduino.cc/en/ Reference/SPI. [Accessed 12 12 2016].

[15.] Wiznet, "W5500," Wiznet, 30 12 2014. [Online]. Available: http:// wizwiki.net/wiki/lib/exe/fetch. php?media=products:w5500:w5500_ ds_v106e_141230.pdf. [Accessed 12 12 2016].

[16.] Arduino, "Ethernet library," Arduino, [Online]. Available: https://www.arduino. cc/en/Reference/Ethernet. [Accessed 12 12 2016].

[17.] M. Margolis, Arduino Cookbook, Sebastopol: O'Reilly Media, 2012.

[18.] MathWorks, "ThingSpeak Channel
       Configurations," MathWorks, [Online].
       Available: https://www.mathworks.com/
       help/thingspeak/channel-settings.html.
       [Accessed 12 12 2016].

[19.] C. P. Lopez, MATLAB Graphical
       Programming, Madrid: Apress, 2014.

[20.] Athmel, "Athmel ATMEGA2560
       datasheet," 2014. [Online]. Available:
       http://www.atmel.com/images/
       atmel-2549-8-bit-avr-microcontroller-
       atmega640-1280-1281-2560-2561_
       datasheet.pdf. [Accessed 13 12 2016].

[21.] R. B. L. M. S. Richard P. Feynman,
       The Feynman Lectures on Physics,
       Massachusetts: Addison-Wesley, 1963.

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