Complex Design of Monitoring System for Small Animals by the Use of Micro PC and RFID Technology

Zoltán Balogh and Milan Turčáni

Abstract The paper describes a complex design of monitoring system handling created by the use of microcomputer Raspberry PI and LF RFID technology for the needs of monitoring and exploring the behavior of small terrestrial mammals and of selected species of birds. Similar systems already exist, but they are demanding and financially not affordable. To create such a system, low-cost products have been used which are easily modifiable, modular and expandable by measuring other activities. The paper concentrates on RFID/PIT technology. PIT tags are a useful tool to identify and follow individuals within a large population to monitor movement and behavior. Tags transmit a unique identifying number that can be read at a short distance that depends on the tag size and antenna design. Passive RFID tags are inductively charged by the reader and do not have a battery. Tags can remain operational for decades.

Keywords Raspberry Pi · Monitoring station · RFID technology · PIT tags · Web application

1 Introduction

The paper deals with the possibility of monitoring animals. While monitoring animals, it is necessary to do a few compromises considering the size of the animals, the price and number of individuals. The ideal transmitter should be light so that the animal can wear it safely. It should be adequately cheap so it can be possible to use it for other individuals. It should be also energy efficient so that the animal does not have wear a battery. It should be able to send the location with

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great accurateness. As an example of methods which are currently supported by a great database about the animal movement, there is MoveBank [1]. Those are for example GPS (Global Positioning System), Argos Doppler system, VHF (Very High Frequency), ringing or tagging, GLS (Global Locating System) and of course RFID (Radio-frequency identification)/PIT (Passive Integrated Transponder) chips.

In the last thirty years, a great number of biological traits of animals have been explored due to PIT tags. It enabled animal growth rates assessment, movement patterns, and survivorship for many species by injecting the markers right into the animals. It was possible in a more reliable approach of external identification marking of animals. The devices have been also used for confirming the animal identity of the zoo, animal identity of pets or protected species illegally carried away from their natural habitat. New approaches bring progress in physiology and conservation biology and encourage greater understanding of social interactions in a population. The devices have their restrictions such as high purchase cost, low detection distance, or potential tag loss. Nevertheless, PIT tags reveal all mysteries of animals which could not have been named effectively [2].

Hedgepeth [3] pointed out that RFID is a wireless data collection technology that uses electronic tags the size of a grain of rice, for allowing an automatic trace and track of individual goods throughout the logistics network. Some researchers even expect that applications of RFID technology will become widespread as a means of tracking and identifying all kinds of animals [4]. So, by its fast, reliable, multi-readable, and non-line-of-sight capabilities [5], the dynamic animal information, like medical records and location, can be monitored and hence used to facilitate diagnosis and animals' behavior patterning.

Boarman et al. [6] used automated reader to demonstrate that the endangered species of desert tortoise (*Gopherus agassizii*) migrated through the sluices built under the highways.

The use of RFID technology in animal monitoring is one of the established methods in many countries in the world. RFID technology is used when monitoring domesticated, wild and farm animals. In the United States, USDA (U.S. Department of Agriculture) monitors deer and elk with RFID chips in order to find out how these animals react to CWD (chronic wasting disease), a severe neurological disorder [7].

By technology improvement, PIT chips are getting more appealing for researchers who want to observe individuals in long-term. In 2014 one chip costs a few cents and the price of the readers is about 700–2000€ and more. It is considered to be expensive but it is still cheaper than telemetry equipment. Automatic scanning is really time efficient in comparison to ringing and tagging. The problem is that if two animals tagged with PIT chip get closer to the reader in the same moment, the reader will be not able to read the chips. This is not a problem in satellite telemetry. Telemetry functions on greater distance while PIT readers are able to scan to a distance of about 100 cm.

In the majority of European countries for tagging animals with PIT chips, certain standards are fulfilled in order to keep compatibility of the chips and scanners. These ISO standards have great international recognition including Europe and

Canada. The International Organisation of Standardization assumes responsibility for the two standards ISO 11784 and ISO 11785. For the needs of international norms, they contain a code of three digits which indicates the country, the producer and also the serial number of the chip.

The paper deals with description, design and creation of monitoring device for automatic animal scanning by the use of microcomputer Raspberry Pi and RFID technology.

2 Material and Methods

The aim of the research was to design a system which was able to automate data collection from spatial activity (for data measurements and collection microcomputer Raspberry Pi was used) and consequently create an application which is able to observe and record the activity of small animals. There was a presumption that the resulting system will be cheaper than the accessible monitoring stations and that the resulting system would have wider use than the usual RFID monitoring stations.

2.1 The Proposed Monitoring Stations

As the controller, micro PC Raspberry Pi was used and its model B. Raspberry provides wide possibilities of use which are proved by various scientific projects based on this micro PC. The Raspberry Pi is a credit card-sized single-board computer developed in the UK by the Raspberry Pi Foundation with the intention of promoting teaching of basic computer science in schools [8]. The Raspberry Pi is based on a system on a chip (SoC) called the Broadcom BCM2835. It contains an ARM1176JZF-S 700 MHz processor, VideoCore IV GPU. First it was conveyed with 256 MB of RAM, which was later upgraded (Model B and Model B+) to 512 MB. The system has Secure Digital (SD) or MicroSD (Model A+ and B+) plugs for boot media and permanent storage [9]. The Foundation provides Debian and Arch Linux ARM distributions for download. Tools are available for Python as the main programming language, with support for BBC BASIC (via the RISC OS image or the Brandy Basic clone for Linux), C, C++, Java, Perl and Ruby. At present, its price ranges around 30–35€. Raspberry Pi (Fig. 1) enables sensors connection through 8 GPIO (General Purpose Input/Output) pins as the other devices through USB, UART, I2C or SPI. Thanks to its size, price and connection possibilities of low-level peripherals, it was a good choice for monitoring system controller.

Monitoring station consists of a controller—micro PC Raspberry Pi, RFIDRW-E-232 reader, signalling bicolour LED, 1 kΩ resistor, WiFi adaptor

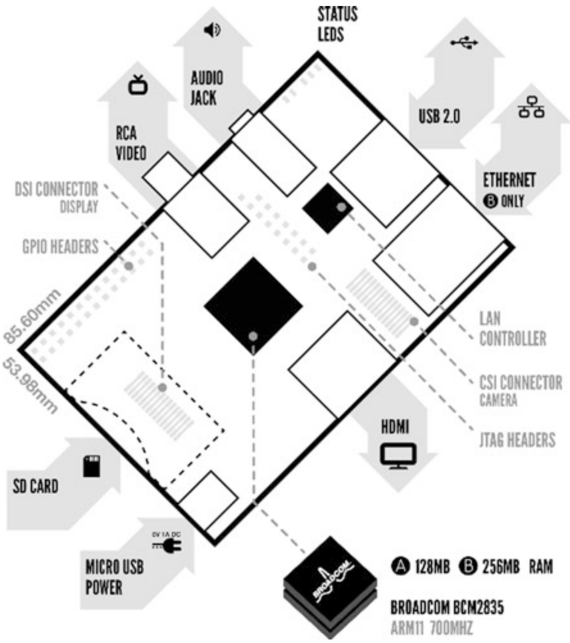

Fig. 1 The Raspberry Pi packs a lot of power into a credit-card size package [10]

(TL-WN725NV2), and a translator from TTL logic to RS232 logic (Fig. 2). The communication takes place by means of two UART pins:

– RXD—pin 10 on Raspberry Pi
– TXD—pin 7 on Raspberry Pi

UART pins and Raspberry Pi work on 3.3 V logic and RFIDRW-E-232 reader works on 5 V logic. Because of this difference, communication had to take place through translator from TTL (3.3 V) to RS232 (−25 to 25 V). Communication between RXD and TXD should have been crossed so the pin RXD on Raspberry Pi

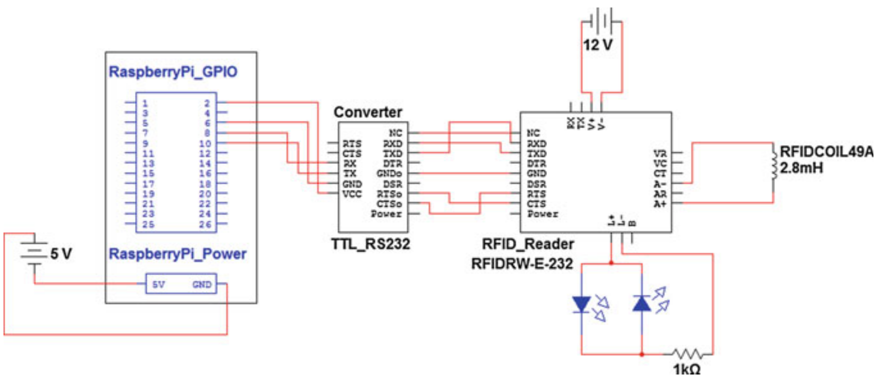

Fig. 2 Schematic diagram of the monitoring station—own design

would be linked with the pin TXD on the reader the pin TXD on Raspberry Pi would be linked to pin RXD on the reader.

The power supply on Raspberry Pi is 5 V and the recommended current is 1A. The converter needed power supply of 5 V which was consequently provided by raspberry Pi from pin number 2, was possible to link the ground to GPIO pin number 6 on Raspberry Pi. The reader needed power supply of 12 V and at least 38 mA. It was possible to link the reader to the bi-coloured LED diode which signalizes chip reading and writing. The diode was connected to pins L+ L−. It was also possible to link a buzzer on pin B.

The principles of communication RFID chip with RFID reader (RFIDRW-E reader) is generated magnetic field by an external antenna, usually on a frequency of 125 kHz or 134 kHz. Passive chips had integrated antenna which was tuned to the same frequency. When the chip was nearby to the magnetic field transmitted by the external antenna of the reader, the chip was able to draw enough energy from the electromagnetic field for the power supply of its own electronics. In the moment the chip was connected, it was able to modulate the magnetic field which was captured by the reader. This way it was possible for the chips to transfer data to the reader. Many types of chips exist which may work on various frequencies. By choosing the right antenna and capacity setting, can be the RFIDRW-E reader tuned to the same frequency as the scanned chip.

2.2 *The Proposed Monitoring System*

While monitoring, researchers dealing with exploring the behavior of small terrestrial mammals and of selected species of birds have to be “present in person” and manually record the behavior of these species. The designed monitoring system consists of two parts, a monitoring station and a server on which affordable micro PCs Raspberry PI were used with attachment and RFID reader.

The designed monitoring system (Fig. 3) consists of two parts, a monitoring station and a server on which affordable micro PCs Raspberry Pi was used. Monitoring station preserved transmitter scanning by a program created in Java and

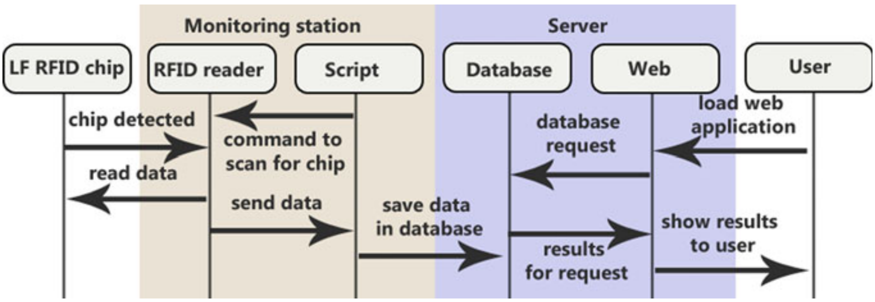

Fig. 3 Communication of monitoring system—own design

RFID chip reader and sending entries into relational database. The server provided WiFi net for all monitoring stations in the monitored zone on which they were connected. The server contained a web server where the web application was placed to access the entries in the relational database. The server contained a DHCP server in order not to set the IP address on each monitoring station separately. It also contained DNS server to simplify the access to web application. DNS server refers to public DNS server from Google for Internet access. Loaded entries were saved by monitoring stations into MySQL database established on servers.

Consequently, it would be possible to get to entries by accessing into WiFi net transmitted by the server. Web application would allow viewing the recordings saved in the database, their export or filtration.

3 Software for Monitoring System

Software for monitoring system contains two parts. The first preserved communication with RFID chip reader and loaded data entry into relational database. The second part was a web application which provided access to data saved in the database.

3.1 Software for Monitoring Stations

The main class that provided communication with RFID reader. Communication with the reader took place by the use of sending chains ended with special character (CR—cursor shift at the beginning of the line) through serial port. Communication through GPIO and serial port was provided by library *pi4j*. Communication through serial port was initiated by the line:

```
serial.open("/dev/ttyAMA0", 9600);
```

Serial port was placed on the path/dev/ttyAMA0 and the number 9600 was given by baudrate (speed of communication).

After opening the serial port, the application tried to establish a connection with the database which was placed on the server. If there is no connection, the application will wait 10 s and will try to establish connection again until it is active. Consequently, a listener was added to serial port in order to record the data which were sent back by RFID reader. The method dataReceived (SerialDataEvent event) provided processing of all data which came through serial port. Data accuracy was examined by checking its length because of possible errors while transfer. If the data are correct, chip identity and reader identity (which read the PIT chip) will be saved into database. While saving data into database, actual time of saving was also added to the record. The method run provided regular querying on RFID reader whether there was a RFID chip around. Any errors while program running were written into log file logy.log. The class Trap provided creation of log file and launch of RFID reader class. While launching, Trap waited 15 s in order to prevent unsuccessful experiments of database connection and to have enough time to launch the database.

3.2 Software for Server

The software for server is a web application which enabled access to data. It was possible to browse data, and export them into format CSV and XML. It was possible to export data according to a given date or according to the given last *x* records. It was also possible to process exported data in any program which supports data import in given formats. Web application also enabled to filtrate the shown results according to date, monitoring station identifier and chip identifier, and to show in what period the chip was found around the monitoring station.

`ConnectionFactory` is what took care of signing-on with the database. Every constant used by the application was saved in the `WebConstants` class, which enabled simple change of main program settings. Communication with the database was enabled by `DataBean`. This class provided data retrieval for each part of the web application.

Web application contained also data display according to holding near the monitoring station. This function displayed data in an extent in which the chip was present near the monitoring station.

4 Result and Discussion

The system took place in laboratory conditions. For testing, the PIT microchip was put into two mice (Mus musculus) which were placed into a big aquarium. Monitoring system consisted of a server and a monitoring station. The created sensor was represented by a plastic tube (Fig. 4) which was opened on one side.

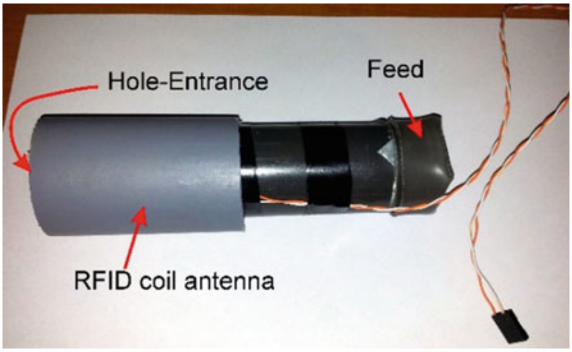

Fig. 4 System with the RFID coil antenna—own design

Here was a RFID coil antenna to load RFID/PIT chips. On the other side of the trap, there was feed for mice.

Testing and verification of the system lasted during 7 days of continuous system operation which was connected through electrical system. Microchips were put into two mice which moved freely around the aquarium. In this testing, 35,744 records have been captured into relational database and the system has shown to be reliable. The system was set so that it could record with the highest frequency of record which represented every 100 ms. The aim was to test system functionality and to obtain the most data. In some cases, when the mouse was under RFID coil antenna, the system scanned it 3× in 1 s. By the use of obtained data, it was necessary to find out system validity according to various statistical methods [11], in order to reduce the frequency of RFID/PIT chip inscription so that no important data would be lost. This way, a lot of energy has been saved which was the assumption for autonomous operation of the monitoring station. The next was testing power monitoring station with a battery of 9800 mAh. The battery powered Raspberry Pi (5 V) and the reader of RFID microchip (12 V), TTL on RS232 converter was consequently powered by Raspberry Pi. In these conditions of consumption ∼800 mA, the battery had stamina of 8 h. In the future there is an assumption of lowering the consumption of monitoring system and testing solar power in combination with high capacity batteries so that the system could work autonomously. To optimize such a system would be possible by various modelling techniques and consequential simulations which would be used in the future [12, 13].

5 Conclusion

The research aim was to design and create a complex autonomous monitoring system which would monitor record and evaluate results of spatial activity. There are assumptions that the resultant system would be cheaper and application-flexible than the accessible monitoring systems. The resultant monitoring system would be spread by other possibilities in order to obtain as much information about spatial activities of terrestrial mammals and of selected species of birds. On the basis of created system there would be space to spread our research task in the field of ecology and other fields such as ambient intelligence [14].

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