Proposal for Spatial Monitoring Activities Using the Raspberry Pi and LF RFID Technology

Zoltán Balogh, Richard Bízik, Milan Turčáni and Štefan Koprda

Abstract The paper describes a new way of activity monitoring of small rodents by the use of Raspberry PI and RFID. The created system deals with complex monitoring, record and acquisition of new entries from spatial activity. Raspberry PI is a full-valued micro-PC with an operating system based on Linux which communicates and controls RFID reader working at the frequency of 125 and 134 kHz. It is needed to read LF RFID chips. Monitoring station preserves transmitter scanning by a programme created in Java and RFID chip reader and sending entries into relational database. The created database is on the central Raspberry PI to which other Raspberry PI monitoring stations have access through WiFi net or LAN net. It is possible to access the central PC by a remote management. The created system is variable, compact and offers wide possibilities of spread, and the last but not least, the system is a cheap alternative of the already existing systems.

Keywords Raspberry Pi · Spatial activity · Monitoring · RFID · Remote management

Z. Balogh (✉) · R. Bízik · M. Turčáni · Š. Koprda
Department of Informatics, Faculty of Natural Sciences, Constantine the Philosopher University in Nitra, Tr. A. Hlinku 1, 94974 Nitra, Slovakia
e-mail: zbalogh@ukf.sk

R. Bízik
e-mail: richard.bizik@student.ukf.sk

M. Turčáni
e-mail: mturcani@ukf.sk

Š. Koprda
e-mail: skoprda@ukf.sk

Q.-A. Zeng (ed.), *Wireless Communications, Networking and Applications*,
Lecture Notes in Electrical Engineering 348,
DOI 10.1007/978-81-322-2580-5_58

1 Introduction

Monitoring the physical activity of the animals helps to understand how individuals and populations behave within one area. From the twentieth century, communicational systems have been improved, batteries have been made smaller and new technologies have been developed. This led to significant improvement of animal physical activity monitoring. From the year 1900, scientists could systematically observe movements and migration of birds when they started with to ring birds. In 1950, researchers started to use radio transmitters. In 1970, a satellite system called Argos provided new method of global animal monitoring. In 1990, GPS system has spread and offered a new method of monitoring with great accurateness.

Before monitoring the 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 in order 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 great accurateness.

Examples of methods which are currently supported by a great database about the animal movement are MoveBank [1], GPS, Argos Doppler system, very high frequency (VHF), ringing or tagging, GLS and of course LF RFID/PIT chips.

Many household pets today have a radio frequency identification chip implanted by their owners. These devices operate as a passive device in the low-frequency range, because they are passive, and the power received back is very small and utilizes inductive coupling to power them. The distance at which these devices can be read effectively is very small because they are operating in low-frequency range and require inductive coupling. By increasing the range, these radio frequency identification devices can be effectively read, and it will open up many types of automated applications to work with existing technology implanted in animals [2].

Radio frequency identification (RFID) is a way of identifying an item or animal from a distance using electromagnetic waves. This paper explores one such application that will allow an application to utilize the existing household pet passive low-frequency RFID microchip that veterinarians implant today. Critical to the implementation of the passive low-frequency RFID technology is the distance at which such a device can be activated and deciphered.

Today, RFIDs are used across our society in fields such as agriculture, research, security, operations and personal use by consumers. Similar to how agriculture management of livestock was used in both controlling medication and hormone doses via RFID animal identification numbers (AIN), researchers frequently use RFID AINs to track wild animals for migration patterns. The unique AIN can provide correct tracking of the research data to a particular animal [3].

While monitoring, researchers dealing with exploring the behaviour of small terrestrial mammals and of selected species of birds have to be “present in person” and manually record the behaviour of these species. Therefore, the paper engages in creating an autonomous monitoring system which monitors, records and evaluates the results of spatial activity of the animals. 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.

2 Research and System Description

While monitoring, researchers dealing with exploring the behaviour of small terrestrial mammals and of selected species of birds have to be "present in person" and manually record the behaviour of these species. The research task is to create an autonomous monitoring system which monitors, records and evaluates the results of spatial activity of the animals.

Therefore, the research question is as follows:

- to design a system which can automate data collection from spatial activity, for data collection measurements, micro-PC Raspberry Pi will be used, and
- to create an application which is able to observe and record the activity of rodents.
- Hypothesis 1: A presumption that the resulting system will be cheaper and application-flexible than the accessible monitoring stations.
- Hypothesis 2: A presumption that the resulting system will have wider use than the usual RFID monitoring stations.

To create a monitoring station, micro-PC Raspberry Pi with RFID reader has been used which is able to identify LF RFID chips.

2.1 Microcomputer Raspberry Pi

The Raspberry Pi is a low-cost single-board computer which has recently become very popular and is controlled by a modified version of Debian Linux optimized for the ARM architecture. The display contains a graphical user interface providing various fields for data entry via an onscreen keyboard. Various fields were provided to display data obtained from a remote host as well [4].

The 32-bit microcontroller has been used in the proposed system. The installation of OS to the microcontroller has become pretty simple and the code size was reduced to about 40–50 %. The enhanced features for increasingly complex algorithm were supported in this system and due to the device aggregation, the cost was also reduced. In this system, the additional features of external connectivity such as Ethernet, USB, CAN, HDMI and code reuse were possible. This system includes efficient real-time operations such as in medical, military applications or other, and it also performs multitasking operations. Availability of tools such as Midori, Python scratch, Python Ideal and LXT terminal is also supported in this system [5] (Fig. 1).

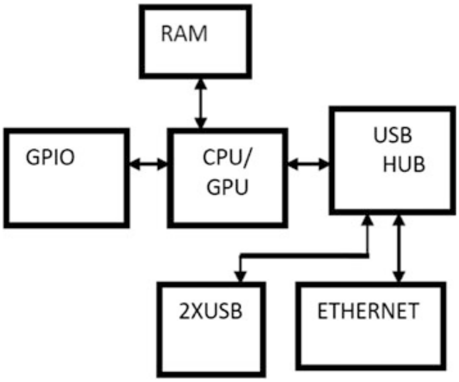

Fig. 1 Block diagram of Model B Raspberry Pi [5]

General Purpose Input/Output (GPIO) is a broadly applicable pin on a chip. At run-time, the behaviour of the pin can be controlled by the user. GPIO pins can be configured to be input or output and they can be also enabled or disabled. Input values are only readable but the output values are readable and writable at the same time [5].

Raspberry Pi (Fig. 2) is a credit-card-sized single-board computer which was developed in the UK by Raspberry Pi foundation in order to stimulate teaching of basic computer science in schools. It has two models: Model A and Model B. Model A has 256 Mb RAM, one USB port and no network connection, while Model B has 512 Mb RAM, 2 USB ports and an Ethernet port. Then it has a Broadcom BCM2835 system on a chip which includes an ARM1176JZF-S 700 MHz processor, Video Core IV GPU and an SD card. The GPU uses H.264 at 40 MBits/s and is capable of Blu-ray quality playback. It has a fast 3D core accessed using the supplied OpenGL ES2.0 and OpenVG libraries. The chip specifically provides HDMI and there is no VGA support. The foundation provides

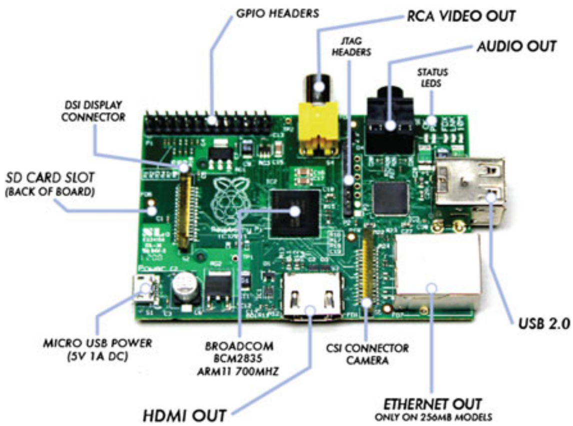

Fig. 2 Raspberry Pi Model B

Debian and Arch Linux ARM distributions and also Python as the main programming language, supporting BBC BASIC, C, and Perl.

Currently, the Raspberry Pi is not a open-source hardware, but the project has openly published schematics and many components of the required device drivers. The Raspberry Pi uses the first ARM-based multimedia system-on-a-chip (SoC) with fully functional, vendor-provided, fully open-source drivers, although some code that runs on the GPU remains closed-source which emphasizes an increasing trend towards open-source hardware as well as software entering mainstream computing [6].

2.2 Uses of RFID

Today, RFIDs are used across our society in various kinds of fields as agriculture, research, security, operations and personal use by consumers. Similar to how agriculture management of livestock was used in both controlling medication and hormone doses via RFID AIN, researchers frequently use RFID AINs to track wild animals and their migration patterns. The unique AIN can provide correct tracking of the research data to a particular wild animal [7].

RFIDs have a wide variety of uses as well as a wide range of operating frequencies. Table 1 shows a list of the types of RFIDs on the market today.

Low-frequency (LF) RFID devices operate in the kilohertz range, and this lower range has the slowest read rate and smallest read distance. However, LF RFID's energy does not get absorbed by water. Because of this reason, LF RFIDs are the only type of RFIDs used as animal implants [3, 7].

LF Passive RIFD operates in either 125 or 134.2 kHz. According to the USDA in 2007, in the United States, 5 % of all household pets had been implanted with a LF RFID microchip. From the implanted ones, a 125 kHz LF RFID was used [8]. According to official RFID devices listed by USDA today, it is a trend to use a passive LF RFIDs operating at 134.2 kHz. LF RFID microchip serves as a lifelong identifier for animal tagging, and suppose that it can be scanned, it can be as reliable as a finger print [9] (Fig. 3).

LF RFID microchips are inactive until they are activated, and hence they do not need internal power supply. If the microchip LF RFID is needed to be activated, it is enough, if it gets into an electromagnetic field which is radiated by the reader.

3 Design and Monitoring Solution

The designed monitoring system consists of two parts, a monitoring station and a server on which affordable micro-PCs Raspberry Pi was used. Monitoring station preserves transmitter scanning by a programme created in Java and RFID chip

Table 1 Types of RFID technology

RFID type	Frequency range	Typical market	Pros	Cons
Active	Microwave and UHF	All listed for UHF and microwave	Greater distance (20–100 M), can hold additional information	Requires power, typical battery life is 10 years, devices are larger than the size of a coin
Passive	All above	All listed	Requires no maintenance, inexpensive, small in size	Limited distance (up to 10 M), only holds unique ID
Microwave	2.45 GHz	Toll collection, airline luggage	Fastest read rates, good read distance,	Very expensive, most energy is absorbed by water
UHF	868–956 MHz	Logistics, supply chain, livestock	Good read distance, faster read rate	FCC restrictions apply, energy is absorbed by water
HF	13.56 MHz	Warehouse inventory, livestock	Good read distance, inexpensive, fast read rate	Devices are external tags to avoid high water content absorbing energy
LF	125 and 134.2 kHz	Animal identification	Very small devices can be implanted	Limited read distance, possible up to about 0.5 m, slow read rate

Fig. 3 LF RFID microchips

reader and sending entries into relational database. The server provides WiFi net for all monitoring stations in the monitored zone on which they are connected (Fig. 4).

The server contains a web server where the web application is placed to access the entries in the relational database. The server contains a DHCP server in order to not set the IP address on each monitoring station separately. It also contains DNS server to simplify the access to web application. DNS server refers to public DNS server from Google for Internet access. Loaded entries are saved by monitoring stations into MySQL database established on servers (Fig. 5).

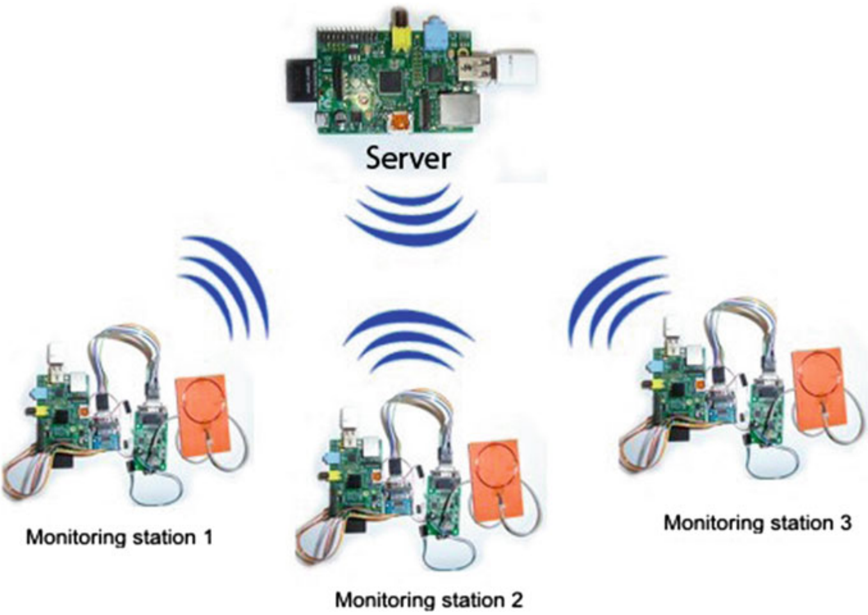

Fig. 4 Monitoring system

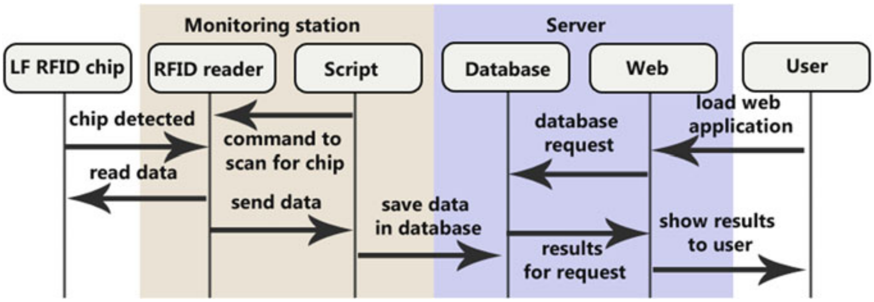

Fig. 5 Communication of monitoring system (own design)

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

3.1 Monitoring Station

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

(TL-WN725NV2), and a translator from TTL logic to RS232 logic. 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 would be linked with the pin TXD on the reader and 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 1 A. The converter needed power supply of 5 V that was consequently provided by raspberry Pi from pin number 2, which 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 reader handled a possibility of setting the antenna frequency by capacitor. The resonant frequency of a tuned circuit can be found using the following formula:

$$f_0 = \frac{1}{2 * \pi * \sqrt{L_R * C_R}}$$

$$C_R = C_E + C_{Ri}$$

where

f_0 = operating frequency
L_R = inductance of the antenna
C_R = value of the tuning capacitor

As an example, use of RFIDCOIL-49A antenna at the frequency of 134 kHz can be mentioned.

The reader supported the antenna RFIDCOIL-49A at the frequency of 134 kHz without any additional capacitor. It was the task of the capacitor and the resistance in the reader to set frequency.

RFIDRW-E reader generated magnetic field by an external antenna, usually at a frequency of 125 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, and it was able to modulate the magnetic field which was captured by the reader. In 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, the RFIDRW-E reader can be tuned to the same frequency as the scanned chip (Fig. 6).

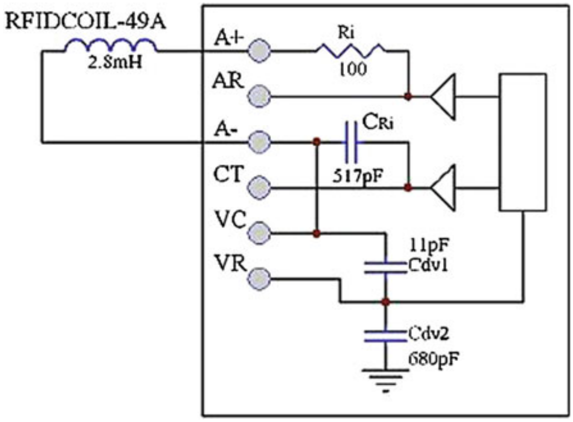

Fig. 6 134 kHz reader with RFIDCOIL-49A

4 Discussion and Results

The system took place in laboratory conditions. For testing, the LF RFID microchip was put into two mice[1] which were placed into a big aquarium. Monitoring system consisted of a server and a monitoring station. Monitoring system was represented by a plastic tube which was opened on one side. Here, an antenna was used to load RFID chips. On the other side of the trap, there was feed for mice. Monitoring system was placed on the aquarium. Monitoring station was connected with the trap with a 2-m-long cable. While testing both, the monitoring station and the server were connected from the electrical system. The testing lasted seven days and no error or failure has occurred. In this testing, 35744 records have been captured into relational database and the system has shown to be reliable. ID LF RFID of microchip, time and ID of monitoring station have been recorded into database. As a further work, it is planned to schedule a web application and automated entry sending from monitoring stations. The server would provide WiFi net for all monitoring stations in the monitored zone on which they would be connected. The server would contain a web server where the web application would be placed to access the entries in the relational database. The server would contain a DHCP server in order not to set the IP address on each monitoring station separately.

[1]All animals on which we experimented were mice. All animal work has been conducted in accordance with animal ethical care. None of the animals have been hurted or harmed during the experiment.

The Ministry of Environment of Slovak Republic, Department of State Administration has allowed the exception from the prohibitions enacted in the laws of Slovak National Council number 543/2002 statute about nature, and landscape protection has consented the research (15th August 2012 in Bratislava), under number 5451/2012-2.2 based on the application of Constantine the Philosopher University in Nitra, Faculty of Natural Sciences, 1 Trieda Andreja Hlinku, 949 74 Nitra from 21st June 2012.

It would also contain DNS server to simplify the access to web application. DNS server would refer to public DNS server from Google for Internet access. Loaded entries would be saved by monitoring stations into MySQL database established on servers. Consequently, it will 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, and their export or filtration. Power supplies from alternative sources are scheduled, such as solar power in combination with high capacity batteries so that the system could work in field conditions where there is no electrical voltage.

5 Conclusion

The designed complex monitoring system was created for needs of monitoring and exploring the behaviour of small terrestrial mammals and of selected species of birds. Similar systems already exist but they are demanding and financially not affordable. Thanks to low-cost products such as micro-PC Raspberry Pi with compatible RFID reader, a complex and easily modifiable system was created which would monitor small terrestrial mammals and selected species of birds with LF RFID chip. The presumptions have affirmed that the resulting system would be cheaper and application-flexible than accessible monitoring stations. Other presumptions were that the system would have wider use than the usual RFID monitoring stations. This means that the monitoring systems could be expanded by cameras, sensors recording temperature, dampness and other physical quantities. The acquired results would be analysed by various statistical methods and optimal results for monitoring would be searched for [10, 11]. By the use of data from various model situations [12–14], it would be possible to define the effectiveness and reliability of the system.

References

1. MoveBank: movebank.org. https://www.movebank.org/node/857 (2013). Accessed 11 Oct 2014
2. Imfeld, W.J.: Low Frequency Radio Frequency Identification Antenna Design. California State University, California State University, Sacramento (2011)
3. Mun, L.N., Kin, S., Hall, D.M., Cole, P.H.: A small passive UHF RFID tag for livestock identification. In: MAPE2005: IEEE 2005 International Symposium on Microwave, Antenna, Propagation and EMC Technologies for Wireless Communications, Proceedings, pp. 67–70 (2005)
4. Sundaram, G.S., Patibandala, B., Santhanam, H., Gaddam, S., Alla, V.K., Prakash, G.R., Chandracha, S.C.V., Boppana, S., Conrad, J.M.: Bluetooth communication using a touchscreen interface with the raspberry Pi. In: Conference Proceedings—IEEE Southeastcon (2013)

5. Chitra, M.P., Shanker, N.R., Preethi, B., Sanu Murugan, M., Soundarya, M.: Kernel level hardware based single chip computer and device control. J. Theor. Appl. Inf. Technol. **52**(3), 316–324 (2013)
6. Bradbury, A.: Open source ARM userland. http://www.raspberrypi.org/open-source-arm-userspace/ (2014). Accessed 7 Nov 2014
7. Violino, B.: The Basics of RFID Technology. http://www.rfidjournal.com/article/view/1337/2 (2014). Accessed 20 Nov 2014
8. Nolen, R.S.: USDA: no authority to regulate pet microchips. http://www.microchipidsystems.com/UserFiles/File/http%20%20%20www.avma.org%20onlnews%20javma%20oct07%20071015c.pdf (2007). Accessed 20 Nov 2014
9. Gibbons, J.W., Andrews, K.M.: PIT tagging: Simple technology at its best. Bioscience **54**(5), 447–454 (2004)
10. Munk, M., Drlík, M., Kapusta, J., Munková, D.: Methodology design for data preparation in the process of discovering patterns of web users behaviour. Appl. Math. Inf. Sci. **7**(1 L), 27–36 (2013)
11. Balogh, Z., Munk, M., Turčáni, M.: Assessment tools and techniques for e-learning evaluation: usage analysis and survey sampling. In: Proceedings of 2013 Science and Information Conference, pp. 38–44. SAI 2013 (2013)
12. Štencl, M., Štastný, J.: Neural network learning algorithms comparison on numerical prediction of real data. In: Mendel, pp. 280–285 (2010)
13. Nemec, R., Hubalovsky, S.: Development of system SMPSL for analog communication. Appl. Mech. Mater. 475–476 (2014)
14. Koprda, Š., Balogh, Z., Turčáni, M.: The influence of control methods in technological process to save electrical energy. In: SISY 2013—IEEE 11th International Symposium on Intelligent Systems and Informatics, Proceedings, pp. 77–82 (2013)