GPS Data Conversion and Analysis for Tapping Animal Movement

Eltimir Stoimenov[1], Tsvetan Shoshkov[2], Rosen Miletiev[3], Ivailo Pandiev[4]

[1]Eltimir Stoimenov is with the Faculty of Electronics at Technical University of Sofia, 8 Kl. Ohridski Blvd, Sofia 1000, Bulgaria
e_stoimenov@tu-sofia.bg

[2]Tsvetan Shoshkov is with the Faculty of Electronics at Technical University of Sofia, 8 Kl. Ohridski Blvd, Sofia 1000, Bulgaria
tsh@tu-sofia.bg

[3]Rosen Miletiev is with the Faculty of Telecommunications at Technical University of Sofia, 8 Kl. Ohridski Blvd, Sofia 1000 Bulgaria
miletiev@tu-sofia.bg

[4]Ivailo Pandiev is with the Faculty of Electronics at Technical University of Sofia, 8 Kl. Ohridski Blvd, Sofia 1000, Bulgaria
ipandiev@tu-sofia.bg

ABSTRACT: *We have used tracking tags to tap the wild animals. The proposed device uses ultra-low power, a minor form of the GPS receiver that helps the correct object identification. Besides, we have used the auxiliary motion sensors with a gyro accelerometer for data recording. The RT transceiver has used the GPS data with the ISM band to convert the base station data. The base station converts the GPS data with networks to the servers located in the central repository.*

In this work, we have used the software called tracking manager to visualise the tracking data. The results are synthesised for optimum inferences.

Keywords: Wild tracking, GPS, Wireless microcontrollers, GSM/GPRS, Google maps, Nine-axis MEMS

Received: 10 October 2022, Revised 22 December 2022, Accepted 31 December 2022

DOI: 10.6025/jio/2023/13/1/22-28

1. Introduction

Wild tracking is from great importance for gain understanding about the way of life of different animals. The tracking could be performed by indirect signs left by the animal as result of its life activities. This signs include tracks, signs, and trails, also known as spoor [1]. One of the first recorded attempts for wild animal tracking was performed in the fall of 1803 by J. Audubon. He studied the migration of the birds and their ability to return to the same place each year. Audubon tied a string around the leg of a bird before it flew south. The following spring, Audubon discovered that the bird had come back [2].

In the late 1950 and early 1960 the telemetry tracking methods become available [3]. These methods allow tracking of the object in real time by means of VHF transmitting devices attached to the animal. By using appropriate receiver and antenna the location of the animal under study could be determined. This approach is a breakthrough in the wild tracking, but when it's used more intensively or for monitoring of widely roaming animals, the method proved to be expensive, timeconsuming, and often poses risks to personnel safety [3].

In the late 1970 the satellite based tracking technologies open a new opportunities in understanding of the wild animal long range migrations [4]. Firstly the launch of the Nimbus 3 satellite and, later, the ARGOS system, it became possible to automatically collect and transmit location data from widely roaming or migrating animals (e.g., polar bear and caribou) using satellite communication technology [3]. The ARGOS system relies on receiving the RF signal emitted by a beacon to a low-level orbiting satellite. The accuracy of ARGOS is dependent upon the number of times a signal is received from a transmitter, while a single satellite is 'visible'. The accuracy of the object positioning is determined by the intensity of the transmission. ARGOS classifies positional fixes into three 'usable' classes according to accuracy:

(1) 350–1000 m;

(2) 150–350 m;

(3) <150 m [5].

The main disadvantages of the Argos tracking method is the increased weight and cost and in some particular cases the poor spatial resolution [6].

Later, the deployment of the NAVSTAR (Navigation Geographic Positioning System - GPS), and GLONASS (Global navigation satellite systems) declared fully operational in 1995 and 2011, respectively, enabled development of animal tracking systems with unprecedented positional accuracy (+/- 5m). The biggest advantage of the GPS-based tracking systems is the very fine spatial resolution. On the other hand GPS systems need direct sky view for proper operation which makes them inappropriate in some cross country terrains. In addition the cost and the power consumption (especially in acquisition mode of operation) of these systems are still relatively high.

Some more avant-garde tracking devices incorporate video camera which allows a real time surveillance of the animal (video tracking systems). At a weight of only 14 g, the smallest units to date are suitable for a wide range of birds, mammals and reptiles [7]. The device is attached to a suitable place on the animal's body so its movement could be captured by the camera. The video-transmission time of integrated videotags for birds is currently in the order of hours, which might be considered as the main disadvantage. Nevertheless the operation time will probably increase in the nearby future with the advancement of the technologies.

Somewhat a new class of short range tracking systems emerged in the recent years. These systems use a VHF tag attached to the tracked animal. The transmitted signal is then received by time synchronized receiver stations and by measuring the time difference of signal arrival (TDOA) the coordinates of the tag could be obtained. As the device is constituted by a simple, low power transmitter the cost per node could be very low. Also the operation time will be greatly increased compared to the methods described above [6]. Unfortunately the need of receiving stations makes the system operation only in a limited range.

The electronic system presented in this paper is intended for tracking of carnivorous mammals from the family of the Mustelidae (from Latin mustela, weasel). The size and weight of the animals from this family could vary largely - from about the size and weight of a mouse to more than 2 m in length and 40 kg in weight [8]. This kind of animals is territorial and could travel more than 10 km per day in search of food [9]. The goal of this research is to develop system capable of tracking the smallest species of Mustelidae. A typical example for such an animal is the weasels. The weasels are specialized in hunting small rodents, birds and their eggs. The weasel's small size (males 194-217mm; females 173-183mm) and weight (males: 106-131 g, females: 55-69 g) enables it to search through tunnels and runways of mice and voles. Weasels can hunt at any time of the day or year. They do not hibernate and can hunt even under deep snow. The lifespan of the weasels is quite limited and only around 10% survive to over 2 years old [10].

2. Block Diagram

The technical specification of the designed electronic system for wild tracking is mainly defined by the specifics of the animal under tracking.

Weight and size. As it is known, the typical maximum allowable tracking device to body weight ratio is 5%, with lower being preferable [6]. If we suppose that the animal weight is about 120 g (for the male species) the device weight should not exceed 6 g.

If we assume that the device is attached to the animal's neck (belt like design) and considering the size of the animal the form factor of the device should be ring with radius off about 1,5 cm.

Operating range and lifetime. The operating range of the device should not be less than the maximum hunting area of the object - 10 km. Having in mind the short lifespan of the animals the lifetime of the system should be not less than one year.

Operating conditions. The device should be able to operate in harsh conditions like rapid change in temperature and humidity, very low temperatures, it should be waterproof and rugged.

Sketch describing the principle of operation of the system is shown on Fig. 1. The system could be divided in two major parts. The first part is the tracking devices (tags) attached to the wild animals, marked with the large white points on Fig. 1. These devices transmit the animal location data to nearby retranslating stations, marked with large black points. The stations, which are the second major part of the system, are equipped with GSM/GPRS transceiver. After the data from the tags has been received the stations transfer it through the GSM/GPRS link to the personal computer (PC) with Internet connection located in a research laboratory.

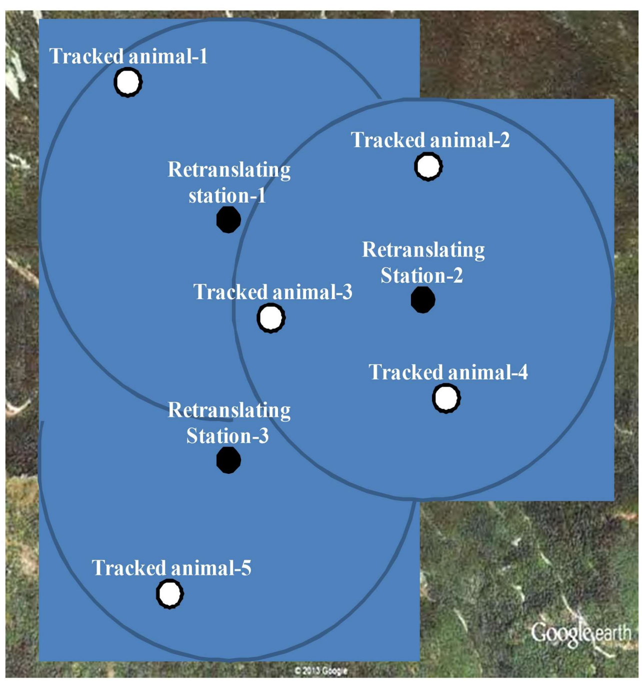

Figure 1. Sketch of the designed wild animal tracking system

2.1. Tracking device block diagram

The block diagram of the tracking device is shown on Figure 2. We choose to determine the position of the tracked animal by using a GPS module as shown on the figure. In order to find the best module for our needs we compared many commercially available modules from different semiconductor manufacturers. Our research shows that UC530M (from UBlox Inc.) GPS module is the most appropriate for our design needs. The module is equipped with embedded chip antenna which reduces the module size and weight. Moreover the power consumption of UC530M is one of the smallest compared with its counterparts which could extend the lifetime of the tag.

The data from the GPS module is transferred through a UART interface to a low power wireless microcontroller. In our design we decided to use a Silabs microcontroller of the 1000 series from Silabs Inc. These microcontrollers have integrated RF transceiver and temperature sensor which reduces the number of external active and passive components. Moreover the output power of the integrated transceiver could vary from +1 dBm (1,25 mW) to maximum +20 dBm (100 mW), which extends the operation range of the device. The RF transceiver operates in the open industrial, scientific and medical (ISM) radio band within frequency range from 902 MHz to 928 MHz with center frequency equal to 915 MHz.

An additional motion sensor MPU-9150 (from Invensense Inc.) which accompanies the GPS module is also incorporated in the block diagram. This device combines a 3-axis gyroscope, 3-axis accelerometer and 3-axis compass in the same chip together with an onboard Digital Motion Processor (DMP) capable of processing the complex 9-axis algorithms [11]. MPU-9150 should serve as a temporary localization device when the GPS module cannot provide location data.

This scenario is possible when there is no clear view to the sky or the battery power is not sufficient for the GPS module proper operation.

When is necessary, the microcontroller could store some amount of GPS data into the logging memory. This will allow some reduction in the power consumption as the data transmission to the base stations will be rarer.

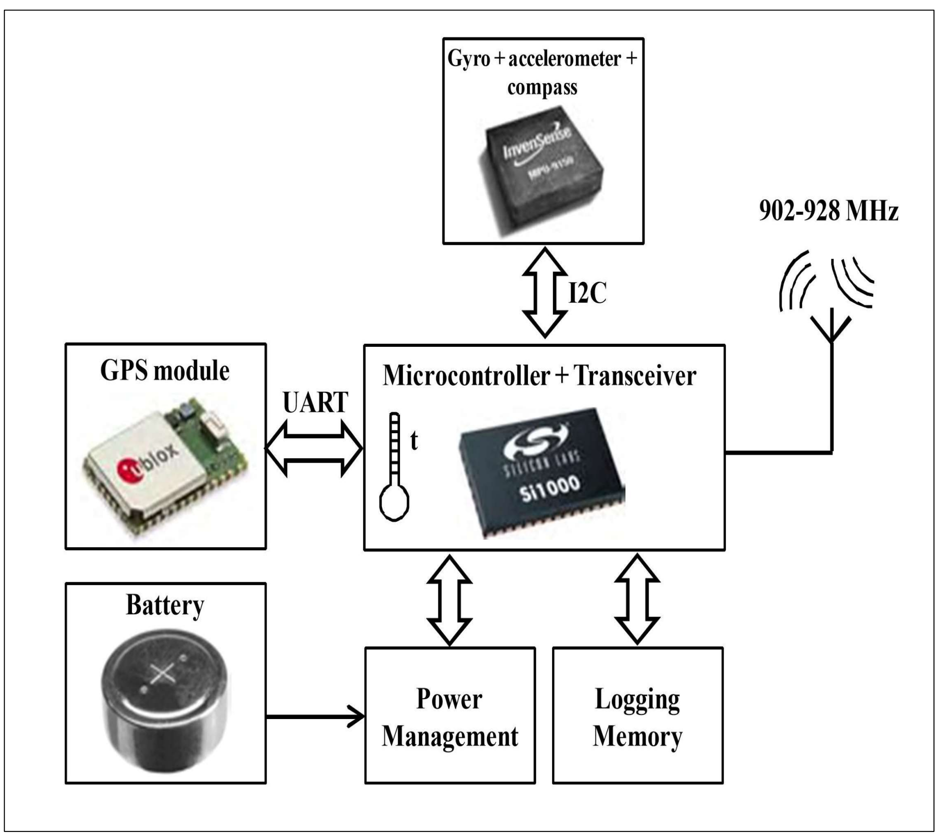

Figure 2. Block diagram of retranslating base station

The power supply of the device is planned to be provided by the battery and the power management block. The choice of the specific battery type depends on various criteria like nominal voltage, capacity, power density, size, maximum discharge current, temperature range and etc. For example the Li-ion batteries seems to be the most advantageous, but more research should be conducted. If necessary, two or more batteries could be connected in parallel or series. The power management block should be able to provide all the necessary supply voltages for the circuitry with maximum efficiency.

After all the components from the block diagram are chosen we can estimate the functional parameters of the tag and compare it with the initially defined values.

The weight of the device is mainly defined by the weight of the GPS module, the battery, the PCB substrate and the casing. We can reduce the weight of the tag if we use flexible PCB. As the substrate material used by these PCBs is polyester or polyimide (Kapton) with very small thickness we can consider their weight negligible [12]. In order to reduce the weight even more, we plan to realize the casing by using conformal coating over the PCB with appropriate material.

Despite all the actions taken for weight reduction our estimations show that the gross weight of the tag will be in the range of 10…15 g. This significantly exceed the initial requirement, but still makes the device appropriate for animals with weight larger than 300 g.

2.2. Retranslating base stations

After the GPS data from the object is obtained, the tag should transfer it for further analysis. Because of energy saving reasons the transmitting power of the tag is quite limited. This requires the usage of retranslating stations located as close to the tracking device as possible. The block diagram of such a station is shown on Figure 3.

The operation of the stations can be described as follows.Firstly the station must receive the GPS data collected by the animal tag. As the output power of the tag is very limited the station should be equipped with highly sensitive transceiver. The received data is accumulated in the external memory.

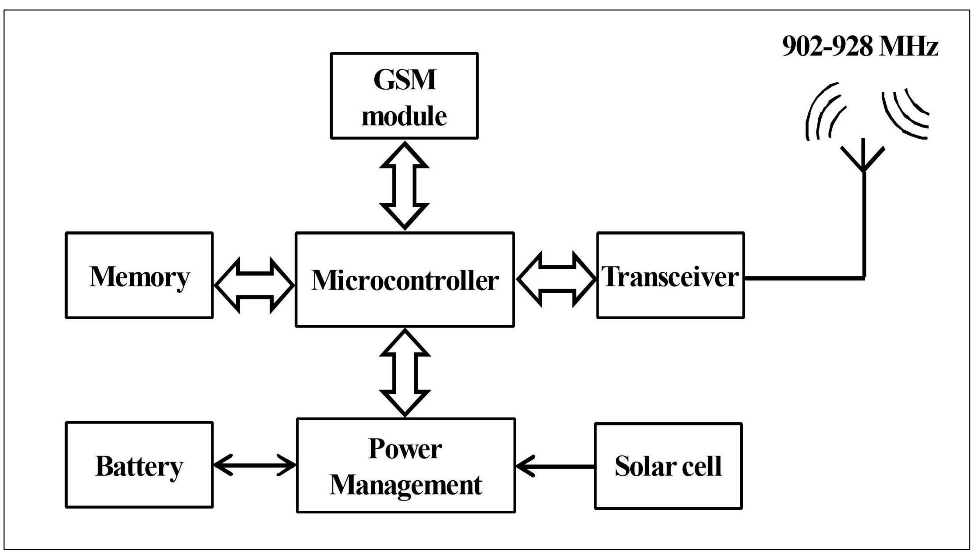

Figure 3. Block diagram of retranslating base station

When demanded the stored information could be transferred through the GSM/GPRS link to a PC. A specialize software application called “tracking manager” will assist to interpret the data and conduct the necessary analysis.

It is worth to say that the retranslation stations are planned to be attached to tall trees and camouflage as birdhouses. Unfortunately the access to the stations for maintenance will be catchy. In this order the power supply of the stations is provided by a high capacity battery so the operating time could be as long as possible. Moreover a solar cell is planned to recharge the battery so the life of the station could be extended even more.

3. Tracking Manager Application For Pc

In order to be processed, analyzed and observed the location tracking details it is developed an application that manages the tracking data.

Main functions of the tracking manager application are:

- Receiving location data from all tracked objects;

- Storing received data in database;

- Processing tracking data;

- Observation of tracking data in various modes.

For utilizing the managing application it is used a PC to receive, organize and visualize the data.

Data receiving is done through a RS232 (or USB) port from a GSM/GPRS receiver. Most important data in the received package contains locations with longitude and latitude.

Each received package of data is stored in a row table in a database. Data are automatically distributed to specific database tables to organize better the data.

Using database requests various data queries can be obtained. Requests are used to output various arrays of data so different cases can be observed:

- Displaying current locations;

- Displaying path that is tracked for a given period of time for a given tracked object;

- Statistics for destination passed for a given amount of time.

Observation of the tracking data is done by using a map API that allows displaying interactive maps. It is used to display current locations with markers and tracked paths by drawing on top of the map. The developed application is flexible and can be developed further to cover more functionalities such as more useful statistics and tracking data analysis. The block diagram of the application is shown on Figure 4.

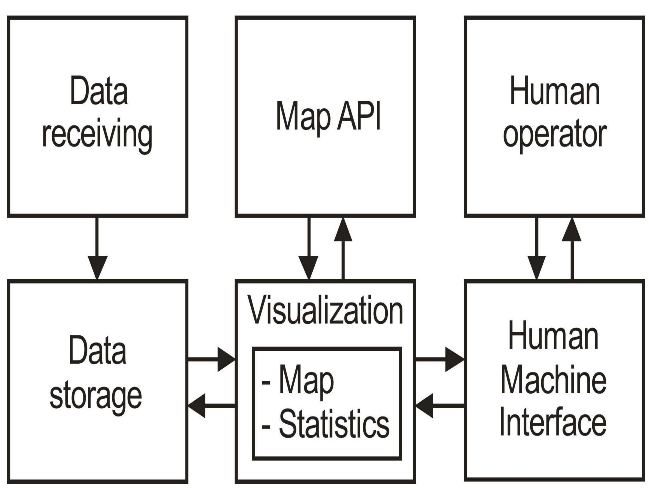

Figure 4. Tracking manager application block diagram

4. Conclusion

Wild tracking devices are one of the most useful instruments in gaining knowledge in the field of zoology. On one hand, designing of such a device is a real engineering challenge as the technical specification is quite tough. The biggest problems are related with the requirements for very small sizes and weight. Moreover a sufficient operating time is necessary as enough amount of information about the animal under study should be gathered. Another obstacle is the harsh conditions of the environment.

At the time problems seems almost impossible to overcome. Nevertheless the technology continues to develop. New electronic devices with reduced power consumption and sizes are constantly introduced to the market. Also new type of batteries with improved parameters like energy density and operating temperature range are emerging.

The paper describes a GPS-based tracking device which is capable of transmitting the location data through a RF link to a nearby retranslating station. Exploiting the GSM/GPRS network the station is capable to transfers the information to the end user. By using specialist software application the user can analyze the data in convenient way. The design presented in this paper is incapable to be used with the smallest species of the Mustelidae, but still is appropriate for animals with weight larger than 300 g. Nevertheless our efforts will not stop and we believe that future research will succeed to overcome the difficulties.

Acknowledgement

This paper is a part of a project which is sponsored by the research program of the Technical University of Sofia, Bulgaria.

References

[1] http://www.wildwatch.com, last accessed April 10, 2013.

[2] Audubon biography, National Audubon Society, http://www.audubon.org/john-james-audubon, last accessed April 10, 2013.

[3] Clark, P., D. Johnson, M. Kniep, P. Jermann, B. Huttash, A. Wood, M. Johnson, C. McGillivan, K. Titus. An Advanced, Low-Cost, GPS-Based Animal Tracking System. *Rangeland Ecology & Management*, vol. 59, no. 3, pp. 334-340, 2006.

[4] http://www.telonics.com/technotes/tracking.php, last accessed April 10, 2013.

[5] Claridge, A., D. Mills, R. Hunt. D. Jenkins, J. Bean. Satellite tracking of wild dogs in south-eastern mainland Australian forests: Implications for management of a problematic top-order carnivore, *Forest Ecology and Management*, vol. 258, no. 5, pp. 814-822, 2009.

[6] MacCurdy, R., R. Gabrielson, E. Spaulding, A. Purgue, K. Cortopassi, K. Fristrup. Real-Time, Automatic Animal Tracking Using Direct Sequence Spread Spectrum, *European Conference on Wireless Technology*, pp. 53-56, 2008.

[7] Rutz, C., L. Bluff. Animal-borne imaging takes wing, or the dawn of 'wildlife video-tracking', Trends in Ecology and Evolution, vol.23, no. 6, pp. 292-294, 2008.

[8] http://en.wikipedia.org/wiki/Mustelidae, last accessed April 10, 2013.

[9] Monakhov, G.. Martes zibellina (Carnivora: Mustelidae). *Mammalian Species*, vol. 43, no. 1, pp. 75-86, 2011.

[10] http://www.mammal.org.uk/ species-factsheets/Weasel, last accessed April 10, 2013.

[11] http://www.invensense.com/mems/gyro/nineaxis.html, last accessed April 10, 2013.

[12] http://www.elcomdesign.com/flexible-pcb.htm, last accessed April 10, 2013.