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Applied Science for
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Welcome

This document presents the proceedings of the 4th Symposium of Applied Science for Young Researchers - SASYR 2024. This scientific event welcomed works by junior researchers on any research topic covered by the following three research centers: ADiT-lab (from IPVC, Instituto Politécnico de Viana do Castelo), 2Ai (from IPCA, Instituto Politécnico do Cávado e do Ave) and CeDRI (from IPB, Instituto Politécnico de Bragança).

The main objective of SASYR is to provide a friendly and relaxed environment for young researchers to present their work, discuss recent results, and develop new ideas. In this way, this event offered an opportunity for the ADiT-lab, 2Ai, and CeDRI research communities to gather synergies and promote collaborations, thus improving the quality of their research. The SASYR 2024 took place at Instituto Politécnico de Bragança, Bragança, Portugal, on the 3rd of July, 2024.

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Smart Small Ruminant Device: An IoT-Based System for Real-Time Monitoring and Management of Sheep and Goat Mobility

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Abstract. The traditional agricultural practice of silvopastoralism, combining cultural heritage and ecological management, plays a vital role in food production and landscape management. This article explores the integration of precision livestock farming (PLF) into silvopastoral landscapes, using Internet of Things (IoT) technologies for monitoring and data transmission. Commercially available tracking devices lack interesting ergonomics, price and autonomy, and most companies do not focus on goats and sheep. A customized IoT device was developed and tested on goats, employing temperature/humidity sensors, relative position, geolocation and a long-range communication module. The system architecture enabled real-time data flow through the sensing, service and interface layers, resulting in data visualization. The results demonstrate the high reliability, low cost, interesting autonomy and appropriate ergonomics of the device, with the animals exhibiting normal behavior during the tests. The study highlights the effectiveness of IoT-enabled PLF for understanding grazing dynamics and animal behavior in silvopastoral systems, highlighting its potential for sustainable landscape management and the welfare of goats and sheep.

Keywords: IoT · Animal Tracking · Animal Monitoring · Precision Livestock Farming · Silvopasture.

1 Introduction

The practice of Silvopasture holds significant cultural and ecological importance in many societies, serving as a cornerstone of food production and landscape management [5, 13]. Beyond its agricultural contributions, Silvopasture fosters social cohesion and identity, embodying a nexus of human interaction with natural systems and providing ecosystem services [1].

The rise of the Internet of Things (IoT) has revolutionized our interaction with the environment, enabling real-time data collection and informed decision-making across diverse sectors. From smart homes to industrial operations and environmental monitoring, IoT has ushered in a new era of connectivity and innovation. Central to this advancement is the development of efficient IoT nodes capable of robust data collection and reliable communication [7].

In recent decades, the need to evaluate and compensate ecosystem services has underscored the importance of integrating technology and data acquisition systems within Silvopastoral landscapes. IoT and PLF methodologies have emerged as a key approach to accurately monitor and quantify grazing activities, essential for assessing and remunerating the ecological benefits of extensive grazing in forested and natural areas.

PLF encompasses a suite of technologies tailored to individual animal monitoring, particularly valuable in extensive grazing systems. By integrating PLF applications, herders can enhance pasture utilization, animal health monitoring, and overall livestock management. Data acquisition forms the foundation of PLF, with parameters ranging from temperature and weight to GPS-based position tracking and grazing behavior analysis [1].

Utilizing technologies like Global Navigation Satellite Systems (GNSS) and Geographic Information Systems (GIS), farmers can efficiently monitor grazing dynamics and pasture utilization. Combining GPS with accelerometers offers deeper insights into grazing behavior and rest patterns, enhancing small ruminant management and theft prevention. The integration of RFID, virtual fencing, UAVs (Unmanned Aerial Vehicles), and other emerging technologies further expands the toolkit for optimizing small ruminant husbandry within silvopastoral systems [12].

The application of IoT and PLF techniques enables precise recording of grazing patterns, contributing critical data for developing localized systems to reward ecosystem services, mitigate fire risks, recycle nutrients, and protect fragile mountain ecosystems [4]. Global Positioning Systems (GPS) have been pivotal in this regard, providing insights into animal behavior and resource utilization that benefit both livestock welfare and ecosystem management [1, 3, 11].

To respond to the need to track small ruminants, companies such as Domodis and Pastoral have developed commercial solutions. Domodis is suitable for farm animals, including horses, sheep, cows, goats and wild animals, although with concerns about the ergonomics of the device for goats and sheep. Pastoral provides a back-mounted tracking device that incorporates a solar panel, but this poses potential risks such as entanglement in vegetation for goats. Despite offering low-cost entry points, starting at 95 dollars, Pastoral's devices generally have a shorter battery life compared to Domodis, which starts at 397.00 euros per unit, and both also require monthly subscriptions for use [2, 9].

This work involves the development of a data acquisition system for goats and sheep based on IoT technologies and architecture. This system must guarantee twenty days of autonomy with acquisitions every five minutes, not exceed 200 euros, not cause any harm to the welfare of the animals, and have a communication range of at least two kilometers. In addition, the data collected is latitude, longitude, speed, temperature and humidity of the environment and the relative position of the animal's neck.

This article is organized into an introduction, which covers the context and importance of the application, materials and methods, which shows which technologies were used and how the system works in general, results, which show the performance of the entire system, followed by a discussion of the benefits of the system developed. Finally, the conclusion provides a summary of the work and a direction for future work.

2 Materials and Methods

This research aims to develop a data acquisition device for sheep and goats and its performance on a collar worn by the animal. The device is part of an IoT architecture and includes a series of sensors to acquire and transmit data.

2.1 Architecture

Although this work is focused on the device, in order for the whole system to work, an IoT architecture has been established that contains all the necessary layers. The layers are divided into an sensing layer, a network layer, a service layer and an interface layer. These layers ensure the flow of acquired data from its collection on the device to its presentation to the end user. Figure 1 gives an overview of the architecture adopted. Fig. 1 gives an overview of the adopted architecture.

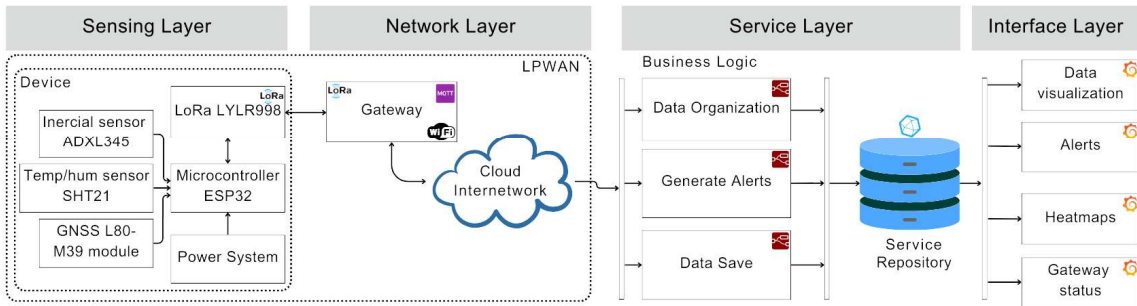


Fig. 1: IoT architecture overview. You can see the data sensing, network, service and user interface layers. Each block indicates a part of the system and some show the technology used.

2.2 Sensing Layer

The sensing layer is responsible for collecting and sending data. Belonging to the this layer, the device developed in this work is equipped with a high-precision GNSS module (L80-M39) that accurately records the animal's spatial movements, operating over a wide range of temperatures and voltages. In addition, temperature and humidity sensors (SHT21) have been incorporated for precise measurements of environmental conditions, as well as an inertia sensor (ADXL345) to detect changes in the movement of the animal's neck. The devices use Long Range (LoRa) communication (LYLR998 module) for long-distance data transmission and low power consumption.

The system's power solution combined a lithium polymer (LiPo) battery with a high-efficiency solar panel, ensuring continuous operation by harnessing solar energy to recharge the battery. All these functions are controlled and integrated by a robust microcontroller (ESP32), which offers various interfaces and peripherals for operation in harsh environments.

2.3 Network Layer

The network layer is responsible for receiving data from the device and forwarding it to the internet. This is done through a gateway that was connected to a local network and configured to forward received via LoRa data packets to a cloud server via the Message Queuing Telemetry Transport (MQTT) protocol, according to the architecture seen in 1. MQTT was chosen because it is extremely efficient in terms of bandwidth and resources, ideal for IoT devices with power and connectivity constraints. It uses a lightweight publish/subscribe model, enabling efficient asynchronous communication between devices and MQTT servers. In addition, MQTT supports distributed network architectures and is highly scalable, making for IoT systems.

LoRa was chosen because of its ability to transmit data over long distances with low power consumption, making it ideal for applications in extensive grazing areas where traditional connectivity may be limited. Its modulation technology allows it to reach greater distances without the need for complex network infrastructures, which makes it suitable for rural environments with varied topography, according to the case study [6].

2.4 Service Layer

The service layer is responsible for executing all the business logic and storing the data, for which purpose a Node-red application was developed to receive, filter, analyze, generate alerts and forward the data to the database. As Node-red is a platform for building task flows, it is easy to integrate and has little code, making it the ideal choice for this application.

The database used in this work is InfluxDB, an open source, highly available and scalable time series database designed to handle large volumes of time series data. It is especially suitable for storing, querying and visualizing data that changes over time, perfect for IoT applications.

2.5 Interface Layer

The interface layer is responsible for presenting all the data, averages, alerts and other relevant information to the end user. To do this, an application was developed in Grafana for data visualization due to its flexible dashboard creation tools and native support for integration with InfluxDB, which is the database chosen for the application. InfluxDB was selected for its efficiency in storing and querying time series data, offering high performance and scalability for handling large volumes of data. In addition, its ability to process queries in real time facilitates the analysis and visualization of the data collected.

With Grafana application, customized dashboards were developed to present historical and real-time data on grazing patterns, environmental conditions and device status.

3 Results

The tests carried out in this experiment provided various analyses of the system and its operation. Analyses ranged from connection reliability to consistent data presentation.

The tests were carried out on sunny pastoral days and the collars were fitted to random adult animals. Four tests were carried out on different days, i.e. the animals only wore the collars with the device while grazing, they were installed at the beginning of the grazing and removed at the end. Fig. 2 shows the collar fitted to the animal before it goes out to graze.



Fig. 2: Device fitted to the animal. In the image you can see the arrangement of the device on the animal, where the top supports all the modules and sensors and the bottom the feeding system. This distribution ensures that the bottom part counterbalances the device so that the top part is always on top of the animal.

3.1 Device Performance and Animal Behavior

During the four grazing tests, the device was programmed to remain idle for 10s. Each data acquisition process took an average of 20s (exiting idle mode, waiting for data from the GNSS and other modules and sending data). With these settings, the device averaged two data collections every minute. There were a few moments when the data was not collected correctly, due to unexpected module failures, but the device still showed a reliability of 98% during the tests. This is due to the reliability of the LoRa technology and the way the data rules are executed on the device.

In bench tests, the device had a consumption equivalent to 37 days of battery life, assuming a linear discharge with data being acquired and sent every five minutes. In addition, with these configurations it is possible to make approximately twelve thousand acquisitions of animal data. In the grazing tests, the solar panel showed a significant difference in the results. In one of the tests carried out, the device showed a gain in charge after grazing, demonstrating the contribution of the solar panel.

Animal behavior in relation to the collar was also analyzed. During all the tests, the animals that received the collar did not show any discomfort, as they grazed normally. The collar did not prevent them from running, eating, walking, climbing trees or any other activity. This guarantees that the shape and weight of the collar are efficient for its purpose.

3.2 Data Visualization

Application made in provides a rich presentation of all the data collected by the device and the status of the gateway. As the main focus of this work is on data relating to the animal's position, the panel that show the heat maps generated by application made in Grafana are more relevant. Fig. 3 shows two heat maps generated in two of the four tests carried out, on the left the heat map generated during a three-hour grazing session and on the right a seven-hour grazing session.



Fig. 3: Heat maps generated by Grafana. These heat maps were generated based on two days of grazing recorded by the system. In both cases, there is a distribution of green and red spots which indicate the areas preferred by the animals (the red ones indicate longer stays by the animals).

4 Discussion

The device developed is a breakthrough in the development of tracking devices for small ruminants. The sensors chosen allow for a series of data analyses and pattern detection that can be put to better use in future work. The price of this device, between 100-140 euros, despite being more expensive than the one developed by Pastoral, is cheaper than Domodis and other commercial devices [8].

Its format, where the power supply system is below the neck and the modules above, ensured that data acquisition and transmission were maximized, mainly by ensuring that the GNSS sensor and LoRa module remained facing upwards. In addition, the device's autonomy proved to be excellent, although further tests to assess the contribution of the solar panel need to be carried out.

The application developed in Grafana allows all the data to be presented in a rich and intuitive way. Heat maps are essential for analyzing animal patterns and their contribution to the silvopastoral system [10]. In addition, the alerts that this application generates quickly show possible risks or dangers that the animals may be facing.

5 Conclusion

The commercial devices available for tracking small ruminants have a number of problems in terms of ergonomics, high cost and autonomy. In this work, an intelligent device integrated with an IoT architecture was developed in order to solve the problems arising from commercial devices.

Due to the choice of three batteries and LoRa, the system had excellent autonomy and range, the shape of the device ensured non-invasive ergonomics for the animals and the choice of low-cost sensors ensured that the device did not exceed the value initially stipulated.

For future work, it is recommended to study the need to use temperature/humidity and relative neck position sensors, the removal of which would ensure a smaller device. In addition, the construction of a waterproof device will ensure that real-life tests can be carried out.

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