Key Technologies and Applications of Wild Animal Satellite Tracking

Tian Huang1,*, Libo Zhou2, Minghui Zhou2

1Hunan City University, No.508, Yingbing Road, Yiyang, China

2Hunan Engineering Research Center for Internet of Animals, No.02, Lujing Road, Changsha, China

*65061902@qq.com

Abstract. Mastering the laws of wildlife activities and family territory is an important task for wildlife protection, habitat restoration, and epidemic surveillance. Aiming at the shortcomings of traditional wildlife monitoring methods, an overall framework of wild animal satellite tracking system is proposed, and key technologies such as MEMS design, energy optimization, miniaturization and lightweight, wearable methods, and big data platform development are discussed and practiced. The results show that the wild animal satellite tracker developed by the above technology has the characteristics of miniaturization and lightweight, which can better solve the problem of energy supply in the field, and the service life can reach more than 5 years. Cloud recording of wild animal tracking data, Cloud Storage, Cloud computing, and Cloud monitoring. It plays a role in ensuring the data security of China's wildlife ecological resources and other sensitive geographic information, and also provides scientific and effective technology tools and data support for China's wildlife research, protection, and management, and is of great significance for serving the national ecological civilization construction.

Keywords: Wild animals; satellite tracking; big data

1. Introduction

Wild animals are an organic part of natural resources. Their survival and development maintain the balance and stability of natural ecosystems and affect the survival of human society. In recent years, with population growth and economic development, urban construction has expanded rapidly, and damage to natural ecosystems has been very serious. The population of many wild animals has declined, habitats and living environments have been destroyed, and species survival has been seriously threatened(Wang et al., 2013, Jia et al., 2013)[1, 2], wildlife conservation work is imminent. On the other hand, wild animals are the main host and vector of zoonotic diseases(Sadeleer et al., 2020, K et al., 2020, Charlotte et al., 2017, Malavika et al., 2017)[3-6], and these diseases can cause huge harm and loss. Taking birds as an example, many scholars have shown that the occurrence and epidemic of highly pathogenic avian influenza in the world are closely related to wild migratory birds(Hiroko et al., 2018, Lisovski et al., 2018)[7, 8], so further understanding of their migration laws
and accurate dynamic patterns. Description is the key to effectively monitor the spread of bird-borne epidemics (Wang, 2018)[9]. Whether it is wildlife protection, animal-derived epidemic research, or the establishment of a basic animal activity database to provide data support for various studies, its basic job is to track and monitor wild animals.

Bird banding is an important method to study the migration dynamics and laws of wild animals. Traditional bird banding methods mainly include flags and radio-tracking (Ma, 2009)[10]. The flag completely relies on manual observation, and the chance of being observed again is less than 0.1% (Fränzi et al., 2014)[11], and the efficiency and success rate are extremely low. The radio-tracking monitoring range is small, the positioning accuracy is low, and it is greatly affected by human factors, which has been criticized by researchers (Haramis et al., 2011, Johansson et al., 2011)[12, 13]. Satellite tracking technology has the advantages of long duration, wide spatial coverage, and rich data volume. It is increasingly used in ecological studies such as animal home range estimation, activity paths, activity patterns, habitat utilization, and protection (Chen et al., 2016)[14].

For a long period of time in the past, Chinese researchers have used foreign wild satellite banding products, and few domestic companies have researched and produced similar products. Due to the high price of foreign equipment, import and export control, monitoring data exist in foreign servers and other problems, which seriously hindered the research and protection of wildlife in our country. The development of domestic wildlife tracking equipment to provide scientific and effective technology tools and data support for my country's wildlife scientific research and protection management is an urgent need to serve the country's ecological civilization construction.

2. System structure
The wild animal tracking system is a multi-technology fusion technology system, which mainly includes positioning technology, communication technology, information processing technology, and GSM data transmission technology. The overall structure of the system is shown in Fig.1 below. The terminal device receives the navigation message sent by the navigation satellite for positioning, uses MEMS to collect coordinates, speed, temperature, exercise volume, and physiological indicators to generate a data package, uploads it to the big data center through the GSM network, and the user obtains wildlife status data through the Internet.

![Fig.1 General structure of the satellite tracking system](image)

3. Key technologies and solutions
3.1. Working framework of MEMS
Wild animal satellite tracker consists of hardware systems and digital signal processing software. The hardware system includes a microprocessor, a Beidou satellite positioning module, a 5G communication module, a behavior sensing module, a power management module, a digital signal processing module, a peripheral interface, and other auxiliary modules. Positioning is achieved by receiving the B1 frequency signal of the "Beidou 2" navigation and broadcasting satellite and the L1 frequency signal of the US GPS satellite, using multiple sensors to obtain bird behavior and activity information, and using the Beidou short message or 5G network to achieve equipment and Datacenter communication and data transmission.

A Beidou multi-card communication terminal is used to establish a Beidou short message relay service station. The communication terminal integrates the Beidou RDSS function. The internal circuit includes an RDSS RF low-noise amplifier, RDSS transceiver chip, power amplifier chip, baseband circuit, etc. The module has a built-in RNSS&GPS module and an internal ARM processor, which realizes the Beidou RDSS multi-card working mode and improves the data transmission volume and frequency of Beidou RDSS short messages. The external self-reset circuit is used to ensure the stability of the equipment for a long time. The control circuit can freely control the power supply of the Beidou RDSS and RNSS modules. The drawer-type card slot design is convenient for card slot management and improving the contact reliability of the card slot.

![Diagram of the tracker](attachment:diagram.png)

**Fig.2 The structure of the tracker**

The microprocessor is the control core of the system, and the microprocessor will greatly affect the performance of the system. The microprocessor of this system adopts the ultra-low-power single-chip microcomputer dedicated to the Internet of Things of TI Company; the model is MSP430F5340. The processor not only integrates a dual serial port, but the satellite positioning and communication module is also connected to it through a serial port to meet the communication needs of the system; secondly, the microprocessor has the advantages of low power consumption, high calculation speed, and strong anti-interference ability.

The high-reliability data management module adopts the method of “first save and then read” to store data, and the “three-lift and two-redundant” redundant method is used to read the data to ensure the accuracy of the data; the never-failure monitoring module has three reset modes, which can ensure the normal operation of the equipment in the complex strong interference environment in the field. The use of 5G communication technology to transmit data in real-time reduces the cost of satellite tracking information transmission. At the same time, it combines the three positioning methods of Beidou, GPS, and base stations to improve positioning accuracy.

### 3.2. Energy harvesting and saving

Wild animal tracking requires long-term outdoor use, long service time, and cannot be charged in the middle. Therefore, the energy supply and energy control of the entire system are a key point of the design and a technical bottleneck that restricts the further development of wild animal tracking.
equipment. Energy unlimited battery life technology includes two aspects: energy harvesting capacity enhancement technology and ultra-low power consumption energy-saving technology.

Adopt solar + lithium battery fusion power supply scheme, customize solar chips of specific shape and size according to the shape characteristics of the equipment, and improve the MPPT circuit to achieve a charging efficiency of 98%. In the non-light environment, the lithium battery is used as the backup power supply to provide energy protection for the continuous operation of the system. On the one hand, energy-saving technology uses suitable low-power devices, and on the other hand, it develops an algorithm for the self-learning ability of the device. The device can intelligently adjust to the optimal working mode according to the animal behavior rhythm, battery status, and external environment. For example, the integrated control unit uses TI's variable frequency ultra-low-power microprocessor MSP430FR5964. The working mode control is mainly composed of a real-time clock circuit, a time-wake module, and a switch module. The time-to-wake corresponding function module works, and all modules without work tasks in the sleep state, energy consumption is reduced as much as possible, and the standby current of the device can be controlled below 10uA.

3.3. Lightweight antenna design
In order to reduce the impact on the normal life of birds, the weight and size of the tracker are very important. The experience of industry experts believes that the weight of the tracker should not exceed 3%-5% of the bird's weight(Barron et al., 2010)[15]. At present, satellite positioning antennas and GSM antennas have not been able to achieve miniaturization applications. The antenna has the problems of heavy weight, large shell, and large space, which limit the miniaturization research and development of wild animal tracking equipment. At the same time, because these two antennas have to be integrated into a miniaturized device, there is mutual interference, which affects the satellite positioning effect and data transmission effect of the device.

The design of the antenna scheme uses an external antenna. The antenna material uses titanium-nickel super-elastic alloy wire. Its good shape retention and toughness ensure the durability of the antenna. The length of the antenna is determined by the calculation of the communication frequency. The single-line dual-frequency method is used to solve the problems of satellite positioning and GSM signal transmission communication by one antenna, which not only improves the positioning accuracy and communication effect but also reduces the weight by 70%.

3.4. Structural design and wearing method
Different birds have different physical indexes, living habits, and behavioral rhythms. They need different appearance structures and wearing methods to improve comfort and reduce the impact on individual life. Foreign mainstream satellite tracking products mainly have two appearance structures of piggyback and neck ring, which can not meet the individual needs of birds. And also often face due to bird feathers is too thick to block the solar panel, resulting in equipment energy supply shortage. In response to these problems, four kinds of wearing ways and a series of appearance structures suitable for birds were designed.

![Fig.3 Appearance structure and way of wearing](image-url)
The piggyback tracker is tied to the bird's back. Because the bird's speed can reach 100 kilometers per hour during the migration, wind resistance will seriously affect the bird's migration behavior. The streamlined shell is designed using aerodynamic principles, which can reduce the wind resistance by 80% compared to the simple square outer box; a feather guide slot is designed to effectively press the feathers of birds under the solar panel, effectively solving the Charging problem caused by hairiness blocking; a buckle structure is designed for the neck ring tracker, the buckle material is selected from nylon material with comprehensive toughness and flexibility, and four equidistant buckle slots are designed on the buckle. Select the appropriate card slot to adjust the size according to the size of the individual bird, increase the matching of the equipment and the bird and the efficiency of on-site installation, and reduce the damage to the bird.

3.5. Design of Big Data Service Platform

Currently, wild animal satellite trackers mainly use "recorder-end user" point-to-point communication and "recorder-data storage service-end user" network communication. The former is limited by the reliability of the communication system and the receiving system. Data loss and transmission failures often occur, which cannot guarantee data security. The latter uses the server to complete data reception and storage, ensuring the reliability and security of the data. But all only provide data download services, and the degree of visualization is relatively low. Data statistics, analysis, and mining can only be completed by other software. With the development of the Internet of Things technology, there will be more and more sensors integrated into the tracker. At the same time, with the increase in the number of tracking individuals, the individual information and tracking data of wild animals will increase massively. How to effectively organize, manage, and distribute these multi-source and heterogeneous data, in-depth research to maximize the value of data is a problem worthy of in-depth research.

Based on cloud, Internet of Things, Internet, database and other technologies, a wild animal tracking big data platform has been established to achieve real-time cloud recording of wild animal tracking data, cloud storage of data, cloud computing of behavior and physiological information, and the use of the Internet to achieve user cloud monitoring of wildlife. The system functional framework and technical framework are shown in Fig.4-5.

Based on Oracle database system, it integrates wild animal status data recording function to realize cloud storage and cloud computing of wild animal life status; research and development of wild animal status data conversion model, based on high sensitivity data recorded by the wild animal status recorder, relying on cloud storage platform, to achieve cloud computing of the physiological state of wild animals; developed a real-time monitoring and visualization integrated system of wild animals, to realize cloud monitoring of wild animal states, the data obtained from the wild animal state data storage and analysis platform, and a network system integrating GIS information, real-time and the sensor network is linked to maintain and manage a large number of sensor devices, thereby assisting researchers to manage, analyze and share data.
4. Questions and discussion
Although the technical scheme proposed in this paper is feasible, it can effectively solve some key problems in the process of satellite tracking of wild animals. However, in the face of a wide range of wild animal species and the complex living environment of animals, there will be many new problems, such as many wild animals are living in dense forests, mountains, or caves. Such an environment makes the working efficiency of the positive energy charging module low, and it can't even work. This needs to continue to optimize the energy scheme. It may be useful to use a high energy density battery. Some animals live in extreme climates, such as penguins living in Antarctica, which brings new challenges to the low-temperature working environment and installation methods of the equipment. In addition, we have not yet tracked and positioned aquatic animals. Because water has a great attenuation effect on energy, the signal transmission of the device will be a problem. In the future, multiple communication modes and auxiliary relay equipment may be used to realize data transmission. In addition, we have accumulated a large number of wild animal location and behavior data. How to deeply analyze and mine these data, and establish different behavior analysis models and model adjustment parameters for different animals are worthy of serious study. These tasks need to have rich zoology and ecology knowledge as the foundation.

Acknowledgments
This study was financially supported by the Natural Science Foundation of Hunan Province (2019JJ40012), Engineering Technology Research Center of Animal Internet of Hunan Province (2017TP2014), Hunan Provincial Engineering Research Center, Intelligent Monitoring of Ecological Environment and Disaster Prevention and Reduction Technology in Dongting Lake Region.

References
[1] Yuyu W, Yifei J, Lei G, Lu C, Guangchun L, Li W and Hua G 2013 Optimizing hydrological conditions to sustain wintering waterbird population in Poyang Lake National Natural Reserve: implications for dam operations. *Freshwater Biology* **58** pp23-66
[2] Yifei J, Shengwu J, Yamian Z, Yan Z, Guangchun L, Guanhua L and Chapman M. G 2013 Diet Shift and Its Impact on Foraging Behavior of Siberian Crane (*Grus Leucogeranus*) in Poyang Lake. *Plos One* **8** pp 65-843
[3] Sandeleer N D and Godfroid J 2020 The Story behind COVID-19: Animal Diseases at the Crossroads of Wildlife, Livestock and Human Health European Journal of Risk Regulation 11

[4] Johnson C K, Hitchens P L, Pandit P S, Rushmore J and Doyle M M 2020 Global shifts in mammalian population trends reveal key predictors of virus spillover risk Proceedings of the Royal Society-B: Biological ences 287

[5] Carne C, Semple S, Maclarnon A, Majolo B and Latitia Maréchal 2017 Implications of tourist–macaque interactions for disease transmission Springer Open Choice 14

[6] Malavika R, Mathew M, Vanessa O and Ezenwa 2017 Pathogen exposure in cattle at the livestock-wildlife interface EcoHealth 14

[7] Nakagawa H, Okuya K, Kawabata T, Matsu A, Takase K, Kuwahara M, Toda S and Ozawa M 2018 Genetic characterization of low-pathogenic avian influenza viruses isolated on the izumi plain in japan: possible association of dynamic movements of wild birds with aiv evolution. Archives of Virology 163

[8] Simeon L, Jacob B, Dijk V, Don, Klinkenberg, Bart A, Nolet, Ron A M, Fouchier and Marcel K 2018 The roles of migratory and resident birds in local avian influenza infection dynamics J. The Journal of applied ecology 55

[9] Wang S 2018 Analysis of the spatial distribution risk wild bird avian influenza on the migration route in eastern China and construction network of nature reserve Northeast Forestry University

[10] Ma Z 2009 Research methods and progress of bird migration. Bulletin of Biology 44 pp 5-9

[11] Fränzi K N, Felix L and Kasper T 2014 A bird distribution model for ring recovery data: where do the European robins go? Ecology and evolution 4

[12] Haramis G M and White T S 2011 A beaded collar for dual micro GPS/VHF transmitter attachment to nutria Mammalia 75

[13] Johansson A T, Johansson and McCarthy T 2011 An automatic VHF transmitter monitoring system for wildlife research John Wiley & Sons, Ltd 35

[14] Wenbo C, Tomoko D, Fujita, Naoya, Hijikata, Ken-Ichi, Tokita, Kiyoshi, Uchida, Kan, Konishi, Emiko, Hiraoka, Hiroyoshi and Higuchi 2016 Migration of tundra swans (cygnus columbianus) wintering in japan using satellite tracking: identification of the eastern palearctic flyway J. Zoological Science 33 p63

[15] Barron D G, Brawn J D, and Weatherhead P J 2010 Meta-analysis of transmitter effects on avian behaviour and ecology. Methods in Ecology & Evolution 1 pp180-187