International Journal of Multiphysics
Volume 18, No. 3, 2024
ISSN: 1750-9548

Research on Forestry Survey and Data Acquisition System Based on Artificial Intelligence

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Abstract

With the rapid development of science and technology, the application of artificial intelligence in forestry is becoming more extensive and in-depth, ushering in a digital era for forestry development. Forestry survey technology and data collection systems are essential means to achieve digital forestry. Based on the study of existing forestry survey 3S technology and data collection systems at home and abroad, this paper proposes a method based on artificial intelligence. By using a tree positioning calibration module, a plane coordinate system is established to facilitate the rapid determination of the central survey location of the forest area, and to statistically analyze the tree information at the survey points.

Keywords: Artificial intelligence, 3S technology, forestry survey, data collection system.

1. Research Review

1.1 Current research status at home and abroad

Artificial intelligence (AI) is a technological science developed through the integration of multiple disciplines such as computer science, cybernetics, and neurophysiology. It is used to simulate, extend, and expand human intelligence and is known as one of the three cutting-edge technologies of the 21st century. Forestry AI technology mainly includes intelligent identification of forest tree species, intelligent monitoring of forest pests and diseases, and intelligent forest management decision-making systems [1]. Currently, in the process of forestry surveying and data collection, survey collection equipment and communication devices are mainly used to collect and transmit forestry data information. This facilitates the acquisition of tree information within forest areas, providing data support for forestry production decisions. However, when surveying and collecting tree information, it usually requires deploying numerous survey collection devices. Due to the lack of effective and reasonable arrangement of the survey collection area, determining the survey route is very troublesome. At the same time, the inability to arrange and determine an effective survey route often leads to survey chaos during the process, making subsequent data processing and storage difficult and increasing the complexity of forestry survey work. Scientific forestry survey technology and targeted data collection systems are particularly important for field operations and research in forestry.

Currently, 3S technology is mainly used for field forestry surveys, which include GIS (Geographic Information System), GPS (Global Positioning System), and RS (Remote Sensing). According to the China National Knowledge Infrastructure (CNKI), there are 1066 articles related to "3S" and "forestry" in domestic research, but only 17 articles specifically address "3S" and "forestry surveys." In "The Application of 3S Technology in Forestry Survey Design," Ma Xiaoqing mentioned that 3S technology is a combination of GIS, GPS, and RS technologies. Each technology has its unique role, and their integration can meet many practical applications, making it the most promising new technology [2]. Tong Liang pointed out in "The Application of '3S' Technology in Forestry

Survey Design" that GPS can accurately and quickly obtain target positions and perform automatic time positioning, providing convenience for subsequent data retrieval and utilization. RS utilizes the differences in the reflection and absorption of electromagnetic waves by different objects to extract electromagnetic waves and achieve ultra-long-distance object recognition and information collection. GIS is software that summarizes and processes the massive information collected and provides functions for automatic error correction and data updating. With real-time updated data provided by RS and GPS, GIS-produced electronic maps also update automatically, helping forestry workers understand real-time conditions in the forest area and providing a basis for optimizing forest area management through remote monitoring [3].

In terms of data collection system design, Le introduced a mobile geographic information system in "Design and Implementation of Forestry Field Survey Data Collection System." This system features satellite positioning, portable intelligent terminals, and wireless interconnected networks. It provides solutions for the digital collection of forestry resource information by developing a forestry field survey data collection system, making traditional cumbersome and complex field surveys and internal organization work more efficient and straightforward [4]. Tu et al. proposed a forestry data collection scheme based on blockchain technology in "Design and Research of Forestry Data Collection System Based on Blockchain Technology." Forestry data collectors use smart terminal devices to input information such as tree species, latitude and longitude, regional information, growth conditions, and photos. These terminal devices connect to the blockchain, transmitting the original data onto the chain to ensure the accuracy of the original data [5].

1.2 Foreign research review

The development of forestry information collection abroad started earlier. In the 1950s, the United States took the lead in introducing computers into forestry, evolving from initial scientific computing tools to integrated information management and decision-making systems, significantly changing forestry management technology and research methods [6] Forestry information technology is widely practiced and applied in developed countries. The forestry field data collection system, supported by 3S technology, is one of its important applications. It mainly completes functions such as field fixed-point data collection, positioning and navigation, tree species information sampling, and sensor information collection. In European and American countries, the application of forestry information collection systems is extensive and has a mature system framework [7]. With technological advancements, the demand for forestry information collection systems has shifted from simple data collection to comprehensive information systems that integrate internet technology, geographic information technology, positioning and navigation technology, and various computing and analysis sub-modules. The objects of collection have evolved from simple timber-related data to more detailed and in-depth investigations of forest resources, timber accumulation, and beyond. Corresponding data collection forms have also transformed into customizable formats that can be diversified and unsealed, characterized by diversified collection targets, integrated management organization, modernized methods, diversified analysis and evaluation, and diversified information services.

Based on the above research, this study has optimized the process by using a tree positioning calibration module to quickly determine the central survey location of the forest area. By creating a circle with the forest area center point as the center, all trees to be surveyed within the forest area are included within this circle, ensuring effective surveying of all trees in the forest area. Additionally, a plane coordinate system is established to mark the positions of each tree within the survey area [8], facilitating the quick determination of the coordinate positions of survey points and the statistical analysis of tree information at these points, achieving reasonable and effective planning of the forest area from a macroscopic perspective.

2. Research Methods

Figure 1 shows the tree positioning calibration module determines the survey area and identifies tree survey points. The survey route determination module identifies the forestry survey route based on tree survey points. The survey equipment installation and debugging module involves installing survey equipment according to the survey route and tree survey points and debugging the equipment.

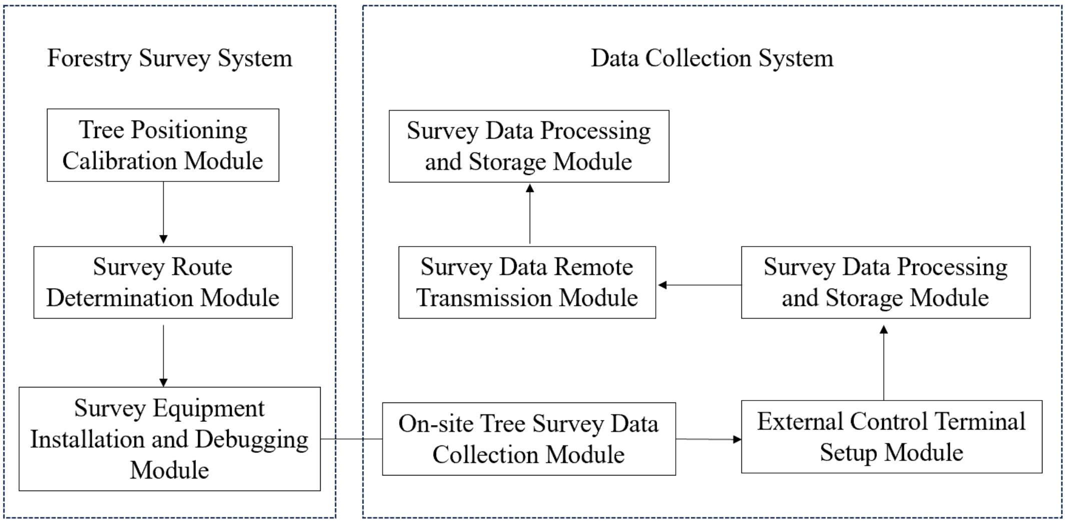

Figure 1 System structure of forestry survey and data collection

2.1 Forestry survey system

The forestry survey system specifically includes the tree positioning calibration module, the survey route determination module, and the survey equipment installation and debugging module [9]. This paper studies the positioning calibration module, which locates and identifies tree survey points in the survey area. It explores a method to conveniently and quickly determine the central survey location of the forest area using the tree positioning calibration module. It analyzes how to draw a circle with the forest center point as the center, ensuring that all trees to be surveyed in the forest area are included within this circle, thus ensuring effective surveying of all trees in the forest area. Meanwhile, it establishes a plane coordinate system to mark the positions of each tree within the survey area, facilitating the quick determination of the coordinate positions of survey points and the statistical analysis of tree information at these points, achieving reasonable and effective planning of the forest area from a macroscopic perspective.

2.1.1 Tree positioning calibration module

Using satellite maps to obtain overhead image information of the forest area to be surveyed and determining the central survey location of the forest area based on the overhead image information. The central survey location of the forest area is pinpointed, and a circle is drawn with this central point as the center, including all trees to be surveyed within this circle. The positions of all trees within this circular area are identified as tree survey points.

Once the central point of the forest area is determined, the position information of this central point is used as the coordinate origin to establish a rectangular coordinate system for the forest area within the computer. In this coordinate system, the positions of tree survey points within the forest area are marked based on the overhead image information of the forest area.

2.1.2 Survey route determination module

Based on the coordinate position information of each tree survey point, the survey route is delineated. When determining the route [10], the central point of the survey forest area is taken as the central area of the survey route. The survey route for tree survey points within the forest area is determined using an expanding "hui" structure with the center as the starting point. The determined survey route is structured as an expanding "hui" from the inside to the outside. The distance between the inner and outer layers of the "hui" structure is set at 5 meters. During the survey, the route is followed in a clockwise sequence along the "hui" structure distribution route.

Figure 2 shows the survey data processing and storage module refers to processing and storing the tree information collected by survey equipment at each tree survey point after receiving it at the remote control terminal. Processing tree information mainly involves classifying the tree information at each tree survey point. First, according to the "hui" structure of the survey route, each layer of the "hui" structure is treated as a large category. The layers are classified sequentially from the inside to the outside of the "hui" structure, specifically into A, B, C, etc., and the survey data information of trees in each layer of the "hui" structure is stored.

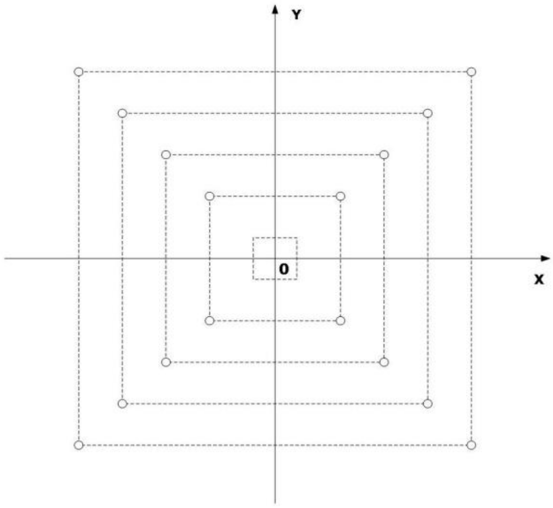

Figure 2 Schematic diagram of "hui" shaped survey route

2.1.3 Survey equipment installation and debugging module

After determining the tree survey points and survey route, survey equipment is installed at each tree survey point according to the determined survey route. Once the survey equipment is installed, it is powered and securely fixed. Finally, the survey equipment is debugged, and tree tests are conducted on-site using the survey equipment. The specific survey equipment includes diameter tapes, height meters, and ground laser scanners.

2.2 Data collection system

The data collection system specifically includes the on-site tree survey data collection module, the external control terminal setup module, the survey data remote transmission module, and the survey data processing and storage module [11].

The tree survey data collection module collects on-site tree information, the external control terminal setup module receives the collected tree information through the external control terminal, the survey data remote transmission module transmits the collected tree information remotely through the external control terminal, and the survey data processing and storage module processes and stores the collected tree information.

2.2.1 On-site tree survey data collection module

The survey equipment installed at each tree survey point is used to collect data information from the trees at each survey point. During the data collection process, the tree information is collected sequentially along the "hui" structure of the survey route in a clockwise direction.

When collecting tree data information, both direct and indirect information of the trees is collected. The direct information of the trees includes tree height, gradient diameter at breast height, basal area at breast height, crown width, and branch height. The indirect information includes tree category, average tree height, average gradient diameter at breast height, average crown width, and the number of main branches within the crown.

2.2.2 External control terminal setup module

The installation positions of the external control terminals are reasonably arranged according to the survey area of the forest, ensuring that the external control terminals can timely and effectively receive the tree information collected by the survey equipment at each tree survey point. The collected data information is stored and transmitted through the external control terminal.

When setting up the installation positions of the external control terminals, the survey route distribution of the "hui" structure is followed, with an external control terminal installed at each corner of every layer of the "hui" structure.

2.2.3 Survey data remote transmission module

After the external control terminal receives the tree information collected by the survey equipment at each tree survey point, the collected tree information data is transmitted remotely and wirelessly through the external control terminal, allowing the on-site collected tree information data to be instantly sent to the remote control terminal.

2.2.4 Survey data processing and storage module

After the remote control terminal receives the tree information collected by the survey equipment at each tree survey point, the survey data information is processed and stored through the control terminal.

Processing tree data information involves classifying the tree information at each survey point. First, according to the "hui" structure of the survey route, each layer of the "hui" structure is treated as a large category and classified in sequence from the inside to the outside, specifically into categories A, B, C, etc., and the survey data information of the trees in each layer of the "hui" structure is stored. Then, each layer of trees is numbered sequentially in a clockwise direction, achieving sub-classification of each tree with its own number, such as A1, A2, A3...An, C1, C2, C3...Cn...N1, N2, N3...Nn. Storing tree data information specifically involves storing the tree survey information in each category according to the classification processing of the tree survey information.

3. Research Conclusions

3.1 Determination of central survey location

Using the tree positioning calibration module, the central survey location of the forest area can be conveniently and quickly determined. By drawing a circle with the center point of the forest area as the center, all trees to be surveyed within the forest area are included in this circle, ensuring effective surveying of all trees in the forest area [12]. Additionally, by establishing a plane coordinate system, the positions of each tree within the survey area can be marked, facilitating the quick determination of coordinate positions for tree survey points and the rapid statistical analysis of tree information at these points. This achieves reasonable and effective planning of the forest area from a macroscopic perspective. By replacing the traditional single survey point positioning method with the establishment of a plane coordinate system, the accuracy of the positioning information for each tree survey point is ensured, and the cumbersome issues of traditional single-point positioning are resolved. This method allows the positioning of tree survey points in the forest area to be achieved simply by using a central positioning point.

3.2 Delineation of survey routes

The survey route determination module uses the coordinate position information of each tree survey point to delineate the survey routes. By determining the survey route for tree survey points within the forest area using an expanding "hui" structure, the survey area can be effectively and quickly stratified. This enables clear and orderly sequential surveying of trees along the layer distribution of the "hui" structure, preventing confusion in tree information during the survey and ensuring the accuracy of subsequent survey data. It also facilitates the processing of survey data.

3.3 Reasonable arrangement of external control terminal installation positions

The external control terminal setup module arranges the installation positions of external control terminals reasonably according to the survey area of the forest. The external control terminal equipment is arranged along the survey route distribution of the "hui" structure, ensuring that the installation positions of external control terminals can timely and effectively receive the tree information collected by the survey equipment at each tree survey point. This guarantees the effectiveness of tree information transmission and reception.

3.4 Processing and storing surveyed tree data

The survey data processing and storage module processes and stores the surveyed tree data information. When processing tree data information, the "hui" structure of the survey route is used to categorize each layer of the "hui" structure as a large category. Classification is done sequentially from the inside to the outside of the "hui" structure, facilitating reasonable and effective division of the survey area in the forest. This allows for quick classification of large categories in sequence. Based on this, each layer of trees is then sequentially numbered in a clockwise direction, achieving sub-classification of each tree and ensuring that each tree has its own number (e.g., A1, A2, A3...An, C1, C2, C3...Cn, N1, N2, N3...Nn). This method of classification, where large categories contain sub-categories, ensures the reasonable and effective collection, classification, and storage of tree survey information within the forest area, facilitating the effective storage and utilization of subsequent data.

4. Discussion

In the future, with the continuous development and innovation of artificial intelligence and technology, forestry survey technology will play a more important role in forestry resource surveys, forest pest and disease monitoring, ecological environment assessment, and other fields. Data collection methods will also become increasingly intelligent and diverse, exhibiting characteristics such as intelligence and automation, integration and fusion, high precision and efficiency, and ecological and sustainability.

4.1 Intelligence and automation

Artificial intelligence will use deep learning and image recognition technology to automatically identify information such as vegetation types, tree species, and growth states in forest areas, greatly improving the efficiency and accuracy of data analysis. This will support the scientific management and protection of forestry resources. Additionally, automated data collection equipment will be able to collect forest environment data in real-time and accurately, providing strong support for forestry management.

4.2 Integration and fusion

By integrating and fusing different technologies and data sources, comprehensive, three-dimensional, and dynamic monitoring of forest resources can be achieved, making forestry surveys and data collection more scientific, comprehensive, and accurate.

4.3 High precision and efficiency

High-precision technologies such as LiDAR and UAV remote sensing can be used for precise measurement and monitoring of forest resources. Utilizing cloud computing and big data processing technologies enables rapid analysis and processing of massive data, thereby improving the efficiency and accuracy of data utilization.

4.4 Ecology and sustainability

During surveys and data collection, it is crucial to fully consider the impact on the ecological environment to avoid damage and waste of forest resources. At the same time, attention should be paid to the sustainable use and protection of forest resources, providing strong support for the long-term development of forestry.

5. Conclusion

With the continuous advancement of basic observation technology, it can be foreseen that measurement theories and technologies that treat a single forest as an independent measured object will bring revolutionary updates to the existing observation system. Theoretically, more scientific methods are needed to deeply study the degree of organization within forests, and through "Gaia-like" means, grant an independent grid position to a single forest. Technologically, how to digitally describe an independently positioned forest, and the continuous adaptation of observation methods to the per-second growth changes of the forest, represent a future inevitable development route where the measured object (forest) and measurement methods are mutually integrated.

Acknowledgments

This paper was supported by the High-level Training Project for Professional Leaders of Teachers in Higher Vocational Colleges of Jiangsu Province (Su Gao Zhi Pei Han [2022] No. 11). Talent Project: Dual-qualification Master Teacher Studio for Hotel Management and Digital Operation in Vocational Education of Jiangsu Province (Su Teacher Han [2022] No. 31).

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