

Research Article

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Wireless network handheld terminal-based green ecological sustainable design evaluation system: Improved data communication and reduced packet loss rate

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Abstract: In response to the challenge of high packet loss rates due to poor mobility of PCs, we introduce a sustainable design evaluation system centered around wireless network handheld terminals. This system combines hardware components, including microprocessor and wireless communication modules, to achieve wireless data transmission and program debugging. In the software domain, a configurable communication protocol is employed to establish an ecological data communication module supporting wireless network handheld terminals. Leveraging real-time monitoring data from multiple points, we introduce an information fusion algorithm and construct a green ecological sustainability design evaluation model. Notably, experimental results reveal that our system outperforms alternatives based on sensor and RFID technologies. It exhibits a lower packet loss rate and extends the distance of zero packet loss, highlighting its advantages in data communication.

Keywords: wireless network, handheld terminal, green ecology, ecological sustainability, sustainable design, system design

1 Introduction

The traditional industrial economy has gradually brought many negative effects after the one-sided pursuit of human material economic growth. The rise of modern ecological

economics and circular economics provides a theoretical basis for human beings to reflect on the path of mutual promotion and harmonious coexistence between their own development and natural coordination. Neoclassical economics points out that the limited supply of the ecological environment and the lack of control of free riding behavior (free riding behavior is a speculative behavior that does not pay the cost but enjoys the benefit of others) have become the root causes of the current bad climate, water pollution, and the gradual deterioration of other public resources in some countries [1]. In the process of continuous development of the ecological environment by human beings, only by maintaining and compensating the environment, can we obtain the balanced evolution of the supply side and the demand side of environmental resources. According to the theory of biological evolution, there is a cumulative process of environmental change from quantitative change to qualitative change. Only by establishing the corresponding evaluation system can we observe the process of environmental change, and through the control and adjustment of relevant factors, we can maintain the balanced, harmonious and orderly development of the existing environment and achieve the goal of sustainable economic development. At present, there are many evaluation methods of green ecological sustainable design, such as ecological footprint method, energy analysis method, system dynamics method, SWOT method, fuzzy mathematics method, and so on. These methods mainly focus on the evaluation of the existing ecological results, and the scope is narrow. In order to evaluate the green environmentally sustainable design accurately and reliably, it is necessary to use the evaluation system to process and analyze the real-time collected data, so as to get the dynamic change process of the ecological environment, and quickly adjust the relevant strategies of sustainable design, so as to maintain the benign state of the existing ecology.

In order to ensure the reliability of green ecological sustainable design evaluation system data, it is necessary to monitor the ecological environment and collect relevant

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environmental data in real time to obtain information for sustainable design evaluation. The existing green ecological sustainable design evaluation system mostly adopts the solution of lower computer monitoring node and PC upper computer. However, as a monitoring center, PC has the disadvantages of poor mobility, high configuration cost, and difficult maintenance and upgrading [2]. And in the actual work, when the regional monitoring personnel and patrol personnel go out to work, they cannot understand the ecological environment of the region in real time, which increases some difficulties for the systematic evaluation. Therefore, the existing green ecological sustainable design evaluation system has been unable to meet the evaluation requirements of human–computer cooperation. The design of wireless network handheld terminal makes up for the blank of middle monitoring layer in the process of data acquisition and monitoring to a certain extent. Through the configuration of wireless network handheld terminal, the area to be evaluated can be subdivided, which can make the staff understand the ecological environment information in real time, and effectively improve the efficiency of system evaluation. Through simple operation, the staff can upload the relevant ecological environment data to the upper processing machine using the wireless network handheld terminal, thus effectively improving the redundancy and unreliability of the evaluation system [3]. On the PC side, through the improvement and optimization of the wireless communication data transmission process, the communication quality can have greater reliability, convenience, and higher efficiency. Therefore, this study designs a green ecological sustainable design evaluation system based on wireless network handheld terminal, in order to realize the online evaluation of comprehensive environmental performance.

2 Method and materials

2.1 Experimental preparation

This study designs a green ecological sustainable design evaluation system based on wireless network handheld terminal. The performance of the system is tested below. The system should operate in a stable operating environment. Microprocessor module was labelled STM32F103ZET6 with ARM Cortex-M3 architecture having clock speed of 72 MHz, flash memory of 512 KB, SRAM 64 KB with two USART interfaces and FSMC type of communication. Chip type was CC2430 by Texas Instruments (TI) following the

ZigBee Wireless Protocol. The operating environment of the system was Windows 10 operating system. Windows Server 2012 and SQL Server 2012 are installed. The CPU is 8-core 3.2 GHz, internal storage is 32 G, hard disk is 2TB, and the software development environment is Eclipse 4.5.0. In practical application, the evaluation system will be affected by many external factors, such as obstacles, air environment and surrounding signal interference, which is a challenge to the performance and stability of the evaluation system. Therefore, aiming at the practical application, the system test environment is built in the real environment in the test phase. According to the requirements of system design parameters, the test point is set in an environment with a length of about 5,000 m and a width of about 3,000 m. A total of ten data acquisition nodes, three repeaters, and two wireless network handheld terminals are set to participate. Test the initialization and networking of the system, the timing of the wireless network handheld terminal is monitored until it receives the data of all nodes accurately. That is, the networking is successful. The test results are shown in Table 1.

Through the system test under the above network configuration environment, the system designed in this work can complete the node networking within 3 s, which shows that the wireless communication protocol of the system meets the design requirements and can ensure the realization of the system functions.

In the multi-point information fusion algorithm section, the feature extraction process is essential for capturing relevant information from the data collected by the wireless network handheld terminals. The algorithms used for feature extraction are:

1. **Empirical mode decomposition (EMD):** This is a noise-aided decomposition method, which adds Gaussian white noise to the signal to evenly distribute its frequency components. The EEMD decomposes the signal into intrinsic mode functions (IMFs), where each IMF represents a specific frequency component of the signal.
2. **Entropy calculation:** The feature extraction process involves calculating entropy measures, which reflect the complexity and information content of the IMFs generated

Table 1: Test results of networking time consumption

Number of connected nodes	Time (s)	Number of connected nodes	Time (s)
1	0.6	6	2.2
2	1.1	7	2.4
3	1.3	8	2.6
4	1.6	9	2.8
5	1.9	10	3.0

by EEMD. The entropy measures provide insights into the energy distribution and uncertainty within the signal.

These algorithms are applied to the data as follows:

1. **EEMD:** The data collected from multiple measuring points are subjected to EEMD. This process separates the data into different frequency components, revealing the inherent structure of the ecological data.
2. **Entropy calculation:** After decomposition, entropy measures are computed for each IMF. This quantifies the information content and complexity of each frequency component.
3. **Information fusion:** To make full use of the multi-point data, a correlation function is applied to establish relationships between the extracted features from different measuring points. The correlation function provides insights into how the data from various points relate to one another.
4. **Comprehensive information:** Through the fusion of these features, a comprehensive information set is generated. This information integrates the data from multiple measuring points, providing a more holistic view of the ecological data and their characteristics.

The feature extraction and information fusion process are crucial for understanding and analyzing the ecological data, as it captures the essential patterns and relationships within the data collected by the wireless network handheld terminals.

3 Result and discussion

On the basis of the above system test, the study further analyzes the advantages of the design system in data

communication performance. Taking the green ecological sustainable design evaluation system based on wireless network handheld terminal as the experimental group, the system based on sensor design and the system based on RFID technology as the control group, the comparative experiment is carried out. Packet loss rate is the main index to measure the performance of data communication. It refers to the ratio of the difference between the number of packets sent by the lower computer monitoring node and the number of packets received by the terminal and the packet delivery rate. The calculation formula can be expressed as follows:

$$\text{plr} = \frac{s_1}{s_2} \quad (1)$$

where plr represents the packet loss rate, s_1 is the number of packets sent, and s_2 represents the number of packets received. The experimental results are shown in Table 2.

According to the test results in Table 2, with the increase in wireless communication distance, the packet loss rate of the three systems also increases. For wireless communication distance in the range of 200–1,200 m, there is no packet loss for wireless network handheld terminal green ecological sustainable design evaluation system designed based on this study. When the wireless communication distance increases to 1,400 m, the packet loss rate of the designed system is 1.2%. When the wireless communication distance increases above 1,400 m, the packet loss rate of the designed system is 3.2%, which is still at a low level and meets the design requirements of the system. The distance between the sensor-based system and the RFID-based system to receive data with zero packet loss rate is significantly less than the system based on wireless network handheld terminal. And with the increase in wireless

Table 2: Experimental results

Wireless communication distance (m)	Packet loss rate (%)		
	Green ecological sustainable design evaluation system based on wireless network handheld terminal	Green ecological sustainable design evaluation system based on sensors	Green ecological sustainable design evaluation system based on RFID technology
200	0	0	0
400	0	0	0
600	0	0	0
800	0	0	1.2
1,000	0	1.3	1.4
1,200	0	1.6	2.2
1,400	1.2	2.5	2.6
1,600	1.5	3.3	3.2
1,800	2.4	4.4	4.3
2,000	3.2	5.1	5

communication distance, the packet loss rate of the two systems in the control group is also greater than that of the designed system. Based on the above experimental results, the design system has good data communication performance, which is helpful to accurately evaluate the green ecological sustainable design and provide decision support for ecological restoration and governance.

3.1 Hardware design of green ecological sustainable design evaluation system

The hardware part of the system design takes the wireless network handheld terminal as the core. The hardware of the whole wireless network handheld terminal is composed of microprocessor, wireless communication, data storage, reset and alarm, power management, and other modules. Wireless network handheld terminal has the functions of network communication, identity recognition, human-computer interaction, data processing, and power management. Sections 4 and 5 describe the microprocessor module and wireless communication module in the system hardware, respectively.

4 Design of microprocessor module for handheld terminal

Microprocessor is the core of the whole architecture, and all peripheral circuit design and software system development are based on it, so the selection of microprocessor determines the overall performance of wireless network handheld terminal. Microprocessor is a high-performance processor based on kernel architecture and different peripherals. The core determines the main performance of microprocessor, and has different characteristics for different applications. Through comparative analysis and combined with the practical application and design requirements of the handheld terminal, the Cortex-M3 processor core is selected, and the microprocessor chip is selected based on the Cortex-M3 processor core [4]. This study selects STM32F103ZET6 microprocessor which is designed and produced by STM32F103ZET6 semiconductor company with excellent performance under ARM Cortex-M3 architecture. STM32F103ZET6 has the highest performance in terms of clock frequency and memory size. The chip has two USART interfaces and FSMC communication interface, so it can provide rich interfaces for a variety of peripheral circuit

design. The microprocessor module circuit is composed of microprocessor chip interface circuit, reset circuit and JTAG circuit. The interface circuit of the microprocessor chip realizes the connection with each module, the reset circuit determines whether the microprocessor can work normally, the JTAG circuit realizes the program download and debugging of the microprocessor, and is responsible for the software maintenance and update of the microprocessor. The interface circuit of microprocessor chip realizes the connection between STM32 chip and peripheral circuit [5]. The reset circuit adopts RC low-level reset mode. When the reset key is pressed, the interface is low-level capacitor C short circuit. When the RESET key is raised, R13 limits the charging current, and the voltage at both ends of C increases slowly. When the C is charged, the reset signal becomes high to complete the reset operation. The charging time of the capacitor is the reset time of the system. The specific reset circuit is shown in Figure 1.

In JTAG circuit, TDI and TDO are data input and output pins respectively. TRST signal is used to reset JTAG debugging module in CPU. TCK is clock input pin. Each pin is connected with microprocessor to realize data download and program debugging.

5 Design of transceiver circuit for wireless communication module

The CC2430 chip is a wireless system-on-chip produced by TI. It is designed for use in wireless communication applications, such as ZigBee and IEEE 802.15.4-based networks. The CC2430 chip combines with an 8051-microcontroller unit (MCU) having a high-performance radio frequency (RF) transceiver. Here is a discussion of the CC2430 chip with standards:

Standard compliance: The CC2430 chip is designed to meet specific industry standards and communication protocols, including IEEE 802.15.4 for low-rate wireless

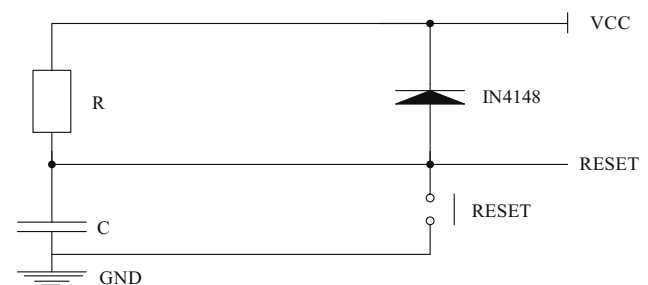


Figure 1: RESET circuit diagram.

personal area networks. This standard defines the physical and media access control layers for low-power, low-data-rate wireless communication. The chip is commonly used in ZigBee wireless networks, which are built upon the IEEE 802.15.4 standard. ZigBee is known for its reliability, low power consumption, and suitability for home automation, industrial control, and sensor network applications. Key Features: The CC2430 chip includes the following key features: MCU which incorporates an 8051-based MCU, which is a widely used and well-established microcontroller architecture. This MCU provides the processing power required for data handling and application control. A high-performance RF transceiver integrated with chip capable of supporting various frequency bands, including 2.4 GHz, enables wireless communication over short to medium distances. The CC2430 is designed for low-power operation, making it suitable for battery-powered or energy-efficient applications. The chip provides multiple communication interfaces, including UART, SPI, and I2C, making it adaptable to different communication needs. The switching time between sleep mode and working mode is short, which extends the battery life [6]. CC2430 also has excellent wireless reception sensitivity and anti-interference, and has two powerful USART supporting multiple groups of protocols to provide conditions for communication with microcontroller. Its powerful and flexible development tool greatly reduces development difficulty. Therefore, CC2430 is used as the core of the wireless communication module in the handheld terminal. Taking CC2430 as the core, the transceiver circuit of wireless communication module is designed [7]. The circuit consists of logic switch circuit, power amplifier circuit, low noise amplifier circuit, impedance matching circuit, and bias circuit. The specific circuit design is shown in Figure 2.

Then, CC2430 sends the data to STM32 microprocessor through serial port.

5.1 Software design of green ecological sustainable design evaluation system

5.1.1 Setting up ecological data communication module

The green ecological sustainable design evaluation system uses the configurable communication protocol to support the handheld terminal of data transmission, and the configurable communication protocol is customized through the web management platform. It also provides services for handheld terminals that can support HTTP protocol for data transmission. The function of data communication

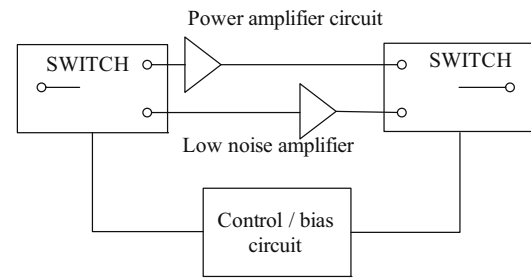


Figure 2: Wireless transceiver circuit diagram.

service is to provide data processing services for different types of ecological environment data collected by wireless communication handheld devices and communication services for users and device terminals [8]. The persistence operation of handheld terminal data is also saved through the database. This part is the key of data processing and communication, and there may be a large number of handheld devices communicating through the system, so the whole system needs to meet the characteristics of sufficient stability and concurrency. In this study, MINA framework is used to build ecological data communication module to support data communication service based on custom protocol. The MINA which stands for “Multipurpose Infrastructure for Network Applications” framework plays a crucial role in enabling efficient network communication and data transmission. MINA plays a pivotal role in system, managing network communication and custom protocols. It interacts with a database for data persistence and retrieval. Specifically, it encodes and decodes data, ensuring proper storage and enabling ecological data processing and analysis. The use of custom protocols, such as “TCP + long connection + heartbeat,” ensures reliable data transmission from handheld terminals. MINA is a socket communication framework, so in the establishment of lower computer (wireless network handheld terminal) or client and server communication must follow certain transmission criteria [9]. Therefore, before the establishment of communication, the user web management platform has been configured with communication protocol, handheld terminal information, and its related environmental data, and the communication protocol is associated with the device. Then, in the data communication module, the handheld terminal needs to be operated synchronously. At the same time, the data communication module designed in this study is for multiple wireless network handheld terminals, each handheld terminal can support different communication protocols, so each handheld terminal will assign a unique ID as the identification of communication transmission. In order to ensure accurate data transmission, the system mainly uses TCP + long connection + heartbeat to realize the communication of

binary sensor data. With long connection, the communication module does not need to create or eliminate sessions continuously, which improves the performance. Under normal circumstances, the handheld terminal regularly reports the collected data for communication according to the set cycle. When the user has a demand, it actively sends the request to the server to report the data immediately. In IoHandler layer, spring is introduced to realize business logic processing, and Spring-Dao is used to realize interaction with MySQL database. In order to facilitate management, managerhelper class is used as the business logic component management class in MINA, and is added to spring through @ service. In the managerhelper class, @ Autowired is used to declare the device business logic interface, data business logic interface, and other information, so as to realize the calling work of each business logic component, and realize the interactive operation in the common Dao component. The communication module encodes and decodes the ecological data, corresponding to the I/O filter layer of MINA. The encoding module is relatively simple. After UTF-8 encoding the incoming IoBuffer, the forwarding operation is carried out directly. The decoding module provides decoding methods for TCP requests, and finally encapsulates the ecological data into POJO token objects and sends them to the data processing module for processing [10]. The advantage of using token object to encapsulate ecological data is that when MINA supports more than one transmission request, different services can be implemented in the same IoHandler layer. The data processing module corresponds to the IoHandler layer of MINA, which processes the object information of different request types and is the core part of the whole system. The data processing module completes the data persistence operation by combining with the database access module. The system realizes the monitoring and analysis of ecological data by calling the data of database.

6 Design multi-point information fusion algorithm

The system is designed for multiple wireless network handheld terminals, which can get real-time monitoring data of multiple measuring points at the same time. In order to make full use of multi-point information, an information fusion algorithm is proposed. Through the correlation function fusion algorithm, the information measured by multiple measuring points is fused into a comprehensive information [11]. Feature extraction is the key of multi-point information fusion, which directly affects the accuracy of information fusion. The combination of EEMD and

entropy can well reflect the working condition of handheld terminals. Therefore, this work selects the entropy feature of EEMD to form the eigenvector [12]. EEMD is essentially a noise aided decomposition method, that is, a certain amplitude of Gaussian white noise is added to the signal for many times to make the extreme points of the signal frequency band evenly distributed, so that the IMF component does not appear faulty on each scale, so as to solve the problem of mode aliasing caused by signal discontinuity. In order to eliminate the influence of added noise on the signal, the mean value of the decomposed IMF component is taken as the final decomposition result [13]. The final value of IMF component can be expressed as follows:

$$\begin{cases} a = \frac{1}{m} \sum_{i=1}^m a_i \\ \varepsilon = \frac{1}{m} \sum_{i=1}^m \varepsilon_i \end{cases} \quad (2)$$

where a represents the average value of IMF components, ε is the average value of IMF decomposition remainder, m is the number of polymerization, i is the number of decomposition, a_i is the IMF component obtained from the i decomposition, and ε_i is the remainder of the i decomposition. The amplitude and aggregation times of white noise have great influence on the decomposition results. When the noise amplitude increases, the number of aggregations should also increase. At the same time, the increase in the number of aggregations will cause the calculation time to increase exponentially. Therefore, the selection of appropriate decomposition parameters is the key to EEMD decomposition [14]. After EEMD decomposition, the frequencies of each frequency band are well separated, and there is no aliasing problem. On this basis, IMF energy entropy and singular spectrum entropy are extracted as feature vectors. IMF energy entropy can reflect the change in amplitude energy of each frequency band, and IMF singular spectrum entropy can reflect the uncertainty of IMF energy distribution on the basis of considering information redundancy. The combination of the two can give full play to their advantages and achieve the purpose of signal analysis. After the fusion of signals collected by wireless network handheld terminal, EEMD is used to decompose a group of IMF components and the sum of the remainder. In order to avoid the IMF components with small amplitude energy being annihilated by the IMF components with large amplitude energy, the energy of each order IMF component is normalized. With the moving of time window, we can get the change rule of energy entropy with time, which reflects the energy distribution of signal in time domain and scale space. The IMF components are decomposed by

EEMD, and the matrix is decomposed by singular value decomposition. Using singular spectral entropy to measure the complexity of signal can better mine the modal features of data itself [15]. The feature vector is composed of EEMD entropy features to represent the information features of wireless network handheld terminal, and the correlation function is used to establish the correlation of each measurement point information, and the multi measurement point information is fused into comprehensive information. Correlation function is a statistic used to describe the correlation between information. By calculating the correlation function of multiple measurement points, we can directly see the correlation between information. Assuming that two random information are $\alpha(x)$ and $\beta(y)$, the correlation function between $\alpha(x)$ and $\beta(y)$ is expressed as follows:

$$r = \frac{1}{s} \sum \alpha(x)\beta(y) \quad (3)$$

where r is the cross-correlation function, s is the total amount of data, x is the number of data of random information $\alpha(x)$, and y is the number of data of random information $\beta(y)$. Then, the correlation coefficient between $\alpha(x)$ and $\beta(y)$ is expressed as follows:

$$\theta = \frac{r}{\sqrt{\sum \alpha(x)^2 \sum \beta(y)^2}} \quad (4)$$

where θ represents the correlation coefficient. According to the principle that the weight is proportional to the correlation coefficient, the weights of each information can be obtained and the fusion information can be obtained by weighting [16]. Through the fusion of multi measurement points information, the monitoring information collected by wireless network handheld terminal is fully utilized, so that the evaluation of green ecological sustainability design is more accurate.

7 Construction of green ecological sustainable design evaluation model

On the basis of multi-point information fusion, this system design uses the dynamic index of ecological efficiency to evaluate the green ecological sustainable design. Ecological efficiency refers to the ratio between the value added in social and economic development and the physical number of resources and environment consumed, reflecting the relationship between economic growth and resources and environment

carrying capacity [17]. However, the efficiency range calculated by traditional Data Envelopment Analysis (DEA) model is only 0–1, which can only distinguish the efficient and inefficient units, while the efficient units cannot be sorted and compared. This system design uses three-stage DEA model, combined with the fusion information of wireless network handheld terminal, to evaluate the green ecological sustainable design [18].

The three-stage DEA model and Tobit regression analysis are pivotal components in the construction of green ecological sustainable design evaluation model. The three-stage DEA model offers a comprehensive approach to evaluate the efficiency and sustainability of ecological design. It has several key advantages:

Efficiency measurement: The first stage of this model focuses on measuring the efficiency of decision-making units, which in our case could represent different ecological designs or approaches. It goes beyond traditional DEA models by allowing for efficiency values greater than 1, enabling ranking and comparison of efficient units.

Productivity analysis: The second stage of total factor productivity (TFP) measurement helps assess how efficiently resources are being used and how technological progress impacts productivity. This provides insights into the sustainability of resource use and technology adoption.

Regression analysis: The third stage involves Tobit regression analysis. This method allows us to understand the relationship between efficiency scores and various influencing factors. In the context of green ecological sustainability, these factors might include ecological environment variables, economic development metrics, or social factors. The three-stage DEA model offers a holistic view of efficiency, productivity, and the influence of external factors. It is particularly useful for evaluating and comparing various sustainable design approaches, making it a robust tool for system.

Tobit regression analysis: Tobit regression analysis is significant in our model for several reasons. Tobit regression allows us to assess how different factors, such as ecological variables, economic development, or social factors, influence the efficiency of ecological design. This helps you understand which elements have the most significant impact on sustainability. In ecological sustainability assessments, data can be censored, meaning it falls within specific limits. Tobit regression is well-suited to handle such censored data, making it a suitable choice for presented model. Tobit regression provides information on the direction and magnitude of the impact of factors on efficiency. This is crucial for making informed decisions about improving sustainability.

The mathematical model of super efficiency DEA is as follows:

$$f = \min \left[w - \mu \left(c \sum \lambda_1 + d \sum \lambda_2 \right) \right] \quad (5)$$

where f is the environmental output variable, w represents the eco-environmental efficiency of the decision-making unit, μ is the higher order infinitesimal, λ_1, λ_2 are relaxation variables, c, d represent the number of decision-making units of slack variables, respectively. The second stage is to calculate TFP index. TFP index is used to measure the change in productivity and decompose the change in productivity into the change in technological progress and technological efficiency [19]. The third stage is Tobit regression analysis. Tobit regression model can be expressed as follows:

$$D = v_0 + \sum_{a=1}^n v_a \omega_a + \delta \quad (6)$$

where D is the value of eco-environmental efficiency, v_0 is the initial regression coefficient, n is the number of influencing factors, v_a is the regression coefficient of evaluation factors, ω_a refers to the ecological environment factors, a is the number of environmental factors, and δ is the residual. Green ecological sustainable design is to reduce the consumption of resources and environmental waste as much as possible, improve the production efficiency of the ecological environment, make the minimum input and output of ecological environment, and maximize the economic and social benefits. In the evaluation of the green environmentally sustainable design, the selection of the ecological environmental input index and output index is very important. Therefore, the integrity of the evaluation index should be considered in the selection of index, the key index should not be omitted, and the evaluation index should not be repeated [20]. Therefore, this study draws lessons from the evaluation index designed in the German environmental economic account and the evaluation index of ecological efficiency studied by Chinese experts and scholars, and divides the sustainable development index into input index and output index. Input index includes environmental pollution index and energy consumption index, and output index includes economic development index and social development index. Based on the above process, this study completes the design of a green environmentally sustainable design evaluation system from both hardware and software aspects.

8 Conclusion

This research designs the green ecological sustainable design evaluation system based on wireless network handheld terminal, and completes the experiment test according to the

design requirements. The experimental results show that the system performance meets the design requirements, and has a lower packet loss rate, and has some advantages in data communication. There are still problems in the process of this study that need to be optimized and improved. When wireless connection and transmission of data are carried out at the same time by multiple wireless network handheld terminals, the anti-interference ability should be strengthened to increase the stability of the system. The complex verification function can be added to the communication protocol and the data can be encrypted, so as to ensure the integrity and correctness of the data. In addition, the system also needs multi communication server to support the access of multi devices. In the next step, the load balancing strategy of communication server will be adopted to divide the background of the system into communication server and directory server. Any device connected to the server for the first time must first access the directory server. The directory server assigns the device to the designated communication server according to the records of the database, so that more handheld terminals can be carried as much as possible.

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References

- [1] Valenzuela-Venegas G, Vera-Hofmann G, Diaz-Alvarado FA. Design of sustainable and resilient eco-industrial parks: planning the flows

- integration network through multi-objective optimization. *J Clean Prod.* 2020;243(Jan.10):118610.1–25.
- [2] Bastianoni S, Coscieme L, Caro D, Marchettini N, Pulselli FM. The needs of sustainability: the overarching contribution of systems approach. *Ecol Indic.* 2019;100(May):69–73.
- [3] Kasimu Y, Simayi Z, Wang L, Bayi X. Response of ecological environment change to urban construction land expansion in Bole city of Xinjiang. *Nongye Gongcheng Xuebao/Trans Chin Soc Agric Eng.* 2019;35(1):252–9.
- [4] Fridman D, Kissinger M. A multi-scale analysis of interregional sustainability: applied to Israel's food supply. *Sci Total Environ.* 2019;676(Aug.1):524–34.
- [5] Lu S, Qin F, Chen N, Yu Z, Xiao Y, Cheng X, et al. Spatiotemporal differences in forest ecological security warning values in Beijing: using an integrated evaluation index system and system dynamics model. *Ecol Indic.* 2019;104(Sep):549–58.
- [6] Kim B, Ji K, Kim C, Kang H, Lee S, Kwon B, et al. Pharmaceutical residues in streams near concentrated animal feeding operations of Korea - occurrences and associated ecological risks. *Sci Total Environ.* 2019;655(Mar.10):408–13.
- [7] Jaiswal D, Pandey J. An ecological response index for simultaneous prediction of eutrophication and metal pollution in large rivers. *Water Res.* 2019;161(Sep.15):423–38.
- [8] Kalabin GV. Ecological sustainability indicators of the mining industry areas in Russia. *J Min Sci.* 2020;56(3):486–93.
- [9] Wang C, Zhao H. Analysis of remote sensing time-series data to foster ecosystem sustainability: use of temporal information entropy. *Int J Remote Sens.* 2019;40(7–8):2880–94.
- [10] Bamgbade JA, Kamaruddeen AM, Nawi M, Adeleke AQ, Salimon MG, Ajibike WA. Analysis of some factors driving ecological sustainability in construction firms. *J Clean Prod.* 2019;208(PT.1-1658):1537–45.
- [11] Amiri Z, Asgharipour MR, Campbell DE, Armin M. A sustainability analysis of two rapeseed farming ecosystems in Khorramabad, Iran, based on emergy and economic analyses. *J Clean Prod.* 2019;226(Jul 20):1051–66.
- [12] Barrahmoune A, Lahboub Y, Ghmari AE. Ecological footprint accounting: a multi-scale approach based on net primary productivity. *Environ Impact Assess Rev.* 2019;77(Jul):136–44.
- [13] Chen W, Cao C, Liu D, Tian R, Wu C, Wang Y, et al. An evaluating system for wetland ecological health: case study on nineteen major wetlands in Beijing-Tianjin-Hebei region, china. *Sci Total Environ.* 2019;666(May 20):1080–8.
- [14] Mondal MM, Speier CJ, Weichgrebe D. Multi-stage optimization approach for sustainable municipal solid waste collection systems in urban areas of Asia's newly industrialized countries. *Environ Manag.* 2019;63(4):1–18.
- [15] Li H, Zhao Y, Zheng F. The framework of an agricultural land-use decision support system based on ecological environmental constraints. *Sci Total Environ.* 2020;717(May15):137149.1–10.
- [16] Quan VD, Momblanch A, Adeloye AJ. Adaptation by Himalayan water resource system under a sustainable socioeconomic pathway in a high-emission context. *J Hydrol Eng.* 2021;26(3):1–13.
- [17] Agarwal S, Patil JP, Goyal VC, Singh A. Assessment of water supply-demand using water evaluation and planning (WEAP) model for Ur river watershed, Madhya Pradesh, India. *J Inst Eng (India).* 2019;100(1):21–32.
- [18] Liu H, Liu Y, Wang H, Yang J, Zhou X. Research on the coordinated development of greenization and urbanization based on system dynamics and data envelopment analysis: A case study of Tianjin. *J Clean Prod.* 2019;214(Mar.20):195–208.
- [19] Esmaeili E, Shahbazi F, Sarmadian F, Jafarzadeh AA, Hayati B. Land capability evaluation using NRCS agricultural land evaluation and site assessment (LESA) system in a semi-arid region of Iran. *Environ Earth Sci.* 2021;80(4):1–14.
- [20] Gainer A, Bresee K, Hogan N, Siciliano SD. Advancing soil ecological risk assessments for petroleum hydrocarbon contaminated soils in Canada: persistence, organic carbon normalization and relevance of species assemblages. *Sci Total Environ.* 2019;668(Jun.10):400–10.