Research And Design of Intelligent Home Potting System Technology By Wireless Sensor Networks

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Abstract. People often put potted plants at home in life, but they neglect to cultivate them due to busy work and study, or the lack of expertise related to potted plant cultivation leads to rotten and withered plants. An Exynos 4412 development board with a Linux system and multiple information acquisition sensors is designed using time series for this life background. The system is an intelligent home potted plant system with a Linux-based Exynos 4412 development board and multiple information collection sensors, using a time-series prediction model, deep convolutional neural network model, message queue telemetry transmission protocol, cloud storage and other technologies. The system realizes automatic scientific irrigation, soil fertility monitoring, and pest and disease warning for potted plants, thus ensuring healthy and robust growth of potted plants, and has a broad market space.

1. Introduction
People regard green plants as an essential element in home design but neglect to cultivate potted plants due to work and study, resulting in rotten roots and withered potted plants [1]. There are many intelligent potted plants on the market under the banner of "smart". However, they are still using sensor technology for data collection, and users can only set parameters manually and mechanically by subjective experience, which lacks guidance for users to cultivate potted plants in a timely and quantitative manner. The intelligent home potted plant is equipped with an Exynos 4412 development board, which is mainly used for intelligent control of irrigation after data analysis through sensor collection and is supplemented by collecting potted plant growth conditions for a personalized user control scheme. The control algorithm of the irrigation system introduces time series prediction method to analyze and predict the water consumption of plants to improve the precise control of irrigation, thus ensuring the healthy growth of plants and improving the efficiency of water consumption. The plant growth is photographed and monitored by camera sensors, and image analysis-based technology for identifying plants and their pests and diseases is introduced to provide timely processing and user alerts for abnormal potted plant growth. The intelligent home potting system reduces the learning cost of users' professional knowledge, changes the traditional control method of irrigation, and realizes real-time monitoring and analysis of potted plants' growth and differential automatic management and control for plant characteristics.

2. Intelligent home potting system overall design ideas
The intelligent potted plant consists of a pot body, soil sensor (soil pH, temperature and humidity, nitrogen, phosphorus, and potassium sensors), light sensor, camera module, XUNWEI Exynos 4412 development board (onboard Bluetooth and Wi-Fi module, CAN/RS-485 module, etc.), LED display, far-red and red-blue light combination of plant fill light, etc. The system structure is designed through the Wi-Fi module of the XUNWEI Exynos 4412 development board. The system structure is connected...
Partial autocorrelation (PACE)

To the home LAN wireless network through the Wi-Fi module of the XUNWEI Exynos 4412 development board, and the data collected by the sensor is uploaded to the cloud Ali cloud server for processing and database storage to realize the communication connection with the mobile App client. Thus, the data detected by the sensor such as light intensity, soil temperature and humidity, pH value, nitrogen, and phosphorus fertilizer, potted plant images are visually displayed to the user. It also gives the prediction plan of potted plant care after data analysis, which helps to grasp the real-time condition of plant growth. The intelligent home potted plants are connected to the Xiaomi IoT platform and support the voice control function of Xiaoxia classmate speakers so that users can communicate with them in a simple dialogue, which makes the planting process more vivid and exciting.

3. Soil moisture prediction and irrigation water consumption prediction

The smart home potting system predicts the time series by introducing regression prediction, a prediction method in which the values of soil moisture and each irrigation water consumption are ranked into the resulting series in chronological order, respectively. The time series is then compiled and analyzed to predict the values that may be reached in the next period based on the trend reflected in the time series. The stable growth environment of a potted plant depends on whether the water content of the soil is within a scientifically reasonable range, and changes in the percentage of soil water content in a potted plant can be sensed in advance by soil moisture prediction and controlled irrigation of the solenoid valve in advance when the potted plant is on the verge of a water shortage state so that the soil moisture varies steadily between reasonable moisture thresholds set for that plant [2]. The change of soil humidity is dynamic, and different weather conditions cause the air humidity and temperature in the room to change and other factors that affect the evaporation effect of the soil. The time series method for predicting soil moisture in the smart home potting system uses an automatic regression moving average model with exogenous inputs (ARMAX model for short). The ARMAX model can integrate these factors into the regression prediction function for soil moisture, making it possible to accurately predict the soil moisture situation at a certain moment in the future, greatly improving the accuracy of the prediction. The water consumption of a potted plant refers to the water consumption caused by the plant's respiration and photosynthesis and the water consumption caused by external factors such as soil evaporation. The water consumption of a potted plant can be considered equivalent to the water consumption of a potted plant during irrigation, so the precise control of the water consumption of a potted plant can be determined by the predicted water consumption of a potted plant. Similarly, the water consumption of potted plants can be predicted by building an ARMAX model. When the irrigation water consumption reaches the predicted potted plant water consumption value, the solenoid valve stops working to keep the soil moisture within a scientifically reasonable range. However, in the beginning, there is no historical irrigation water consumption record in the database, so we can only control the irrigation water consumption by setting the initial threshold value of soil moisture and then detecting the change of soil moisture after each irrigation to control the soil moisture within a reasonable range. When there is enough irrigation water consumption data, the electronic valve is then controlled using the potted plant water consumption prediction. Subsequently, at each irrigation, the system builds a water consumption prediction model with data such as the historical water consumption of potted plants and the peak value reached by soil moisture after that irrigation to ensure that the prediction model is dynamically updated in real-time. The ARMAX modelling process is as follows: (1) pre-process the data series to obtain a smooth series; (2) generate the autocorrelation (ACF) function and partial autocorrelation (PACE) function respectively from the series before modelling. (2) Before modelling, the correlation graphs of the autocorrelation function (ACF) and partial autocorrelation function (PACF) were generated, and the characteristics of the correlation graphs selected the ARMAX model based on the ARMA model; (3) the optimal order of the ARMAX model was determined by using the criterion of red pool information; (4) the unknown parameters of the model were estimated; (5) the predicted values of the model were analyzed by the cumulative and sequential analysis method (CU-SUM) to determine whether the potted plants were water-deficient and the water consumption of the potted plants. ARMAX model prediction expressions are as follows: $y_k = a_1 y_{k-1} + \cdots + a_n A y_{k-n} + a_{n+1} u_{k-1} + \cdots + b(1) y_{k-d(1)} + \cdots + b(n) u_{k-n} + u_{k}$
The data in the system are stored using a MySQL database, and the stored data include information on potted plant species, values of temperature, humidity, nitrogen, phosphorus and potassium collected by sensors, watering water consumption data, and predicted values [3]. Soil moisture prediction and irrigation water consumption prediction system module is mainly controlled by Exynos 4412 development board, soil sensor is connected to RS-485 port of development board and inserted into potted plant soil, watering pump module is connected to relay. Finally, to verify the accuracy of the model, soil moisture prediction is used as an example, and the predicted value of soil moisture stored in the database at regular intervals and the actual detected value are compared by function. The fair comparison shows that the fluctuations of the two lines are the same, and the fit is good. The Exynos 4412 RS-485 port principle is shown in Figure 1.

**Figure 1. Exynos 4412 RS-485 port principle**

### 4. Plant pest and disease identification

Data collection shows that the appearance of disease spots on the leaves of plants is often the basis for the appearance of most plant diseases and pests, and the texture, colour and shape of the disease spots on the leaves are different for different diseases, and the leaves survive for a long time and are easy to collect [4]. The colour of leaf images is essential for plant disease and pest recognition, so three-channel CNNs are constructed and applied to plant disease and pest recognition. In the study of plant disease leaf image feature extraction and disease classification, the process is summarized as follows:

1. Image collection and pre-processing. The original images of pest and disease leave corresponding to common potted plants grown at home are collected, and the leaf pest and disease images are collected by offline shooting as well as online crawling, using random flipping, colour dithering, and multi-angle rotation for each image to get a large number of datasets. And then randomly divided into training and test sets to avoid overfitting when training the model. The imread function processes each pest leaf image in MATLAB to get an RGB three channel spatial image and then normalized as the first convolutional layer object of the input layer into CNNs.

2. Model design. A three-channel CNNs model is designed for the intelligent home potting system. If the size of the input bilinear interpolation cropped leaf images are all n × n, the size of the convolutional kernel is k × k, the size of the local window using the maximum value for pooling operation is p × p, the number of neurons in the fully connected layer is about 1000, and the output layer is outputting C neurons of C plant disease types. The convolutional layer is obtained by a convolutional kernel of size k × k. Each neuron is convolved in a k × k field of perception specified by the input pest leaf image to obtain several different feature maps of size (n - k + 1) × (n - k + 1), which are then computed by the ReLU activation function and output to the pooling layer. The pooling layer downsamples the feature maps of the previous convolutional layer [5]. The maximum pooling operation used downsamples the maximum value in the p × p region of the feature map of the previous convolutional layer for aggregation statistics, but the feature map size remains unchanged. The two fully connected layers F contain 1000 fully connected neurons to S3. A SoftMax classifier is selected in the output layer to calculate the probability of the input samples falling into each category, and then image recognition is performed.
(3) Parameter initialization. Before starting training CNNs, the weight and bias parameters need to be initialized, often in the range of \([-0.5,0.5]\) or \([-1,1]\). (4) Fine-tuning. Fine-tuning uses the training database to train the trained CNNs to make the trained model parameters fit the current database, and the experimental results of four common indoor potted plants were cross-validated with ten folds and repeated 60 times. The recognition effect of the three-channel CNNs-based pest recognition method used for intelligent home potted plants is excellent (see Figure 2).

![Figure 2. The Relative soil moisture](image)

5. Conclusion
In conclusion, intelligent home potted plants are irrigated and controlled by soil moisture prediction and irrigation water consumption prediction based on the time series prediction method. The soil temperature and humidity, nitrogen, phosphorus, and potassium data are accurately monitored to provide a suitable growth environment for plant growth plants to thrive. Intelligent home potted plant automatic management control will free consumers from learning professional planting knowledge boring, anytime, anywhere a variety of ways to view the growth of potted plants, access to the Mi Home IoT platform, Xiaoxia classmates intelligent voice control for potted planting adds fun and convenient. Other home equipment scene linkage allows consumers to integrate into a comfortable, healthy, efficient, intelligent, bright home life.

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