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# Research on the Optimization of Machine Learning - Based Agricultural Irrigation Equipment

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**Abstract:** ***This article proposes a machine learning-based optimization method for agricultural irrigation equipment. Firstly, data and discretization processing are applied to irregular farmland to extract edge data and internal data points. Secondly, the k-means clustering algorithm is employed to optimize the positions of sprinklers, minimizing the distance between sprinklers within the same group and maximizing the distance between different groups, achieving intelligent allocation of sprinkler positions. Finally, a specialized agricultural irrigation equipment optimization software is designed and developed, capable of importing farmland data, setting random seeds and sprinkler quantities, applying the k-means clustering algorithm for optimization, and displaying the optimized results. This method utilizes machine learning algorithms to achieve intelligent optimization of agricultural irrigation equipment, enhancing water resource efficiency, reducing irrigation costs, and providing support for sustainable agricultural development.***

**Keywords:** Alien farmland; Sprinkler optimization; Programming; K-means algorithm.

## 1. INTRODUCTION

With the continuous growth of the global population and the impact of climate change, agricultural production is facing greater challenges. Irrigation, as a crucial component of agricultural production, not only directly affects the growth and development of crops but also holds significant importance in the rational utilization of water resources. In order to improve the efficiency of field irrigation and conserve water resources, the introduction of machine learning technology for optimizing agricultural irrigation equipment has become a current research hotspot. Basil Manos et al. [1] proposed a mathematical model based on multi-objective planning for sustainable optimization of agricultural production. This model serves as a tool for analyzing agricultural production plans and studying the impact of agricultural policies. Mo Li, Ping Guo, and Vijay P. Singh [2] presented a dual-objective planning model to address the fuzzy uncertainty in irrigation water allocation. The model aims to maximize agricultural water resource productivity while minimizing irrigation water shortages. Songhao Shang and Xiaomin Mao [3] introduced a simulation-optimization model for winter wheat irrigation scheduling to achieve higher crop yields under limited irrigation water conditions. The model considers soil water balance and dated crop water production functions, obtaining optimal irrigation scheduling through the Nelder-Mead nonlinear simplex method. Results indicate that optimal irrigation dates and corresponding relative yields are closely related to irrigation quotas and initial soil moisture conditions. This model can guide irrigation management. Huang et al. [4] proposed a two-stage interval quadratic programming (TIQP) method for agricultural water resource planning and management. This method can handle nonlinearity in cost-effectiveness objectives and uncertainty represented in probability and interval forms. Basil Manos et al. [5] introduced a multi-objective planning-based agricultural production optimization model to enhance the policy-making process and simulate more realistic decision processes. The model simultaneously optimizes total revenue maximization, fertilizer use minimization, and labor use minimization, automatically estimating the quantities of fertilizer and irrigation water use. Ajay Singh [6] provided a review of various programming techniques used in the past for irrigation planning and management. Enrique Playa´n [7] suggested that improving irrigation management in modernizing irrigation systems is more economically beneficial than enhancing irrigation infrastructure.

This study primarily utilizes machine learning algorithms to optimize irrigation equipment for irregular-shaped farmland, providing a general model and solution.

## 2. OPTIMIZATION DESIGN OF AGRICULTURAL FIELD IRRIGATION EQUIPMENT

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### 2.1 Digitization and Discretization of Irregular-shaped Agricultural Fields

In practical agricultural production, the shapes of agricultural fields often exhibit complex and irregular features. This irregularity poses a series of challenges for the rational layout of irrigation equipment, potentially leading to issues of resource wastage. To address this problem, the first step is to digitize and discretize these irregular agricultural fields. When facing the challenge of irregular field shapes, digitization allows us to collect and organize a large amount of geographical information, land survey data, and crucial data related to field boundaries. This process helps establish detailed maps of the agricultural fields, accurately documenting essential information such as the shape, size, and geographical location of each piece of land. Advanced technologies such as Geographic Information Systems (GIS) and satellite remote sensing tools can be utilized to accomplish this task.

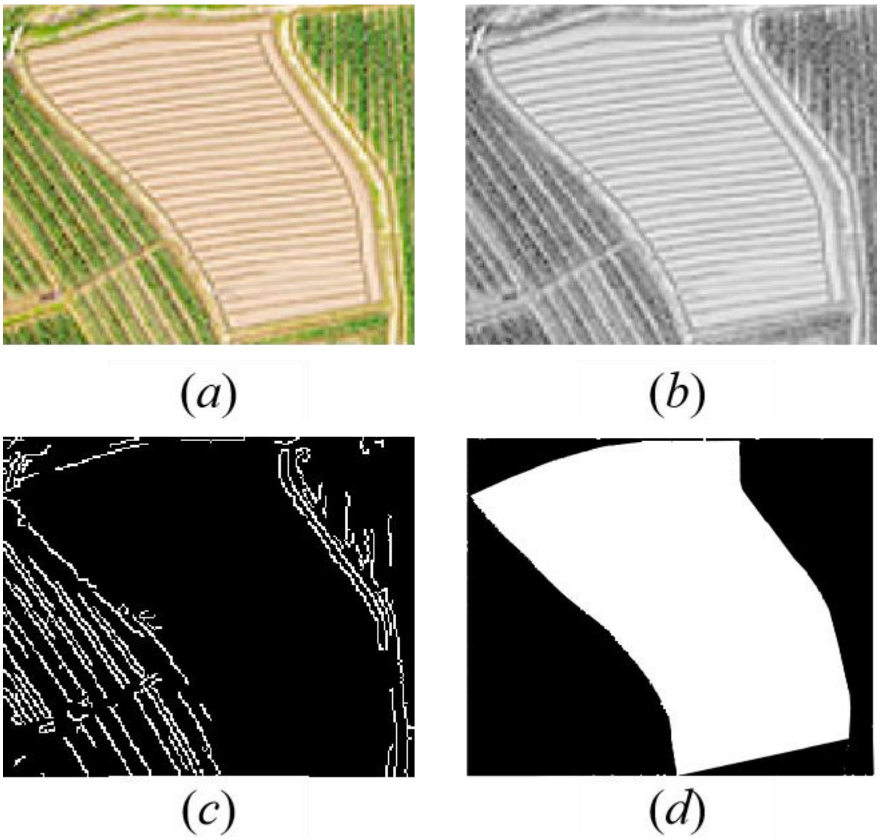



**Figure 1:** Effect Diagram of Irregular Farmland Processing

As shown in Figure 1, image (a) illustrates the initial state of the irregular farmland. To obtain this image, we initially employed an aerial photography approach to comprehensively capture the overall shape of the farmland. After obtaining the image, we conducted grayscale processing, as depicted in image (b). The purpose of this step is to simplify the image information in preparation for the subsequent extraction of the farmland contours. Following the grayscale processing of the image, we utilized the Canny algorithm for edge detection, resulting in data points outlining the farmland edges, as shown in image (c). The application of the Canny algorithm aids in accurately capturing changes in the edges of the image, thereby better depicting the contours of the farmland. Based on these edge data points, we successfully obtained the internal regions of the farmland, as depicted in image (d).

Through this series of image processing steps, we achieved information extraction and data processing for irregular farmland, laying the foundation for further farmland management and planning. This approach not only simplifies the shape of the farmland but also enhances the accuracy of the farmland contours, providing a reliable basis for the layout of irrigation equipment and the management of agricultural production.

With the preliminary processing of irregular farmland, edge data and internal regions of the farmland can be obtained. Furthermore, we discretize the internal regions of the farmland, as shown in Figure 2.

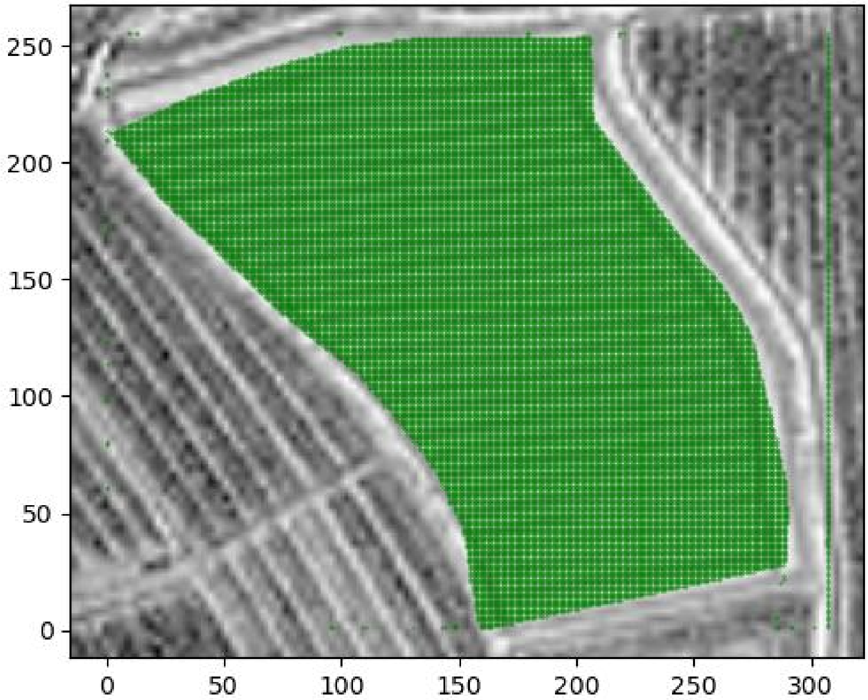



**Figure 2:** Discretization of Farmland Internal Data

By discretizing the internal data of farmland, the positions of data points within the farmland can be obtained, providing crucial data for optimizing the placement of irrigation equipment in subsequent stages.

### 2.2 Optimization of Irrigation Equipment Placement

This article utilizes a k-means clustering model to optimize the placement of irrigation equipment. For ease of description, the following concepts are defined in this article:

Definition 1 Xi is the i-th object to be clustered, where Xi =(xi1,xi2,...,xim) and xij represents the j-th indicator of the i-th object. i = 1, 2, ..., n. j = 1, 2, ..., m.

Definition 2 Li is the classification label of the i-th object. Li ∈{1, 2, ..., k}. i = 1, 2, ..., n.

Definition 3 Ci represents the centroid of the i-th cluster. Ci =(ci1,ci2,...,cim), i = 1, 2, ..., k.

Definition 4 Ui represents the i-th cluster, Ui ={Xj(i)}, where Xj(i) represents the j-th object assigned to the i-th cluster.

|Ui |denotes the number of objects in Ui.

STEP1: Randomly select (without replacement) k samples from the dataset as initial cluster centers.

**Table 1:** Process of Randomly Selecting Cluster Centers

| Step | Operation |
|---|---|
| Step 1 | i takes 1. H = {X1, X2, ... ,Xn} |
| Step 2 | Ci = random(H) , where random(X) randomly selects an element from set X. |
| Step 3 | H = H/{Ci} |
| Step 4 | If i<k ,then i = i+1 and return to Step 2; otherwise, end. |

STEP2: Assign labels to the samples.

**Table 2:** Assigning Labels to Samples

| Step | Operation |
|---|---|
| Step 1 | i takes 1. |
| Step 2 | Calculate the distance Dij between sample Xi and Cj, j = 1, 2, ..., k. |
| Step 3 | Li = argmin(Di1, Di2, ..., Dik), where argmin(x1,x2,...,xj) returns the index of the minimum value. |
| Step 4 | If i < n ,then i = i+1 and return to Step 2; otherwise, end. |

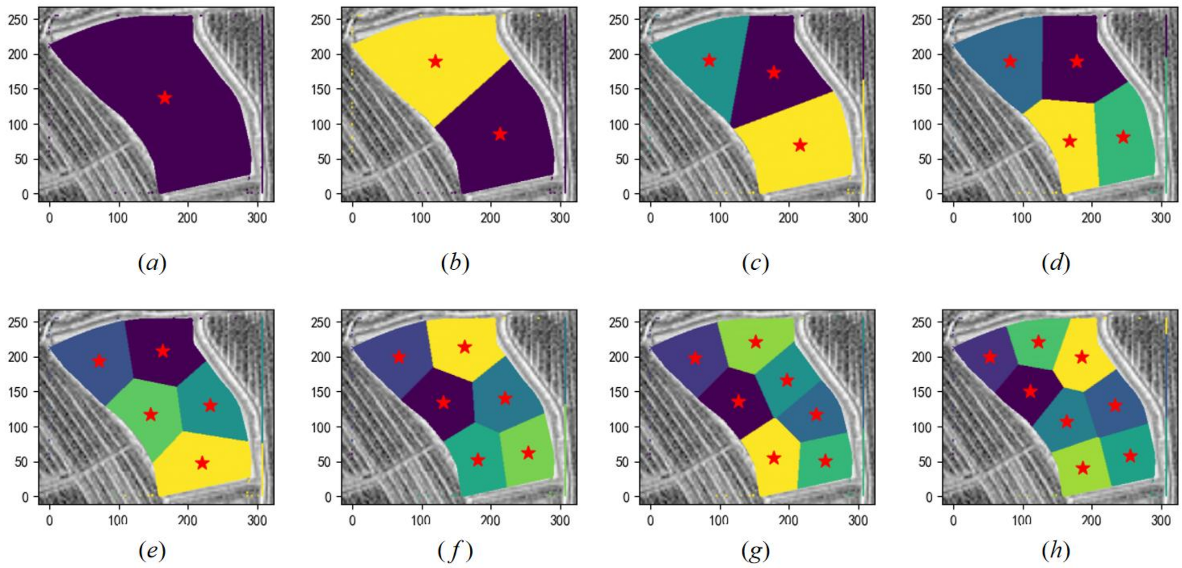
In Step2 of Table 3, Dij calculations use Euclidean distance.

$$D_{ij} = \sqrt{\sum_{h=1}^{m} (x_{im} - c_{jm})^2} \tag{1}$$

STEP3: Optimizing Cluster Centers

$$c_{ij} = \frac{1}{|U_i|} \sum_{h=1}^{|U_i|} x_{hj}^{(i)} \tag{2}$$

Irregular farmland underwent k-means clustering, yielding the results shown in Figure 3.



(a) (b) (c) (d)
(e) (f) (g) (h)

**Figure 3:** Clustering Effect of Irregular Farmland Irrigation

As shown in Figure 3, we conducted tests for eight scenarios with different numbers of sprinklers ranging from 1 to 8, displaying the corresponding optimal positions in (a) to (h). It can be observed from the Figures that the coverage areas of each sprinkler are relatively uniform, ensuring efficient utilization of sprinkler resources. This testing and analysis contribute to finding the most effective sprinkler layout, enhancing water resource utilization efficiency.

To further optimize the positions of the sprinklers, we employed the k-means clustering algorithm. This algorithm clusters the sprinkler positions, grouping them into several clusters to achieve position optimization. The goal of clustering is to minimize the distance between sprinklers within the same group while maximizing the distance between different groups. Through this approach, we can arrange the sprinkler positions more rationally to achieve optimal irrigation results.

This optimization method based on the k-means clustering algorithm provides an intelligent solution for the layout of irrigation equipment in irregular farmland, with the potential to improve water resource utilization efficiency, reduce waste, and promote sustainable development in practical agricultural management.

## 3. DESIGN OF IRRIGATION EQUIPMENT OPTIMIZATION SOFTWARE FOR FARMLAND

To conveniently optimize irrigation equipment for different farmlands, our team has developed a specialized software designed to address such problems more effectively.
Upon opening the software interface, you will find a clean window containing buttons for importing farmland data, setting random seeds, conFigureuring the number of sprinklers, as well as buttons for starting optimization and saving results, as illustrated in Figure 4.


**Figure 4:** Software Interface

Click the "Import Data" button in the window, and the system will prompt a file selection dialog. You can choose an .xlsx spreadsheet file containing farmland data and proceed with the import, as shown in Figure 5.

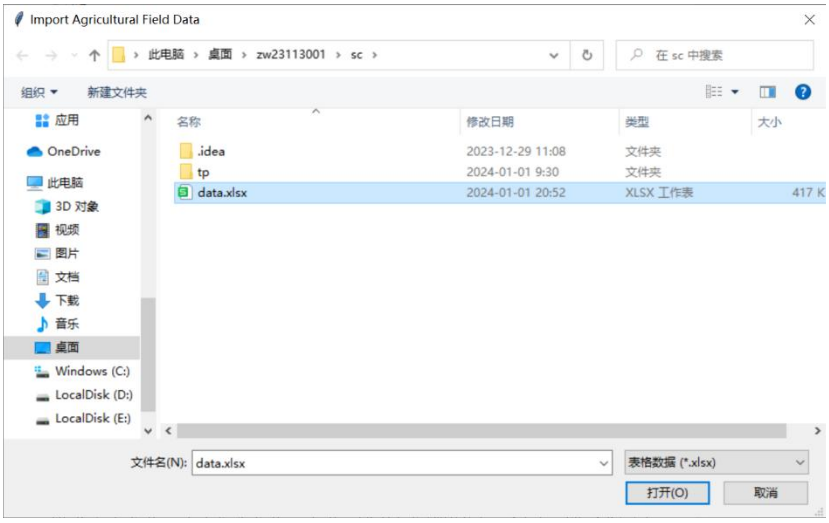



**Figure 5:** File Selection Dialog

After successful import, the software will display a scatter plot of agricultural field data, allowing you to intuitively understand the data distribution, as shown in Figure 6.

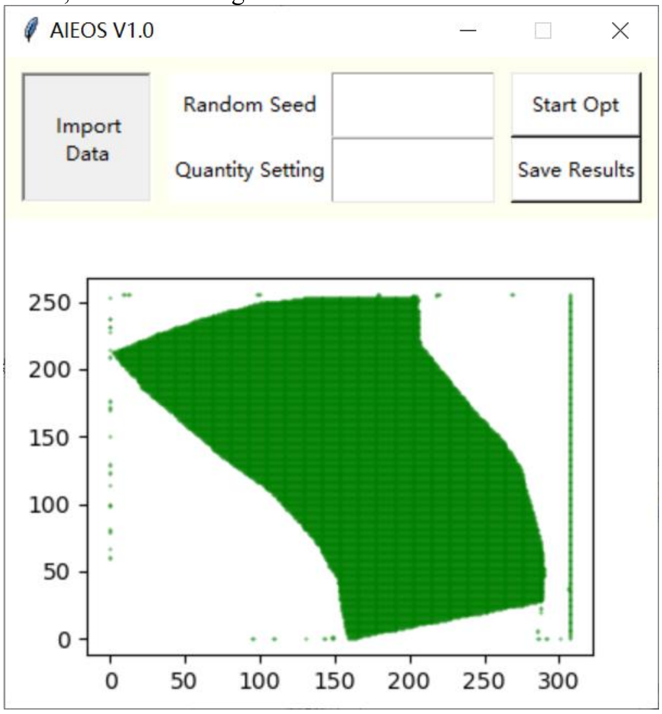



**Figure 6:** Data Presentation

Locate the "Random Seed" and "Sprinkler Quantity Settings" tabs on the interface, and input the corresponding values. The random seed affects the algorithm's random initialization, while the sprinkler quantity determines the number of clusters in the clustering process. Make sure to input integer values. After entering the random seed and sprinkler quantity, click the "Start Optimization" button. The software will apply the K-means clustering algorithm to optimize the imported farmland data. During the optimization process, the software will display the algorithm's progress and eventually present a visualization of the optimized clustering results, marking the cluster centers of each cluster, as shown in Figure 7.

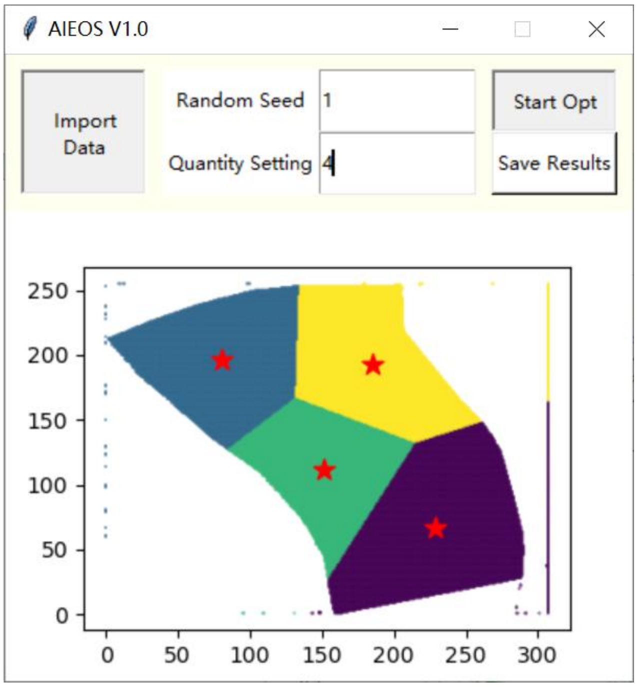



**Figure7:** Optimization Results Display

Through the simple steps outlined above, this agricultural irrigation equipment optimization software can be easily utilized to provide personalized irrigation solutions for various farmlands. This helps enhance water resource utilization efficiency and reduce irrigation costs.

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