Scholar Publishing Group
Kinetic Mechanical Engineering
https://doi.org/10.38007/KME.2022.030102
ISSN 2790-2676 Vol. 3, Issue 1: 9-17

A Solar Panel Classification System Incorporating Finite Difference Method

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Keywords: Finite Difference Method, Solar Panel, Classification System, Polycrystalline Silicon Solar Panel

Abstract: At present, some manufacturers still use the human eye to detect the color and defects of classified solar panels. Due to the easy fatigue of human eye, it is easy to cause misjudgment, which eventually affects the quality of solar panels. In order to solve the shortcomings of the existing solar panel classification research, this paper briefly discusses the data collection and development environment of the classification system based on the discussion of solar panel types and the stability conditions of the finite difference method solution. And the design of solar panel classification system by finite difference method is discussed, and finally the accuracy of finite difference method for solar panel polycrystalline hanging defects classification is compared with classification decision tree (DT), neural network (RNN) and SVM for experimental analysis. The experimental data show that the classification accuracy of finite difference method reaches the highest 91.7% and the lowest 89.8%. The classification accuracy of the other three methods was significantly lower than that of the finite difference method. Therefore, it is verified that the solar panel classification system incorporating the finite difference method has good performance results.

1. Introduction

The main carrier for converting light energy into electricity is crystalline silicon for the solar cells widely used in the market. Since polycrystalline silicon solar cells have many defects in the production process. Defects in a single cell can even affect the overall power generation efficiency of the entire photovoltaic group. Therefore, the defect detection of solar cells is of great significance to improve the production quality and the economic efficiency of enterprises.

Nowadays, more and more scholars have conducted a lot of researches through various technologies and system tools in the dissemination of the concept of education of Internet teaching culture, and after practical researches, certain research results have also been achieved.Bray proposes a machine vision-based solar panel defect detection for the problems of low efficiency, slow detection speed and low detection accuracy of traditional solar panel defect detection methods. method, using a combination of software and hardware. According to the requirement of measurement accuracy, a mobile platform suitable for solar panel image capture is designed, based on which a support vector machine (SVM) image classification system is used to detect solar panel defects, and a classifier is generated using classification samples. Experiments show that the defect detection accuracy of this method is higher than 95% and the method has wide practical value [1].Izumo established an end-to-end fault detection system based on electroluminescence (EL) imaging to detect and locate faults in solar panels. And proposed the design and implementation of an end-to-end system that first divides solar panels into individual solar cells, then these cell images are passed through a classification + detection pipeline to identify the fault type and locate the faults inside the cells A hybrid architecture is proposed that contains the integration of multiple CNN model architectures for classification and detection. The integrated system is capable of providing both monocrystalline and multicrystalline solar panels. The proposed system greatly helps to improve the efficiency of solar panels and reduce warranty and maintenance costs [2].Danmaraya I A created a world map of solar panels. The location and total surface area of solar panels are determined within a given geographical area. The location of solar panels and their surface area are automatically detected using deep learning methods using aerial images. The framework consists of two branching models, using an image classifier and a semantic segmentation model, trained on a satellite image dataset we created. This study provides an efficient and scalable method for detecting solar panels, achieving a classification accuracy of 0.96 and [3]. Although there is a wealth of existing research on the dissemination of the nurturing concept of Internet teaching culture, there are certain shortcomings in the research on the dissemination of the nurturing concept of Internet teaching culture based on digital media technology.

The progress of solar power technology is relatively slow, and an important factor is that the photoelectric conversion efficiency of solar panels is not high enough. The surface grain boundary pattern of polycrystalline silicon solar panels has a certain influence on the photoelectric conversion efficiency of solar panels. In order to enrich the existing solar panel classification research, this paper designs a set of fusion by classifying monocrystalline silicon, polycrystalline silicon, amorphous silicon solar cells and compound solar cells on the basis of the discussion of the four panel classifications and the analysis of the stability conditions of the finite difference method solution. A classification system of polycrystalline silicon solar panels with finite difference method is designed. The performance of the solar panel classification system incorporating the finite difference method is tested based on the collected data set. The feasibility of the finite difference method for solar panel classification is verified.

2. Solar Panel Classification System Incorporating Finite Difference Method

2.1. Solar Panel Classification

(1) Monocrystalline silicon solar cells

Monocrystalline silicon solar cells are solar cells developed with high purity monocrystalline silicon as raw material. Compared with polycrystalline silicon cells and amorphous silicon cells, monocrystalline silicon cells have the highest photoelectric conversion efficiency [4-5]. The crystalline silicon of monocrystalline silicon cells is pure and has uniform optical, mechanical and electrical properties. For the characteristics of high conversion efficiency, large cost and good performance of monocrystalline silicon cells, monocrystalline silicon solar cells are currently mostly used in photovoltaic power plants, aircraft power supplies and focused photovoltaic power generation systems [6].

(2) Polycrystalline silicon solar cells

Due to the different production processes, the performance, cost, color and monocrystalline silicon solar cells are also very different, there are mainly the following significant differences [7].

1) photoelectric conversion efficiency: the photoelectric conversion efficiency of polycrystalline silicon solar panels is relatively lower than that of monocrystalline silicon, generally about 17% [8].

2) physical properties: the electrical, mechanical and optical properties of polycrystalline silicon panels are much inferior to those of monocrystalline silicon panels [9].

3) production costs: compared with the high price of monocrystalline silicon cell materials and complicated processes, polycrystalline silicon cells are less expensive to produce, the production process is relatively easy, and can be achieved in large-scale industrial production [10].

(3) Amorphous silicon solar cells

Amorphous silicon solar cells, also known as thin film solar, amorphous silicon solar cells manufacturing process is different from crystalline silicon solar cells, its process is simple, silicon consumption is low [11]. The biggest advantage of amorphous silicon solar cells is that it can significantly reduce the pollution of silicon materials brought about by the production of production, further reducing the possibility of environmental pollution [12].

(4) Compound solar cells

Compound solar cells are solar cells made of multiple elements doped with semiconductors. At present, compound solar cells have not been able to achieve large-scale industrialization, mainly because: the efficiency improvement is not significant, the material contains highly toxic, high material costs, the production process is cumbersome [13]. Therefore, compound solar cells are still in the stage of research and development testing.

2.2. Finite-Difference Method

In the finite-difference method, we sample the electromagnetic field in a discrete pointwise manner, however, this operation must be limited to ensure the stability of the whole algorithm. That is, the two steps we mentioned before must conform to certain numerical relations between them, then we must find the corresponding relations between Δc and Δi, Δj and Δk to guarantee the stability of our algorithm [14].

The Courant stability condition for the two-dimensional numerical wave is:

$$v\Delta c \le \frac{1}{\sqrt{\frac{1}{(\Delta i)^2}+\frac{1}{(\Delta j)^2}}} \tag{1}$$

This formula can well restrict the stability between two steps, and we can obtain the numerical stability condition of the 3D FDTD by analogy, which is a natural extension of the above formula in the form of:

$$\Delta c \le \frac{1}{\sqrt{(\frac{1}{\Delta i})^2 + (\frac{1}{\Delta j})^2 + (\frac{1}{\Delta k})^2}} \tag{2}$$

If a uniform cube network is used, that is, there exists an equation $\Delta i = \Delta j = \Delta k = \Delta t$. Substituting this equation into the above equation (2), we obtain the stability judgment formula of the following type:

$$\Delta c \le \frac{\Delta t}{v\sqrt{3}} \tag{3}$$

3. Investigation and Research on The Construction of Solar Panel Classification System Incorporating Finite Difference Method

3.1. System Development Environment

The solar panel classification system designed in this paper mainly runs on two major programming environments: MATLAB and C++, with MATLAB version 2016a selected for MATLAB and the OpenCV library under C++11 standard selected for C++, with OpenCV version 3.2 [15]. In order to test the performance and stability of the program, in this paper, after the code was completed, the program was debugged on several hardware machines and different operating systems, and the list of hardware devices and operating platforms is shown in Table 1 [16].

Table 1. hardware configuration and operating platform parameters

Project	LenovoY400	Desktop
System	Windows10 Enterprise edition	Windows10 Enterprise edition
CPU	Core(TM)i5-3230M	AMDRyzen51600
Memory	8GB	16GB
Hard disk space	1TB Mechanical drive	256GBSolid state drives
The operating system	MATLAB7.0 VS2019	MATLAB7.0

3.2. Data Collection

In the finite difference method for detecting classification tasks, the original data set is divided into a training set, a validation set and a test set. The training set is used to determine the difference format, stability of the solution, and absorption boundary conditions [17]. In addition to a portion of the training set that is directly involved in the training process of classification, another portion is used as the validation set to validate the trained model. The test set is used to examine whether the model detection classification accuracy and classification efficiency can meet the practical requirements [18]. The test samples were collected by the staff of solar cell manufacturers to form the data set for this test. However, due to the uneven number of samples collected for each type of defects, a data enhancement method was used to add a few types of samples to ensure a balanced amount of data and to meet the data requirements for model training. The distribution of the number of samples is shown in Table 2.

Table 2. data distribution

The data set	Swim vortex defects	High purity	The edge is not pure	There are too many dislocation defects	The total number
The training set	450	510	480	520	1490
Validation set	490	530	620	580	2220
The test set	460	570	610	550	2190

4. Application Research on The Construction of Solar Panel Classification System Incorporating Finite Difference Method

4.1. Calculation Process Design of Solar Panel Classification With finite Difference Method

Based on the above research results and discussion, this experiment takes the optimization scheme of the defect location and area comparison characteristic difference as the main classification method for the polycrystalline hanging defects of solar panel, and the test classification of the sampling gray equivalence curve fitting standard deviation and finite difference method difference calculation for monocrystalline cinnamon wafer. Therefore, according to the above analysis, we can use the finite difference method for wafer defect detection method, and the constructed finite difference method detection classification model is shown in Figure 1.

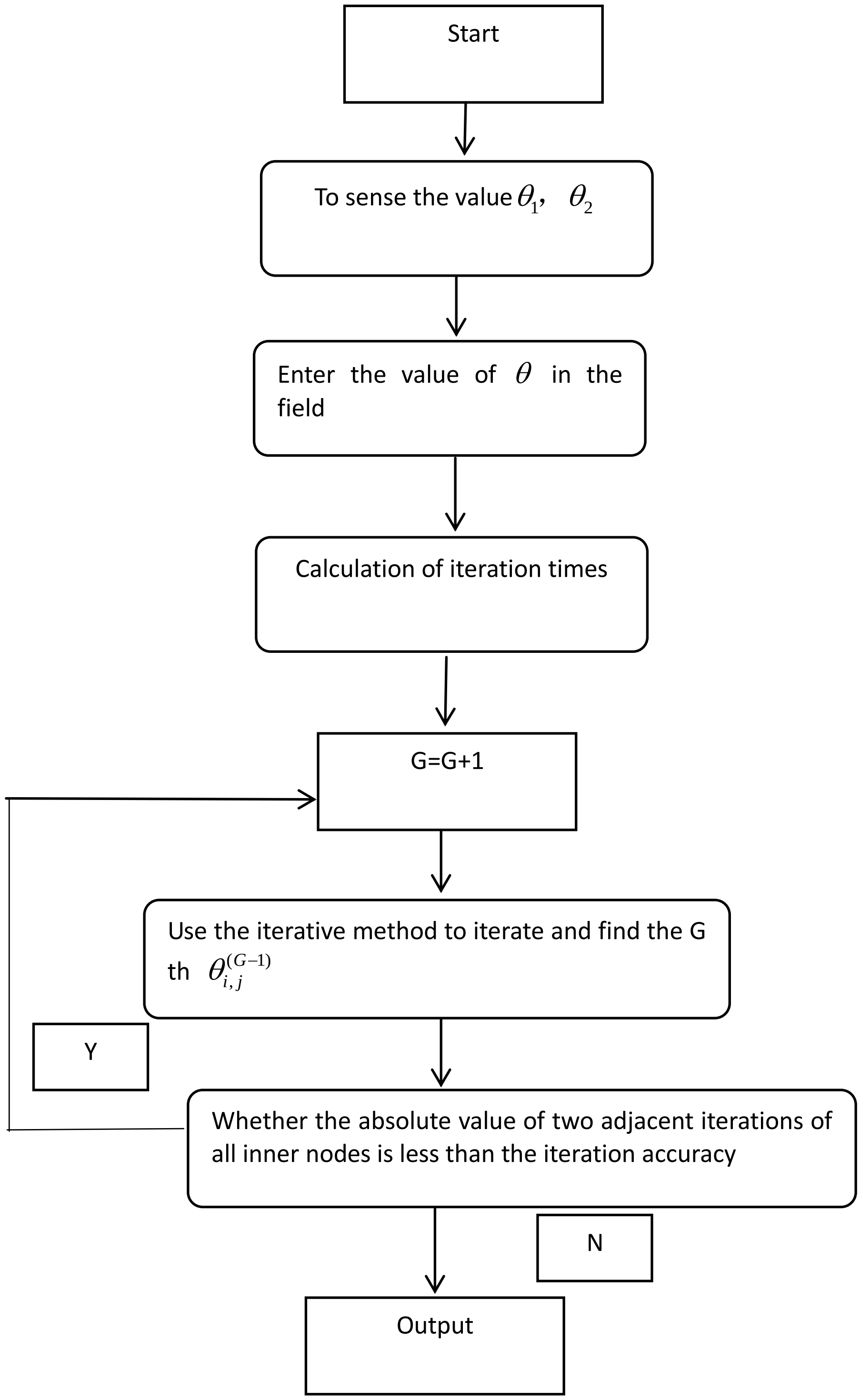

Figure 1. Finite difference method detection and classification calculation flow

From the finite difference method detection classification model in Figure 1, it can be seen that the method used in this paper for polycrystalline cinnamon sheet detection classification is, in principle, to know the distribution of defects in any one of the solar panel polycrystalline hanging field, and by the finite difference method difference calculation can be obtained from the unqualified case of swimming vortex defects, high impurity, edge impurity and too many dislocation defects, the qualified case of acceptable proportion of dislocation defects and the absence of swimming defects. situation. But the solar panel polycrystalline pendant two-dimensional field of five kinds of non-conformity and two qualified cases of the edge value after all, there are two kinds: one is the outer boundary value of 1, one is the outer boundary value of a 1. Therefore, as long as the two boundaries of the polycrystalline pendant within the edge value calculated, the remaining distribution of non-conformity is completely similar, so that you can visually analyze the non-conformity and qualified cases in the polycrystalline pendant.

4.2. Application of Fused Finite Difference Method for Solar Panel Classification System

In order to verify the fusion finite difference method (FDM) in the solar panel classification system for the detection and classification of solar panel polycrystalline hanging defects. In this paper, the system performance is tested by selecting five sets of panel sample data for the accuracy of its detection and classification. And selected decision tree (DT), neural network (RNN) and SVM for accuracy comparison, the specific experimental data are shown in Table 3.

Table 3. accuracy comparison data

Sample	DT	RNN	SVM	FDM
100	88.6%	85.7%	90.5%	91.7%
200	86.4%	87.2%	86.7%	90.9%
300	85.9%	88.1%	87.9%	89.8%
400	89.5%	86.4%	88.3%	91.5%

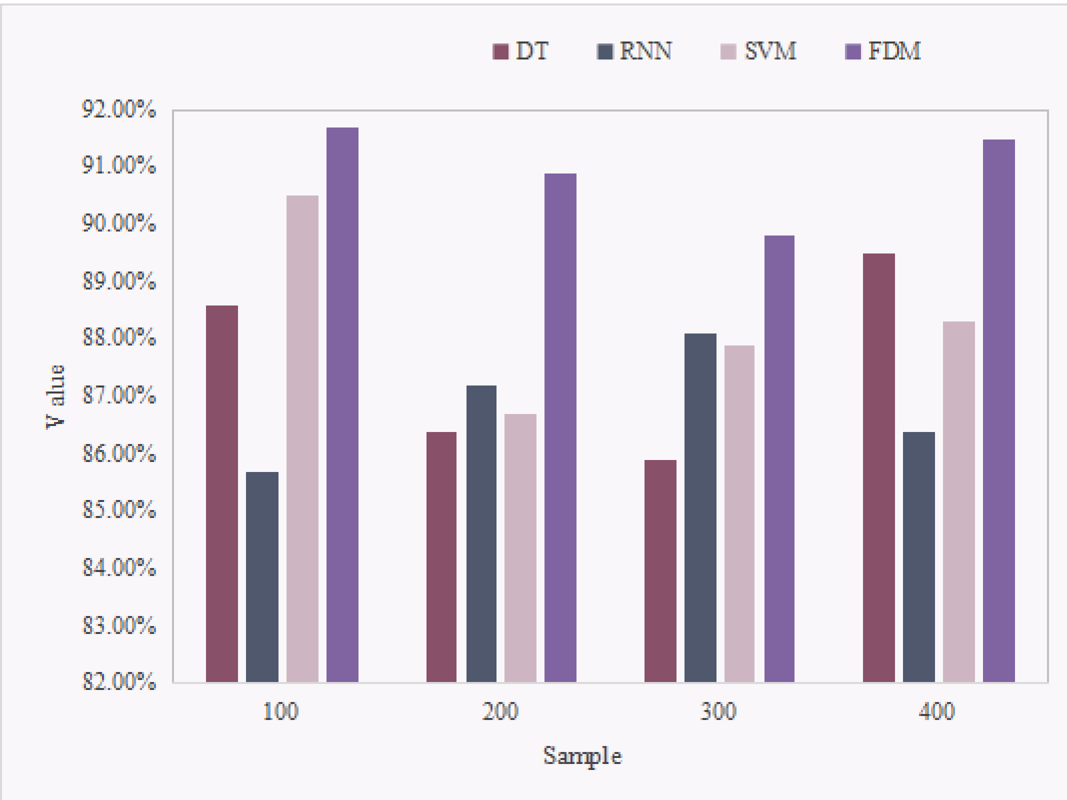

Figure 2. Comparison of classification accuracy

From the data in Figure 2, it can be seen that the finite difference method achieves 91.7% accuracy in detecting and classifying 100 samples of solar panel polycrystalline hanging defects. In contrast, the classification accuracies of RNN, DT and SVM only reach 85.7%, 88.6% and 90.5%, respectively. Among them, SVM also achieves more than 90% classification. The finite difference method achieves 90.9% accuracy in detecting and classifying 200 solar panel polycrystalline hanging defect samples. In contrast, the classification accuracies of RNN, DT and SVM only reached 86.4%, 87.2% and 86.7%, respectively. The accuracy of detection and classification of 300 solar panel polycrystalline hanging defect samples by finite difference method reached 89.8%. In contrast, the classification accuracies of RNN, DT and SVM only reached 85.9%, 88.1% and 87.9%, respectively. The finite difference method achieves 91.5% accuracy for detecting and classifying 300 solar panel polycrystalline hanging defect samples. In contrast, the classification accuracies of RNN, DT and SVM only reached 89.5%%, 86.4% and 88.3%, respectively. In summary, it can be seen that although the classification accuracies of RNN, DT and SVM are all above 85%, the finite difference method has a better classification effect.

5. Conclusion

In this paper, based on the analysis of the type of solar panel and the stability of the finite difference method solution, the detection and classification of the defects of the solar panel polycrystalline hanging and the finite difference method is used to calculate the difference of the laurel sheet. And the whole calculation process structure is designed to realize the application of solar cell laurel defects detection and classification, detection and classification of defects including high impurity, edge impurity, dislocation defects of polycrystalline laurel wafers and single crystal wandering defects. The system software has been tested by specific experiments, and the experimental results show that the accuracy of detection and classification by finite difference method has reached more than 90% on average, which can meet the requirements of practical applications and experiments, and prove the rationality of the system software design in this paper.

Funding

This article is not supported by any foundation.

Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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