Aerospace Magnesium-Aluminum Alloy Casting Defect Diagnostic Expert System

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Abstract: Sand casting, as a leading traditional casting process, is widely used in various scales of casting production due to its accessible materials and simplified manufacturing. However, frequent occurrences of casting defects such as pores, shrinkage cavities, and cracks not only impact product quality but also increase production costs and scrap rates, posing a severe threat to the economic benefits and reputation of casting enterprises. Therefore, rapidly and accurately determining the causes of casting defects is crucial to enhancing product quality.

This study developed an expert analysis system specifically targeting casting defects in aviation transmission load-bearing gearboxes. By leveraging advanced machine learning technology combined with casting expertise, the system achieves automatic diagnosis, classification, and cause analysis of defects. The system collects relevant textual data on casting defects and interacts with the SQLite database through a user interface designed with PyQt5, facilitating users' queries and browsing of defect information. In the recognition section, the system comprehensively collects defect features, including morphology, size, distribution, and other critical information. After multiple experimental validations, the Bernoulli Naive Bayes algorithm model has demonstrated superior performance on the dataset, enabling rapid and accurate automatic classification and diagnosis of user-selected defect features.

Moreover, the system supports semi-automated updating of domain knowledge, ensuring alignment with the latest casting technologies. The research findings provide a novel approach for quality control in aviation transmission load-bearing gearbox casting and serve as a reference for similar fields. In the future, we will continue to refine and enhance the system to adapt to the analysis needs of a broader range of casting defects, driving the sustained progress of the casting industry.

Keywords:sand casting;bernoulli naive bayes algorithm; expert system

1 Introduction

In the aviation industry, which requires high precision and reliability, the quality of the transmission system load-bearing casing is directly related to flight safety and performance. However, although the traditional sand casting process is mature and widely used, defects such as porosity, shrinkage porosity, and cracks will inevitably appear in the casting process, which not only reduces product quality but also increases production costs and scrap rates, posing a severe challenge to the economic benefits and brand image of aviation enterprises.

The system mainly includes four functional modules: user management, analysis and diagnosis, defect knowledge, and defect acceptance criteria, of which the user management module includes user registration, user login, and user registration code verification functions; The analysis and diagnosis module includes defect reasoning, defect category creation, defect feature creation, defect picture display, defect knowledge graph display, defect identification result formation cause and prevention measures display, defect identification result acceptance standard display functions. The defect knowledge module is mainly used to display defect knowledge, including defect description, defect theoretical causes, actual causes, improvement measures, and what kind of improvement measures will have any effect. The Defect Acceptance Criteria module provides defect acceptance criteria documents.

2 Experimental procedure

In order to meet this challenge, we have successfully developed an expert analysis system for casting defects in the load-bearing casing of the aero drivetrain. The system deeply integrates advanced machine learning technology with deep casting expertise, aiming to achieve fast and accurate identification, classification, and cause analysis of casting defects, and provide strong technical support for casting quality control.

The system adopts a hierarchical architecture, and the front-end interface is designed with Qt to interact with the SQLite database. As an intermediate layer, the Qt program is responsible for passing data between the front-end interface and the database and completing the corresponding logical processing. As the backend of data storage and management, MySQL database is responsible for data persistence and management. The advantage of using a layered architecture is that there is less coupling between the layers, and their respective responsibilities are clear, making it easy to maintain and upgrade. At the same time, the architecture is also scalable, and each layer can be scaled and optimized according to specific needs.

In Qt, we can implement the MVC architecture using Qt's MVC framework and signal slot mechanism. Qt's MVC framework provides a Model-View/Delegate architecture that helps us manage and present data. At the same time, Qt's signal slot mechanism can help us

communicate and collaborate between various components, making the logic of the application clearer and easier to maintain.

3 Result and discussion

The system uses PyQt as the front end in the knowledge database of experts on key assembly processes of the engine. PyQt is a cross-platform Python application framework with a variety of features, including GUI, networking, databases, scripting, XML, OpenGL, and more. PyQt provides a number of classes and functions that make it easy for developers to develop cross-platform applications. The advantage of PyQt is that it is cross-platform and efficient, as it supports multiple operating systems including Windows, Linux, macOS, etc. This means that developers can use PyQt to develop cross-platform applications, reducing development costs and time.

In addition, PyQt uses a mechanism called meta-objects that automates signal and slot connections, which makes PyQt's programming model more flexible and efficient. Signals and slots are one of the most important concepts in PyQt, as they are used to communicate between objects, making it easy for developers to implement a variety of interactions and event handling. Through signal and slot connections, developers can extend and modify various functions without changing the code structure. This flexibility and efficiency is what makes PyQt unique and one of the reasons why it is so widely used.

4 Conclusion

In this study, an expert analysis system was successfully developed to solve the frequent defects in the casting process of the load-bearing casing of the aero transmission system. Through the deep integration of advanced machine learning technology and casting expertise, the system realizes automatic diagnosis, classification, and cause analysis of casting defects, providing an efficient and accurate solution for casting quality control.

In the process of system development, we used the combination of SQLite database and PyQt5 user interface to realize convenient data management and visual display and provide users with a good operation experience. At the same time, through several experimental verifications, we choose the Bernoulli naïve Bayes algorithm model as the core classifier, which shows superior performance on the casting defect dataset and can quickly and accurately complete the classification and diagnosis tasks of defect features.

The application of this expert analysis system not only significantly improves the accuracy and efficiency of casting defect identification, reduces the scrap rate and production cost, but also helps enterprises to find and solve problems in the casting process in a timely manner, and improves the overall quality and reliability of products. This is of great significance for the manufacture of key components such as the load-bearing casing of the aviation transmission system, which helps to ensure flight safety and enhance the market competitiveness of aviation enterprises.

Looking ahead, with the continuous development of foundry technology and the continuous innovation of machine learning algorithms, we believe that this expert analysis system will continue to be refined and optimized to meet the needs of a wider range of foundry defect analysis. At the same time, we also expect that the system can be promoted and applied in more fields, and contribute more to the sustainable development of the foundry industry.