AI-Empowered Display Industry: Innovative Breakthrough in Defect Inspection

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Abstract

Based on artificial intelligence technology and using deep learning image classification principles, factory product defects are automatically classified. The AI model algorithm is upgraded and empowered to support intelligent image retrieval, batch automatic annotation, and small sample generation technology to assist defect detection, achieving a closed-loop management and operation of defect data and hardware. This paper innovatively adopts three innovative measures: self-developed algorithms based on U-Net structure, self-developed display large models based on VIT architecture, and self-developed high availability K8S monitoring and scheduling SDK. In addition, the use of machine learning intelligent factor analysis algorithms enables AI big data agile analysis to identify commonalities, display analysis results with one click, and improve the effectiveness of AI intelligent monitoring based on attribution classification. Therefore, our independently developed ADM system is the first to achieve efficient process closed-loop for intelligent defect detection, analysis, stop loss, root cause identification, and improved monitoring, promoting the positive management of process quality management in the LCD industry and achieving a spiral upward trend.

Keywords

Independently-developed Artificial-Intelligence(AI) Closed-loop–management Automatic-Defect-Classification(ADC) Display Manufacturing

1. Introduction

At present, technological competition is becoming increasingly fierce, and the semiconductor display Manufacturing is also in a state of "weak growth, rebalancing" development. The new industrial revolution led by artificial intelligence is poised to erupt, becoming a new quality productivity that can trigger the restructuring of the industrial competition pattern and become a key indicator of industry competitiveness. In the production process of the semiconductor display industry, defective products often occur due to various factors such as personnel, equipment, and complex processes. To this end, automatic optical inspection (AOI) equipment is introduced after key process nodes to detect common defects through optical principles. Although traditional ADCs achieve automatic classification, centralized management, and auxiliary repair to overcome the difficulties of manual detection. As consumers' demands for product quality in the market continue to increase, it is necessary for industry factories to continuously improve the accuracy and efficiency of process quality inspection. Hence, in practical applications, there are still the following challenges: Firstly, due to the scarcity of bad data images and difficulty in labeling, the management and operation closed-loop cycle is long and the iteration is slow; Secondly, existing data analysis tools have strong limitations, such as data silos, insufficient utilization of AOI data (AI discrimination information), and a trend of fragmented and decentralized management, which limits the speed of defect localization and improvement, resulting in incomplete optimization of personnel actions, limited personnel experience barriers, and the inability to quickly present analysis decisions in a one click loop investigation dilemma; In addition, limited to personnel root cause classification and monitoring improvement, it forces the entire process to be abnormally poor, inefficient, and closed-loop, resulting in difficulties in implementing intelligent defect management without closed-loop, and losing key opportunities to focus on improving resources, seriously affecting the factory's manufacturing capacity and profits.

2. Procedure Description

2.1 Design Thought

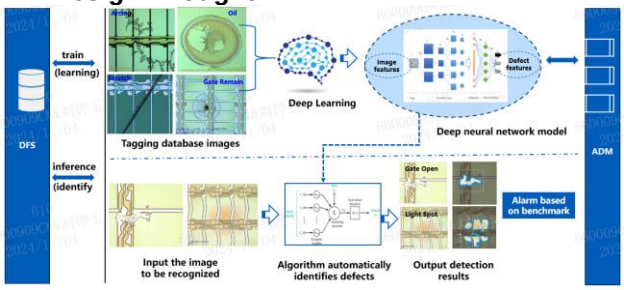

Figure 1. ADM system technology implementation flowchart

We adopt brilliant engineer (Display Manufacturing) and team of Our artificial intelligence As the exploration mode of the team's large model： The team has developed an AI Defect Management (Abbreviated as ADM) software independently, using AI visual technology to refresh concepts and break through external purchasing technology bottlenecks and service boundaries. At the same time, relying on the concept of lean process quality management, the entire operation process is optimized to minimize the waste of personnel actions, and the analysis and decision-making process is integrated at the bottom layer with one click display. The intellectual cost is solidified and flexibly combined to achieve intelligent defect detection, analysis, stop loss, root cause identification, and improved monitoring of the process closed-loop management, reducing the annoyance of manual labor and the impact of experience threshold.

Besides, visualizing the trend of key indicators and process fluctuations, exploring new problems and ideas from the trend, reducing costs and increasing efficiency, and assisting operations, the main design ideas are:

(1)Innovative measures for intelligent quality inspection algorithms: the platform is independently developed, long-term self controllable, and self generating.

Primarily, team of BOE artificial intelligence based on the self-developed derivative algorithm of Defect detection, BOE a customized iteration of the general model in virtue of the

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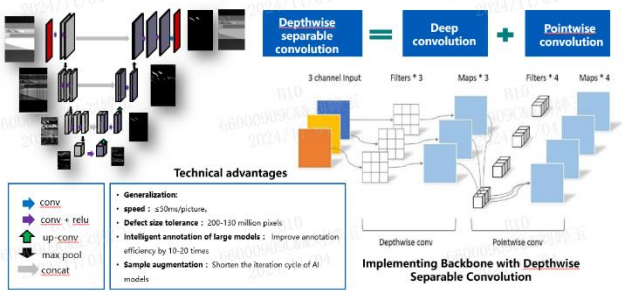
knowledge of the display manufacturing industry has been carried out. It has the characteristics of strong generalization, fast speed, large tolerance, and sample augmentation, which enables it to



intelligently and accurately detect and discriminate the damage area and location of Open class defects for precise repair, improving yield or contribution level.

Figure 2. Introduction to Recognition Algorithm Principles

Posteriorly, the self-developed VIT architecture display large model innovatively integrates the display defect image segmentation large model and defect data generation technology. The algorithm uses a CNN convolutional neural network with U-Net architecture to construct a deep convolutional feature extractor for image feature extraction, reasonably improving the detection rate and reducing over detection. The constructed data lake can cover over 90% of defect types in the display field. Surprisingly，BOE Display's defect detection visual model only requires drawing a point or box prompt Currently for the first time, and can automatically annotate in batches afterwards, achieving a more than 10 fold increase in annotation efficiency. It can intelligently complete high completeness, high detail, and high-precision defect information segmentation, replacing the time-consuming and labor-intensive situation of manual polygon annotation, shortening the AI model iteration cycle, and quickly improving accuracy.

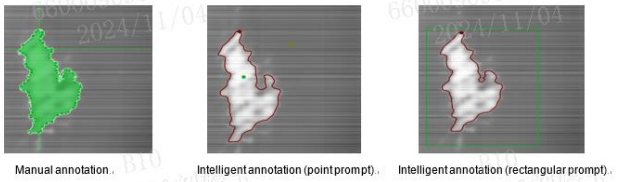


Figure 3. Interactive automatic annotation

One Last Innovation, Our self-developed high availability K8S monitoring and scheduling SDK mechanism can automatically transfer hardware failures, ensuring high concurrency and availability during annotation, training, and inference processes; Its software can be based on state machine, asynchronous event driven, and distributed transaction task lifecycle control management; Furthermore, the ADM system has high scalability and can be linked with BOE's other self-developed intelligent scheduling, intelligent question answering, yield big data platform, Auto Repair and other systems in the future.

(2)Process closed-loop management mechanism: one-stop data fusion co creation, promoting positive management of process quality management spiral upward.

①The AOI images in the four major process stages in Array, Cell, Color Filter, Module（referred to as ACCM） of the Display manufacturing industry are intelligently analyzed and judged by AI models (fast, accurate, and stable). When production process Glass or Lot triggers the benchmark, the Alarm will automatically sound an alarm and handle anomalies automatically, such as Hold/Rework/Decap/Scrap/Repair/NG operations. Abnormal stop loss focuses on strengthening accident minimization and avoiding capacity loss.

②Agile analysis of AI big data with low experience threshold, from experience decision-making to precise data science decision-making, quickly locate key points, find root causes (line type/personnel type/time/downtime/ equipment life/ PM/contact points/coordinate centralization, etc.), break through personnel experience limitations, and break the cycle of "firefighting" management in post process quality inspection.

③AI self-monitoring improvement, categorizing and tracing the root causes of defects, can prevent recurrence, and the system serves the closed-loop management of each defect management task. Quality inspection engineers can classify the root causes of poor management tasks and also refine key opportunities that require focused resource improvement. They can focus on strengthening on-site management, conducting technical, process, or product design improvements and innovations, and promoting process quality management to ultimately achieve a positive spiral upward cycle.

Thus, AI big data analysis Model will present the analysis results to our staff, thereby optimizing their actions from empirical decision-making to data science decision-making。

2.2 Implement

The platform project is oriented towards solving practical problems and aims to address the four major business pain points of quality inspection positions in the industry: multiple system interfaces, high risk of missed inspections, slow search for common causes of defects, and high training costs. Our engineers collaborate with the group's artificial intelligence team for high-quality cooperation, introducing the concepts of integrated platform, AI quality inspector, AI analyst, and AI instructor from the four aspects of software, interception, analysis, and consolidation. We have proposed an application plan for the ADM system to promote the comprehensive improvement of process quality management and team operation level.

2.2.1 One stop management platform: Software control improvement

Multiple AOI software are integrated and unified, integrating the three major system software of production, monitoring, and analysis. From multi interface monitoring, the operation is cumbersome to simple and direct. Thanks to the integrated platform, our exception handling efficiency has been increased by 2.7 times, and the problem of dedicated personnel has been solved, promoting a threefold increase in the number of multi skilled workers.

2.2.2 AI intelligent discrimination and operation: precise detection of defects

（1）Automatic identification and repair: With the help of AI, the automatic image judgment achieves a manual substitution rate of 85%, and achieves a color image sampling rate of 31.03% to comprehensive monitoring of 100%. Not only does it achieve full inspection of color images, but it also covers Map Mura and gray images, realizing the transformation from intelligent quality inspection, real-time quality inspection, and manual sampling to full quality inspection. The processing volume of defect images

is 20 times that of the original. The transformation from manual judgment to human-machine cooperation and automatic repair based on AI code judgment. AOI achieves the contribution of maintenance from no repair to repair at all levels, improving the yield rate, such as Array stage Yield ↑0.53%.

（2）The AI big model makes defect detection possible with very few samples, combining AIoT technology with the knowledge of the display manufacturing industry for customized iteration. This innovative solution integrates the display defect annotation big model and defect data synthesis technology, which can automatically synthesize more realistic and diverse defect data than traditional solutions, making defect detection possible with very few sample defect data. It effectively helps to improve the efficiency of defect model iteration and detection system online by more than 10 times.

2.2.3 AI Root Cause Search and Tracking: Efficient Process Closed Loop

(1) Real time monitoring: View the map aggregation, common points, color and grayscale detection status of multiple Lots or Glass, personnel, AI accuracy/recall/warning rate, equipment comparison (including cross), mapping, defect tracing, op defect analysis, product type, time concentration, and other real-time monitoring and output results to avoid manual data brushing and improve equipment detection and process AI interception capabilities. Integrate production and yield data for real-time visualization.

(2) Comprehensive regulatory system: Abnormal efficient linkage, automatic triggering of Hold/Alarm and other abnormal alerts beyond rules, reminding personnel to confirm and push notifications; Besides, AI helps us integrate LOT data and conduct intelligent analysis, automatically alerting process personnel to confirm equipment abnormalities and prevent batch accidents by identifying defects or process commonalities: more efficient, intelligent, and comprehensive. In addition, for the root cause classification of abnormal tasks, dimensionality enhancement is needed to extract key opportunities that require focused improvement of tilted resources.

2.2.4 AI intelligent guidance and supervision: efficient human-machine iteration

Empowering AI as a mentor, starting from both Worker and machine aspects, focusing on guiding employee growth and model iteration, ensuring the continuous effectiveness of personnel quality awareness and process quality management.

In terms of employee growth, AI instructors will establish comprehensive training files for employees and use system solutions as guidance to develop their advanced abilities; Further evaluate the effectiveness of training through competitive platforms; In addition, through regular education, accident review, automatic push of relevant defect analysis, improvement plan experience, and providing reference for analysis ideas, the output of intelligence and experience is solidified to maintain the quality awareness of testing personnel in the long run. As a result, the 6-month training period for experienced engineers has been shortened to within 2 months, accelerating personnel growth by 4 times.

In terms of model iteration, self-monitoring of the model is used to ensure its performance meets expectations. During monitoring, self inspection is carried out to promptly push personnel adjustment information if it is not applicable. Ultimately, algorithm self adjustment is achieved to enhance business flexibility through intelligent iteration of the model.

3. Result

At present, BOE has integrated the AOI, equipment history, yield, equipment parameters and other data of the ACCM process section of the LCD process, intelligently operated and formed an ADM system that runs through the entire factory. One stop data fusion and co creation have formed a complete comprehensive supervision process closed-loop system: in terms of manual savings, yield improvement, quality abnormal stop loss and production capacity contribution income of ⩾ 13.93 million RMB/year/production line, it helps BOE intelligent Manufacturing upgrade and high quality development.

(1) Due to the implementation of intelligent detection in the ADM platform system, there is a process closed-loop management of analysis, stop loss, root cause identification, and improved monitoring, resulting in an average annual labor savings of 49 people, a 96% increase in the calculation efficiency of defective positioning data, an 87% reduction in analysis cycle, and a 50% increase in disposal response rate. As a result, it is possible to achieve a quality anomaly accident stop loss of ⩾ 7 times, a 63% reduction in accident occurrence rate, an ACCM comprehensive yield increase of at least 0.22%, and a production capacity material loss of 5H/month.

（2）Another major contribution of the ADM system platform is to assist in sending for repair. In June 2024, the Array process section fully introduced the ADM system for automatic classification and auxiliary repair functions, creating a new detection and maintenance operation mode: Repair is composed of AOI assistance and electrical testing. This is mainly reflected in two aspects:

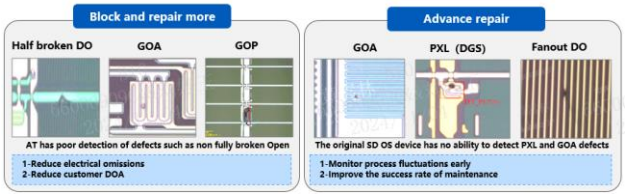


Figure 4. Multiple blockages, repairs and pre maintenance

On the one hand, with the help of the ADM system, the electrical system can detect defects such as open, GOA, GOP, etc., and fully utilize AOI abnormal automatic stop loss to reduce Array missed detections by 0.27% (a decrease of 38%), reducing the customer DOA occurrence rate by ⩾ 30%, thereby achieving multiple blockages and repairs;

On the other hand, the original SD OS electrical equipment PXL and peripheral defects have no detection capability, and the defects original that were only repaired in Final layer are placed in the SD layer repair Presently by Judging AI Code Based on ADM System. Thus, we can more accurately monitor process fluctuations in advance, improve maintenance success rates, and enhance backend Q/T/N levels.

After importing the AI model, the contribution rate of Array maintenance increased by 0.13% for GT Yield, 0.35% for DT Yield, and 0.43% for AT Yield; Contribute to the backend CT level, with a 0.24% increase in the combined contribution of point defects and line defects (G → T/Q/N).

4. Discussion and Conclusion

（1）Using artificial intelligence technology and deep learning

image classification principles, defects in LCD panel factory products are automatically classified. Corresponding defect intelligent classification, real-time warning, abnormal automatic processing (Rework/Hold/Decap/Repair, etc.), abnormal efficient linkage, AI agile analysis to find commonalities, AI monitoring and other functions are developed based on business needs. AI vision technology is used to refresh concepts, improve the accuracy and efficiency of process quality inspection, reduce the impact of manual "complexity" and experience threshold, achieve intelligent defect detection, analysis, stop loss, root cause identification and improve monitoring process closed-loop management, and control the "door" of quality. Enhance customer stickiness, satisfaction, and product competitiveness through high-quality services.

（2）Differences from previously published research and its application work: This article no longer focuses on intelligent defect detection, accuracy, and simple repair aspects, but avoids the circular dilemma of "firefighting" management after the fact, and promotes the positive cycle management of process quality management that spirals upwards:

One side，model operation and maintenance management closed loop: intelligent image retrieval, batch fitting automatic annotation, model training, model evaluation, and high uniformity: centralized operation and maintenance, model sharing, data sharing, hardware sharing;

The other side，process closed-loop management: an efficient process closed-loop system for intelligent defect detection, analysis, stop loss, root cause identification, and improved monitoring. It optimizes personnel actions, automatically handles anomalies, breaks through the experience threshold of personnel, displays results with one click, makes advance process wave and scientific data decisions, classifies root causes, improves effective comprehensive supervision and efficient closed-loop system, and avoids the cycle dilemma of "firefighting" management after the fact.

（3）Suggestions for further in-depth research on the application of this topic in the future: Primarily, AI technology enhancement: management and operation control: In order to fully utilize the platform, make the business layer process closed-loop and operation management more effective, achieve a "low code platform", lower the AI threshold, invite our AIOT to open source certain code permissions, and develop quick functions through drag and drop methods, etc., to facilitate the development of practical needs such as data dashboards in the future.

Finally, horizontal output of results: We will explore more application scenarios in the future, such as EGIS/film edge detection in the LCD panel industry, Cell PI film surface Mura and shell Mura recognition applications, AI automatic repair effect reevaluation and other industrial scenarios. We will enable AI quality inspectors to take on the responsibility of intelligent manufacturing, replace manual quality inspection, achieve the integration of production, process monitoring, and yield data, form a good decision-making and effect feedback mechanism.

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