

Design of customer service management system for blown film equipment manufacturing industry

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Abstract: This paper addresses the pain points in the traditional service model of the blown film equipment manufacturing industry, such as slow pre-sales response, scattered equipment monitoring, cumbersome after-sales processes, and inconvenient accessory procurement. It designs and implements a customer service management system that spans the entire customer lifecycle. The system adopts a microservices architecture combined with edge computing, integrating four core modules: intelligent customer service powered by a large language model, AI image recognition for accessory purchases, intelligent equipment monitoring, and digital after-sales service, to establish a data processing system that facilitates edge-cloud collaboration. Each device is equipped with an independent edge computer to handle monitoring, computing, and alert functions, capable of operating offline and reporting critical status, alarm events, and aggregated data to the cloud database. The system supports access through both the web and WeChat mini-programs, with the expectation to support concurrent monitoring of over a hundred devices and concurrent access by hundreds of users. The AI customer service response time is controlled in seconds, and the accuracy rate of accessory image recognition exceeds 90%. This provides a reference implementation path for the service digital transformation of similar equipment manufacturing enterprises.

Key words: film blowing equipment; customer service management; microservices architecture; edge computing; artificial intelligence

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0 Introduction

Blown film equipment is the core equipment in the plastic packaging industry. With the upgrading of the packaging industry, customers' demands for equipment operational stability, after-sales service response speed, and convenience of accessory procurement are increasing. However, the industry as a whole is still in the initial stage where equipment sales are the mainstay and service revenue is secondary. Common pain points include slow pre-sales response, lack of equipment monitoring, cumbersome after-sales processes, and inconvenience in accessory procurement. Technologies such as the Industrial Internet, artificial intelligence, and

edge computing are becoming increasingly mature. National-level standard frameworks such as "Made in China 2025" and the Smart Manufacturing Capability Maturity Model have been successively released, providing technical paths and capability benchmarking for the digitalization of equipment manufacturing services.

This article integrates mainstream digital technologies

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such as microservice architecture, large language models, the Internet of Things, AI image recognition, and edge computing into industrial equipment service scenarios. Based on specific business practices in the blown film equipment industry, it provides a complete solution that can serve as a reference implementation template for similar equipment manufacturing enterprises.

1 Relevant technical and theoretical basis

1.1 Microservice architecture

The microservices architecture divides the system into independent and loosely coupled service modules. Combined with cloud-native technologies such as container orchestration, service mesh, and observability, it has become the mainstream architecture choice for enterprise-level complex business systems. This system divides pre-sales consulting, equipment monitoring, after-sales service, accessory mall, training services, etc. into independent services according to business domains, and provides external capabilities through an API gateway.

1.2 Edge computing and industrial IoT

Edge computing sinks some computing tasks closer to the data source, significantly reducing data transmission latency and cloud load, making it suitable for industrial sites with high real-time requirements and unstable network conditions. The MQTT protocol, as the de facto standard for industrial IoT, can be combined with edge computing to build a data processing system that integrates edge and cloud capabilities.

1.3 Artificial intelligence service technology

In the field of customer service, artificial intelligence primarily manifests in two types of capabilities: natural language understanding and generation based on large language models, which support scenarios such as intelligent customer service, document question answering, and product selection recommendation; and image recognition based on deep learning, which is used in industrial scenarios such as accessory identification and defect detection.

1.4 Smart Manufacturing Capability Framework

The national standard for the maturity model of intelligent manufacturing capability divides enterprises'

intelligent manufacturing capabilities into five levels, providing a framework for enterprises to assess their digitalization level and plan their capability development paths. This system incorporates relevant capability requirements in its design across dimensions such as system integration, data connectivity, and equipment interconnection.

2 System requirement analysis

2.1 Analysis of industry pain points

Pre-sales service relies on manual labor, with slow response times and significant variations in professional competence. Equipment monitoring data is scattered across different systems, making it difficult for customers to view remotely, and fault handling often involves intervention after the occurrence of a fault. After-sales service relies on traditional methods such as telephone and WeChat, with opaque workflows for work orders and reliance on experienced engineers for fault diagnosis. Parts identification relies on verbal descriptions or model searches, which are inefficient and prone to errors.

2.2 User roles and functional requirements

The system serves six types of user roles: potential customers focus on product consultation and selection advice; equipment operators focus on real-time status, troubleshooting, and training resources; equipment administrators focus on operation reports, maintenance plans, and accessory procurement; after-sales service engineers focus on work order receiving and service records; accessory salespersons focus on order processing and shipment tracking; system administrators focus on permission configuration and system operation and maintenance.

Focusing on the entire customer lifecycle, the system provides five core functions: pre-sales consultation, intelligent equipment monitoring, digital after-sales service, smart accessory mall, and unified authentication. The key implementation points of each module are outlined in Chapter 4.

2.3 Non-functional requirements

In terms of performance, the system needs to support concurrent monitoring of over a hundred units and concurrent access by hundreds of users; page load time should be controlled at the second level; API response should be in the

millisecond level; and AI question-answering response should be within 30 seconds.

In terms of reliability, the system adopts an edge computing architecture: each device is equipped with an independent edge computer to undertake core functions such as monitoring, data collection, computation, and early warning. It reports key statuses, alarm events, and aggregated data to the cloud database and possesses the ability to operate offline. Even in the event of network interruption, it can still independently complete monitoring and early warning, significantly reducing the pressure on cloud servers and network dependency.

In terms of data, equipment operation data needs to be stored for a long time. In terms of security, data transmission is encrypted using HTTPS, sensitive information is stored in encrypted form, and an access control mechanism based on user identity recognition and the principle of least privilege is established. The system runs stably 24/7, with standardized API interfaces reserved for easy expansion.

2.4 System integration requirements

The system needs to be interconnected with the enterprise's existing platform data: synchronize real-time data with the device data platform via MQTT protocol; share the

association between devices and documents with the digital manual platform; synchronize customer, device, and inventory data with the ERP system to facilitate the push-down of accessory orders; and integrate with the official website to provide a unified AI customer service window and service entry.

3 Overall system design

3.1 Architecture design philosophy

The system adopts a microservices architecture with front-end and back-end separation. Each business module is independently deployed and upgraded; the front end supports access from both the web and WeChat mini-program; a data hub is built to achieve unified management of core data; standardized API interfaces are reserved for system integration.

3.2 Overall architecture of cloud-edge-device collaboration

The system adopts a five-level edge-cloud collaborative architecture consisting of film blowing equipment, edge computer, cloud database, cloud server, and cloud platform browser (see Figure 1). The data flow converges from bottom to top, while the command flow is issued from top to bottom.

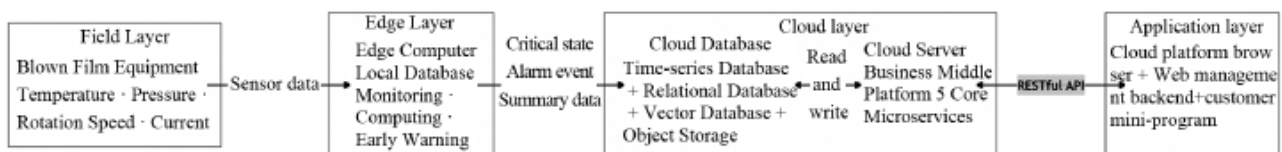


Figure 1 System edge-cloud collaborative architecture

The on-site layer consists of the film blowing unit and sensors; at the edge layer, each device is equipped with 1 unit of industrial computer as the edge computer, responsible for core functions such as data collection, local storage, real-time computation, and abnormal warning; the cloud layer is composed of cloud database and cloud server, where the cloud database aggregates key status, alarms, and summary data from edge hosts, and the cloud server hosts the five microservices of the business platform; the application layer provides service entry through the Web management backend and client mini-program.

3.3 Core module design

The functional positioning and value of the five core

modules are shown in Table 1.

Key implementation points of each module: Pre-sales consultation centers around AI intelligent customer service, built upon a large language model and domain knowledge base, supporting 7×24h multimodal interaction, with complex issues being transferred to human support; the selection guide collects parameters through guided questionnaires and recommends machine types based on a rule engine. Device monitoring collects sensor data in real-time at the edge and performs status evaluation and anomaly detection according to preset algorithms, with alerts being pushed through a dual channel of on-site sound and light, SMS, and WeChat; the cloud aggregates key statuses for historical queries, trend

Table 1 Functions and values of the five core modules of the system

Module	Core Competence	Business value
Pre-sales Consultation Center	AI intelligent customer service, intelligent model selection, inspection appointment	Improve response efficiency and reduce labor costs
Intelligent equipment monitoring center	Real-time monitoring, abnormality warning, predictive maintenance, and OEE analysis	Make equipment status transparent to reduce unplanned downtime
Digital after-sales service center	Service work orders, AI-based Q&A, video tutorials, online training	Standardize after-sales processes to enhance service efficiency
Smart Accessories Mall	AI image recognition, intelligent recommendation, online ordering	Simplify the procurement process and enhance transaction conversion
Unified Authentication	Unified identity authentication, minimum privilege control	Ensure system security and simplify user usage

analysis, and cross-device comparisons. The after-sales service work order system implements a closed-loop process from repair reporting to evaluation (see Table 2); AI device Q&A integrates manuals, fault cases, and maintenance manuals based on a knowledge graph, automatically transferring to human support when unable to answer. The accessory mall enables photo-based accessory search through AI image recognition,

intelligently recommending accessories based on multiple dimensions such as device runtime, browsing history, and fault work orders. Orders support WeChat payment and corporate transfer, and electronic receipts automatically update device maintenance records. Unified authentication enables unified login for both the web and mini-program terminals, assigning access scopes following the principle of least privilege.

Table 2 Service work order status transition

Status	Operator	Main operations	Exception branch
Pending	customer	Submit a ticket	Cancelled → Closed
Accepted	Customer service	Review and confirmation	Rejected → Closed
Assigned	Customer service	Selection Engineer	Re-dispatching
In service	engineer	On-site processing	Service failure
To be evaluated	customer	Rating and Review	—
Completed	System	Ticket Archiving	—

3.4 Data layer design

The relational database stores core business data such as customer profiles, equipment profiles, work orders, orders, and accessories; the time-series database stores high-frequency time-series data of equipment; the caching database is used for accelerating hotspot data; the object storage carries unstructured data such as images, videos, and documents; and the vector database supports similarity retrieval for AI intelligent customer service and image recognition. The data mid-platform centrally manages and standardizes customer, equipment, and order data scattered across various business systems through a unified data model and master data management mechanism, ensuring that a customer, a unit of equipment, a work order, and an order have globally consistent identifiers and status views in the system.

4 Key technologies and design points

4.1 Industrial vertical application of large language models

When applied in industrial vertical domains, general

large language models face two major challenges: insufficient depth in understanding professional terminology and difficulty in ensuring output stability. This system adopts Retrieval Augmented Generation (RAG) technology: it constructs a vector knowledge base from product manuals, failure cases, and process standards of film blowing equipment; when a user asks a question, relevant knowledge fragments are first matched through semantic retrieval, and then the retrieval results are sent to the large model along with the question to generate an answer, thereby constraining the large model from free-form generation to knowledge-based generation. In implementation, an Embedding model for Chinese scenarios is selected for vectorization, and a distributed vector database is deployed to support high-concurrency retrieval; prompt word templates are used to constrain the output format; a confidence threshold and sensitive question filtering mechanism are set up, and when the model determines insufficient credibility, it automatically transfers the request to human customer service; a continuous feedback mechanism for dialog logs is established to achieve continuous system optimization.

4.2 Data processing for edge-cloud collaboration

The device operation data is characterized by high frequency, massive volume, and time-series sensitivity. This system adopts a two-tier processing architecture with edge priority and cloud aggregation: the edge computer undertakes core functions such as data collection, local storage, real-time computation, and anomaly warning, and can independently complete monitoring and warning tasks in case of network interruption; the cloud database aggregates key statuses, alarm events, and aggregated data from various edge hosts, supporting advanced applications such as historical query, trend analysis, and cross-device comparison. This edge-cloud collaborative architecture not only meets the strict requirements of industrial sites for real-time performance and reliability, but also significantly reduces the pressure on cloud servers and network bandwidth usage by sinking computational tasks to the edge side, making it particularly suitable for real-world environments with unstable network conditions in industrial sites.

4.3 Application of AI image recognition in accessory purchase

Image recognition of industrial components faces challenges such as limited samples, small differences between classes, and large differences within classes. This system adopts a two-stage approach combining object detection and classification networks: the first stage locates components and extracts appearance features, while the second stage determines specific models and specifications. To improve recognition accuracy, the system combines OCR technology to recognize the text on component nameplates and cross-validates with image recognition results. During the training stage, samples are augmented through data augmentation; during the deployment stage, a model-as-a-service approach is adopted, with response times in milliseconds; and a user feedback loop is established to support periodic iteration of the model.

4.4 Microservice governance strategy

Service registration and discovery utilize a service registry to achieve dynamic instance management; the configuration center manages configurations for various environments in a unified manner and supports dynamic updates; the circuit breaker and degrading mechanism prevent

a single service failure from causing an avalanche; the distributed transaction mechanism addresses cross-service data consistency issues, especially ensuring data integrity in core business scenarios such as work order creation and order submission.

5 System implementation

The backend is built using the Java ecosystem along with the Spring Boot and Spring Cloud ecosystems, due to the maturity of the enterprise-level ecosystem, the richness of components, and the abundant talent pool. The frontend is constructed using Vue 3 and Element Plus to build a web management backend. The customer mini-program is developed natively using WeChat. Data visualization is handled by ECharts. In terms of databases, MySQL meets transactional and complex query requirements, InfluxDB supports high-frequency data writing and querying for devices, Redis supports high-concurrency access, object storage uses a distributed system compatible with the S3 protocol, and RabbitMQ is chosen for message queuing. In terms of containerization, Docker is used to package applications, and Kubernetes is employed for container orchestration and cluster management, enabling elastic scaling, rolling updates, and fault self-healing.

Implementation path of real-time device monitoring: The edge computer collects sensor data at a set sampling frequency through the MQTT protocol, performs state evaluation and anomaly detection according to a preset algorithm, and pushes alerts through dual channels of local sound and light, as well as remote SMS and WeChat. Key status and aggregated data are reported to the cloud-based time-series database. Implementation path of AI intelligent customer service: User requests are routed to the conversation service through the API gateway. The conversation service calls the Embedding service to vectorize the question, retrieves relevant knowledge fragments from the vector database, combines the retrieval results with the conversation history to form prompts, and sends them to the large model service to generate responses. Implementation path of service work order: After the customer submits a work order, the system automatically generates a work order number. The customer service accepts the work order and dispatches it. The engineer updates the service status

and fills out the service report. After receiving the completion notification, the customer evaluates the service.

6 Conclusion and outlook

This article addresses the industry pain points of customer service in the blown film equipment manufacturing industry, designing and implementing a customer service management system based on microservice architecture and AI technology. The system integrates five core modules: pre-sales consultation, equipment monitoring, after-sales service, accessory mall, and online training. By integrating with existing enterprise systems, it achieves digital and intelligent services throughout the entire customer lifecycle. The innovations are reflected in: combining large language models with industrial knowledge bases for intelligent question answering in professional fields; integrating edge computing with cloud computing to build a data processing system with edge-cloud collaboration;

and applying AI image recognition to industrial accessory purchasing.

The system still has room for improvement in the following directions: First, the digital twin direction, where a digital twin of the equipment is constructed based on real-time data from the equipment to enable remote diagnosis, virtual debugging, and predictive maintenance; second, the predictive maintenance upgrade direction, where the rule-based reminder mechanism is upgraded to a fault prediction model based on machine learning and equipment big data; third, the ecological platform direction, where APIs are opened to the upstream and downstream of the industrial chain to build an Internet ecosystem for the blown film equipment industry; fourth, the AR remote assistance direction, where AR technology is introduced during engineers' remote guidance of on-site operations, transforming abstract guidance into intuitive visual operation guidance.

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