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Application of Artificial Intelligence in Diagnostics and Repair of Household Appliances: Increasing Efficiency and Reducing Costs

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Abstract: ***The article describes the assessment of the impact of artificial intelligence on the efficiency of diagnostics and repair of household appliances. The relevance of the topic lies in the growing complexity of modern equipment, which nowadays includes many different sensors, microprocessors and control systems. The novelty of the study lies in the study and correlation with predictive maintenance of such key performance indicators as the accuracy of fault detection, reduction in repair time and optimization of maintenance costs. The study analyzed data from sensors, error codes and historical usage logs. A comparison of traditional diagnostics and diagnostics using AI was also conducted. The purpose of the study is to demonstrate how to reduce operating costs and improve service quality by applying automation and machine learning methods. The study used a comparative method, statistical data processing and case study analysis. The results confirm the potential of AI in predictive maintenance and its optimization. The conclusions describe the economic benefits of AI integration and its implementation prospects in the field of household appliance repair. The article will be useful for service companies, engineers and researchers studying AI - based solutions in technical diagnostics and maintenance.***

Keywords: household appliances, artificial intelligence, machine learning, repair optimization, predictive maintenance

1. Introduction

In today's home appliance repair industry, AI is becoming increasingly important. It serves as a tool for automating processes, improving diagnostic accuracy, and optimizing repair work. Its use allows analyzing large amounts of data, identifying hidden patterns, and predicting potential malfunctions, which helps improve service quality and reduce operational risks.

Washing machines, refrigerators and microwave ovens are household appliances that are present in almost every home. However, year after year their technological complexity grows, including more and more sensors, microprocessors, etc. For example, washing machines with the function of automatic dosing of detergents or refrigerators with climate control systems. Such equipment demonstrates a high level of functionality, but its diagnostics and repair require more and more labor. The increase in the number of components and software elements requires deep knowledge of electronics and programming from technicians. This complicates the process of detecting faults and leads to an increase in service time and an increase in the likelihood of errors, which, in turn, creates additional calls to technicians and increases repair costs.

The problem of increasing efficiency and reducing costs in the process of servicing household appliances is relevant in the conditions of the specified complexity of devices. Traditional diagnostic methods based on manual inspection and the experience of specialists are not productive enough, which leads to an increase in equipment downtime and an increase in operating costs of service companies. Low speed and accuracy of diagnostics also negatively affect customer satisfaction. There is a need to implement approaches that would automate the main stages of service, reduce the time for identifying and eliminating faults, and minimize errors.

The purpose of the study is to demonstrate the capabilities and assess the economic benefits of artificial intelligence as a tool for improving the diagnostic and repair processes of household appliances. An analysis of economic benefits was conducted, including reduced maintenance costs and increased overall efficiency.

2. Materials and Methodology

To validate the effectiveness of artificial intelligence in home appliance diagnostics and repair, existing research results were analyzed. These included the works of A. Papaioannou et al. [1], who investigated AI - based methods for detecting operating phases in refrigerators; T. Fonseca et al. [5], who studied datasets for predictive maintenance of home appliances using machine learning; Service Alliance Group [2], who presented an AI - based diagnostic tool for home appliance repair; Oracle [4], who investigated the application of AI in predictive maintenance strategies; and GE Appliances [6], who implemented AI - based smart home solutions for proactive appliance maintenance. These studies provided a comprehensive framework for evaluating the role of AI in improving diagnostic accuracy, reducing repair times, and optimizing service processes.

The practical part of the study involved a comparative analysis of AI - based diagnostic models and traditional troubleshooting methods. A dataset containing sensor readings, error codes, and historical logs of home appliance usage was used to train machine learning algorithms. Statistical analysis of the data was performed to measure the effectiveness of AI in detecting faults, predicting failures, and providing repair recommendations. Surveys and expert articles from technical experts were reviewed to assess the impact of AI - based diagnostic tools on maintenance efficiency and cost reduction.

3. Results and Discussion

Artificial intelligence is significantly transforming the process of diagnosing household appliances by automating it through the analysis of data from various sources [1]. The basis of this approach is the use of information obtained from sensors installed in devices, error codes generated by devices, and their operating history. Sensors, for example, in a washing machine, can record anomalies in the electric current of the motor, such as overload or instability, which AI interprets as signs of a potential malfunction, such as a broken motor. Error codes generated by modern household appliances provide AI with specific indications of problematic components, allowing the system to quickly correlate them with known failure patterns. The operating history, including the frequency of use of the appliance or its operating modes, helps AI identify patterns related to the wear of parts. This makes diagnostics more predictive and accurate. This approach eliminates the need for lengthy manual inspection, reducing the time to identify the problem and reducing the likelihood of errors typical of traditional methods. Figure 1 illustrates the scheme of application of AI in repair of household appliances, described in [5].

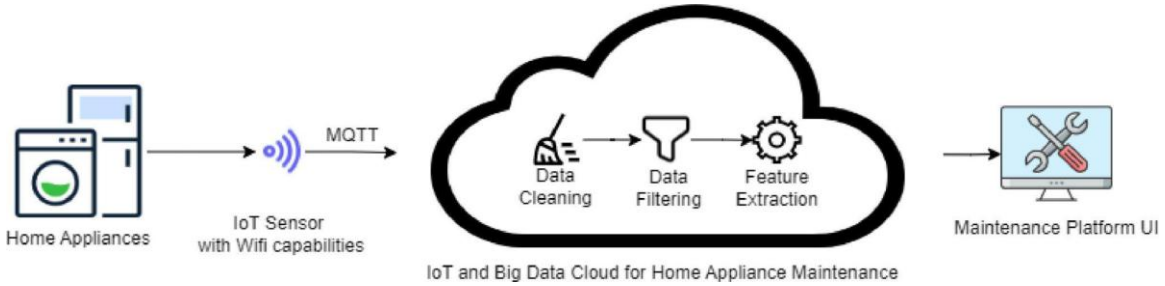

Figure 1: Algorithm for using AI in household appliance repair [5]

Machine learning is useful in automating diagnostic systems, detecting faults based on sensor data, and optimizing repairs. Its algorithms analyze historical repair data, sensor anomalies, and error codes to identify correlations and predict failures, such as compressor failures in refrigeration systems [2]. Learning improves diagnostic accuracy, especially in multifunctional devices (e. g., smart refrigerators). Predictive analytics tools [3] use historical and current data to predict failures, changing maintenance strategies from reactive to proactive. Systems like those from Service Alliance Group [2] automate diagnostic reports, streamline technician workflows, and speed up repairs.

ML further optimizes repair processes by creating step - by - step instructions, recommending tools and parts, and reducing downtime. Research [4] shows that AI integration reduces equipment downtime by 5–20%. By processing sensor data, usage history, and error patterns, ML reduces the human factor inherent in experience - based diagnostics and detects even small anomalies in operation, providing greater accuracy. Real - time adaptation based on feedback from technicians or device data improves recommendations, an example of which is AI - based diagnostics for refrigeration equipment that analyzes temperature, pressure, and energy consumption to improve fault detection [5]. Examples of the sensor data obtained are shown in Figure 2.

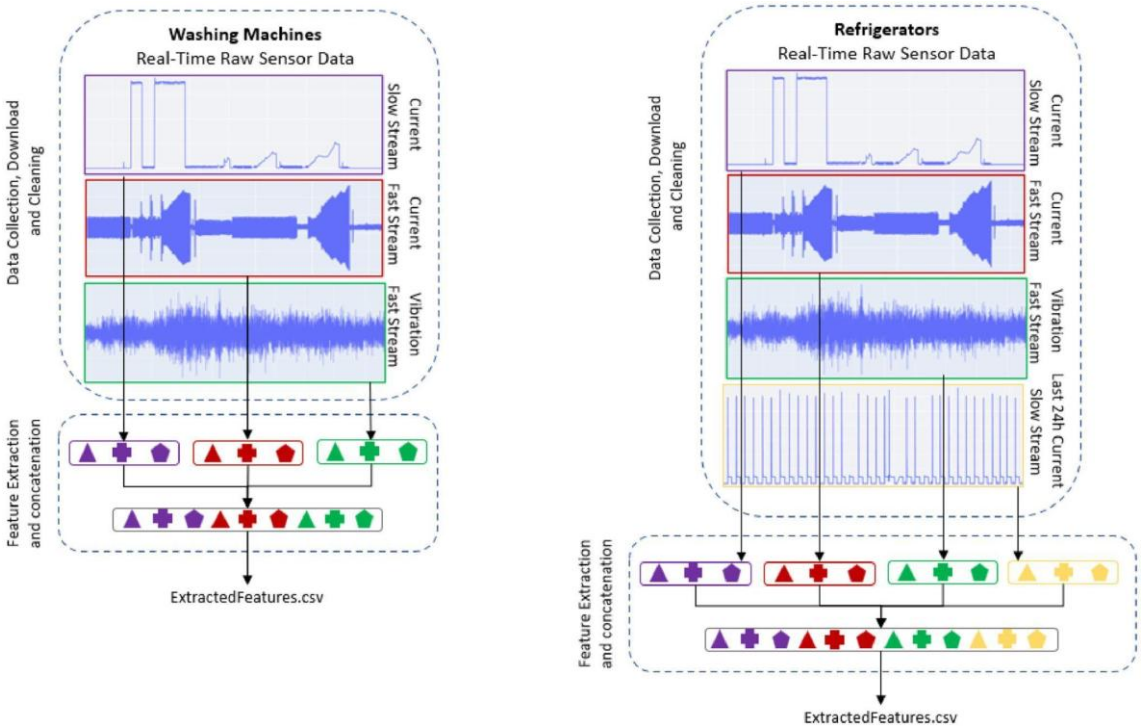

Figure 2: Example of data received from sensors in washing machines and refrigerators [5]

Artificial intelligence improves the efficiency of appliance repair businesses by streamlining operational processes and reducing overhead costs. Traditional fault diagnosis based on manual tests and basic tools was time - consuming. It provides fast and accurate diagnostics that reduce repair times through automated analysis of sensor data, error codes, and usage history. This enables more customers to be served in a shorter period of time, which directly improves revenue streams. In addition, AI - powered logistics optimization, namely analysis of technician location, workload, and geography of service requests, reduces travel costs and maximizes daily repair volume.

For end users, AI reduces repair costs and increases service availability through advanced diagnostic automation. By reducing service providers' operating costs, competitive pricing becomes possible. AI - powered diagnostic accuracy not only helps resolve issues immediately, but also identifies hidden problems that could lead to future failures and reduces repeat service calls. Predictive capabilities also enable preventive maintenance to avoid breakdowns before they occur. The above benefits of implementing AI in home appliance service for service companies and customers are summarized in Table 1.

Table 1. Benefits of implementing AI in household appliance servicing for service companies and customers (compiled by the author)

Table 1: Benefits of implementing AI in household appliance servicing for service companies and customers (compiled by author)

Benefits for Service Companies	Benefits for Customers
Automation of diagnostics and reduced workload on personnel	Faster and more accurate diagnostics of malfunctions
Reduction in time required to identify and fix malfunctions	Lower repair costs due to efficient troubleshooting
Optimization of logistics and routes for technicians	Minimized downtime of household appliances
Decrease in the number of repeat service visits	Increased reliability of devices through predictive maintenance
Reduction in costs for diagnostics and repairs	Reduced likelihood of repeated malfunctions
More efficient management of spare parts	More convenient and transparent interaction with service companies
Improved diagnostic accuracy, reducing the likelihood of errors	Automatic recommendations for preventive maintenance
Ability to perform predictive maintenance to prevent breakdowns	Ability to remotely monitor the condition of household appliances
Enhanced customer service and user satisfaction	Reduced repair waiting time due to optimized technician routes
Increased competitiveness through technological advantage	Access to innovative technologies and an improved user experience

Take GE Appliances, for instance. It operates on the SmartHQ system, which is based on AI, hence advanced device management features based on cloud technology [6]. Among the features is the capability to control connected devices through voice assistants across the availability of their real - time statuses. This precedes identifying potential failure precursors in advance, affirming the most favorable operating modes, and even automatically prompting service upon any critical issue detection. Research [7] indicates that AI is automating a significant number of jobs in different sectors, one of which is an area like that of repair jobs - up to about 50% of the duties being potentially automated.

In summary, the optimization of routes, claims processing, and diagnostics automation in the repair industry is an overview of changes brought by AI tools. The net effect is an improvement in output as well as savings on costs. Future seamless integration of AI will unlock improved potential for the industry to deliver swift, precise, and cheaper service with enhanced customer service and decreased operating costs.

4. Conclusion

The integration of AI - based diagnostics will improve the accuracy and efficiency of the detection of malfunctions in home devices. Having sensor data, error codes, and usage history, and other dependency middleware information proves to be very handy for AI systems to be able to detect potential faults very quickly and with very low human - induced error compared to traditional ways of diagnostics. This will reduce total time taken in diagnostics, optimally repaired, and optimized operating cost for service companies, which in the end improve their cost - effectiveness.

Continuum machine learning would lead to definite diagnoses of a system because of optimal and optimal diagnostic AI when applied to a complex unit of devices. On its part, AI will advise on the best service strategy and make a selection concerning the replacement components. This shall advance the work of maintenance itself, reducing cost on the two parties. It will also enhance the general quality of service as it will lower downtime and the frequency at which service calls have to be placed. At this moment, it speeds up the journey toward predictive maintenance in determining breakages of devices based on historical and current real - world data.

To sum up, AI has brought great benefits to the sector. This is through ensuring better and accurate diagnostics, sustainability in cost reductions, and improved customer contentment in the use of the service. These improvements are expected to continue inspiring the future of the industry by new doors for both the service company and the customer.

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