Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 12, No. 3, 2024

AI-Driven Hardware Testing: Overcoming the Challenges of Modern Hardware Architecture and Power Management

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Abstract: With the rapid development of hardware technology, the diversity of architectures, the complexity of hardware modules, and the growing demand for real-time capabilities, enhanced power management, adaptability, and flexibility all present new challenges. These challenges include managing the complexity of hardware architecture, performance, and energy efficiency, which traditional testing methods struggle to address effectively. To solve these problems, this paper proposes a new standard for integrating Artificial intelligence with hardware test systems. The system can automatically identify key performance indicators according to the hardware characteristics, dynamically adjust the test strategy, optimize the test process, improve efficiency, and ultimately shorten the time to market.

Keywords: Hardware technology development, Artificial intelligence integration, Test optimization and efficiency.

1. Introductions

The rapid development of the manufacturing field has brought about the diversity and complexity of hardware design architectures. Traditional hardware testing methods are more and more difficult to meet the intelligent, efficient and complex needs of modern industrial manufacturing. The differences in function and performance of CPU, GPU, memory and other modules lead to their different testing requirements for each type of hardware. The traditional test process is usually a set of fixed steps, lack of flexibility, can not be effectively adjusted according to the dynamic performance of the hardware. Therefore, the study of intelligent hardware test system based on AI technology can not only improve the accuracy and coverage of the test, but also reduce the test time and resource consumption, so as to improve production efficiency.

2. Architecture Design of AI-driven Autonomous Test System

2.1. System Architecture Overview

AI models of deep learning and reinforcement learning are at the heart of autonomous hardware test systems. The model can learn and analyze the characteristics of different hardware modules, and dynamically adjust the test strategy according to the real-time operation. The whole system works as follows:

The first step is Data acquisition module: real-time monitoring of key performance indicators in hardware operation, such as power consumption, temperature, processing speed, etc.

The second step is AI Autonomous models: Use deep learning models to analyze hardware characteristics and predict the best test sequence and intensity.

The third step is Dynamic test engine: Flexibly adjust the test flow according to the recommendations of the AI model to ensure test coverage and efficiency for different hardware modules.

Of these three steps, the second part of the AI model is the key.

2.2. AI model design

AI models are based on deep learning and reinforcement learning algorithms that learn how to optimize testing strategies from historical test data and real-time hardware metrics. Therefore, the design of the AI model is a key part of the system.

The model works as follows: there are thousands of pieces of data in the hardware run log, and the AI model extracts important data and characteristics about the hardware, such as the type of hardware (such as CPU or GPU), temperature changes, computing speed, power consumption, and so on.

Model training: Through deep learning algorithms, the AI system is able to predict the optimal test step based on historical data of different hardware, and reinforce the learning data to further help the model learn in real time during testing and continuously adjust its strategy according to the dynamics.

3. Independent Optimization of The Test Process

Different types of hardware have different testing requirements. For example, cpus and Gpus each have different functions and design goals, so their testing needs are different. The CPU is the central processing unit responsible for performing most computing tasks, usually involving multi-threading, multi-tasking and other requirements. Gpus are graphics processing units that are mainly used to process a large number of graphics computing tasks in parallel, and are gradually being widely used for general-purpose computing tasks, such as deep learning. So the CPU and GPU were tested in a completely different direction than the requirements.

Traditional hardware testing methods cannot be flexibly adjusted for these differences, but AI autonomous systems can dynamically change test sequence and strategies based on hardware characteristics and real-time. When testing CPU and GPU, adding autonomous AI system can achieve good

results.

The following is a discussion of adding AI autonomous intelligence systems to CPU testing:

3.1. Multi-Threaded task processing

CPU testing needs to evaluate the performance of each core in a multithreaded environment. Multi-core synchronization and load sharing testing are key to ensuring that multi-core architectures work efficiently. The test includes task switching time, thread scheduling, thread synchronization, shared resource usage, and cache consistency. According to research, in terms of multi-threaded task processing, certain test models such as the SPEC CPU test set can be used to measure the performance of the CPU under load balancing tasks. Through these tests, you can verify how multiple cores coordinate to handle a large number of tasks under high load conditions. [1]

3.2. Cache Consistency and memory latency

Cpus have multiple caches, and cache consistency testing is often used by researchers to ensure that data in multi-core systems remains consistent when accessed by different cores. According to the MESI (Modified, Exclusive, Shared, Invalid) cache consistency protocol, you need to verify that caches can maintain synchronization when multiple cores access shared data at the same time. The performance of the cache's access timeliness can be evaluated using specific benchmarks, such as the STREAM benchmark. This type of test not only measures the cache hit rate, but also evaluates the efficiency of the cache system when dealing with complex tasks. [2]

3.3. Power Consumption and thermal management

CPU at high load operation will produce a lot of heat, heat is too large on the machine consumption is huge, will increase the loss rate of equipment. Therefore, power management testing is particularly important. The autonomous test can dynamically adjust the power test scheme, simulate the power change in the actual working scene, and measure the impact of different tasks on temperature and power consumption, so as to optimize the test scheme. Traditional testing methods only focus on the performance of the CPU under extreme conditions, and fail to consider the energy performance under dynamic load. Therefore, it is very important to add an autonomous AI test system to the CPU test. [3]

4. Application Scenarios

AI autonomous systems can be widely used in hardware testing of traditional computing devices (such as desktops, servers, etc.). Generic hardware designs often include multiple different modules (CPU, GPU, etc.), and autonomous AI test systems can automatically adjust the test plan to the specific needs of each module, ensuring that all possible failure modes are covered.

Dedicated hardware (such as AI accelerators, 5G chips, etc.) often have more complex test needs, and autonomous intelligent systems can automatically adjust test strategies according to the unique architecture of these hardware, monitor the dynamics in real time, and provide customized test solutions. This will help improve the accuracy of dedicated hardware and increase productivity benefits.

5. Conclusion and Future Outlook

Ai-driven autonomous hardware testing system provides an optimized solution for the field of hardware testing. By analyzing and learning the characteristics of different hardware through AI models, the system can dynamically adjust the test strategy, improve the test comprehensiveness, reduce the time and test resource consumption, and achieve the purpose of environmental protection and efficiency. In the future, with the further complexity and diversification of hardware design, AI autonomous adaptation test systems will have a wider application prospect.

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