AI-Driven Testing for IoT and Embedded Systems in a Rapidly Changing World

BCS SPECIAL INTEREST GROUP IN SOFTWARE TESTING

SIGiST 2025 SUMMER CONFERENCE

Finding Calm in Chaos: Applying Testing to a Changing World

19th June 2025 - In Person and Online

Open to all BCS Members and Non-Members

bcs The Chartered Institute for IT

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🔧 **Role**: Hardware Design Engineer

Defining IoT and Embedded Systems

IoT: Network of interconnected devices collecting, exchanging and acting upon data (e.g., smart thermostats, wearables, industrial sensors)

Embedded Systems: An embedded system is a specialized computer system—a combination of a computer processor, computer memory, and input/output peripheral devices—that has a dedicated function within a larger mechanical or electronic system

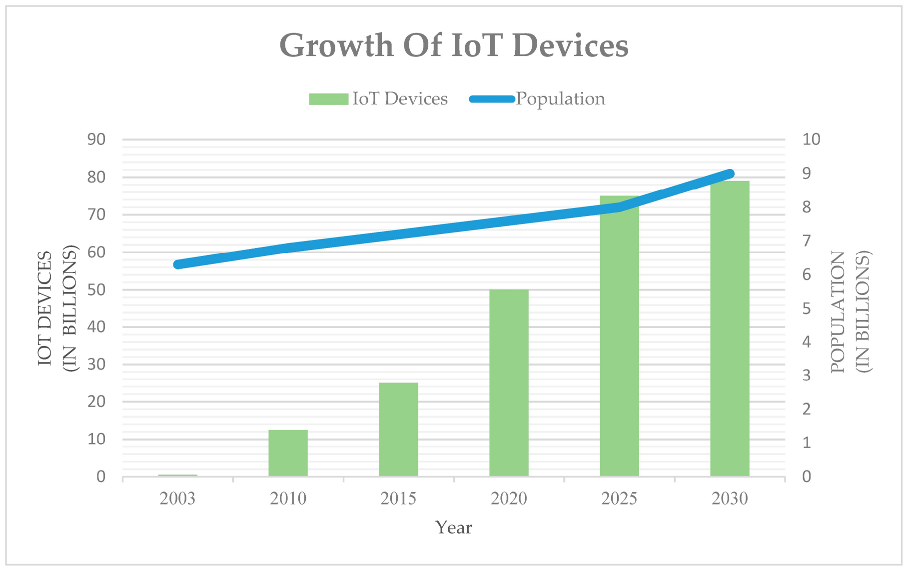
Embedded Systems vs IoT Systems – Key Characteristics

Aspect	Embedded Systems	IoT Systems
Real-time Operation	Must respond quickly to inputs (e.g., airbags, medical monitors).	Often operates in real time, especially in critical apps (e.g., smart grids).
Data Handling	Processes data internally for control or monitoring.	Collects, transmits, and sometimes analyses data externally or in the cloud.
Reliability & Stability	Highly reliable; expected to run for years without failure or reboot.	Reliability is critical, but network, cloud, or sensor faults can affect uptime.
Hard-coded Functionality	Software is usually fixed, tightly integrated, and purpose-built.	Often supports updates, reconfiguration, and remote management.
Connectivity	Typically, standalone or locally connected.	Designed to be networked—communicates with other devices/cloud via Wi-Fi, etc.

APPLICATION
OF
IOT AND EMBEDDED SYSTEMS

The Growth of IoT

- *75 billion devices expected by 2030*
- Examples: Smart meters, wearable health monitors, autonomous vehicles.

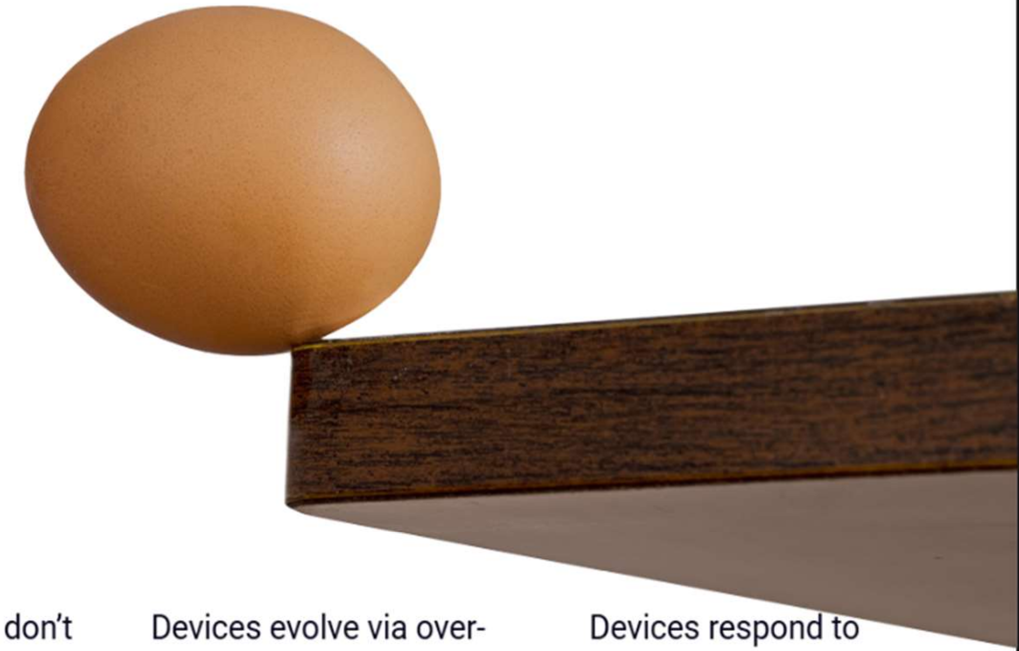


Problem Statement:

As the digital landscape evolves, IoT and embedded systems become the backbone of modern innovation, from smart homes to autonomous vehicles.

This increasing reliance on interconnected devices highlights a critical need for scalable, intelligent, and adaptive testing solutions that traditional methods can no longer fully address.

Testing in a Connected Era



Traditional testing frameworks struggle to keep pace with dynamic systems.

Manual testing is slow, inflexible, and often reactive.

Static test scripts don't adapt well to evolving devices.

Devices evolve via over-the-air updates.

Devices respond to diverse data inputs.

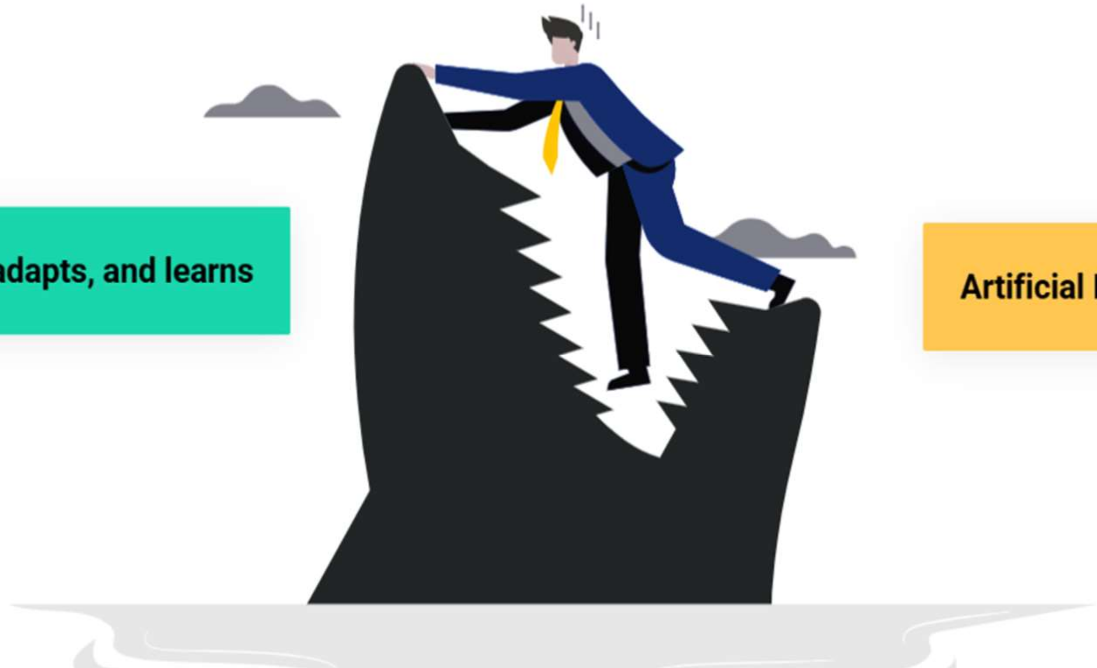
IOT AND EMBEDDED SYSTEM TESTING CHALLENGES

	IoT Testing Challenges	Embedded Testing Challenges
Environment	Highly dynamic (cloud, network, edge)	Often real-time, resource-constrained
Communication	Network-dependent (latency, loss)	Local interaction with hardware
Scalability	Many devices, difficult to emulate	Hardware-dependent, fewer units
Test Approach	Simulation, virtualization, fuzzing	Manual, deterministic unit tests

The Testing Gap

Testing capabilities lag behind the pace of innovation

Need for intelligent testing approaches



Testing that scales, adapts, and learns

Artificial Intelligence's role in testing

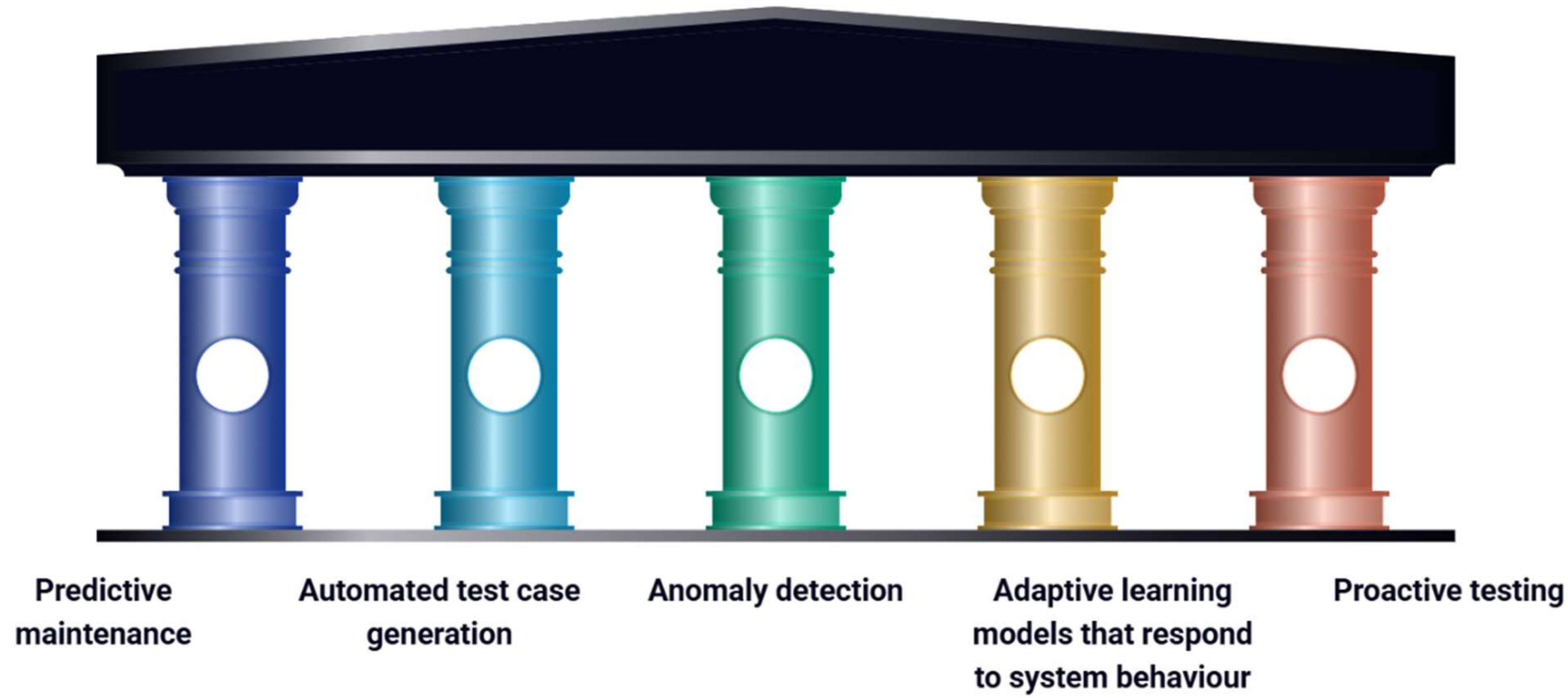
🔹 **Definition of AI:**

Artificial Intelligence (AI) refers to the simulation of human intelligence by machines, especially computer systems, to perform tasks such as learning, reasoning, and self-correction.

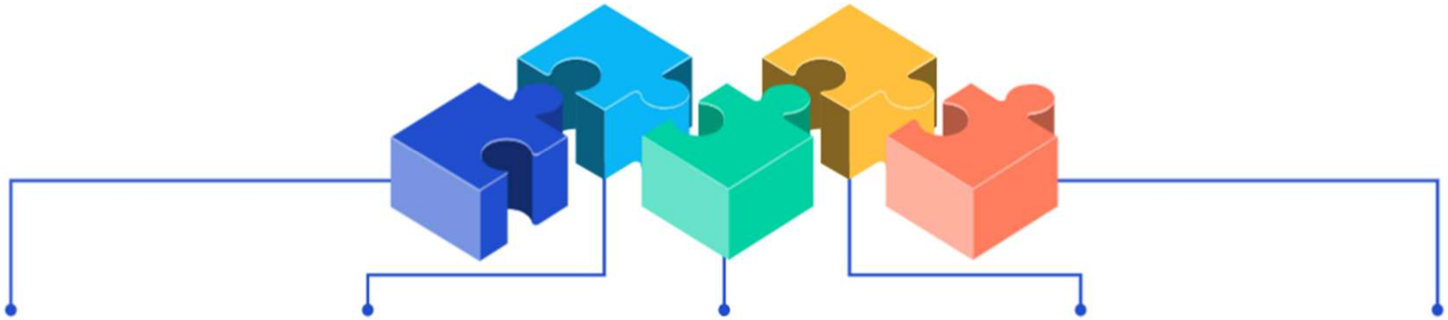
🔹 **Key Subfields:**

Subfield	Description
Machine Learning (ML)	Systems that learn patterns from data to make decisions
Deep Learning (DL)	A subset of ML using neural networks for complex pattern recognition
Natural Language Processing (NLP)	Understanding and generating human language
Reinforcement Learning (RL)	Learning through trial and error to make optimal decisions

Introducing AI in Testing



What Makes AI Suitable for IoT Testing?



- IoT systems generate massive volumes of data.
- AI thrives on data.
- Classify normal vs abnormal behaviour.
- Forecast failures before they happen.
- Automatically validate results across diverse conditions.

AI Testing Pipeline Overview

- **Data Collection** – From sensors, logs, telemetry
- **Pre-processing** – Cleaning, labelling
- **Model Training** – Using supervised or unsupervised learning
- **Inference Engine** – For real-time test execution
- **Feedback Loop** – Continuous learning from outcomes

Techniques in AI-Driven Testing

Deep Neural Networks to detect anomalies

NLP for parsing test specs or generating test cases

Reinforcement Learning for discovering optimal test paths

Fuzzy Testing with ML for identifying unexpected edge cases

Tools Empowering AI Testing

Applitools – Visual validation using AI

TensorFlow, Keras – For building custom models

Test.ai – For app and UI testing using AI agents

Jenkins, GitHub Actions – CI/CD integrations for automated AI testing

Case Study 1 – Smart Meter Grid

In a smart grid deployment, we used AI to identify packet loss and latency patterns.

Predictive models alerted us before outages occurred.

Result: downtime reduced by 30%.

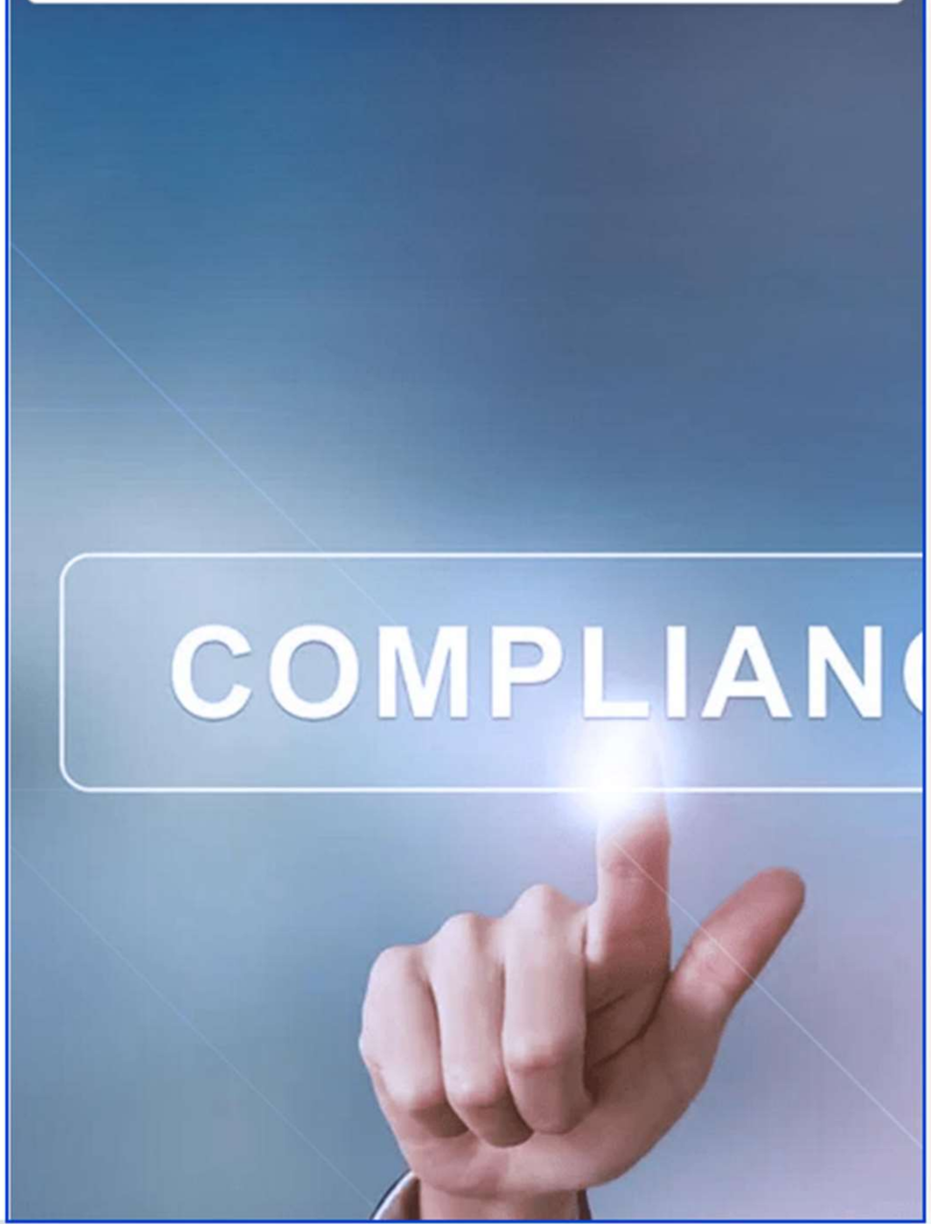
Customer satisfaction improved.

Case Study 2 – Healthcare Embedded Devices

Medical devices require rigorous compliance testing.

We trained models on historical test data to flag likely failure points.

This reduced our testing cycles by 40% while maintaining safety standards.



AI Testing: Powerful but Not Perfect

While AI testing is a critical step in ensuring system performance and reliability, several key risks remain:

- **Bias in Training Data**: Inherent biases can lead to unfair, discriminatory, or inaccurate outcomes, especially in sensitive applications.
- **Lack of Transparency**: Black-box models often obscure how decisions are made, making it difficult to explain or audit results.
- **Over-Reliance on AI**: Excessive trust in AI systems can cause humans to overlook edge cases, anomalies, or system failures.
- **Ethical Concerns**: Responsible deployment requires *human-in-the-loop* mechanisms to ensure accountability, fairness, and public trust.

Standards and Compliance

- We must align AI testing with regulatory standards:
- ISO/IEC 29119 – Software testing
- ISO 26262 – Functional safety for automotive
- IEC 62304 – Software lifecycle for medical devices
- AI needs to be explainable, traceable, and auditable.

The Future of AI Testing in Embedded Systems

Edge AI will enable on-device, real-time testing capabilities

Digital twins will provide simulation environments for training and testing

Explainable AI will enhance trust and compliance

CONCLUSION

AI-driven testing improves how we check IoT and embedded systems, making it faster and more effective

Thank you very much!