Intelligent Edge AI: When Even Bolts Think for Themselves

Our infrastructure often ages faster than maintenance teams can respond. Bridges, wind turbines, and industrial plants consist of thousands of critical connecting elements, the condition of which has previously been checked manually. Neuromorphic computing opens up new possibilities here: With a NeuroQ-Bolt, an intelligent bolt with an integrated ADELIA AI chip, continuous self-monitoring directly on the component becomes a reality. This allows damage to be detected even before it becomes visible.

Bolts carry enormous loads and are crucial for the safety of large structures. However, the large number and inaccessibility of these locations make regular inspections costly. A NeuroQ-Bolt fundamentally changes this process. It combines sensor technology, AI processing, and energy-autonomous communication in a compact unit that remains permanently in the component.

Neuromorphic computing in the component

Neuromorphic computing refers to brain-inspired AI hardware that executes neural networks directly and extremely energy-efficiently in the hardware itself. The neuromorphic AI chip ADELIA, a dedicated low-power processor for edge-based neural signal analysis, is built on precisely this principle and forms the heart of a NeuroQ-Bolt:

Its analog in-memory computing enables the execution of complex neural networks with less than 1 mW of power consumption. This efficiency allows the complete analysis to be performed directly in the bolt – without the cloud, without external computers, and powered exclusively by energy harvesting. Even slight temperature differences or small ambient light levels are sufficient to power a whole NeuroQ-Bolt.

ADELIA processes the signals from several integrated sensors: the piezoresistive DiaForce® thin-film system measures the preload force, while other sensors detect vibrations and acoustic events. Neuromorphic algorithms classify these signals in real time, detecting anomalies, incipient cracking, and atypical load curves, even in noisy or vibration-intensive environments.

A future scenario at sea: edge-AI driven predictive maintenance with self-monitoring bolts instead of manual inspections

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Self-sufficient monitor with a wide radio range

If the bolt detects any abnormalities, it sends an energy-efficient warning via the LPWAN system mioty®. A base station can connect up to 30,000 bolts over distances of up to 10 km. Each message requires only 54 mWs – ideal for years of autonomous operation.

Greater efficiency and sustainability

With its local AI processing, a NeuroQ-Bolt enables true predictive maintenance. Inspections only occur where necessary, rather than at fixed intervals. This drastically reduces material, energy, travel, and costs. Areas that are particularly difficult to access, such as offshore wind farms, bolted motorway or railway bridges or large industrial plants, benefit greatly from this technology.

Pioneering for infrastructure and industry

A NeuroQ-Bolt could be a solution for edge-AI driven predictive maintenance of critical infrastructure. Yet the underlying technologies – ADELIA, energy harvesting, mioty®, Q-Bo® and DiaForce® – already exist and can also be deployed as modular add-ons for existing bolts, for example. They impressively demonstrate how neuromorphic computing is making the leap from research to real-world applications. A bolt that thinks and reports for itself: small in size, big in potential for a more sustainable and secure infrastructure.

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