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Bridging Nature and Artificial Intelligence for Smart Electronics Technology

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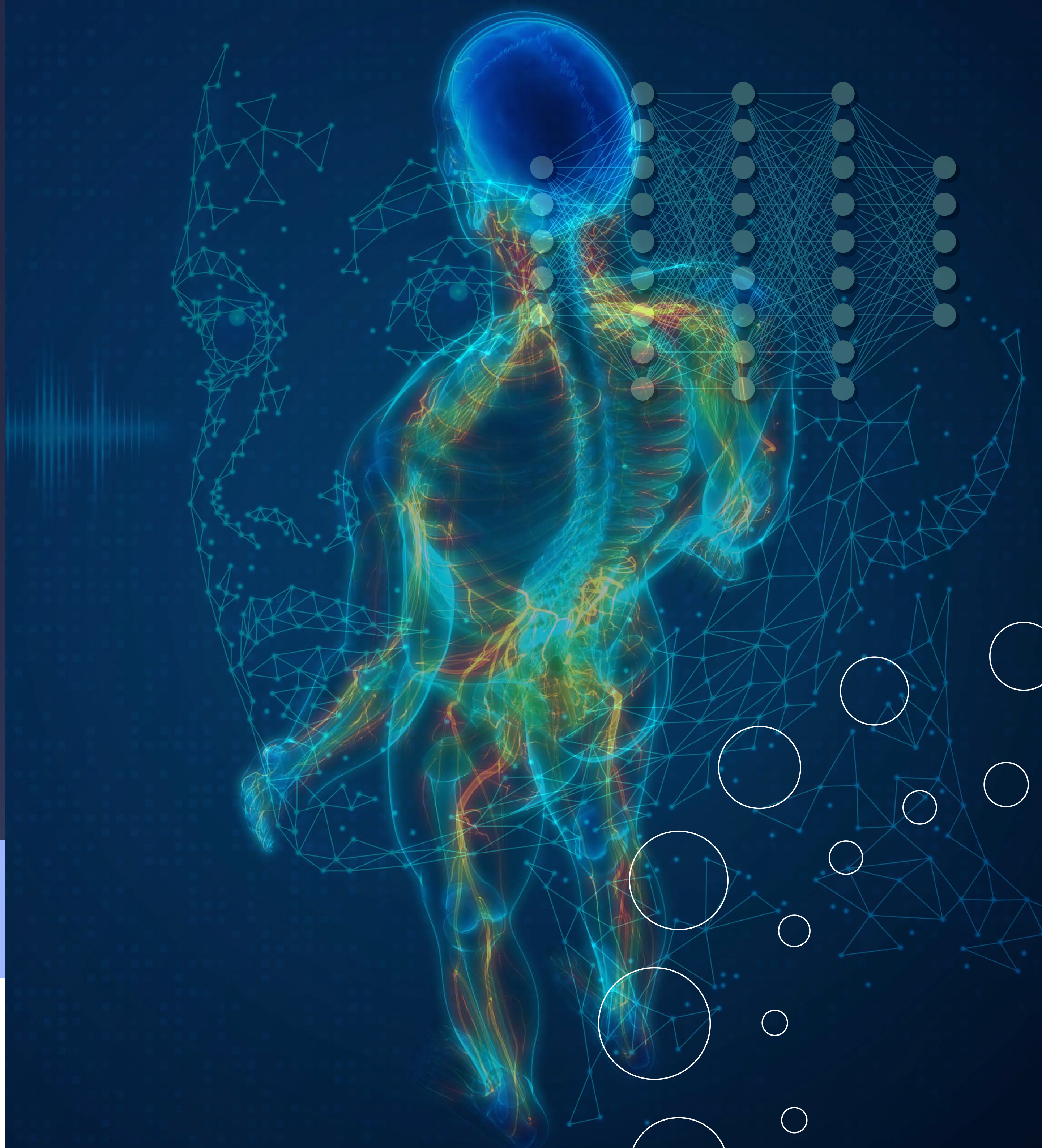

Bridging Nature and Artificial Intelligence for Smart Electronics Technology

The ever-developing world of artificial intelligence (AI) stands at the tip of a transformative breakthrough. Professor Martin Trefzer from the University of York and Professor Jim Harkin from Ulster University have introduced a revolutionary approach to neural network design. They work on an electronic system based on AI that forms the basis of the cross-disciplinary project called Nervous Systems, which aims to build electronic neuromorphic devices with an artificial intelligence system mirroring the adaptability and responsiveness of biological neural systems.

The Nervous Systems Project

A team of researchers from the Universities of York and Ulster, led by Professors Martin Trefzer and Jim Harkin, are working on an exciting project called Nervous Systems. They are developing an electronic nervous system inspired by how living organisms detect changes and respond to anomalies.

At its core, the Nervous Systems project seeks to advance electronic devices, ranging from computers to smart gadgets, with AI. This innovative integration aims to increase the capacity of devices to actively perceive their operational state. In living beings, the nervous system is like a built-in radar, constantly alert to internal changes and changes in the environment. It provides organisms with a level of self-awareness that equips them with monitoring capacity and the ability to respond to any situation and to adapt. The researchers envision a similar concept for electronic devices, whereby smart devices could sense how they are doing and automatically fix any problems they encounter. If a computer embedded with this system senses an error, it can self-repair.

In practical terms, the successful realisation of the Nervous Systems project could yield devices that are not only more efficient and reliable but also exhibit a level of autonomy that simplifies users' experiences. Imagine the future where your computer not only alerts you of potential issues but also takes the initiative to search for the cause and the resolution!

Artificial Neural Microcircuits

The Nervous Systems project builds on vast existing research into neural networks but also incorporates several new ideas. Professors Trefzer and Harkin drew the observation of how animals move and react to threads to develop the artificial neural microcircuits that form the basis of the Nervous System project. The artificial neural microcircuits are small and versatile units that mimic the behaviours found in nature. For example, just as a crayfish uses specific neural circuits to coordinate motion and quick escape reactions when needed, artificial neural microcircuits can be used to help electronic devices adapt to different situations.

To make this electronic system flexible, the researchers use a library of behaviours, much like a collection of tools. Imagine having a toolbox with various gadgets for different tasks; similarly, this project creates a catalogue of different behaviours that the microcircuits can apply when needed.

Ensuring these microcircuits work effectively involves testing their responses to different situations, much like checking if a tool in your toolbox works for a specific job. The team uses Novelty Search, a method emphasising diverse behaviours, to create a catalogue that covers a broad range of scenarios. To avoid overwhelming the electronic system with too many tools, the researchers introduced a pruning function. This function trims unnecessary elements, ensuring the system stays efficient and focused on essential tasks. It is like refining a collection of tools to keep only the ones you need.

From Neural Concepts to Electronic Reality

Biological nervous systems provide a novel perspective on neuromorphic systems with their unique ability to perform real-time information processing and integration at multiple scales and levels of abstraction, if successfully translated to electronic systems. In particular, their plasticity and adaptation capabilities handle dynamic and uncertain environments. In the relentless pursuit of realising the Nervous Systems project, Professors Trefzer and Harkin meticulously follow a systematic methodology for the generation and evaluation of artificial neural microcircuits. This methodological approach leads to the seamless integration of the microcircuits into an electronic nervous system with unparalleled adaptability.

The team starts by generating an algorithm designed to produce a diverse array of artificial neural microcircuits, each representing a unique behaviour. Drawing inspiration from the biological neural circuits, the algorithm functions as the architecture of a comprehensive toolbox of microcircuits.

The next step is to ensure the adaptability of the artificial neural microcircuits. To make the components as versatile as possible, the team leverages neural circuit motifs, a concept inspired by identified patterns of biological neural circuits in animals. These motifs act like the building blocks of artificial neural microcircuits, allowing them to perform different tasks without being tied down to a specific rulebook. The team wanted these components to be as adaptable to different challenges as possible. So, instead of one rulebook, they introduced the idea of 'substrate agnosticism'. This way, the electronic systems can tackle a range of tasks without getting bogged down by rigid rules. The goal here is to create components that can handle various jobs without being too rigid, being ready to adapt to whatever task you throw at them.

Heroes of the Digital World

Professors Trefzer and Harkin and their colleagues conducted a crucial experiment to test the efficacy of the proposed methodology in generating artificial neural microcircuits in practice. The focus was on determining whether these microcircuits could provide clear and consistent responses to inputs. To test this, they used a simulated environment with a sample text with 2,300 characters. Each character became a unique signal, translated into a language the microcircuits could understand. They created 100 microcircuits and let them evolve over 50 rounds of testing. Each time, the microcircuits exchanged traits, mixed and matched, and even learnt new tricks. Imagine having a group of digital creatures that get better at their job over time!

Professors Trefzer and Harkin wanted to make sure that the microcircuits would not follow strict approaches to performing their jobs. So, they encouraged them to share their skills and try new things. They watched and measured the performance of the microcircuits like they were living organisms, but of course, they were artificial neural networks. The aim was to ensure the microcircuits had diverse and useful skills, mimicking the toolbox full of gadgets for various tasks.

Out of the unique 5,000 microcircuits born from this experiment, 50 stood out as having a particularly useful set of skills. They showed they could understand and respond well to different characters in the sample text, much like recognising different tools in the toolbox. Some were good and responded strongly, while others were much slower and weaker. From the initial research exploration, Professors Trefzer and Harkin agreed that some of these microcircuits could be heroes of the digital world, understanding and reacting to all the bits and pieces of information they encounter.

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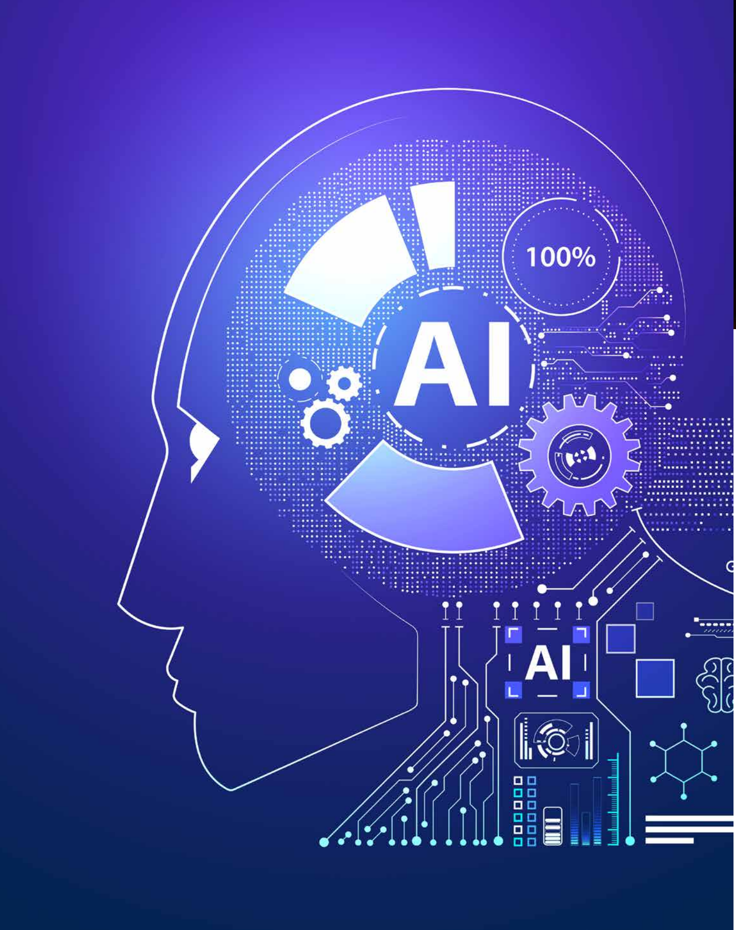

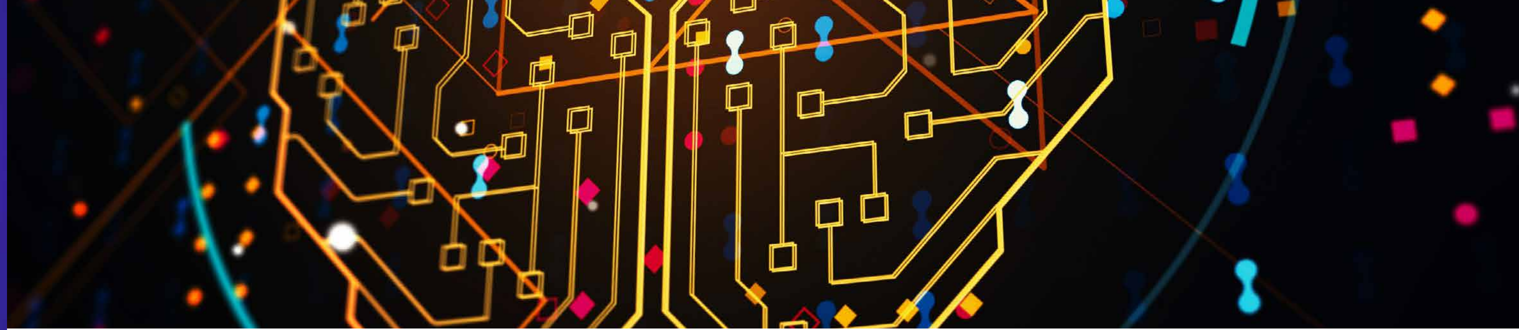

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Overcoming Faults

Combining multiple microcircuits into one large functional device is not an easy task. There are many hiccups that researchers can encounter in the process, including manufacturing defects, issues with overheating, and radiation-induced faults. Detecting these faults is extremely important so that the devices can withstand different challenges. The traditional methods do not pay attention to what caused the error in the first place – which is what Professor Trefzer and his colleagues wanted to overcome.

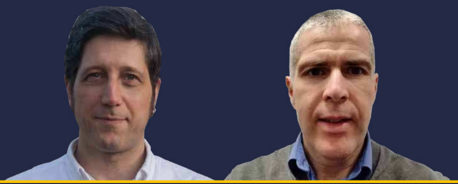
They developed a new system that works as a detective, identifying and addressing the faults. This system is designed to be flexible, fitting to various devices without any brand-specific limitations. It is like having a universal tool that works across different tech brands, ensuring the gadgets run reliably. The heart of this system is the fault injection unit that strategically trains the systems to discover potential disruptions and related causes. A crucial advantage of the fault injection unit is its dynamicity in offering a controlled yet adaptive approach to fault detection. This is a significant step towards creating a more reliable technology with an extra layer of protection. As part of the Nervous Systems project, the team created a series of tutorials on how to use the fault injection unit, which they regularly held for other researchers.

Questions for Future Research

The team now wants to know if there is a method that could be used to label the behaviours of the microcircuits easily. This is an important question to ask because it opens avenues for improving interpretability and understanding of the microcircuits’ actions. The ability to assign clear labels to specific behaviours will allow Professors Trefzer and Harkin and other researchers to decipher and categorise the functionalities performed by individual microcircuits. This will provide a structured framework for further analyses and will advance the Nervous Systems project even further.

The endeavours to establish an effective labelling method hold profound real-life implications. As artificial neural microcircuits progress towards practical applications, their successful integration into various technologies can significantly impact people’s lives in meaningful ways. It is a technical challenge for researchers, which, if implemented successfully, can result in a much better experience for users of technical devices. This fascinating work brings us closer to a future where intelligent systems are not only advanced but also transparent, adaptable, and aligned with humans’ needs.

MEET THE RESEARCHERS



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Professor Martin Trefzer is based at the School of Physics, Engineering and Technology at the University of York, UK. His research interests include novel and unconventional computing models and substrates, neuromorphic systems, variability-aware hardware design, biologically inspired models of hardware design, evolutionary computation, and autonomous fault-tolerance.

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Professor Jim Harkin is Head of the School of Computing, Engineering and Intelligent Systems at Ulster University. He leads research on the design of biologicaly-inspired embedded systems and focuses on developing electronic computing systems that can self-repair under the presence of errors.

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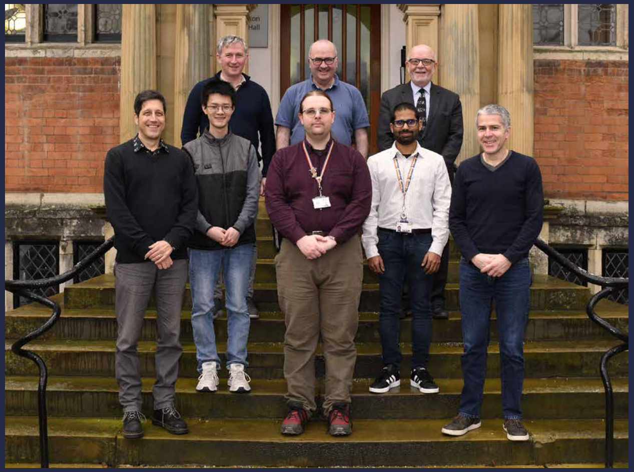

NERVOUS SYSTEMS PROJECT

Led by Professor Trefzer and Professor Harkin, this cross-disciplinary team of researchers are pioneering work to exploit artificial spiking neural networks in a novel way for the creation of an embodied 'electronic' nervous system. Core to the research ist the development of a novel nervous system-inspired design methodology and hardware architecture, and the validation of the these advances in real-world tasks. The researchers envisage a self-aware electronic system with an embedded artificial nervous system that can sense its state and performance, and exploit the structure and computational power of these kinds of bio-inspired mechanisms for autonomous fault tolerance.

W: https://www-users.york.ac.uk/~mt540/nervous-systems/index.html

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FURTHER READING

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