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New possibilities for reservoir computing with topological magnetic and ferroelectric systems

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Yin and yang from ferroelectric (blue) and magnetic patterns (red). Credit: R. Msiska/J. Schaab/D. Meier/amb design & illustrations

Speech recognition, weather forecasts, smart home applications: Artificial intelligence and the Internet of Things are enhancing our everyday lives. Systems based on reservoir computing are a very promising new field.

The research group led by Prof Dr. Karin Everschor-Sitte at the University of Duisburg-Essen (UDE), is conducting research in this area. They are primarily investigating new possibilities for reservoir computing, for example using magnetic materials.

Now, together with specialists from the field of ferroelectric materials, the team has shown that these systems are also suitable for processing complex data faster and more efficiently. Their results have been published in *Nature Reviews Physics*.

Put simply, reservoir computing utilizes a large network (the reservoir) to convert complex tasks into a form that is easy to process. "Any system that has four core properties is suitable as a physical reservoir: complexity, short-term memory, non-linearity and reproducibility," explains UDE professor Everschor-Sitte.

"Magnetic patterns on the nanoscale are very interesting, especially so-called skyrmions. These magnetic vortices can be moved and excited—for example by electrical currents, temperature, voltage or light pulses—causing them to grow, shrink or deform.

"Because these systems are easy to manipulate and measure, energy-efficient and easy-to-control reservoirs can be constructed. They are compatible with our current computer hardware."

With their research, Everschor-Sitte and her team laid the foundation for magnetic reservoir computing about seven years ago. Now, in cooperation with colleagues from the Norwegian University of Science and Technology (NTNU), they have developed the idea of a new variant: ferroelectric reservoir computing, which is based on the special properties of ferroelectric materials.

"They can store energy well, they can change their electrical polarization, for example through an electric field or temperature; they have fast switching behavior and they can be mechanically deformed," says co-author Dr. Atreya Majumdar (UDE).

Because both magnetic and ferroelectric materials are so versatile, the systems can also be multidimensional and hybrid: This means they have much greater ability to process data, recognize complex patterns and display information. Past inputs can also be better stored and utilized, which is particularly important for time-dependent data.

With the new possibilities of reservoir computing, more powerful applications could be developed in the future that have to do with speech and image recognition, sensor technology or embedded systems. "Smart home applications and the Internet of Things need compact systems that are fast and consume little energy," says Majumdar. "Reservoir computing is a promising solution here."

More information: Karin Everschor-Sitte et al, Topological magnetic and ferroelectric systems for reservoir computing, *Nature Reviews Physics* (2024). DOI: 10.1038/s42254-024-00729-w

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