Walking down a street, we are constantly bombarded with sensory impressions. You see a vehicle or a familiar face, you hear the ongoing traffic and conversations, you smell the food stalls … All these external impulses instantly produce massive neural activity in your brain, so that you can recognize the passing bus, a good friend or a car horn and that the smell of freshly baked waffles makes you hungry.

When recognizing faces in a crowd, we are unaware that our brain not only analyzes each trait, but it also classifies these faces and compares them with known ones. Differentiating a tree from a car, the sound of a piano from a car horn, the brain draws information about external stimuli from the transient electrical signals generated by its neurons in response to what our senses perceive.

It is precisely this form of information processing in neural networks that has inspired researchers to create systems that mimic the brain's information processing capabilities, radically different from current computer based schemes.

Neuroscientists exploit an analogy between the human brain’s response to external stimuli and the reaction of water to external perturbations, such as a pebble thrown into it. From the pattern of waves generated by the impact and the way these waves die out, one can conclude where and when the pebble hit the surface, with which force and which weight. Similarly, the brain draws information about external stimuli from the transient electrical signals generated by its neurons in response to what our senses perceive.

In this article, the authors propose to implement a reservoir computer in which the usual structure of multiple connected nodes is replaced by a dynamical system comprising a nonlinear node subjected to delayed feedback. Let us now explain what is « delayed feedback ».

Time delays are intrinsic in many real systems. In engineering, time delays often arise in feedback loops involving sensors and actuators. Another interesting and exciting area for time delay modeling emerges in traffic dynamics where the delay is introduced to account for the finite reaction time of drivers. In laser dynamics, models with time delay play an important role as a delayed feedback typically occurs due to unwanted external reflections. On the one hand, time delays tend to destabilize lasers leading to the inclusion of expensive optical isolators, but, on the other hand, chaotic outputs caused by delays can be used. In general, systems subject to time-delayed feedback present a rich variety of dynamical regimes.

It is this variety that is exploited by the authors, showing that a single nonlinear node with delayed feedback can replace a large network of nonlinear nodes. Their results demonstrate that this new structure performs well in a variety of tasks, such as time series prediction and speech recognition. The authors suggest that applying this simpler structure in complex networks, such as electronics or photonics systems, could potentially be more resource-efficient. Instead of needing to build hundreds or even thousands of artificial neurons, it would suffice to implement only one single hardware node,
in combination with a delay line. The fact that delay is easily implementable in photonic or optical structures may lead to the implementation of ultra-fast all-optical computational units and Ultimately, this research might lead to a new information-processing paradigm.

This research was partially supported by the Belgian Science Policy Offi ce, under grant IAP P6-10 ' photonics@be ', by FWO and FRS – FNRS (Belgium), MICINN (Spain) under projects FISICOS (FIS2007-60327) and DeCoDicA (TEC2009-14101) and by the European project PHOCUS (EU FET-Open grant: 240763).

Illustration of a speech recognition task: The spoken digit recognition task is generally accepted as a basic speech recognition task. The input dataset for the spoken digit recognition consists of a set with ten spoken digits (0...9), each one recorded ten times by five different female speakers. Purpose is that the network successfully recognizes the spoken word, relating it to the correct digit. Our experimental and numerical results show the single node with delayed feedback performs comparable to or even better than « classical » neural networks composed of more than 1,200 nodes.