TREND 2020

Reservoir Computers: A Simple Way to Model Complexity

DEFINITION:

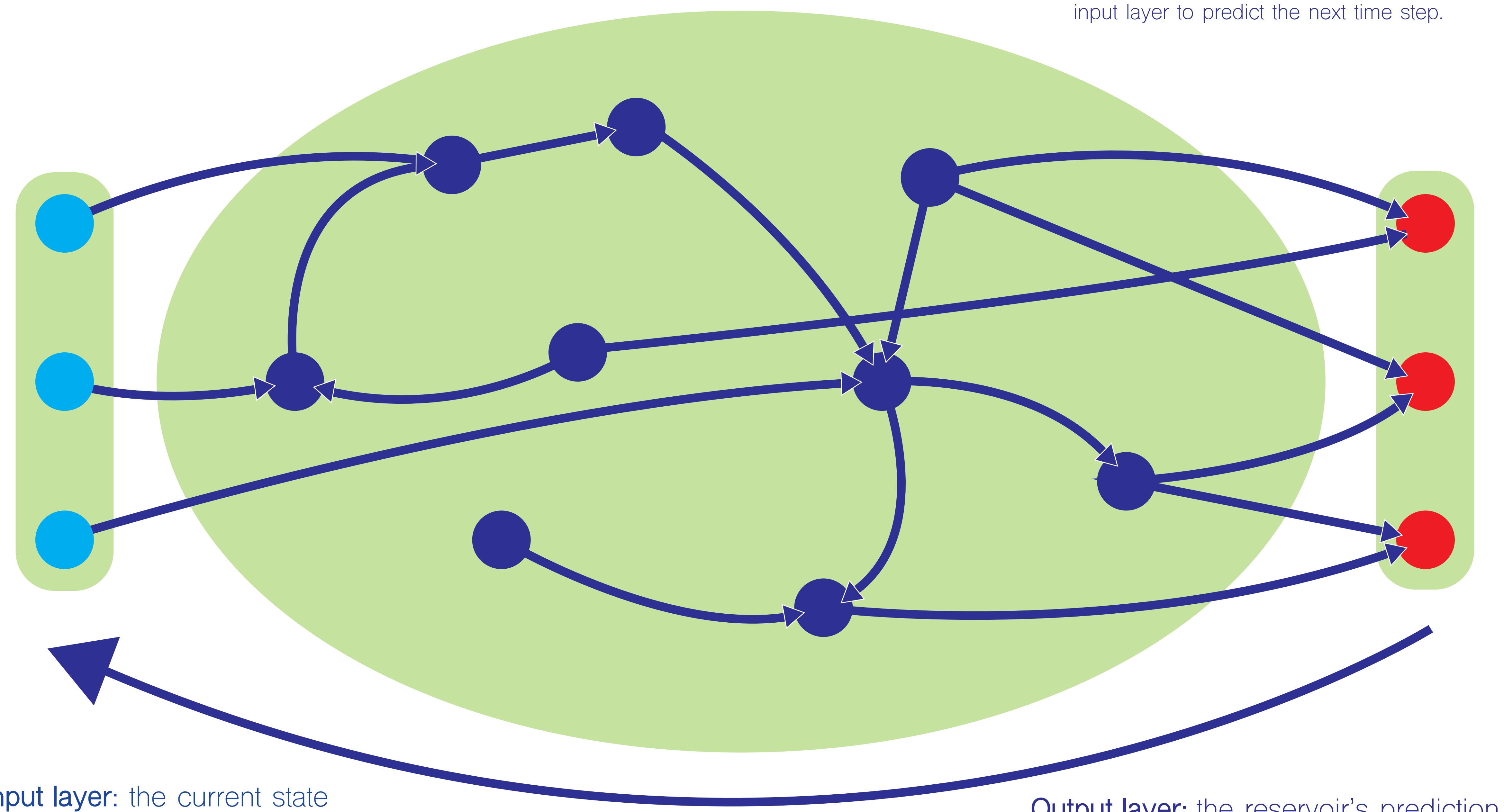
Reservoir computers are a type of neural nework suited to modeling chaotic, nonlinear systems. While in a standard neural network, the input weights, internal weights, and output weights are trained, in a reservoir computer only the weights from the internal "reservoir" neurons to the output are trained.

The reservoir is trained with data from a nonlinear system; the system state at the current time step is the input, and the system state at the next time stvep is the target we train the reservoir to predict. The reservoir, with random fixed weights between neurons, does complicated non-linear processing on the input data; the linear combination of the reservoir neuron states which best fits to the training data is then found.

This simplified variety of neural networks enables extremely fast and accurate prediction of the evolution of complicated, nonlinear systems.

WHAT'S UNIQUE ABOUT RESERVOIR COMPUTERS?

The input goes through the reservoir and produces an output signal; the output is then fed back to the input layer to predict the next time step.



Input layer: the current state of the physical system. Input weights are randomly fixed

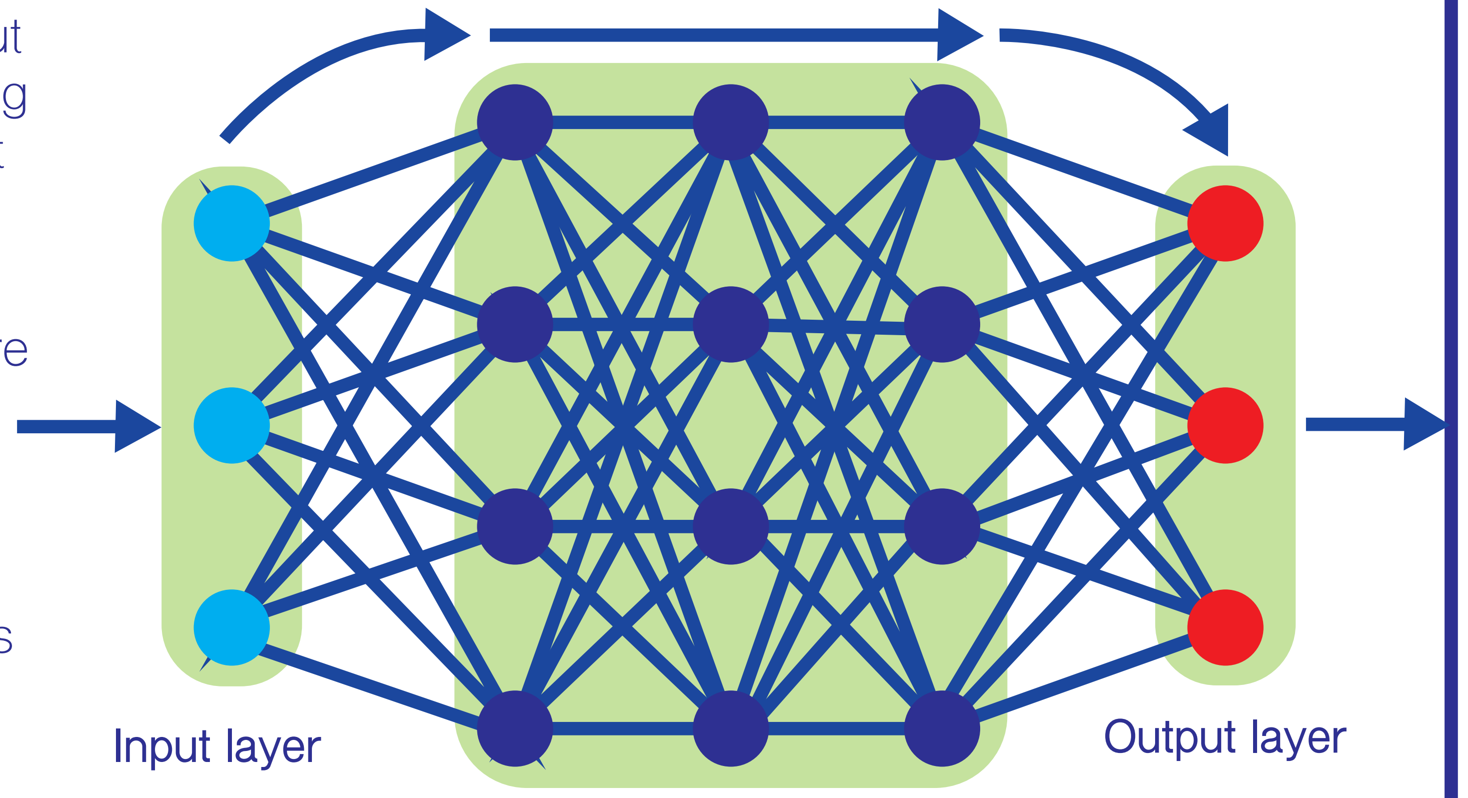
Reservoir: hundreds or thousands of neurons with random, fixed connection weights. This visual shows a simplified example of a possible reservoir.

Output layer: the reservoir's prediction of the system state at the next time step. Only the weights to the output layer are trained.

COMPARISON WITH THE STANDARD NEURAL NETWORK:

Input, inner layers, and output weights are all trained. Having many more weights makes it take much longer to train a standard neural nework.

While reservoir computers are specialized for time series prediction, standard neural networks are more general purpose, performing well at image classification problems and optical character recognition.



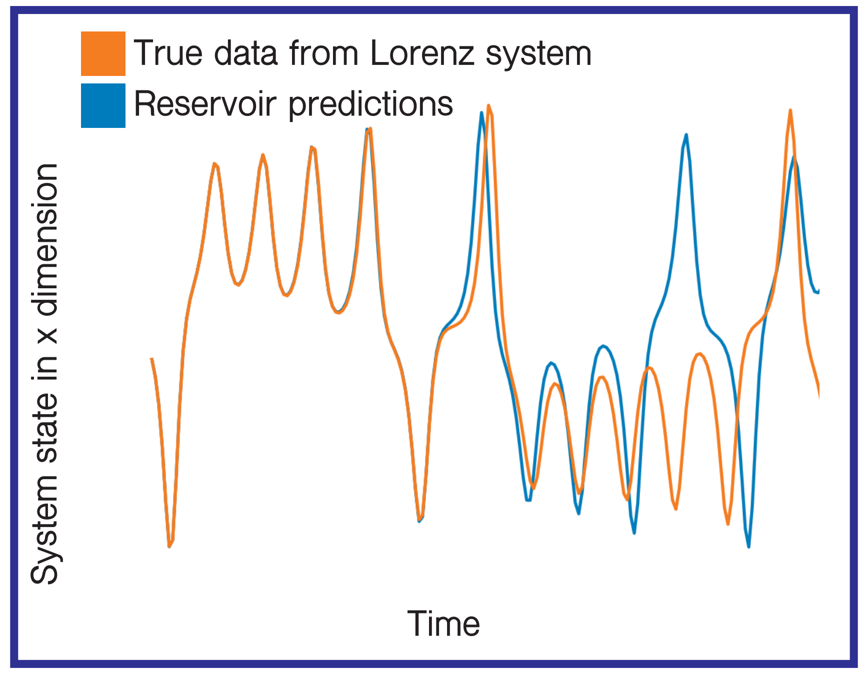
Inner layers: orderly, layered structure

APPLICATION:

In training, the reservoir computer "learns" how a chaotic, nonlinear system evolves. This allows modelling of the evolution of complex systems for which no exact equation can be found. For instance, a reservoir can learn the behavior of the Lorenz equations on the right.

$$dx/dt = 10(y - x),$$
$$dy/dt = x(28 - z) - y,$$
$$dz/dt = xy - 8z/3.$$

A reservoir can accurately predict the evolution of the Lorenz equations for a short time, but it can also reproduce the "climate" of the Lorenz system in the long term. In this graph, the reservoir prediction in blue at first matches the true values from the Lorenz system in orange, then diverges from the orange line while continuing to look like a trajectory that could have come from the Lorenz equations.



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