Intelligent Sensor Interconnection Networks Performing Signal Classification

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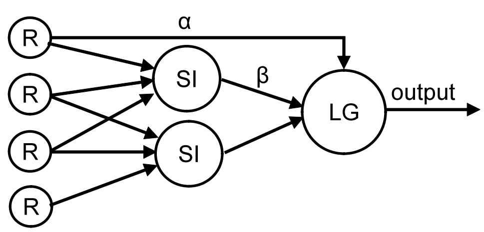
Sensor networks are often required to collect and process vast amounts of broadband data for making rapid decisions. For example, phased-array sensor systems can contain thousands of antennas that need to operate together to detect, process and identify multiple signals while rejecting others in a dynamic way. The interconnection networks supporting these arrays may be required to carry and process thousands of Gbits/sec of data. Using optical processing at the front-end of such networks can greatly facilitate making fast and reliable decisions with both a low false-alarm rate and low miss rate.

Toward this goal, we have developed and demonstrated an intelligent sensor network architecture that effectively performs signal feature classification of analog signals such as those employed in broadband sensor arrays [1]. The architecture of this network is shown below. A set of antenna elements R receives signals that are passed along to two stages of optical processing devices, S1 and LG. A signal α from one sensor is fed directly to the second stage, which is designed to be triggered quickly, but has a high threshold, so α alone is insufficient in magnitude to produce a response at the output. At the same time, signals from all sensors are fed through an interconnection network to the first stage S1 that performs matched filtering and classification of the input patters. Not shown are weights and delays in the front-end interconnection network that enable temporal and spatial filtering of the input patterns.



Each of the optical processing devices S1 and LG consist of an optical matched filter at its front end followed by a nonlinear optical loop mirror thresholder. It has been previously demonstrated that these devices can perform signal identificaiton [2]. Here we demonstrate cascading these devices so they can perform both classification of signals and rapid decision-making, as would be required, for example, in front-end processing to rapidly reconfigure and steer beams to/from phased array antennas. This system employs fast signal integration based on cross-absorption modulation in electro-absorption modulators and ultrafast optical thresholding in a highly Ge-doped nonlinear optical loop mirror. By adjusting the weights and delays of the inputs, the device can be configured to classify different signal features. The basic model consists of two cascaded integrators and one optical thresholder. The first integrator is configured to respond to a set of signals with specific features. The output spikes from the first neuron are thresholded and become the input of the second integrator. The second integrator has a fast integration time to provide a quick response and a high threshold to ensure a low false alarm rate, and further selects a subset of the signals from a set determined by the weights and delays of an optical finite impulse response filter. The second integrator responds only when the input signal and the signal from the first integrator arrive within a very short time interval. The device can be configured to response to different sets of input patterns by simply varying the weights and delays of the inputs. In this paper, we will present the results of this demonstration and discuss applications of this processor to intelligent optical interconnection networks.

[1] D. Rosenbluth, K. Kravtsov, M. P. Fok, and P. R. Prucnal, "A High Performance Photonic Pulse Processing Device," *Optics Express*, vol. 17, iss. 25, pp. 22767–22772, December 2009.
[2] M. P. Fok, D. Rosenbluth, K. Kravtsov, and P. R. Prucnal, "Lightwave Neuromorphic Signal Processing [In The Spotlight]," *IEEE Signal Processing Magazine*, vol. 27, iss. 6, pp. 158 – 160, November 2010.