SIGNAL PROCESSING

Holographic correlation improves on DSP by six orders of magnitude

Researchers at Northwestern University (Evanston, IL), Massachusetts Institute of Technology (Cambridge, MA), and Digital Optical Technologies (Somerville, MA) have used holographic methods to improve on the image-identification speed of digital signal processing (DSP) by six orders of magnitude, according to a postdeadline paper presented at the annual Conference on Lasers and Electro-Optics (CLEO) in May.

A simple holographic optical correlator (HOC) uses the inherent parallelism of optics to improve upon DSP processing speeds by three orders of magnitude, according to Selim Shahriar of Northwestern University who presented the results. While digital signal processing relies on a very fast computer for bit-by-bit comparison of target images to stored images, holographic optical correlation uses angular multiplexing to compare whole images to data stored in holograms.

"Holography allows you to do the search in a parallel fashion," Shahriar said. He added that conventional digital memory has become so inexpensive and increased in capacity to such a degree that interest in holographic data storage and retrieval has now focused on applications, such as pattern and character recognition, implementations of optical interconnections in hybrid optoelectronic parallel computers, computer and robotic vision, and artificial neural network technologies, where increased access speeds through parallel processing could make a signif-

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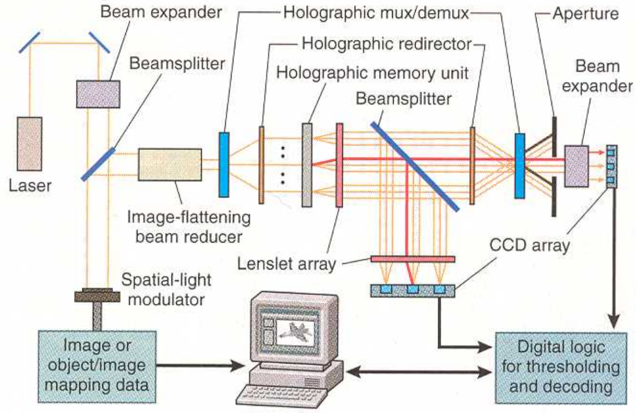
icant difference. The research is primarily driven by the U.S. Department of Defense for applications such as identifying enemy aircraft and missile threats, he said. But civilian applications might also include biologically based identification processes such as fingerprinting or comparison of dental images.

The parallel searching capacity of existing holographic optical correlators is limited, however, by the number of images that can be stored in a single 2-mm^2 location, which is on the order of 10,000. "That's a lot but not enough," Shahriar said. "If you are trying to track and identify an enemy plane, it could appear at different distances and in different orientations. So you may need 10,000 pictures in the database for all the possible orientations of just one plane."



A super-parallel holographic optical correlator enables single-query searching through images stored in distinct spatial locations simultaneously. An image gathered by a camera or synthetic-aperture radar, for instance, is read into the system via a spatial light modulator, and a holographic multiplexing and demultiplexing device produces multiple copies of the image for simultaneous searches through separate storage locations in the holographic memory unit. A correlation diffraction beam (shown in red in the diagram) leaving the holographic memory unit at a specific angle indicates a match between the target image and a database image. The rest of the correlator architecture locates the matched database image in two steps, each concluding in a charge-coupled-device (CCD) detector array. The CCD array at the bottom of the diagram identifies the spatial location in the database where the match occurred. The CCD array on the far right identifies the beam angle, which corresponds to a specific image within a spatial location.

Data storage can be increased significantly by including multiple storage locations in one crystal. Two thousand locations with 10,000 images each would hold 20 million images, for instance. But search efficiency would plummet if 2000 locations had to be searched serially—with each search taking about 1 ms—or if 2000 holographic optical correlators had to be used for a simultaneous search of the 20 million images.

Optical correlator

Shahriar and his colleagues appear to have gotten around this limitation by building what they call a super-parallel holographic optical correlator based on a holographic multiplexing and demultiplexing unit that makes identical copies of the target image that can be compared to images in all database locations simultaneously (see figure).

So far, they have successfully demonstrated the ability of the holographic multiplexer-demultiplexer to produce identical copies of the target image. They have also demonstrated the super-parallel holographic optical correlator architecture on a small-scale image-identification problem in which each of three storage locations contained eight images. The next step is to scale up to 1600 image locations, each containing about 8000 images; Shahriar hopes to complete that portion of the project in about eight months. "Then we have to make it into a product so that anybody could use it," he said. "The product stage would take about a year and a half at least."

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