DEMONSTRATION: A PHOTOREFRACTIVE CORRELATOR FOR ROBOTIC APPLICATIONS

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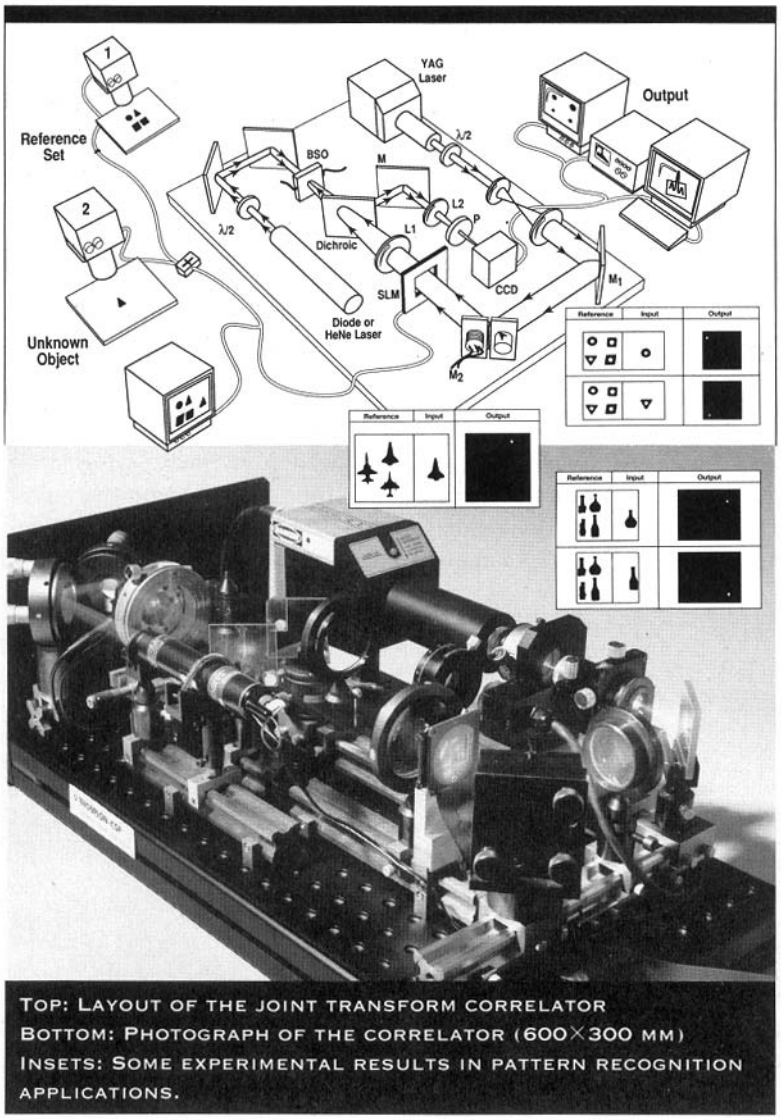
Recent advances in solid state lasers, liquid crystal spatial light modulators, computer generated holograms, and nonlinear optical materials have opened new opportunities for photonic technologies in the field of parallel processing and computing. To explore some industrial applications of these technologies, the Commission of the European Communities started in 1989 an ESPRIT* project, bringing together, in a precompetitive consortium, industrial partners (Thomson-CSF in France, KRUPP in Germany), a national research center (RISØ in Denmark), and a university (Universitat Erlangen in Germany).

This project—New Architectures for Optical Processing in Industrial Applications (NAOPIA)—resulted this year in the first demonstration of a prototype compact photorefractive correlator for pattern recognition in robotic applications.[1,2] The optical correlator, (see figure) performs joint Fourier transform correlation between a set of reference objects (R) and an unknown object (S) displayed under CCD cameras. The recombined video signal is relayed to a liquid crystal spatial light modulator (SLM). After transmission through the SLM, an expanded laser beam from a mini solid state diode-pumped visible YAG laser carries the coherent image (R+S). The Fourier transform lens L_1, located behind the SLM, generates the complex Fourier transform field at a photorefractive BSO crystal. The refractive index of this material is modified in real time by the local intensity distribution. By this mean, the product of the Fourier transform fields $\tilde{R} \cdot \tilde{S}$ is recorded as a dynamic phase volume hologram. This hologram is reconstructed in real time by a plane wave from a red laser, *e.g.*, a visible laser diode or a HeNe laser. The diffracted field amplitude is extracted using a dichroic mirror and, upon an inverse Fourier transform by lens L_2, provides the correlation function R⊗S at a CCD sensor.

The whole optical system, including the laser sources, the SLM, and the photorefractive crystal is designed to be easily transportable (600 × 300 × 300 mm) and used in a pre-industrial environment (see photo). With video rate correlation operations performed on images containing 10^5 pixels, the correlator has an equivalent computing power of the order of 250 Mop/sec.

Various applications have been successfully tested, including industrial tool sorting, the task for which the correlator was initially designed (see inserts). Flexibility is indeed a built-in feature, since the set of reference objects is also a real time input to the correlator (camera 1 in the figure). Electronic post-processing techniques can be used to fully exploit the correlator capabilities. In particular, electronic neural networks are being investigated to permit learning and improve the robustness of the processor.[3] Finally, to further increase the computing power and performance, we envisage a breadboard version of a multichannel correlator, for which 10 or more correlation operations on high resolution images (10^6 pixels) are performed in parallel.

*ESPRIT: European Strategic Programme for R&D in Information Technology



TOP: LAYOUT OF THE JOINT TRANSFORM CORRELATOR
BOTTOM: PHOTOGRAPH OF THE CORRELATOR (600×300 MM)
INSETS: SOME EXPERIMENTAL RESULTS IN PATTERN RECOGNITION APPLICATIONS.

REFERENCES

1. H. Rajbenbach *et al.*, "A compact photorefractive joint transform correlator for industrial recognition tasks," in Optical Computing Topical Meeting Technical Digest **6**, OSA, Washington, D.C., 1991, paper TUD5.
2. H. Rajbenbach *et al.*, "An optical photorefractive correlator for robotic applications," to be published in *Esprit Conference*, November 25-29, 1991, Brussels.
3. J. Figue *et al.*, "Neural optoelectronic correlator for pattern recognition," SPIE Annual Meeting, 1991.