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Optical Correlators for Automated Rendezvous and Capture

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Two dimensional image correlation is a robust technique for recognizing known objects and determining their position with respect to the sensing platform. This capability is of paramount importance to vehicles which must rendezvous and capture using only on-board sensors and processors. Standard digital processors can provide the necessary correlations, but their speed, weight, size and power consumption make them undesirable components of an on-board tracking system. Optical correlators provide correlation results comparable to digital systems, but with a fraction of the size, weight and power and often many times faster. This presentation discusses the application of optical correlators to Automated Rendezvous & Capture (AR&C), and the specific work being done at the Johnson Space Center and DARPA in developing optical correlator technology.

The Johnson Space Center (JSC) has been pursuing hardware and algorithm development for optical correlators since 1985. JSC has pioneered key hardware developments in the form of Spatial Light Modulators (SLMs) and algorithms for building "smart" correlation filters. JSC is also closely involved with a multi-million dollar Defense Advanced Research Projects Agency (DARPA) effort to build optical correlators for **fieldable** systems. JSC is providing SLM hardware development, filter theory and operational considerations for the DARPA effort. This DARPA project will result in two optical correlator systems which will be small enough and rugged enough to fit inside a missile and will perform hundreds of correlation measurements per second. Comparable digital implementations would be significantly larger and slower. These optical correlators will be complete in the Fall of 1993. This time frame and form factor make optical correlation a very attractive technology for NASA's near-term automated missions requiring Automated Rendezvous and Capture (AR&C) capability such as Lunar/Mars missions, Cargo Transfer Vehicle (CTV) and others.

While DARPA is providing the optical correlator optics and system electronics, JSC has been developing SLM hardware and filter algorithms to insert into these systems. Spatial Light Modulators are the electro-optic devices which encode the image or filter information onto the laser beam. Once the information is encoded onto the laser beam, the physics of optics and the propagation of light perform the necessary processing. It is this ability to encode the image information onto the laser beam which has made *optical* correlators viable. JSC has been pioneering the development of a specific type of spatial light modulator with Texas Instruments (TI) known as a Deformable Mirror Device (DMD). The TI DMD provides orders of magnitude greater light efficiency, light processing capability and size reduction over competing SLMs. The DMD development is proceeding in parallel with the hardware being developed by DARPA and will be ready to support the final systems in 1993.

Currently available DMDs have been used in our research at JSC for over four years. In that time, we have developed sophisticated algorithms to not only compensate for the realistic performance of the device, but also for optimizing the correlation process in the presence of various types of noise. This optimization of the correlation process with realistic devices has given us significant signal to noise improvements and has allowed us to do more with a filter than just compare an input scene with a reference object. With these techniques we can improve the robustness of the correlation process to compensate for distortions in the input scene (in-plane and out-of-plane object rotations and magnification differences). In addition, we can apply multiple filters to a scene to *estimate* these distortion parameters allowing us to recognize the target and its pose with reduced filter storage requirements. These techniques combine to improve the robustness of the optical correlation process while reducing its storage requirements.

Correlation by itself is a very powerful target identification technique. Optical correlators have significantly improved the size, weight and power requirements, increased the operating speed, and maintain comparable accuracy of digital systems. Optical implementations of correlators are becoming very mature. The DARPA correlators will demonstrate the form factors achievable with optics, and JSC's involvement with the program will ensure that they are thoroughly tested in NASA's applications.