Detecting Asteroids with a Multi-Hypothesis Velocity Matched Filter. B. D. Shucker[1] and J. S. Stuart[1], [1]MIT Lincoln Laboratory (MIT Lincoln Laboratory, 244 Wood Street, Lexingotn MA 02420, bshucker@ll.mit.edu, stuart@ll.mit.edu).

Introduction: We present a novel approach to image processing for optical detection of faint asteroids. Traditional methods of asteroid detection require observations in multiple frames taken over a period of time, but are limited by the signal-to-noise ratio in a single frame. Our approach is based on a velocity matched filter (VMF) [1], which combines the signal from multiple frames in order to increase the aggregate SNR for dim objects. By generating a series of hypotheses about the apparent velocities of potential objects, we create a set of highly sensitive velocity-specific filters, the results of which are combined to achieve complete coverage of the search space. Each filter collapses a set of sidereal frames into a single frame through a shifted sum operation, thus aggregating the signal from the entire frameset and increasing SNR for objects matching the hypothesized velocity. We also present additional signal processing steps designed to filter out a variety of noise sources such as stars, spacecraft, and background gradients.

While the computational cost of our algorithms is high, the entire set of filters may be run in parallel, and individual operations within each filter are easily parallelized as well. This fact, along with other optimizations, makes our implementation computationally efficient enough to use in practice without a priori knowledge about the velocity of an observed object. We have applied our implementation to process data from the Lincoln Near-Earth Asteroid Research (LINEAR) [2] project. Preliminary results indicate an increase in effective sensitivity of 0.5 mag. Since the cost of added computational resources is low compared to other methods of improving sensitivity, this approach is an extremely cost-effective way to increase discoveries.

Algorithm Development and Testing: Before running the VMF, the images are processed to remove a variety of noise sources. These include removing stars, removing charge transfer tails from bright stars, removing background gradients and large scale diffuse sources, normalizing the images to account for changes in atmospheric transparency during the data collection, convolving the images with a model of the point-spread function to correct for changes in seeing and focus during the data collection, and removing bright streaks from satellites.

The VMF is then run on the 5 image frameset to detect asteroids moving with constant velocity. After the VMF, post-detection filters are used to eliminate false alarms. These filters include checks that overlapping detections correspond to a cluster of similar velocities, and that brightness of a detected asteroid does not vary too much from frame to frame. We plan to investigate formal methods from classification theory to discriminate between false detections and real asteroids.

Results on Archived and New Data: Since late 2002, LINEAR has archived all images, resulting in a database of over 5 million images of 5 megapixels each. This image archive, along with the results of the operational detection algorithms, has provided a large test set. Each night of operations, LINEAR acquires 800-1200 sets of 5 images each. We are testing the VMF against new data and intend to make it part of the operational image processing system. To verify the detections from the VMF, we compare against the detections made by the operational pipeline. We find, typically, that the VMF misses ~5-10% of the (primarily bright) detections made by the operational system, while producing ~25-50% more detections overall, with most of the new detections being faint for the operational system. We are developing methods to classify detections from the VMF to find those most likely to be real asteroids, and will soon forward follow-up requests to the 2.4 m telescope of the Magdalena Ridge Observatory for confirmation.

Despite the high computational complexity of the VMF, our implementation is efficient enough to process all the new data on a daily basis using a single commercial off-the-shelf workstation per telescope.

References: [1] Reed I.S., Gagliardi R.M., and Stotts L.B. (1988) *IEEE Trans. Aero. & Elec. Sys.*, 24-4, 327-336. [2] Stokes G.H. et al (2000), *Icarus* 148, 21-28.

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