Wide-field Infrared Survey Explorer (WISE)

Summary of Results from the WISE Moving Object Pipeline Subsystem Operational Readiness Test

Version 1.1

30-November-2009

Prepared by: James Bauer

Infrared Processing and Analysis Center
California Institute of Technology

WSDC D-T019

Revision History

Date	Version	Author	Description
11/23/2009	1.0	Bauer	Initial Draft
11/30/2009	**1.1**	**Bauer**	

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INTRODUCTION

Scope & Goals of Test

A full-scale operations test of the WISE Moving Object Pipeline Subsystem (WMOPS) was conducted on November 17th, 2009. The WMOPS detection software was run on the simulation generated by Ned Wright for ORT3 and general WSDC testing. Input for the WMOPS test was the set of level 1b products as generated by the WISE frame and scan processing pipeline, version 3.2. The WMOPS test was not a full "end-to-end" test, but assumed scan/frame processing was complete and started the WMOPS procedures from that point. The interval from observations by WISE to the production of the necessary 1b products will nominally be approximately 3 days. This simulation contains *known* objects for positions predicted to be observed by WISE on Jan 13-15, 2010.

This test focused on the process of operating the WMOPS software and QA activities. The simulations omitted some light-travel-time factors when predicting object positions, and therefore did not yield meaningful initial orbit fits for many of the objects in the ***wmopsqa*** processing. Orbit fitting is a major criterion for "sound" vs. "anomalous" tracklet vetting, therefore *all* of tracklets fell into the "anomalous" category, requiring eyes-on evaluation of each tracklet. This process takes a significantly longer time, and so our test time for the QA evaluation should be interpreted as an "upper limit". Furthermore, the results of the Minor Planet Center (MPC) processing are likely effected by the light travel time discrepancies, so that completeness and reliability statistics based on MPC findings are not likely to reflect the true capabilities of WMOPS. That being said, the goals of the WMOPS Operational test were:

1) to test the implementation and readiness of the WMOPS detection software and its ability to run to completeness, generating the preliminary products (MPC and SIDS files) that list candidate tracklets for the WMOPS QA,
2) to successfully perform QA on the WMOPS candidate lists, evaluating the candidate tracklets for authentic moving object detections,
3) to submit to the MPC reports of the vetted candidate tracklets,
4) to validate that the software run time meets the allocation for ***wmops*** and the ***wmopsqa*** routines on a realistic 30-scan data set equivalent to what WMOPS will encounter during normal operations (2 hours of full-cluster usage every 2 days),
5) to verify that the evaluative time scale for the candidate tracklets generated by WMOPS is within the 10 day limit of reporting near-Earth objects to the community, from the spacecraft object-track-detection-midpoint time to reporting the object to the MPC.

6) to verify the potential processing timescale of the MPC from the submission time of our tracklets to the posting of candidate tracklets to the community,
7) to assess the WMOPS completeness and reliability statistics on a typical (30-orbit) data set,
8) and to guage the MPC processing time of the submitted WMOPS tracklets.

Acronyms & Definitions

MPC – The Minor Planet Center; the International Astronomical Union's recognized reporting center for new observations of solar-system minor bodies.

MPC files – reports of minor bodies that are specially-formatted in ASCII text according to the MPC's standard.

SIDS files – Lists of source-IDs (from photometry processing) corresponding to candidate tracklets.

"tracklet" – A list of detections corresponding to candidate moving objects.

WMOPS – Wise Moving Object Pipeline Subsystem (note: software indicated by lower-case bold).

WMOPS QA – Wise Moving Object Pipeline Subsystem Quality Assurance (note: software indicated by lower-case bold).

wmops – Wise Moving Object Pipeline Software; the primary detection software and the initial routine that starts the WMOPS processing.

wmopsqa – Wise Moving Object Pipeline Quality Assurance Software routine; creates products, such as plots and web-pages, for the WMOPS QA processing.

WSDS – Wise Science Data System.

WSDC – Wise Science Data Center.

TEST ACTIVITIES

The test began at 9:15am, when WISE Ops started the *wmops* tracklet detection routine. The routine completed analysis of the input frames by 9:55am. Immediately after ***wmops*** completed its run, the automated quality-assurance routine, ***wmopsqa,*** was initiated. This second routine generates QA products, performs initial tracklet orbit fits, and evaluates

tracklets. For this test, all objects were flagged as anomalous, and none were automatically vetted owing to the nature of the data (see above) and the need for eyes-on evaluation of the tracklets.

The ***wmopsqa*** routine completed its analysis in under 45 min, ending at 10:39am. WMOPS team members Grav, Dailey, and Bauer then conducted eyes-on evaluation of the tracklets over the next 6 hours, utilizing the prototype web-tool which allowed rapid viewing of detection thumbnails, time vs. mag, psf-fit residuals, & color, and sky-plane position (RA/dec) plots of the tracklets. During these 18 work-hours (3 team members for 6 hours), the first eyes-on evaluation of the entire set of 2535 ***wmops*** generated tracklets was completed. Starting at 9AM on the 18th, Massiero conducted an evaluation of a subset of tracklets examined by each of the first-run reviewers, as a control against reviewer variation in tracklet evaluation. Lists were spilt into the accepted and rejected tracklets, and an MPC-formatted tracklet report was generated for submission to the minor planet center via ftp. A final look over the data was conducted, and at 2pm on the 18th, a tracklet report was transferred to the MPC's anonymous ftp site, and an email notice was sent to the wise contacts at the MPC, Williams & Spahr. This concluded the WSDC activities, less than 29 hours from the start of the test. The MPC made a preliminary report of the tracklets at 5:54pm on the 18th, and a final evaluation on the following day (11/19) at 1:53pm, just under 53 hours from the start of the test.

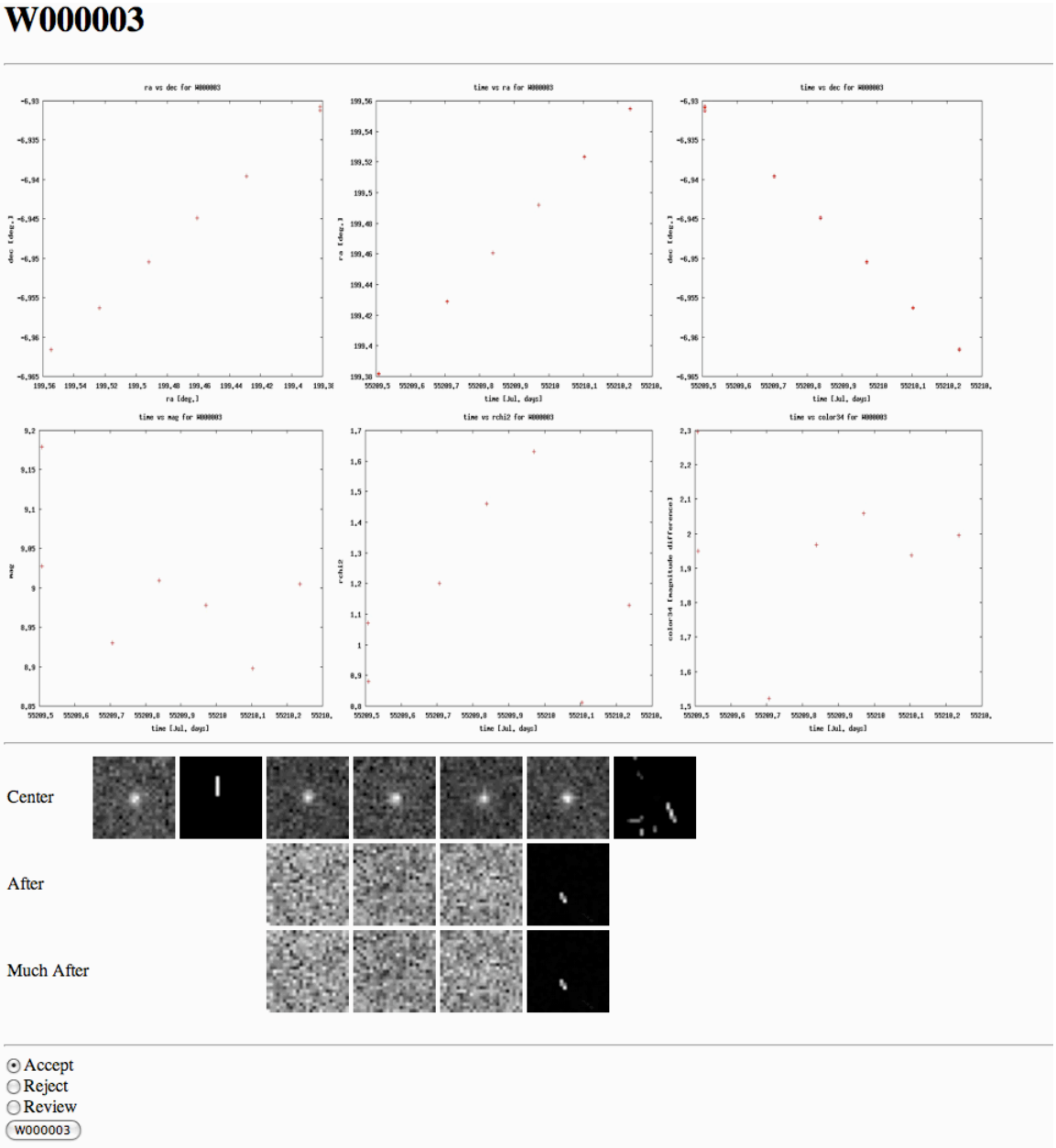

Figure 1: Example of the web–based eyes-on QA of a single WMOPS tracklet. Plots of sky-position, magnitudes, psf-fit goodness (*rchi2*), and object color are shown, along with thumbnails of the detections images and the sky-positions pre and post-detection.

RESULTS

By the time of the submission of candidate tracklets to the MPC, within 29 hours of the start of the test, the WMOPS team had confirmed that the first 5 goals of the test had been met. The ***wmops*** and ***wmopsqa*** routines ran to completeness, generating the moving object tracklets and the necessary (though minimal) products to perform evaluation of the candidate tracklets. Furthermore, the software's total run-time was 85 minutes, with full-cluster usage, and thus only 71% of the allotted time allocated for regular use by the subsystem.

The eyes-on evaluation of the tracklets served as an upper limit to the true evaluation time expected during operations, as noted above. Assuming a 3-day observation, download, and processing time, the WMOPS team was still able to conduct complete vetting of the full tracklet set by-eye in under 29 hours. Assuming 3 days from the mid-point of the WISE observation to the completion of scan/frame processing, this yields a total time of 4 days and 5 hours for reporting the tracks to the MPC. This is well within the allotted time of 10 days specified as an operational goal for WMOPS. The number of tracklets may be greater during operations, but the vetting of sound tracklets for immediate reporting to the MPC will considerably lessen the by-eye evaluation required for each wmops run (which is planned to take place once every 2 days).

The MPC also evaluated the tracklets within 1 day of the WMOPS tracklet delivery. The format for reporting to the MPC was confirmed as correct (with the exception of the case of a single character on the second line, which has already been fixed in the report-generating code). Likewise, the MPC acknowledge the method and location of delivery of the tracklets as correct.

The evaluation of the tracklets by the MPC yielded the result that 94% of the objects reported correlated with the motions of real, known objects, but that the locations in the simulation were as much as 300 arcsec off-position. Our internal evaluation of the tracklets was also performed which checked object positions against truth-table positions provided with the simulation. The reliability of the tracklets generated by WMOPS and the completeness of the objects detected were thus evaluated from the truth tables provided by Ned Wright. For the initial output from WMOPS, without the eyes-on QA, and using the old definitions of *completeness* and *reliability* (see WMOPSdev wiki link for formalized definitions), we achieved 93.5% completeness, but only 35% reliability. However, if we regard any track with the majority of points as non-noise points from a single track, we get 51% reliability from the start. Its worth noting that this latter criterion doesn't give near-ambiguous tracks in the simulation data set, where for example a track of length 7 has 4 good detections and 3 bad (or second object) detections, but rather the tracks show a clear majority of good detections, with at least 70% good detections in a given tracklet. For the by-eye vetted QA results, we eliminated 21 good tracklets (where

all detections were from the same object, and had no noise points) and 735 bad tracklets. This dropped the completeness down to 91.8%. However, our reliability (as more rigidly defined) was 50%, and with the less stringent definition above, was 82%. This is lower than the MPC evaluations for three possible reasons. First, our checking software does not search for object correlations in positions outside of 2 pixels from the predicted center. Second, our criterion for matches are generally more strict, but less heuristic, than a criterion of a successful object detection as in the MPC correlations. Rather, a certain majority fraction must be good points, even with our less stringent criteria. Finally, a small fraction of the tracklets that WMOPS reported may have been false, but correlated by-chance in the MPC's search with certain objects that should be in the WISE fields of view on January 13-15; detector latents are notoriously effective at mimicking real object motions. Either reliability levels of 82% or 94% met our desired goals for performance, as did the 92% completeness level.

LESSONS LEARNED

The critical lesson confirmed that overall, the automated QA and pre-vetting of a majority fraction of the good tracklets into "sound" tracklets not requiring eyes-on evaluation will have to be implemented to make the tracklet evaluation process practical. Otherwise, the work-load will be too great for the QA and WMOPS teams. Towards that end, in addition to the criterion for "sound" tracklets of a realistic initial orbit fit, the following tracklet flags would raise the effectiveness of the automated evaluation step:

- Polar tracks should be flagged as suspect.
- Tracks with large color dispersions should be suspect.
- Tracks with large $r\chi^2$ dispersions should be suspect.
- Tracks with bimodal color distributions are likely latents.
- Tracks with small ΔRA should also be flagged as suspected latents.

A minor bug was identified, and has already been fixed, in our MPC-report generating routine, whereby a lower-case character was required by the MPC's own software in place of an upper-case letter. This is a common error in reports submitted to the MPC, and did not impact the processing. There were a handful of several code improvements that could be made as revealed by the WMOPS-ORT:

- Error Bars should be added on Time vs. Magnitude & Time vs. color plots.
- A bug should be fix that will allow the retrieval of more pre and post-detection thumbnail plots of like sky-positions (done, as of this writing).
- Time vs. Mag. plots for both bands 3 & 4 should be provided for eyes-on QA.
- Add detection-time thumbnails in band 4 as well.
- Adjust scaling for color and magnitude (flipping y-scale for magnitudes) vs. time plots, and enlarge letter font and objects on plots.
- Create additional plot of residuals from a linear-fit of points on the sky.
- Fix scaling in thumbnails, especially in nails containing cosmic rays.

- Add an additional thumbnail at center-nail's pixel position on the previous scan-frame, to better identify potential latents.

These improvements would ease the eyes-on and summary QA steps.

SUMMARY

The WMOPS ORT met the major goals and evaluation criteria for the testing. During the ORT, WMOPS operated within the desired performance goals for regular WSDS scan-mode processing as well. However, automated QA will be critical for practical implementation of the moving object pipeline by keeping the workload reasonable for the personnel involved in running the subsystem. The runtime of the software routines is in some sense a fair estimate of the actual runtime we may expect during regular WISE scan operations. Where there may very well be more object detections by a factor of a few, the automated evaluation, which will vet sound tracklets for immediate reporting to the MPC, will significantly lessen the number of objects requiring by-eye evaluation, and so the load required to generate tracklet-level products for by-eye evaluations, like image thumbnails. Currently, it is the ***wmopsqa*** routine that takes the most runtime.

Acknowledgements: Many Thanks to the WMOPS core team members Dailey and Grav, who worked hard to get a functioning system in preparation for this testing. Special thanks to Heidi Brandenburg, Gareth Williams, and Tim Spahr for extra support during the testing. Thanks also to Robert McMillan and Joe Messario for help in the post-testing analysis of the results.