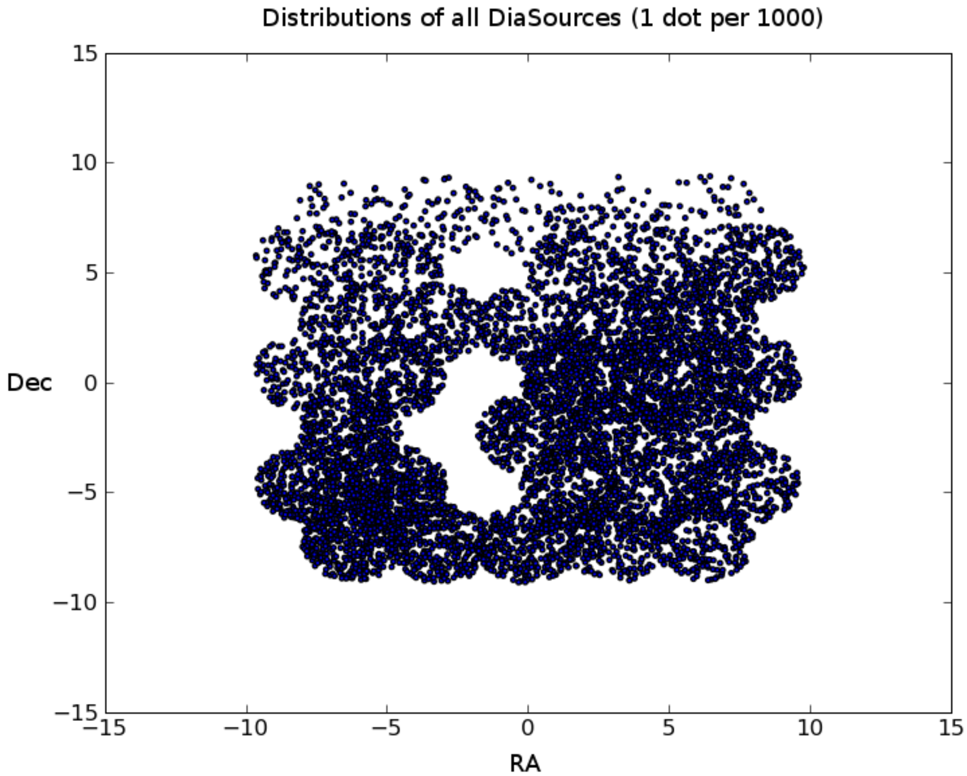

Fig. 6.—: A reduced-density plot of simulated asteroid detections (DiaSources) used in our simulated catalog. Detections from several fields were missing, but we expect that our results should be reasonably representative nonetheless.

2.5. NightMOPS Resource Usage

The costs of running NightMOPS are expected to be negligable compared with the costs of running DayMOPS. NightMOPS (fed from a database of real known objects) has been run in past data challenges and has not imposed a significant cost.

3. Development Plan

Though the core algorithms of MOPS have been implemented in LSST-appropriate style, further research and development are needed.

Tracklet generation runtime:	2,355 sec (.6 hours)
Track generation runtime:	39,713 sec (11 hours)
Total linking runtime:	42,068 sec (11.7 hours)
Peak memory usage:	2.2 GB
Number of tracklets:	4,502,224
Tracklet % true:	43.4%
Number of tracks:	3,318,539
Track % true:	26.6%
Estimated OD cost (assuming 1000 OD/sec):	3,318 sec (.9 hours)
Estimated total resource usage:	45,386 sec (12.6 hours)
Number of findable objects:	186,344
Number of objects found:	176,080
% Found / findable:	94.5%

(a) Summary of results

Object class	Number found	Number findable	Percent found/findable
Main-belt objects	172,539	182,285	94.7%
Near-earth objects	276	504	54.8%
Comets	1,374	1,534	89.6%
Trojans	1,593	1,696	93.9%
Trans-Neptunian objects	254	281	90.4%
Scattered disk objects	44	44	100%

(b) Found objects by type

Fig. 7.—: In-depth results from our simulated survey of full-density asteroid sources from a subset of the visible sky.

3.1. Long Duration Survey Performance

Current simulations cover fairly short time periods, and therefore emphasize the problem of initial object discovery. In the course of the full survey, we expect that many detected sources will be attributed to already-discovered objects. Because initial object discovery phases are relatively expensive and ephemeris calculation is relatively fast, we expect that the resource usage of the system will decline over time, as more objects are discovered and the size of input catalogs is reduced. This expectation needs to be verified and quantified.

SSM Density	#DiaSources	#Tracklets	#Tracks	Linking Runtime (sec)	Track % True	Found/Findable
.1	827021	211,635	122,160	669.27	75.97%	95.31%
.025	2070722	649,907	401,895	3664.36	57.94%	94.71%
.05	4140278	1,618,205	1,116,346	17304.11	40.70%	94.91%
.75	6197009	2,897,291	2,085,296	46076.54	32.14%	94.74%
1.0	8274898	4,502,224	3,318,420	98847.96	26.61%	94.56%

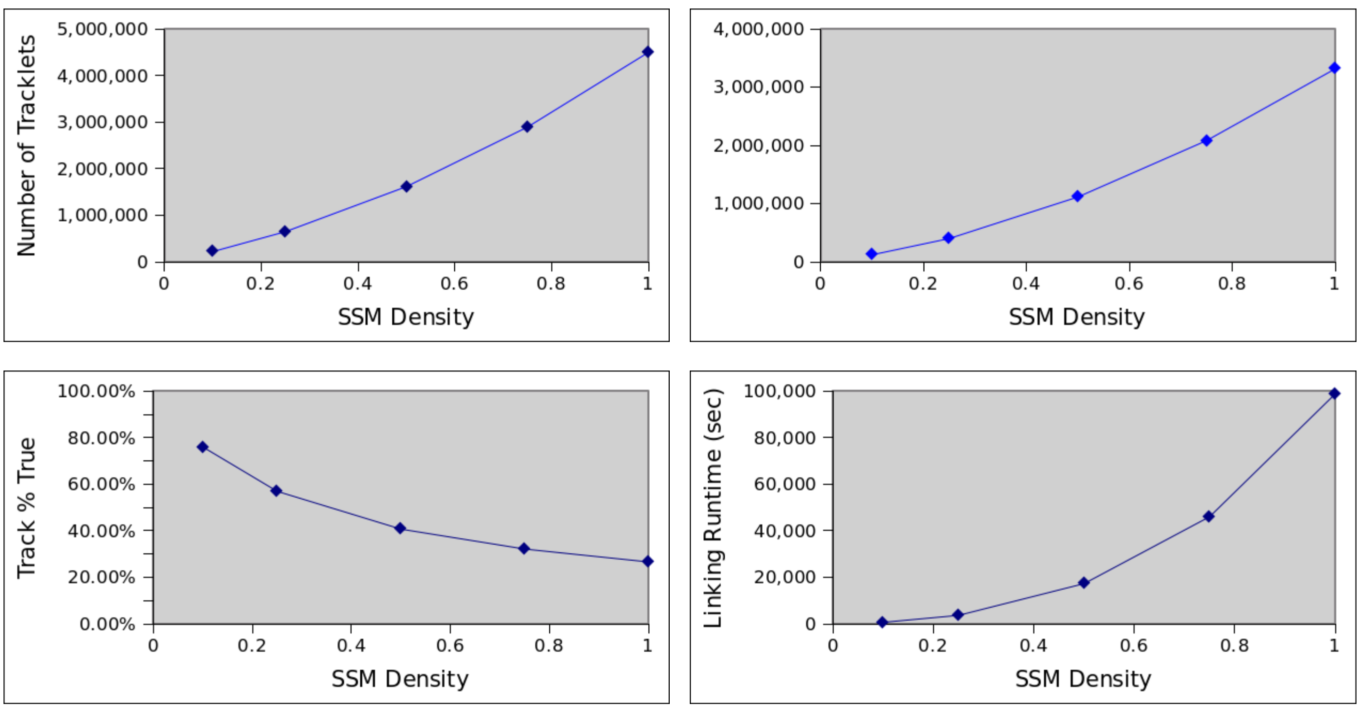

Fig. 8.—: Results from running DayMOPS linking methods on reduced-density source catalogs.

Noise Points / Image	% Noise	#Tracklets	#Tracks	Linking Runtime (sec)	Track % True	Found/Findable
0	0.0%	1,618,205	1,116,346	8,413	40.70%	94.91%
500	20.63%	1,947,235	1,127,355	9,996	40.28%	94.90%
2,500	56.51%	4,107,233	1,202,270	19,321	50.36%	94.87%
5,000	72.21%	8,693,128	1,361,796	51,008	33.14%	94.80%
10,000	83.87%	23,989,975	1,951,794	256,565	22.89%	94.62%

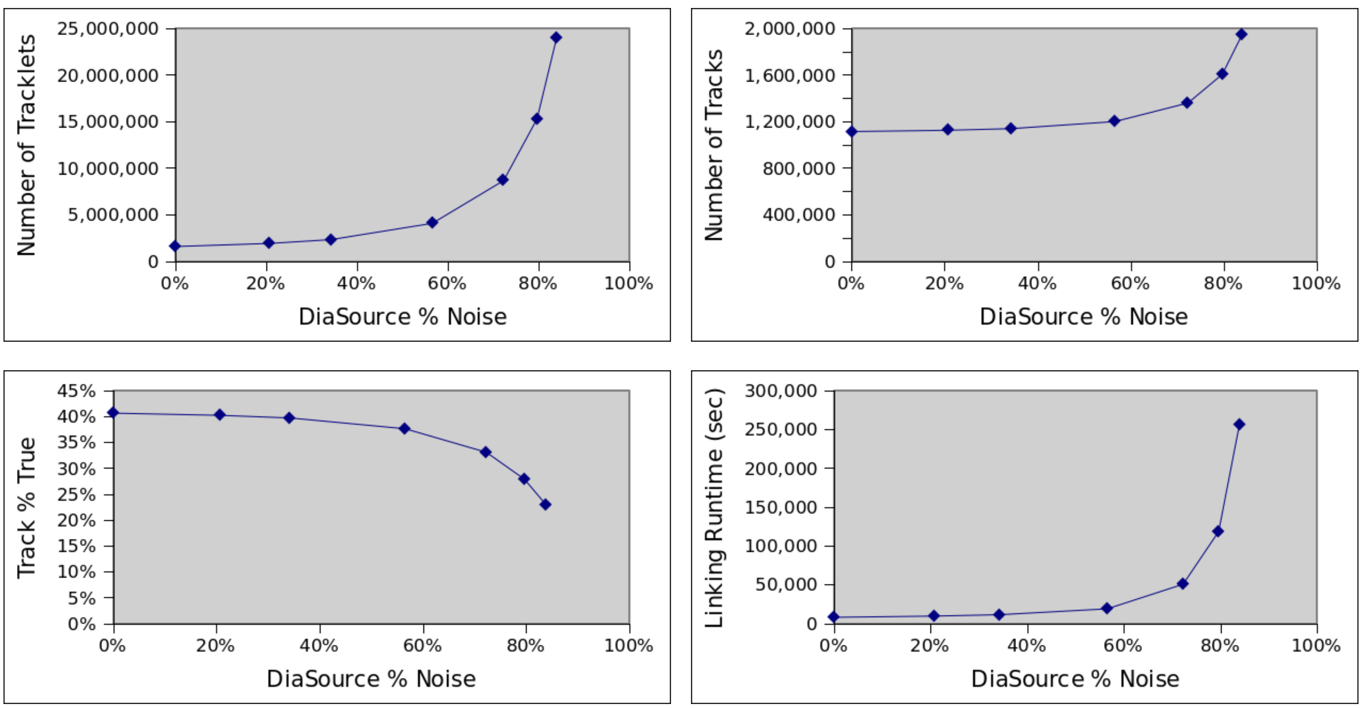

Fig. 9.—: Results from a simulated survey using a 50%-density SSM and varying numbers of randomly-distributed “noise” (non-asteroid) sources per image.

Attribution, precovery and Moving Object management and refinement of the Moving Object table are not yet implemented in LSST-compliant software. Developing this software should be a significant development task. However, we hope that by using the algorithms from the PanSTARRS MOPS we can avoid any significant research tasks.

To test this software, we will need to generate simulated input catalogs which span longer time periods. Accomplishing this will require either significant compute-resources or improved tools for generating input catalogs.

3.2. Filtering on Trailing for Near-Earth-Object Searching

Near-Earth Objects tend to have the highest sky-plane velocity. This presents a significant challenge; as we increase the maximum velocity limit of our tracklet generation, the potential for mislinkage increases significantly, leading to higher numbers of tracklets and increased costs.

Fortunately, fast-moving NEOs will generate visible trails in our images. By requiring all tracklets to show trails consistent with their apparent sky-plane velocity, we expect that it will be possible to filter most false tracklet linkages, thus rendering the problem of NEO searching manageable.

The ability to filter on trailing is dependent almost entirely on our ability to correctly identify trails in images. Currently, the ability of image processing to detect trails is not well quantified. To remedy this, we will need to generate simulated images which include asteroid trails and send them to image processing; further refinement of image processing algorithms may be neccesary.

3.3. Distribution/Parallelization of Software

Current software implementations and simulations presented in this document use only a single processor. Performance has been sufficiently fast for this to be reasonable; however, as we increase the size of the simulated sky, extend the linking window, and increase non-asteroid source density, it will likely become necessary to parallelize some core algorithms.

The PanSTARRS MOPS can inform our decisions on parallelization and distribution. Some phases of processing are trivially parallel, such as Initial Orbit Determination, in which the same operations are performed to a large variety of tracks; this should be very easy to accomplish in using LSST Pipeline Middleware.

Other tasks will be more difficult; in distributing sky-plane linking, PanSTARRS MOPS divides up the data by field of view and distributes the workload along this axis. This has the advantage of distributing the workload in a straightforward way, but potentially generating poorly load-balanced workloads. We plan to investigate this method, but leave open the possibility of attempting other approaches as well.

REFERENCES

Bentley, J. 1975, Commun. ACM, 18, 509

Blanco, & McCuskey. 1961, Basic Physics os fthe Solar System (Addison-Wesley)

Denneau, Jr., L., Kubica, J., & Jedicke, R. 2007, in Astronomical Society of the Pacific Conference Series, Vol. 376, Astronomical Data Analysis Software and Systems XVI, ed. R. A. Shaw, F. Hill, & D. J. Bell, 257–+

Granvik, M. 2007, PhD thesis, University of Helsinki, Helsinki, Finland

Granvik, M., Virtanen, J., Oszkiewicz, D., & Muinonen, K. 2009, Meteoritics and Planetary Science, 44, 1853

Grav, T., Jedicke, R., Denneau, L., Chesley, S., Holman, M. J., & Spahr, T. B. 2011, PASP, 123, 423

Kubica, J. 2005, PhD thesis, Robotics Institute, Carnegie Mellon University, Pittsburgh, PA

Kubica, J., Moore, A., Connolly, A., & Jedicke, R. 2005, in Proceedings of the eleventh ACM SIGKDD international conference on Knowledge discovery in data mining, KDD '05 (New York, NY, USA: ACM), 138–146

Milani, A., Gronchi, G. F., Vitturi, M. D., & Knežević, Z. 2004, Celestial Mechanics and Dynamical Astronomy, 90, 57

Milani, A., et al. 2006, in IAU Symposium, Vol. 229, Asteroids, Comets, Meteors, ed. L. Daniela, M. Sylvio Ferraz, & F. J. Angel, 367–380

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