Spaceguard Research Vol. 2, 27-29 (2010)

小惑星自動検出アルゴリズムの構築

坂本 強[1]・西山 広太[1]・奥村 真一郎[1]・浦川聖太郎[1]・浅見敦夫[1]・橋本就安[1]・
高橋典嗣[123]・吉川真[14]

[1] 日本スペースガード協会[2] 明星大学 [3] 千葉大学[4] JAXA

Automatically asteroid-detection algorithm

T. Sakamoto[1] ・K. Nishiyama[1] ・S. Okumura ・S. Urakawa ・A. Asami[1] ・N. Hashimoto[1] ・
N. Takahashi[123] ・M. Yoshikawa[1,4]

Abstract

The present file has been made as a print sample of the camera-ready manuscripts for the Spaceguard meeting. Its text or describes instrution to prepare the manuscripts; layout; the font styles and sizes; and others. If you replace the text or the figures of the present file by your own ones, using Cut and Paste procedures, you can easily make your own manuscripts.
This English Abstract has narrower width than the main text by 10mm for the left and the right margins of the main text, respectively. Font size used here is 10pt. the length may be less than 150 words.

Key Words: asteroid detection method

1 Introduction

Advent of mosaic CCD cameras have recently provided wide-field surveys by 1-m class telescope for Near Earth Asteroids (hereafter NEAs) that have a semi-major axis less than 1.3 AU, such as Catalina Sky Survey (Larson et al. 1998, 2003), Lincoln Near-Earth Asteroid Research (Stokes & Kostishack 1997), Spacewatch (Perry et al. 1996). These surveys obtained about 10 GB or larger volume of data per day and discovered about one thousand NEAs per year.
Asteroids have typical daily motions of 15 arcminutes or larger across the sky, and undertaking followup observations soon after their detection is important for determination of their orbital properties. In particular, the NEAs move a few degrees per day and often become fainter because they go away from the Earth. Thus, determination of the orbits of the NEAs requires us for completing data processing of a large volume of images within several hours and starting follow observations all over the world.
Previous works constructed the algorithms of detecting very faint main-belt asteroids automatically by utilizing the matched filter or by combining multiple frames along the typical motion of main-belt asteroids (Gural et al. 2005; Yanagisawa et al. 2005).
For several years, fully-depleted CCDs and computer processors have great improvements. First, the fully-depleted CCDs have advantage of high quantum efficiency up to $¥sim 9000 ¥AA$, and highlight on observation at longer wavelength that asteroids are brighter. However, the fully-depleted CCDs are sensitive to the cosmic-ray events and produce many cosmic rays of various shapes and sizes. The cosmic-rays are found to occupy $¥sim 0.2-0.7¥%$ of the whole image of the fully-depleted CCDs from our investigation, and these robust identification and removal in a single frame are very important. Second, multi-core PCs have become widely used, and appropriate parallel processing plays roles in fast detection of asteroids from large volume od data. In particular, previous works mainly focused on detection of main-belt asteroids, and construction of the fast detection algorithm for the asteroids that moved in various directions and quantities is vital.
Motivated above, we constructed a new algorithm
that quickly detects the asteroids with

various motions from the imaging data provided by fully-depleted CCDs. We describe the new algorithm in detailed in Section 2, and apply the algorithm for some imaging data in Section 3.

2 Method

The algorithms to reduce the cosmic-ray events from a single frame were constructed (Rhoads 2000; van Dokkum 2001; Pych 2004). Farage & Pimbblet (2005) performed a benchmark test by applying the algorithm for artificial images having various cosmic ray events. They found that the method of van Dokkum have the highest performance in various factors, such as the fraction of detected cosmic-ray pixels and spurious pixels, and thus we first remove cosmic-ray events by using the method.
However, some elongated events could not be removed completely; in many cases they are resolved into a lot of sources concentrated much more centrally than stars. We thus remove such compact sources by utilizing the parameters in sextractor software (Bertin ¥& Arnouts 1996), i.e., the value at the peak of the source relative to the totally integrated value (Robin et al. 2007) and the number of the pixels having values larger than the threshold.

We summarize the procedure of the asteroid detection below.

- We remove cosmic-ray events by using the method of van Dokkum (2001), Robin et al. (2007), and the number of the pixels having values larger than the background (typically 9 pixels).
- We determinate the parameters of World Coordinates System (WCS) with high precision by fitting the 3rd or 5th polynominal for distortion correction We adopt the USNO-SA2.0 for astrometric catalogs.
- We detect the astronomical objects with sextractor software by applying convolution. For detection of the faint asteroids, the theshold of the objects is 1$¥sigma$ above background.
- We remove known stars and galaxies by using the USNO-B catalog (Monet et al. 2003) and the Seventh Data Release of the Sloan Digital Sky Survey (Abazajian et al. 2009).
- We divide into some subimages with overlap regions and search for moving objects with O-C residual less than 1.5″. The area of subimages is provided by the maximum quantities of the motion of the target asteroids, i.e., (the maximum daily motion of the asteroid) x (the observation duration between first and latest frames).

We perform parallel processing for determination of the WCS parameters, removal of the stars and galaxies, and search for moving objects.

3 Results

We apply the new algorithm for real imaging data. The 2KCCD camera mounted on 1-m Schmidt telescope at Kiso observatory covers 50' x 50' with pixel scale of 1.5″. Unfortunely, the camera do not use fully-depleted CCD chip, and the cosmic-ray events occupies only 0.04 % of the image. We obtain a set of 9 imaging data at about 1 hour west of the opposition on 13 October, 2004 by using Subaru-Mitaka-Okayama-Kiso Archive System (Baba et al. 2002). The exposure time of the data is 240 sec and the observation duration is about 50 minutes. We use Intel(R) Xeon(R) 2 QuadCore X5470 3.33 GHz processor for the detection of the asteroid.
Table 1 shows the number of the asteroids that are detected by our algorithm and eyes, as a function of the magnitude predicted from the orbital parameters provided by the Minor Planet Center. The detection denotes the fraction of the asteroids detected with the O-C residual less than 1.5″ by our algorithm for the asteroid confirmed by naked eyes. We confirmed 11 main-belt asteroids and 1 comet by naked eyes in the fields. Our algorithm does not detect 3 main-belt asteroids. One of them moves around the stars during observation, whereas the remainning two asteroids have relatively low S/N, S/N $sim 7$.
The former asteroid is detected as astronomical objects, but their O-C residuals are $¥sim 2″$. The latter asteroids are not detected as astronomical objects.

For this detection, it takes about 10 minutes. Most of the time It consists of 5 minutes for removal of cosmic-ray events, 40 sec for determination of the WCS parameters, 1 minute for removal of star and galaxies, 2 minutes for search of the moving objects, and 20 sec for others.

4 Summary

We constructed a new fast algorithm for asteroids with various motions, which is applicable for the images of fully-depleted CCDs. The algorithm is optimized for currently widely used multi-core PCs.

参考文献

1) Abazajian, K. N., Adelman-McCarthy, J. K., Agueros, M. A, et al. 2009, ApJS, 182, 543
2) Baba, H., et al. 2002, ADASS XI, eds. D. A. Bohlender, D. Durand, ¥& T. H. Handley, ASP Conference Series, 281, 298
3) Bertin, E., ¥& Arnouts, S. 1996, A¥&AS, 117, 393
4) Farage, C. L., ¥& Pimbblet, K. A. 2005, PASA, 22, 249
5) Gural, P. S., Larsen, J. A., ¥& Gleason, A. E. 2005, AJ, 130, 1951
6) Larson, S., Brownlee, J., Hergenrother, C., ¥& Spahr, T. 1998, Bulletin of the American Astronomical Society, 30, 1037
7) Larson, S., Beshore, E., Hill, R., Christensen, E., McLean, D., Kolar, ¥& S., McNaught, R., Garradd, G. 2003, Bulletin of the American Astronomical Society, 35, 982
8) Monet, D. G., Levine, S. E., Canzian, B., et al. 2003, AJ, 125, 984
9) Perry, M. L., McMillan, R. S., Barr, L. D., Bressi, T. H., & Gehrels, T. 1996, Bulletin of the American Astronomical Society, 28, 1096
10) Pych, W. 2004, PASP, 116, 148
11) Rhoads, J. E. 2000, PASP, 22, 1
12) Robin, A. C., Rich, R. M., Aussel, H., et al. 2007, ApJS, 172, 545
13) Stokes, G. H. & Kostishack, D. F. 1997, Annals of the New York Academy of Sciences, 822, 544
14) van Dokkum, P. G. 2001, PASP, 113, 1420
15) Yanagisawa, T., Nakajima, A., Kadota, K., Kurosaki, H., Nakamura, T., Yoshida, F., Dermawan, B., ¥& Sato, Y. 2005, PASJ, 57, 399

(2010年1月27日受付, 2010年2月14日受理)