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Eliminating Virtual Impactors with Mega-Precovery (VIMP)

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Abstract

Part of the EURONEAR project, we developed the VIMP tool to search for Virtual Impactor asteroids (VIs) included in the Sentry and NEODyS lists, using our *Mega-Precovery* archival image collection. It identifies candidate images probably holding VIs which are prioritised and scrutinised by human reducers. First, we applied VIMP to the Blanco-DECam archive (about 300,000 images) which resulted to date in 25 VIs being precovered or recovered, from which 12 VIs were elliminated from at least one list.

1. Introduction

Identifying and measuring fixed objects appearing serendipitously in archival images is relatively straightforward, but searching for moving Solar system sources becomes more complicated, needing the intersection in space and time of the trajectories with archives holding hundreds of thousand of images. In particular, near Earth asteroids (NEAs) and Virtual Impactors (VIs) are very appealing for searches, due to their potential hazardous status. To our best knowledge, there are only two public web servers able to search for asteroids in huge archive collections indexing millions of images, namely *Mega-Precovery* (hosted by EURONEAR since 2010, [3, 7, 9]) and *SSOIS* (hosted by CADC since 2012, [1, 2]).

2. VIMP Software

Since 2006, the EURONEAR project[1] aims to increase the European contribution in the near Earth asteroids research. Besides new observations, we identified data mining of image archives as a great tool to ameliorate orbits, which could involve educational and citizen science projects [5, 6, 8].

[1] http://www.euronear.org

In Nov 2015 we started a project aiming to search for all known Virtual Impactors using the Mega-Precovery server (acronym VIMP), with the aim to improve their orbits and hopefully eliminate their VI classification. The VIMP software has been written in Python. It uses a VI database merged from the Sentry Impact Table[2] and the NEODyS Risk List[3], adding now around 1000 VIs (Apr 2019). VIMP calls the NEODyS server[4] to extract accurate ephemerides and uncertainties of the searched objects (using a variable step to accommodate close approaches) then it intersects these regions with the fingerprints of all images included in our *Mega-Archive* collection. Each intersection generates one *candidate image* which is tabulated and prioritised based on two parameters: the telescope limitting magnitude (used as a threshold to cut fainter objects), and the location of the uncertainty area in respect to the image frame. Then, the candidate images are downloaded and scrutinised by trained reducers of the VIMP project, assisted by tools to overlay the search area (identifying the CCD(s) of the mosaic cameras possibly holding the targets) and the uncertainty regions over the actual FITS images.

3. Application on the Blanco-DECam Archive

The most appealing archives are those carried by larger telescopes equipped with survey mosaic cameras, one of these being the Blanco-DECam instrument (*etendue* $A\Omega = 38\ m^2 deg^2$), which contains about 300,000 images. In August 2018 we run VIMP on the DECam image archive and the available VI database, and since then the reducer L. Curelaru took part in the searches. We selected only the candidate images outside the current observed period, to enlarge the arcs and substantially improve the orbits.

[2] https://cneos.jpl.nasa.gov/sentry/vi.html
[3] https://newton.spacedys.com/neodys/index.php?pc=4.1
[4] https://newton.spacedys.com/neodys/index.php?pc=0

By 25 April 2019, 99 VIs were searched from which 25 VIs could be precovered or recovered in the Blanco-DECam archive. Other 44 VIs could not be found, and the search of other 29 objects is under completion. In Table 1 we include the 25 p/recovered objects, listing their observed arc (before/after our findings), orbital uncertainty, number of impact orbits in SENTRY (IOS) and NEODyS (ION) - zero (*/0) meaning that the VI status was eliminated.

Most findings (72%) are related to the NEA survey carried out by L. Allen et al. [4] which generated many VIs with very short arcs (mostly 1-2 days) which failed to be detected by the automated detection pipeline and were neglected to be searched later. Nevertheless, there are 7 other objects (2014 EU, 2014 UU56, 2015 XP, 2016 SA2, 2016 WM1, 2017 FB102 and partially 2014 HT197) which were p/recovered in images taken serendipitously by other surveys or PIs.

Table 1: 25 VIs precovered or recovered by VIMP in the Blanco-DECam image archive by 25 April 2019. 13 VIs were elliminated from at least one list (marked with */0 in the last two columns).

Designation	Arc	U	IOS	ION
2014 EU	23/24	6/4	9/5	??/5
2015 HE183	2/5	9/6	3/3	??/4
2015 XP	3/28	6/1	1/1	??/1
2014 HJ198	1/3	8/5	124/1	??/3
2016 WM1	5/14	2/6	—	1/0
2016 JP38	1/3	NA	29/0	11/??
2014 HS197	1/2	6/4	7/2	11/3
2016 SA2	10/13	4/2	11/12	11/12
2017 FV	16/28	6/4	—	3/0
2016 JT38	1/10	NA/6	29/1	16/4
2014 HN199	4/7	6/4	16/0	9/??
2014 HD199	2/4	9/8	2/0	—
2014 UU56	4/7	6/6	—	4/6
2017 FB102	6/6	6/6	5/5	5/5
2015 HS182	3/4	9/8	113/0	38/0
2015 HV182	1/7	7/8	189/8	118/13
2015 KA158	2/3	9/6	36/0	15/0
2016 JG38	2/3	NA/6	127/0	1/10
2016 JL38	1/3	NA/8	108/0	—
2014 HK197	1/2	9/7	56/0	17/5
2014 HN198	1/6	4/7	97/0	148/0
2014 HN197	1/2	5/9	2/56	59/54
2014 HT197	2/3	8/7	4/0	2/1
2014 JU79	1/2	5/8	10/0	18/2
2015 HO182	2/5	8/7	30/6	32/6

4. Conclusions

Following the footsteps of the EURONEAR data mining projects, the VIMP software was built in 2016 to allow searches of known Virtual Impactor asteroids (VIs) serendipitously encounter in the Mega-Archive image collection (15 million images taken by 111 instruments by 2019). This code identifies candidate images which are prioritised and later scrutinised by human reducers. In August 2018 we applied VIMP to the Blanco-DECam archive (300,000 images) which resulted to date (25 Apr 2019) in 25 VIs precovered or recovered, from which 12 were elliminated from at least one list. Other few dozen objects continue to be scrutinised and other archives are planned to be searched in the near future.

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