

A Set of Data Mining Tools for Double Stars Measurements Using the EURONEAR Mega-Archive

Lucian Curelaru¹, Marcel Popescu², Ovidiu Vaduvescu³

1. Brasov, Romania lucian.curelaru@gmail.com

2. Instituto de Astrofisica de Canarias, Tenerife, Canary Islands, Spain
and Universidad de La Laguna, Tenerife, Canary Islands, Spain

3. Isaac Newton Group, La Palma, Canary Islands, Spain

Abstract: This article presents a set of three web tools for data mining work of double stars using archive images taken by various professional telescopes. These tools are based on the EURONEAR resources (i.e. Mega-Archive) and are freely available to use from <http://www.euronear.org/tools.php>. They help the user to identify CCD images of double stars in world-wide archives, thus making the data mining work more efficient. In order to exemplify the use of these tools, a set of measurements of neglected doubles is shown.

1. Introduction

Searching for known objects in astronomical images (i.e. data mining) has become more common in the last decades. This happened gracefully to CCD astronomy which is strongly supported by the fast growing access to better IT connected technologies like very fast computers, fast and wide networks and accessible Internet resources. There are huge collections of astronomical images stored in digital archives available on the Internet. Most of them can be freely used for research purposes by any professional or amateur astronomer. Thanks to this opportunity, some new methods of handling big astronomical data have risen. We are able now to create software to help searching in this huge amount of data and allowing the data to be used for a different purpose than the one for which the image was taken. As a consequence of the huge amount of images available nowadays, data mining has increased success in different areas of astronomy. Moreover, data mining can help to retrieve information about objects long time in the past, which can become very useful when multiple observations spread in time are needed.

During one decade, the EURONEAR project [1] has identified the potential of data mining, developing some tools to help astronomers to datamine image archives in the search for asteroids. Because the images are distributed in multiple web accessible archives all over the world, we have developed a database, named Mega-Archive, which unifies basic observing infor-

mation about astronomical images stored by multiple archives [2]. Currently (May 2018), the Mega-Archive contains meta-data for about 15 million images collected by 111 instruments. The Mega-Archive is growing daily, due to automated update tools which web-crawl known archives for new images, while new instruments and archives are sometimes added to this collection. Since 2008, EURONEAR project accessed the Mega-Archive with newly developed tools to allow few data mining projects, with results published in some papers [3]. With the aim to improve the orbits and physical knowledge of double stars and in particular of the neglected ones, we updated/improved/modified/adapted our software which exploit Mega Archive for this type of project. This was done by using as search targets the double stars included in the WDS Catalogue [4]. Moreover, searching for fixed objects is much simpler than searching for moving objects, due to the fact that some of the Solar System objects have high differential rates (like near Earth asteroids) or larger uncertainties of their positions.

The data mining of double stars imaged by instruments mounted on large telescopes has a huge potential and could become very efficient by an automated search. Presently, many double star astrometry projects are carried out by amateur astronomers using their own small instruments. However, in this case they can produce limited astrometric and photometric quality data for fainter targets. Using for free the existing images

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taken with large telescopes located in very good observatories, these limitations can be clearly solved, and the additional effort and time used for observations are saved. Although some of this time will be replaced by the identification of the interesting targets in the archives, though this work can be automated. In the following sections our paper will present such a few tools to assist double star researchers.

2. Flowchart of Mega-Archive and Connection with the Tools

The EURONEAR asteroids data mining tools aim to assist the user to identify potential existing images that could contain any Solar system object (known for longer time or newly discovered). In order to do this, it has been necessary to have a reliable and consistent database of observations logs of world-wide telescopes. It seems impossible to deploy search scripts at the location of many archives existent in different world sites, so our solution was to build in only a given site some index which contains basic spatial and temporal metadata characterising all images, which are relatively easily retrievable from many observatories. This index was named the Mega-Archive and it is described in an older article [3]. The architecture of the Mega-Archive can be seen in Figure 1. The main engines

which update Mega-Archive are some custom made website calling scripts (known as web crawlers in the IT world [5]) able to query different image collections. These scripts automatically extract the necessary information, saving it into a single MySQL database by collecting the new data on a daily basis and updating the index to facilitate rapid searches. The Mega-Archive database contains the following fields which are required by data mining tools:

- Fields defining the images:
 - Instrument ID - which refers to the instruments table
 - Image ID - The image ID (file name or number) from the original archive
 - Right ascension and Declination - The coordinates of the center of the image (usually coinciding with the telescope pointing)
 - Start exposure time - Time in UT of the exposure start
 - Exposure time - The length in seconds of the exposure
 - Filter - The filter used for this image
- Fields defining the instruments:

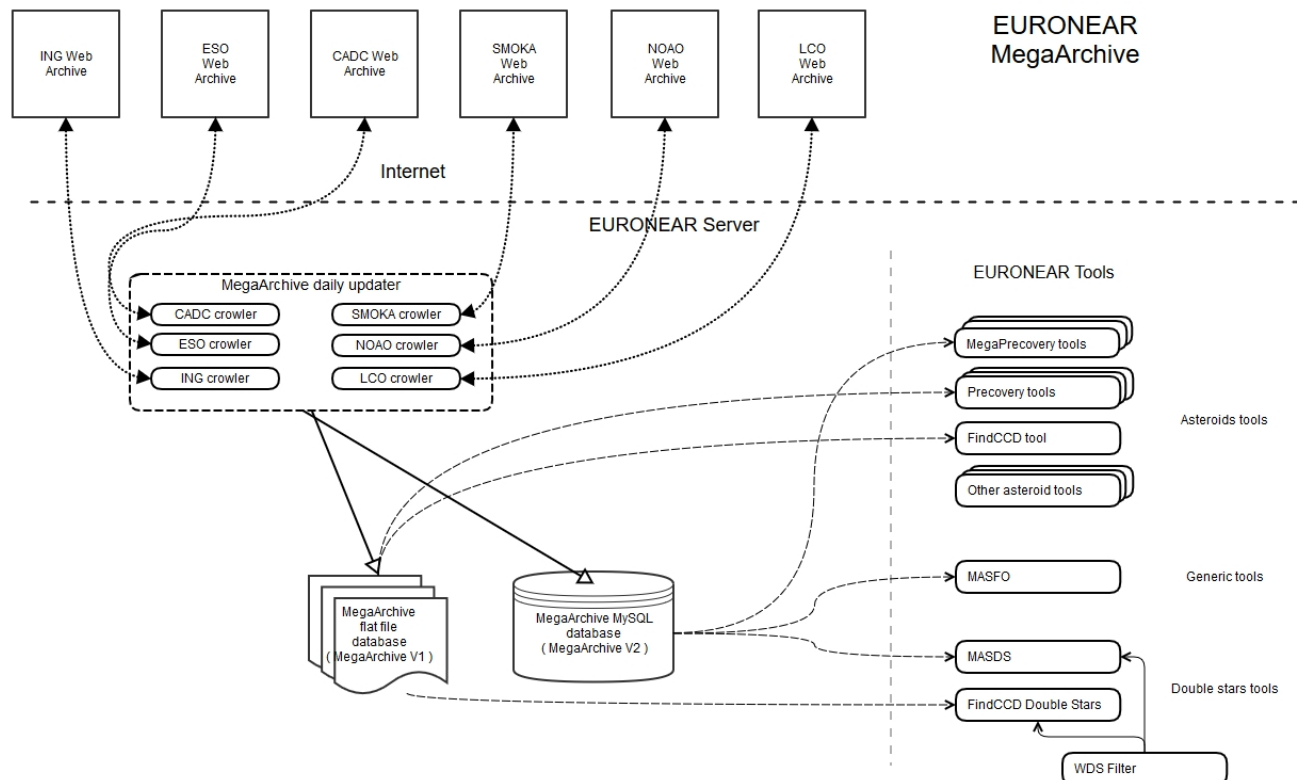


Figure 1. The EURONEAR Mega-Archive architecture including the new tools

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- ID - A unique number allocated to the instrument ID for references
- Name - The name of the instrument
- Abbreviation - A short name of the instrument
- FieldX, FieldY - The size of the field in degrees across the RA and DEC directions (assuming non-rotated instruments)
- Magnitude limit - Estimated magnitude limit (V-band) which the given instrument can reach in best weather conditions in relatively short exposures (few minutes)
- Area - The area of the primary telescope mirror in square meters
- URL - The URL to access the original instrument archive containing the images
- MPC Code - The MPC code associated with the

observatory which hosts the instruments if such a code exists (important only for close flybys of asteroids).

Given a huge collection of images, this basic information should suffice to automatically evaluate which images could be useful for a given search, without the need for physical analysis of many images.

By using this index, within the EURONEAR framework, we implemented several tools (Precovery and Mega-Precovery) to easily compare the ephemerides of any minor planet with some parts or the entire Mega-Archive. The matching algorithm used ephemerides computed dynamically by third party tools which overlap the asteroid track over the archive images parameters, identifying the images potential to contain the object. A human assistant has to download the candi-

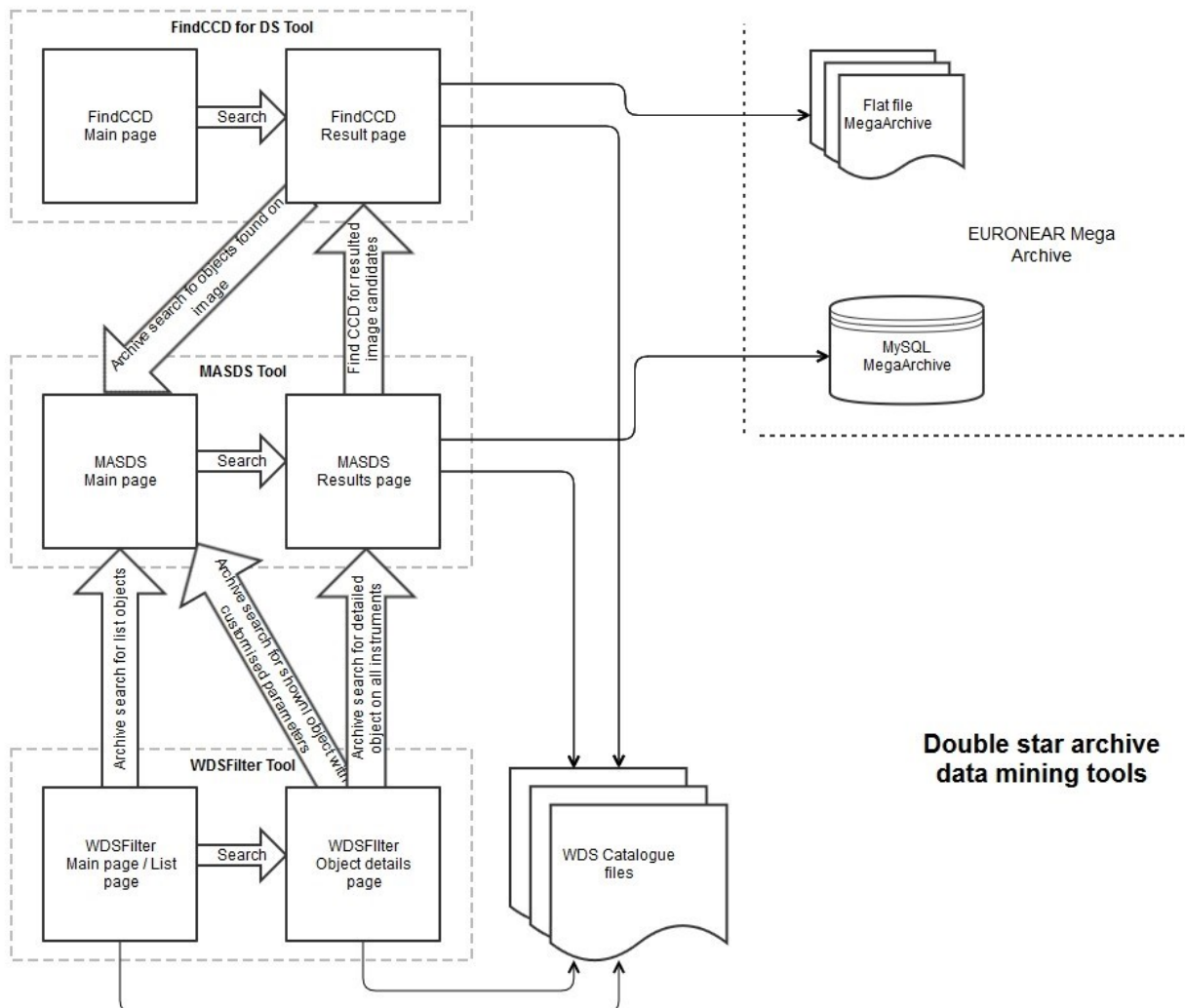


Figure 2. Double star archive data mining tools architecture

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date image, to find the asteroid given its ephemeride prediction, then measure its position or magnitude. To assist the CCD identification in major mosaic cameras, the FindCCD tool was developed to show exactly where the asteroid should be located.

Inheriting these asteroid search tools we have developed a set of similar tools which can search double stars, namely:

- MASDS (Mega Archive Search for Double Stars) - searches for images containing one or more specified WDS Catalog double stars;
- FindCCD for Double Stars - identifies the CCD by overlaying the double star position (WDS Catalogue) searched in a few major mosaic cameras;
- WDSFilter - A WDS catalog search tool integrated with MASDS in order to handle lists doubles in data mining projects.

These tools are described in detail in the next sections, their workflow being depicted visually in Figure 2. They were programmed under the PHP language. The database used by Mega-Archive is a MySQL plat-

form. Some of the older tools use a flat file version of the Mega-Archive which is also updated daily by the Mega-Archive web crawlers. In the near future these tools will be upgraded to work with the MySQL Mega-Archive.

3. Mega Archive Search Double Stars (MASDS)

MASDS is a tool which allows searching the Mega-Archive for images that contain one or more double stars given in the input. According to Figure 3, there are several available parameters to be provided as input for the search, including the selection of instruments. Multiple objects can be also specified by inserting a comma separator between objects. In both cases the objects can be specified either by the WDS discoverer code or by the WDSID identification. The result is a list which contains all candidate images containing the searched object (sample output in Figure 4). For the mosaic instruments, there is an option to open the FindCCD for Double Stars tool for each candidate object for plotting its estimated position in the instrument field. This way one can check if the object may fall into

EURONEAR - Tools - MASDS

Description: MASDS is the acronym for "Mega Archive Search Double Stars".
It searches for WDS catalogue double stars in the Mega Archive (15 million images by Mar 2018).
Input: Object WDSID or WDS Discoverer code.
Output: Table with images possible to hold the searched object(s), including the name of the archive/instrument, image ID, observing date/time (start), exposure time (s), some estimated magnitude limit for the telescope/instrument (in best conditions), filter (and maybe other comments from observer) and the distance between the object and the camera center (in degrees) plus a percentage (compared with a circular field).
Also you can see the exact position in the camera field and also other double stars in field by pushing the corresponding button from "Position in CCD field".
IMPORTANT: Unfortunately only a part of the fields are supported by this function. The supported instruments are extending continuously.

Current archive info:

- Total instruments :111
- Total images :14562713
- Archive interval :1989-11-30 - 2018-04-02

Searched object(s):
Please enter WDSID(s) or WDS Discoverer code(s)
If you want to search at once for two objects or sets of positions, then separate them in a few lines.

☐ **Raw text output**
Chose raw output mode to receive a CSV style output. Otherwise, a HTML table output will be produced.

Safety search border (deg):
The size in degrees of a band around the images to accommodate possible pointing errors.

Instrument Selection:

ID	Instrument	AΩA (sq.m × sq.deg × nr.img)	FOV (sq.')	Start Date	End Date	Images
0	<input checked="" type="checkbox"/> ALL Instruments					
1	<input type="checkbox"/> AAT-WFI	14830.83	1089.00	2000-08-21	2006-02-05	4453
2	<input type="checkbox"/> CADC/APASS	42241.94	31329.00	2010-04-11	2014-06-02	121350
3	<input type="checkbox"/> CADC/CFHT-aobir	183.68	1.44	1997-12-10	2011-11-23	45108
4	<input type="checkbox"/> CADC/CFHT-aobvis	6.41	1.44	1996-05-04	1999-03-30	1573
5	<input type="checkbox"/> CADC/CFHT-CFHTIR	1396.50	17.64	2001-01-10	2005-11-17	27996
6	<input type="checkbox"/> CADC/CFHT-Megacam	1464861.28	3600.00	2003-02-22	2013-05-09	143896
7	<input type="checkbox"/> CADC/CFHT-MOCAM	421.20	225.00	1995-05-28	1995-11-29	662
8	<input type="checkbox"/> CADC/CFHT-REDEYE	240.83	4.41	1993-02-04	1998-09-03	19312
9	<input type="checkbox"/> CADC/CFHT-WIRCam	415260.31	466.56	2005-11-18	2018-04-01	214824

Figure 3. MASDS tool main page with selectors for object, instruments and parameters.

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 Also you can see the exact position in the camera field and also other double stars in field by pushing the corresponding button from "Position in CCD field".
 IMPORTANT: Unfortunately only a part of the fields are supported by this function. The supported instruments are extending continuously.

Current archive info:

- Total instruments :111
- Total images :14562713
- Archive interval :1989-11-30 - 2018-04-02

Searched the following archives: ALL

Results for object **STF2727AB**

ID	Discoverer code	RA	DEC	Magnitudes	Observations	Observing period	Position angles	Separations	Notes
20467+1607	STF2727AB	20h 46m 39.50s (20.7775)	+16° 07' 27.40" (16.1242)	4.36 / 5.03	530	1755 -> 2016	280° -> 266°	12.0" -> 9.0"	NO Z

Found following 30 images that contains object STF2727AB

Archive/Instrument	Image	Obs Time	TExp (s)	Lim Mag	Filter	Dist	Safety	Position on CCD
CADC/APASS	s110907.0191	2011/09/07 02:27:02	180	17	B	1.49 (70.5%)	0.02°	N/A
CADC/APASS	s110907.0194	2011/09/07 02:30:38	180	17	g	1.49 (70.6%)	0.02°	N/A
CADC/APASS	s110907.0196	2011/09/07 02:35:15	90	17	V	1.33 (62.7%)	0.02°	N/A
CADC/APASS	s110907.0197	2011/09/07 02:35:17	180	17	B	1.32 (62.2%)	0.02°	N/A
CADC/APASS	s110907.0198	2011/09/07 02:37:09	90	17	r	1.33 (62.7%)	0.02°	N/A
CADC/APASS	s110907.0200	2011/09/07 02:39:02	90	17	i	1.33 (62.7%)	0.02°	N/A
	http://dr9.sdss3.org/fields/runCameoField2run--48268	2004/09/17				0.02		

Figure 4. MASDS result page containing lists of candidate images and links to FindCCD tool.

a CCD gap, helping to judge which of the candidate images are more appropriate to be scrutinized for measuring the object. This facility is important for saving time with subsequent archive image search, download and visual analysis of the fields, which in some cases might not contain useful data. In the candidate list the tool also displays the exposure time of each image, which is also helpful in choosing the most appropriate image, like long exposure for faint targets or shorter exposures for close doubles with bright or medium components, depending also on the telescope mirror.

For fast moving doubles, the MASDS tool can be also used to find images which contain positions spaced during the years or older positions, which are the best for improving the double system orbits. The Mega-Archive currently contains images since 1990 to present day. It covers some of the most complex and wide digital archives in the world. In the near future we also plan to include some older digitized archives.

The original tool used to build MASDS was

MASFO, a similar EURONEAR tool which searches for fixed objects giving their coordinates. It was designed following a similar concept as Mega-Precovery software which is dedicated to Solar System bodies. First, MASDS loads from the WDS catalogue (locally saved as a file) the coordinates of each searched object. Then it runs an SQL script on the Mega-Archive database with the purpose to identify all archive entries containing the searched coordinates, for each of the selected instruments. Finally, the findings are displayed in multiple lists, one for each instrument.

The Mega-Archive database contains the center coordinates of each image and a reference to the instrument which acquired it. The SQL script filters all images which have the searched coordinates inside an image, by calculating the image borders using the centre coordinates, and the instrument field size in order to compare them with the searched coordinates. We mention that the matching considers a small safety band around images allowing for telescope pointing errors

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and offsets not registered in the observing logs.

The MASDS tool can be accessed from the EURONEAR Tools page or by using the following link: <http://www.euronear.org/tools/dstars/masds.php>

4. FindCCD for Double Stars

The FindCCD for Double Stars tool shows all WDS double stars contained in any image from the selected archive which include few major mosaic cameras. The required inputs are the image ID and the instrument. Optionally, the instrument sky position angle could be added (if known), but there are extremely few cases of such rotating cameras. As seen in Figure 5, the output will be a graphic representation plotting the estimated objects that could be found in respect to the given mosaic camera. Sometimes objects are shown and listed outside the field, for safety reasons.

As of May 2018, the tool supports seven mosaic instruments. We plan to add more instruments, considering with higher priority the largest field ones. The MASDS includes links to FindCCD for each

candidate image listed. It is user friendly and it is accessed by clicking the button associated with a MASDS found object which submits the instrument ID and image ID automatically. Then it opens directly the results page from FindCCD. This version of the tool is available also in stand alone flavor because it may be also used to find out which double star objects are contained in a field of particular image without using MASDS. This could be useful for instance if a user already have some images downloaded from an archive for other purposes and wants to mine them for doubles as well. The FindCCD for Double Stars is just an adaptation of the asteroid FindCCD code. It first searches the image details using the image ID and the instrument from the Mega-Archive. After retrieving the coordinates and the field information it loads the local WDS catalogue and identifies the objects by comparing the borders with the WDS object coordinates. Then, it builds a list with all objects that fit the conditions. Finally, the tool generates an image where firstly it draws the CCD grid using a predefined grid dimension

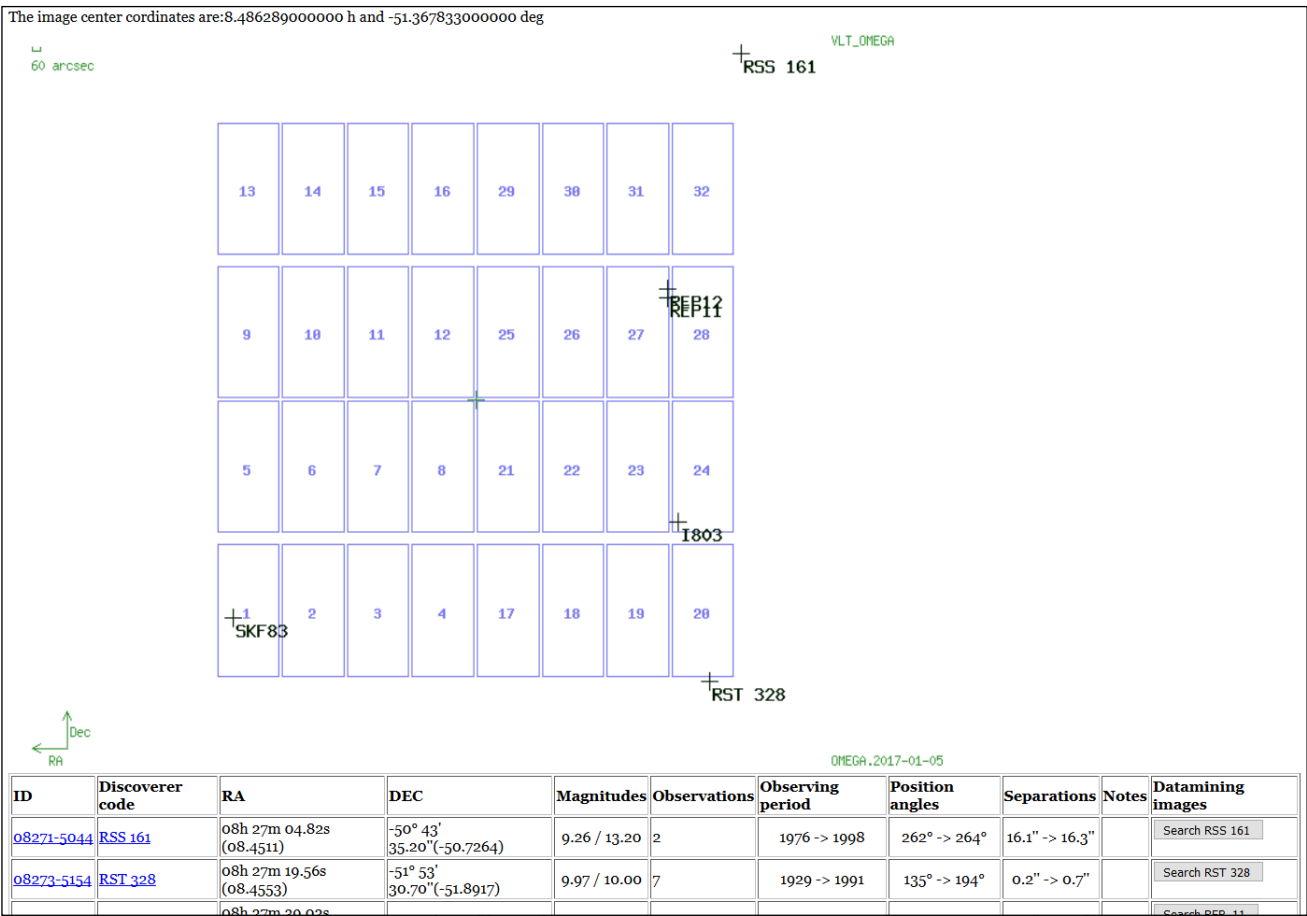


Figure 5. FindCCD tool results page. The camera overlay with CCD numbers can be seen in the upper part, while the list of found objects and links to other tools appears at the bottom.

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WDSFilter / A double stars filter with datamining support

Description: This is a filtering tool for double stars from the WDS Catalogue

You will be able to search and generate lists of double stars on a wide number of parameters.

Also for each object you can see a detail page with a lot of information useful for double star work.

Both in the list and in the details page you will find buttons which helps you find objects in a wide archive of almost 15 public million images. These images are available at different archives and can be downloaded from there but our search have an huge index with them which is constantly growing by daily updates. So we are able to indicate where the searched object can be found on already existing images

Input: Filtering parameters

Output: A list with all objects which fulfill the required limitations.

WDS data last updated in April 02 2018

Filter			
RA	from: 1 01 12	to: 1 30 00	
Declination	from: 14	to: 15	
Magnitudes	from: 13	to:	
Magnitude difference	from:	to:	
Separation	from:	to: 10	
Observations	from:	to:	
Last observed year	from: 1998	to:	
Discoverer code			
<input type="checkbox"/> If checked the list will contain the number of MegaArchive fields containing each object. IMPORTANT: Checking this option will SLOW down considerably the search			
<input type="button" value="Apply"/> <input type="button" value="Reset"/>			

ID	Discoverer code	RA	DEC	Magnitudes	Observations	Observing period	Position angles	Separations	Notes	Datamining images
01026+1430	LDS2808	01h 02m 34.82s (01.0428)	+14° 30' 45.90" (14.5125)	18.0 / 18.2	3	1954 -> 2000	103° -> 101°	4.0" -> 4.7"		Search LDS2808
01129+1420	UC 519	01h 12m 51.46s (01.2142)	+14° 19' 57.60" (14.3325)	16.4 / 16.4	9	1952 -> 2010	107° -> 106°	6.1" -> 7.1"	V	Search UC 519
01190+1424	CVR1072	01h 18m 58.31s (01.3161)	+14° 23' 55.00" (14.3986)	16.2 / 16.8	4	1998 -> 2010	14° -> 18°	4.2"	R	Search CVR1072

CSV with selected objects:

```
01026+1430,LDS2808 ,01 02 34.82,+14 30 45.90, 18.00 / 18.20,101,4.7,2000
01129+1420,UC 519 ,01 12 51.46,+14 19 57.60, 16.40 / 16.40,106,7.1,2010
01190+1424,CVR1072 ,01 18 58.31,+14 23 55.00, 16.20 / 16.80,18,4.2,2010
```

3 object(s) filtered

Any feedback or suggestions are welcome. You can send them [here](#)

This webpage has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory.

Reference: Please include the following acknowledgement in any publication using this service:

- Include in the acknowledgement: "This paper used the WDSFilter Tool (footnote(<http://www.euronear.org/tools/dstars/wdsfilter/wdsfilter.php>))."

Authors: Lucian Curelaru

Figure 6. WDSFilter tool main page with resulting objects based on given input parameters.

array for the searched instrument. Afterwards, it over-
lays the objects by computing their position according
to the image size, and coordinates for the center. The
object list is also displayed in details and includes links
to a more detailed page fed by another tool (WDSFilter)
for each object, in order to assist work further.

FindCCD for Double Stars can be accessed from
the EURONEAR Tools page or by using the following
link: <http://www.euronear.org/tools/dstars/findccddstars.php>

5. WDSFilter

WDSfilter is a tool developed by the first author in
the past, namely a double star search tool and a list gen-
erator for doubles from WDS catalogue. This tool was
extended by integrating it with MASDS tool in order to
help users for data mining projects involving multiple
objects. It can be used to generate lists of doubles by
some criteria and afterwards search the targets with
MASDS. With the cost of a longer run, it can provide
information about instruments from Mega-Archive
which could contain the searched objects, saving the
time of running MASDS manually for every object.

WDSFilter uses a locally file saved WDS Cata-

logue which is periodically updated. For the future, we
consider also to move the WDS Catalogue data to the
already MySQL database available in the EURONEAR
server. This should give some search speed improve-
ments, but for the moment we considered the file ap-
proach is fast enough. It also has the advantage of a
simplified update.

The WDSFilter tool shows the WDS objects by
using the filtering criteria required by the end user. The
main screen of the WDSFilter can be seen in Figure 6,
where one can notice some multiple but optional filter-
ing parameters and also an example list holding result-
ed objects containing some summary information. By
clicking on an object, the user will see a detailed page
similar to Figure 7, with detailed WDS info about the
object, a list of neighborhood objects, a small Aladin
preview, some data mining info and MASDS search
buttons. The MASDS buttons are available both in
main list of WDSFilter but also in the details page for
objects where it can be used with two flavors, automat-
ic search on all instruments and custom search where
the user can select instruments and set other parameters
in an intermediary step. Otherwise the WDSFilter can

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Object LDS2808 details

Right Ascension: 01h 02m 34.82s
Declination: +14° 30' 45.90"
Magnitudes: 18.00 / 18.20
Observations: 3
Time interval: 1954 -> 2000 (46 years) | Not observed for 18 years
Position Angles: 103° -> 101° (d = -2 °)
Separations: 4.0" -> 4.7" (d = 0.7")
Spectral:
Primary Proper Motion (RA): +021
Primary Proper Motion (DEC): -056
Secondary Proper Motion (RA):
Secondary Proper Motion (DEC):
Durchmusterung Number:

Datamining:
Mega archive search for LDS2808
Search preview: Found object on 128 images :
NVO/BLANCO-DECAM = 13
SDSS5 = 4
SMOKA/Kiso-KWFC = 111

Aladin cmdline:

Main data CSV:

Aladin previewer

Target
 Go
☒ B&W ☐ Color
01 02 34.82
+14 30 45.90
POSSII/F/DSS2

Target coordinates (J2000):
RA: 01 02 34.8
Dec: +14 30 45
Size and definition:
12.9' x 12.9'
768 x 768 pixels
Survey:
Palomar Observatory Sky Survey (POSSII)
Color:
Red (F)
Origin:
Space Telescope Science Institute ()
Digitizing machine:
Plate Densitometer Scanner (FDS)
Available images:
[the same in fits](#)

This software uses source code created at the Centre de Données astronomiques de Strasbourg, France.

Notes:

Other objects with same coordinates (potentially components of same object):
NONE

Neighbourhood objects (in 30 arcmin range) - potentially in the same field:
[SLW 50](#)
Right Ascension: 01h 04m 10.49s
Declination: +14° 20' 22.70"
Magnitudes: 15.50 / 19.10
Time interval: 1954 -> 2010 (56 years) | Not observed for 8 years
Position Angle: 164°
Separations: 75.5" -> 75.7" (d = 0.2")

Discoverer info:

LDS	LDS	Luyten p.m. catalog	(from additional DD list)

Figure 7. WDSFilter tool details page.

be also used for any classical object search or as a target object list generator based on specific criteria.

The WDSFilter tool can be accessed from the EURONEAR Tools page or by using the link: <http://www.euronear.org/tools/dstars/wdsfilter/wdsfilter.php>.

6. The Measurements

In this section we present some small data mining tests using a sample of 21 double stars. We selected the ESO/VST archive images [6], archive also used in another similar data mining project [7]. In order to have an appropriate set of doubles that needs to be measured, we considered several criteria to match objects that are not easily accessible to most observers but accessible to a large telescope like the VST and the OmegaCam imager.

Besides the commonly used recommendation for an object to have the last observation be more than twenty years old (generally used to select neglected doubles), we added some additional filters in order to select difficult objects which are out of reach for most neglected stars observers. One supplemental condition was to search objects in the southern hemisphere, because there are probably less observed. Another condition is to target objects fainter than 15 magnitude, which are difficult to be observed by amateurs. Finally the last condition is to target objects with a separation between 3 and 5 arcseconds because of the difficulty to measure accurately small separations with a small telescopes. A lower limit of 3 arcsec was used because this is feasible for the ESO-VST telescope, as demonstrated in a past article[7], but most probably in fact this limit can be

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lowered more, due to the excellent Paranal seeing and the instrument resolution which could be tested in a future project. These criteria were introduced in WDSFilter tool and a set of candidates was obtained. Finally the MASDS tool was used to find images and the FindCCD to locate the objects. The WDSFilter detail page was used to analyze some difficult objects.

We used the Astrometrica software to calibrate the images and perform the position measurements of the main and secondary components. After each object was identified using FindCCD and the WDSFilter details page, the position was saved in the Astrometrica report. From the report we've copied the measured coordinates in a google spreadsheet built also by the authors in a past double stars project. The spreadsheet computes the position angle and the separation from RA and DEC coordinates of the main and secondary stars. All this process of measuring VST-VLT telescope images is described also in a past article. [7]

Besides the doubles selected as described before, we were able to easily identify, by using the FindCCD tool, other doubles on the images downloaded for targeting the initial 21 candidates. These other incidental doubles could be also measured. In a few cases, we could measure objects with separations just under the 3 arcsec limit which happened to fall in the images. For this reason the reports will contain few other doubles, besides the main targets. The resulted measurements and notes can be found in the following paragraphs.

It has to be mentioned, as noticed also in other past projects, that photometry is not very precise using Astrometrica. In particular, the bright targets observed with big telescopes tend to be saturated. The uncertainty in magnitudes could reach up to one magnitude, which is quite unacceptable. But the main target of the project was to obtain astrometry for neglected objects using archival images, and this has proven to be precise.

6.1 Neglected measurements

Table 1 includes a list of 13 neglected double stars measured with the tools presented in this paper.

Table 2 presents two measurements for the same object LDS2097. There is a difference between them and the catalog data: there is a star at the catalog coordinates with corresponding magnitude and also seems to be a secondary close in magnitude next to it. But the PA and separation differ quite a lot. The only existing WDS measurement was made in 1954 and indicates a PA of 71 degrees and a separation of 3 arcsec, while the object from a recent image has a PA of 347.5 and a separation of 11.3 arcseconds. The PA maybe could be explained as a quadrant error because the difference is close to 270. The separation probably could change

with 8 arcseconds in such a big period of time like in this case. In order to get some extra information we decided to search the object on multiple images from the same archive but more sparse in time. Using MASDS we found two images that contain the object observed five years apart. As can be seen in Table 3, the object PA and separation vary pretty much during this time, also the separation changes but not so much to explain 8 arcsec in the passed interval if we expect the movement to be quite uniform. Thus, it is difficult to draw any firm conclusion. Clearly the object is changing in time, but it is not clear if it can fit the original observation or maybe some errors with the original measurement could explain this. Maybe some future observations of this object, next to our findings, will help clarify this case.

6.2 Other double star measurements

In Table 3 we include a list of 17 double stars measured with the presented methods.

6.3 Missing objects:

In this section we present 7 missing objects with some explanations and presumptions.

- The following objects could not be found, despite the great telescope resolution: LDS6361, LDS2982 and LDS2101. There was no star at the catalogue coordinates and no candidate was found in the close neighborhood (the CCD which is 7x14 arcmin large). There are probably errors at catalog coordinates, big enough to place these object outside the searched field or maybe the object became very close and can not be separated.
- The object LDS5265 was not encountered but a 13 magnitude single star was found at that position. No close candidates were visible in the neighborhood. These are probably catalog coordinate mistakes as well.
- For the object LDS4139 there is no star at the catalogue position. But at arcseconds distance there is a 15.5 mag star and another 17 mag star which seem close but they are separated by 13 arcsec and have a PA of about 246. Catalogue values for LDS4139 are 100 for PA and 3 for separation. It is difficult to say if this is the real object but having multiple errors in catalogue like wrong quadrant and also quite different separation (maybe a typo from 13 to 3?). Probably some extra observation could clarify this situation.
- The object GWP 426 was not found, but an elliptical galaxy was identified right over the expected position. No close candidates were visible on the same FITS image. There are probably errors at cat-

(Text continues on page 13)

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Table 1. Neglected Double Stars Measured on Analyzed Images

NAME	RA+DEC	MAGS	PA	SEP	DATE	N	NOTES
LDS9101	00476-1812	18.4 19.0	128.4	3.27	2012.874	1	
RUZ 5AB	12041-2822	15.5 16.5	346.9	4.24	2016.163	1	
LDS4271	12479-2923	14.8 17.3	47.8	3.42	2017.252	1	
LDS4493	14433-2238	15.1 16.5	29.3	3.31	2016.321	1	
LDS6384	22380-1323	17.7 18.1	11.4	4.78	2013.690	1	
LDS2953	22450-2826	15.4 16.1	117.1	2.65	2014.301	1	
LDS6399	23285-2306	16.0 15.4	220.3	5.29	2013.676	1	
LDS2992	23414-3205	16.9 17.9	124.2	3.40	2012.877	1	
SKF 166	23501-2911	14.0 14.6	297.6	3.19	2013.953	1	
REP 12	08277-5110	14.0 15.6	329.8	4.51	2017.013	1	
RST1633	12019-2811	9.9 11.7	297.9	3.63	2016.163	1	
REP 11	08276-5111	17.6 16.8	344.5	3.35	2017.013	1	1
BRT2841	00127-2707	12.2 12.1	100.7	30.25	2015.653	1	2

Table 1 Notes:

1. The magnitudes seems reversed. The star from catalog coordinates is weaker than the other.
2. The main star at exact position but PA and separation is quite different. Magnitudes match. No other closer candidate visible.

Table 2. Two measurements five years apart of the probable real values for the object LDS2097 using the ESO -VST images

NAME	RA+DEC	MAGS	PA	SEP	DATE	NOTES
LDS2097	00103-3227	14.1 20.4	347.5	11.31	2017.671	1
LDS2097	00103-3227	14.5 21.0	351.3	11.17	2012.581	

Table 2 Notes:

1. Precise coordinates for this object: 00 10 20.989 -32 26 42.90

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Table 3. Other Double Stars Found in Analyzed Images

NAME	RA+DEC	MAGS	PA	SEP	DATE	N	NOTES
BVD 46	00080-3139	11.6 11.7	328.7	20.38	2017.67	1	
LDS2104	00134-2717	16.6 16.7	339.1	75.34	2015.653	1	1
LDS 7	00154-3219	11.1 12.5	143.8	13.07	2017.922	1	
J 1583	11574-1939	9.9 12.1	72.4	8.42	2016.097	1	
RUZ 5AC	12041-2822	15.5 15.0	270.9	4.03	2016.163	1	
HJ 4553	12508-2944	10.5 11.8	345.5	11.55	2017.252	1	
UC 2415	12508-2851	10.9 14.6	319.3	23.01	2017.252	1	
REP 39	16266-2346	15.6 17.1	132.3	2.24	2017.184	1	2
REP 37	16263-2409	15.6 20.0	358.1	5.08	2017.184	1	
UC 4559	21467-2116	10.7 11.5	188.7	37.1	2015.702	1	
HJ 5355AB	22386-1404	6.2 7.2	289.2	83.67	2013.69	1	
HJ 5355AC	22386-1404	6.2 10.5	359.3	106.88	2013.69	1	
HJ 5355BC	22386-1404	7.2 10.5	44.4	111.03	2013.69	1	
DAM 656	22449-2822	14.8 14.9	329.8	13.56	2014.301	1	
AOT 124	23323-2303	13.6 14.5	338.8	13.42	2013.676	1	
SEE 486AC	23301-2240	8.4 12.4	149.1	23.01	2013.676	1	
SKF 163	23403-3142	15.2 14.9	247.6	17.09	2012.877	1	

Table 3 Notes:

1. The secondary is much brighter.
2. The secondary clearly weaker than primary. In the catalog, the stars have similar magnitudes.

(Continued from page 11)

alog coordinates as well.

- The object TDS8545 has an expected catalogue separation around 1 arcsec. Even this is under our proposed limit but we could not identify any star. We expected to see at least some ellipsoid at this resolution, but there is no sign of duplicity. Of course there is a possibility that the object became very tight in the meantime.

7. Conclusions

The data mining of existing image archives seems very promising for different areas of astronomy, including double star astrometry. We consider that data mining can become much more efficient if some dedicated tools are developed in order to help search for images and object identification. We hope that this freely available package of web tools will assist other double star enthusiasts in their projects and maybe encourage some observers to use data mining images for double star astrometry, besides their own observations.

The measurements presented here confirmed that the developed tools are working correctly. During the development phase the software has been well tested from a technical point of view.. Comparing with the last data mining project performed on the same archive in the past [7], there are clear improvements in the identification and measurement process. A considerable amount of time is saved especially in the effective identification of the object on the images using the FindCCD tool and also in selecting the most appropriate images for downloading. Measuring an object with the help of these tools is taking now considerably less time on average than it took in the past during the previous project.

8. Acknowledgements

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EURONEAR official page [1], other details about some of the data mining activity from EURONEAR can be seen in [3] and [8].

The project is based on data obtained from the ESO Science Archive Facility [9] under following request numbers: cluci339304, cluci39324, cluci339474, cluci339497, cluci339658, cluci339659, cluci340840, cluci341529, cluci342256, cluci342257, cluci342259, cluci342489, cluci342545, cluci342693, cluci342700, cluci342715, cluci342995, cluci343080, cluci343096, cluci343511, cluci343523, cluci343532, cluci343534, cluci343549, cluci343550, cluci343573, cluci343574, cluci343577, cluci343579

This research has made use of the Washington Double Star catalogs maintained at the U.S. Naval Observatory [4].

Data reduction was carried out using the Astrometrica software developed and maintained by Herbert Raab [10] using UCAC Catalog [11] and NOMAD catalog [12].

This research has made use also of "Aladin sky atlas" developed at CDS, Strasbourg Observatory, France http://cdsads.u-strasbg.fr/cgi-bin/nph-bib_query?2000A%26AS..143...33B&db_key=AST&nosetcookie=1 and http://cdsads.u-strasbg.fr/cgi-bin/nph-bib_query?2014ASPC..485..277B&db_key=AST&nosetcookie=1 . [13]

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Lucian Curelaru is a senior software engineer in a multinational company living and working in Brasov, Romania. He is also a member of the Romanian Society for Meteors and Astronomy. He owns a small private astronomical observatory which is MPC enrolled with the code L13 used for both asteroid and double stars astrometry.

Dr. Marcel Popescu is a professional astronomer at Astronomical Institute of the Romanian Academy. Currently, he is following a post-doctoral contract at Instituto de Astrofisica de Canarias. His research topics concern the Solar System astronomy with emphasis on the minor bodies, asteroids, and comets. He has co-authored more than 20 articles for main astronomical journals with subjects related to spectroscopy, astrometry, dynamical and mineralogical modeling of minor bodies. He has obtained one of the largest databases of near-infrared colors of asteroids (MOVIS) based on VISTA-VHS survey.

Dr. Ovidiu Vaduvescu is a professional astronomer based in La Palma, a member of the Isaac Newton Group (ING), and co-founder and leader of the EURONEAR project. One decade ago he identified near Earth asteroid data mining of large telescopes image archives as a possible contribution involving amateur astronomers which has led to 4 ISI publications.