

New Common Proper-Motion Pairs from the PPMX Catalog

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Abstract: We use data mining techniques for finding 82 previously unreported common proper motion pairs from the PPM-Extended catalogue. Special-purpose software automating the different phases of the process has been developed. The software simplifies the detection of the new pairs by integrating a set of basic operations over catalogues. The operations can be combined by the user in scripts representing different filtering criteria. This procedure facilitates testing the software and employing the same scripts for different projects.

Introduction

In previous papers (Caballero 2009, Caballero 2010) we data mined different catalogs using some criteria to obtain new common proper-motion pairs (CPMP's from now on) not included in the WDS (Washington Double Star Catalog, Mason, et al., 2003). This idea is not new and has been used for instance by Greaves (2004).

During the development of the projects it became clear that the process was almost the same in all the cases, with a few changes due to the particular characteristics of each catalog. Therefore it seemed interesting to develop a special-purpose software. Such a project was suggested as a Master's thesis topic at the faculty of Computer Science at the University Complutense of Madrid (Spain). The project was developed by Blanca Collado-Iglesias, Sara Pozuelo-González and Antonio Fernández-Sánchez, and directed by Rafael Caballero. This paper presents 82 new CPMPs from the PPM-Extended catalog (PPMX, see Röser, 2008) obtained with the help of this application.

The Data Mining Process

The overall data mining process can be described as follows:

1. Downloading (part of) the main catalog C , usu-

- ally from the online VizieR Service web page (Allende & Dambert 1999). Sometimes portions of auxiliary catalogs are also needed, for instance to complete the information about spectra, visual magnitude, etc.
2. Importing C data into a relational database such as Access or MySQL (and also the auxiliary catalogs).
3. Obtain the Cartesian product $D = C \times C$. D is thus a table of pairs.
4. Delete from D all the pairs with separation greater than some arbitrary number, for instance 100 seconds.
5. Remove from D all the pairs that are already part of the WDS.
6. Apply some criteria, in order to keep in D only possible CPMPs. A typical case is the Halbwachs' criteria (Halbwachs, 1986).
7. If possible, introduce further criteria that can help to increase the data quality, i.e. to reject those pairs that are more likely not physically attached.
8. Finally, check every pair in the photographic plates available at ALADIN (Bonnarel et al., 2000), looking for two stars with noticeable motion and roughly the same astrometry data in the expected position.

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9. Complete the data with astrometry and other suitable data from auxiliary catalogs.

The Software Application

The opening screen of the application is shown in Figure 1. It was developed in the Java programming language. This language was chosen because it easily allows connecting to different databases using a convenient JDBC (Java Database Connectivity) driver. Initially, the system is configured for using the relational database MySQL, but it can be readily adapted for other databases such as Oracle or Access. The program allows the user importing catalogs obtained from Vizier in text format with the fields separated by “;”. By parsing the header produced by VizierR, the type and size of the different attributes is detected, and a suitable SQL table created.

Other options for general management of catalogs are included. Probably one of the most useful ones is the “Join Catalogs” option. With this option the user can cross two tables containing individual stars yielding a new table containing those pairs with separation less than a parameter in seconds (steps 3 and 4 of the overall process described in the previous section). This table will contain the set of initial candidates.

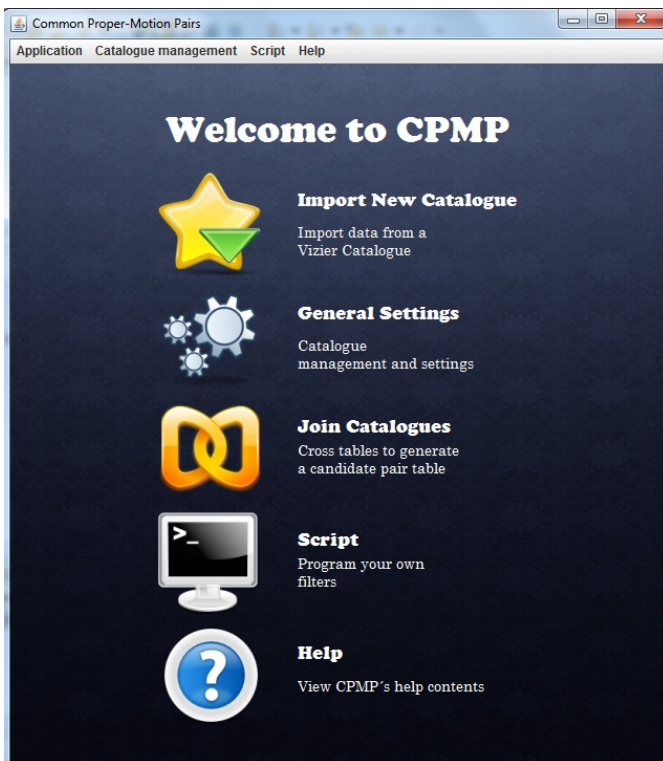


Figure 1: Application main screen.

However, the most appealing feature of the program is that it allows the users to program their own scripts for filtering the candidate pairs. The scripts can be saved and are defined by combining a few core operations, like adding a new field to an existing table, setting the value for some field for all the rows fulfilling some condition, combining catalogs to produce a new one, or deleting all the rows that do not satisfy a given condition. Furthermore, the system allows defining parameterized functions that will be used from different scripts. As a simple example consider the following user-defined function:

```
function setFilterPM(2)
begin
temp1<-newAttribute($1,mu,double);
temp2<-newAttribute(temp1,b_mu,double);
temp3<-attribute(temp2,mu,'sqrt
(pmra*pmra+pmde*pmde)')[true];
temp4<-attribute(temp3,b_mu,'sqrt
(b_pmra*b_pmra+b_pmde*b_pmde)')[true];
$2<-filter(temp4)[mu>=50 and b_mu>=50];
end
```

The function receives as input a table \$1 of pairs, which is assumed to contain fields *pmra*, *pmde*, *b_pmra*, and *b_pmde*, which represent the proper motion in RA and DEC of the two components, and it creates a new table \$2 such that:

- It contains two new fields *mu* and *b_mu* such that for each row $mu = \sqrt{(pmra^2 + pmde^2)}$ and $b_mu = \sqrt{(b_pmra^2 + b_pmde^2)}$.
- It only contains those rows verifying $mu \geq 50$ and $b_mu \geq 50$ (i.e. both components with proper motion over 50 millisecond of arc/year).

The function is self-explanatory: the two first statements after the reserved word *begin* add the new fields, both of type *double* (real numbers). The two next lines give value to the new fields. The condition *[true]* at the end of each statement specifies that the new values must affect all the rows. Finally, the last statement before the reserved word *end* removes all the rows corresponding to pairs where some of the components have proper motion below 50 mas/yr.

A Test Case: the PPMX Catalog

In order to check the software the PPMX catalog was chosen. In particular we started downloading the catalog for entries with available V magnitude and with proper motion over 50 milliseconds of arc per

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year. Then we used the option “join catalogs” to produce the initial set of candidate pairs. 2171 pairs with separation under 100 seconds were obtained. Then a new, more restrictive, version of the Halbwachs’ criteria was applied (see next section), further reducing the set of pairs to 979. Then the pairs already in the WDS, or those likely to be included in the catalog in the near future, were removed leaving 85 pairs. Another three pairs were excluded after using the Reduced Proper Motion (RPM) discriminator proposed by Salim & Gould (2003). Finally, all the pairs were checked in the photographic plates, finding all of them. The summary of this process is shown in Table 1.

Table 1: Summary of the data mining process for PPMX

Phase	Rows
PPMX initial subset	172115
Candidate pairs	2171
After (modified) Halbwachs criteria	979
After removing pairs already in WDS	213
After removing pairs in other lists	85
After RPM criterion	82
After checking photographic plates	82

Halbwachs revisited

The three criteria originally proposed by Halbwachs for distinguishing physical and optical pairs from their proper motion are:

1. $(\mu_1 - \mu_2)^2 < -2 (\sigma_1^2 + \sigma_2^2) \ln (0.05)$
2. $|\mu_1|, |\mu_2| \geq 50 \text{ mas/yr}$
3. $\rho / |\mu_1|, \rho / |\mu_2| < 1000 \text{ yr}$

where μ_1, μ_2 are the two proper motion vectors, σ_i is the mean error of the projections on the coordinate axes of μ_i , and ρ is the angular separation of the two stars. The first condition checks if the hypothesis $\mu_1 = \mu_2$ is admissible with a 95% confidence considering the given errors σ_1 and σ_2 . If $\mu_1 = (\mu_{11}, \mu_{12})$, $\mu_2 = (\mu_{21}, \mu_{22})$ then this condition can be rewritten as

$$(1') (\mu_{11} - \mu_{21})^2 + (\mu_{12} - \mu_{22})^2 < -2 (\sigma_{12} + \sigma_{22}) \ln (0.05)$$

However in previous experiences it was observed that

this criterion allowed pairs with noticeably different values in some axes, and thus some additional criterion was needed. In this project we propose using the condition for each axis separately, i.e. to replace condition (1) (or (1')) by:

$$(1.a) (\mu_{11} - \mu_{21})^2 < -2 \sigma_{12} \ln (0.05)$$

$$(1.b) (\mu_{12} - \mu_{22})^2 < -2 \sigma_{22} \ln (0.05)$$

It is straightforward to check that the conjunction of (1.a) and (1.b) imply (1'), and therefore the new condition is more restrictive. In particular, in the case of the PPMX project replacing the condition (1) by (1.a) and (1.b), results in 15 additional pairs filtered out. These pairs are precisely those with noticeable differences in any axis. Hence, we think that substituting (1) by (1.a) and (1.b) is a good practice that improves the quality of the results.

Results

Table 2 shows the final list with the new CPMP obtained. The astrometry (precise coordinates, position angle, separation, and date) have been obtained from the 2MASS catalog. The visual magnitudes correspond to the values in PPMX. The pair separation ranges from 8.64" to 99.40", and the visual magnitudes are between 6.25 and 13.07. The pair at RA-dec 21 36 58.08 -35 53 02.93 is especially remarkable, since the parallax of both components is known and compatible: $14.95 \pm 0.93 \text{ mas}$ for A and $15.09 \pm 1.21 \text{ mas}$ for B. In this case it seems quite safe to say that this bright pair (mags. 7.35 and 8.60) is physically attached. For another 15 pairs the parallax of the primary is known, and for a larger number the spectral type of one or the two components is available either from Hipparcos (Perryman, 1997) or from Tycho-2 (Wright, 2003). In three cases the secondary of the new pair is a close pair already in WDS, see notes 13, 21, and 34.

Table 3 contains the proper motion data of the new CPMP. The data corresponds to PPMX.

Conclusions

Ensuring the data quality must be one of the main goals of any data mining project. With this purpose we have developed a software application that simplifies the different phases of the project. The filters for selecting and reducing the number of candidate pairs are easily prepared by the user by employing a small subset of basic operations over catalogues, which constitutes the core language offered by the application. The

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Discovery Designation	RA DEC	Mags	PA	SEP	DATE	NOTES
CBL	00 32 19.099 -21 50 33.69	11.7 12.29	208.45	49.78	2000.783	
CBL	00 55 33.213 -43 16 11.73	12.24 12.63	134.53	28.20	1999.713	
CBL	01 00 52.512 -18 56 57.08	11.44 11.57	220.88	25.25	1998.626	
CBL	01 52 27.571 -49 31 25.56	9.04 9.16	207.56	42.41	1999.812	(1)
CBL	02 04 18.761 -70 59 40.88	10.48 11.77	103.88	24.05	1999.894	
CBL	02 05 27.334 +38 20 57.02	12.29 13.07	130.16	31.88	1998.810	
CBL	03 10 41.550 -20 06 41.54	7.62 10.61	313.69	59.79	1998.878	(2)
CBL	03 24 54.681 -43 12 55.77	9.86 11.62	192.09	26.63	1999.648	(3)
CBL	03 46 09.569 -41 12 22.33	9.25 11.48	257.08	66.28	1999.629	(4)
CBL	04 23 48.192 -76 43 09.45	11.13 11.29	265.20	45.21	1998.840	
CBL	05 01 36.173 -44 49 49.05	7.55 10.58	265.53	50.77	1999.722	(5)
CBL	05 23 39.978 -38 18 48.09	11.82 12.20	193.43	24.06	1999.173	
CBL	05 57 24.758 -40 23 51.78	8.15 11.28	350.10	45.10	1999.190	(6)
CBL	06 15 01.664 -63 20 38.82	11.71 12.57	219.59	15.59	1998.947	
CBL	06 38 17.669 +18 28 24.58	11.44 11.79	63.63	55.81	1997.898	
CBL	07 03 08.446 -73 50 13.91	11.12 11.34	140.15	51.35	2000.167	
CBL	07 08 55.244 -11 23 29.58	11.22 12.32	31.21	48.15	1999.138	
CBL	09 33 19.911 -07 11 24.75	6.25 10.78	19.14	57.81	1999.048	(7)
CBL	09 51 08.004 -18 39 31.43	7.37 10.83	115.95	50.68	1998.322	(8)
CBL	10 14 38.104 -13 33 29.10	9.04 10.34	177.99	28.62	1999.299	(9)
CBL	10 15 08.028 -65 26 11.04	11.15 11.47	304.57	31.11	2000.230	
CBL	10 16 15.352 -17 11 13.12	10.67 11.78	282.61	41.57	1998.234	
CBL	10 32 03.297 -30 28 05.49	11.46 11.78	29.56	14.49	1999.223	
CBL	10 47 27.741 -11 54 08.72	9.83 10.46	48.64	27.76	1998.256	(10)
CBL	11 29 03.259 -38 17 05.77	9.48 11.35	109.61	38.72	1999.272	(11)
CBL	11 35 52.047 -40 40 36.43	11.85 12.18	247.31	20.08	1999.275	
CBL	11 53 22.088 -67 07 05.56	10.78 11.88	119.24	36.11	2001.121	
CBL	12 05 25.156 +17 17 21.69	7.63 10.04	311.55	43.20	1998.033	(12)
CBL	12 13 30.463 -48 47 46.64	8.80 10.57	347.83	49.99	1999.357	(13), (14)
CBL	12 34 19.535 -35 22 46.48	10.46 11.63	162.81	44.30	1999.258	
CBL	12 35 15.748 -09 10 57.84	10.91 10.95	142.98	28.20	1999.089	

Table continues on next page.

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Discovery Designation	RA DEC	Mags	PA	SEP	DATE	NOTES
CBL	12 35 43.067 -03 00 58.10	8.49 9.79	280.18	60.70	1999.149	(15)
CBL	12 36 16.407 -79 31 34.45	10.95 11.34	254.57	14.99	2000.102	
CBL	13 17 35.429 -11 57 01.34	11.04 12.70	344.71	24.29	1999.138	
CBL	13 53 54.390 -07 45 44.87	11.30 11.84	216.02	18.76	1999.163	
CBL	14 08 01.294 -13 16 09.22	11.84 12.31	180.53	13.24	1999.299	
CBL	14 12 31.776 -30 06 17.68	11.48 11.77	216.48	31.32	1999.262	
CBL	14 35 32.025 -35 26 39.17	11.44 11.72	211.37	41.19	2000.310	
CBL	14 37 23.205 -66 50 27.83	9.95 10.47	305.18	27.02	2000.258	(16)
CBL	14 53 52.152 -63 53 53.17	9.28 11.02	83.26	41.56	2000.223	(17)
CBL	14 55 28.254 -56 48 55.15	9.85 11.00	265.59	26.29	2000.146	(18)
CBL	14 58 31.045 -27 24 06.18	10.79 11.48	91.00	15.09	1998.486	
CBL	15 04 08.091 -26 23 26.83	10.97 11.56	322.81	26.24	1998.486	
CBL	15 07 12.834 -41 41 31.12	9.36 9.46	286.51	8.64	1999.374	(19)
CBL	15 13 59.433 -58 37 15.68	9.88 10.30	319.51	45.32	1999.431	(20)
CBL	16 31 42.851 +70 55 59.84	8.22 11.45	312.31	39.95	1999.398	(21), (22)
CBL	16 37 35.305 +69 19 17.25	9.07 10.76	124.95	99.40	1999.399	
CBL	17 01 49.674 +14 42 27.70	10.37 10.63	12.39	19.29	1999.158	
CBL	17 40 21.442 +05 43 37.44	11.19 11.98	342.16	34.69	2000.404	
CBL	17 54 51.203 +28 51 38.93	11.27 12.36	244.01	41.01	2000.204	
CBL	17 56 59.673 -46 06 31.92	10.91 10.94	207.38	11.21	1999.551	
CBL	17 59 53.975 -45 17 20.72	10.94 11.67	192.86	14.26	1999.551	
CBL	18 07 28.944 +00 29 27.19	11.23 11.54	355.05	49.82	1999.548	
CBL	18 13 05.162 +18 40 45.60	8.37 10.50	260.54	34.30	2000.209	(23)
CBL	18 21 26.185 -15 22 18.08	9.72 11.08	26.29	18.82	1999.333	
CBL	18 22 44.038 -40 44 59.30	10.32 10.73	159.99	12.69	2000.427	
CBL	18 27 24.762 +21 51 53.42	10.22 11.99	159.94	26.67	2000.242	
CBL	18 38 36.531 +49 00 42.13	9.42 10.72	260.52	47.47	1998.478	(24)
CBL	18 41 25.436 -44 32 30.63	10.78 11.14	53.29	36.30	2000.474	
CBL	18 45 04.604 -23 15 07.22	8.45 11.24	93.96	25.15	1998.478	(25)
CBL	18 54 43.138 -50 07 46.85	9.18 11.72	280.23	27.51	1999.726	(26)
CBL	19 01 33.281 -24 08 28.08	9.20 11.43	83.49	31.00	1999.262	(27)

Table concludes on next page.

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Discovery Designation	RA DEC	Mags	PA	SEP	DATE	NOTES
CBL	19 07 06.084 -14 04 09.97	8.64 10.38	317.61	20.69	2000.247	(28)
CBL	20 06 03.948 -41 37 36.45	11.49 11.68	8.99	23.71	1999.505	
CBL	20 33 53.250 -27 10 17.31	9.35 11.97	39.94	52.00	2000.561	(29)
CBL	20 36 05.730 -67 05 22.53	10.50 11.32	107.53	24.53	2000.542	
CBL	20 46 51.514 -49 28 39.62	10.71 11.39	197.77	27.90	1999.710	
CBL	21 10 18.359 -13 04 05.84	11.13 11.15	246.88	16.80	1999.483	
CBL	21 16 13.422 -40 40 51.94	11.30 12.07	151.91	31.23	1999.691	
CBL	21 29 36.229 -44 13 50.10	10.36 10.71	261.71	90.54	1999.633	
CBL	21 36 58.092 -35 53 03.02	7.35 8.60	265.34	78.45	2000.562	(30)
CBL	21 54 22.594 -44 09 46.37	11.10 11.90	73.80	17.96	1999.718	
CBL	22 08 27.535 -57 06 52.51	11.08 11.45	327.83	26.33	2000.543	
CBL	22 09 42.632 -33 45 15.41	9.28 10.25	278.32	49.90	1999.560	(31)
CBL	22 32 09.402 -13 35 51.81	7.72 9.71	93.97	41.94	1998.481	(32)
CBL	22 33 45.700 +61 45 26.85	9.94 10.90	222.22	38.29	1999.746	
CBL	22 41 49.606 +59 47 35.64	9.03 11.02	104.02	47.92	1999.741	(33)
CBL	22 47 55.497 +03 36 07.26	11.28 11.35	154.24	23.20	2000.608	
CBL	22 53 55.679 -37 09 40.50	10.22 10.59	313.30	54.44	1999.734	
CBL	22 54 19.523 +30 22 18.31	10.46 11.40	233.61	14.46	1998.473	
CBL	23 28 08.467 -02 26 53.36	8.05 8.43	226.37	57.33	1998.730	(34), (35)
CBL	23 37 40.086 +00 46 36.37	10.63 12.3	156.89	34.18	2000.658	

Table Notes:

1. Parallax primary: 8.29 ± 1.06 (Hipparcos). Spectral Type primary: F7V (Hipparcos), spectral type secondary: G (Tycho-2 Spectral Type Catalog).
2. Parallax primary: 3.57 ± 0.91 (Hipparcos). Spectral Type primary: G8/K0IV (Hipparcos).
3. Spectral Type primary: G5/8 (Tycho-2 Spectral Type Catalog).
4. Parallax primary: 12.1 ± 1 (Hipparcos). Spectral Type primary: G5/G6 (Hipparcos).
5. Parallax primary: 10.1 ± 0.72 (Hipparcos). Spectral Type primary: G8/K0 (Hipparcos).
6. Parallax primary: 7.84 ± 0.71 (Hipparcos). Spectral Type primary: F0 V (Tycho-2 Spectral Type Catalog).
7. Parallax primary: 7.75 ± 1.4 (Hipparcos). Spectral Type primary: K0 (Hipparcos).
8. Parallax primary: 8.94 ± 0.89 (Hipparcos). Spectral Type primary: F6/F7V (Hipparcos).
9. Spectral Type primary: G6 IV (Tycho-2 Spectral Type Catalog).
10. Spectral Type primary: K5 (Tycho-2 Spectral Type Catalog).
11. Spectral Type primary: F3/5 V (Tycho-2 Spectral Type Catalog).
12. Parallax primary: 9.94 ± 0.94 (Hipparcos). Spectral Type primary: F2 (Hipparcos).
13. The secondary is TDS8273.
14. Parallax primary: 3.49 ± 1.25 (Hipparcos). Spectral Type primary: K1III (Hipparcos).
15. Parallax primary: 13.2 ± 1.11 (Hipparcos).

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- 16. Spectral Type primary: F7/G0 (Tycho-2 Spectral Type Catalog).
- 17. Spectral Type primary: F2/5 III/IV (Tycho-2 Spectral Type Catalog).
- 18. Spectral Type primary: F8/G0 V (Tycho-2 Spectral Type Catalog).
- 19. Spectral Type primary: F3/5 V (Tycho-2 Spectral Type Catalog).
- 20. Spectral Type primary: F6/8 V (Tycho-2 Spectral Type Catalog).
- 21. The secondary is TDS 819.
- 22. Parallax primary: 7.32 ± 0.61 (Hipparcos). Spectral Type primary: F5 (Hipparcos), spectral type secondary: F8 (Tycho-2 Spectral Type Catalog).
- 23. Spectral Type primary: G5 (Tycho-2 Spectral Type Catalog).
- 24. Spectral Type primary: F8 (Tycho-2 Spectral Type Catalog).
- 25. Parallax primary: 14.4 ± 1.16 (Hipparcos). Spectral Type primary: G3/G5V (Hipparcos).
- 26. Spectral Type primary: G0 (Tycho-2 Spectral Type Catalog).
- 27. Spectral Type primary: G8 V (Tycho-2 Spectral Type Catalog).
- 28. Spectral Type primary: G0 (Tycho-2 Spectral Type Catalog).
- 29. Parallax primary: 15.2 ± 1.35 (Hipparcos). Spectral Type primary: G8V (Hipparcos).
- 30. Parallax primary: 14.95 ± 0.93 (Hipparcos), parallax secondary: 15.09 ± 1.21 (Hipparcos). Spectral Type primary: F3V (Hipparcos), secondary: G5V (Tycho-2 Spectral Type Catalog).
- 31. Spectral Type primary: G0 V (Tycho-2 Spectral Type Catalog).
- 32. Parallax primary: 9.78 ± 1.1 (Hipparcos). Spectral Type primary: G0V (Hipparcos).
- 33. Spectral Type primary: G0 (Tycho-2 Spectral Type Catalog).
- 34. Secondary is RST4724.
- 35. Parallax primary: 8.84 ± 1.09 (Hipparcos). Spectral Type primary: F2 (Hipparcos), spectral type secondary: F5 V (Tycho-2 Spectral Type Catalog).

Table 3: Proper Motion of Each Component (mas/yr)

RA DEC	μ_1	μ_2	σ_1	σ_2
00 32 19.099 -21 50 33.69	(58.0, -2.6)	(63.8, 0.5)	(2.8, 3.1)	(2.8, 3.1)
00 55 33.213 -43 16 11.73	(14.3, -87.7)	(7.3, -89.7)	(2.2, 2.2)	(2.2, 2.2)
01 00 52.512 -18 56 57.08	(50.5, -7.8)	(53.2, -11.3)	(2.3, 2.3)	(2.3, 2.3)
01 52 27.571 -49 31 25.56	(31.2, -51.8)	(29.6, -50.5)	(1.5, 1.4)	(1.5, 1.4)
02 04 18.761 -70 59 40.88	(119.0, -29.9)	(124.9, -33.4)	(1.7, 2.0)	(1.9, 1.9)
02 05 27.334 +38 20 57.02	(33.1, -70.5)	(23.5, -83.2)	(2.4, 2.3)	(10.1, 10.6)
03 10 41.550 -20 06 41.54	(60.9, 3.4)	(65.7, 4.4)	(1.8, 1.8)	(2.4, 2.5)
03 24 54.681 -43 12 55.77	(3.0, 53.4)	(3.7, 58.6)	(1.8, 1.8)	(2.1, 2.1)
03 46 09.569 -41 12 22.33	(66.6, 25.0)	(71.9, 24.9)	(0.7, 0.8)	(2.1, 2.1)
04 23 48.192 -76 43 09.45	(36.4, -43.3)	(38.4, -43.5)	(1.4, 1.4)	(1.4, 1.4)
05 01 36.173 -44 49 49.05	(8.3, -65.8)	(5.2, -68.8)	(1.6, 1.6)	(2.1, 2.0)
05 23 39.978 -38 18 48.09	(29.5, 41.5)	(34.1, 37.2)	(2.3, 2.2)	(2.3, 2.3)

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Table 3 (continued): Proper Motion of Each Component (mas/yr)

RA DEC	μ_1	μ_2	σ_1	σ_2
05 57 24.758 -40 23 51.78	(-1.3, 62.8)	(-3.0, 60.5)	(1.5, 1.5)	(2.3, 2.3)
06 15 01.664 -63 20 38.82	(-2.4, 84.8)	(-7.4, 83.7)	(3.8, 3.8)	(3.9, 3.9)
06 38 17.669 +18 28 24.58	(-78.3, -21.0)	(-73.4, -20.9)	(1.6, 1.6)	(1.6, 1.6)
07 03 08.446 -73 50 13.91	(-7.6, 64.2)	(-5.1, 57.0)	(6.0, 6.3)	(1.9, 1.9)
07 08 55.244 -11 23 29.58	(-5.5, -74.1)	(-2.4, -73.0)	(1.6, 1.7)	(2.0, 2.1)
09 33 19.911 -07 11 24.75	(-59.3, -26.5)	(-59.9, -23.8)	(1.5, 1.7)	(2.2, 2.2)
09 51 08.004 -18 39 31.43	(-97.4, 26.1)	(-101.1, 21.8)	(1.7, 1.6)	(3.0, 3.0)
10 14 38.104 -13 33 29.10	(-50.9, -17.8)	(-52.5, -21.1)	(1.3, 1.3)	(1.6, 1.6)
10 15 08.028 -65 26 11.04	(-62.0, 13.9)	(-60.0, 15.2)	(2.2, 2.2)	(2.2, 2.2)
10 16 15.352 -17 11 13.12	(-94.0, -27.8)	(-94.1, -35.4)	(2.6, 2.7)	(2.5, 2.5)
10 32 03.297 -30 28 05.49	(28.3, -42.4)	(38.2, -35.9)	(4.1, 4.1)	(3.4, 3.4)
10 47 27.741 -11 54 08.72	(21.8, -63.6)	(20.0, -64.3)	(1.5, 1.5)	(1.9, 2.0)
11 29 03.259 -38 17 05.77	(-9.3, -70.4)	(-12.1, -68.8)	(2.4, 2.5)	(2.9, 2.9)
11 35 52.047 -40 40 36.43	(-84.5, 8.0)	(-78.7, 10.5)	(2.8, 2.8)	(2.9, 2.9)
11 53 22.088 -67 07 05.56	(-9.1, -55.5)	(-5.9, -56.8)	(2.3, 2.3)	(2.4, 2.4)
12 05 25.156 +17 17 21.69	(-62.8, -53.3)	(-63.9, -51.8)	(1.1, 1.2)	(1.2, 1.3)
12 13 30.463 -48 47 46.64	(37.1, -54.7)	(33.7, -53.0)	(1.5, 1.5)	(2.0, 2.0)
12 34 19.535 -35 22 46.48	(-60.9, 8.7)	(-63.7, 3.6)	(2.5, 2.5)	(2.8, 2.8)
12 35 15.748 -09 10 57.84	(-49.4, -13.5)	(-48.5, -13.9)	(1.8, 1.9)	(1.9, 1.9)
12 35 43.067 -03 00 58.10	(-76.3, 13.9)	(-76.1, 14.3)	(0.7, 0.6)	(1.5, 1.5)
12 36 16.407 -79 31 34.45	(-58.2, -11.7)	(-60.5, -5.6)	(1.6, 1.6)	(2.0, 2.0)
13 17 35.429 -11 57 01.34	(-85.6, 35.8)	(-82.6, 36.2)	(1.7, 1.7)	(2.1, 2.1)
13 53 54.390 -07 45 44.87	(-48.1, -26.1)	(-45.8, -28.9)	(2.0, 2.0)	(2.7, 2.7)
14 08 01.294 -13 16 09.22	(-68.9, 0.9)	(-55.9, -15.5)	(9.7, 12.0)	(2.1, 2.1)
14 12 31.776 -30 06 17.68	(-72.7, -15.6)	(-67.0, -23.3)	(2.7, 2.7)	(2.7, 2.7)
14 35 32.025 -35 26 39.17	(-41.8, -28.4)	(-43.9, -25.8)	(2.3, 2.4)	(2.4, 2.4)
14 37 23.205 -66 50 27.83	(-56.1, -14.1)	(-55.0, -16.2)	(1.9, 1.9)	(1.8, 1.8)
14 53 52.152 -63 53 53.17	(86.2, -26.2)	(85.7, -25.7)	(2.7, 2.7)	(3.4, 3.2)
14 55 28.254 -56 48 55.15	(-46.1, -37.2)	(-51.6, -41.0)	(2.1, 2.1)	(2.2, 2.2)
14 58 31.045 -27 24 06.18	(13.8, -104.4)	(8.9, -104.8)	(3.7, 3.5)	(3.5, 3.4)
15 04 08.091 -26 23 26.83	(56.8, -8.6)	(52.8, -4.9)	(3.5, 3.2)	(2.7, 2.5)

Table continues on next page.

New Common Proper-Motion Pairs from the PPMX Catalog

Table 3 (continued): Proper Motion of Each Component (mas/yr)

RA DEC	μ_1	μ_2	σ_1	σ_2
15 07 12.834 -41 41 31.12	(-44.4, -25.3)	(-46.0, -28.6)	(1.8, 1.8)	(2.4, 2.4)
15 13 59.433 -58 37 15.68	(-61.8, -45.9)	(-62.2, -42.9)	(1.6, 1.6)	(2.4, 2.4)
16 31 42.851 +70 55 59.84	(-65.0, 22.5)	(-63.5, 23.4)	(1.3, 1.4)	(1.9, 1.9)
16 37 35.305 +69 19 17.25	(-82.0, 103.8)	(-82.4, 105.4)	(1.3, 1.4)	(1.8, 1.8)
17 01 49.674 +14 42 27.70	(-17.9, -47.2)	(-19.0, -47.1)	(1.6, 1.7)	(0.9, 0.9)
17 40 21.442 +05 43 37.44	(-24.4, -74.9)	(-25.2, -68.4)	(2.9, 2.9)	(2.9, 2.9)
17 54 51.203 +28 51 38.93	(-20.1, -47.0)	(-23.5, -45.9)	(1.7, 1.7)	(1.7, 1.7)
17 56 59.673 -46 06 31.92	(70.6, -20.9)	(72.6, -19.3)	(1.8, 1.8)	(1.8, 1.8)
17 59 53.975 -45 17 20.72	(5.9, -55.5)	(6.4, -53.5)	(2.1, 2.2)	(2.2, 2.3)
18 07 28.944 +00 29 27.19	(-18.2, -48.3)	(-18.4, -49.4)	(1.8, 1.8)	(1.8, 1.8)
18 13 05.162 +18 40 45.60	(5.4, -50.6)	(5.1, -52.0)	(1.1, 1.1)	(1.6, 1.6)
18 21 26.185 -15 22 18.08	(12.8, -82.3)	(12.2, -82.8)	(1.7, 1.8)	(1.8, 1.8)
18 22 44.038 -40 44 59.30	(-32.4, -38.8)	(-31.2, -40.2)	(2.2, 2.2)	(2.3, 2.4)
18 27 24.762 +21 51 53.42	(-16.4, 53.7)	(-18.0, 50.4)	(1.5, 1.5)	(2.2, 2.2)
18 38 36.531 +49 00 42.13	(69.8, 43.1)	(65.8, 42.7)	(1.4, 1.4)	(1.1, 1.1)
18 41 25.436 -44 32 30.63	(16.7, -51.9)	(14.9, -56.7)	(2.2, 2.2)	(2.2, 2.2)
18 45 04.604 -23 15 07.22	(17.7, -119.5)	(21.4, -126.1)	(1.7, 1.6)	(2.8, 2.8)
18 54 43.138 -50 07 46.85	(-2.6, -76.9)	(-1.7, -75.8)	(1.5, 1.5)	(2.2, 2.2)
19 01 33.281 -24 08 28.08	(-25.6, -83.0)	(-30.1, -82.5)	(1.6, 1.5)	(2.5, 2.6)
19 07 06.084 -14 04 09.97	(94.3, 27.6)	(91.4, 28.0)	(1.6, 1.6)	(2.2, 2.1)
20 06 03.948 -41 37 36.45	(59.1, -53.6)	(58.6, -57.6)	(2.1, 2.1)	(2.1, 2.1)
20 33 53.250 -27 10 17.31	(68.4, -82.3)	(71.2, -89.2)	(1.6, 1.6)	(3.3, 3.3)
20 36 05.730 -67 05 22.53	(-29.0, -63.8)	(-28.6, -67.9)	(1.7, 1.7)	(1.8, 1.8)
20 46 51.514 -49 28 39.62	(71.9, -2.3)	(74.1, -1.0)	(2.1, 2.2)	(2.2, 2.2)
21 10 18.359 -13 04 05.84	(73.1, -41.2)	(65.6, -42.8)	(5.2, 6.4)	(2.1, 2.1)
21 16 13.422 -40 40 51.94	(45.3, -27.1)	(46.0, -27.0)	(1.8, 1.8)	(1.8, 1.8)
21 29 36.229 -44 13 50.10	(86.8, -53.0)	(86.4, -49.2)	(2.0, 2.0)	(2.0, 2.1)
21 36 58.092 -35 53 03.02	(90.9, -10.1)	(90.7, -9.2)	(0.8, 0.5)	(1.4, 1.4)
21 54 22.594 -44 09 46.37	(13.7, -89.1)	(18.8, -92.5)	(2.1, 2.2)	(3.1, 3.1)
22 08 27.535 -57 06 52.51	(10.6, -73.0)	(11.0, -68.4)	(2.3, 2.3)	(2.4, 2.4)
22 09 42.632 -33 45 15.41	(49.3, -84.1)	(47.8, -82.7)	(1.5, 1.4)	(2.4, 2.4)

Table concludes on next page.

New Common Proper-Motion Pairs from the PPMX Catalog

Table 3 (continued): Proper Motion of Each Component (mas/yr)

RA DEC	μ_1	μ_2	σ_1	σ_2
22 32 09.402 -13 35 51.81	(-19.4, -65.9)	(-20.1, -62.8)	(1.6, 1.6)	(1.5, 1.5)
22 33 45.700 +61 45 26.85	(-18.6, -61.7)	(-15.8, -58.4)	(2.3, 2.1)	(2.0, 2.0)
22 41 49.606 +59 47 35.64	(16.9, -79.0)	(15.4, -77.5)	(1.2, 1.3)	(1.6, 1.6)
22 47 55.497 +03 36 07.26	(67.9, 3.3)	(69.6, 3.3)	(1.9, 1.9)	(1.6, 1.6)
22 53 55.679 -37 09 40.50	(108.1, 5.4)	(106.4, -0.8)	(1.4, 1.6)	(3.1, 3.1)
22 54 19.523 +30 22 18.31	(142.7, -4.6)	(142.0, -9.8)	(1.5, 1.5)	(1.6, 1.6)
23 28 08.467 -02 26 53.36	(69.8, 10.4)	(70.5, 8.4)	(1.2, 1.3)	(1.3, 1.4)
23 37 40.086 +00 46 36.37	(-30.0, -69.7)	(-29.8, -85.9)	(1.7, 1.8)	(10.7, 10.7)

(Continued from page 208)

advantages of this approach are:

- The basic core operations are easier to test and debug than the usual complex operations required by the data mining process.
- Assuming that the basic operations have been thoroughly checked, the whole process becomes less prone to errors. This holds true because the different filters are now written in a higher abstraction level, instead of directly in SQL. This makes them more understandable and easier to test and modify.
- The same user-scripts can be employed in different projects, facilitating the reusability of the code. The language allows defining parameterized functions with this purpose.
- This possibility of easily modifying the code is very useful for proving variations of the same filter and designing new ones. In our case it has been crucial for comparing the two versions of the first Halbwachs' condition examined above.

Currently, we are improving the application in order to make it publicly available in the near future. Regarding our test-case, the PPMX catalog, we would like to point out two main conclusions:

- The catalog was chosen to check the software, assuming that all the interesting pairs had been already extracted. Indeed most of them were in the WDS, but still there were a few possible interesting pairs to find.

- In all the projects examined up to now many of the pairs detected by data mining did not exist in the plates. Instead they corresponded to erroneous data obtained while processing the images. However, in this catalog no false pairs were found, attesting to the quality of its data.

As usual, it is important to remark that we don't claim that the CPMPs found are true binaries. The data mining process only suggests that these pairs might deserve more measurements and a deeper study.

Acknowledgements

This research makes use of the ALADIN Interactive Sky Atlas and of the VizieR database of astronomical catalogs, all maintained at the Centre de Données Astronomiques, Strasbourg, France, and of the data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation. This work has been partially supported by the Spanish projects TIN2008-06622-C03-01, S-0505/TIC/0407, S2009TIC-1465 and UCM-BSCH-GR58/08-910502.

References

Allende Prieto, C; Dambert D.L.; 1999, "Fundamental parameters of nearby stars from the comparison with evolutionary calculations: masses, radii and effective temperatures". *Astronomy and Astrophysics*, 352, p.555-562 (1999)

New Common Proper-Motion Pairs from the PPMX Catalog

- Bonnarel, F.; Fernique, P.; Bienaymé, O.; Egret, D.; Genova, F.; Louys, M.; Ochsenbein, F.; Wenger, M.; Bartlett, J. G.; 2000, "The ALADIN interactive sky atlas. A reference tool for identification of astronomical sources", *Astronomy and Astrophysics Supplement*, 143, p.33-40.
- Caballero, R.; 2009, "Finding New Common Proper-Motion Binaries by Data Mining", *Journal of Double Star Observations*, 5(3), 156-167.
- Caballero, R.; 2010, "New Northern Hemisphere Common Proper-Motion Pairs from the UCAC-3 Catalog", *Journal of Double Star Observations*, 6(1), 97-113.
- Greaves, J., 2004, "New Northern hemisphere common proper-motion pairs". *Monthly Notices of the Royal Astronomical Society* 355, 585-590.
- Halbwachs, J.L., 1986, "Common proper motion stars in the AGK3". *Bull. Inf. Centre Donnees Stellaires*, 30, p.129.
- Mason, B. D.; Wycoff, G.; Hartkopf, W. I., 2003, "The Washington Double Star Catalog", <http://ad.usno.navy.mil/proj/WDS/wds.html>
- Perryman, M. A. C.; ESA, 1997, *The HIPPARCOS and TYCHO catalogues. Astrometric and photometric star catalogues derived from the ESA HIPPARCOS Space Astrometry Mission*, Publisher: Noordwijk, Netherlands: ESA Publications Division, 1997, Series: ESA SP Series vol no: 1200, ISBN: 9290923997.
- Röser, S.; Schilbach, E.; Schwan, H.; Kharchenko, N. V.; Piskunov, A. E.; Scholz, R.-D.; 2008 "PPM-Extended (PPMX) – a catalogue of positions and proper motions". *Astronomy and Astrophysics*, 488 (1), 401-408.
- Salim, S.; Gould, A., 2003, "Improved Astrometry and Photometry for the Luyten Catalog. II. Faint Stars and the Revised Catalog", *The Astrophysical Journal*, 582, 1011-1031.
- Wright, Candace O.; Egan, Michael P.; Kraemer, Kathleen E.; Price, Stephan D.; 2003, "The Tycho-2 Spectral Type Catalog", *The Astronomical Journal*, 125(1), 359-363.

