LinOccult

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1 Introduction

Observations of stellar occultation by asteroids will make significant impact in several areas of astronomy. Observations of these events by professional and amateur astronomers are extremely important since they can provide unique information about the size of asteroids and improve their orbit elements dramatically. To predict such events **LinOccult** has been developed. The main purpose of **LinOccult** is to calculate time and location of star occultations by minor planets.

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3 LinOccult history and philosophy

LinOccult was created by me in my spare time beside the basic work and house duties. Development of this project has begun in the end of 2003 when I became interested in algorithms used in the celestial mechanics. Similar programs already existed, in particular **WinOccult**. However to my surprise I found that source code for these programs are inaccessible to studying and updating.

Because I belive that scientific programs should be distributed with source code, I have choose GNU General Public Licence for **LinOccult**, so that all interested in celestial mechanics algorithms could start to study them by playing with a working program. As the most suitable environment for scientific

programs development is UNIX, I have decided to create **LinOccult** for this operating system.

Certainly, the idea that I began from scratch is not absolutely true. I used the fine book "Astronomy on a personal computer" [1] despite a monstrous quantity of typing errors in Russian edition. I also used GNU Open Source code for reading the major planets ephemeris, taken from a site www.projectpluto.com, and a code for work with kdtree, taken from a site www2.imm.dtu.dk/~jab.

As it will be easy to notice further, **LinOccult** deduces results in the various formats compatible with many fine Open Source applications for processing, displaying, and storing occultation events.

In the middle of 2004 all necessary features to calculate occultation events in **LinOccult** had been realized, and it was a time to present **LinOccult** to world community, as has been done at ESOP XXIII conference in the Paris observatory [2]. **LinOccult** was able to calculate shadow path of asteroid and to use the specified values of asteroid updated orbit elements from Steve Preston[1] and Jan Manek[2] sites. For asteroid orbit calculation the major planets position were read from a DE405 ephemeris. The results of calculation were output both in a text format and in a format of **PovRay** program for the subsequent 3D picture with a map of shadow path creation. As the program allowed asteroids with eccentricity close to 1, I found some interesting predictions of occultations by TNOs and some other objects. Lack of **LinOccult** for that moment was that the program worked long enough and could not calculate occultations in particular observation point. As the project continued to develop as Open Source, I have made a decision to place the source code on my site www.newtech.ru/~andyp, http://andyplekhanov.narod.ru and on a site http://linoccult.sourceforge.net.

For the next year a set of new features has been realized. In particular the kdtree algorithm for fast search of stars in the asteroid neighbour area in the sky has been implemented. This algorithm has considerably impoved the program performance and has eliminated the need for indexing of the star catalogue. I also implemented storage of a calculated asteroid orbit in the form of Chebyshev polynomials approximation. It has even more accelerated search of occultation events on long time intervals. Except for that I implemented storage of calculation results in an internal database and in external MySQL[3] database. By using internal and MySQL databases I added opportunities to calculate occultation circumstances for a particular observation point and generate interesting occultation analysis across the world. In the end of 2004 I added support for observation points file to process occultation circumstances in many points with individual parameters at each point. The output occultations list include text, html and LATEXformats. Except for that **LinOccult** began to support a special file with the list of updated orbit elements that has essentially raised accuracy of predictions. It has allowed me to create my email list to send occultation predictions monthly to many observers in the world. I have given the report on all above achivements at ESOP XXIV conference in Helsinki. [3]

In 2008 **LinOccult** version 2.0.0 was released. In this version I tune a code to be closer to pure C++, change libraries and some procedures in **LinOccult**.

In 2013 I migrated **LinOccult** to 64 bit platforms and did some improvements in source code.

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[1]http://www.asteroidoccultation.com
[2]http://mpocc.astro.cz/updates
[3]MySQL is registered trade mark of MySQL AB

4 Hardware and software requirements

LinOccult is developed for use in UNIX[4] (in particular Linux) and was ported to Windows[5] by my friend Eugene Malakhov.

LinOccult can function on a computer with not so great volume of core memory, however the further narration concerns to a computer with 512 mbytes of core memory. If quantity of core memory on your computer less the than specified size, look in the section "What to do if in my computer has not enough core memory?"

Also it is necessary to allocate about 1 gbyte of an empty space on a disk for following files:

- Gaia14.bin - the star catalogue

- astorb.dat - asteroids orbit elements

- unxp2000.405 - major planets ephemeris

5 Optional software used with LinOccult

For pictures creating, representation result in a pdf format and storing results in an external database **LinOccult** uses the following programs:

- PovRay (http://www.povray.org)

- EarthView (http://earthview.sourceforge.net)

- TeXLive

- MySQL (http://www.mysql.com)

6 For Windows users

For Windows users not familiar with UNIX philosophy **LinOccult** functioning may seem a little bit unusual at first sight. As **LinOccult** is the console application it working without the graphic user interface (GUI). However in UNIX environment this is usual practice which have a set of advantages. For example, if it is necessary to start **LinOccult** several times with different parameters, it is possible to make one batch file to start it for the night. Thus there is no necessity to wake up at night to press buttons in the menu for switching modes. All control information is contained in configuration files (these are usual text files) and there is no necessity to search for the necessary parameter in depths of dropping out menus.

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[4]UNIX is registered trade mark The Open Group

[5]Windows is registered trade mark Microsoft Corporation

7 Where to get the files necessary for LinOccult work

LinOccult need the following files:

- Gaia14.bin - the star catalogue in a format of the **WinOccult** program. You may download it from site:
  http://www.lunar-occultations.com/iota/occult4.htm

- astorb.dat - asteroids orbit elements. You may download it from site:
  ftp://ftp.lowell.edu/pub/elgb/astorb.dat.gz

- unxp*.405 - major planets ephemeris. Depending on for what period you are going to do a calculation you may download the corresponding ephemeris file from JPL site:
  ftp://ssd.jpl.nasa.gov/pub/eph/export/unix
  If your calculations will be within 2000-2050 period, it is possible to get one file unxp2000.405.

8 Program installation

- UNIX(Linux) Download LinOccult_x.x.x.tar.gz from my site:
  http://andyplekhanov.narod.ru/occult/occult.htm where x.x.x - version number.

  - Untar and unzip it in any directory: tar zxvf LinOccult_x.x.x.tar.gz
  - Download the following files: Gaia14.bin, astorb.dat, unxp2000.405 and save them in any place on your computer.
  - Go to Examples directory and select linoccult.config file.
  - Setup correct path to the above files in linoccult.config file.

- Windows Download LinOccult_x.x.x.zip from my site:
  http://andyplekhanov.narod.ru/occult/occult.htm

  - Unzip it in any directory.
  - Download the following files: Gaia14.bin, astorb.dat, unxp2000.405 and save them in any place on your computer.
  - Open linoccult.config file and setup correct path to the above files

9 Configuration files

As already has been mentioned above, configuration files play the important role in **LinOccult** work. These text files contain the list of parameters. Here we consider these parameters and how they are represented.

Parameters in a configuration file can be one of three types:

- Integer number (int).

- Number with a floating point (double).

- Text string (string).

Each parameter in a configuration file takes one line and looks like the follow:

```
Type Name Value
```

A symbol # in the first position of a line does the given line by the comment. For example:

```
int AsteroidNumber 723
double OrbitE 0.05925106
string AstOrbFilePath /home/andyp/MyAstroData/astorb.dat
```

These parameters value are set in three places:

- In the program (default value)

- In linoccult.config file

- In project file

linoccult.config should be in a current directory. Project file keep parameters for particular **LinOccult** run. It is possible to have as many project files as you want but **LinOccult** use only one for one run. To start **LinOccult** type the following command in the console:

```
linoccult <project_file_name>
```

project_file_name file keep individual parameters for this run and usually has extention .config

Value of each concrete parameter which will be used by **LinOccult** turns out under the following scheme:

1. Default value from the **LinOccult** is taken.

2. linoccult.config file is looked through for this parameter. If it is present here, value of parameter is replaced with value from a file linoccult.config.

3. Project file from command line is looked through for this parameter. If it is present here, value of parameter is replaced with value from a project file.

LinOccult has many parameters. The majority of parameters are set in the program by default and usually their value does not vary by the user. The parameters common for all projects are usually setup in a linoccult.config file, for example a path to a astorb.dat file:

```
string AstOrbFilePath /home/andyp/MyAstroData/astorb.dat
```

At concrete **LinOccult** run it is possible to use different astorb.dat file (for example for the previous date). In this case the path to this file should be setting in the project file. So the parameter can simultaneously be present both at a linoccult.config and project files. In this case parameter value will get from a project file.

10 How to start LinOccult

- UNIX:

  1. Run a console.
  2. Change directory to LinOccult_x.x.x/Examples:
     cd LinOccult_x.x.x/Examples
  3. Start **LinOccult**:
     ../linoccult Example1.config

- Windows:

  1. Run a console - in Start select "run", and then type "cmd" in command line. Or run something like WinCommander.
  2. Change directory to LinOccult_x.x.x
     cd C:\LinOccult_x.x.x
  3. Start **LinOccult**: linoccult Example1.config

LinOccult deduces results of work on the console. If you wish to receive them in a file, redirect them to a file:

```
linoccult Example1.config > Example1.txt
```

or use "tee" program (in UNIX):

```
linoccult Example1.config | tee Example1.txt
```

11 Using LinOccult for calculating predictions

By this moment you should adjust paths in linoccult.config file and try to start **LinOccult** with one example. Now we shall try to use **LinOccult** for calculations.

- Example 1.
  Let's calculate a shadow path for 1315 Bronislawa on 11 March 2005 . For this purpose it is necessary to create a project file Example1.config.

  ```
  # First example - calculate path for asteroid 1315 Bronislawa
  int StartDay 11
  int StartMonth 3
  int StartYear 2005
  int AsteroidNumber 1315
  ```

  The first line is a comment. The next three lines set the day, month and year of a occultation event. The last line setup asteroid number.

  Run **LinOccult**:

  ```
  linoccult Example1.config
  ```

- Example 2.
  If you need to calculate occultation events for several days (for one asteroid) you should setup start and end day of a period:

```
# Second example - calculate occultations for asteroid 983 Gunila
int StartDay 26
int StartMonth 6
int StartYear 2005
int EndDay 13
int EndMonth 7
int EndYear 2005
int AsteroidNumber 983
```

- Example 3.
  Shadow path calculation in previous examples occured with the high accuracy and accordingly takes many computer resources. Such mode does not convenient for occultations search on the big time interval. Therefore we shall replace last line in the previous example:

```
int AsteroidNumber 983
```

into these two lines:

```
int StartAsteroidNumber 983
int EndAsteroidNumber 983
```

```
# Fast search for occultations
int StartDay 26
int StartMonth 6
int StartYear 2005
int EndDay 13
int EndMonth 7
int EndYear 2005
int StartAsteroidNumber 983
int EndAsteroidNumber 983
```

This example works much faster.

- Example 4.
  StartAsteroidNumber and EndAsteroidNumber parameters allow to set a range of asteroids for occultations search:

```
# Fast search for occultations
int StartDay 1
int StartMonth 1
int StartYear 2006
int EndDay 31
int EndMonth 1
int EndYear 2006
int StartAsteroidNumber 1
int EndAsteroidNumber 10
```

- Example 5.
  However it is not a unique way to choose asteroids for processing. It is possible to set the minimal and maximal values of semimajor axis, and also minimal and maximal values of asteroid diameter:

```
int StartDay 1
int StartMonth 1
int StartYear 2006
int EndDay 31
int EndMonth 1
int EndYear 2006
double MinA 3.0
double MaxA 4.0
double MinDiameter 20.0
double MaxDiameter 25.0
```

  As it is easy to notice, in this Example the range of asteroid numbers is not set. In this case all asteroids which satisfy to the given criteria will be chosen from a file astorb.dat. In the beginning of calculation **LinOccult** will deduce quantity of such asteroids.

- Example 6.
  LinOccult output results with an 1 minute interval by default. If it is necessary to set other step, it is possible to set parameter ScanStep. The step of output will be equal to 86400/ScanStep in seconds:

```
int StartDay 11
int StartMonth 3
int StartYear 2005
int AsteroidNumber 1315
int ScanStep 14400
```

- Example 7.
  The output is limited by those points where the height of the Sun does not exceed 0 degrees. It can be changed by means of parameter SunElev:

```
int StartDay 26
int StartMonth 6
int StartYear 2005
int StartAsteroidNumber 983
int EndAsteroidNumber 983
double SunElev 20
```

  In this example **LinOccult** will output all point in shadow path where height of the Sun does not exceed 20 degrees.

- Example 8.
  It is often necessary to do calculation only for stars which brightness does not surpass some star magnitude. It can be made by means of parameter MaxMv:

```
int StartDay 1
int StartMonth 1
int StartYear 2005
int EndDay 31
int EndMonth 12
int EndYear 2005
int StartAsteroidNumber 983
int EndAsteroidNumber 983
double MaxMv 10.0
```

In this example **LinOccult** process stars with magnitude equal or less than 10.0^m.

- Example 9.
  If you search occultations by TNO objects it is necessary to know a shadow path even if it passes outside the Earth. It can be made by means of parameters IfExtraRadius and ExtraRadius:

```
int StartDay 1
int StartMonth 1
int StartYear 2006
int EndDay 31
int EndMonth 1
int EndYear 2006
double MinA 30.0
double MinDiameter 200.0
int IfExtraRadius 1
double ExtraRadius 5.0
```

- Example 10.
  If you know asteroid orbit elements, you can set them in a configuration file. The updated orbit elements can be taken from Steve Preston's or Jan Manek's sites. These orbit elements might be for any epoch not just elements calculated for the given event. Orbit elements include 7 values. These elements have replaced elements from an astorb.dat file for this particular asteroid. To setup orbit elements IfOneAsteroid parameter with asteroid number should be added to configuration file with 7 orbit elements parameters:

```
int IfOneAsteroid 3028
# Mean anomaly
double OrbitM 268.1498521874252
# Arg. of pericenter
double OrbitW 12.0328241475572
# Long. of node
double OrbitO 189.8183951669222
# Inclination
double OrbitI 9.5071891791671
# Eccentricity
double OrbitE 0.024687685580059
```

```
# Semimajor axis
double OrbitA 3.01926921249583
double ObservationEpoch 53743.280
int StartDay 8
int StartMonth 1
int StartYear 2006
int AsteroidNumber 3028
```

- Example 11.
  In previous Example the specified elements for one asteroid were used. In case of calculation for more than one asteroid, the orbit elements can be stored in a special file which format is described below. Parameter UpdatesFilePath is used to setup path to this file. One more parameter UpdatesExpirePeriod is used. It define how old updated orbit elements can be used:

```
int StartDay 8
int StartMonth 1
int StartYear 2006
int AsteroidNumber 3028
string UpdatesFilePath ./UpdateExample.txt
```

- Example 12.
  At exact calculations of a shadow path not only precise asteroid elements is used, but also a star presice position. Star presice position can be setting up by means of parameter IfOneStar with a number of additional parameters:

```
int StartDay 19
int StartMonth 11
int StartYear 2005
int AsteroidNumber 1994
int IfOneStar    1218008681
int RA_Hour     2
int RA_Min      28
double RA_Sec   4.8329723
double pmRA     0
int Dec_Deg     19
int Dec_Min     59
double Dec_Sec 47.266972
double pmDec    0
int OneStarCatalog 128
double OneStarMv 9.28
double OneStarParallax 0.0365
```

- Example 13.
  The default results output is in text mode. If it is necessary to deduce results in other format, it is possible to use parameter OutputType. In this example **LinOccult** output data in **PovRay** format to create 3D map. To do this OutputType is used:

```
int StartDay 11
int StartMonth 3
int StartYear 2005
int AsteroidNumber 1315
int OutputType 1
```

- Example 14.
  To output occultation events circumstances in the set of points, it is necessary to keep calculation results in an internal database. For this purpose it is necessary to add parameter OutputEventsFilePath to specify a path to a file in which this database will be created:

```
int StartDay 1
int StartMonth 1
int StartYear 2006
int EndDay 31
int EndMonth 1
int EndYear 2006
int StartAsteroidNumber 1
int EndAsteroidNumber 10
string OutputEventsFilePath ./EventsExample.bin
```

- Example 15.
  To output occultation circumstances in the set of points, it will be necessary to create a file with the list of observation points in a format which it is shown below. For each observation point it is possible to set the values for the maximal star magnitude, the minimal event duration, the minimal magnitude drop, the minimal probability of event and so on. Parameter SitesFilePath setup a path to this file. In this mode calculation is not made, so it is necessary to specify also parameter CalculationMode equal 0. Also it is necessary to specify a database with results of calculation by mean of InputEventsFilePath parameter:

```
int StartDay 1
int StartMonth 1
int StartYear 2006
int EndDay 31
int EndMonth 1
int EndYear 2006
string SitesFilePath SitesExample.txt
string InputEventsFilePath ./EventsExample.bin
int CalculationMode 0
```

  LinOccult will create up to three files with occultations list for each observation point.

- Example 16(For UNIX only).
  One option in **LinOccult** is storing results in MySQL database. To use this option it is necessary to set parameter IfMySQL and, if necessary, StartSQLNumber. Before starting **LinOccult** you should start MySQL:

```
int StartDay 1
int StartMonth 1
int StartYear 2006
int EndDay 31
int EndMonth 1
int EndYear 2006
int StartAsteroidNumber 1
int EndAsteroidNumber 10
int IfMySQL 1
```

12   LinOccult output format

Let's discuss **LinOccult** output format. In the beginning of the work **LinOccult** outputs the information about the current version and Copyright. Then the information about parameters which will be used in current run and source file where these parameters have been received. For each found event **LinOccult** output the information on a covered star - the catalogue and number, visual star size Mv, coordinates of a star, asteroid diameter (Diameter), its brightness (Brightness), magnitude drop (Delta), one root-mean-square uncertainty σ (Uncertainty) expressed in angular seconds and kilometers. Then **LinOccult** output data about circumstances of this event - distance from a star to the Sun (Sun dist) and the Moon (Moon dist) in degrees and also a phase of the Moon (Moon phase) in percentage.

For each point **LinOccult** output date and time in UTC, a longitude of the given point, latitude of the given point, height of a star above horizon, height of the Sun and duration of event in seconds.

13   Additional LinOccult tuning

As already mentioned above, **LinOccult** is used a file with asteroid orbit updates, a file with a set of observation points and also MySQL database. We will discuss a format of these files and **LinOccult** tuning.

13.1   Asteroid orbit updates file

The asteroid orbit updates file is used for presice orbit elements storage. This file is necessary because astorb.dat file not always possess orbit elements with sufficient accuracy. Updated orbit elements can be taken from Steve Preston's site (http://www.asteroidoccultation.com) and Jan Manek (http://mpocc.astro.cz/updates) site. These elements should be placed in a special text file. Path to this file should be defied in UpdatesFilePath parameter. Parameter UpdatesExpirePeriod sets number of days during which orbit elements from this file will have a priority in relation to data from astorb.dat. At start **LinOccult** reads a file astorb.dat and an asteroid orbit updates if it exists. Then **LinOccult** check if updated orbit elements exists in an updates file for each asteroid. If updated orbit elements exist, **LinOccult** compare the date updated orbit elements with elements from astorb.dat file. If the orbit elements from updates file is newer than from astorb.dat minus UpdatesExpirePeriod, orbit elements from orbit updates file is selected.

Now about a format of the asteroid orbit updates file. It is a text file in which one line corresponds to one update. A symbol # in the first position of a line does the given line by the comment. A format of a line of one update is the following:

1. Asteroid number

2. Observation epoch

3. Mean anomaly in degree

4. Argument of pericenter in degree

5. Longitude of node in degree

6. Orbit inclination in degree

7. Eccentricity

8. Semimajor axis in astronomical units

9. 1 sigma uncertainty ellipse (major, minor, PA)

See UpdateExample.txt as an Example.

13.2   Observation points file

LinOccult use a special text file to keep a list of observation points. The path to this file is set in SitesFilePath parameter. One line in this file corresponds to one observation point. A symbol # in the first position of a line does the given line by the comment. **LinOccult** select occultation events which satisfy to a set of restrictions defined for each point. A format of one line is the following:

1. Observation point name. This name is used as a files name with appropriate extentions

2. Observer e-mail

3. Integer number - output files type

4. Integer number - how to sort observation events

5. Observation point longitude - in degree (decimal format) or in degree-minute-seconds formats

6. Observation point latitude - in degree (decimal format) or in degree-minute-seconds formats

7. Radius of the area near observation point. Is used to select occultation events which path intersect with this area

8. Maximal star magnitude

9. Minimal event duration

10. Maximal Sun altitude

11. Minimal star magnitude drop

12. Minimal event probability in this point

13. Minimal event probability in the center of shadow path

14. Minimal star altitude

The type of output files and type of sorting of events is required further explanation.

The type of output files - is an integer which is formed by a rule "or" or "+".

- Value 1 corresponds to a text file

- Value 2 corresponds to a file in a LATEXformat

- Value 4 corresponds to a file in HTML format

Names of files will be

```
Observation_point_name.txt
Observation_point_name.ltx
Observation_point_name.htm
```

It is possible to output results in different formats. For example value 3 corresponds to files in text and LATEXformats (3=1+2). To get pdf format from LATEXyou should run **pdflatex** program:

```
pdflatex <Observation_point_name.ltx>
```

The sorting types is also an integer which is formed by the same rule, as output files format:

- Value 1 corresponds to sorting by time

- Value 2 corresponds to sorting by asteroid number

- Value 4 corresponds to sorting by magnitude drop

- Value 8 corresponds to sorting by to a nearest point in the center of shadow path

- Value 16 corresponds to sorting by occultation duration

- Value 32 corresponds to sorting by event probability in observant point

- Value 64 corresponds to sorting by probability in the center of a shadow path

- Value 128 corresponds to sorting by star magnitude

- Value 256 corresponds to sorting by uncertainty

It is possible to get several tables sorted differently. For example number 6 means two tables sorted by asteroid number and by magnitude drop.

As an example of observation points file see SitesExample.txt.

13.3 Tuning LinOccult with MySQL

LinOccult can output results directly to MySQL database. It is useful if you do a statistical analysis of events or you search of interesting and unusual events all over the world. To output results in MySQL database, it is necessary to adjust MySQL on your computer as it is specified in MySQL user manual.

Then it is necessary for you to create the user "linoccult" with the password "linoccult" and to create a database "occult". In this database it is necessary to create the following table:

```
CREATE TABLE Events (
  EVENT_ID               int UNSIGNED NOT NULL AUTO_INCREMENT,
  ASTEROID_ID            int UNSIGNED NOT NULL,
  ASTEROID_NAME          varchar(18),
  ASTEROID_DIAMETER      float,
  EPHEMERIS_UNCERTAINTY  float,
  STAR_NUMBER            int UNSIGNED NOT NULL,
  STAR_MV                float NOT NULL,
  BEGIN_OCC_TIME         datetime,
  END_OCC_TIME           datetime,
  EARTH_FLAG             tinyint,
  MAX_DURATION           float,
  STAR_RA                float NOT NULL,
  STAR_DEC               float NOT NULL,
  MOON_PHASE             float,
  SUN_DIST               float,
  MOON_DIST              float,
  BRIGHTNESS             float,
  BRIGHT_DELTA           float,
  UNCERTAINTY            float,
  PRIMARY KEY( EVENT_ID ),
  INDEX( BEGIN_OCC_TIME )
);
```

Before start of **LinOccult** it is necessary to be convinced, that demon MySQL is started and works and to add in **LinOccult** configuration file parameter IfMySQL equal to 1. As it is possible to write to MySQL database many times, it is necessary to take care of parameter EVENT_ID as it should be unique. **LinOccult** does not trace it. Use parameter StartSQLNumber before start that there was no crossing values EVENT_ID. After MySQL database will be filled, it is possible to do its analysis by means of standard SQL applications.

14 LinOccult run modes

LinOccult has several base run modes. First of them is an presice calculation of a shadow path. This mode is switched on by parameter

```
int AsteroidNumber asteroid_number
```

It is necessary to tell, that number of an asteroid is actually number of a line in a astorb.dat file so it is possible to process not numbered asteroids.

In this mode it is possible to use the updated orbit elements from Steve Preston's (http://www.asteroidoccultation.com) and Jan Manek's (http://mpocc.astro.cz/updates) sites. For this purpose it is necessary to set parameter

```
int IfOneAsteroid asteroid_number
```

and the updated orbit elements parameters. It is necessary that asteroid number in both parameters AsteroidNumber and IfOneAsteroid coincided. Also it is possible to set a path to a file of with updated orbit elements:

```
string UpdatesFilePath path
```

If you have presice star position, it is possible to set star coordinates and other appropriate star parameters.

```
int IfOneStar star_number
```

Usually this mode is used if asteroid number and occultation date are known. The given mode the most presice, but need more computing resources.

The second **LinOccult** mode - occultation events search. For this mode you should set the following parameters:

```
int StartAsteroidNumber
int EndAsteroidNumber
```

or diameter and orbit restrictions. In this mode it is possible to use a file with asteroid orbit element updates. Parameter AsteroidNumber should not be present at this mode.

The third **LinOccult** mode - output information about occultation events in observation points. This mode switched on by setting the follow parameter:

```
int CalculationMode 0
```

You should also provide path to observation points file and to file with internal database file with results of calculations in the second mode.

15 Parameters list

LinOccult use the following parameters:

- **AstOrbFilePath** This parameter of type **string** sets a path to a file astorb.dat.

- **StarCatalogFilePath** This parameter of type **string** sets a path to file Gaia14.bin.

- **JPLEphemFilePath** This parameter of type **string** sets a path to a file unxp2000.405.

- **StartYear** This parameter of type **int** sets year of the beginning of the period of calculation.

- **StartMonth** This parameter of type **int** sets month of the beginning of the period of calculation.

- **StartDay** This parameter of type **int** sets day of the beginning of the period of calculation.

- **EndYear** This parameter of type **int** sets year of the end of the period of calculation.

- **EndMonth** This parameter of type **int** sets month of the end of the period of calculation.

- **EndDay** This parameter of type **int** sets day of the end of the period of calculation. If parameters **StartYear**, **StartMonth** and **StartDay** omitted, **EndYear**, **EndMonth** and **EndDay** are accepted equal to **StartYear**, **StartMonth** and **StartDay** and calculation is made for 1 day.

- **AsteroidNumber** This parameter of type **int** sets number of an asteroid (more precisely number of a line in an astorb.dat file). If this parameter is set, the most exact calculation mode is switched on.

- **IfOneStar** This parameter of type **int** sets calculation mode for one star. By default **IfOneStar** value is equal to 0.

- **RA_Hour** This parameter of type **int** sets hours of a direct ascention of a star. It is used if the parameter **IfOneStar** is set.

- **RA_Min** This parameter of type **int** sets minutes of a direct ascention of a star. It is used if the parameter **IfOneStar** is set.

- **RA_Sec** This parameter of type **double** sets seconds and shares of second of a direct ascention of a star. It is used if the parameter **IfOneStar** is set.

- **Dec_Deg** This parameter of type **int** sets degrees of declination of a star. It is used if the parameter **IfOneStar** is set.

- **Dec_Min** This parameter of type **int** sets minutes of declination of a star. It is used if the parameter **IfOneStar** is set.

- **Dec_Sec** This parameter of type **double** sets seconds and shares of second of declination of a star. It is used if the parameter **IfOneStar** is set.

- **pmRA** This parameter of type **double** sets star proper motion in an arcsec/year on a direct ascention. It is used if the parameter **IfOneStar** is set. By default **pmRA** value is equal 0.

- **pmDec** This parameter of type **double** sets sets star proper motion in an arcsec/year on declination. It is used if the parameter **IfOneStar** is set. By default value **pmDec** is equal 0.

- **OneStarCatalog** This parameter of type **int** sets type of the star catalogue. 2 - HIP 130 - UCAC2 128 - TYC. It is used if the parameter **IfOneStar** is set.

- **OneStarMv** This parameter of type **double** sets visible star magnitude. It is used if the parameter **IfOneStar** is set.

- **OneStarParallax** This parameter of type **double** sets value of a parallax in an arcsec/year. By default value **OneStarParallax** is equal 0.

- **ScanStep** This parameter of type **int** sets a output time step. The output time step will be equal to 86400/ScanStep seconds. By default **ScanStep** is equal to 1440 (one minute).

- **IfExtraRadius** This parameter of type **int** defines, whether results outside the Earth will be output. By default value of this parameter is equal to 0. To output results outside the Earth it is necessary to set this parameter equal to 1.

- **ExtraRadius** This parameter of type **double** sets distance equal to quantity of radiuses of the Earth for which results of calculation will be output. By default value **ExtraRadius** is equal 3. It is used if the parameter **IfExtraRadius** is set.

- **ET_UT** This parameter of type **double** sets a difference between ephemeris and usual time.

- **MinA** This parameter of type **double** sets the minimal value of semimajor axis of asteroids in astronomical units for which calculation will be made.

- **MaxA** This parameter of type **double** sets the maximal value of semimajor axis of asteroids in astronomical units for which calculation will be made.

- **MinDiameter** This parameter of type **double** sets the minimal value of diameter of asteroids in kilometers for which calculation will be made.

- **MaxDiameter** This parameter of type **double** sets the maximal value of diameter of asteroids in kilometers for which calculation will be made.

- **IfOneAsteroid** This parameter of type **int** defines an asteroid number for which the precise orbit elements parameters is set. By default value **IfOneAsteroid** is equal 0.

- **ObservationEpoch** This parameter of type **double** sets an epoch in MJD days. It is used if the parameter **IfOneAsteroid** is set.

- **OrbitM** This parameter of type **double** sets mean anomaly in degrees. It is used if the parameter **IfOneAsteroid** is set.

- **OrbitW** This parameter of type **double** sets argument of pericenter in degrees. It is used if the parameter **IfOneAsteroid** is set.

- **OrbitO** This parameter of type **double** sets a longitude of the ascending node in degrees. It is used if the parameter **IfOneAsteroid** is set.

- **OrbitI** This parameter of type **double** sets an inclination of an orbit in degrees. It is used if the parameter **IfOneAsteroid** is set.

- **OrbitE** This parameter of type **double** sets eccentricity. It is used if the parameter **IfOneAsteroid** is set.

- **OrbitA** This parameter of type **double** semimajor axis in astronomical units. It is used if the parameter **IfOneAsteroid** is set.

- **OutputType** This parameter of type **int** sets a type of output information. At value 0 information of a shadow path output in standard text format. At value 1 information of a shadow path output in format, suitable for creation 3D pictures by the program **PovRay**. At value 2 information of a shadow path output in the fields divided by a comma, convenient for input in other programs, for example in spreadsheets.

- **InputEventsFilePath** This parameter of type **string** sets a path to a file with an internal database for input events data.

- **OutputEventsFilePath** This parameter of type **string** sets a path to a file with internal database for output events data.

- **SitesFilePath** This parameter of type **string** sets a path to a file containing the list of observation points.

- **CalculationMode** This parameter of type **int** sets an operating **LinOccult** mode. At value 1 (value by default) is set calculation mode. At value 0 the output of results is made for the observation points, defined by the parameter **SitesFilePath**.

- **IfMySQL** This parameter of type **int** defines, the additional output into MySQL database. Value by default - 0 (the output is not necessary). To switch on the additional output into MySQL database it is necessary to establish this parameter to 1.

- **StartSQLNumber** This parameter of type **int** defines initial value of record in MySQL database. Value by default 1. It is used if the parameter **IfMySQL** is set.

- **SunElev** This parameter of type **double** sets the maximal value of height of the Sun at which the points on a shadow path will be output. Value by default 0.

- **MaxMv** This parameter of type **double** sets the maximal value of star magnitude for which calculation will be made.

- **UpdatesFilePath** This parameter of type **string** sets a path to a file containing asteroids updated orbit elements.

- **UpdatesExpirePeriod** This parameter of type **int** sets the period in days which defines the source of asteroid orbit elements - astorb.dat or file with updates. Value by default 730 days.

- **StartAsteroidNumber** This parameter of type **int** sets the first asteroid for calculation of asteroids in a range. Value by default 1.

- **EndAsteroidNumber** This parameter of type **int** sets last asteroid for calculation of asteroids in a range. If this parameter and parameter **StartAsteroidNumber** is set, fast calculation mode is switched on.

16 LinOccult algorithms

Here I want to tell about **LinOccult** algorithms. The program **LinOccult** in the beginning of the work reads out a configuration file linoccult.config and the project configuration file from a command line, defines from them parameters, in particular path to a file astorb.dat, to the star catalogue and path to planets epemeris. Then, depending on the parameters set creates the list of asteroids for processing and an time interval. **LinOccult** also reads out the star catalogue and creates kdtree index for fast search of stars in some area. Calculation is made by numerical integration of asteroid coordinates with use of planets perturbations. Planets positions are read from file DE405. In a search mode **LinOccult** approximated asteroid orbit by Chebyshev polynomials. After that neithbour stars are searched all and for each of them the occultation is searched. If the occultation is found, it is output to the console and if necessary save in an internal database and MySQL database.

17 Changelog

LinOccult_1.0.0beta:

1. Performance of the program has increased in 5 - 10 times due to use of kdtree algorithm in star search procedure

2. Output of the results to MySQL database was added

3. Save calculation results in an internal database

4. Developed and implemented new text and pdf formats

5. Support of the list of observation points of was implemented.

6. Several bugs were fixed

7. New configuration parameters were added

LinOccult_1.1.0:

1. File with updated orbit elements was added.

2. HTML output format was added

3. StartAsteroidNumber, EndAsteroidNumber parameters were added

4. MaxMv parameter was added

5. Parallax processing was added

6. OneStarCatalog, OneStarMv, OneStarParallax parameters were added

7. Asteroid brightness calculation algorithm was updated

LinOccult_1.1.1:

1. Support of a new astorb.dat file format with 6 digits for asteroid number was added

LinOccult_2.0.0:

1. All libraries and application code were updated to use "pure" C++ code with namespaces, streams and STL.

2. Obsolete code was removed.

3. Vector and matrix ariphmetics, integration and Chebyshev polynomials were moved to mathematical library.

4. Structure of input/output library was changed.

5. New input/output formats were added to use in **OrbSearch**.

6. Two new libraries were added: **APSAstroData** for astronomical databases and **APSAstroAlg** for astronomical algorithms.

7. Some minor bugs were fixed.

8. Calculation of preliminary events was changed.

LinOccult_2.1.0:

1. Make files were added (Andrew Moore).

2. Compilation problems in Ubuntu 8.10 were fixed.

3. Output format for OccultWatcher was added.

4. Several bugs were fixed.

LinOccult_2.1.1:

1. Bug was fixed in output to OccultWatcher.

2. Uncertainty of star position was added to asteroid uncertainty.

LinOccult_2.2.0:

1. Migration to 64 bit platforms.

2. Some code updates to comply with modern compilers.

3. In kdtree float was changed to double.

LinOccult_2.3.0:

1. Gaia catalog is used instead of Tycho2.

2. Stars position calculation was improved.

LinOccult_2.4.0:

1. Gaia EDR3 catalog.

18 Inside LinOccult

LinOccult is written on C++ and include libraries which can be reused in other projects:

- APSLib - general purpose library for application developing. Contains classes for work with parameters, files and also a number of useful procedures.

- APSMathLib - general purpose library with vector and matrix arithmetics, work with Chebyshev polynomials and other mathematical procedures.

- APSAstroIO - library containing procedures for input/output into various formats of astronomical databases, for example an astorb.dat file.

- APSAstroData - library with support of astronomical data bases (i.g. DE405).

- APSAstroAlg - library with support of astronomical algorithms.

19 ToDo

Though all the basic options for occultation calculation and search in **LinOccult** already exist, I am going to develop and support **LinOccult**.

References

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[3] *LinOccult - Overview of New Features* 24th European Symposium on Occultation Projects, Helsinki 26-31 August, 2005 http://www.ursa.fi/ursa/jaostot/pikkuplan/tapahtumat/ESOP2005/lecture_11.html

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