CelNav Flash Applications

Introduction

CelNav1 and CelNav2, collectively called CelNav, are a collection of useful programs for learning celestial navigation. These programs were written for my own use to speed the process of obtaining a fix using celestial sights. Others may find them useful as well. The idea is to reduce a large portion of the mathematical tedium associated with deriving a line of position (LOP) obtained from the observation of a celestial body. The TI calculator does all of the necessary number crunching, reducing the chance of an arithmetic or transcription error. Two or more celestial LOPs can then used to calculate a fix using a traditional paper chart.

Terms and Conditions

Technical Stuff

All CelNav programs were written entirely in TI Basic, tested on the TI-83+ (emulator) and my TI-84+, and converted into applications using BasicBuilder. *No assembly language was used.* The benefit of this approach is that any errors in the program will simply cause a halt in program execution...even if the program crashes or behaves unexpectedly, the user hits the "ON" button and all is forgiven. However, everything has a price: this safety and utility comes at the expense of speed and code efficiency. The CelNav applications would undoubtedly be faster if written in assembly but the scope of the applications would have made the code unmanageable...at least for me!

The original intent was for all the CelNav programs to be placed under a single application but the resulting file size was too large to convert into an application using BasicBuilder; hence, the utilities were placed into two separate applications. There are seven programs in the CelNav1 application and 10 in CelNav2.

About This Guide

What this guide is not: A primer on celestial navigation. A functional knowledge of both celestial navigation and the use of a sextant is needed to make effective use of the various CelNav programs. For an excellent primer on celestial navigation, including the

Sumner and Saint-Hilaire method, see Henning Umland's superb e-book “A Short Guide to Celestial Navigation” at http://www.celnav.de/.

What CelNav is not: An integrated suite of programs. It will not graphically plot positions, maintain a dead-reckoning plot, calculate speed over ground, distance to next waypoint, convert to your local time zone, compute tides and currents, interface with your GPS unit, or any of that stuff.

CelNav1 programs and descriptions:

1. *Sun LOP*: Obtain a LOP from a sun sight.
2. *Star LOP*: Obtain a LOP from any one of 58 navigational stars, including Polaris.
3. *Planet LOP*: Obtain a LOP from a sighting of any one of the four navigational planets.
4. *Moon LOP*: Obtain a LOP from a moon sight.
5. *Prediction/ID*: Generate a list of all navigational stars including altitudes and azimuths, useful in identifying the celestial body observed, and as an aid to sight planning.
6. *BestSight*: Used to pick the most representative of a series of sights of the same celestial object.
7. *Recall LOP*: Recalls the stored LOP information generated using Sun LOP, Moon LOP, Planet LOP, or Star LOP.
8. *Quit*: Exit CelNav1.

CelNav2 programs and descriptions:

1. *Rise/Set/Transit*: Calculates the time of sunrise, sunset, twilight, and meridian transit (local noon) for the sun on any given day.
2. *Calc LAN*: Calculates the time of Local Apparent Noon (LAN) based on up to eight sights.
3. *Auto Calc Fix*: Using and unlimited number of sights, automatically calculates a fix using the averaging algorithm detailed in the Nautical Almanac.
4. *Lat by Sun LAN*: Calculates the observer’s latitude based on the determination of the time of LAN and the observed altitude of the sun.
5. *Lat by Polaris*: Calculates observer’s latitude based on the observed altitude of Polaris.
6. *Calc Refr Corr:* Calculates the refraction correction error that must be applied to apparent sextant altitude (Ha) to obtain the observed altitude (Ho) of the celestial body.
7. *Calc Dip Corr*: Calculates the dip correction that must be applied to sextant altitude (Hs) to obtain Ha.
8. *Calc Hc/Zn*: Calculates the computed altitude (Hc) and azimuth (Zn) of a celestial body.
9. *Sumner Method*: Yields data that can be used to plot a LOP using the Sumner method.
10. *Cleanup Memory*: Deletes the variables, lists, and matrices used to store information for the CelNav programs. Note that it will not delete stored “pics” used for storing output screens for Sun LOP, Star LOP, Planet LOP, Moon LOP,

and AutoCalc.

11. *Quit:* Exit CelNav2.

Notes on data entry:

All CelNav programs assume UT using a 24 hour clock. Thus, a time such as 11:15:55 PM UT should be entered as 23 15 55.

Southern latitudes and declinations should be entered as a negative number. Longitudes in the western hemisphere are also entered as negative numbers. As an example, 23°15'N would be entered as 23°15', while 34°23'S would be entered as -34°23'. Similarly, a longitude of 085°15'W would be entered as -85°15', while the corresponding entry for 074°43'E would simply be 74°43'.

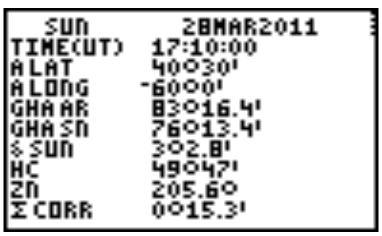
Use the numerical entry for the month. As an example, January is "1", June is "6", and so on. The year is always entered using 4 digits.

Recall that sextant altitude (Hs) + Index Correction (IC) + Dip Correction = apparent altitude (Ha), and Ha + Σ Corr = Observed altitude (Ho).

Program Descriptions

A. Sun LOP (CelNav1):

- The program will prompt for the user to enter the month, day, and year.
- Next, enter the hour, minute, and second of the observation time as prompted.
- The program will then ask for the observer's assumed latitude. Enter as deg/min/sec using the calculator's "Angle" menu. Do the same for the assumed longitude.
- The program will ask whether an Upper or Lower Limb observation is being made. Choose as applicable.
- The output screen will appear. An example is shown below. Note that in addition to the azimuth and intercept of the celestial body, the program will give the total correction that should be made to apparent sextant altitude (Ha). This value includes refraction, semi-diameter, augmentation, and parallax errors if applicable. It does **not** include dip or sextant index error. Hit ENTER to continue.



The values shown are:

- Body observed and date
- Time of the observation
- Assumed latitude (A LAT)
- Assumed longitude (A LONG)
- GHA Aries (GHA AR)
- GHA Sun (GHA SUN)
- Declination of the Sun (δ SUN)
- Calculated Altitude (Hc)
- Calculated azimuth (Zn)
- Summary correction value (Σ CORR)

The program will then ask whether you wish to calculate data for an observation made using an artificial horizon. Choosing "YES" will display the necessary corrections that should be used instead of the summary correction. Specifically, when using an artificial horizon:

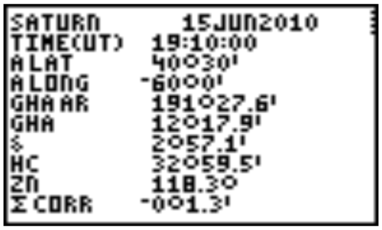
- ☒ Add the IC to Hs.
- ☒ Do not apply the Dip Correction.
- ☒ Divide the above sum by 2. The result is Ha.
- ☒ If the image was sighted as upper-limb to lower-limb, apply the semi-diameter (SD) correction as well as the refraction correction to obtain Ho. If the images were superimposed, apply only the refraction correction to obtain Ho.

B. Planet or Star LOP:

Planet and Star LOP work similarly to Sun LOP, with the following differences:

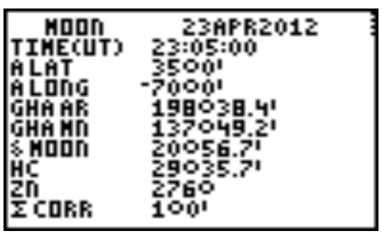
- Use the menu to select the planet or star observed.
- No option for upper or lower limb, and no artificial horizon data is not available.

An example output from Planet LOP is shown below.



C. Moon LOP (CelNav1):

Moon LOP works identically to Sun LOP, except that there is no option for an artificial horizon shot. Like Sun LOP, the user will have to choose whether the observation was upper or lower limb. After entering date/time etc, expect 3-4 minutes before the program asks for the next input (assumed latitude and longitude)... the Moon LOP program is computationally intensive. An example output is shown below.

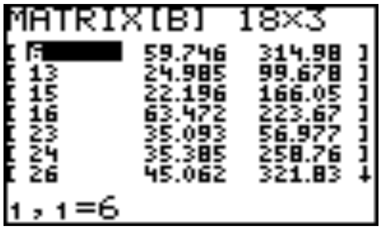


D. Prediction/ID:

The 1st menu choice, “GEN TABLE” produces two matrices. The first, Matrix A, is a list containing 62 rows and 3 columns. Each row in the matrix contains the index number, calculated altitude, and azimuth of the 58 navigational stars plus Venus, Jupiter, Mars, and Saturn. The index number is contained in column 1, the altitude in column 2, and the azimuth in column 3. Like Moon LOP, the calculator will take 3-4 minutes to complete the calculations. The program will return to the **Prediction/ID** menu screen after the table has been generated.

Although “GEN TABLE” will create an altitude/azimuth list of all the navigational stars and planets, some of those bodies will not be visible at the chosen time or particularly useful for observations. For sight planning, bodies that are both visible and that have altitudes between 15 and 60 degrees are stored in Matrix B.

To view the tables, exit CelNav1 and go to the Matrix Editor. Use the MATRIX EDIT function to view the matrix more easily to aid in sight planning. An example is shown below:



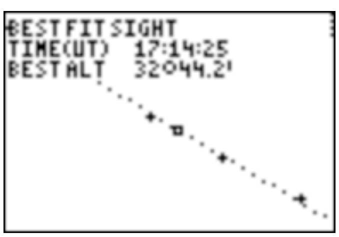
From the example, we see that body #6 has an altitude of 59.746º and an azimuth of 314.98º. To determine the name of body #6, use the 2nd menu option in Prediction/ID. When prompted, enter the number of the body; the program will yield the name as a result (#6 is Alioth).

A complete list of all the navigational stars and planets is also included in the file "Name list.xls". This may be printed for easy reference.

Prediction/ID can also be used to identify an unknown celestial body that has been observed. After recording the altitude and azimuth of the observation, inspect Matrix B to find the body that most closely matches both the observed altitude and azimuth.

E. Best Sight (CelNav1):
This program takes as an input up to five uncorrected sextant observations and finds the most representative observation of the set. This approach minimizes the impact of a single bad observation…the sights are smoothed utilizing a least-squares curve fit. The total time span from the 1st to the last observation must be less than 5 minutes.

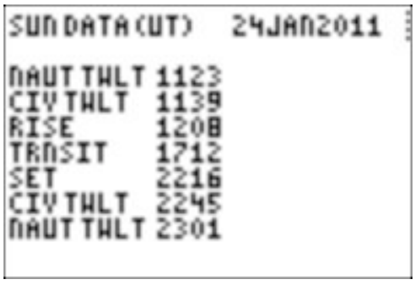
- When prompted, enter the time of sight #1, then the altitude of sight #1 (in hours-min format). Do likewise for the following sights.
- The output will display a screen with the sights plotted, along with the "best sight". The time/altitude of the best sight are clearly displayed in the upper left corner of the screen .



Each observation is plotted on the output screen with a "+", with the best-fit line plotted through all points. The best sight is plotted with a "□". Mathematically, it is the calculated midpoint of the best-fit line. The best sight is normally not the same as any of the observed points. Note that for a good round of observations, all of the individual sights should lie close to the plotted line. Those that do not are suspect and should be discarded from the observation set.

F. Recall LOP (CelNav1)
Allows the user to recall the last output screen for Sun LOP, Moon LOP, Planet LOP, and Star LOP. Choose as appropriate. If there is no output stored for that LOP, the program will produce an error.

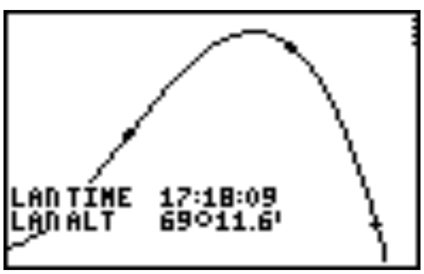
G. Rise/Set/Transit (CelNav2)
Calculates complete data for the sun for a given day. This includes morning nautical and civil twilight, sunrise, meridian transit (noon), sunset, and finally evening civil and nautical twilight. If the sun is circumpolar at that latitude the output will state “SUN IS CIRCUMPOLAR”. An sample output is shown below.



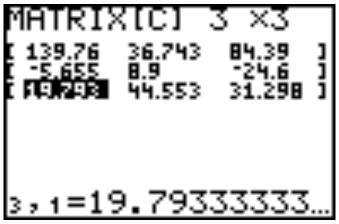
H. Calc LAN (CelNav2)
Using between four and eight observations near Local Apparent Noon (LAN), the program calculates the time of LAN and the altitude of the sun at LAN. For best accuracy, the sights should be equally spaced around the estimated time of LAN. In any event at least one observation must be made before noon, and at least one after LAN.

- When prompted, enter the number of sights.
- When prompted, enter the time of sight #1, then the altitude of sight #1 (in hours-min format). Do likewise for the following sights.

The output will display a screen with the sights plotted, the calculated LAN data, and the best-fit polynomial curve used to derive the time and altitude of LAN. An example is shown below.



I. Auto Calc Fix (CelNav2)
Calculates a fix based on any number of observations (minimum is two). The data for the observations first needs to be entered in Matrix C. For each sight that you desire to include in the fix calculation, enter the GHA, declination, and Observed Sextant altitude (Ho) in row 1, 2, and 3 respectively. Note that Ho is used; this is the apparent sextant altitude with all corrections applied. Below is a screenshot of Matrix C with data entered for three observations:



In column one, the body observed has a GHA of 139.76° , declination of -5.655°, and Ho of 19.793°. In column two, the body observed has a GHA of 36.743°, declination of 8.9°, and Ho of 44.553°, etc. Note that the data can be entered in Deg-Min-Sec format using the ANGLE menu of the calculator, but will be displayed in the Matrix Editor in decimal form.

Once the data is entered in Matrix C, return to CelNav2 and choose the "CALC FIX" option to begin the calculation. After entering the number of observations (equal to the number of columns in Matrix C), assumed latitude and assumed longitude, the program will compute a fix. The program will halt execution if Matrix C does not contain any values, or if the number of observations does not match the number of columns in Matrix C. The output from the example data set is shown below:

The "RECALL FIX" option is used to recall the last AUTOCALC output screen.

J. Lat by Sun LAN (CelNav2)

Used to calculate latitude based on the observed altitude of the sun at Local Apparent Noon (LAN). When prompted, enter the assumed latitude, observed altitude, month, day, year, hour, minute and second. The program will output the calculated latitude (CALC LAT). It will also yield the estimated longitude (EST LON), based on the time of the LAN observation. Due to the inherent difficulty (and inaccuracies) in determining the exact time of LAN, the displayed EST LON is at best a reasonable estimate.

K. Lat by Polaris (CelNav2)

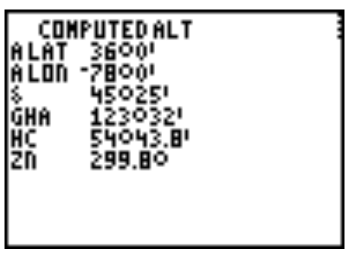
Calculates the latitude based on an observation of Polaris. When prompted, enter the month, day, year, hour, minute, second, assumed latitude, assumed longitude and sextant altitude. You will also have to enter the dip correction and sextant Index Correction (IC). Dip and IC are entered in degrees-minute format using the calculator's ANGLE menu. Recall that the value for the dip correction is always negative.

The program will output the calculated latitude (CALC LAT) and will also display GHA of Aries (GHA AR).

L. Calc Refr Corr (CelNav2)
Calculates the refraction correction based on the sextant altitude. This refraction correction value is already included in the Σ CORR value displayed as an output in Sun LOP, Planet LOP, Moon LOP, and Star LOP.

M. Calc Dip Corr (CelNav2)
Calculates the dip correction based on the observer's height of eye. Choose either "DIP", for observations against a distant horizon, or "DIP SHORT" for observations made on some nearer body of water when the horizon is not available. For "DIP SHORT", also enter the distance to the horizon being utilized in nautical miles.

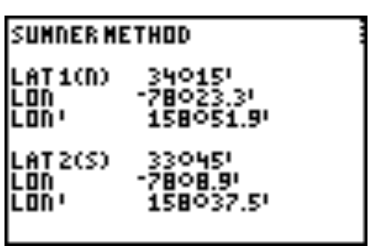
N. Calc Hc/ZN (CelNav2)
Calculates the computed altitude (Hc) and computed azimuth (Zn). Input the assumed latitude, assumed longitude, declination and GHA of the celestial body. An example output is displayed below.



O. Sumner Method (CelNav2)
The Sumner Method of obtaining a LOP from a celestial observation is based on circles of equal altitude. It was long ago superseded by the more intuitive altitude-intercept (Saint-Hilaire) method but is still useful for obtaining a celestial LOP.

To use the Sumner program, enter the GHA, declination, and observed altitude (Ho) of the celestial body. Next, enter a latitude north of your estimated latitude (LAT 1). Finally, enter a latitude south of your estimated latitude (LAT 2).

The output of the Sumner algorithm is a pair of points that are plotted on a chart. The celestial LOP for the observation is obtained by drawing a line through the two plotted points. An example output is posted below.



Note that for each latitude, there are two possible longitudes. The user simply chooses whichever longitude is closest to the estimated longitude. The other longitude will most likely be in the other hemisphere. In this example, the assumed position was 34°N, 78°W. The points that will be plotted are 34°15'N/78°23.3W and 33°45'N/78°8.9W, since the longitude of the estimated position was 78°W.

Celestial bodies that are too close to the observer's meridian may not be suitable for the Sumner method. The program's algorithm will check for this condition and display a message if the celestial body is unsuitable.

P. Cleanup Memory (CelNav2)
CelNav creates dozens of lists, pics, and variables to store information. Executing the Cleanup program will delete all of this data and release valuable calculator RAM, the only exception being stored pics. These must be deleted separately by the user.

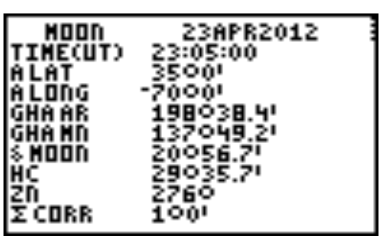
Acknowledgements

CelNav1 and CelNav2 are based almost entirely on algorithms described in Jean Meuss' " Astronomical Formulae for Calculators", including the perpetual nautical almanac for the sun, moon, stars, and navigational planets (Mars, Jupiter, Saturn, Venus). Necessary corrections for the positions of Saturn and Jupiter are derived from algorithms on Paul Schlyter's website, http://stjarnhimlen.se/english.html. CelNav was not intened for historical research but should be accurate for a century or so on either side of the current year.

For a straightforward and concise treatment of celestial navigation including the underlying mathematical principles, see Henning Umland's "A Short Guide to Celestial Navigation", available on his website at http://www.celnav.de/.

Notes on precision

The TI-84+ is a powerful calculator but it does have limitations. For data concerning the moon, CelNav sacrifices some accuracy in order to keep computational time reasonable. High-precision data for the moon requires calculating hundreds of terms, a task that would require so much time on the TI-84+ that the program would be of little practical use.



The above sample output is the same as the one shown in the Moon LOP description. As a basis for comparison, the corresponding values from the US Naval Observatory website are: GHA Moon 137°47', δ Moon 20°57', Hc 29°37.6', and Zn 276°. CelNav achieves moderate precision (within ~ 2 arcminutes) for the moon after 3-4 minutes of computational time. Data for Jupiter and Saturn are treated in a similar manner and achieve a similar level of precision. Data for the sun, Mars, Venus, and stars are generally accurate to less than ½ arcminute.