Introduction

The plugin facilitates celestial navigation by providing visual verification of measurements. It expands on the concept of Line of Position (LOP) by incorporating measurement error and displays true positions, typically as circles (COP). Notably, it allows sights based on bearing as well as altitude.

Taking Sights

Celestial Navigation Sights form is the first Celestial Navigation form you see when the application opens. It contains all of your sights. You can track up to approximately 30 sights. You can select NEW to enter a new sight. Duplicate an existing sight. EDIT to view and make changes to an existing sight or make changes to a sight you just duplicated. DELETE a sight or DELETE ALL sights. You can track up to approximately 30 sights on this form. If the form freezes up, you probably exceeded the limit. Delete a few sights.

First time, Select New to input a new sight.

Make the Sight Visible. Make visible the “eye” icon. The field before type

Sight Properties form, Sight Tab. There are 3 types. Altitude, Azimuth, Lunar. Altitude is the most common method for Celestial Navigation. We’ll start off with that. And discuss Azimuth and Lunar later on.

Celestial Body: You can select Sun, Moon, Venus, Mars, Jupiter, Saturn, Mercury, and 57 Navigation Stars that are visible in either the Northern or Southern Hemisphere plus Polaris.

Before taking a sight, adjust your sextant to remove errors. Know your Index Error. And know your Height of Eye above sea-level. These are important inputs of your sights in Celestial Navigation Plugin.

During the day, the Sun is an excellent body for a sight. The Moon is also an excellent body when above the horizon during the day. Venus is often bright and visible during the morning or evening. It too can make an excellent body during day light.

Before Sunrise or Sunset, make a plan and select stars and planets that will be visible above your horizon between Sunrise Nautical to Civil Twilight or Sunset Civil to Nautical Twilight.

Limb: For Sun or Moon, choose the lower limb unless obscured; then use upper Limb. For lunar sights with the sun, select upper Limb for outer limbs, lower for inner limbs, center if both upper or lower.

Sight Measurement (Hs): Enter your sextant reading. Integer degrees in the Degrees field, and decimal minutes in the minutes field. Your sextant can only measure 0.1 minutes of arc.

Minutes Certainty determines the width of the plotted circle or line of position. You can make minutes of uncertainty small, like 0.1 or less, which becomes more visible as you zoom into the

Open CPN chart. And you can make Minutes of Certainty 10 or larger if you are looking at a Chart for the entire world.

Date and Time tab: Be as accurate to the second as possible. Celestial navigation uses the positions of stars, the sun, and the moon relative to the observer's position on Earth. Because the Earth rotates, the Geo Position of all celestial bodies change every moment. Each second can account for over 0.1 nautical mile change in position. Thus navigators use precise to the second time of observation to calculate their location.

Recording: to improve time accuracy when taking a sight, after you lower the body to just touch the visible horizon and after you rock the sextant like a pendulum to confirm it is at the nadir, say “Mark” so an assistant can record the watch time. Then read and record the altitude from the sextant. If you are solo, try using a recording timer app on your cell phone with a wired microphone.

Watch Error.   If you have a digital watch, you have no watch error. If you have a mechanical watch, you can determine time by monitoring WWV and WWVH broadcast time signals via radio at 2.5, 5, 10, 15, and 20 MHz. A ticking sound for each second and voice announcement of the UTC time every minute. Track your watch error through your cruise.

Time (UTC) Tab: In the Celestial Navigation plugin, you Input the Universal Date and Time, not local date and zone time of your sight.   If your digital chronometer is set to Universal time, then you are set. But, if your mechanical watch is set to your local time zone, you’ll need to calculate Universal Time. Record the Watch time of your sight. When reducing the sight, Add or subtract your watch error (add if slow, subtract if fast). Then add your Zone Description. If you are not sure of your Zone Description, divide your DR Longitude by 15 and round the result.   For instance Longitude 55 W divided by 15 is 3.66. That rounds to ZD +4.   To get to Universal time, if West longitude, add 4 hours to your watch time. For instance, you recorded your a sight at 15-21-20 and your watch was 3 seconds slow. Add 3 seconds to make the Zone Time be 15-21-23. Then add +4 hours to 15 hours. UTC is thus 19-21-23. Remember that if after adding Zone Description you are over 24 hours, that’s the next day. You need to add 1 day and subtract 24 hours from the hours calculation.

Time Certainty defaults to 0 seconds and shows a single darker line on the Circle of Position. A time certainty of N seconds will show two darker lines the equivalent of N seconds apart.

After entering your time, Switch back to the SIGHT Tab.   And press the **FIND BUTTON**

Find Celestial Body. (The Find button).
Altitude (Hc). This is the Altitude of the body assuming you are at the DR Location. The DR Location defaults to be the Boat’s Location.   If you are keeping a DR Plot, you should be advancing the Boat along your track based on your speed.
Azimuth (Zn). This is the Bearing of the body from your Boat’s location to the body. It defaults in TRUE direction. When you select Magnetic, it will display the Azimuth in Magnetic direction using OpenCPN’s WMM algorithm.
Intercept (nm). This is the distance between the assumed DR Position and the Observer’s position (measured by the Sextant). The intercept is either Away or Towards the Azimuth Bearing.   If the DR position was determined by a GPS, the Intercept is your Sextant measurement error. Your estimated position is somewhere on the circle of position, most likely the closest distance of the Circle of Position to the DR, a perpendicular line.

The default DR location is the Boat's current position. But, you can input the Latitude and Longitude (in decimal degrees) of the DR position of when you took the Sextant Sight. This would be more accurate than Boat Position if it took you awhile to find the time to reduce the sight.

FIX: If taking a two body or three body sight within 20 minutes while moving, that can be a fix. Make visible the 2 or three bodies, then Press the FIX button. A calculated Fix for sights made visible will be displayed on the Chart (Big Red X).

The calculated Fix uses the Boat's Position as an initial estimate (you can change the latitude and longitude estimate) and then uses least squares to determine a position.

For shifted sights or magnetic north azimuth sights, the math is complex and not implemented. Currently, fixes are computed from Altitude sights. Azimuth sights may be supported in the future.

DR Shift Tab: This is useful for plotting a Running Fix. Select the earlier sight from the Celestial Sights form, make if visible, and press DR shift tab. Input Bearing, which is your boat's track (aka course) and Distance (nm) made between the earlier sight and the current sight. It will shift the earlier sight's circle of position in that bearing direction and that distance. Select the current sight from Celestial Sights form and make visible. Assuming you are following an accurate DR course, the shifted circle of position from the earlier sight should intersect with the current sight. And the intersection of the two circle of positions is a Running Fix. You can press the FIX button also. If you want to remove the Running Fix, then eliminate the Bearing and Distance from the earlier sight.

Clock Offset Tab. If doing traditional celestial navigation using a digital watch or a mechanical watch with a monitored watch error (WWV or WWVH), leave Clock Offset Tab to 0. Sean suggests adjusting the global "Clock Offset" until COP converge to determine local clock accuracy. No matter how Watch Error is adjusted, do it consistently to ensure precise navigational calculations based on Celestial observations.

Configuration Tab: Select color and transparency appearance. It does not affect results.

Parameters Tab: These are important settings for accurate sight reductions. You can save the data as defaults for future sights.

- **Index Error** is the Error from your sextant. It is the error you read when you observe the horizon and adjust the index so that the horizon appears to be a straight line across. The index error can be Positive or Negative.
- **Height of Eye** is the distance in meters between your eye and the water level below.
- **Temperature and Pressure**. Temperature and Pressure you took your sight. Temperature in Celcius, Pressure in Millibars. Amount of refraction is affected by temperature and pressure.

Calculation Tab: Shows the sight calculations.

Improved Accuracy which you can control

Accurate Time.

Well adjusted Sextant.   Adjust your sextant to minimize the index error. After that, know your index error before each sight taking session.

It is easy to mis-read the degrees and minutes on the Index arm. Or misread the micrometer drum for decimal minutes.   Each .1 minute error is .1 nm.

Accuracy in reading the visible horizon

For improved accuracy, take a run of 3 to 5 sights for a body a minute or so between sights. Plot Altitude (Hs) by time, and throw out the outliers.

After taking a run of sights and if they all appear valid, average the sight altitude (Hs) and time. And reduce the average.

During the day, a Meridian Transit of the Sun at Local Noon will give you Longitude.

Consider doing a mid morning and mid afternoon Sun sights while maintaining a DR Track will give you a Running Fix. It is better than an Estimated Position.

Polaris is the famous North Star, but it isn’t the best star for taking a sight. That’s because during morning or evening twilight, it is a dim star. However, If you can see Polaris and use your sextant to measure its altitude to the visible horizon, it will give you Latitude.

To enhance position accuracy, take a two body fix. The optimal 2 body sight is a 90 degree Bearing (Zn difference between 2 bodies) between the bodies. That’s hard to achieve. It should be greater than 45 degrees and no larger than 135 degrees. The Moon and Sun or Moon and Venus often make excellent two body fixes during daylight.

Even better, take a three body fix. If your horizon is unrestricted, the optimal angle between the 3 bodies is 120 degrees. Certainly the inner and outer bodies of the 3 bodies should be greater than 30 degrees. A 3 body fix will form a triangle of Lines of Positions. Your fix is inside the triangle. The tighter the triangle the better the sight.

The more practice in taking and reducing sights to see your personal error (sextant error), the better you will become. A beginner in average conditions should be able to determine position within 5 nm. A more advanced navigator should be 3 nm accurate. An expert should be inside of 1 nm.

Navigation in principle

Of course, if you already know where you are, there is no point in trying to determine it from the formulas above. But when you actually navigate, the odds are you don't know quite where you are, so how do we use the above formulas?

We draw what is called a position line or Sumner line. Although the modern position line is not quite a real Sumner line but it is close enough.

Like all good inventions, Sumner lines were discovered by chance by a fellow called, you guessed right, "Sumner", Thomas H. Sumner to be precise (maybe related to the late professor Julius Sumner-Miller). Sumner was a ship captain on his way from Charleston (South Carolina) to Greenock (Scotland). And he was worried because he had been sailing for several days in bad weather, the wind was blowing from the South East making Ireland a lee shore, and he had not been able to see the sun or any stars, the coast was getting near, and he did not know exactly where he was. Suddenly there was a break in the clouds, so he grabbed his sextant and snatched a quick sun sight, before the clouds covered the sky again.

Now he was wondering what to do with this information, so he played a "what if" game. He did not use the bearing formula above, because nobody had worked it out in quite that form yet, but he knew the altitude formula and he said "what if my latitude is... " and calculated the corresponding longitude and he plotted it on the chart, then he tried it again with another latitude, got another point on the chart. After doing that three or four times he suddenly realized that all the points he was marking on the chart seemed to fall on a straight line. Without thinking about it any more, he saw that the line needed pushing north by a few odd miles to lead straight over Small's light, so he turned north for those few miles, then turned to starboard until he was sailing parallel to that very first "Sumner line". His crew were a bit perplexed at that, wondering if the captain had gone mad, but when suddenly they arrived right at the very light, they thought he was a flaming genius. And so did the rest of the sailing community.

So why did the points fall on a straight line? They did not really but Sumner did not realize it at the time. The points Sumner was plotting were the points on earth from which any one would have seen, at the same moment as he did, the sun with exactly the same altitude. All those points are on a circle centered at the point on earth directly below the sun. Because this circle is usually huge, a small part of it appears straight on a Mercator projection chart.

So this is how we proceed in practice:

1. We assume we know where we are , we call this DR (for Dead Reckoning).

2. We calculate, based on the latitude and longitude of the DR, what the bearing and the
altitude of the celestial object would be at the time of observation.

3. We draw the bearing line passing through DR.

4. We compare the actual measured altitude with what it would have been had we been at
DR, the difference, in minutes of arc, is equal to the number of nautical miles that we have to move along the bearing line to find our position line. ie if the angle measured is greater than the calculated one by say 13' of arc, then we move towards the celestial object by 13 nautical miles, and if say the measured angle was less by 7' of arc than the calculated one, we would move away from the celestial object by 7 nautical miles.

5. Finally we draw a line at the right angle to the bearing line, passing by the point we have just found. This line is our position line and all we can tell is we are somewhere on this line.

Note the difference between our position line and Sumner's original one: our line is the tangent to the circle at the point nearest to DR, Sumner's was the circle. Sumner's line is in theory more accurate, but the circle is usually so large that the loss of accuracy is insignificant. Note also that in the tropics the circles can be extremely small, I remember reading about a P&O captain who used to obtain all his fixes without any calculation, he would take several observations when the sun was nearly dead overhead (say over a 15 minute period) for each time observation, he would plot the coordinates (GHA,DEC) of the Sun on his map then draw a circle of radius equal to (90 degrees -

measured altitude). Since over the 15 minute period he would probably have collected 4 or 5 observations, he would draw 4 or 5 circles which would all intersect at one point. Simple but effective especially as in the tropics, position lines usually end up running all almost North-South giving good longitude information but lousy intercepts and large errors in latitude. The noon sight is damn important then.

If you wait a few hours, the sun will change position, and you will be able to repeat the operation and determine a 2nd position line which will intersect the first. Provided you haven't moved in the interval, you are at the intersection.

If you have moved (and the odds, are you would because it can be pretty boring sitting around doing nothing on a boat that's just bobbing up and down in the middle of the ocean), then all you need do is translate the original position line in the same direction, and the same distance as you have travelled. Your position will be at the intercept of the new line and the translated one. Sailors call this the SUN RUN SUN method.

The above information was edited from Eric De Man siranah.de