# The Navigational Scales of the Triangular Quadrant

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## Introduction

The Triangular Quadrant could be used both as a traditional sector and as an observational instrument. Gunter rules and sectors, even combined in a single instrument, have been used in navigation for a long time, but usually as a calculation aid.[1] Although they can be considered navigational instruments (i.e. instruments used in the art of navigation), it was John Browne who intended to use this sector to actually make observations with it, not only for astronomy and land surveying (see Figure 1), but also for navigation. Already on the title page of his 1662 work we read that the instrument was a *"...Quadrant on a Sector[,] Being a general Instrument for Land or Sea Observations: Performing all the Uses of the ordinary Sea Instruments, as Davis Quadrant, Forestaff, Crossstaff, [and] Bow..."*.[2] Browne thus explicitly wrote that it was made to take observations with, a property he further elaborates upon throughout the 1662 work.

*Figure 1: The Triangular Quadrant as an observational instrument (J. Browne, 1661).*

In order to make observations with the Triangular Quadrant it needed several accessories and dedicated scales.[3] Among the accessories were "...four or five sights..." and a plummet.[4] The plummet served as a vertical reference in forward observations on land or at sea (i.e. like a mariner's or land surveyor's quadrant). The instrument could however also be used in a backward manner like a *"... Davis Quadrant, [...] Crossstaff [sic.], [and] Bow, With more ease, profitableness, and conveniency [sic.], and as much exactness as any or all of them."*[5]

The five sights consisted of one "turning sight", one "(sliding) horizon sight", and *"...the object (or shaddow [sic.]) sight, of which there be 3. all differing according to your use and occasions: one to slide to any place, the other 2. to be put into certain holes..."* which were made for the purpose in the instrument.[6] Three of the sights are depicted in a drawing in his 1662 work (see Figure 2).[7]

The sights and plummet could be placed at several locations on the Triangular Quadrant, depending on which of the many possible configurations of the instrument was used (for nomenclature of these locations see Figure 3). The turning sight was either placed at the 'leg center' [sic.] (also known as 'foot center' [sic.]) or 'head center' [sic.] (also known as the 'rectifying point').[8] The horizon sight was either used at the inside of the cross-piece or at the outside of the moveable leg. Finally the location(s) for the objects sight(s) were the object sight centres at the end of the head leg and moveable leg, and the 00, 10, 20, and 30 degree marks on the cross-piece. A plummet could be suspended from a pin in the leg centre of the head leg.

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[1] O. van Poelje, 'Gunter Rules in Navigation', in: *Journal of the Oughtred Society, Vol. 13, No. 1,* (2004), pp.11-22. J. Browne, *The Description and Use of a Joynt-Rule Fitted with Lines for the finding the Hour of the Day and Azimuth of the Sun, to any particular Latitude; Or, to apply the same generally to any latitude. Together with all the uses of Gunters quadrant applyed thereunto ... Contriv'd & written by J. Brown, Philom.,* (London, 1661).
[2] Browne, *The Triangular Quadrant...*, (London, 1662), title page.
[3] For a more elaborate discussion on the use of the Triangular Quadrant as a navigational instrument see N. de Hilster (in press), 'The Triangular Quadrant as a Navigational Instrument', in: *The Bulletin of the Scientific Instrument Society*.
[4] Browne, *The Triangular Quadrant...*, (London, 1662), p.4.
[5] Browne, *The Triangular Quadrant...*, (London, 1662), title page.
[6] idem, p.4.
[7] N. de Hilster (in press), 'The Triangular Quadrant...'
[8] Browne used the spelling 'center', which is now considered the American spelling of this word. For this reason the same spelling is used in Figure 3. For the sight settings see Browne, *The Triangular Quadrant...*, (London, 1662), pp.7-18.

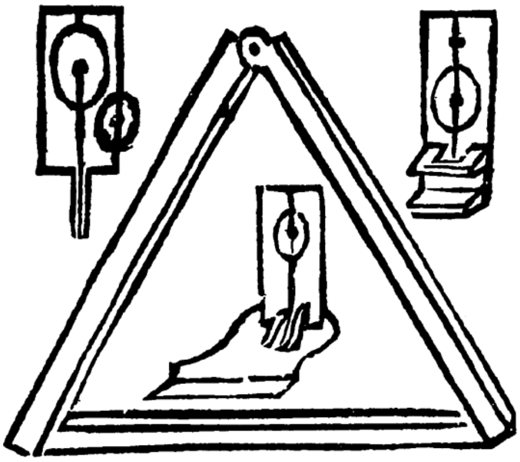

*Figure 2: The Triangular Quadrant with three of its sights according to Browne (London 1662).*

There were twelve different basic set-ups for the instrument, each for its specific use.[9] Using twelve propositions the set-ups are explained to the user without, however, any further images. The first proposition dealt with its mathematical use as a sector, while the other eleven propositions, numbered with Roman numerals, with the 4 in the additive form (i.e. 4 is written as IIII instead of IV), all deal with the observational side of the instrument. The last three of the propositions are variations of ones already mentioned, but instead of observing the celestial body's altitude, the observer's latitude is directly observed by setting one of the sights at the current declination.

Some of the propositions reveal details of how the navigational version of the Triangular Quadrant could be recognised. The first proposition dealing with observations is proposition II. It uses the Triangular Quadrant in a forward fashion. A turning sight is attached to the head centre, an object sight to the end of the head leg, and a horizon sight to the inside of the cross-piece. Due to the slight offset of the head centre in respect to the hinge, the altitude scale on the inside of the cross-piece would have run from roughly 3 degrees at the head leg end up to about 57 degrees at the moveable leg end as shown in the image in Browne's 1671 work.[10]

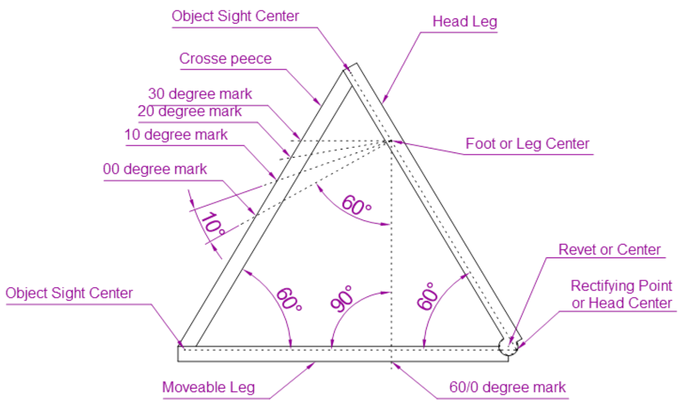


*Figure 3: The parts of the Triangular Quadrant with annotation in period spelling*

According to proposition III, two object sights were placed in *"...two holes at the end of the line of naturall [sic] signs..."*. These holes would normally take a pin or sight to fix the mortise and tenon joints when the cross-piece is attached. In order to accommodate the sight these holes must have been of considerable, at least a few millimetres, in diameter. The way Browne described the method of determining the angle observed in Proposition III was however mathematically incorrect. He wrote that using a compass one should *"...take the parallel sign of 30 and 30 [of the lines of natural signs on both legs], and measure it from the Center [of the hinge], and it shall reach to the sign of half the angle required [on the line of natural signs]"*. The resulting angular error exceeds a whole degree around 35 degrees aperture of the instrument, when this method is applied (see Figure 4). It could well be that Browne was aware of this as he proposed to use the method only in case *"... an altitude be required to be had quickly..."*.[11]

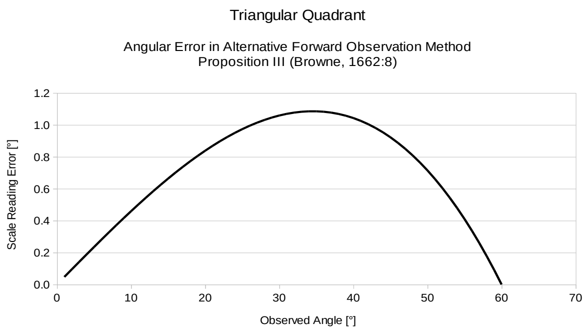


*Figure 4: The altitude error of the alternative forward method*

[9] N. de Hilster (in press), 'The Triangular Quadrant...'
[10] See figure 2 in W. Rudowski, 'The Triangular Quadrant', in: *Slide Rule Gazette, Issue 15, Autumn 2014*, (Fordham, 2014), pp.31-39.
[11] Browne, *The Triangular Quadrant...*, (London, 1662), p.8.

Even more holes appear in propositions IIII and V (for their locations see Figures 3 and 5). Proposition IIII discusses the first set-up in the backward manner. A turning sight (TS in Figure 5, OS refers to the Object Sight, HS to the Horizon Sight) was set at the leg centre, while *"...one of the object sights [was placed] in the hole by 00. on the outer edge of the crosse peece [sic.]..."*.[12] The proposition was limited for near zenith observations as one ran out of space on the moveable leg scale. When observing altitudes around 90 degrees, the horizon vane would have to be placed near the hinge while the scale at the moveable will not continue beyond about 87 degrees (see Figure 6). For this in proposition V the object sight was placed *"... to a hole or two further as suppose at 10, 20, 30 degrees more, towards the further end of the crosse peece [sic.] and then observe as you did before in all respects, as with a Davis quadrant..."*.[13]

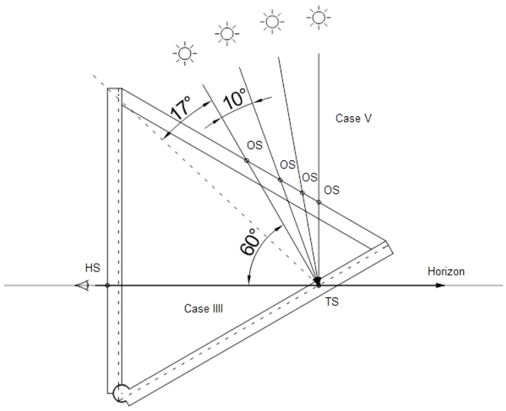


*Figure 5: Propositions IIII and V*

Proposition V was to solve the problem for near zenith observations, but nothing is said about the other direction (the near horizontal) in proposition IIII where one is limited to a minimum altitude of about 17 degrees altitude (see Figure 5). This minimum angle is about twice the minimum angle that could be observed using other period back sight instruments. Perhaps there were another few holes in the opposite direction in the cross-piece, but these are not mentioned in proposition V and as no cross-pieces are known to have survived this issue remains unsolved for the moment.

As mentioned before, propositions X-XII allowed us to directly observe the latitude instead of the altitude. This was accomplished by setting one of the sliding object sights at the current declination on the cross-piece and using the sliding horizon sight on the moveable leg. Proposition X then explains how to take the latitude in a forward manner as in Proposition II. Proposition XI does the same for the backward manner discussed in propositions IIII and V, while proposition XII shows this for the plummet method. When using the plummet method a scale on the moveable leg provided the angle.

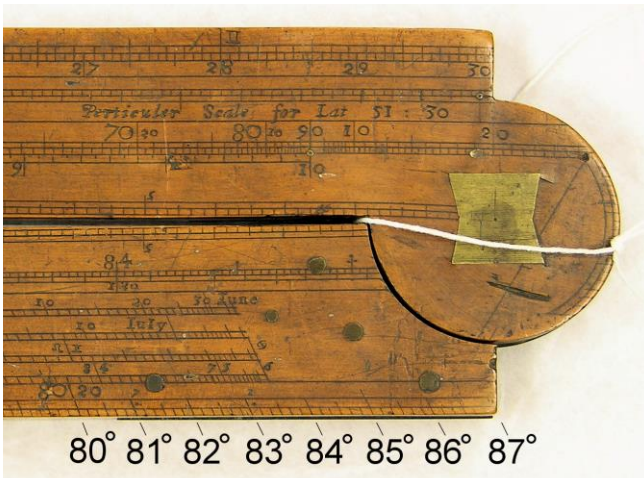


*Figure 6: The altitude scale near the hinge on the movable leg of the 30" Triangular Quadrant at the MHS (Picture by the author)*

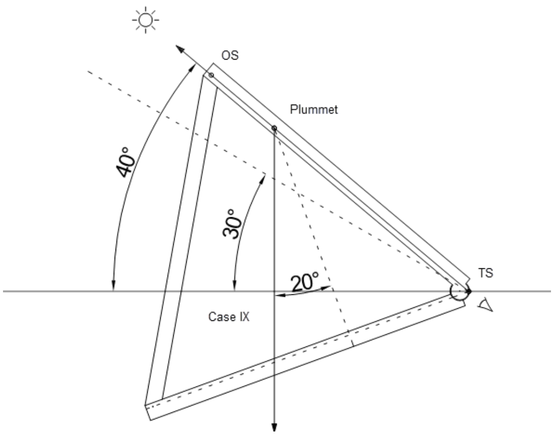


*Figure 7: Proposition IX*

[12] idem, p.9.
[13] ibid.

**Recognising navigational Triangular Quadrants**

First of all the size is a good indication as Browne tells us that the larger ones, with a radius between 18 and 36 inches, were intended for navigation.[14] The mortise and tenon joints had holes drilled through them so that the object sights could be used to lock the cross-piece into place. These holes were not arbitrarily drilled but had to be in line with the line of signs, one of which would be present on both legs of the instrument. The size of these holes is not given, but it should be large enough to make the pin of the object sight sturdy enough to keep the sights perpendicular against the body of the instrument, so at least a few millimetres in diameter.

The cross-bar not only had scales on its face, but also on at least one of its sides. The side of the outer edge would have a scale with 00 almost or perhaps even exactly in the centre and have several holes drilled along the edge to have the object or shadow sight fixed at 00, 10, 20, and 30 degrees. There may have been further holes in the opposite direction along the same edge to accommodate observations of lower altitudes. The inner edge of the cross-piece also would have had an altitude scale with roughly 3 degrees at the head leg end and running up to about 57 degrees at the moveable leg end. For convenience of reading this scale may have been continued on the inside of the cross-piece.

None of the known surviving Triangular Quadrants have all of these indicators, although it has to be commented that, as mentioned above, no cross-pieces are known to have survived, so it is not possible to judge the surviving instruments based on this scale. The largest instrument in the MHS collection has a radius of 30 inches and thus is large enough for navigational purposes, but the holes for the object sights to hold the cross-piece seem to be too small in diameter and are not drilled in line with the line of signs. One of the specimens in Taylor's collection does have holes of sufficient diameter and drilled at the proper locations, but with 12 inches radius its size is far too small. All other specimens are too small and lack the holes for the object sights. It therefore seems that, as far as we know, no navigational Triangular Quadrant survived.

***Editor's Note***: Throughout the article, "line of signs" ≡ "line of sines" in modern terminology.

**Image references**

Figure 1: Browne, *The Description and Use of a Joynt-Rule* ..., (London, 1661), © British Library Board. All Rights Reserved (Shelfmark 1136.f.45.(1.)).

Figure 2: Browne, *The Triangular Quadrant...*, (London, 1662), p.2, © British Library Board. All Rights Reserved (Shelfmark 1136.f.45.(2.)).

Figures 3, 5 and 7: Sketches by N. de Hilster.

Figure 4: Graph by N. de Hilster.

Figure 6: Picture by N. de Hilster.

[14] In 1661 Browne wrote that the navigational ones measured between 24 and 36 inches, while ten years later he increased this range to 18 to 36 inches, see Browne, *The Triangular Quadrant...*, (London, 1662), p.2 and Browne, *The Description and Use...*, (London, 1671), p.1.