Direction is one of the fundamentals of navigation. It is so important that navigators seldom refer simply to ‘direction’ as such, but use a variety of technical terms such as course, heading, bearing, and track to refer to specific types of direction – such as the direction from one object to another, or the direction a boat is pointing.

Different kinds of direction
As navigators, we have to deal with many different kinds of direction. To distinguish between them, each one has a different name. each of these technical terms has its own, specific meaning: course and heading for instance, are not interchangeable!

Bearing is the direction of one object from another.

Course is the direction the vessel is intended to be steered.

Heading is the direction in which the vessel is actually pointing at any given moment. It is very seldom exactly the same as the course.

Track Angle is the direction the vessel is actually moving over the surface of the Earth. He effects of wind and tide mean that it is not usually the same as the heading. In practice, the word angle is often omitted. Ground Track, Course Made Good (CMG) and Course over Ground (CoG) all mean the same thing.

Water Track is used by marine navigators to refer to the direction the vessel is moving through the water. It is sometimes called Wake Course.

The formal definitions of north, south, east, and west are all based on the Earth’s rotation. Directions between these four cardinal points can be given names, too. Southeast, for instance, is mid-way between south and east, southwest is mid-way between south and west, and so on. Further sub-division produces eight quarter cardinal points, such as south southwest, west southwest. Even these can be sub-divided to produce 16 by-points, with names such as north by west – meaning ‘a little bit west of north’.

Directions could be specified to a precision of just over five degrees by a further subdivision into half points. It’s very difficult to steer a small boat any more accurately than this, so the points system survived in yachts and small commercial craft until the latter half of the twentieth century. Cardinal points, half cardinals, and quarter cardinals are still used for approximate directions (in weather forecasts, for instance) but for navigational purposes they have been almost entirely replaced by the three-figure notation.

Three-figure notation is now virtually universal. Directions are referred to as angles, measured in degrees, counting clockwise from north, so east is 090°, southeast is 135°, and so on.

Directions should always be written and spoken as three distinct figures. This isn’t pure pedantry! Many small boat compasses are marked at ten degree intervals, with the final zeros left out to save space, so if you ask a helmsman to steer “thirty five” there is a very real risk that he will steer 350° (to the 35 mark) rather than the 035° you intended.

Measuring direction – in the real world

In order to measure direction, any boat should carry at least one compass. Most carry two or more. One is usually fixed to the boat itself, and is used to show the direction she is pointing, so it is called the steering compass. The other is a smaller, hand-held version used for measuring bearings, and known as a hand-bearing compass.

Sometimes, one compass can be used to do both jobs: a and bearing compass mounted in a suitable bracket, for instance, can be used as a steering compass, and is particularly suitable for cruising dinghies, small keelboats and RIBs. At the other extreme, many ships use a sighting arrangement called a pelorus or azimuth circle mounted on top of the main compass for taking bearings.

It’s not unusual, though, for even quite small yachts to have several compasses. A yacht with tiller steering, for instance, may well have one steering compass on each side of the cockpit; a flybridge motor cruiser usually has one at each steering position. There may also be one at the chart table or over the skipper’s berth, and another to control an autopilot.

Magnetic compasses

Although there are several alternatives available, the overwhelming majority of yachts and small motor boats use compasses that work by sensing the direction of the Earth’s magnetic field. Essentially, the Earth behaves as though there is a gigantic bar magnet embedded in its core. Of course, there isn’t really a magnet there, and it is still a matter of some conjecture exactly what is going on to produce the effect. Nevertheless, for centuries, navigators have been able to make use of the fact that a free-swinging needle-shaped magnet will turn to point north south.

Small compasses, such as the ones used for back packing and orienteering on land, still use a singe magnetised needle as a north pointer. Most marine compasses, however, use several magnets, or a single ring shaped magnet mounted on a circular card. The card is marked with a scale of degrees or compass points, and is suspended in a bowl filled with a mixture of water and alcohol. Of course, there are many variations on this theme: some compasses are designed to be looked up from above; some are designed to be seen edge-ways on, and there are even some that are intended to be viewed from underneath. The extent of the damping also varies: compasses intended for motor boats, in particular, are usually much more heavily-damped than those aimed at sailing boats, in order to cope with the rapid pitching motion.

An alternative kind of magnetic compass, known as a flux gate, has no moving parts, but uses electronics to sense the direction of the Earth’s magnetic field. This has enormous advantages: a flux gate compass is compact, can easily be linked to other electronic equipment such as a autopilot or radar, and its output can be automatically processed to correct for errors. Because the sensor and display can be separate, it’s even possible to reduce errors at source, by mounting the sensor wherever it will be least affected by stray magnetic fields. Apart from its dependence on electrical power, the big weakness of a flux gate compass is that it is very susceptible to tilt: for every degree that the sensor is tilted, it can easily produce two degrees of direction error. This problem can be overcome electronically, but most flux gate compasses also have quite sophisticated stabilising arrangements.

Compass Errors

Variation

All magnetic compasses – needle, swinging card, or flux gate – depend on the assumption that the Earth's magnetic field is lined up with its north-south axis. Unfortunately that isn't quite true: in 2003, the Earth's magnetic North Pole was nearly 900 kilometres away from the real North Pole.

This means that there is a discrepancy between the north shown by a magnetic compass and the represented by the meridians on a map or chart. The discrepancy is called variation because it varies from year to year (as the magnetic North Pole moves) and from place to place.

For example, in 2003, in parts of Alaska and Newfoundland, variation was about 25°W. In Denmark and parts of Norway, however, it was less than 1°W. Around the British Isles, it is greatest on the west coast of Ireland (about 7° 30'W) and gradually reducing.

The amount of variation can always be found by looking on the navigational charts, where it can usually be found in each compass rose or else in the information panel just below the chart title.

It will be given in the form 5° 15'W 2000 (9'E). This means that Magnetic North was 5° 15' west of True North in 2000, and was moving eastwards y 9 minutes per year (9'E). in 2003, therefore, it will have changed by 3 x 9' = 27'.

As the variation was originally west, and the change is eastward, the variation must be reducing, so it has become 5° 15'W – 27' = 4° 48'W. (Note that there are sixty minutes in a degree). For practical navigation purposes, though, this level of accuracy is unnecessary, and the answer can be rounded off to 5°W.

What this means is that if you measure the bearing of a lighthouse as 130° using a hand-bearing compass, the True bearing of the lighthouse is 125°. If you then look at the chart and find that you need to steer 240°(True), it means that the helmsman, using a magnetic compass, needs to steer 245°.

Once you know about an error, you're usually at least half way to correcting it, and in this case it is a matter of simple arithmetic:

To convert from Magnetic to True add easterly variation or subtract westerly variation.
To convert from True to Magnetic add westerly variation or subtract easterly variation.
There are several mnemnics to help remember this.
One is the simple rhyme, Error west, Compass Best; Error east, Compass Least (best in this case meaning biggest!).

Another is the CadET rule, which is a reminder that to get from C (Compass) to T (True) you have to 'ad' (add) E (Easterly errors).

Magnetic Anomalies
The Earth's magnetic field is very weak, so it is easily distorted by large metal structures such as wrecks, pipelines, and jetties. Fortunately, these man-made structures are generally relatively small, so their effects on a compass are extremely

localised. Various types of naturally-occurring magnetic material can have a more pronounced effect, and cover a wider area.

Where such magnetic anomalies are known to occur, they are marked on the relevant navigational chart. There is very little you can do about magnetic anomalies, other than to be aware of their existence and to bear in mind that, if you are in an affected area, the compass will be less reliable than usual. It will not, however, spin on its axis or self-destruct!

Deviation

Significant magnetic anomalies are relatively rare, and their effects are generally short-lived. Almost every boat, however, includes a number of magnetic components, including a few such as electric motors and loudspeakers that include powerful magnets, and others, such as electric wiring, that sometimes generate magnetic fields. The boat, in other words, carries its own magnetic anomalies around with it. The individual components may be small, compared with an under-sea deposit of iron-ore, but they are very much closer to the compass, so they are responsible for a third type of compass error, known as deviation.

Deviation is almost always present, to some extent, but it changes as the boat alters course and, to a lesser extent, as she heels or pitches. It is easy to see why, if you think of a boat with a magnetic object such as a radio, mounted just ahead of the steering compass.

When the boat is heading north, the north-seeking pole of the compass needle is attracted towards the object. Of course, this doesn't matter, because that is the direction the needle should be pointing anyway.

Much the same applies when the boat is heading south.

When the boat is heading east or west, however, you can visualise the compass needle being pulled in two directions at once; with the Earth's magnetic field trying to keep it in north-south alignment, while the magnetic object on board tries to turn it east-west. If the deviating object were to one side of the compass – a steel gas bottle in a cockpit locker, for instance – the principle would be the same, but its effect would be different: deviation would be negligible when the boat is heading east or west, and at its maximum when the she is heading north or south.

Things which are directly underneath (or above) the compass have virtually no effect so long as the boat is upright. As she heels over, though, the geometry changes; an object which was originally below the compass moves to port when the boat heels to starboard, and vice versa. As soon as it is on one side of the compass rather than directly below, it starts to have a deviating effect, producing what is known as 'heeling error'.

In real life, most compasses are surrounded by many deviating influences, each of which has its own particular characteristics. Their combined effect, however, can be measured. A skilled compass adjuster can even counteract their influence, to reduce deviation, by fitting small magnets and iron rods in and around the compass bowl. Some compasses even have corrector magnets built in, adjusted by screw on the outside of the bowl.

Compass adjustment is a skilled and specialised job, but every navigator needs to know how to keep deviation to a minimum, how to check it, and what to do about it.

Minimising Deviation

As deviation is caused by magnetic objects near the compass, the obvious preventative measure is to keep magnets and magnetic materials as far away from the compass as possible. In the case of an electronic instrument, designed specifically for marine use, look for a label indicating its 'compass safe distance' – the distance at which it will deflect a compass by less than one degree.

Be particularly wary of movable objects such as toolboxes, tinned food, portable radios, and mobile phones.

Checking for Deviation

There are many different ways of checking and measuring deviation. Essentially, they all involve comparing the direction indicated by the compass with some known direction – a process known as swinging the compass. A compass adjuster will carry out a swing before and after making any adjustment, but it's a good idea to do it yourself at least once a year, and certainly after any repair or maintenance work that might have affected it.

The most straightforward method is known as a 'swing by distant objects'. It involves taking the boat to an accurately-known position, and then turning it round to point at each of several distant landmarks in turn. The true bearing of each landmark can be found from the navigational chart, and converted to a magnetic bearing. The difference between the magnetic bearing and the bearing shown by the boat's compass represents the deviation on that particular heading.

Suppose, for instance, that the chart shows that the True bearing from our present position to Berry Head lighthouse is 172°, but when the boat is pointing straight at the lighthouse, the steering compass reads 174°. First convert the charted bearing from True to Magnetic using the CadET rule – in this case Variation is 6° west.

$$\begin{array}{l} 172° \text{ (True)} \\ \underline{+\ \ 6}° \text{ W} \\ 178° \text{ (Magnetic)} \end{array}$$

Then, find the difference between the Magnetic and Compass bearings:

$$\begin{array}{r} 178° \text{ (Magnetic)} \\ \underline{-174}° \text{ (Compass)} \\ 4° \phantom{\text{ (Compass)}} \end{array}$$

Finally, name the deviation east or west, according to the 'Error east, Compass Least,' rule. In this example, the compass bearing is 4° less than the magnetic bearing, so the deviation is 4°E.

Exactly how accurate your initial position needs to be depends on the accuracy you hope to achieve and the distance to your distant objects. An accuracy of one degree can be achieved if you know your position to within 100 metres and use landmarks that are three miles away. If the landmarks are six miles away, the position accuracy can be correspondingly less – 200m. this level of accuracy can easily be achieved by motoring in slow circles around a charted wooden post or beacon, by finding the intersection of two transits, or by GPS.

A single transit (two objects that appear to be in line with each other) is useful for a quick check of the compass, because it is easy to draw a line on the chart that represents your line of sight passing through both objects. When the two objects appear to be in line with each other, you must be somewhere on that line. If, at the same moment, you point the boat straight at the two objects, then its heading, as shown by the steering compass, should correspond with the magnetic bearing of the transit.

Be careful, though, that in tidal waters or if there is a cross wind, there may be a distinct difference between the heading required to point straight at the transit (for a compass check) and the heading required to stay on the transit line.

Correcting for Deviation
Once a compass adjuster has done his best to remove deviation, he will draw up a deviation card, showing any residual errors that could not be removed.

If the compass has not been professionally adjusted, it is even more important to produce your own deviation card summarising the deviation and showing how it changes.

If the deviation is very small – less than about two or three degrees - it is common practice to ignore it, on the basis that it is impossible to steer that accurately anyway. On the other hand, correcting for small amounts of deviation is a very simple arithmetical process, identical to the procedure for correcting for variation:

To convert from Compass to Magnetic add easterly deviation or subtract westerly deviation.

To convert from Magnetic to Compass add westerly deviation or subtract easterly deviation.

The mnemonics that are used to handle variation are equally applicable to deviation.

Deviation and hand bearing compasses
The information given on the deviation card is only true if the magnetic geometry of the boat is unchanged. If you move a gas bottle from one side of the cockpit to another, it could have an effect.

The effect would be even more noticeable if you moved the compass, because you would almost certainly be taking it away from some deviating influences but towards others that could well be pulling the needle in a completely different direction.

This means that it is impossible to produce a deviation card for a hand-bearing compass which, by its very nature, may be used anywhere on the boat. Rather than risk applying a ‘correction’ for deviation which could make matters worse, it is normal practice to assume that the deviation of a hand-bearing compass is zero.

Bear in mind, though, that this does not mean that a hand-bearing compass is immune from deviation. If it were possible to produce a deviation-free magnetic compass, that technology would certainly have been applied to steering compasses.

It is a good idea to get into the habit of using a hand-bearing compass only in areas that are well clear of obvious sources of deviation… and never, ever, be seduced by the suggestion that a hand-bearing compass can be used to check the deviation of a steering compass. The error of a hand-bearing compass can change significantly even in the space of a few metres, but it's possible to carry out a simple, snapshot test of its accuracy by taking a bearing along a transit, in much the same way as a transit can be used to check the accuracy of a steering compass.

Deviation and flux gate compasses
Flux gate compasses are just as susceptible to deviation as any other magnetic compass. They have the advantage that the sensor can be placed anywhere in the boat, where deviating influences may be less than at the steering position, but this is partly outweighed by the fact that the sensor is usually a small black component, out of sight and out of mind in a locker. It is very easy for anyone to unwittingly place deviating objects close to it without being aware of the consequences.

A major disadvantage of flux gate compasses is that they almost all include an automatic calibration facility that measures and corrects for deviation automatically. The procedure varies, but usually involves turning the boat slowly through 270°. It is easy, quick and costs nothing, so there is no reason not to do it regularly. Once it has been done, the flux gate's display should show deviation-free magnetic directions – but it is still worth checking by carrying out a conventional compass swing or by spot-checking against any convenient transit.

Combining compass errors
The existence of two correctable errors – variation and deviation – mean that we have to get used to dealing with three different kinds of north, and be able to convert directions from one form to another.

Until recently, most charts showed Magnetic directions as well as True, but this practice is becoming less common. In any case, the most useful ways of expressing direction are 'Compass' (as shown by the boat's compass) and 'True' (referring to the real world and to the parallels and meridians of latitude and longitude shown on the chart).

Magnetic directions are mainly used as a stepping stone in the conversion process from one to the other.

As the arithmetic involved in correcting for variation and deviation is essentially the same, it is quite possible to combine the two. Suppose, for instance, we are steering 150°(C) and need to convert it to True in order to plot it on the chart. Variation (taken from the chart) is 6° W and deviation (taken from the Deviation Card) is 5°E.

The full calculation looks like this:

Compass heading	150° (C)	
Correction for Deviation	+ 5° W	(Add easterly error)
Magnetic heading	155° (M)	
Correction for Variation	- 6° W	(Subtract westerly error)
True Heading	149° (T)	

In this particular example, the end result is a change of only one degree, so it hardly seems worth all the effort. It would be easier, quicker, and more reliable if we looked at the two errors, and applied a combined correction, like this:

Westerly error	6°
Easterly error	5°
Combined error	1° W
Compass heading	150° (C)
Combined correction	- 1° W (Subtract westerly error)
True Heading	149° (T)

This method is perfectly acceptable so long as both errors are small – less than about 10°. The stepping stone analogy is useful: if you were crossing a very small stream, with stepping stones close together, it might be better to cross in a single step, rather than risk slipping in the middle.

Coping with large errors

If the gaps between the stepping stones are large, however, it is safer to take them one step at a time – and the same is true when dealing with large compass errors.

The reason becomes clear if you think of the situation in northern parts of the USA and Canada, where variation is in the order of 20 degrees. Suppose, for instance, that we need to steer a course of 070°(T), and need to convert it to Compass. Variation (taken from the chart) is 22°W.

The deviation card shows that on a heading of 067½°, the deviation is 2°E. From this, the combined error method of calculation suggests that the compass course should be:

Westerly error	22°
Easterly error	2°
Combined error	20° W
Compass heading	070° (T)
Combined correction	+ 20° W (Add westerly error when going from True
True Heading	090° (T) to Compass)

The trouble is that on a heading of 090°(C), the deviation card shows an error of 4°, not the 2° we have used!

So long as the Deviation is generally small this problem can be prevented simply by doing the calculation in full, step-by-step.

The mnemonics: True Virgins Make Dull Companions (TVMDC) and Cadbury's Dairy Milk Very Tasty (CDMVT) may help you to remember that Variation (V) separates True (T) and Magnetic (M), and that Deviation separates Magnetic (M) from Compass (C).

If the deviation is also large, the process may warrant a further refinement known as second error correction. In effect, this involves doing the deviation calculation twice.

The first time gives an approximate answer, which is then used to make a more accurate estimate of the amount of deviation to apply.

Suppose, for instance, that we need to convert a course of 090°(T) to Compass, in an area where variation (taken from the chart) is 22°W, and on the boat whose deviation card is shown here.

True heading	090°(T)
Correct for variation	+22° W
Magnetic heading	112°(M)
Correction for deviation	-18° E
Compass heading	094°(C)

The first error correction suggests that the deviation is more like 13°E than 18°E. using this to revise the calculation gives a second error correction result of 097°.

Non-magnetic compasses
Variation and deviation are undeniably a nuisance; navigation would be much simpler, more accurate, and less prone to human error if compasses indicated direction relative to True north.

At present, there are at least two completely types of compass available which can do exactly that. They are the gyro compass and GPS compass. Others, such as ring laser gyros which are used in military applications and aircraft, may eventually trickle down to recreational craft.

Gyro compasses and GPS compasses are both heavy, expensive and dependant on electrical power. Of the two, gyro compasses have been tried, tested, and developed for longer, and have the advantage of being completely independent, but they are also the more expensive, and suffer from the drawback that they must be switched on several hours before they are required. A gyro compass will usually withstand temporary interruptions to its power supply (though the associated display equipment may not!) but because it is essentially a mechanical device, its performance will eventually deteriorate as wear and tear take their toll. Accuracy also deteriorates as speed increases – a feature which can be predicted and therefore corrected, but which is inherent in the way the compass works.

GPS compasses are a spin-off from the Global Positioning System. At present, they are relatively expensive compared with magnetic compasses, but are cheaper than gyros, and offer similar accuracy without the need for ‘running-up’ in advance. They have no moving parts, so maintenance is minimal, but any failure of the power supply will cause an instant failure of the compass. They are also totally dependant on the Global Positioning System.

How a gyro compass works
The heart of a gyro compass is a heavy metal wheel – typically several kilograms in weight – turning at high speed. This gyroscope has two properties that make it useful as a compass: gyroscopic inertia; and precession.

Gyroscopic inertia means that a gyroscope naturally tries to keep its spin axis pointing in the same direction in space. In other words, if you started it spinning with its axis pointing towards a distant star, it would keep tracking the star even while the Earth turned underneath it. If the star happened to be rising over the eastern horizon at the time, the gyro would gradually tilt upwards as the star rose, then turn and tilt downwards again as the star set.

Precession is a curious characteristic of gyroscopes. If you try to divert the axis of the spinning rotor, gyroscopic inertia means that it resists your efforts. Precession, however, means that it will move – albeit slowly – but at right angles to the force you apply.

If the gyroscope is mounted in a ballasted frame, then as it tries to tilt to track the star, the frame will apply an opposing (downward) force to the eastern end of the shaft. The gyroscope's response is to precess the eastern end of the shaft southward.

This process continues until the gyroscope eventually settles with its shaft aligned with the Earth's axis of spin – pointing True North.

How a GPS compass works

A GPS compass consists of two or three antennas – typically small, mushroom-shaped units – mounted on a horizontal bar or tripod mounting and linked to a single processing unit. The GPS satellites transmit microwaves, with a wavelength of about 20cm. like all radio waves, they are made up of fluctuating electrical and magnetic fields, but it is easier to visualise as though they were ripples on a pond, spreading outwards from the satellite.

If the two antennas are exactly the same distance from a satellite, the processor will receive two copies of the signal – one through each antenna – at precisely the same moment, and perfectly in phase wit each other (i.e. with the 'crests' and 'troughs' of the signal arriving at one antenna perfectly in step with those arriving at the other).

If one antenna is slightly further away from the satellites than the other, however, the central processor will receive two versions of the signal, slightly out of phase with each other. If, for instance, one antenna is receiving the 'trough' then one antenna must be 10cm nearer to the satellite than the other.

The satellite signal includes details of its precise position in space, so the GPS compass knows where the signals are coming from. From the phase difference between the signals received by its two antennas, the compass can also calculate its own orientation relative to the satellite. By combining the two, it can calculate the vessel's heading.

Measuring direction on a paper chart

Direction, on a chart, is shown in two ways:

- The meridians and parallels that make up the grid of latitude and longitude.
- Compass roses – representations of a compass card, dotted around the chart. All compass roses have a ring of graduations showing directions relative to True north. Some, but not all, have a second, inner ring showing graduations relative to Magnetic north at the time the chart was produced. Some older charts have a third ring inside the other two, showing compass points.

Unfortunately, although everyday navigation often involves drawing a line in a particular direction, or measuring the direction of a line that you have just drawn, those lines hardly ever pass through the centre of a compass rose. Literally dozens of different gadgets have been invented to overcome this problem, but they can usefully be divided into four groups:

- Protractors
- Parallel rulers
- Swinging arm plotters
- Breton type plotters.

You don’t need to be able to use all of them, but it’s essential to be thoroughly familiar with at least one type, and useful to be able to manage one or two alternatives in case you ever need to navigate with someone else’s choice of equipment.

Protractors
Several types of protractor are sold for chart work. Their shapes vary from semicircular, like those used in school geometry lessons, through navigational triangles, to squares or rectangles, but essentially they all consist of a flat piece of transparent plastic, marked with a scale of degrees. Most have a small hole at the centre of the scale.

There are two ways of using a protractor, depending mainly on whether the scale of degrees is marked in a clockwise or anti-clockwise direction. Some, including the Douglas Protractor and its variants, have two scales running in opposite directions, so you can use either.

To measure the direction of an existing line using a clockwise scale
Put the central hole on the line, preferably where it crosses either a north-south meridian or an east-west parallel of latitude. Line up the grid of the protractor with the meridian or parallel, and read off the direction where the line you are measuring cuts the scale marked on the protractor.

To draw a line in a particular direction using a clockwise scale
Put the central hole of the protractor on the point at which you intend to start the line, and rotate the protractor so that the grid marked on it is parallel to the grid of meridians and parallels on the chart. Make a pencil mark through the central hole, and another one next to the point on the scale that corresponds to the direction you are interested in. then use a straight edge (either a separate ruler or the edge of the protractor itself) to draw a line passing through the two marks.

If you want to draw the reciprocal (a line heading in the opposite direction), so that it represents the direction from something rather than the direction to something), it can easily be achieved by exactly the same process, but using the protractor upside down, so that its north mark points south.

To measure the direction of an existing line using an anticlockwise scale
Place the protractor on the chart, with its 000°-180° line (or one of the edges or grid lines that is parallel to it) along the line on the chart. Slide it along the line until its central hole is over a meridian, then read off the direction where the meridian passes through the anticlockwise scale.

To draw a line in a particular direction using an anticlockwise scale
Place the hole in the centre of the protractor over a suitable meridian, and rotate the protractor until the meridian passes through the appropriate mark on the anticlockwise scale. Keeping this alignment, slide the protractor up or down the meridian until the

ruling edge (one that is parallel to its 000°-180° line) passes through the starting point of your intended line. Then use the ruling edge to rule the line.

Parallel rulers

Parallel rulers, consisting of two straight rulers held together by a linkage that keeps them parallel to each other but allows them to move closer together or further apart, are the traditional tool for measuring and plotting courses, tracks and bearings. Originally, they achieved this by being lined up with a compass rose printed on the chart, and then 'walking' to wherever the course, track, or bearing was to be drawn. Measuring the direction of a line was the reverse: the parallels had to be lined up with the line in question, and then walked to the nearest compass rose.

The business of walking across the chart gave them a bad name – and justifiably so. On a large, stable platform they were fine. On a small, bouncing, jolting chart table, they tended to slip, particularly if the linkages were stiff.

A later variation consists of a single, much wider ruler, with a roller set into each end. The two rollers were linked by a shaft, so if one end rolled forward, the other end had to roll forwards exactly the same distance, so the ruler kept its orientation as it was rolled around the chart. The trouble with such 'rolling parallels' is that they need a big chart table that is perfectly flat.

Now, however, clear acrylic has replaced the brass and boxwood rulers of old, and Captain Fields' markings – or markings very similar to them – are virtually standard.