Surveying II – Practical 1
Orientation

In this lesson, the carrying out of the orientation on a known station is covered.

The orientation angle

Using the I. fundamental task of surveying, we can compute the coordinates of any unknown point by measuring or calculating the horizontal distance and the whole circle bearing (WCB) between the unknown point and a known station. We first calculate the coordinate differences between the station and the unknown point and add them to the coordinates of the station. However, the WCB cannot be directly measured using any common surveying instrument as it would require us to establish very accurately where the north direction lies. What we can measure using a theodolite or a total station in everyday surveying work is the so called mean direction (MD) which is the angle measured clockwise from the 0 mark of the instrument's horizontal circle to the direction of the unknown point. Looking at Fig. 1, we can see that there is a constant difference between the WCB and the MD, which is the so called orientation angle (z). This angle can also be considered the whole circle bearing of the 0 mark of the horizontal circle. The orientation angle remains constant for a station so long as the instrument (or rather, the horizontal circle inside) is not moved. This means that whenever we change stations, we have to carry out the orientation again.

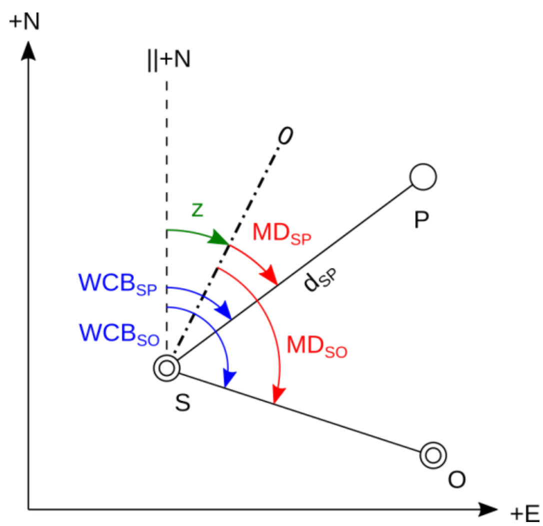

Figure 1. The whole circle bearing, the mean direction and the orientation angle.

Computing the orientation angle

In order to compute the orientation angle, we first have to find an orientation target that can be seen from our station. Any point with known coordinates can be considered an orientation target, but they are most commonly established by church towers, tall chimneys or other tall structures that can be sighted from many places and from long distances.

Referring back to Fig. 1, we can see that if we compute the WCB between our station and orientation target O (using the II. fundamental task of surveying) and also measure the MD of the direction between the two points, then by subtracting the MD from the WCB, we find the orientation angle z. If we have acquired z, we can add its value to the MD measured from our station to the unknown point P to find the WCB to the unknown point. We also measured the horizontal distance between our station and point P (using e.g. a tape or a laser distance meter), so we can utilize the I. fundamental task to compute the coordinates of the unknown point.

In reality, we rarely use only one orientation target. The reason for this is that if for some reason the coordinates of the orientation target are flawed (due to deformation or movement of the point for example), all the unknown points that we compute from that station will contain an error as well. To counter this possibility, we use 2, 3 or more orientation targets (up to a reasonable limit) and compute the orientation angle using each of these targets. If we find an outlier (an orientation angle which doesn't conform to the other values) we can assume that there is a discrepancy in the coordinates of that target and drop it from the rest of the computation. In the end, we find the weighted average of the orientation angles using the distances between the station and the orientation targets as weights. This is called the mean orientation angle. We use the distances as weights, as we can assume that the same amount of error in the coordinates causes a smaller error in the angle measurement if the target is farther from the station.

Steps of calculating the orientation and the coordinates of the unknown point

We have a station with known coordinates and measured the MD's of n number of orientation targets and one unknown point P. We also measured the horizontal distance between our station and the unknown point P.

1. Using the II. fundamental task of surveying, we compute the distance and the WCB between our station and each of the orientation targets: $d_{S-O1}, d_{S-O2}, \dots, d_{S-On}, \mathrm{WCB}_{S-O1}, \mathrm{WCB}_{S-O2}, \dots, \mathrm{WCB}_{S-On}$
2. We compute the orientation angle for each orientation target using the WCB's calculated in step 1 and the measured MD's:
$$z_i = \mathrm{WCB}_{S-Oi} - \mathrm{MD}_{S-Oi} \ .$$
3. We check for outliers in the orientation angles and if we find any, drop them from the calculation. After that we compute the mean orientation angle as the weighted average of the orientation angles:
$$\bar{z} = \frac{\sum z_i \cdot d_{S-Oi}}{\sum d_{S-Oi}} = \frac{z_1 \cdot d_{S-O1} + z_2 \cdot d_{S-O2} + \cdots + z_n \cdot d_{S-On}}{d_{S-O1} + d_{S-O2} + \cdots + d_{S-On}} \ .$$
4. We compute the WCB between the station and the unknown point P using the mean orientation angle and the measured mean direction:
$$\mathrm{WCB}_{S-P} = \mathrm{MD}_{S-P} + \bar{z} \ .$$
5. We find the coordinates of the unknown point P using the I. fundamental task of surveying.

Example 1: computing the mean orientation angle on station S and the coordinates of unknown point P.

Table of coordinates for the station and the orientation targets

Point ID	Easting [m]	Northing [m]
S	655 478.67	248 588.14
O1	656 374.81	248 040.32
O2	656 485.63	247 639.84
O3	657 329.69	248 205.78

Table containing the measurements and the computed values

Station	Target	Mean Direction	Orientation angle / Mean orient. angle	Whole Circle Bearing	Distance [m]
S	O1	202-52-14	*278-34-02*	*121-26-16*	*1050.32*
	O2	214-42-08	*278-34-46*	*133-16-54*	*1383.20*
	O3	183-05-23	*278-34-54*	*101-40-17*	*1890.10*
	P	152-05-57	**278-34-39**	**70-40-36**	1561.61

Computational steps:

1. Using the II. fundamental task and the coordinates of orientation targets and the station, we computed the horizontal distances and the WCB's. The values for O1 for example:

$$d_{S-O1} = 1050.32\text{ m} \qquad \mathrm{WCB}_{S-O1} = 121-26-16$$

2. Subtracting the MD's from the WCB's, we found the orientation angles for each orientation target. For O1:

$$\begin{aligned} z_{O1} = \mathrm{WCB}_{S-O1} - \mathrm{MD}_{S-O1} &= (121-26-16)-(202-52-14) = \\ &= -81-25-58\ (+\ 360-00-00) = 278-34-02 \end{aligned}$$

3. We check whether the differences between the orientation angles computed using the different targets are small. In our case, the biggest difference is less than one arc minute, so we accept all of the computed values and compute the mean orientation angle:

   To make the computation easier, we can subtract 278-34-00 from every orientation angle and only use the remainders in the computation of the weighted average.

$$\bar{z} = \frac{2''\cdot 1050.32+46''\cdot 1383.20+54''\cdot 1890.10}{1050.32+1383.20+1890.10} = 39''$$

   We add the 278-34-00 previously subtracted to acquire the final value of the mean orientation angle: 278-34-39.

4. We calculate the WCB between the station and the unknown point:

$$\begin{aligned} \mathrm{WCB}_{S-P} = \mathrm{MD}_{S-P} + \bar{z} = (152-05-57)+(278-34-39) &= 430-40-36\ (-360-00-00) \\ &= 70-40-36 \end{aligned}$$

5. We use the I. fundamental task of surveying and compute the coordinates of the unknown point.

$$E_P = E_S + d_{S-P}\cdot\sin(\mathrm{WCB}_{S-P}) = 656\,952.31\text{ m}$$
$$N_P = N_S + d_{S-P}\cdot\cos(\mathrm{WCB}_{S-P}) = 249\,104.87\text{ m}$$

The layout of the points in example 1 can be seen on fig. 2.

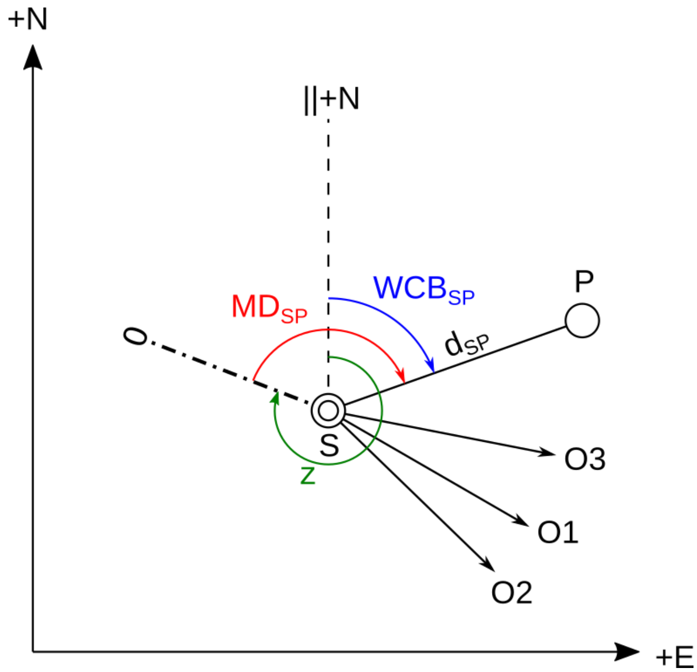

Figure 2. Layout of the points in example 1.