Surveying for Civil Engineering-4th Week

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Measurement Science Introduction

The difference between observations and measurements :

- Observation work: work that is done to get one single value directly and without correction of the device or surveying tool .
- Measurement works: are the actions which take place (before, during and after) the observation process for the final surveyed value (closest to the true value).

Measurement Science Introduction

- Works before observation : Calibration - set the device to the point.
- During the observation: allocating, tightening tape - reading device.
- Work after observation: taking averages of readings - make tables accounts.

Any person can carry out the observation, but surveying engineer which is only able to carry out the observation and correct the measurements.

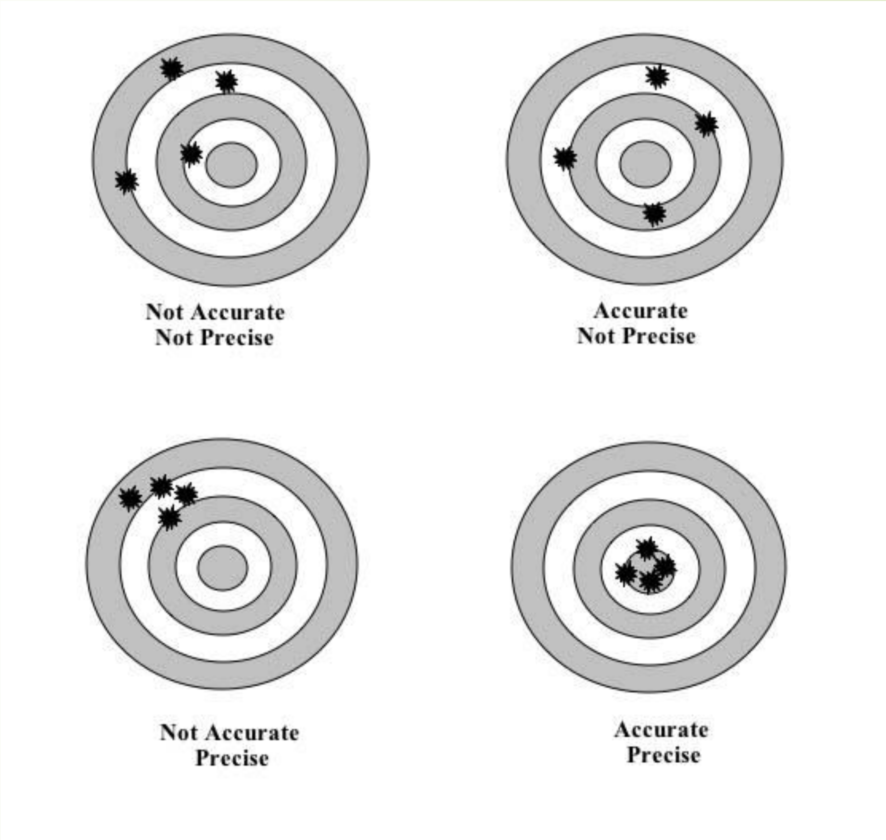
Facts about measurements

- - All measurements contain errors.(No measurement is exact) .
- - You can not determine the absolute value of the error
- -But you can determine the values closest to the true values through standards and statistical standards.

Accuracy and Precision in Surveying

- To surveyors, “accuracy” refers to how closely a measurement or observation comes to measuring a "true value," since measurements and observations are always subject to error. // Nearness of a measurement to the true value.

- “Precision” refers to how closely repeated measurements or observations come to duplicating measured or observed values. // The amount by which a measurement deviates from its mean.



Accuracy and precision

Suppose that you measure the same line five times;

- The first party reports the following measurements: 36.80, 36.70,36.75,36.85, and 36.65m [more accurate]
- The second party reports the following measurements: 36.42, 36.40,36.40,36.41, and 36.40m [more precise]
- The true length of the line is 36.72m

Errors

- For purposes of calculating errors, the ***true value*** is determined statistically after repeated measurements. In the simplest case the true value for a distance is taken as the mean value for a series of repeatds measurements.

Sources of Errors :

- - Natural Errors: Errors that occur as a result of natural phenomena such as heat - wind and Moisture .
- -Instrumental Errors: result from lack of precision -in the manufacture of devices and in grading and measurement units or as a result of the different in materials used in manufacturing .
- -Personal Errors : As a result of defect in the observer vision or lack of familiarity with the technical work in the field.

Type of errors:

- 1- Blunder error (Gross Errors):- error is due to carelessness of human. These are serious mistakes made by surveyor, such as reading 15.45 instead of 5.45 or writing 9.64 instead of 6.94.
- 2- Systematic error(Constant error) :- (mathematic model) cause by environment, i.e. elongation or Shrinkage , and have cumulative effect. As an example, you have a meter to measure distance with a production error. It shows 1 meter but in reality the distance is 99.5 cm. Then you measure always longer than the real distance

Type of errors:

- 3- Random error :- An error always there due to instrument and human, Itis not easy to detect (small value) i.e. Reading , Recording, positioning
- 4- Accidental Errors These are unavoidable errors arising from weather condition, change in temperature, humidity, mood of observer, etc.

Mistakes

Mistakes are blunders made by survey personnel. Examples of mistakes include transposing figures (recording a tape value of 68 as 86), miscounting the number of full tape lengths in a long measurement, measuring to or from the wrong point, and the like.

Students should be aware that mistakes **will** occur. Mistakes must be discovered and eliminated—preferably by the people who made them. All survey measurements are suspect until they have been verified. Verification may be as simple as repeating the measurement, or verification can result from geometric or trigonometric analysis of related measurements.

As a rule, **every** measurement is immediately checked or repeated. This immediate repetition enables the surveyor to eliminate most mistakes and, at the same time, improve the precision of the measurement.

MEASUREMENT Errors

1- Absolute Error (t)

*True error: ei = xi - x

X : true value

Xi : measured value

Gerçek hata = Ölçü – Gerçek değer

$$\varepsilon_i = l_i - x \qquad (i=1, 2, \dots n)$$

$$t = \pm \frac{[|\varepsilon_i|]}{n} \qquad (n \rightarrow \infty)$$

*Estimated error: vi = xi – $\bar{x}$ → when true value is not given, this is used

Xi : measured value

$\bar{x}$: average value

The *mean*, $\bar{x}$, of the *n* measurements is computed as follows:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}.$$

$$v_i = l_i - x \qquad (i=1, 2, \dots n)$$

$$t = \pm \frac{[|v_i|]}{n} \qquad (n \rightarrow \infty)$$

- **2-RMS / root mean square error (m_0) :**

$$m_o = \pm\sqrt{\frac{[\varepsilon\varepsilon]}{n}} \quad (n \to \infty), \qquad m_o = \pm\sqrt{\frac{[vv]}{n-1}}$$

- **3-Relative Error (b)**

b= m_0/ $\bar{x}$ → (average of measurements)

- **4-Possible Error (r)**

It is median of the absolute errors of n measurements in increasing or decreasing order.

m_0>t>r

Attention!!!

- Measurements that has high precision has small standard . Measurements has high accuracy if it is close to the true value. High precision does not necessary mean also high accuracy
- Measurement that has highly precise is also highly accurate if it is contain little or no systematic error . To obtain high precision and high accuracy :
  - 1- eliminate all blunders
  - 2- eliminate or correct all systematic errors
  - 3- minimize random errors

Örnek: Bir GPS ağına ait on adet üçgen kapanma hataları aşağıda verilmiştir. Duyarlık ölçütlerini hesaplayınız.

No	**Hata (ε_i) mm**	$\varepsilon_i \varepsilon_i$
1	-2.123	4.507
2	1.132	1.281
3	-1.674	2.802
4	-2.591	6.713
5	-1.772	3.140
6	2.979	8.874
7	0.475	0.226
8	4.414	19.483
9	-0.717	0.514
10	0.763	0.582

$n = 10 \qquad [|\varepsilon_i|] = 18.640 \qquad [\varepsilon_i \varepsilon_i] = 48.124$

Mutlak Hata $\quad t = \frac{18.640}{10} = \pm 1.864 \text{ mm}$

Ortalama Hata $m_o = \pm\sqrt{\frac{[\varepsilon\varepsilon]}{n}} = \pm\sqrt{\frac{48.124}{10}} = \pm 2.194 \text{mm}$

Olası Hata

0.475 0.717 0.763 1.132 **1.674** **1.772** 2.123 2.591 2.979 4.414

$$r = \pm\frac{1.674 + 1.772}{2} = \pm 1.723 \text{mm}$$

Gerçek hata = Ölçü – Gerçek değer

$\varepsilon_i = l_i - x \qquad$ (i=1, 2, … n)

$t = \pm\frac{[|\varepsilon_i|]}{n} \qquad (n \to \infty)$

$m_o = \pm\sqrt{\frac{[\varepsilon\varepsilon]}{n}} \quad (n \to \infty),$

Örnek: Bir uzunluk on kez ölçülmüş ve aşağıdaki ölçü değerleri elde edilmiştir. Duyarlık ölçütlerini hesaplayınız.

No	$l_i(m)$	$v_i = l_i - x$ (cm)	$v_i v_i$
1	180.57	-3	9
2	180.62	2	4
3	180.63	3	9
4	180.65	5	25
5	180.56	-4	16
6	180.62	2	4
7	180.57	-3	9
8	180.61	1	1
9	180.62	2	4
10	180.55	- 5	25

$x = \dfrac{l_1 + l_2 + \ldots + l_n}{n} = 180.60\text{m}$ **(kesin değer)**

$n = 10 \qquad [|v_i|] = 30 \qquad [v_i v_i] = 106$

Mutlak hata $t = 3\,\text{cm}$

Ortalama hata $m_o = 3.43$ cm (n-1)

1 2 2 2 **3** **3** 3 4 5 5 **Olası hata** $r = \pm \dfrac{3+3}{2} = \pm 3$ cm

Bağıl hata $b = \dfrac{3.43}{18060} = 0.00019 = \dfrac{1}{5265}$

Görünen hata = Ölçü – Kesin değer($x = l_{ort}$)

$v_i = l_i - x \qquad$ (i=1, 2, … n)

$t = \pm \dfrac{[|v_i|]}{n} \qquad$ (n →∞)

$$m_o = \pm \sqrt{\frac{[vv]}{n-1}}$$

$$b = \frac{m_o}{l_{ort}}$$

Örnek: Uzunluğu 100.00 m olan bir ayar bazı iki ayrı ölçme ekibince mm birimine kadar ölçü yapılarak çelik şeritle on kez ölçülmüştür. Hangi ölçme ekibi daha duyarlıklı sonuç elde etmiştir.

No	1. ekip			2. ekip		
	$l_i(m)$	$\varepsilon_i = l_i - 100.000$ (mm)	$\varepsilon_i \varepsilon_i$	$l_i(m)$	$\varepsilon_i = l_i - 100.000$ (mm)	$\varepsilon_i \varepsilon_i$
1	100.002	2	4	100.000	0	0
2	99.998	-2	4	99.999	-1	1
3	99.995	-5	25	100.005	5	25
4	100.003	3	9	100.007	7	49
5	100.000	0	0	99.994	-6	36
6	100.003	3	9	99.995	-5	25
7	100.001	1	1	99.997	-3	9
8	99.998	-2	4	100.002	2	4
9	99.998	-2	4	100.003	3	9
10	100.004	4	16	99.998	-2	4

$n = 10$ $\quad [\lvert\varepsilon_i\rvert] = 24$ $\quad [\varepsilon_i \varepsilon_i] = 76$ **Mutlak hata** $t = 2.4$ mm **Ortalama hata** $m_o = 2.8$ mm 0 1 2 2 **<u>2</u>** **<u>2</u>** 3 3 4 5 **Olası hata** $r = \pm 2$ mm **Bağıl hata** $b = \dfrac{2.8}{100000} = 0.0000276 = \dfrac{1}{36274}$	$n = 10$ $\quad [\lvert\varepsilon_i\rvert] = 34$ $\quad [\varepsilon_i \varepsilon_i] = 162$ **Mutlak hata** $t = 3.4$ mm **Ortalama hata** $m_o = 4.0$ mm 0 1 2 2 **<u>3</u>** **<u>3</u>** 5 5 6 7 **Olası hata** $r = \pm 3$ mm **Bağıl hata** $b = \dfrac{4.0}{100000} = 0.0000402 = \dfrac{1}{24845}$

Sonuç: 1 numaralı ölçme ekibi için duyarlık ölçütleri daha küçük çıktığından bu ekibin ölçme doğruluğu diğer ekipten daha yüksektir.

Duyarlık ölçütleri arasında **Ortalama hata > Mutlak hata > Olası hata** yani $m_0 > t > r$ ilişkisi vardır.

Kaynaklar

- https://celebrating200years.noaa.gov/magazine/tct/accuracy_vs_precision.html
- https://sudeshnairs.webs.com/Surveying/3_UELSurveyingMeasurement.pdf

- *Fundamentals of Surveying: Sample Examination,George M. Cole PE PLS*
- *Basic Surveying,Raymond E Paul (Author), Walter Whyte*
- ITU DEPARTMENT OF GEOMATICS ENGINEERING

Extra Info

- **Errors in Surveying**
  Linear Measurement
  There are lots of things which we call errors. We also use a lot of other terms for this. The fundamental issue is that we can never know the true value of any measured quantity, so we always have some uncertainty associated with the value we adoptWe can use a lot of methods to try to minimize our errors, but we can never eliminate them. For the purposes of working with errors, we can divide them into three groups: gross, systematic and random errors. This division is based on what causes the errors and how we deal with them, rather than any other aspect of their nature. You will see other classification
  schemes, but this one is both comprehensive and useful.

- **Gross errors**
  are those which we can also call `blunders'. They can be of any size or nature, and tend to occur through carelessness. Writing down the wrong value, reading the instrument incorrectly, measuring to the wrong mark; these are gross errors. They can be caused by people, machinery, weather conditions and various other things. We deal with gross errors by
  careful procedures and relentless checking of our work.

- **Systematic errors**
  are those which we can model mathematically and therefore correct. They are caused by the mathematical model of the procedure that we are using being different to what is going on in the real world. We reduce and compute with measurements on the basis of models and if the models are not complete, we will have discrepancies. For example, if we measure a distance without allowing for the slope of the tape, we will have a systematic error, which can be eliminated if we use the correct model of the measurement process. We can eliminate, or at least minimize, systematic errors by careful work, using the appropriate model for the process in use, and by using checks that will reveal systematic errors in measurements. Note that checks that use the same measurement processes may not detect some systematic errors, so you have to be fairly creative in developing methods for detecting systematic errors.

- **Random errors**
  are those which have no apparent cause, but are a consequence of the measurement process itself. All measurements have to be done to some limit of precision and we cannot predict the exact measurement we will obtain. However, random errors have very definite statistical behavior and so can be dealt with by statistical methods. Random errors are the small differences between repeated measurements of the same quantity, often of the order of the finest division in the measuring scale. We can eliminate or minimize the effects of
  random errors by statistical procedures: for example we can adopt the mean of a set of measurements as the value to be used in later calculations.
  With the idea of the ubiquity of errors in all our measurements and everything we do, we can
  now look at one measurement process and see how errors affect it. We will begin by looking at linear measurements, such as those we make with tapes and such equipment as EDM.