Distance Measuring
Two principles of measuring distance

1) It takes two points to form a line.
2) The shortest distance between two points is a straight line.
In surveying, the term “distance” has two uses.

The common use is to measure the displacement (distance) between two or more points.

Distance can also be used to define the dimensions of an object.
Selecting The “Best” Method

The best distance measuring method/device to use is influenced by many factors.

- Environment
- Use of the data
- Equipment available
- Expertise of individuals
- Personal preference
- Topography
- Client specifications
- Regulations
- Standard practice

The most important factor is the intended use of the data.
Example--selecting best method/device

What unit of measure should be used to determine the size of a wetland?

- Decimal feet?
- Foot?
- Miles?
- Acres?

What unit of measure should be used to determine the size of a chemical spill?

What unit of measure should be used to record the location of a site?
Distance Measuring Methods/devices

- Pacing
- Odometer
- Chaining
- Stadia
- Electronic Distance Measuring (EDM)
- Global Positioning System (GPS)
Distance Measuring Methods--Pacing

• Measuring distance by counting steps (paces).
• Distance is calculated by multiplying the number of paces by the individual’s pace factor.

• Advantages
  – Simple
  – Low tech
  – No specialized equipment

• Disadvantages
  ❖ Topography affects accuracy
  ❖ Requires practice to take a consistent pace.
  ❖ Must be able to traverse the distance.
  ❖ Only measures slope distance.

• With practice, accuracy is about 2% of distance paced
Distance Measuring Methods--Odometer Wheel

• An **odometer** is a mechanical revolution counter.
• An **odometer wheel** is a wheel which uses an odometer to count the rotations of the wheel.
• The gear ratio of the odometer is usually designed to provide a measurement of the distance in standard units--feet, decimal feet, feet and inches and/or meters.

• **Advantages**
  – Easy to use
  – Low tech

• **Disadvantages**
  – Accuracy is influenced by surface conditions.
  – Must be able to traverse distance.
  – Only measures slope distance.

Error 1% of distance
Distance Measuring Methods--Chaining

• Traditional method of measuring distance.
• Usually 100 foot lengths.
• Two common types.
  – Add (extended foot)
  – Cut (first foot)
• Available in steel and cloth.

• Advantages
  – High precision
  – 0.001 foot accuracy
  – Can be used to measure horizontal distances.

• Disadvantages
  – Multiple people
  – Must have a clear, travelable route.
  – High precision requires temperature and tension correction.

Error 0.1% of distance.
Steel Chain Temperature Correction

• Steel expands and contracts at fixed rate dependent upon the temperature.
• The temperature correction for a steel tape is:

\[ C_t = L \times \alpha \times (T - T_s) \]

- \( C_t \) = correction (ft or M)
- \( L \) = Length of tape (ft or M)
- \( \alpha \) = coefficient of thermal expansion
  - \( 6.5 \times 10^{-6} \text{ ft/}^\circ\text{F} \)
  - \( 1.15 \times 10^{-5} \text{ ft/}^\circ\text{C} \)
- \( T \) = Measurement temperature (°F or °C)
- \( T_s \) = Tape standardized temperature (°F or °C)
Example

- Determine the correction for a steel tape when used to measure a distance of 250 feet when the air temperature was 100 °F and the standardized temperature is 72 °F.

\[ C_t = L \times \alpha \times (T - T_s) \]
\[ = 250 \text{ ft} \times 6.5 \times 10^{-6} \times (100 - 72) \]
\[ = 0.0455 \text{ ft} \]
\[ = 0.5 \text{ in} \]
Distance by stadia requires an instrument with stadia cross hairs.

The distance between the stadia crosshairs is designed so that the divergence of the sights across the two stadia crosshairs is 1.0 feet when the instrument is 100 feet from the rod.

(Assuming an instrument stadia factor of 100.)
The distance between the TSR and BSR is called the stadia interval. This results in the equation:

\[ \text{Hor. Dist.} = \text{SI} \times \text{SF} \]

- **SI** = Stadia interval
- **SF** = Stadia factor

### Disadvantages of stadia
- Must have instrument with stadia crosshairs.
- May require multiple instrument setups.

The accuracy is 1.0 ft when direct reading and 0.1 ft when using the target.
Because $SI = TSR - BSR$, the more common equation is:

$$\text{Hor. Dist.} = (TSR - BSR) \times SF$$

- For modern instruments the stadia factor (SF) is 100.
- What is the stadia distance for the illustration?

$$\text{Dist} = (TSR - BSR) \times SF$$
$$= (6.01 - 5.47) \times 100$$
$$= 0.54 \times 100$$
$$= 54 \text{ ft}$$
Determine the distance for the stadia reading in the illustration using the target and Vernier scale?

\[
\text{Dist} = (\text{TSR} - \text{BSR}) \times \text{SF}
\]

\[
= (7.844 - 4.619) \times 100
\]

\[
= 3.225 \times 100
\]

\[
= 322.5 \text{ ft}
\]

Using the Vernier scale on the target, the stadia distance is 321.5 feet.
Horizontal Distance--1/2 Stadia

When the top or bottom stadia hair rod reading is obscured, a process called 1/2 stadia can be used. When 1/2 stadia is used the elevation crosshair, and which ever stadia crosshair that can be read, is used. Because this stadia interval is 1/2 of the standard interval, it is multiplied by two.

\[
\text{Horizontal Distance} = \left[ (\text{TSR} - \text{Elev}) \times 2 \right] \times 100
\]

Example: Determine the horizontal distance when the TRS = 7.34 and the elevation = 6.21.

\[
= \left[ (7.34 - 6.21) \times 2 \right] \times 100
= 226 \text{ ft}
\]
Distance Measuring Methods--EDM

- EDM = Electronic Distance Measuring
- The term EDM is used to describe a category of instruments that measure distance using an electronic signal.
- The instrument broadcasts a focused signal that is returned by a prism or reflection from the object.

How the process works can be shown using the velocity equation.

\[
\text{Velocity} = \frac{\text{Distance}}{\text{Time}}
\]

Rearranging the equation for distance results in:

\[
\text{Distance} = \text{Velocity} \times \text{Time}
\]
Distance Measuring Methods--EDM~cont.

Therefore, if the speed of the signal is known (speed of light), and the time for the signal to travel to the target and back is known, the distance can be calculated.

Advantages of EDM’s

1. Precise measurement of distance.
2. Line of sight instrument
3. Capable of measuring long distances
4. Reflectorless are single person operation

Disadvantages of EDM’s

1. Electronic = batterers
2. Accuracy affected by atmospheric conditions.
3. Can be expensive

Error $\pm (2 \text{ mm} + 2 \text{ ppm} \times D)$
Distance Measuring Methods--GPS

• GPS (global Positioning System) is a system of 21-24 satellites in orbit around the earth.
• Each satellite knows its position and uses a unique signal to continuously broadcasts this information.
• Along with the position information is a time signal.

• When a GPS receiver receives a signal from at least four (4) satellites it can compute its position by trilateration.
• The receiver position can be expressed in degrees of latitude and longitude, or distance (meters) using Universal Transverse Mercator (UTM) coordinates.
• Because UTM distances are based on a x-y coordinate system distances between points can be determined by simple math.

• Example: Determine the distance between Stillwater and Oklahoma City when the UTM coordinates for Stillwater are 675087E & 3998345N and the UTM coordinates for Oklahoma City are 639982E & 3925518N
Distance Measuring Methods--GPS~Example

- Subtracting the coordinates gives the two sides of a right triangle.
- The hypotenuse of the triangle is the distance between the two towns (44.6 mi).

\[
HD = \sqrt{39996^2 + 72255^2} \\
= 82586211 \text{ m} \\
= 44.6 \text{ mi}
\]

Note: this is the plane distance between these points not the surface distance.
Distances can be measured in two ways:
1. Horizontal distance
2. Slope (surface) distance

The horizontal distance between two points is the distance between those points measured on a horizontal plane.
The slope distance between two points is a distance measured along the surface of the earth.

When should horizontal distance be used?
When should slope distance be used?
Horizontal Distance

When horizontal distance is required, the individual has two choices.

1. Use equipment and techniques that record horizontal distance.

2. Record slope distance and collect the additional information required to calculate horizontal distance.
Measuring Horizontal Distance

- Chain
- Stadia
- EDM
Horizontal Distance-cont.

Chaining

- To measure horizontal distance with a chain, a level and plumb bob must be used.
  - The chain is held level, horizontal, and the measurement at the elevated end is transferred using a plumb bob.
  - This method is limited to slopes of 5% or less.

- When horizontal distances are measured by chaining on slopes > 5%, the technique called “breaking chain” must be used.
Horizontal Distance-cont.

Breaking Chain

- “Breaking Chain” is used when ever the slope is > 5% because when a 100 foot chain is used on a 5% slope, the elevated end will be 5 feet above the ground.
- “Breaking the Chain” into shorter segments reduces the height of the elevated end of the chain.
- Using a standard distance reduces the change of errors.
- A standard distance was not used in the illustration.
Horizontal Distance-cont.
Stadia

- The stadia method measures distance by line of sight through an instrument.
- When the instrument is level, the distance measured is a horizontal distance.
Electronic Distance Measuring (EDM)

- The signal from an EDM travels in a straight line.
- When the instrument is level, the distance is horizontal.
- If the instrument is not level, the distance is slope measurement.

Note: some instruments, such as total stations, measure slope distance and vertical angle and will output horizontal distance, vertical distance or slope distance.
To calculate horizontal distance you must know the slope distance and one additional bit of information for each measurement.

You must know either one of the following.
- % slope
- Change in elevation
- Vertical angle.
Questions

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