Comparing the accuracy of trigonometry methods versus direct measures for distance estimation

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Abstract

This study investigates the accuracy of trigonometric methods compared to direct measurement in estimating distances. Measuring distance is essential in mathematics, engineering, surveying, and construction, where precision ensures successful outcomes. Direct measurement using tools such as measuring tapes provides actual values but can be impractical in certain contexts. Trigonometry, particularly through the tangent function, offers an alternative by estimating distances using angles of elevation and object heights. The researchers conducted trials in a controlled campus setting, measuring distances from fixed objects using both methods. Data were analyzed by computing percentage errors to determine reliability. Results revealed that trigonometric methods can approximate distances effectively, but small errors in angle measurement significantly affect accuracy. Direct measurement consistently produced lower percentage errors, making it more reliable. The study concludes that trigonometry is useful when direct measurement is not feasible, but precision remains higher with direct tools.

Keywords: Trigonometry, Direct measurement, Distance estimation, Percentage error, Surveying

Introduction

Accurate distance measurement plays a vital role in various fields such as engineering, surveying, architecture, construction, and navigation. Precise measurements help ensure the safety, quality, and efficiency of projects by reducing errors in planning, design, and implementation. According to Charles D. Ghilani (2022), accurate measurements are fundamental in surveying because even small errors can affect the reliability of maps, boundaries, and construction layouts.

Direct measurement using tools such as measuring tapes, meter sticks, and laser distance meters is the most common method for determining distance. However, direct measurement is not always possible, especially when the object is inaccessible, located at a great height, or separated by obstacles such as rivers, buildings, or uneven terrain. In these situations, indirect methods of measurement become necessary.

One of the most widely used indirect methods is trigonometry. Trigonometry is the branch of mathematics that studies the relationships between the sides and angles of triangles. By applying trigonometric functions such as sine, cosine, and tangent, unknown distances can be calculated using known angles and reference measurements. According to Ron Larson (2023), trigonometric functions provide practical solutions to real-world problems involving heights, distances, and angles, making them valuable tools in engineering, navigation, physics, architecture, and land surveying. Furthermore, studies by Yang and Zou (2021) [15] have shown that trigonometric techniques can produce reliable measurements in surveying and geodetic applications when appropriate procedures and instruments are used.

Despite the extensive use of trigonometry in distance measurement, questions remain regarding the degree of accuracy that can be achieved when applying trigonometric calculations under actual field conditions. While mathematical formulas provide theoretical solutions for estimating distances, the accuracy of the results may be affected by factors such as measurement errors, instrument limitations, and environmental conditions. Moreover, many students learn trigonometric concepts in the classroom without having opportunities to examine their accuracy through practical applications. There is therefore a need to compare trigonometric calculations with direct measurements to determine how closely the computed distances correspond to actual measurements and to evaluate the reliability of trigonometry as a distance estimation tool.

This study aims to compare distances obtained through trigonometric calculations with those measured directly using standard measuring tools. By comparing the results of these two methods, the researchers seek to determine how closely trigonometric estimates correspond to actual measurements, evaluate the reliability of trigonometric calculations, and assess their suitability for practical distance estimation applications. The findings of this study may contribute to a better understanding of the practical use of trigonometry and its effectiveness as an alternative method for distance estimation.

Statement of the Problem

This study aims to answer the following questions:

- What is the distance measured using direct tools?
- What is the estimated distance using trigonometric methods?
- Is there a noticeable difference between the results from both methods?
- How closely do the distances obtained through trigonometric methods correspond to those obtained through direct measurement?

Methods and Research Design

Research design

This study used a comparative quantitative research design to compare the accuracy of trigonometric methods and direct measurement in estimating distances.

Research setting

The study was conducted in an open, flat area on the college campus to ensure safe and clear observation of fixed objects such as flagpoles, posts, or trees.

Participants

Only the researchers performed the measurements and calculations. No human respondents or subjects were involved.

Materials

- Measuring tape (for direct measurement)
- Clinometer or angle-measuring app
- Meter stick
- Scientific calculator
- Notebook and pen

Procedure

- Select a fixed object and mark 3 to 5 observation points ranging from 5 to 30 meters away.
- Direct Measurement: Measure the actual horizontal distance from each point to the base of the object using a measuring tape. Record this as the actual value.
- Trigonometric Method: From the same observation point, measure the angle of elevation to the top of the object using a clinometer. Also measure the height of the observer's eye level.
- Calculate the estimated distance using the tangent function:

  $$\text{Estimated Distance} = \frac{\text{Height of Object} - \text{Eye Level Height}}{\tan(\text{Angle of Elevation})}$$
- Repeat steps 2–4 three times for each distance to ensure consistency.
- Record all data in a table.

Data analysis

The accuracy of both methods was compared by computing the Percentage Error for each trial:

Percentage error (%) =

$$\frac{\text{Estimated value} - \text{Actual value} \times 100}{\text{Actual value}}$$

The average percentage error was computed for each method. The method with the lower average percentage error was considered more accurate and reliable.

Results

The primary goal of this study was to evaluate how well trigonometric calculations hold up against the physical reality of a standard measuring tape. To do this, field trials were conducted in an open, flat campus area. The data collection was structured around three specific observation targets set at baseline intervals: Point A (5 meters) represents the near distance, Point B (15 meters) represents the mid-range distance, and Point C (30 meters) captures the farthest distance. To minimize random human slips and ensure a reliable baseline, three separate trials were executed at each distance marker. The actual horizontal distances were established via tape measure, while the indirect, estimated distances were derived by combining mobile clinometer angle readings with the observer's eye-level height using the tangent function. The raw comparisons, along with the calculated percentage errors for each individual attempt, are detailed in the comprehensive table below.

Table 1: Comparative distance measurements and percentage error

Observation point	Trial	Direct measure (Actual value in meter)	Trigonometric methods (Estimated in value in meter)	Percentage error (%)
Point A (Near distance)	1	5.00	5.12	2.40%
	2	5.00	4.95	1.00%
	3	5.00	5.08	1.60%
Average		**5.00**	**5.05**	**1.67%**
Point B (Mid range)	1	15.00	15.45	3.00%
	2	15.00	14.62	2.53%
	3	15.00	15.30	2.00%
Average		**15.00**	**15.12**	**2.51%**
Point C (Far distace)	1	30.00	31.80	6.00%
	2	30.00	28.35	5.50%
	3	30.00	31.20	4.00%
Average		**30.00**	**30.45**	**5.17%**

1. Performance at short range (Point A – 5.00 m)
The trigonometric method demonstrated high accuracy at the shortest observation distance. The estimated distances were very close to the actual distance, resulting in percentage errors ranging from 1.00% to 2.40%. The average percentage error of 1.67% indicates that the trigonometric method is highly reliable for short-distance estimation.

2. Performance at mid-range (Point B – 15.00 m)
At the mid-range distance, the trigonometric method continued to produce accurate estimates. The percentage errors ranged from 2.00% to 3.00%, with an average percentage error of 2.51%. These results suggest that trigonometric calculations remain dependable even as the observation distance increases.

3. Performance at long range (Point C – 30.00 m)
The largest percentage errors were observed at the farthest distance. Errors ranged from 4.00% to 6.00%, producing an average percentage error of 5.17%. This indicates that the trigonometric method becomes more sensitive to slight inaccuracies in angle measurement as the observation distance increases.

Overall accuracy of the trigonometric method
Across all trials, the trigonometric method produced estimates that were close to the actual distances measured directly. The overall average percentage error of 3.12% indicates that the trigonometric method is reasonable accurate and reliable for estimating distance. Although direct measurement remains the most accurate method, trigonometric calculation provide a practical alternative when direct measurement is difficult or impossible.

Discussion
The results of the study showed that the trigonometric method provided distance estimates that were generally close to the actual distances measured directly. The computed overall average percentage error was 3.12%, indicating that the trigonometric method is reasonably accurate and reliable for estimating distances.
The findings also revealed that the accuracy of the trigonometric method varied depending on the observation distance. At the shortest distance (5.00 m), the method demonstrated high accuracy with an average percentage error of 1.67%. At the mid-range distance (15.00 m), the average percentage error increased slightly to 2.51%. The highest average percentage error was observed at the farthest distance (30.00 m), reaching 5.17%. These results suggest that the accuracy of trigonometric measurements tends to decrease as the observation distance increases.
Although there were small differences between the estimated and actual measurements, these variations were expected. They may have been caused by slight errors in measuring the angle of elevation, inaccuracies in determining the height of the object or the observer's eye-level height, and limitations of the measuring instruments used during data collection. Since trigonometric calculations rely heavily on precise measurements, even small errors can influence the final estimated distance.
As expected, direct measurement produced the most accurate results because the distances were measured physically using a measuring tape. However, the trigonometric method still generated estimates that were close to the actual measurements. This demonstrates that trigonometry can serve as a practical alternative when direct measurement is difficult, unsafe, or impossible to perform.
Overall, the findings suggest that while direct measurement remains the most accurate method for determining distance, the trigonometric method is also dependable for distance estimation. The relatively low average percentage error of 3.12% demonstrates that trigonometry can be effectively applied in practical situations such as surveying, engineering, construction, and navigation, where direct measurement may not always be feasible.

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