

Sonic Surveyor

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Introduction

Surveyors use accurate instruments to make measurements of geographical features. Using these measurements they can determine exact dimensions and elevations. We will obtain range data from a fixed point in a room to the room walls and then use this data to reconstruct the dimensions of the room. This lab uses a CBL Motion Detector or a CBR to measure distances. The data can easily be collected in 15 to 20 minutes and distributed to the students for their analysis and conclusions. This experiment offers an excellent opportunity to explore the relationship between rectangular and polar coordinates. Knowledge of trigonometry and linear equations are prerequisites.

Setup

Equipment Required:

CBL unit

TI-89 graphics calculator with a unit-to-unit link cable

TI CBR unit or CBL Motion Detector

Stool

Protractor

Ruler or Yardstick

Use the protractor to make a compass rose calibrated in 10° increments on a piece of paper. Construct a pointer to place under the CBR so that it may be rotated to precise angles.

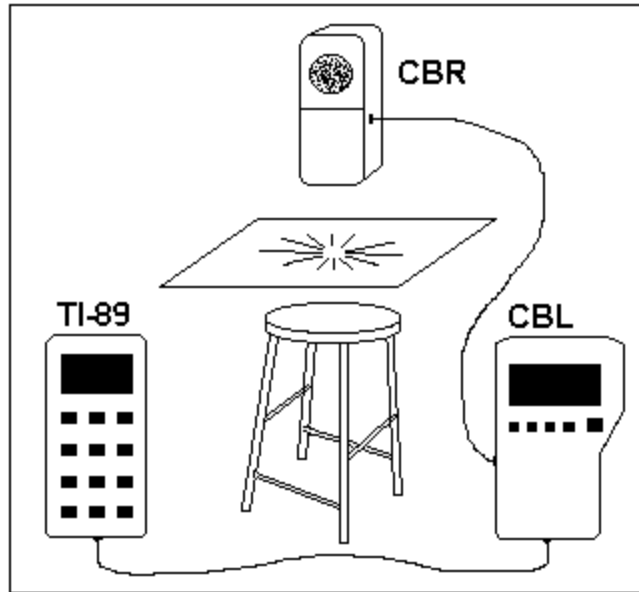


Figure 1: Equipment Setup

Equipment Setup Procedure

Connect the equipment as shown by Figure 1:

1. Connect the CBL unit to the TI-89 calculator with the unit-to-unit link cable using the I/O ports located on the bottom edge of each unit. Press the cable ends in firmly.
2. Connect the CBR unit to the motion detector channel (SONIC) on the left side of the CBL unit.
3. Place the CBR unit on the pointer, which is placed on the compass rose, which is placed on the stool in the middle of a classroom. The stool must be placed high enough so that the CBR unit can obtain unobstructed range information to the walls of the room through 360° of horizontal rotation. The distance to any wall must be less than 6 meters.
4. Turn on the CBL unit, CBR unit, and the calculator.
The CBL system is now ready to receive commands from the calculator.

Measure the room

Can we determine room dimensions and room area without measuring the dimensions of each wall? This experiment allows students to discover and investigate the mathematical relationship between polar and rectangular coordinates and to use the equations of lines in a practical application..

Program Listing

This experiment requires that you download or enter the **ROOMDATA.89P** and the **ROOMPIC.89P** programs listed in the appendix into your TI-89 calculator.

Collect the Data

1. Place the rubber feet of the CBR unit on the pointer and align the pointer with the 10° mark on the compass rose. One student should be assigned the task of aligning the CBR unit.
2. Make sure the CBL is turned on. Start the program **ROOMDATA** on the TI-89. The program will prompt **Enter degree increments**. We are using 10° increments in this example but any fraction of 360° may be used.
3. The student who is positioning the CBR unit must carefully line up the pointer with the 10° mark on the compass rose. This position must now be held until the data is collected.
4. The program will then prompt:
**Press ENTER
to collect data**
5. The TI-89 will now display the degree (10) and the range to the wall in feet. On the line below this information the program prompts for NEXT POINT. The student positioning the CBR must rotate the CBR so that the pointer lines up with the 20° mark on the compass rose. Press [ENTER] on the TI-89 to collect the next data point. Continue in this manner until all 36 measurements have been made.
6. After the last data point is collected, a plot of range (in ft) vs. degrees (in degrees) appears on the calculator screen. The plot should look similar to the one shown in Figure 2. Make a print-out of this graph using TI-GRAPH LINK or save it as a PIC variable to be printed later. Attach this print-out to your worksheet. Be sure to include appropriate scales and axis labels on the print-out. The data is saved in lists L_4 and L_2 . It would be prudent to save these lists to lists with new names, perhaps R_1 and R_2 , as subsequent experiments will erase L_4 and L_2 .
7. Notice that the data seems very scattered. Its presentation in rectangular coordinates is not very revealing of the dimensions of the room. Some further work is necessary.

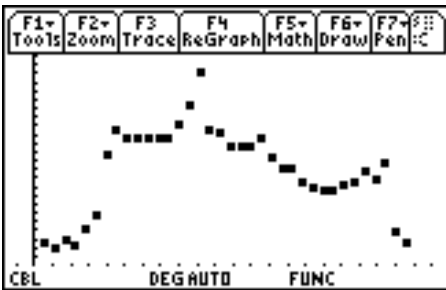


Figure 2.

Analyze the data

How can we use the data gathered by the **ROOMDATA** program be used to reconstruct the room dimensions? We will use the power of the TI-89 to help us answer this question.

If the data collected is examined carefully we can see that range to the wall is a function of the angle of rotation. We can probably visualize the corners of the room by finding local maximum ranges. But other characteristics of the room are not clear. How many wall sections are there? How long are the walls? Are the walls straight or are they curved? Are the walls at right angles to each other? What is the area of the room? These questions can not answered from the data in its current form. We must convert the data to a more revealing format.

The raw data was obtained in polar form. Each data point (r, θ) , represents a range at a certain angle. Our problem is that this polar data is plotted in a **rectangular** coordinate display with r as a function of θ . We need to plot the polar data in a **polar** coordinate display to reveal the dimensions of the room. Another problem is that the TI-89 will only plot data in rectangular form. So we need to convert our polar data to rectangular form and then plot it in rectangular coordinates. We will use the conversion equations:

$$x = r \cos \theta$$

$$y = r \sin \theta$$

We will then store the converted data in lists L_5 and L_6 and plot this data on the TI-89.

Procedure

1. We will let the calculator do some of the work for us. Run the program **ROOMPIC**. The converted polar (r, θ) data will be stored as rectangular (x, y) data in lists L_5 and L_6 , respectively. The program will also plot the data in Plot2. Plot1 remains intact for reference.

2. After the data is converted, a scatterplot of the (L5, L6) data appears on the calculator screen. The plot should look similar to the one shown in Figure 3. It should look more like a room than Plot1. Make a print-out of this graph using TI-GRAPH LINK or save it as a PIC variable to be printed later. Attach this print-out to your worksheet. Be sure to include appropriate scales and axis labels on the print-out. The data is saved in lists L5 and L6. It would be prudent to save these lists to lists with new names, perhaps R3 and R4, as subsequent experiments will erase L5 and L6.

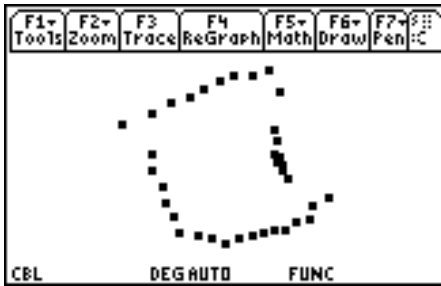


Figure 3.

Analysis and Conclusion

1. Are the walls at right angles to each other? We can answer this question by comparing the slopes of the equations of adjacent walls. Use Trace to find two points in each wall section. Compute the point-slope equation for each wall. Do the slopes indicate that adjacent walls are perpendicular? Use the following equations as they apply:

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

$$m = \frac{(y_2 - y_1)}{(x_2 - x_1)}$$

$$y = m x + b$$

$$m_1 = \frac{-1}{m_2}$$

2. Enter the wall equations into your calculator and graph them together with Scatterplot2. Your plot should now look like Figure 4. Are the lines a good fit with the walls? Compute the area of the room and record the result.

3. How long are the walls? Find points that are the intersection of the lines found in Step #1 and #2 (use intersect). Use the distance formula to find the distance between two points at the ends of each wall section (use Solver). Make a column in your lab notebook for each wall section. For each section record its length, equation, and slope. Are opposite walls the same length?

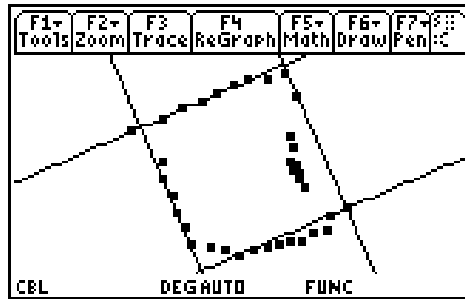


Figure 4.

4. Now make measurements of the room using a meterstick. Compare the lengths you measure with those found in Step #3 and record them in your lab notebook.
5. Repeat this experiment using 5° increments. Is the room more clearly defined than before? How do the results compare with the first set of data? How do they compare with the actual measurements? Record all relevant data on your worksheet, as before.

ROOMDATA

```
Prgm
1»n
setMode("ANGLE", "DEGREE")
ClrHome
ClrDraw
ClrIO
Send {6, 0}
Send {1, 0}
Send {1, 11, 3}
Disp "Enter degree increments"
Input d
newList(int(360/d))»I 2
newList(int(360/d))»I 4
newList(10)»I 3
ClrIO
Disp "Press ENTER to"
Disp "collect data"
Pause
Lbl Ip
n*d»I 4[n]
ClrIO
Send {3, .25, 10, 0}
Get I 3
(sum(I 3)-max(I 3)-min(I 3))/8»I 2[n]
Disp I 4[n], " ", I 2[n]
Disp "NEXT POINT"
Pause
n+1»n
If n*d>360
Goto pl
Goto Ip
Lbl pl
d»xscl
3»yscl
NewPlot 1, 1, I 4, I 2, , , , 4
ZoomData
DelVar I 3, d, q
EndPrgm
```

ROOMPIC

```
Prgm
setGraph("AXES", "OFF")
PlotsOff
newList(n-1)»I5
newList(n-1)»I6
For i, 1, n-1
I2[i]*cos(I4[i])»I5[i]
I2[i]*sin(I4[i])»I6[i]
EndFor
NewPlot 2, 1, I5, I6, , , , 4
ZoomData
ZoomSqr
EndPrgm
```

Example Sonic Surveyor Worksheet

wall #	points		equation	intersection points	
1	x_1	8.2797	$Y_1 = - .48479X + 13.881$	x_1	-6.2626
	y_1	9.8673	length	y_1	16.9174
	x_2	2.2549	computed : 22.0850	x_2	-16.9375
	y_2	12.7881	measured :	y_2	-2.4164

wall #	points		equation	intersection points	
2	x_1	-7.9758	$Y_2 = - 1.811X + 28.2600$	x_1	-16.9375
	y_1	13.8146	length	y_1	-2.4164
	x_2	-17.2862	computed : 19.0172	x_2	.4680
	y_2	-3.048	measured :	y_2	-10.0782

wall #	points		equation	intersection points	
3	x_1	-9.7020	$Y_3 = - .44019X - 9.8721$	x_1	.4680
	y_1	-5.6014	length	y_1	-10.0782
	x_2	-1.6153	computed : 21.3729	x_2	10.4574
	y_2	-9.1611	measured :	y_2	8.8116

wall #	points		equation	intersection points	
4	x_1	1.4497	$Y_4 = 1.89097X - 10.9631$	x_1	10.4574
	y_1	-8.2218	length	y_1	8.8116
	x_2	4.8618	computed : 18.5791	x_2	-6.2626
	y_2	-1.7696	measured :	y_2	16.9174

Formulas :

$$m = \frac{y_2 - y_1}{x_2 - x_1}$$

$$y - y_1 = m(x - x_1)$$

$$m_1 = - \frac{1}{m_2}$$

Sonic Surveyor Worksheet

wall #	points		equation	intersection points	
1	x_1		$Y_1 = \text{______}X + \text{______}$	x_1	
	y_1		length	y_1	
	x_2		computed :	x_2	
	y_2		measured :	y_2	

wall #	points		equation	intersection points	
2	x_1		$Y_2 = \text{______}X + \text{______}$	x_1	
	y_1		length	y_1	
	x_2		computed :	x_2	
	y_2		measured :	y_2	

wall #	points		equation	intersection points	
3	x_1		$Y_3 = \text{______}X + \text{______}$	x_1	
	y_1	-5.6014	length	y_1	-10.0782
	x_2	-1.6153	computed :	x_2	10.4574
	y_2	-9.1611	measured :	y_2	8.8116

wall #	points		equation	intersection points	
4	x_1		$Y_4 = \text{______}X + \text{______}$	x_1	
	y_1		length	y_1	
	x_2		computed :	x_2	
	y_2		measured :	y_2	