2D Spatial Reconstruction Using a Rotating Time-of-Flight Sensor

Ozobot Editor Lesson—Student Guide

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Introduction

Ozobot Ari is the perfect device to use for 2D spatial reconstruction in the science lab. There are two reasons for this. First, Ari has the ability to rotate. Second, Ari has a built-in time-of-flight (ToF) sensor. Its infrared beam travels at the speed of light, and the reflected beam then returns to the sensor. The distance to the object causing the reflected light can then be calculated from the well-known formula $d=vt$. Here, v is the velocity of light, approximately $3\text{x}10^8$ m/s, t is half the time taken by the round-trip beam, and d is the distance to the object in m. In effect, Ari's ToF sensor measures ***distance*** in meters to the object that caused the reflection of the infrared beam. This forms the basis of LIDAR—Light Detection and Ranging.

The left half of Figure 1 shows a typical setup for investigating 2D spatial reconstruction using Ari. A semicircular strip of cardstock has been inserted into a rectangular cardboard box. Ari is placed inside the box facing the direction toward the 0° mark. Using a movement rotate block, Ari is set to rotate 3.6° counterclockwise a total of 100 times, with a time of flight reading taken after each of the 100 rotations. The value of the total angle rotated since the start and the corresponding sensor reading are recorded in the IO Console after each of the 100 rotations. After the final 3.6° rotation, the contents of the IO Console is then copied and pasted into an Excel spreadsheet. The spreadsheet then produces the 2D spatial reconstruction show in the right half of Figure 1

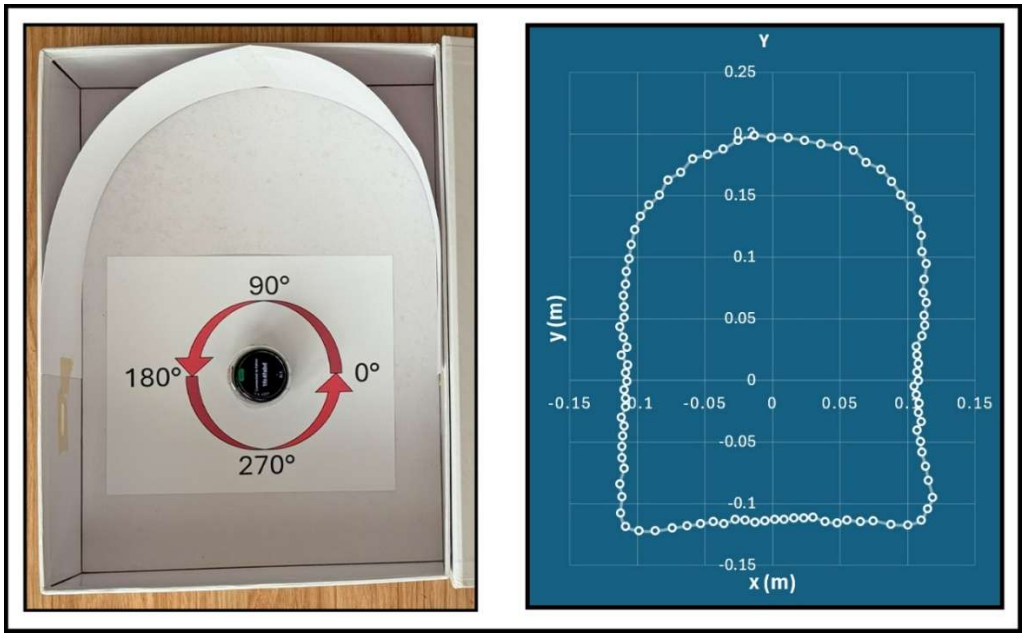

Figure 1

You can undoubtedly come up with a myriad of spatial designs that you could use in this lesson. Keep in mind that the maximum distance measurable by the Ari ToF sensor is about 1 meter. Also keep in mind that the beam's field-of-view (FoV) is about 18º, or about 1/20 of a full circle. You should use matt surfaced object, *i.e.*, not glossy or mirror-like surfaces. Lighter colored surfaces are best. The author found that standard brown cardboard boxes also work well.

Throughout the remainder of our discussion, we will be making use of the setup that was shown in the left-half of Figure 1. The discussion, however, applies to any applicable setup that you might create.

The Ozobot Editor Program

Figure 2 shows the Ozobot Editor program for our 2D spatial reconstruction. The *count with* loop varies the angle of rotation from 0 to 360° by 3.6°. The author had to adjust the rotate angle from 3.6° to 3.8°, to correct for the fact that Ari was a tad short of a complete circle after the 100 rotations. You may have to make a similar adjustment, either for being a tad short or a tad too much, with the Ari that you are using.

A text consisting of three items is then printed to the IO console: the value of the total rotation angle in radians, a blank space, followed by the ToF sensor distance reading in meters. Note that we converted the degree reading to radians because Excel's trigonometric sine function expects angle measurements to be in radians. One degree is equal to 0.0175 radians.

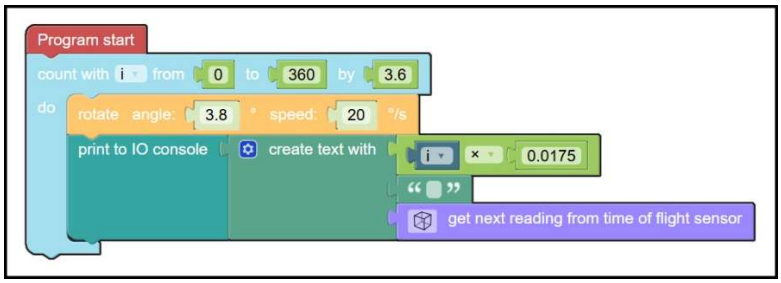

Figure 2

Figure 3 shows the first five lines of the IO console output from running this program. There are actually a total of 100 lines. Note the blank space between the angle and ToF readings. This is the data that you will copy from the IO console and then paste into Excel.

```
0.0 0.108
0.06300000000000001 0.107
0.12600000000000003 0.109
0.18900000000000003 0.109
0.25200000000000006 0.11
```

Figure 3

The Excel Spreadsheet

Figure 4 shows the first several rows and columns of the spreadsheet whose title is *2D Spatial Reconstruction Spreadsheet.xlxs*. This spreadsheet can be downloaded by going to this URL https://drive.google.com/uc?export=download&id=1w2KOEdTdwzuy6-r2v_uaNs5BjzHGFn_8. We will now discuss each of the columns A through H.

	A	B	C	D	E	F	G	H
1	Paste the data from the Ozobot Editor IO Console below:	**Character string** before the blank space:	Number of characters after the blank space:	**Character string** after the blank space:	Angle as a **number** in radians:	Distance as a **number** in meters:	x coordinate in meters:	y coordinate in meters:
2	0.0 0.108	=LEFT(A2,FIND(" ",A2)-1)	=LEN(A2)-FIND(" ",A2)	=RIGHT(A2,C2)	=VALUE(B2)	=VALUE(D2)	=F2*COS(E2)	=F2*SIN(E2)
3	0.063000000000000001 0.107	=LEFT(A3,FIND(" ",A3)-1)	=LEN(A3)-FIND(" ",A3)	=RIGHT(A3,C3)	=VALUE(B3)	=VALUE(D3)	=F3*COS(E3)	=F3*SIN(E3)
4	0.12600000000000003 0.109	=LEFT(A4,FIND(" ",A4)-1)	=LEN(A4)-FIND(" ",A4)	=RIGHT(A4,C4)	=VALUE(B4)	=VALUE(D4)	=F4*COS(E4)	=F4*SIN(E4)
5	0.18900000000000003 0.109	=LEFT(A5,FIND(" ",A5)-1)	=LEN(A5)-FIND(" ",A5)	=RIGHT(A5,C5)	=VALUE(B5)	=VALUE(D5)	=F5*COS(E5)	=F5*SIN(E5)
6	0.25200000000000006 0.11	=LEFT(A6,FIND(" ",A6)-1)	=LEN(A6)-FIND(" ",A6)	=RIGHT(A6,C6)	=VALUE(B6)	=VALUE(D6)	=F6*COS(E6)	=F6*SIN(E6)
7	0.31500000000000006 0.116	=LEFT(A7,FIND(" ",A7)-1)	=LEN(A7)-FIND(" ",A7)	=RIGHT(A7,C7)	=VALUE(B7)	=VALUE(D7)	=F7*COS(E7)	=F7*SIN(E7)

Figure 4

Column A *(Green)*

The data from the Ozobot Editor IO Console is pasted here. Each of the cells from A2 through A101 will contain a ***string*** similar to those shown in Figure 3.

Columns B *(Light Purple)*

The Excel LEFT function grabs the portion of the string up to but not including (explains the -1) the blank space that separates the radian measure from the ToF reading.

Column C *(Dark Purple)*

We need to know the number of characters after the blank space. This is found by taking the length of the string and subtracting the index of the blank space.

Column D *(Light Purple)*

The Excel RIGHT function grabs the string at the far right of the string from the IO Console whose length is obtained from the formula in column C.

Column E *(Orange)*

The Excel VALUE function convert a string to a number so that calculations can be made when needed. Here, the radian measure is converted to a number.

Column F *(Orange)*

Here, the VALUE function converts the ToF distance from a string to a number.

Column G *(Blue)*

The final step is to convert the polar coordinates (angle in radians, ToF reading in meters) to Cartesian coordinates (x, y). The x-coordinate is given by the formula x = Tof Distance * cos(angle).

Column H *(Blue)*

The y-coordinate is given by the formula y = ToF distance * sin(angle).

The 2D Spatial Reconstructed Graph

The graph is created by selecting columns G and H and then selecting *Insert/Chart/Scatter* from the Excel ribbon menu. All spreadsheet calculations and the graph will appear automatically immediately after the Ozobot Editor IO Console data has been pasted into column A of the spreadsheet. You can also paste a different set of IO Console data into column A and the result and graph will be recalculated.

Finally, note that at the bottom of the Spreadsheet you will see that there are six identical spreadsheets named *Sheet1* through *Sheet6*. This means that you can make 2D spatial reconstructions for six different unique creations of your own.

Running the Ozobot Editor Program

While you certainly can run the program in the Blockly Editor, it will run *much faster* if you run the program in the Python Editor. This is because time is not being used up highlighting blocks when using the Python Editor. Once the program has been loaded and connected to Ari (Share code ***oizquz3***), simply click on the *Load* button, and then select "Open in Python Editor". See Figure 5. You then click on the Run button whenever you have properly placed Ari in your construction. You need not deal with the Python code or know anything about Python.

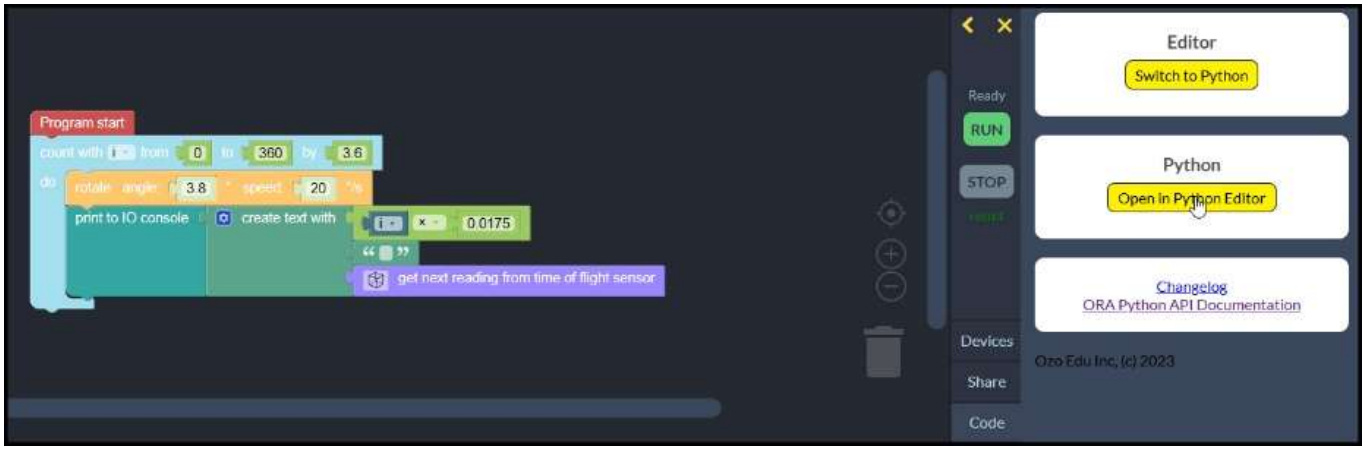

Figure 5

Transferring the IO Console Data to Excel

When the program has completed running in the Python Editor:

1. Drag the left mouse button in the INPUT/OUTPUT area until all of the data is highlighted with a gray background. See Figure 6.
2. Right-click anywhere in the gray background. Click on "Copy" from the popup window. This will copy the I/O Console data to the Windows clipboard. *Note that Ctrl-C will **not** copy the IO Console data to the clipboard*.
3. With the Excel spreadsheet open with any one of the six sheets in view, right click on cell A2 and then select the left-most Paste icon. Your data will be pasted, and the graph will be updated to match your construction.

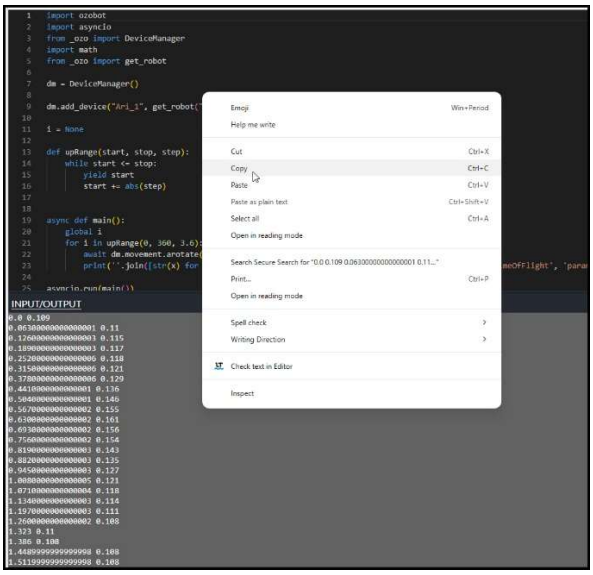

Figure 6

One More Example Construction

The example in Figure 7 shows how some things laying around the house can provide for interesting 2D spatial reconstruction using Ozobot Editor and Ari! You can also make some interesting constructions by cutting and folding cardstock into patterns. Have fun and be creative!

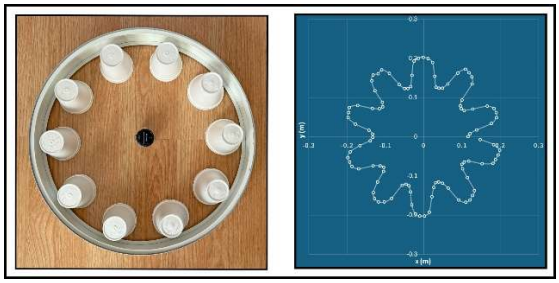

Figure 7