# THE INTERSECTION OF LINES TO FIND POINTS

New Mexico Supercomputing Challenge

Final Report

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## Introduction

By definition, surveying is "a branch of applied mathematics that is concerned with determining the area of any portion of the earth's surface, the length and directions of boundary lines, and the contour of the surface and with accurately delineating the whole on paper."[i] This process is time consuming, can require great quantities of calculations, and is vulnerable to human error. We hope to be able to simplify this process to merely inputting the desired "blueprints," setting out our equipment, and pushing a button.

This is why our team decided to design an apparatus that will allow us to easily find specific points on a two-axis plane. This will be useful not only for surveying, but also for building fences or pens, marking sites for foundations, or any other purpose where you have to find a specific point.

We will accomplish this by using lasers on stepper motors connected to a computer. The position of the points will be drawn into the computer; the computer will determine the angles from the location of each motor to a certain point. The lasers will form two intersecting lines, and where the lines intersect is the physical location of the point.

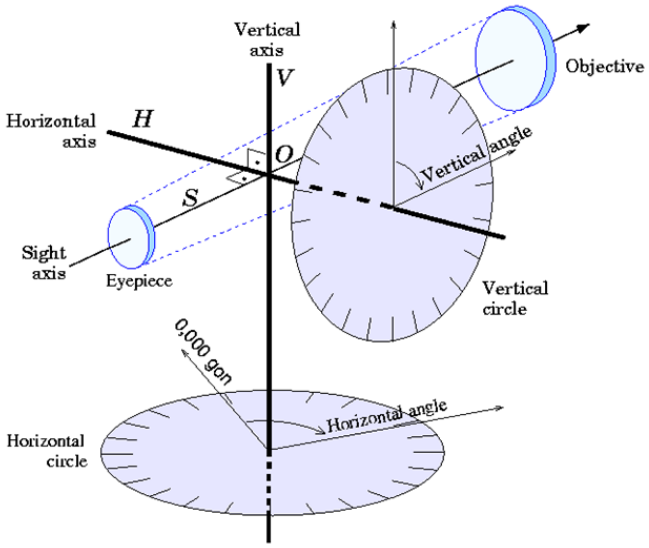
Our project requires several pieces of equipment, including: two tripods, two stepper motors with the equipment and software needed to connect them to a computer and control them, and two laser pointers.

## Previous Methods

Previously, tools such as a theodolite, different lengths of chain, and compasses were

used in conjunction with triangulation methods to survey.[ii] Surveying was almost always performed by somebody with special training and a license. Recently, the GPS has revolutionized much of the surveying field; however, the cost of using a sub-inch GPS is higher than any of the other surveying methods. This would be used in large scale projects such as roads. Older methods are still used when precise measurements are needed, like in land sales.

For finding points on a smaller scale, such as setting anchor bolts in cement, similar methods of measuring and triangulation are used.




**Axes and circles of a theodolite**

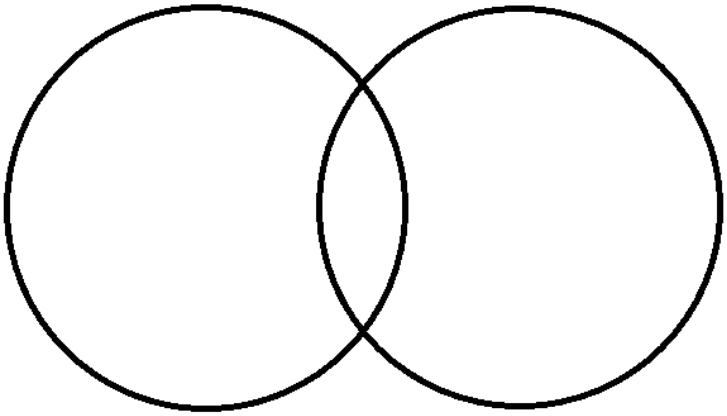
Often, people do not have all of the equipment necessary for precise measurements and markings, so they improvise. I have seen people use everything from just "eye balling it," to binoculars, to guns with scopes for alignment. These improvisations are often inaccurate.

**Our Methods**

We investigated three types of methods that we would be able to use in our system. They

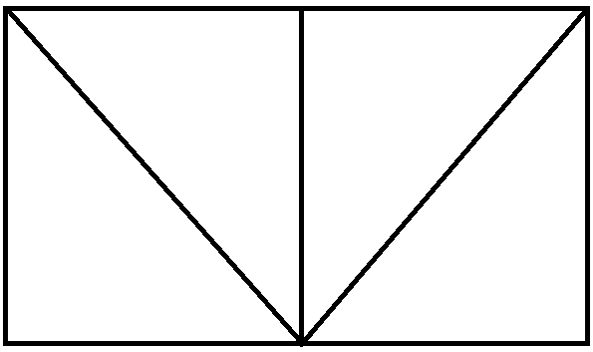
include: a two circle system, a triangular system, and a computer system.

The first idea we examined was a two circle system. This would use angles and distances in ways similar to using polar coordinates.

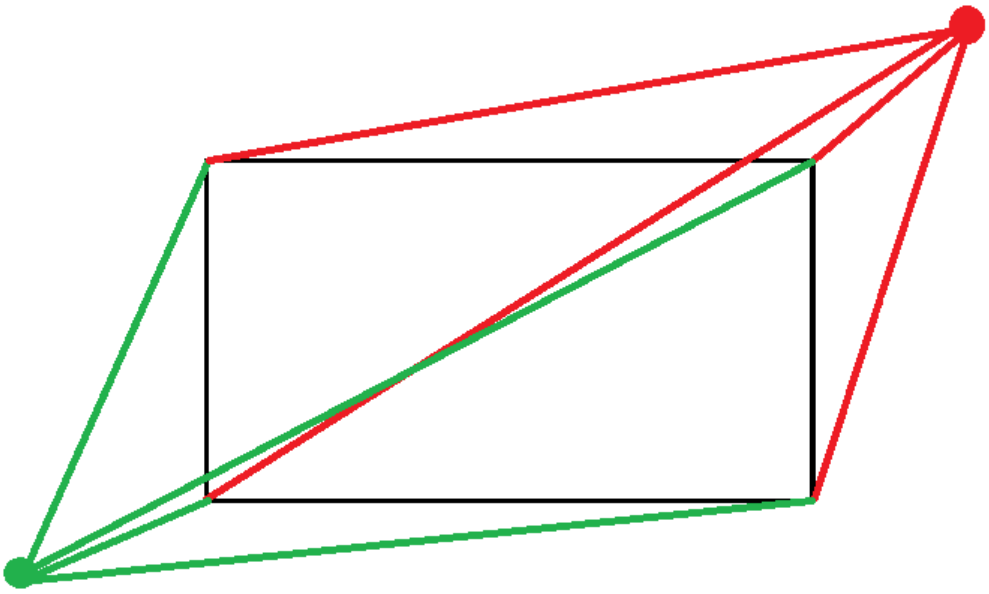


In this system, where the circles intersect is where the points would be. We chose not to use this system because overlapping circles intersect at more than one point, which could cause erroneous results.

The next method that we contemplated was a system of right triangles. This would be based upon a series of geometric proofs. The first is the fact that all rectangles can be divided into a series of congruent right triangles.



With all right triangles, every aspect of the shape can be determined using trigonometric functions such as sine, cosine, and tangent.

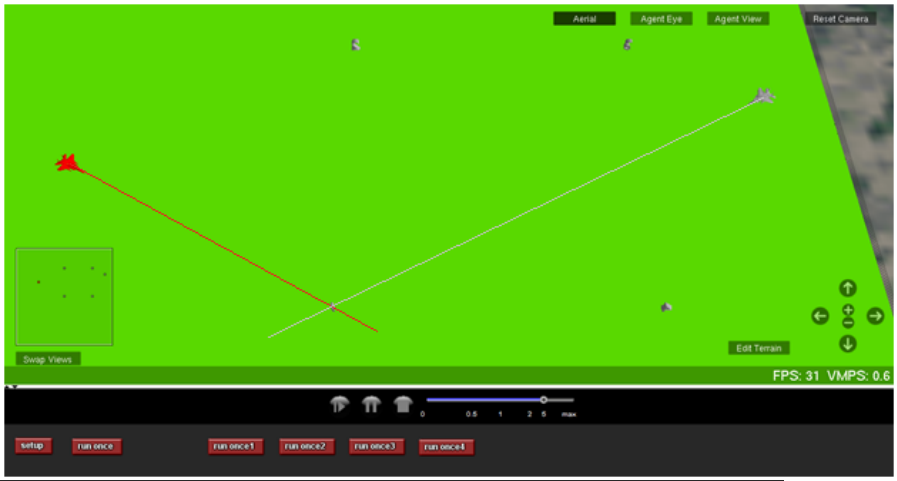


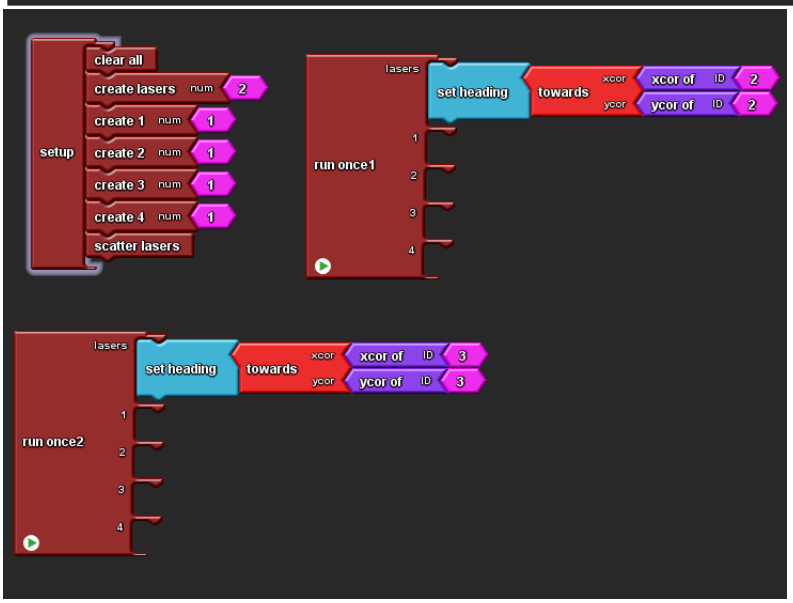
As you can see from this diagram, the angle from each point to any other point is different, and most of the angles are not right angles. This system would require us to further divide the shape until all aspects of it can be described in terms of right triangles. This along with the fact that the equations would be dependent upon where the lasers are placed, that it would require having to know distances, and the sheer amount of math involved was why we chose not to use this system. This system would also limit the designs we could implement to rectangles and triangles.

The last method that we looked at and finally decided upon was the use of the computer to determine everything without the use of equations on our part. This method will allow us to simply input the blueprints into the computer, set the location of the lasers, and the computer would just set the heading of both lasers towards one point.

To see if this would work, we made a simple preliminary model in StarLogo TNG. It

worked just as we had planned and had the exact headings, so we decided to use this method for the final product.




**Possible Problems and Limitations**

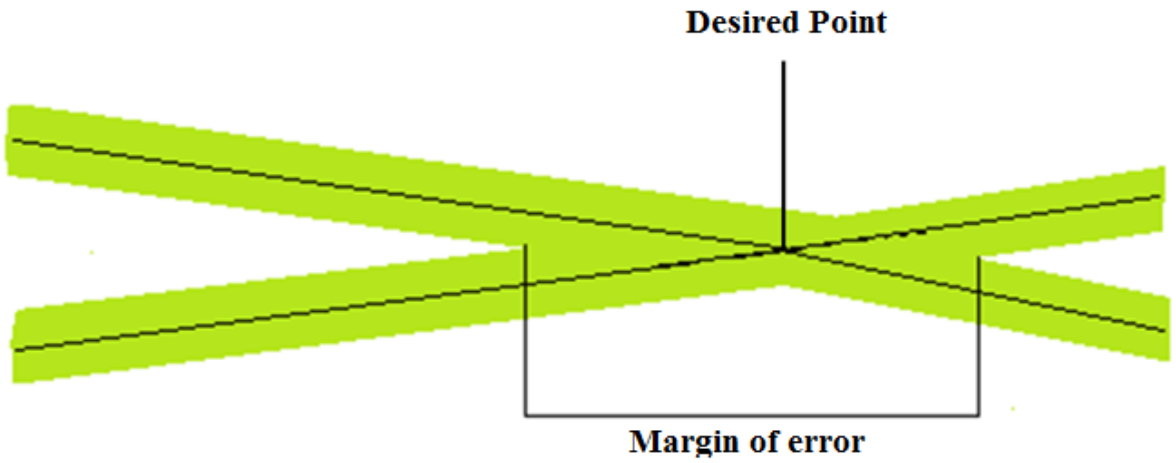
As with the other methods, this idea does have its problems and limitations. One such problem is the possibility of human error in the setting up of the tripods with the lasers. A small mistake in the positioning of the laser will cause the whole project to shift. We plan to solve this problem by setting the tripods at two of the desired points, or calibrating the lasers to two of the

desired points. This will help us make sure that the lasers are properly oriented.

Another is if the laser is shaken or moved after it is calibrated. That would cause the later points to not be in line with the other points, or cause part of the project to shift. It wouldn't make a big difference on small projects, but large scale projects could be greatly affected.

The main non-human problem causing factor is topography and vegetation being in the desired path of the beam, thus keeping it from reaching its goal.

Another problem that could conceivably arise deals with the resolution of the laser beam. At greater distances, the beam will become less focused and thus, larger in diameter. This will create a greater margin of error, especially at extreme acute and obtuse angles. Such situations should be avoided if possible.




A limitation that we have to consider, albeit unlikely, is the curvature of the earth. The only time this would have an impact would be in very large scale projects over very flat topography. However small of a difference it may seem, it sets a distinct limit on how great of distances this will work. At 10 miles, the change in the ground in relation to the laser would be

about sixteen feet.[iii] Since the laser will not bend around the earth, we will be limited to places that are visible from the location of the laser.

This could become a factor when surveying ranches, or over large expanses of water; however, the resolution of the lasers will be so expanded by that time that we will probably only use this for smaller scale projects.

**Summary**

We have acquired and developed all the necessary equipment. We have the stepper motors and lasers mounted on the tripods, and have developed a preliminary program to show how we will run the motors.

Currently, we are trying to make the computer, connections and software work together to achieve our purposes.

*We would especially like to thank BobCAD-CAM for donating the computer control software that is necessary for our systems to operate.*

[i] Merriam-Webster's Dictionary, Surveying

[ii] http://www.civilprojectsonline.com/tag/triangulation-survey/,
Triangulation Survey,
Classification of Surveys and Surveying methods in Engineering

[iii] http://mathforum.org/library/drmath/view/54904.html