3D CAD Approach for Vector Graphics

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I. Introduction

The purpose of this study was to investigate the effectiveness of the 3D CAD approach in the analysis of concurrent coplanar and non-coplanar vector systems. Much engineering data is graphical in nature. Graphical methods utilizing such data can provide comparable accuracy for analysis of vectors, such as forces, velocities and accelerations, in mechanics, machine design and structural analysis [1]. When two or more vectors act on an object through a common point, it is called a concurrent vector system. It is often necessary in engineering practice and design work to resolve a known vector into concurrent coplanar or non-coplanar components. Many textbooks in descriptive geometry discuss this so-called polygon method or vector-polygon method in the chapter of vector graphics [2,3]. Solutions are usually handled with the graphical construction of vector polygons.

Today, the CAD systems with solid modeling capability are becoming more popular in engineering design. Many researchers investigated the potential application of 3D CAD in descriptive geometry with diversified emphasis [4,5,6]. Although every one of them addressed the possible application of 3D CAD for one topic or the other in descriptive geometry, no one discussed the application of 3D CAD for the analysis of vector systems. The purpose of this study was to investigate how the 3D CAD approach could be utilized in solving concurrent coplanar and non-coplanar vector systems. Both the 3D CAD approach and the traditional approach (polygon method) that requires the manual construction of vector polygons are used to deal with the same set of problems, and therefore, can be evaluated for their effectiveness.

II. Concurrent Coplanar Vector System

Figure 1 depicts a coplanar vector system that has forces that lie in the same plane. The hoisting system, which has a pulley mounted at the end of the boom C, is used to support a weight of 50,000 pounds through cable A. If boom C is held in place by chain B, find the forces in both B and C.

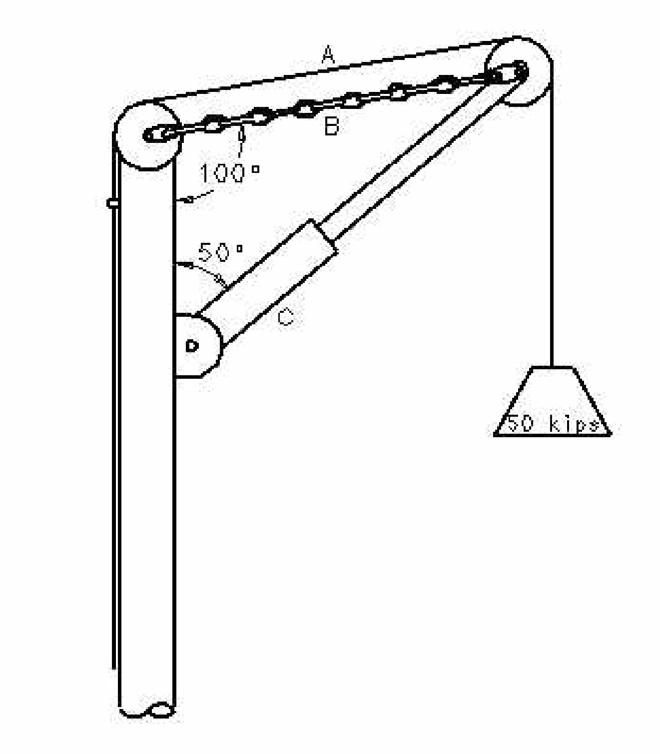

Figure 1. Space Diagram of a Concurrent Coplanar System

Traditional Approach

1. Draw the downward vector to scale to represent the load (50 for 50 kips or 50,000 lbs) as shown in Figure 2.
2. Draw vector A, which has the same length as the load, parallel to its direction. This is because the loads in the cable on both sides of the pulley must be equal.
3. Draw vectors C and B parallel to their directions. To complete the vector polygon, place arrowheads of all vectors head-to-tail.
4. Find the forces in chain B and boom C by measuring vectors B and C, respectively, based on the same scale.

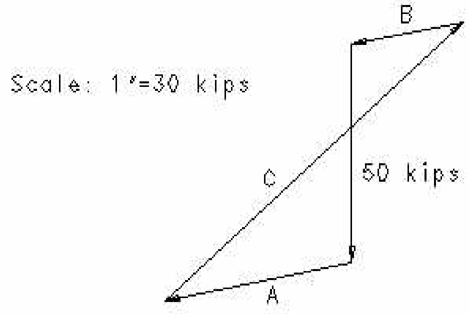

Figure 2. Vector Polygon – Traditional Approach

3D CAD Approach

1. Construct a wireframe but make sure one of its edges is vertical as depicted in Figure 3. This can be achieved by applying the "vertical ground" command [7] provided by the software.
2. In order to have a fully constrained wire frame, apply a linear dimension of 50 (for 50 kips) and angular dimensions of 100^0 and two 30^0 using the "dimensioning" command. These angular dimensions are the angles between different members. For instance, 100^0 is the complement of the angle between the load and chain B.
3. Set the linear dimension of vector A as a reference dimension (50 at bottom) using the "modify" command, so it would change with the linear dimension of the load.
4. Find the forces in chain B and boom C by measuring their corresponding edges in the wireframe using either the "measurement" or "dimensioning" command.

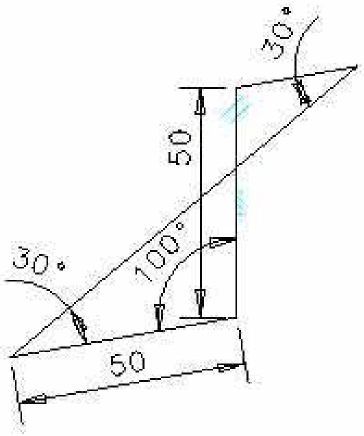

Figure 3. Constrained Wireframe

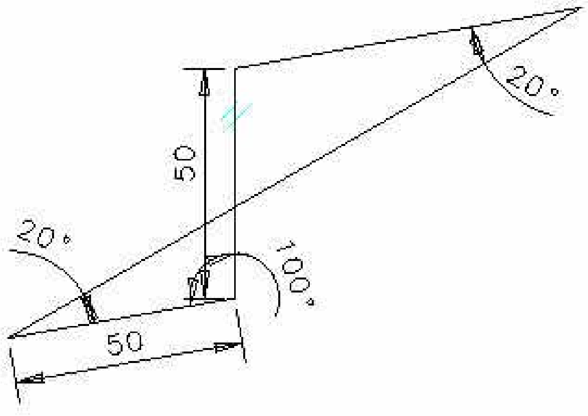

Figure 4. Revised Constrained Wireframe

Discussion

The advantage of using constraints, including grounds and dimensions, in the 3D CAD approach is that they permit the user to examine different situations for a coplanar system quickly without the need to re-construct the vector polygon manually. For instance, Figure 4 shows how the wireframe from Figure 3 would automatically adjust its shape and size by simply applying the "modify" commend. If the angle between boom C and the supporting column changes from 50^0 to 60^0 (the same as the change of the angle between boom C and chain B from 30^0 to 20^0), the forces in cable A and chain B would change accordingly. The application of these constraints is particularly powerful while dealing with a more complex coplanar force system, such as a truss that has multiple joints (points of application). The examination of design alternatives for a coplanar truss only involves the modification of existing wireframe used for an original design. It is easy to see that the revision of wireframe is as swift and accurate as the use of CAD commands.

III. Concurrent Non-Coplanar Vector System

A non-coplanar vector system means vectors act in different planes. Figure 5 represents such system that has non-coplanar forces. A weight of 80 pounds is applied to the point of application (where the three members meet). If members A and B overlap in the front view, find the compression in all three members.

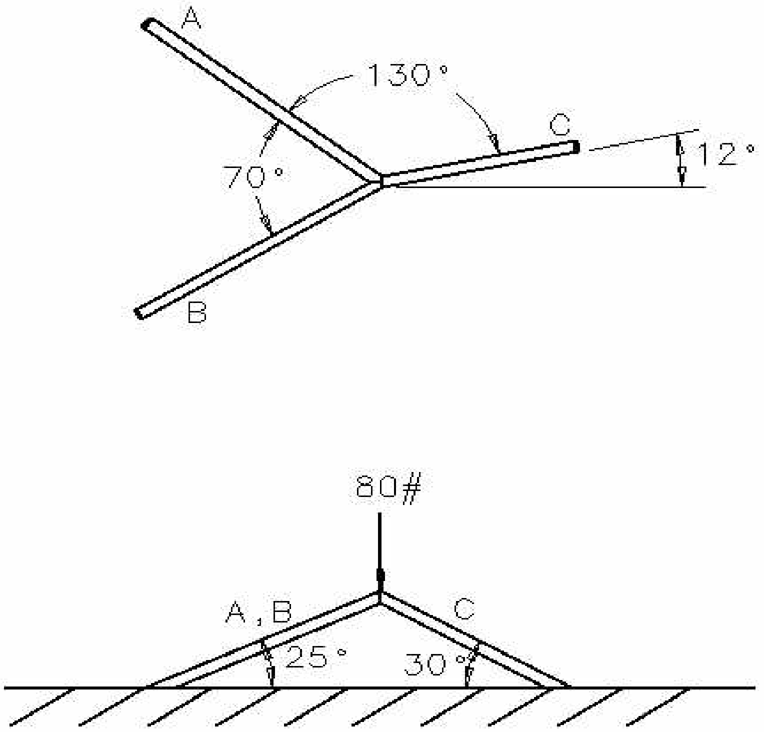

Figure 5. Space Diagram of a Concurrent Non-Coplanar System

Traditional Approach

1. Draw a vector to represent the load (80 lbs) downward first in the front view of the vector polygon as shown in Figure 6. The construction begins in the front view because two forces, A and B overlap here, resulting in only two unknowns in this view.
2. Draw two unknown vectors, C and "combined A and B", parallel to their directions to complete the front view of the vector polygon. Vectors A and B are inseparable, because the point of intersection of vectors A and B is unknown at this time.
3. Draw vector C in the top view of the vector polygon next. Make sure its head and tail are aligned between the top and front views. Complete the top view of the vector polygon by placing vectors A and B parallel to their directions.
4. Project the point of intersection of vectors A and B in the top view to the front view to separate these vectors.
5. To determine the compressions in members A, B and C, construct the true-length diagram with the top view of the vector and the vertical height of the vector for the horizontal leg and vertical leg of the true-length diagram, respectively.

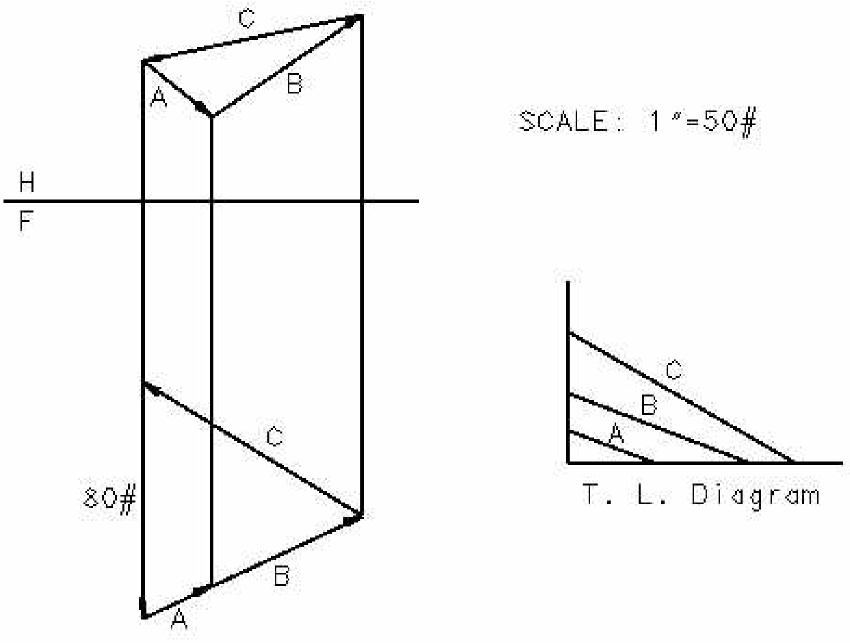

Figure 6. Vector Polygons – Traditional Method

3D CAD Approach

1. Construct a triangular wireframe shown in Figure 7 that represents the front view of the vector polygon shown in Figure 6. The wireframe is constrained by applying a linear dimension of 80 (for 80 lbs of vertical load) and angular dimensions of 65^0 and 60^0 (for the angles between the load and members, the same as the complements of 25^0 and 30^0, respectively, shown in the front view of space diagram).

2. Extrude the triangular wireframe into a solid as shown in Figure 8. The thickness of the extrusion can be randomly selected. Repeat steps 2 and 3 if the thickness is too small, which can be easily detected at the end of step 3.
3. Attach a coordinate system to this solid at one of its upper corners. Sketch the second triangular wireframe, which represents the top view of the vector polygon, on X-Z plane of the coordinate system. Figure 9 represents the top view of the completed wireframe. 12^0 between member C and the folding line, 50^0 between members A and C (the complement of 130^0), and 20^0 between members B and C (the complement of 70^0) are used to determine the shape and size of this wireframe.
4. Extrude the second wireframe to shape the existing solid by intersection as depicted in Figure 10. Measure the edges to find the compressions in members (A in green, B in yellow, C in red, and the resultant that represents the load is in pink).

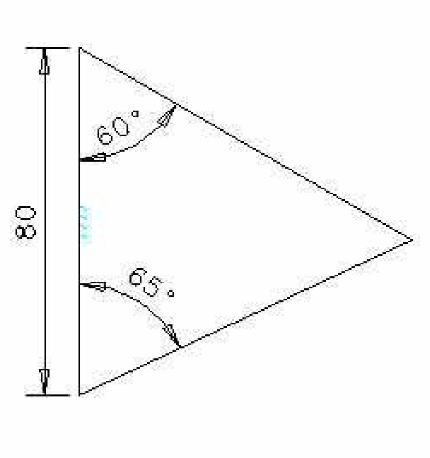

Figure 7. Constrained Wireframe

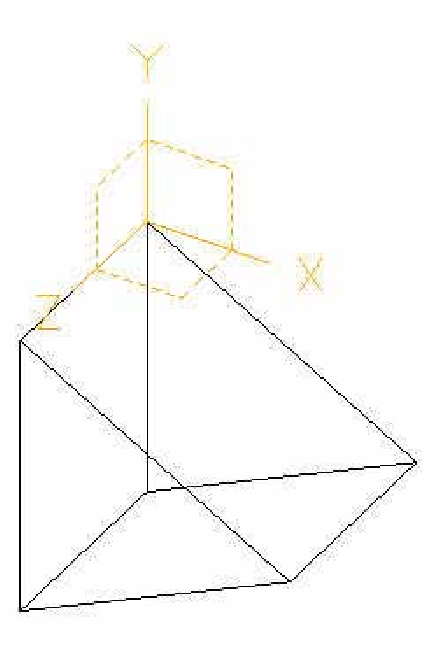

Figure 8. Solid Part Extruded from Wireframe

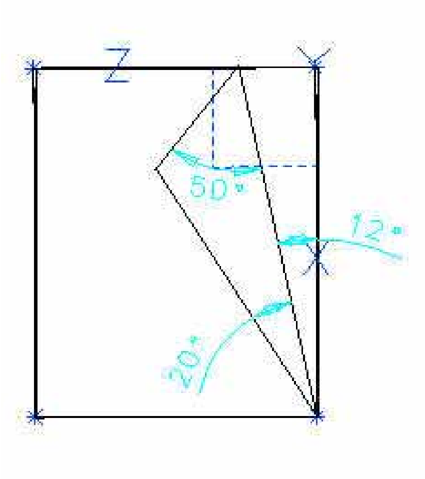

Figure 9. Top View of Wireframe Sketched on X-Z Plane of A Coordinate System

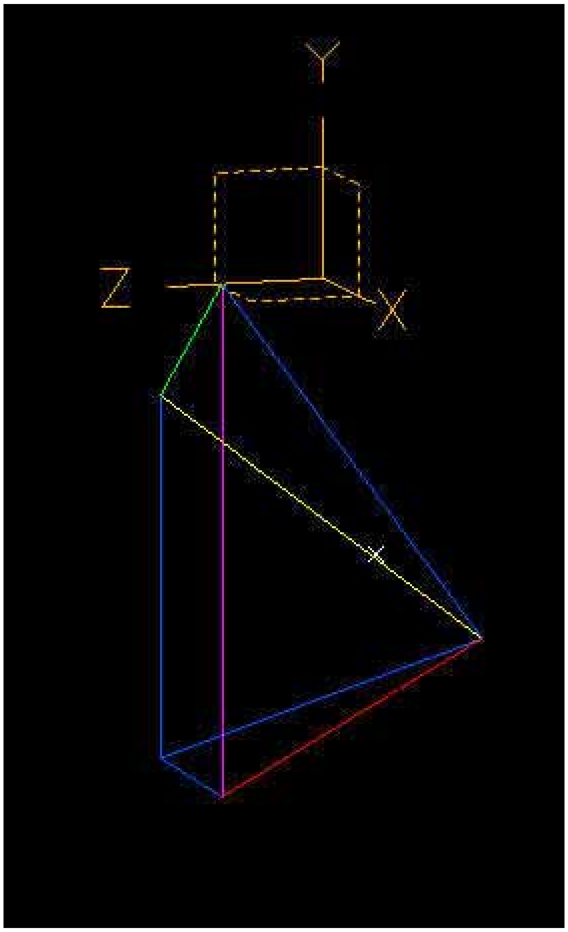

Figure 10. Solid Part with Edges Representing Compressions in Members

Discussion

It is just as quick and accurate to examine design alternatives for a non-coplanar system. Figure 11 shows the modified solid with the load increased from 80 to 105 pounds. The angle between member A (or B) and the ground in the front view is increased from 25^0 to 35^0, and the angle between member C the ground is increased from 30^0 to 40^0. This new design allows about the same compression in each of the three members, even the load applied increases by 25 pounds. All the changes can be achieved by using the "history tree" command that is ideal for modifying a solid. The history tree displays the sequence of commands used to model a solid part. One can use the history tree to modify the dimensions of the solid before update the part using the "update" command.

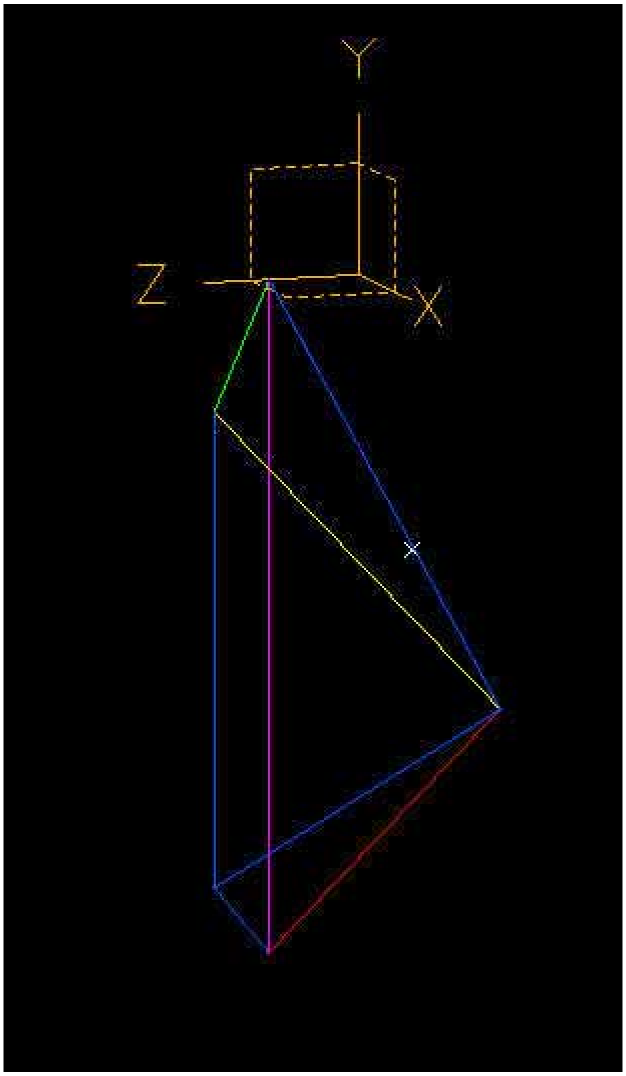

Figure 11. Solid Part with Modified Dimensions

IV. Conclusion

The problems presented in this paper demonstrate that the 3D CAD approach is much more effective in solving concurrent coplanar or non-coplanar vector systems versus the traditional approach. In each of these problems, 3D CAD is less time-consuming yet more accurate, because it just requires the application of proper CAD commands instead of manually scaled vector polygon construction. The 3D CAD approach also proved it is a very powerful approach for examining design alternatives. With the 3D CAD approach, the analysis of other vector systems required in engineering design can also be solved quickly. Solutions can be obtained following the similar 3D CAD approach presented in this paper with minimum modifications. Although the success of the 3D CAD approach relies heavily on how effectively one can deal with various commands, it is not difficult to see that 3D CAD doesn’t limit the use of geometric and spatial reasoning. As a matter of fact, the concepts and geometric rules have not changed regarding descriptive geometry solutions of vector systems. The combination of descriptive geometry with 3D CAD provides new possibilities for creative engineering design. 3D CAD can become a powerful and efficient means of learning and understanding descriptive geometry.

Bibliography

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