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A COMPUTER GRAPHIC TEACHING AID
FOR THE SYNTHESIS OF FOUR-BAR LINKAGES

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ABSTRACT

This project involves developing software for the use as a teaching tool in the classroom. The "four-bar linkage mechanism", often used in kinematic movement, is the main subject.

The software provides a working environment to perform a graphical synthesis of a four-bar linkage to move one of the links through three specified positions in the plane. The construction process is facilitated by the built in kinematic intelligence so that the student can quickly and easily visualize the process. The construction lines are dynamically updated as the free parameters in the design are modified. This is particularly beneficial because it allows the student to see the dynamic nature of the solution, as opposed to considering it as a static situation. Once the synthesis task is completed, the four-bar linkage is animated to provide immediate verification of the satisfaction of the original motion specifications.

The software can be run on the Mechanical Engineering Department computer network.

INTRODUCTION

The traditional way of teaching relies heavily on static blackboard and pictures in the text books. Some teaching tools also depend on cardboard modelling, but this method is only good for a simple rotation of motion. Many students have difficulties in visualizing the dynamics of the mechanisms. A computer aided software environment is being developed to provide kinematic intelligence to the simulated blackboard [1]. This computer graphic animation enhances the efficiency and quality of education. Diagrams and graphic pictures can be drawn to precise dimensions, thus eliminating rough sketches often drawn by instructors on the static blackboard. This software supported computer graphic animation will help the students in understanding the motion and movement concepts more easily. This concept is applicable not only in engineering fields, but also in other areas such as in architecture, physic and chemistry.

No one can deny the important role of an instructor in the classroom. However, the author feels that this computer graphic animation will assist the instructors in bringing the point across to the students more effectively; especially on the subjects that demand a high degree of imagination. This powerful teaching method will undoubtedly increase the productivity of the instructors and students. The instructors and students will share the same ideas and visualize the same concept, thus eliminating unnecessary repetition of explanations and demonstrations. Consequently, this can enhance the communication between the two parties.

This computer software is not only designed to teach the concepts in the course, but to increase the students interest in the course as well. This interactive nature can change the way students think and learn. With the help of this computer graphic animation, students will have a strong foundation in introductory kinematics of mechanisms. At the same time, students will improve their overall computer usage skills. This will help students in preparing for their real life environment after they have finished their college education.

The author's project emphasized one aspect of the overall kinematics environment, namely three positions synthesis. Three positions synthesis involves motion generation of four-bar linkages, in which three positions of a line in the plane are specified. It is desired to determine the dimensions of a four-bar linkage configuration to move it to each of those positions [2].

Following is an example on constructing a four-bar linkage using synthesis method:

Refer to figure 1 for the following construction:
1. Draw three design positions. The points are denoted as A1, A2, and A3.
2. Draw a construction line from point A1 to A2 and from A2 to A3 . Then draw a bisector line between point A1 and A2, and also between A2 and A3.
3. Ground pivot (G1) is determined by the intersection of both bisector lines.
4. Connect G1 with A1 and call it R2 (input) link.

Refer to figure 2 for the following construction:
5. Pick any point on the plane and call it B1. The relationship between B1 and A1 must be fixed (rigid). Now use B1 to define the three positions of the link.
6. Draw a construction line from point B1 to B2, and from B2 to B3.
7. Draw a bisector line between B1 and B2, B2 and B3.
8. Draw a ground pivot (G2) point, where it is determined by the intersection of both bisector lines.
9. Connect G2 with B1 and call it R4 (output) link.
10. Connect A1 with B1 and call it R3 (coupler) link (rigid body).

Note the construction lines are lines connecting two given points. Bi-sector lines are lines drawn through the mid-point of construction lines and are perpendicular to the construction lines.
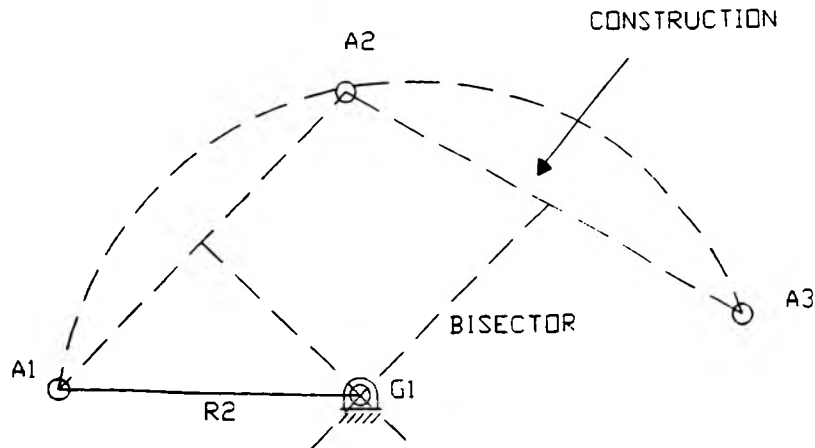

Figure 1. Construction lines, Bi-sector and Ground Pivot.
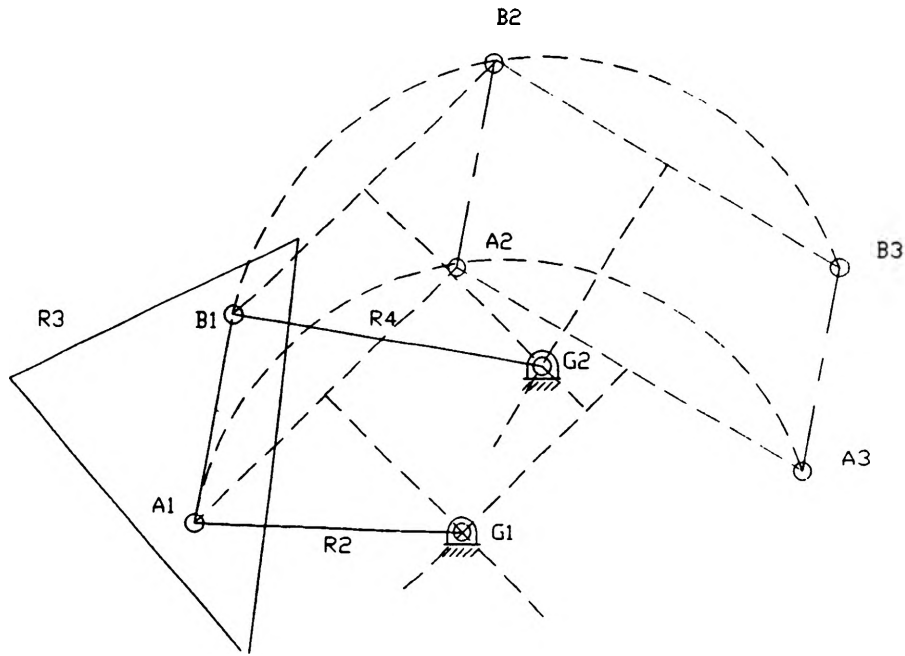
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Figure 2. Three positions motion synthesis.

R2 and R4 are very unique links. R2 will rotate from point A1 to A2 and to A3 and vice versa by making an arch with respect to the G1. R4 will rotate from point B1 to B2 and to B3 and vice versa, by making an arch with respect to the G2. The number of free choices for three precision positions is four, (x and y for each moving pivot point). Therefore, the number of free choice for each bar is two (x and y).

The actual four-bar linkage is shown in figure 3. It is important to note that any two points on R3, such as A and B, can define as a rigid body. Points A and B can be anywhere on the rigid body, thus creating an infinity of solutions [2].

The obtained solution is guaranteed to assemble in all three positions, but there is no guarantee that
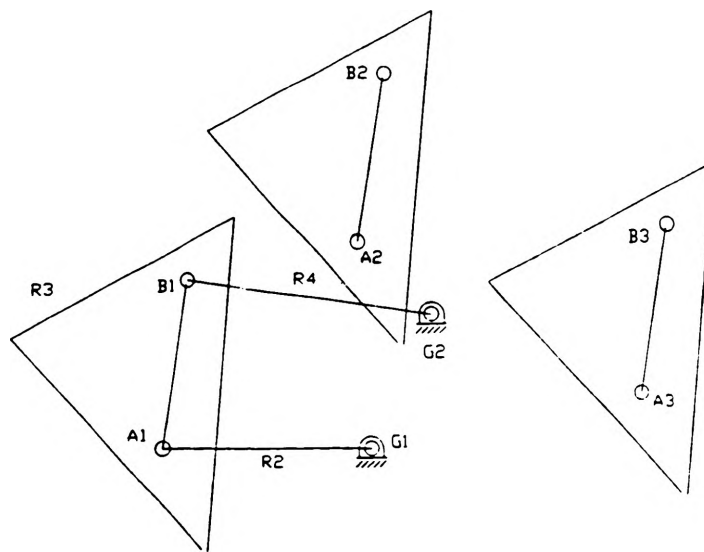

Figure 3. Sample four-bar linkage.

the linkages will move between those precision positions. The resulting linkage may be incapable of moving from one precision position to another due to the presence of a toggle condition or other constraint. The toggle condition is undesirable because the linkages can not reach all of the specified design positions without disassembly of the linkages. The reason for the undesired linkages is simply because of the poor ground pivot locations. Sometimes the toggle condition is very useful because it can provide a self locking feature. In order to see whether the resulting linkages will move to all precision points, the animation process can be used.

This software involves three easy steps in the drawing process:
1.   Data Entry - involves entering data for the first three position points
      (P1, P2, and P3) and three angles.
2.   Dragging Process - finding a second set of three position points and using them to
      determine a desired four-bar linkage.
3.   Animation Process - the actual process of the kinematic rotation of the four-bar
      linkage.

DRAWING PROCESS

Drawing Method
1.   The method of sketching the graphic using this software is very easy. The computer window such as the one shown in figure 4 will be displayed as soon as the program is executed. Data for x's, y's and angles are to be entered in given fields under 'Menu'. Students are given a second chance to re-enter any data before accepting 'y' (yes) key. The software will start executing the data as soon as the 'y' (yes) key is pressed. The software will execute any data entered, regardless of the values. The actual size of the output display will remain the same. The
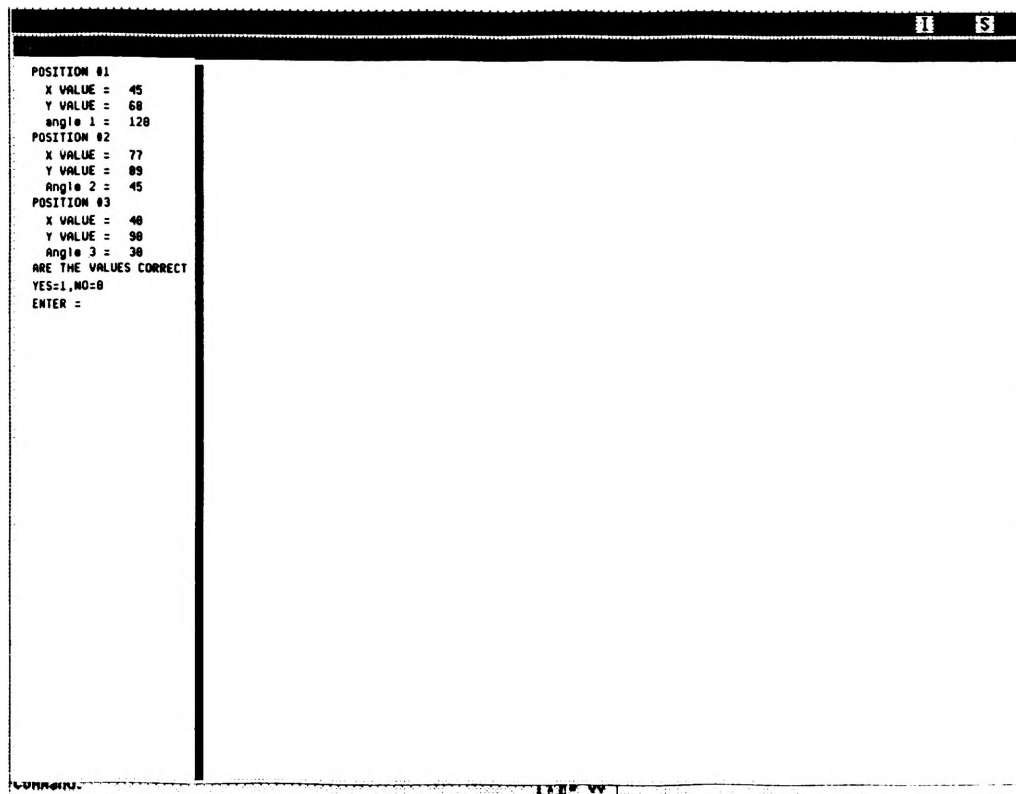

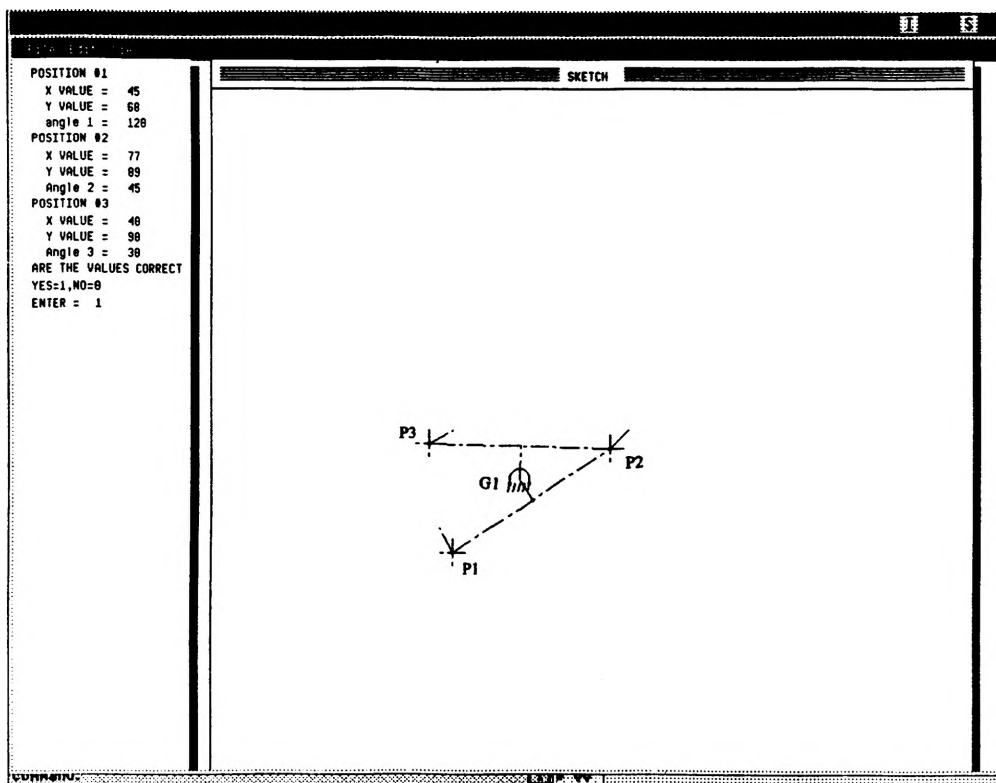Figure 4. Computer Graphics Screen.

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Figure 5. Three Precision Positions Diagram.

program is written to scale the given data to fit in the graphics window.

2. After all data are entered and accepted, the diagram such as shown in figure 5 will display. Construction lines, perpendicular bisector lines, ground pivot and three position points (P1, P2 and P3) selected will be displayed. Note that there is an extended line at every point. These lines are drawn as a result of the input angles.

3. In order to construct a four-bar linkage, two moving pivot points must be chosen on the coupler link. One of the points is chosen by default at the precision position. The other moving pivot must be specified in relation to the first precision position. To select the moving pivot, a mouse pointer is used. Once the mouse pointer is clicked, new construction lines will be sketched (figure 6). The moving pivot in its first position (P1') is determined by how far the pointer is dragged away from the first precision position. The second (P2') and third (P3') locations of the moving pivot will be sketched automatically as soon as the first position (P1') is chosen. Simultaneously, the second ground pivot (G2) will be determined. When the mouse button is released, the four-bar linkage will be displayed (figure 6). The sketching for any new construction lines can be repeated by dragging the mouse until the proper linkages and ground pivots are found. The desired dimensions of the linkages (when the mouse button is released) will be stored temporarily for animation purposes.

Animation

There are two types of animation processes, a single-step and a continuous animation through the full range of motion. Animation can be activated by choosing the animation option under the 'View' menu. Single-step animation allows the linkage to move one step at a time when any key is hit; while continuous animation will cause the linkage to rotate continuously around the ground pivots. Beginners are encouraged to select single-step animation because the motion of the linkage is easier to observe and analyze. From this observation, students are able to see whether it is a desired linkage or not, simply by looking at the toggle condition. If the linkage reaches a
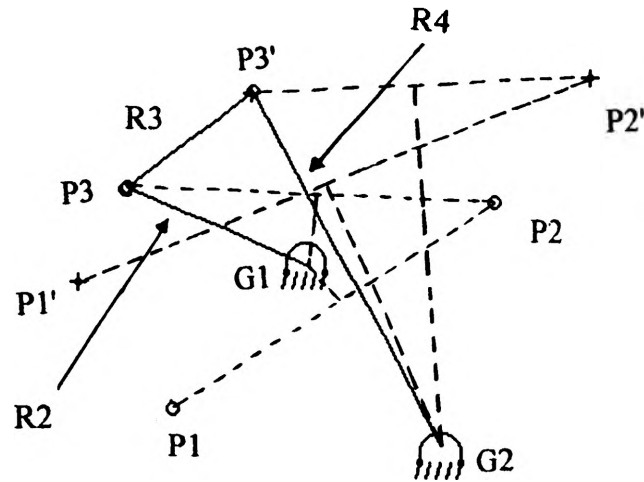
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Figure 6. Four-bar Linkage

toggle position, the 't' key can be used to display the linkage on the other side of the toggle position. Figure 7 illustrates a single-step animation.

CONCLUSIONS AND RECOMMENDATIONS

The software supported computer graphic animation shown in this project is expected to improve the method of teaching in the classroom. It should increase interest, depth of understanding, and intuition. More importantly, students have the luxury of visualizing a graphic output of dynamic constructions in a way which can never be done on static blackboards or cardboard modelling. It can also ease the students confusion and difficulties in visualizing the dynamic phenomena.

It is recommended that classes are to be taught with the help of computer graphic animation. Students who have seen the kinematic motion themselves through this software have a deeper image embedded in their mind. This method of teaching is not only limited to classes in
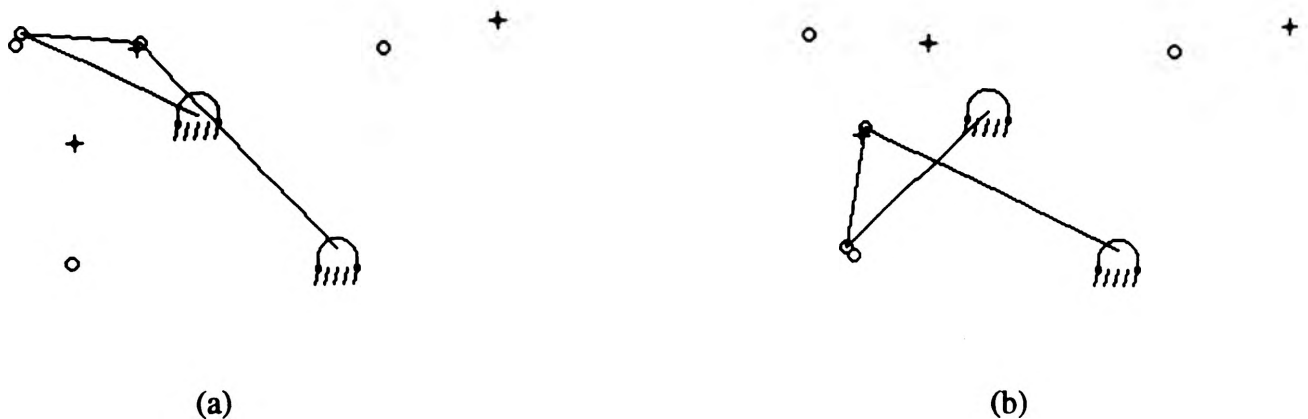

(a) (b)

Figure 7. Four-bar Linkage - Single-Step Animation.

engineering fields, but also to other education disciplines. Students will enjoy learning more and have less feelings of frustration.

ACKNOWLEDGMENTS

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