Title:
Computer-aided Design for Two-dimensional Simulation of the Mechanism of a Three-dimensional Pantograph

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Introduction:
Insects and mollusk are part of the culture and ecosystem around the world. Biologists study them using the methods of geometric morphometry [1] or mark-break [2] to analyze their growth and the morphological changes that both insects and mollusks have undergone due to climate change.

Using these two methods involves a lot of time and effort for biologists because the work is initially done manually by marking the landmarks. They then use computer programs for their analysis, description, and evaluation.

Therefore, we propose a paradigm shift to find the numerical values of the reference points, that is, the x and y coordinates and the curves of the insect and mollusk parts using a three-dimensional pantograph.

Geometrically our three-dimensional pantograph is based on Gaspard Monge's method of representation [3]. Having the following parts: (1) a table with wheels that moves back and forth on the z-axis through a band; (2) a rectangular base on a rail that moves right and left on the x-axis through an Acme threaded rod. On this base are the pointer and the tip of the pencil. And (3) two threaded Acme rods to move the rail up and down on the y-axis (Fig 1).

Fig. 1: Photographs of the three-dimensional pantograph prototype.

To find the numerical values of the x and y coordinates of the reference points of the exoskeleton curves according to the movements of the pantograph, we created a computer program using the object-oriented language ActionScript 3 to perform the two-dimensional simulation of the three-dimensional pantograph mechanism.

Methodology

The methodology used to perform the two-dimensional simulation of the three-dimensional pantograph mechanism consists of three parts. In the first part, we define the operation of the three-dimensional pantograph from the geometric point of view (Fig.2).

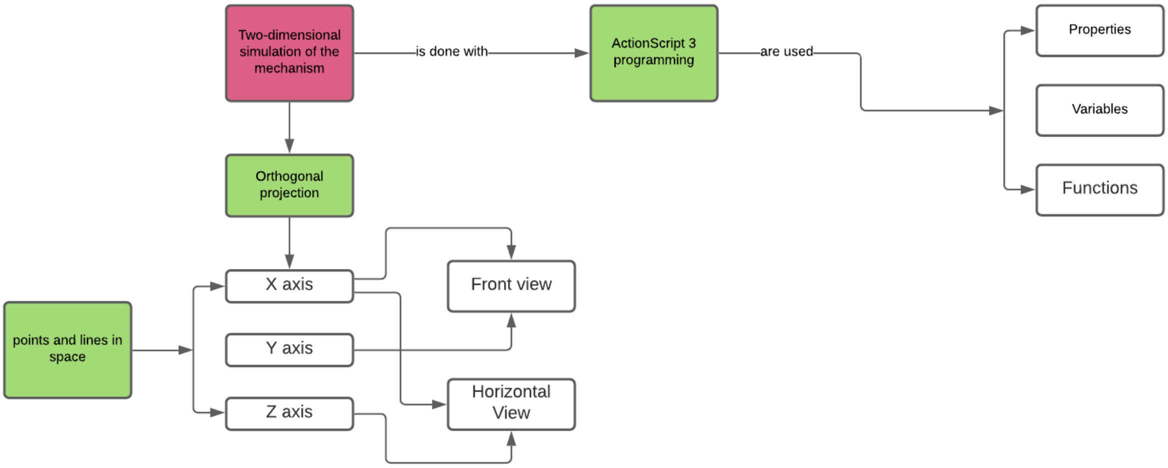

Fig. 2: Operations from the geometric point of view.

In the second part, the algorithm was defined (Fig 3).

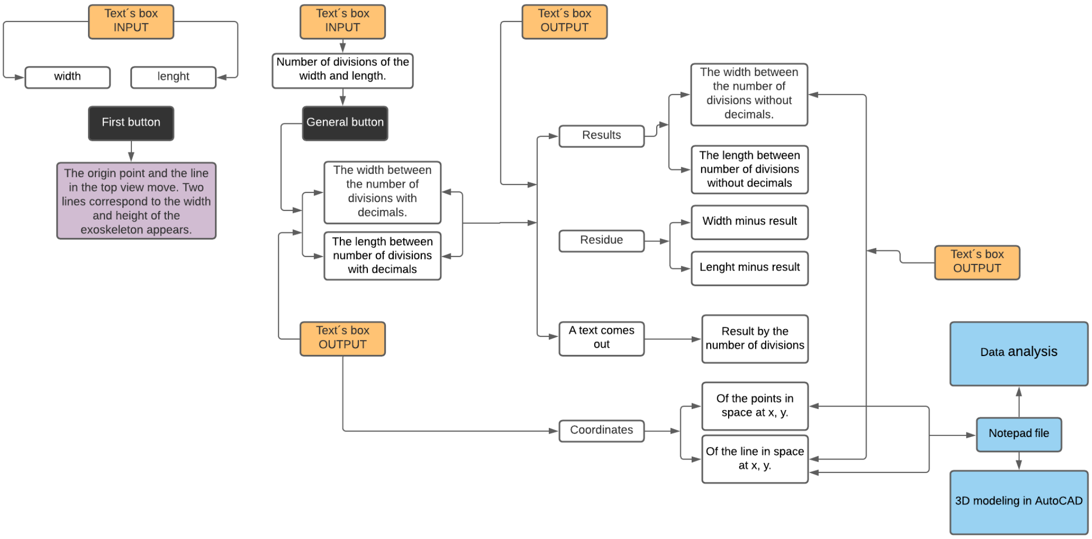

Fig. 3: Algorithm.

And in the third part, the graphic user interface was defined (Fig 4).

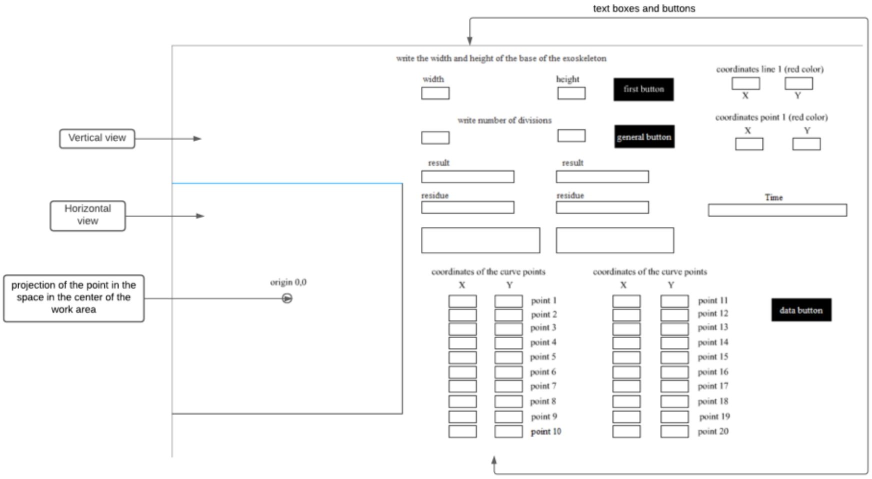

Fig. 4: Graphical user interface.

Design implementation

In the computer program, the input data is the width and length of the exoskeleton and the number of parts it is divided into vertically and horizontally to create a grid.

```
inputAncho = Number(anchoEntrada.text);
inputLargo = Number(largoEntrada.text);
```

The program processes and stores the numerical values of the number of divisions and the remainder. The remainder is the numerical value after the decimal point.

```
function ancholargoResultado(e: MouseEvent) {
        resultadoAncho.text = String(Number(anchoEntrada.text) / Number(anchoDivisiones.text));
        var numAncho: Number = (Number(resultadoAncho.text));
        var valorAncho: Number = Number(int(numAncho));
        resultadoAnchoSinDecimales.text = ("distancia divisiones:" + valorAncho);
```

With these numerical values, we program the animation to recreate the two-dimensional simulation of the three-dimensional pantograph, were the red line moves from bottom to top; the red point moves to the right many times as the number of divisions. Each time the pointer touches a point on the exoskeleton curve, it simulates the points marked on the paper.

An Array is used in programming to show all the points that simulate the trace on the paper.

```
var circulos: Array = new Array(circulo1, circulo2, circulo3, circulo4, circulo5, circulo6, circulo7, circulo8, circulo9, circulo10, circulo11, circulo12, circulo13);
for each(var circulo in circulos) {
    if (nuevaLinea1.hitTestObject(circulo)) {
        nuevaLinea1.y == circulo.y;
        var circuloVerde: Sprite = new Sprite();
        circuloVerde.graphics.beginFill(0x605858);
        circuloVerde.graphics.drawCircle(nuevaLinea1.x, (nuevaLinea1.y - 150), 5);
        circuloVerde.graphics.endFill();
        addChild(circuloVerde);
        removeEventListener(Event.ENTER_FRAME, bajarLineaY);
```

Once the animation ends, we have the numerical values of the coordinates x and y of each of the points of the exoskeleton curve.

We finish the programming with the file reference. The numerical values of the x and y coordinates of each point of the exoskeleton curve are in the notepad.

```
fileRef = new FileReference;
fileRef.save(textToSave, "matematicas5_4_5");
```

In programming, we consider a timer. The Timer indicates the time it will take for the three-dimensional pantograph to complete the journey.

```
var tiempo = 0;
        var timer: Timer = new Timer(1000, 200);
        timer.addEventListener(TimerEvent.TIMER, contarTiempo);
        timer.start();
        function contarTiempo(e: TimerEvent) {
                tiempo++;
                cajaTiempo.text = tiempo.toString();
```

Results

In the graphical user interface are a series of boxes where the user enters the width, length, and the number of divisions into which they will split the exoskeleton vertically and horizontally. There are three buttons. Pressing the "first button" the point and the red line change position. Pressing the "general button" performs the mathematical operations to find the numerical values of the reference points, and the animation and time begin to run. Pressing the "data button" saves the numerical values of the x and y coordinates of the reference points in the notepad (Fig. 5).

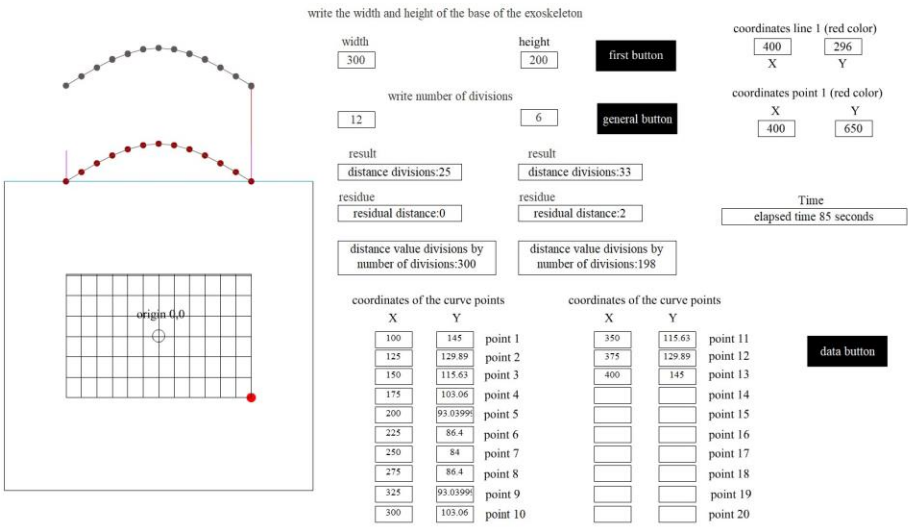

Fig. 5: Results in the graphical user interface.

We mathematically verified the distances between the traces of the AutoCAD™ program and the results of the y coordinates of the computer program we made

The numerical values of the coordinates x and y are copied from the notepad and passed to the AutoCAD™ to trace the curve. The points on the curve are backward because the origin of the Adobe Animate 2022™ program is at the top, and in AutoCAD™, it is at the bottom. So, the points are rotated 180° to position them correctly in the isometric projection (Fig 6).

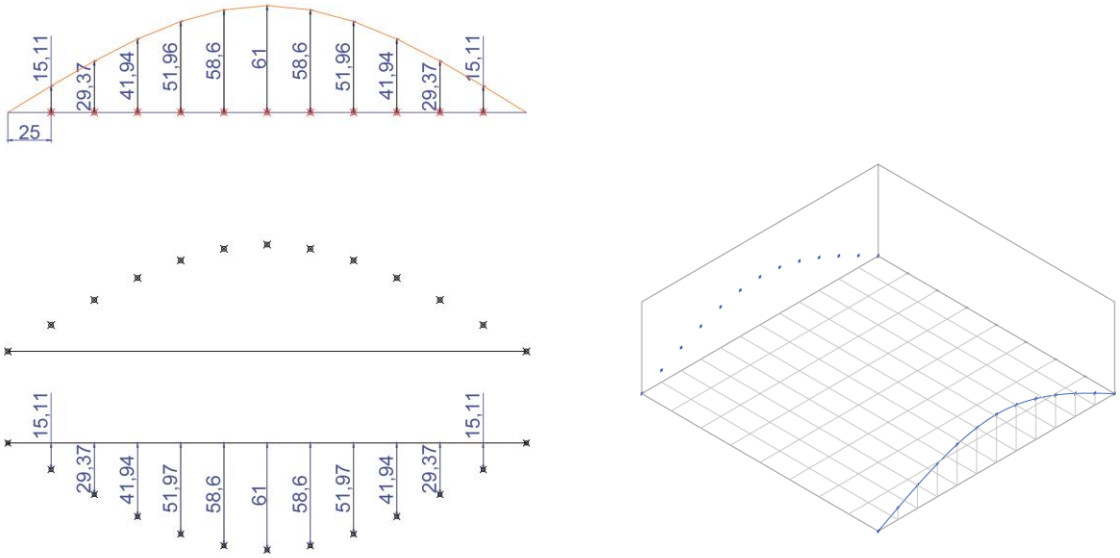

Fig. 6: (a) Trace and distances of the curve, (b) Curve points rotated, (c) Comparison of distances, and (d) Outline of the first curve of the exoskeleton in the isometric projection.

We perform several tests to check the program. The second trial's total distance is 300 units with 12 divisions every 25 units (Fig 7) In this case, the curve is different from the first test. The total distance of the third trial is 400 units with 18 divisions every 22 units and a remainder of 4 units (Fig 8).

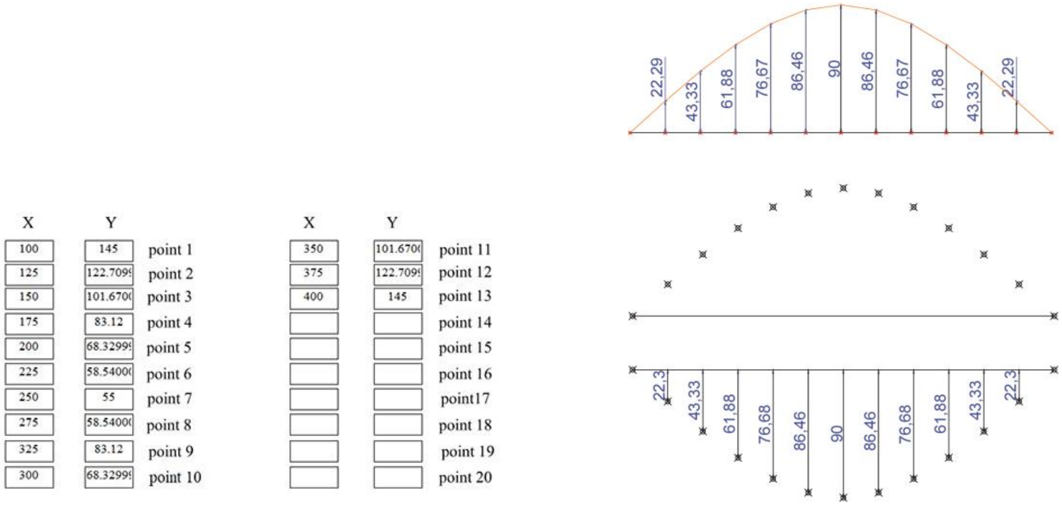

Fig. 7: Second trial (a) Results of the graphical interface, (b) Trace and distances of the curve, (c) Curve points rotated, and (d) Comparison of distances.

We mathematically verified the distances between the traces of the AutoCAD™ program and the results of the y coordinates of the computer program we made.

The time the program takes to recreate each of the curves is 90 seconds in the first trial, 78 seconds in the second trial, and 138 seconds in the third trial.

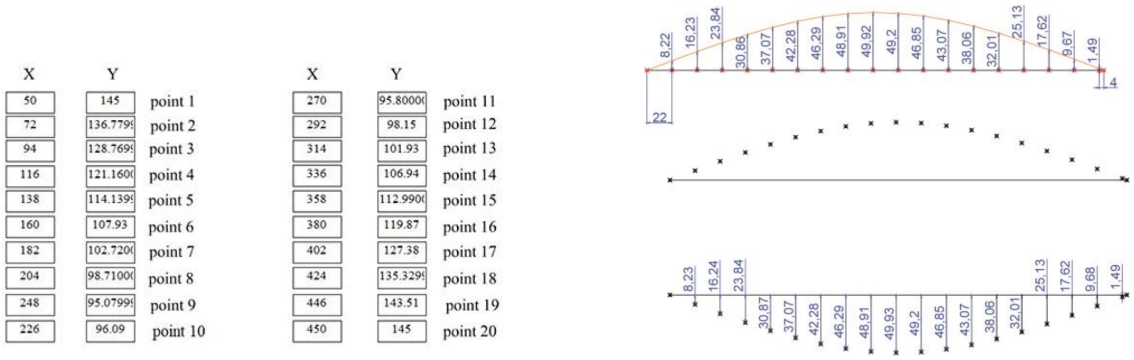

Fig. 8: Third trial (a) Results of the graphical interface, (b) Trace and distances of the curve, (c) Curve points rotated, and (d) Comparison of distances.

Conclusions:

Since we verify that the computer program we designed works correctly and that it throws us time, we conclude that we will be able to optimize the mechanism of the CNC three-dimensional pantograph.

The work that remains is the modeling and 3D printing of the exoskeleton so that biologists can describe, understand, and predict the changes that occur in nature. And geometers can analyze the structure of insects and mollusks.

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