Optimization of a Linkage System with Slider Joints and Gears

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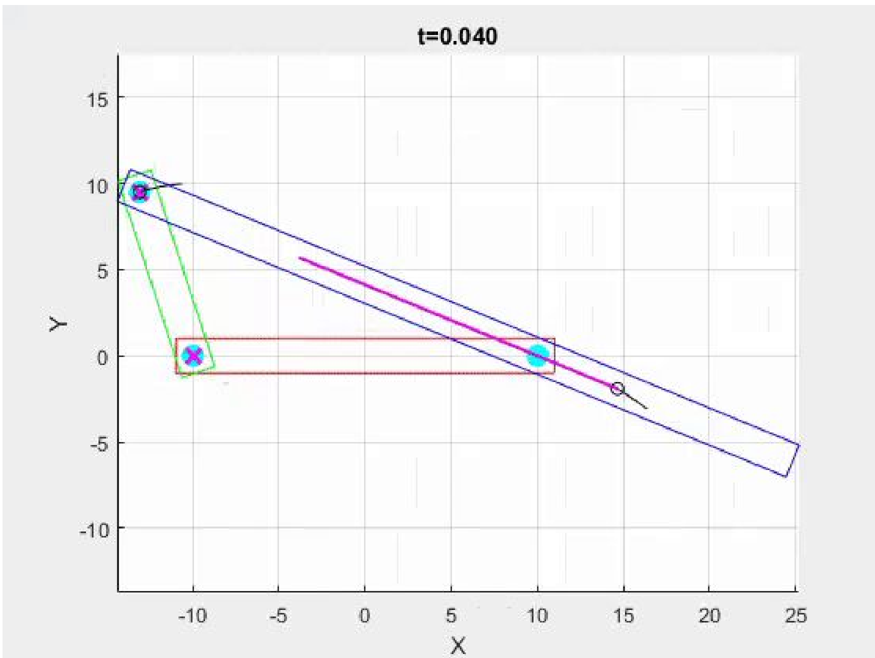
Abstract

Linkage systems are emphasized in many fields because of their usefulness and versatility. Mechanisms, systems of parts working together, have been helping humans to accomplish large feats for thousands of years. A better understanding of the relationship between different parts in a mechanism and being able to model mechanisms has allowed even greater leaps of innovation. I present a graphical model using matlab which can be used to create links, pins, slider joints, and “gearpins” working together in a system, modeling the motion of a physical system. Links can be standard linkages or gear linkages. Pins constrain a linkage to a position in relation to another linkage. Slider joints allow movement across a linkage, within the range of the slider. “Gearpins” are defined to indicate that a gear and another gear should have opposite and proportional rotation. These tools allow a user to create a large assortment of existing linkages as well as model their own.

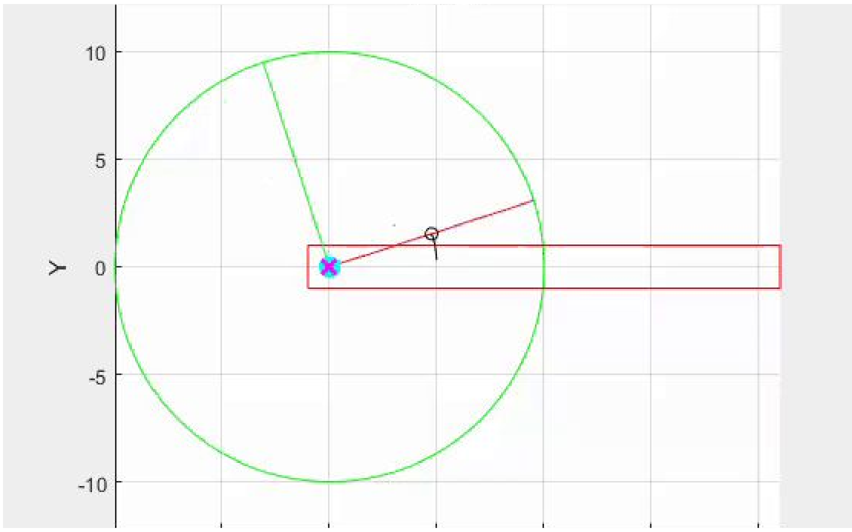
Steps for Slider

1. Draw the desired line
2. Set up the constraints
    a. Constraint that a slider should restrict a pin to move in-line of the slider
    b. Constraint that a pin should stay within the bounds of the slider

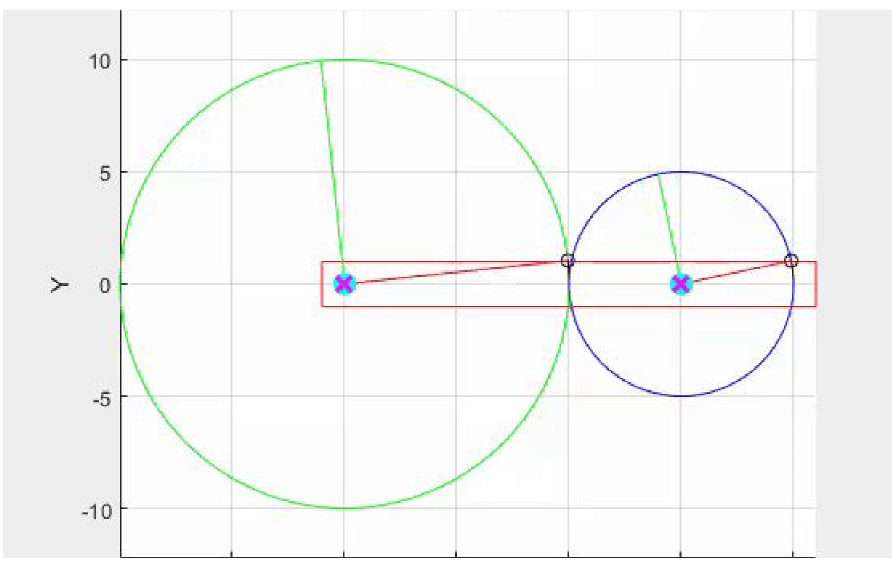


Steps for Gears

1. A single gear
    a. Mostly involved adjusting the drawScene function

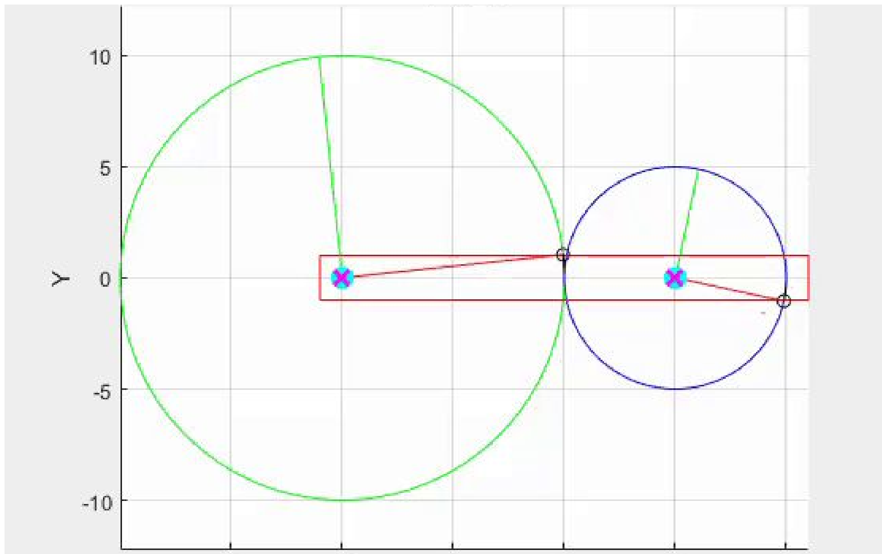


2. Two gears
    a. Create a second gear
    b. Add the gear constraint for proportional rotation



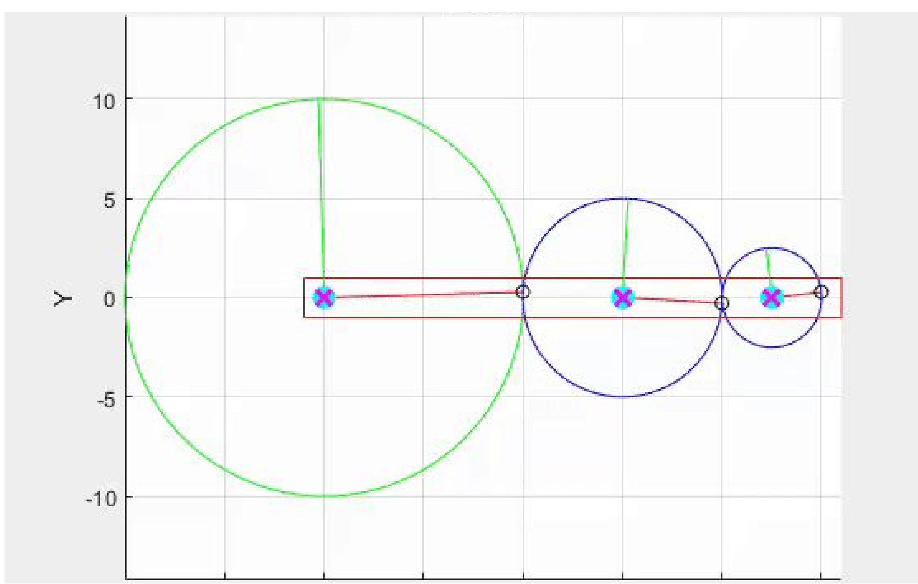
3. Fix rotational direction

   a. Change direction of rotation by changing constraint from - to +

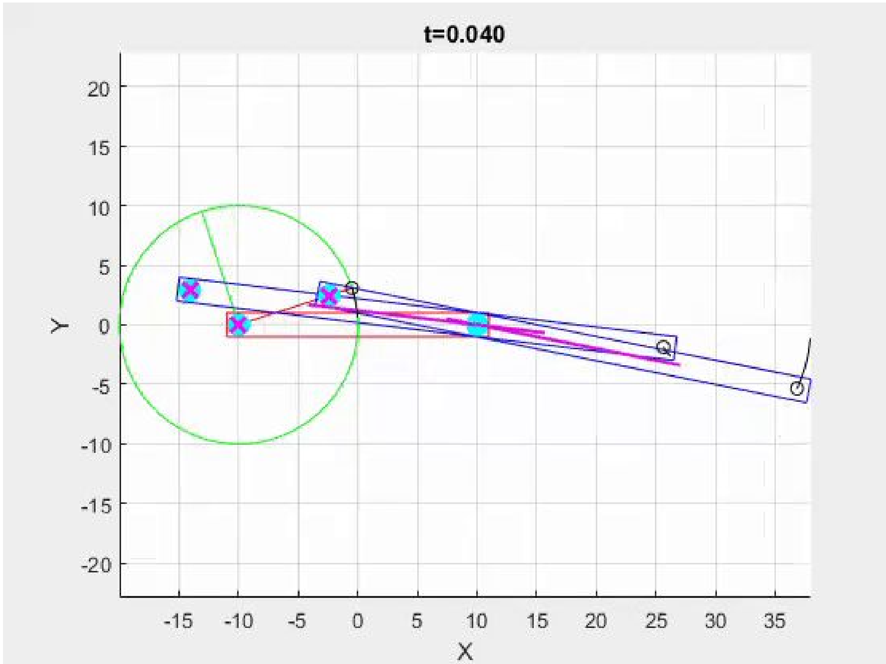


4. Align multiple gears

   a. Add another gear and gearpin to ensure that multiple gears in sequence work properly.



Representing Linkages



The above gif shows a grounded linkage (red), with pins (light blue dots) connecting a driver gear (green) to the left side and holding two other linkages through a slider joint. Links that are not gears are represented through rectangles, gears are represented through circles with a red and green line marking the original x and y axis of the gear for reference. This axis allows visualization of the rotation of the gear. Slider joints are represented through the deep purple lines through the center of the bar linkage. Tracer particles are used to monitor the motion of the linkages and leave black lines where they traverse. The two tracer particles on the right show the movement of the end of the two blue bar links. The motion of this mechanism is caused by the driver link, in this case, the green gear. Other motions are caused by the constraints placed on the motion of the links by pins, sliders, or gearpins.

Constraints

- Driver, Grounded, or Gear link
    - Set the position and angle of the link to the target position and angle. Gear links should not need to change position.
    - C = link.pos - link.targetPos
    - C = link.angle - link.targetAngle
        - (targetAngle is changed in the time step function)

- Pins
    - Translate local positions of links to their world positions from the position of the link and rotation matrix of the link.
    - Set the with respect to the world on the first attached link to equal the second attached link.
    - c = $\text{pointA}^{\text{world}}$ - $\text{pointB}^{\text{world}}$

- Sliders
    1. The position of the pin on linkA should be in line with the two positions on linkB that make of the slider. This can be achieved by ensuring the area of the triangle made by all 3 points is 0.
        - xa = $\text{pointA}^{\text{world}}$
        - xb1 and xb2 = $\text{pointB1}^{\text{world}}$, $\text{pointB2}^{\text{world}}$

```
c = .5* det([xa(1) xb1(1) xb2(1);
             xa(2) xb1(2) xb2(2);
               1      1      1 ]);
```

2. The position of the pin on linkA should be between the two positions on linkB that make the slider.
    - This can be achieved by ensuring the sum of the distance between the pointA and the ends of the slider (pointB1 and pointB2) are equal to the distance between pointB1 and pointB2.
    - c = dist(xb1, xb2) - (dist(xa, xb1) + dist(xa, xb2))

- Gearpin
    - The gearpin designates that two gears are connected and should spin in opposite directions at a proportional rate determined by their radius. I chose to use circumference (which is simply a scalar of radius by 2*pi).
    - c = (linkA.angle)*c1 + (linkB.angle)*c2

Ease of Use

1. Adding a slider

```
% Right-top
sliders(1).linkA = 1;
sliders(1).linkB = 3;
sliders(1).pointA = [20,0]';
sliders(1).pointB1 = [30,0]';
sliders(1).pointB2 = [10,0]';
```

2. Adding a gear

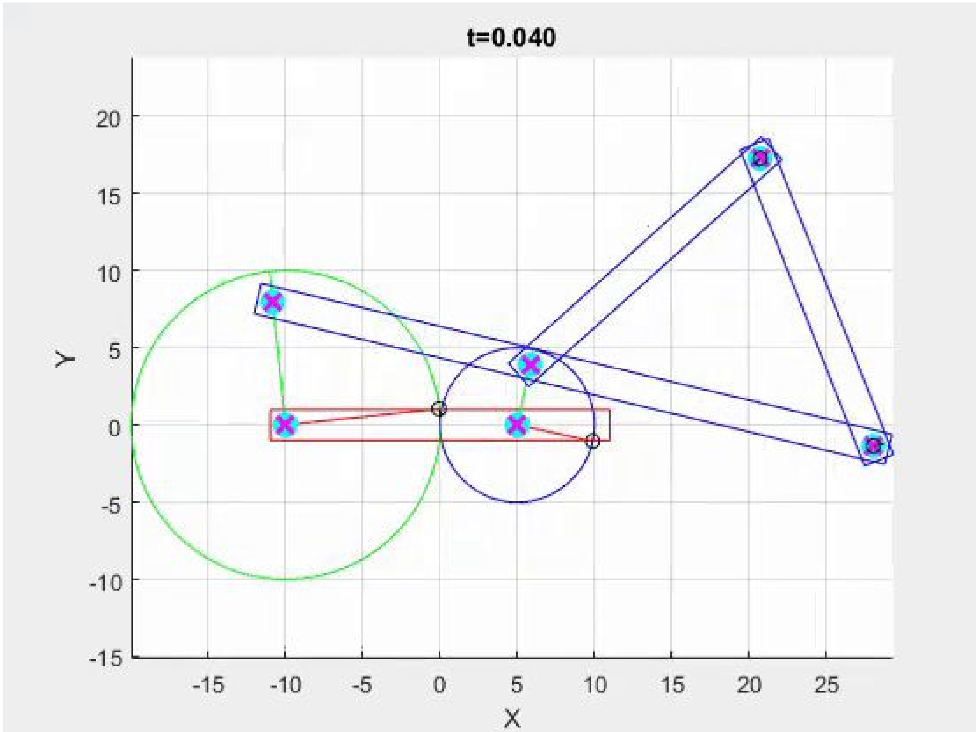
```
%Second Gear
links(3).gear = true;
links(3).angle = 0;
links(3).pos = [5 0]';
links(3).radius = 5;
links(3).verts = [
     0
     0
    ];
```

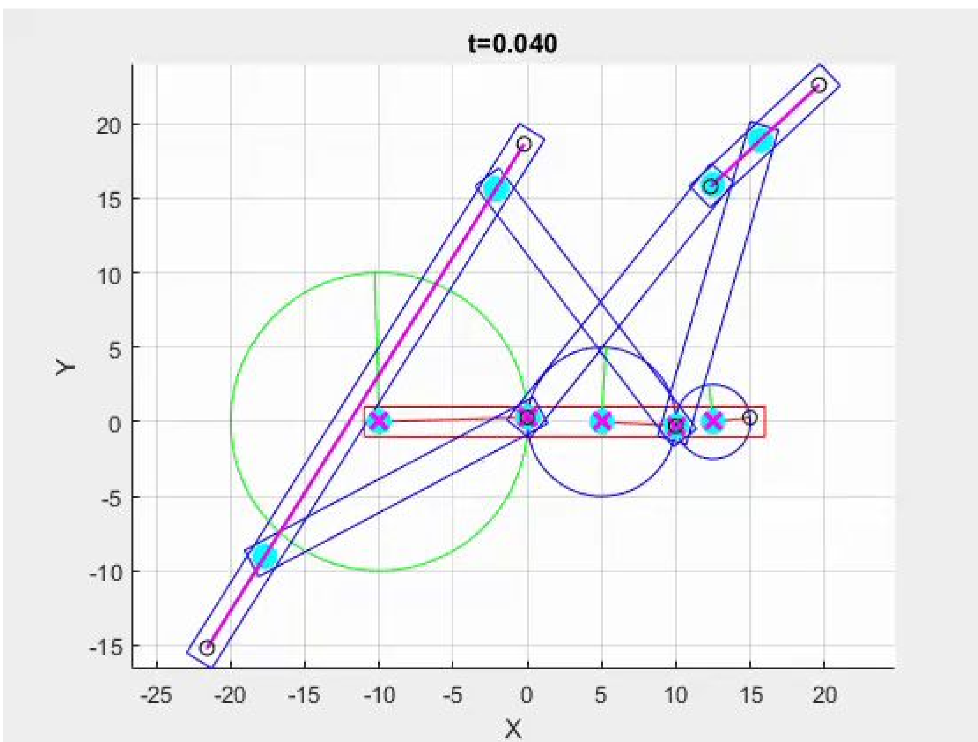
2. Adding a gearpin constraint

```
gearpins(1).linkA = 2;
gearpins(1).linkB = 3;

gearpins(2).linkA = 3;
gearpins(2).linkB = 4;
```

Results





References

Assignment 5:

http://courses.cs.tamu.edu/sueda/CSCE689/2017F/assignments/A5/

Stack Overflow - Area of a Triangle:

https://math.stackexchange.com/questions/516219/finding-out-the-area-of-a-triangle-if-the-coordinates-of-the-three-vertices-are

Dr. Sueda!!!