16-311 Spring 2016
Final Exam

Name ______________________

Group Number ______________

Read all of the following information before starting the exam:

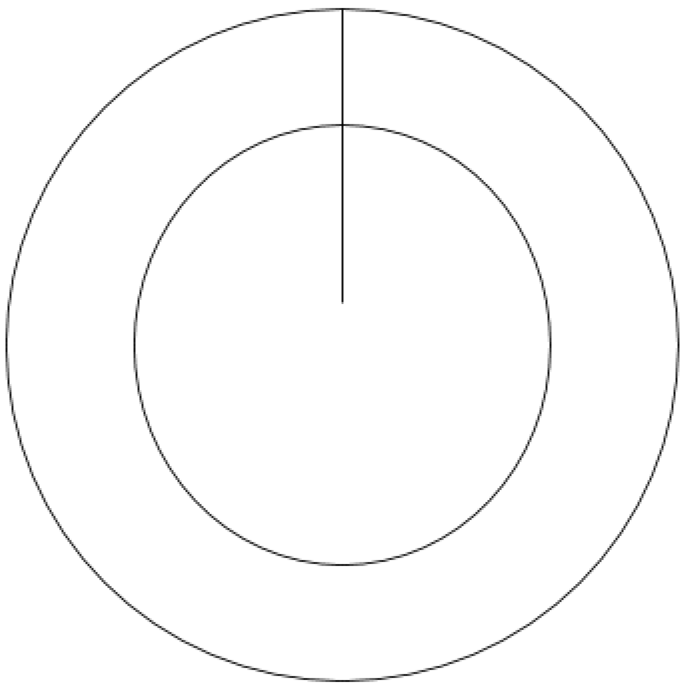
- You have 2hr and 0 minutes to complete this exam.
- When drawing paths, be sure to clearly indicate rounded edges vs sharp edges.
- When in doubt, explain your answer as you might get partial credit.
- Justify your answers algebraically whenever possible to ensure full credit.
- Circle or otherwise indicate your final answers.
- Please keep your written answers brief; be clear and to the point.

Question 1: Sensors, Robots, and Problem Solving (19 points)

Part 1 Sensor Design

In this problem you will design an absolute rotary encoder that can distinguish between forward and backward motion. The encoder need to have an accuracy to within 60 degrees. Your sensor can only sense if a light sensor is being blocked or not. The hardware can be setup to check if the light is being blocked at a fixed rate or to run a function every time that the sensor goes from blocked to unblocked, but it can not distinguish between the two state changes.

On the diagram below the line marks where the light sensor is located, fill the ring in with a pattern that you can use to detect the orientation of the ring to within 30 degrees. (5 points)



Part 2 firmware Design
Now using the following functions write pseudo code that will constantly set the global variable **angle** to be the current angle of the rotary encoder, assume all functions return instantly and no race conditions exist. (8 points)

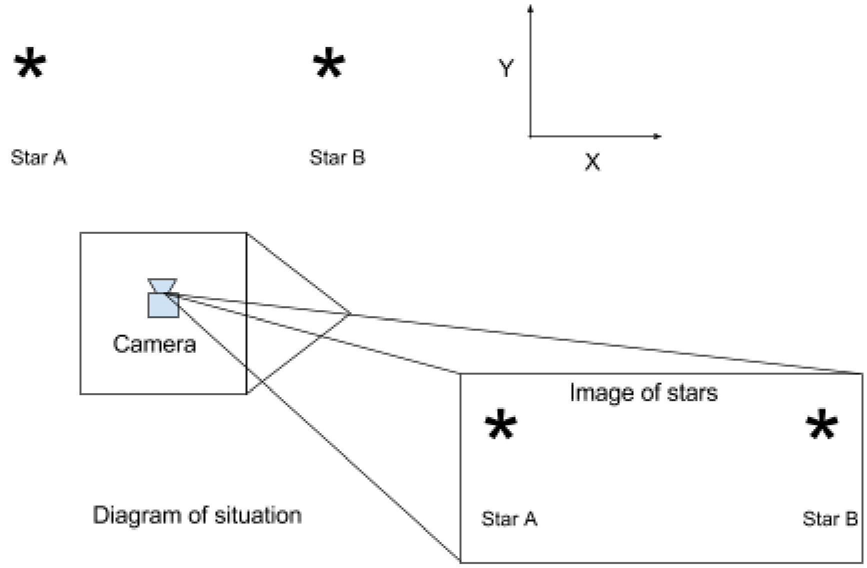
Boolean getLightReading(); // returns true if the light sensor is being blocked false otherwise.
Long getTimeMilli(); //returns the current time in milliseconds

Void registerLightReadingCallBack(function* your_function); will cause your_function to be called everytime the light sensor reading changes from blocked to unblocked or from unblocked to blocked.

Part 3 Ultrasonic Sensors
Describe how an ultrasonic sensor can be used to get distance to an object. List 1 pro and 1 con of using an ultrasonic sensor (3 points)

2. Lost in space (12 points)

You are on a spacecraft that is lost in space and you need to retriangulate using the stars, luckily you took 16311 while at cmu and have a pinhole camera. Given the following image of stars taken from inside a spacecraft and known locations of those stars figure out the position of the spacecraft. The focal length of the imager is .5 units. Each pixel is .00001 units.



Star A is located at pixel (10,10) Star A is really at X = 100,000; Y = 200,000; Z = 300,000
Star B is located at pixel (10, 110) Star C is really at X = 130,000; Y = 200,000; Z = 300,000
What is the X,Y,Z location of the spacecraft (12 points)

3. PID (22 points)

Part 1 Velocity PID (12 points)

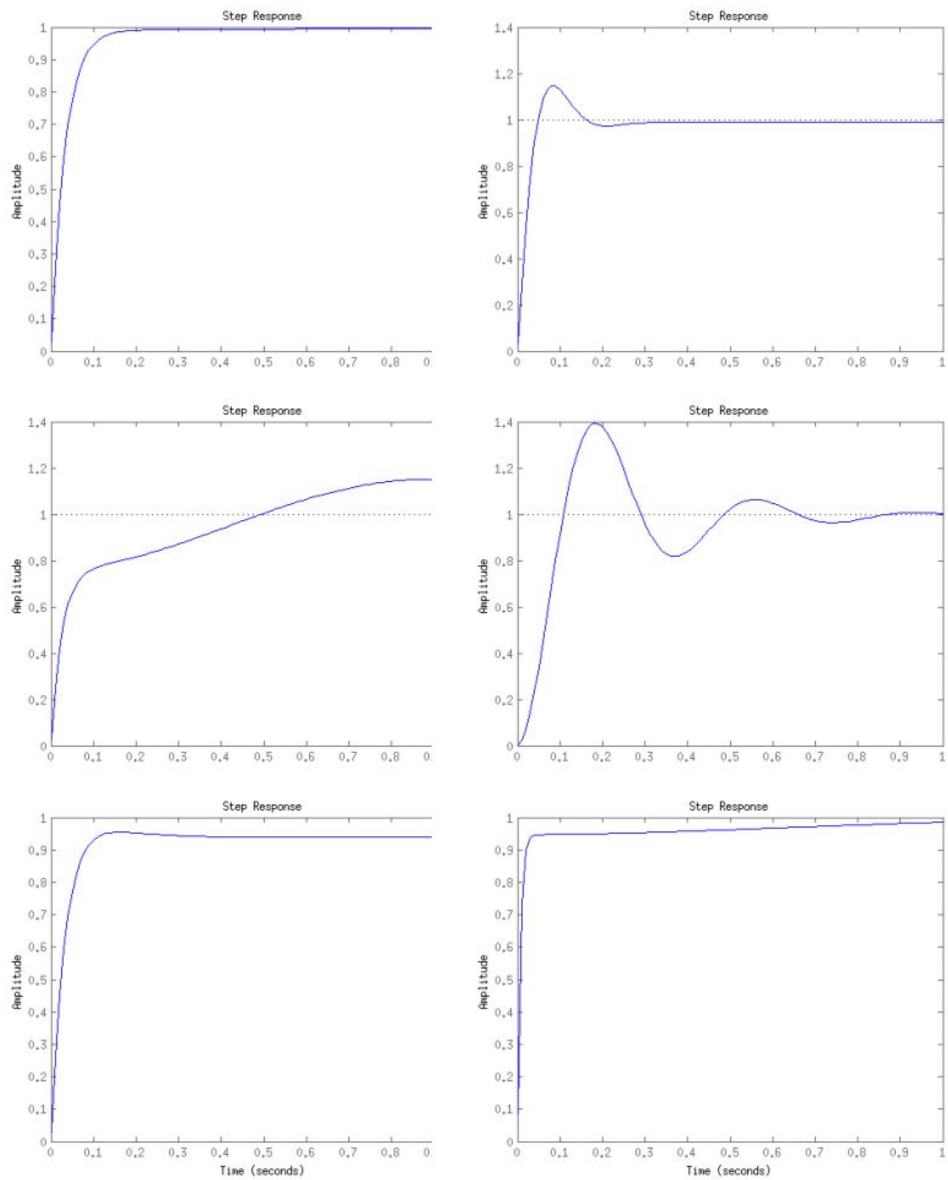
Draw the block diagram for a velocity pid controller which can drive the output to track an input reference velocity.(4 points)

Write the pseudocode for a velocity pid controller, you can use the following thread safe functions.(8 points)

Double getDesiredVelocity();
Double getCurrentPosition();
Long getTimeMili();
Void setVelocity(double desiredVelocity);

Part 2 Fix the controller (10 points)

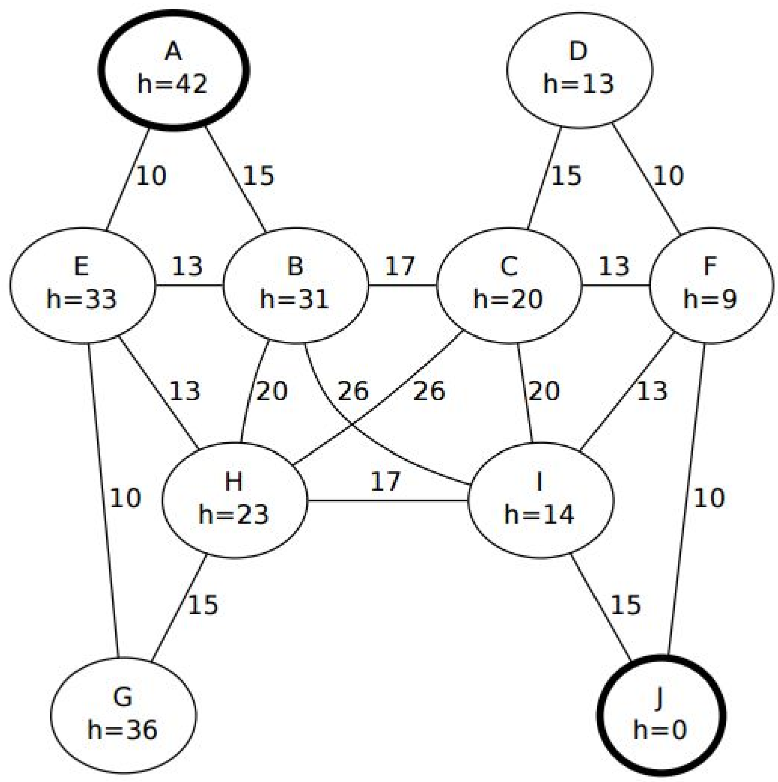
You are given the following response curves for a PID controller. The first one is the desired response, the remainder have had one parameter adjusted either up or down. Which gain would you need to tweak to demonstrate the behavior as in the first graph. When you give a parameter make sure to also say in which direction (i.e. what would you have to do to get back to the desired response)? For each drawing. Write your answer on or next to each of the graphs.



(e) (f)

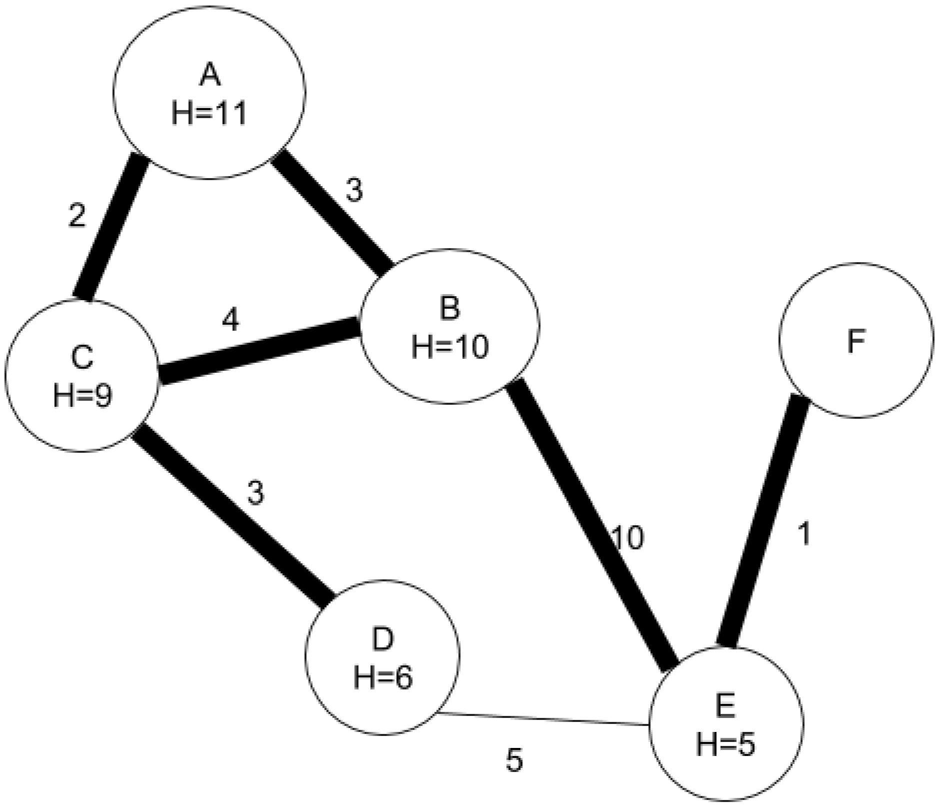
4. Search 12 points

You developed a robot operating on mars that needs to transmit a message via a statile network back to its homebase in Pittsburgh. In this problem you will use A* to find out which satellites the message should travel through.



Part 1: Using A* find a path from point A to point J in the above graph .List the order in which nodes were expanded and what the frontier is at each step (10 points)

Part 2:

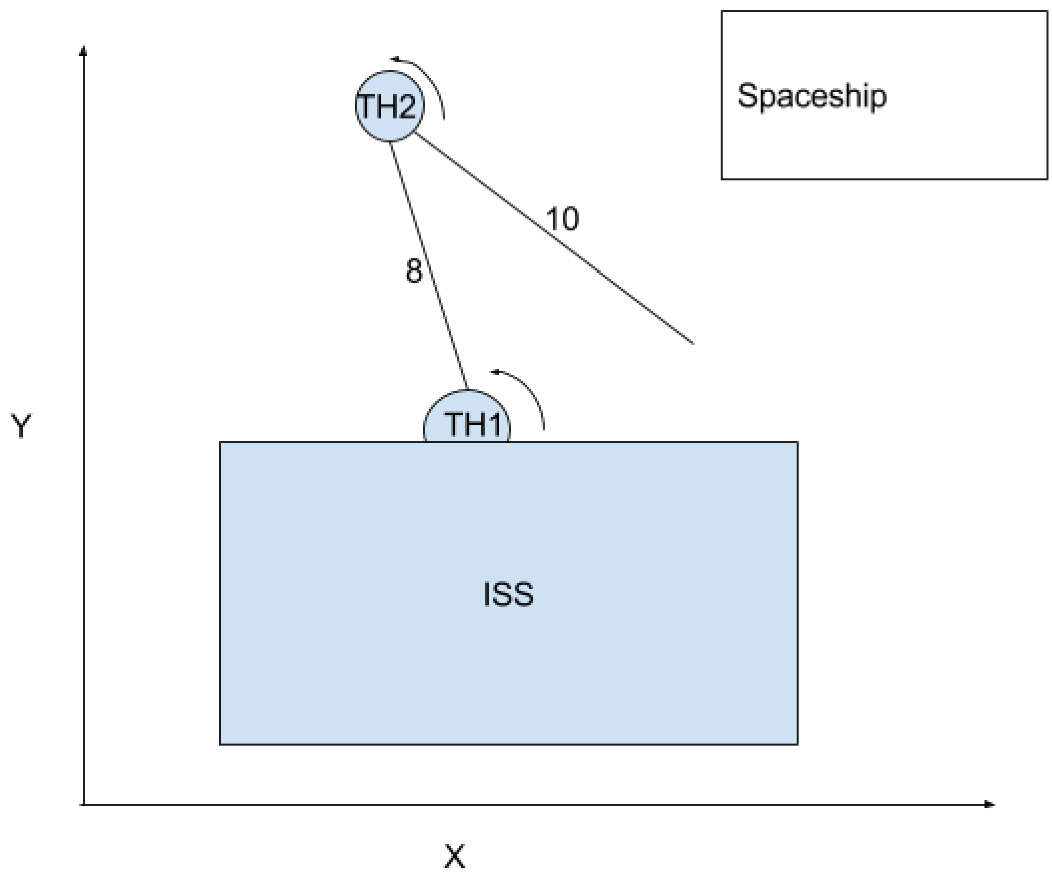


In order for A* to find the optimal path in optimal time, what heuristics would you change, and to what values, if the edge between D and F were to be removed. The start is at A and the goal is at F. (2 points)

5. Inverse kinematics In SPACE! (23 points)

Note the numbers in this problem are not what they are for the real world. Also the robotic arm described is much simpler than what is actually on the ISS.

The Canada arm is attached to the International Space Station(ISS) and is sometimes used to capture incoming spacecraft. In this problem you will be controlling a 2 link arm that serves the same purpose as the Canada arm but is much simpler.



You know the desired contact point on a spacecraft is going to be at (X = 1000, Y = 2000, Z = 250000) at zero rotation in earth's inertial frame. At the same time the ISS's reference frame will be at (X = 0003 , Y = 2010, Z = 249999) and 0 degrees rotation along all axis relative to the Houston reference frame. The Houston reference frame is (1000,0,0) at zero rotation along all axis relative to the earth inertial frame. The base of the arm is located at (x = 1, y = 1, z= 1), and zero rotation along all axis in the ISS reference frame. Assume the joint angles are unlimited, except that no part of the arm can run into the ISS.

Part 1: What is the transform (4 x 4 matrix) from the base of the arm reference frame to the arm's end effector reference frame? (5 points)

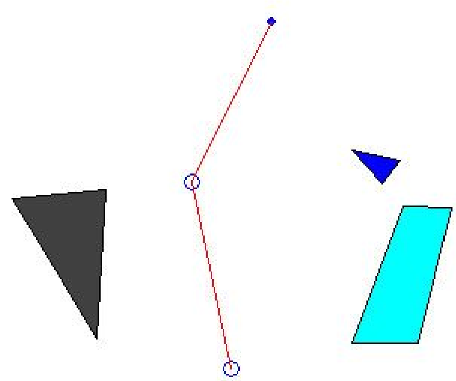
Part 2: Draw a picture of the frame transforms from the spacecrafts desired contact point to the end effector of the ISS's arm (4 points)

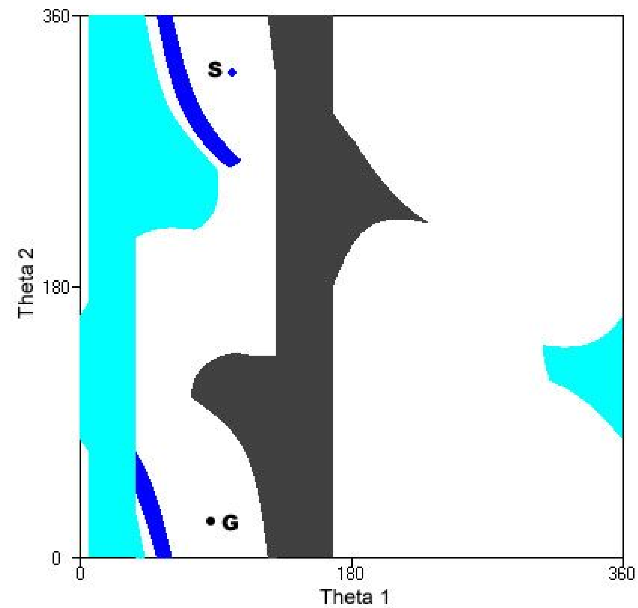
Part 3: Write down the chain of transforms from the spacecraft to the arm's end effector with each transform being only a rotation or only a translation(6 points)

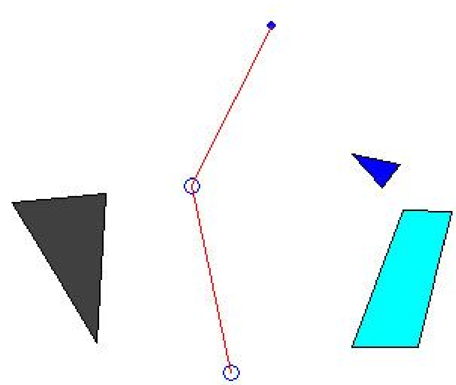
Part 4: What joint angles are needed to make contact with the desired contact point on the ISS's incoming spacecraft (8 points).

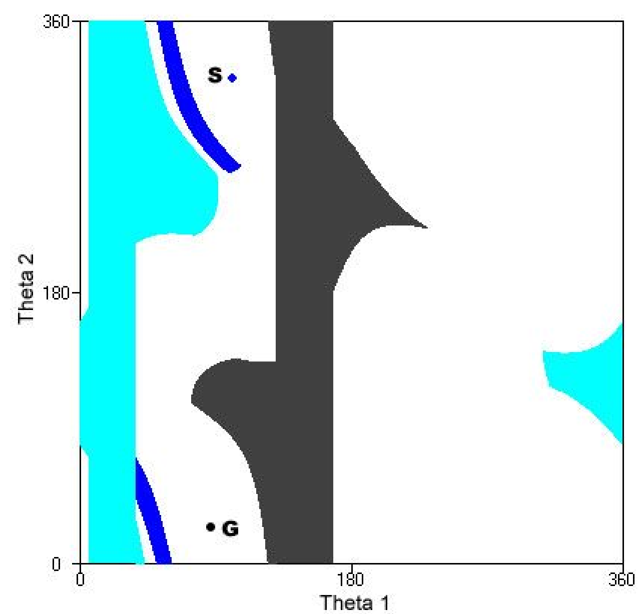
6. Configuration Space (12 points)

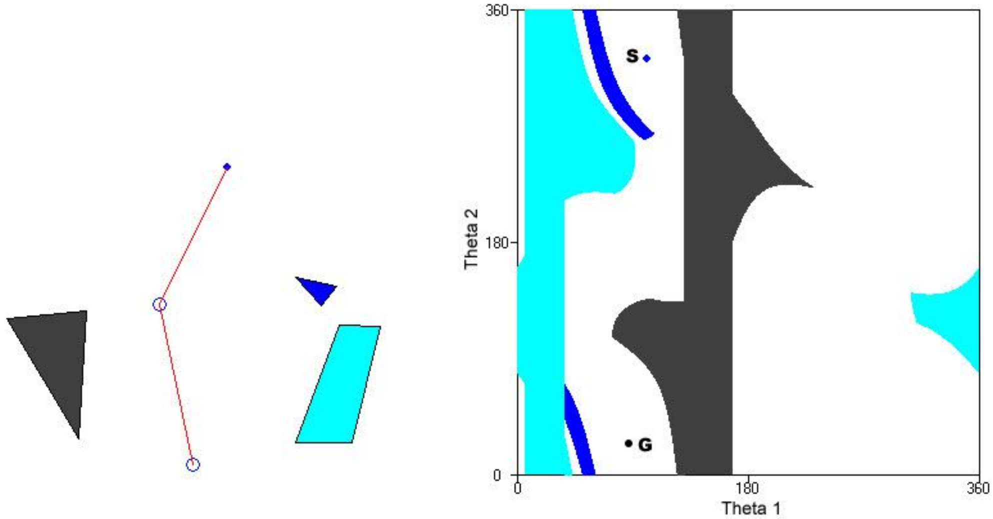
Part1: Given the following workspace (*with robot shown at start configuration*) and configuration space, use the Wavefront planner to find a path in configuration space from the start configuration to the goal configuration. You may use any metric you want, but be sure to state which you are using. Draw the path on the figure. *Note*: Theta 1 is the first joint angle and Theta 2 is the second joint angle. The black dot is the end effector, and the joints have no joint limits. Draw in the workspace five intermediate configurations between the start and goal configurations, and show their location in the configuration space. We have provided extra copies of the workspace and configuration space.







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Theta 2
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180
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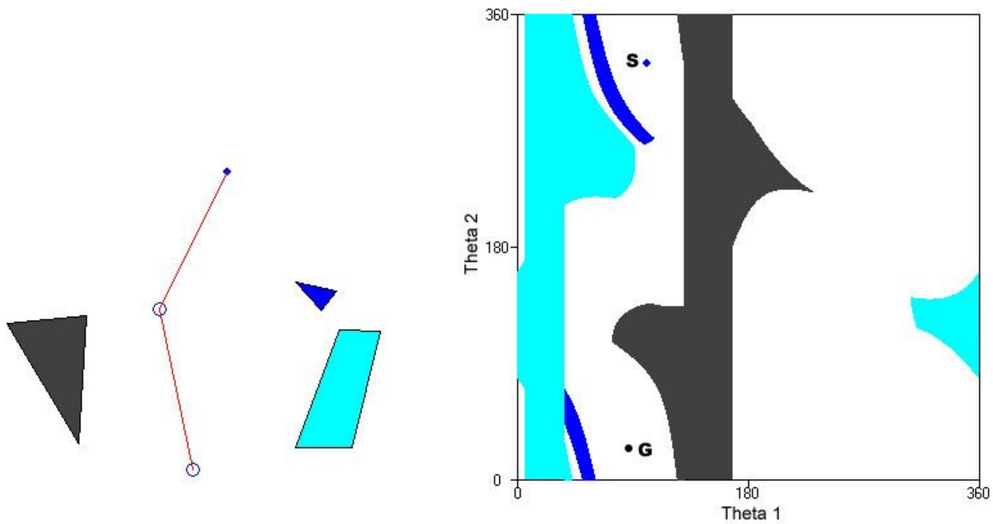
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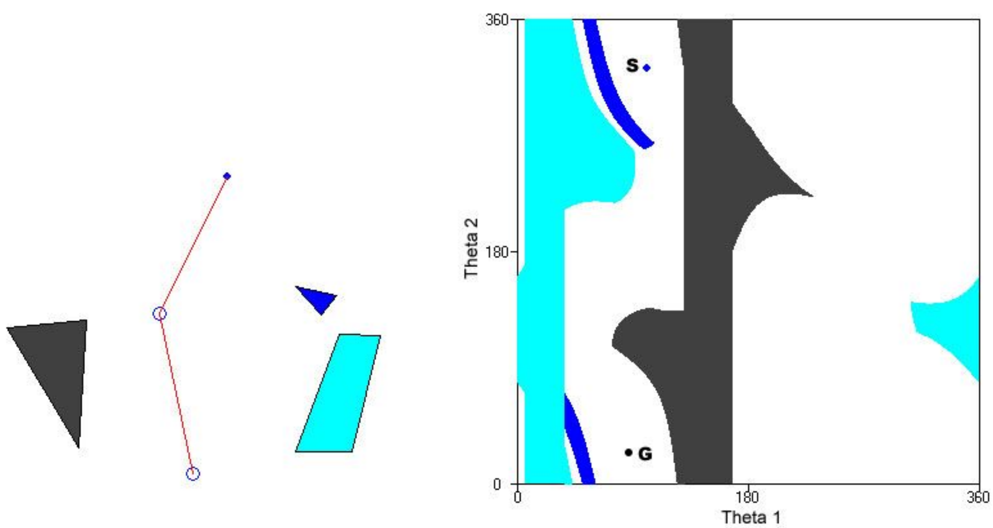
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