Investigating the Relationship Between Multi-Robot Geometry and Human Perception of Robot Groups

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Abstract

As multi-robot systems have been more prominent in human social spaces, there is a lack of effective communication between humans and robot groups. People communicate using motion naturally and read into motions others do such as through verbal communication to get points across and demonstrating physical actions to be replicated. There has been no extensive research on how groups of robots can expressively communicate in human settings. We create a framework that focuses on what robots need to communicate expressively and how individuals perceive them. In this paper, our focus in within the geometrically formation to develop a novel set of features for generating complex, multi-robot expressive motion.

I. INTRODUCTION

Everyone reacts and responds differently to robotics for a multitude of factors. The first that comes to mind is appearance; is the robot appealing to the individual which they will approach with a great experience, or an unattractive robot that may be perceived as a negative one. Others may be based on the actions of the robots, and past work has shown culture contributes to how groups may feel.

The problem we face is as multi-robot systems have been significantly immersed over time in our social setting, there is a lack of effective communication between humans and robot groups. How do we know a robot is doing what a human would do? Will it be able to have common sense in specific situations? Despite all of these issues, there has been little research on how groups of robots can communicate expressively in human settings. We achieve a solution to this by creating a framework that focuses on what robots need to communicate expressively and how individuals perceive them.

Our eventual goal is to explore how people's emotions are affected by the geometric formation of multi-robot groups. We turn to past work in psychology evaluating how different shapes are correlated with people's emotional response.

II. RELATED WORK

We are focusing on three categories of geometrical shapes, and we want to study the effects of emotion on human interaction—our reasoning which the choice of these shapes correlate with psychological responses individuals when seeing them. This setting will allow us to see if there is a correlation of emotion amongst robots.

A. Rounded Shapes

Emotions are on a spectrum that can range in different areas. Where rounded shapes fall into this, they are found to become much friendlier shapes than the others for encompassing other images within. Shapes without having any angles make circles feel softer, and they tend to "invite" the viewers into their "completeness" [1]. Creating geometric features of rounded robots is our goal to illustrate a picture for the individual to experience the same emotion to psychological studies have concluded.

These features can be found in the arts and create the exact purpose of creating an emotion an individual feels by visualizing it. These specific features have been considered to make an innocent and youth figure [2] through pictures and video games. A fine example was the Nintendo character Kirby from *Kirby's Dream Land* in 1992. The character possessing all of these features allows a welcoming and friendly impression.

B. Angular Shapes

On the other end of the emotion spectrum lies angular shapes illustrated by other geometrical models. The angularity of a shape induces negative, arousing, and intimidating attributions that may be depicted visually. Therefore, it is essential to note the orientation at which these angular shapes are angled and contribute to emotion. V-shapes and downward pointing triangles are shown to become significantly more associated with negative attributions than similar shapes with a different orientation [3]. How different would this become with an upward direction? Would it even matter?

The angular shapes also change tone through appearance and generate a shift in style within the environment compared to rounded features. For example, this can be seen within the Lord of the Rings Trilogy. The good-natured hobbits represent the innocent, youthful circle: from the curl of their hair, rounded shoulders, and shirt buttons; to the round Hobbit holes; and even the curves of the landscape. At the other end of the shape spectrum, we find Sauron, who is aligned to the aggressive triangle: from his sharp fingertips; to the triangular volcano on the landscape [2]. These environments change tremendously despite still being in the same fictional world due to the geometric features we see around.

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C. Combination Shapes

Covering the opposites of geometrical emotion, where does a middle ground result? These shapes resemble rounded and angular characteristics. The responses to how individuals feel are very curious.

1) Squares: Looking at what a square is, it retains the angular edges of the sides of the figure; however, the area of a square is much greater than a triangle's area. These characteristics of the shape obtain interesting results when visualizing. For example, some found that a square gives viewers a sense of reliability and security, and these attributes make people feel safe and contained [1]. It is also essential to take into consideration how people may perceive rectangles. For example, positively reacting to a rectangle and negatively to a square, then, when presented later with several rectangles, the most robust response will be to the rectangle [3].

Squares are also found to illustrate maturity, stability, balance, and stubbornness. You see this in structures, and the arts, which fall between rounded and angular geometric shapes [2].

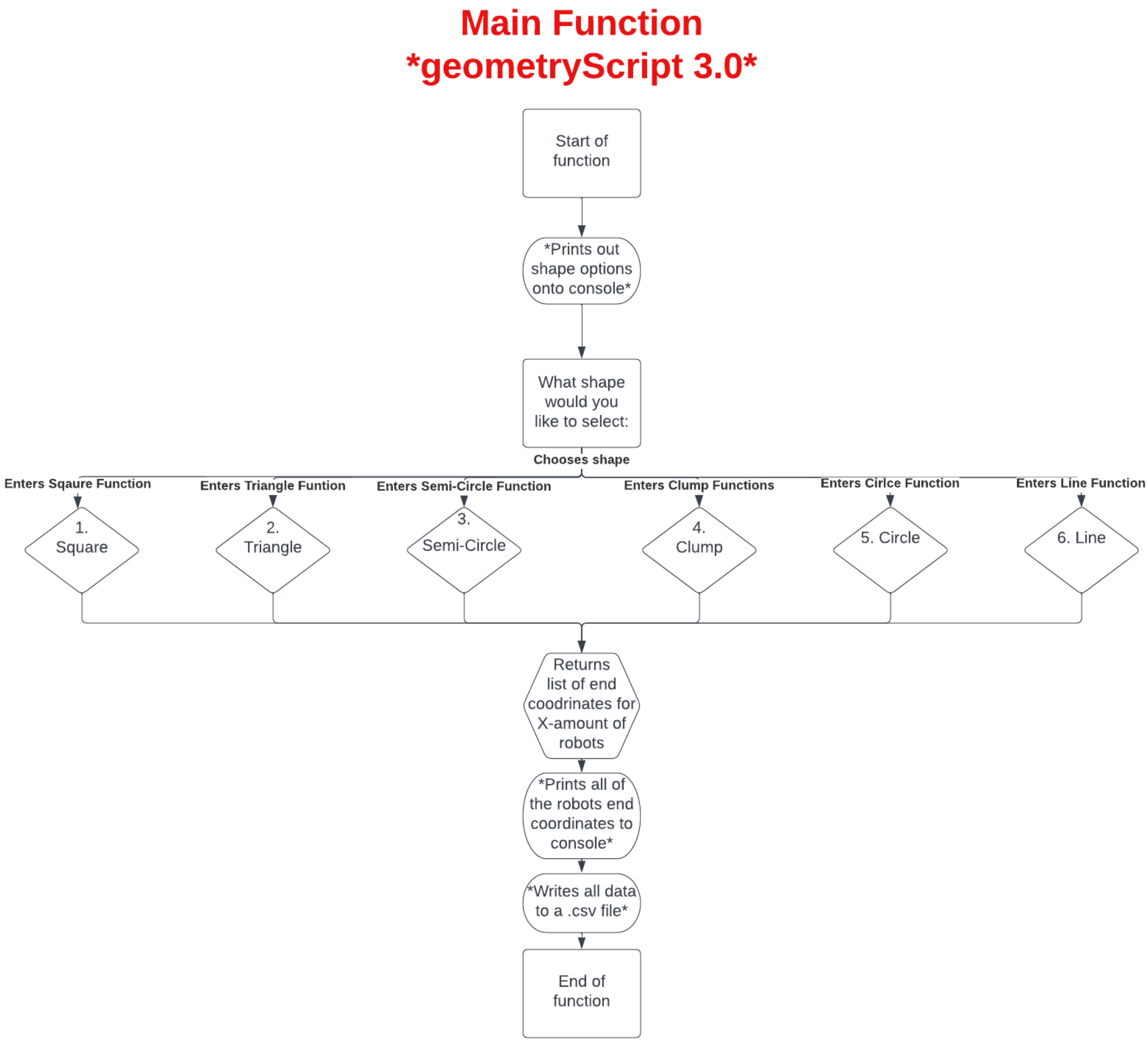
2) Clumps: Many may not know that a clump is considered a geometric shape despite having no distinct shape; however, they do express unique features that aren't bounded by straight edges or rounded lines. Without definite assurance, emotion will be exerted and become unique amongst the other shapes. Having the geometry be asymmetrical will create heightened arousal [3]; however, it was found that despite being a clump, some sharp or rounded features can still be seen which it may still be expressing emotions such as found previously mentioned [4].

III. SOFTWARE IMPLEMENTATION

The scripting for the geometric calculations are very similar to each other. Down below will be flowcharts in which how the process is with the functions created in the program.

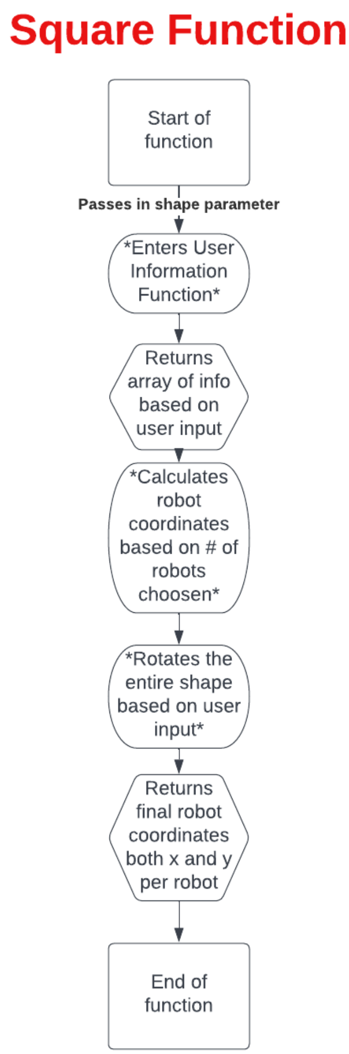
A. Main Function:

The functions purpose is to call all other functions and output where the robots final coordinates are with printing it to a csv file.



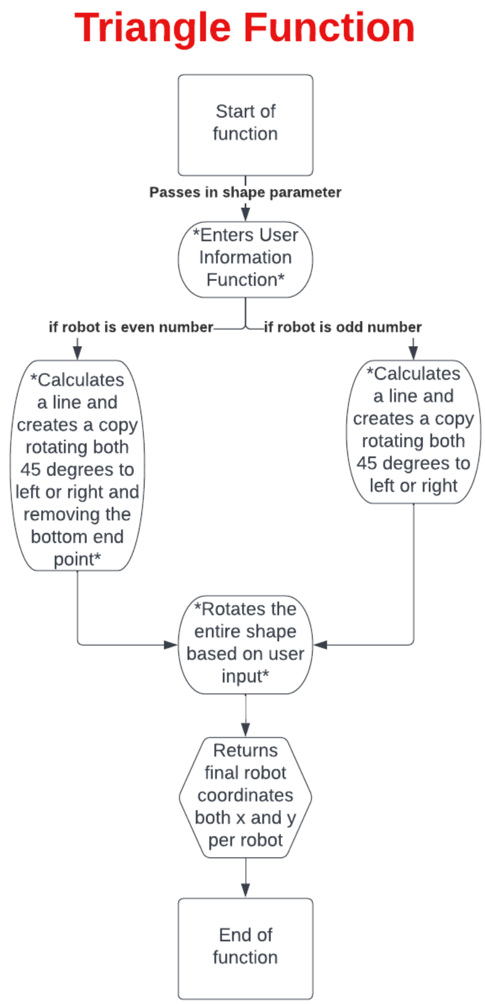
B. Square Calculations Function:

This function's purpose is to calculate the position of the robots based on a square formation.



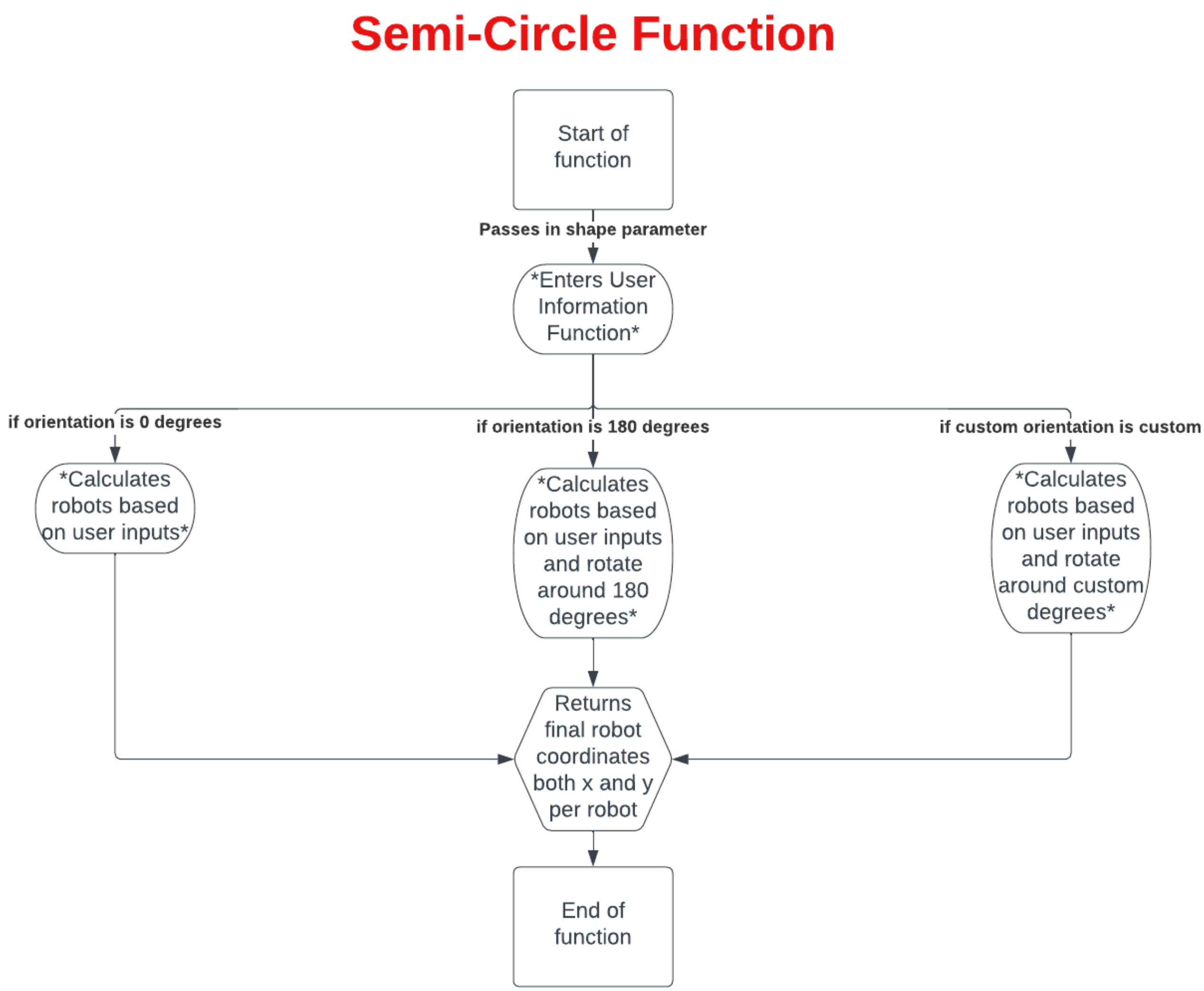
C. Triangle Calculations Function:

This function's purpose is to calculate the position of the robots based on a triangle formation.



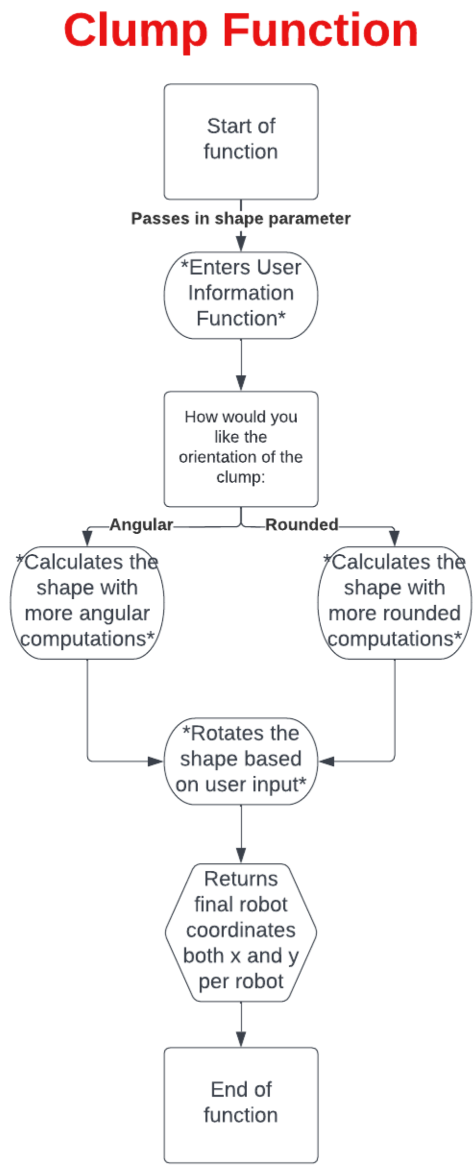
D. Semi-Circle Calculations Function:

This function's purpose is to calculate the position of the robots based on a semi-circle formation.



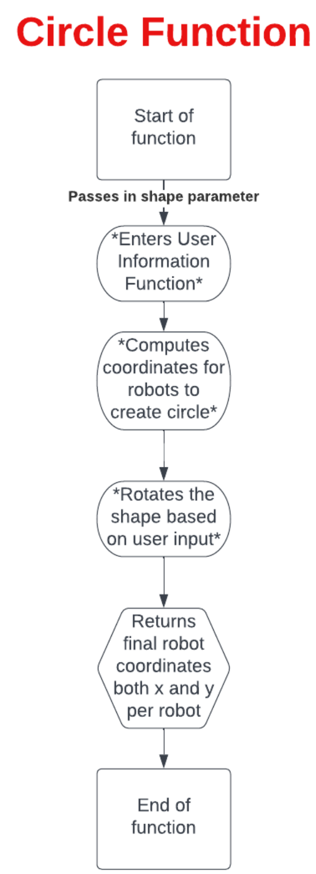
E. Clump Calculations Function:

This function's purpose is to calculate the position of the robots based on a clump formation.



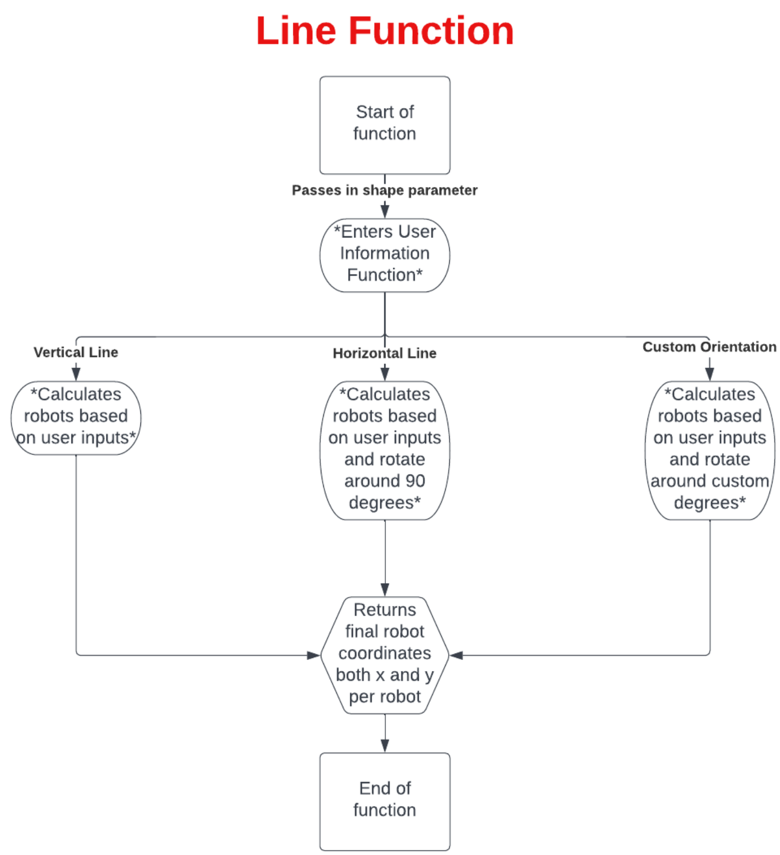
F. *Circle Calculations Function:*

This function's purpose is to calculate the position of the robots based on a circle formation.



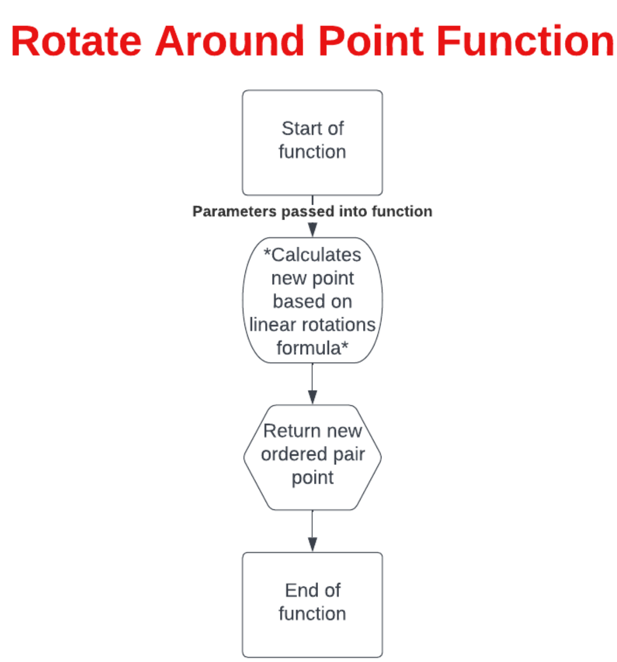
G. Line Calculations Function:

This function's purpose is to calculate the position of the robots based on a line formation.



H. Rotation Adjustments Calculations Function:

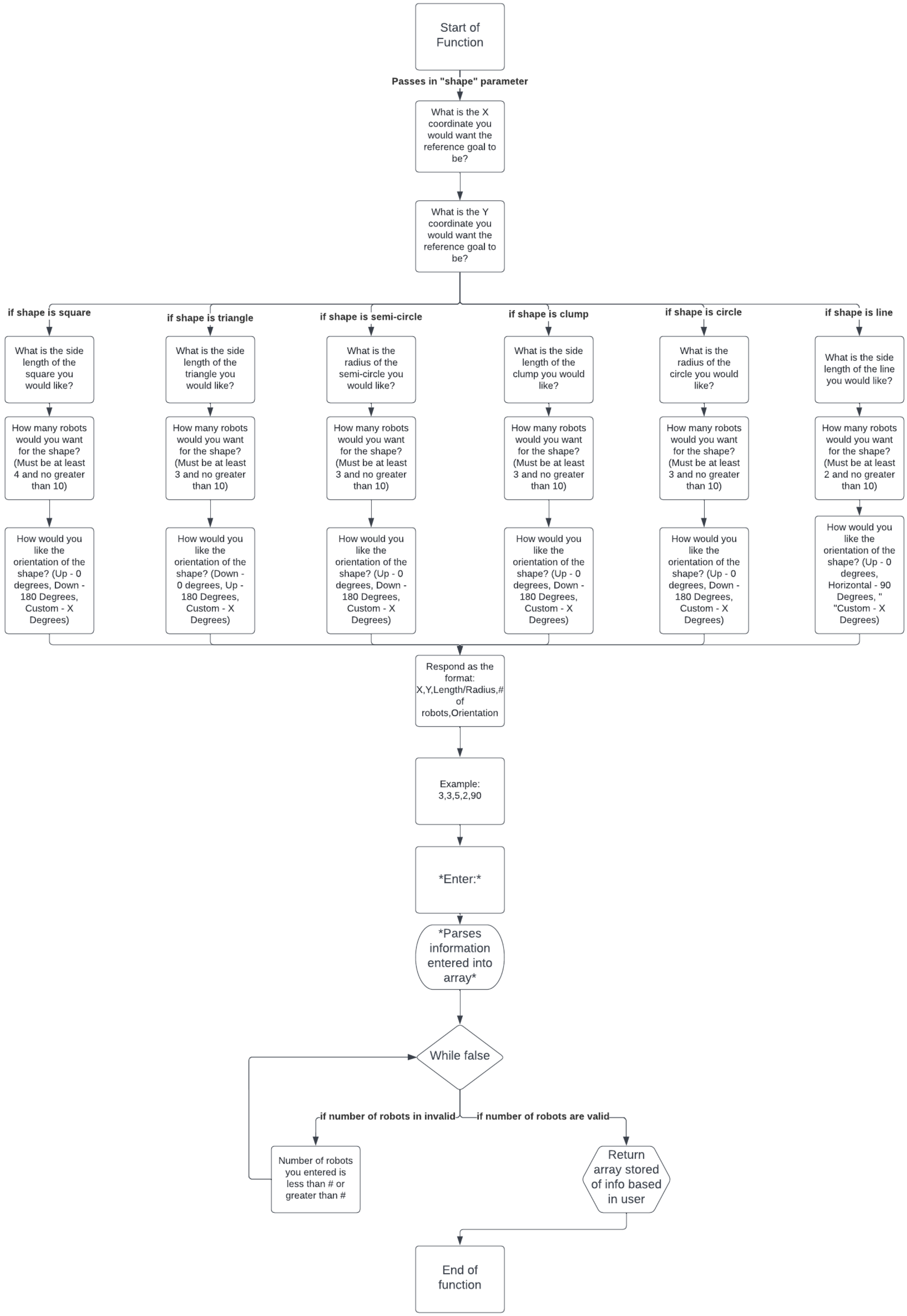
This function's purpose is to calculate the position of the robots based on the user rotation preference about the reference goals.



I. User Inputs Function:

This function's purpose is to store the inputs which the user is asked.

User Information Function



IV. Geometric Calculations

All of the calculations found are to create the respective geometrical shape based on X amount of robots. With this goal, we have constraints of have a maximum of 10 robots in configuration and the least amount varying pending on how many are required to distinctly create the shape. These are calculated through: a reference goal point, size of shape, the number of robots, and the orientation.

The subsections below show that each geometrical shape will have math for each robot. These calculate for the final position they are placed - pathway calculations are not included in this section. Instead, we illustrate each robot's math equation for the x-coordinate and a y-coordinate on a 2D plane. Each of the shapes orientation is rotated by a rotation matrix which the user enters there desired rotation of X degrees.

For each shape, S represents the side length of the shape and R represents the shape's radius. N represents the number of robots the configuration of the shape is using.

A. *Square*

To distinguish a square, the minimum amount of robots required is four. We began starting at the four corners, and as we added more robots, we adjusted them to the shape's perimeter. In our programming, we hard-coded these points for robots of four to ten.

The math designed for this shape is by going half the side length away from the reference goal point. Going in each direction, we can create a square geometrically.

Here are the coordinate for each of the robots for a configuration of four robots:

Robot 1 - Top Left Corner

$$X = X_{Goal} - \frac{S}{2}$$

$$Y = Y_{Goal} + \frac{S}{2}$$

Robot 2 - Top Right Corner

$$X = X_{Goal} + \frac{S}{2}$$

$$Y = Y_{Goal} + \frac{S}{2}$$

Robot 3 - Bottom Left Corner

$$X = X_{Goal} - \frac{S}{2}$$

$$Y = Y_{Goal} - \frac{S}{2}$$

Robot 4 - Bottom Right Corner

$$X = X_{Goal} + \frac{S}{2}$$

$$Y = Y_{Goal} - \frac{S}{2}$$

As more robots are added to the configuration, they will be placed on the borders of the square between the corner points of the square. With nine robots, the ninth robot will be placed in the center of the shape and the tenth robot will be placed amongst the top row of the square having four robots in the row.

B. *Triangle*

For a triangle, the minimum amount of robots required is three. This shape aims to create angular coordinates positioned in different orientations to retrieve other emotions.

The math designed for this shape is by creating two lines that rotate 45 degrees to create a V-shape figure. One line is rotated 45 degrees from the vertical while the other line is rotated -45 degrees from the vertical line from the origin point of the line itself (the reference goal). To take in accountability for even and the odd number of robots, the even amount of robots, we took away the pointed tip of the shape, while with odd, we keep the point there for the shape.

Each X coordinate for the robot is calculated by following this equation:

$$X = X_{Goal}$$

The Y coordinate is calculated by beginning at the bottom endpoint of the line. Once the endpoint is calculated (the X and Y reference goal), the Y will be added on by using this equation until all robots are given a coordinate.

$$Y = \frac{S}{N-1}$$

Once this is done, with using linear rotation matrices, the line will be rotated -45 degrees while another line is duplicated to be rotated 45 degrees.

C. Semi-circle

The minimum amount of robots required is three for a semi-circle. This shape aims to create rounded coordinates positioned in different orientations to retrieve other emotions.

The shape is formulated using the unit circle from 0 to π. Both X and Y coordinates will have a K variable which starts at 0 which increments by 1 each time a new robot is assigned their new coordinates.

Each X coordinate for the robot is calculated by following this equation:

$$X = X_{Goal} + \frac{R * \cos K\pi}{N-1}$$

Each Y coordinate for the robot is calculated by following this equation:

$$Y = Y_{Goal} + \frac{R * \sin K\pi}{N-1}$$

Once this is done, with using linear rotation matrices, the line will be rotated based on the users input.

D. Clump

To distinguish a clump, the minimum amount of robots required is three. This shape aims to create random coordinates that may vary every so little each run of the experiment while still holding either angular or more rounded features.

Both X and Y reference goals retain the formula in which random numbers are generated based on and calculated. The math for the angular feature has more predefined coordinates than the rounded feature based on the unit circle. To best describe this, the round quality has a parent function of calculating the coordinates just as a circle. Still, it has slight translations by randomly adding/subtracting the X and Y coordinates. The angular feature has a parent function of constants with nuanced translations by randomly adding/subtracting the X and Y coordinate for each of the robots in the configuration. The letter A will represent a random number and B will represent another random number generated.

1) Angular: Each X coordinate for the robot is calculated by following this equation:

$$X = X_{Goal} + \frac{S * A}{B}$$

Each Y coordinate for the robot is calculated by following this equation:

$$Y = Y_{Goal} + \frac{S * A}{B}$$

Once this is done, with using linear rotation matrices, the line will be rotated based on the users input.

2) Rounded: Each X coordinate for the robot is calculated by following this equation:

$$X = X_{Goal} + \frac{\frac{R * \cos 2K\pi}{N-1}}{A} + B$$

Each Y coordinate for the robot is calculated by following this equation:

$$Y = Y_{Goal} + \frac{\frac{R * \sin 2K\pi}{N-1}}{A} + B$$

Once this is done, with using linear rotation matrices, the line will be rotated based on the users input.

E. Circle

For a circle, the minimum amount of robots required is three. This shape aims to create rounded coordinates.

The shape is formulated by using the unit circle from 0 to 2π.

Each X coordinate for the robot is calculated by following this equation:

$$X = X_{Goal} + \frac{R*\cos 2K\pi}{N-1}$$

Each Y coordinate for the robot is calculated by following this equation:

$$Y = Y_{Goal} + \frac{R*\sin 2K\pi}{N-1}$$

Once this is done, with using linear rotation matrices, the line will be rotated based on the users input.

F. Line

A line's minimum amount of robots required is two. This shape aims to create unstructured coordinates. The figure is formulated by using the length of the individual desires.

1) Vertical: Each X coordinate for the robot is calculated by following this equation:

$$X = X_{Goal}$$

The Y coordinate is calculated by beginning at the bottom endpoint of the line. Once the endpoint is calculated (the X and Y reference goal), the Y will be added on by using this equation until all robots are given a coordinate.

$$Y = \frac{S}{N-1}$$

Once this is done, with using linear rotation matrices, the line will be rotated based on the users input.

2) Horizontal: The X coordinate is calculated by beginning at the left endpoint of the line. Once the endpoint is calculated (the X and Y reference goal), the X will be added on by using this equation until all robots are given a coordinate. Each X coordinate for the robot is calculated by following this equation:

$$X = \frac{S}{N-1}$$

Each Y coordinate for the robot is calculated by following this equation:

$$Y = Y_{Goal}$$

Once this is done, with using linear rotation matrices, the line will be rotated based on the users input.

V. FUTURE WORK

In the future we hope to evaluate these shapes in a user study. We have collected godspeed questions to evaluate how individuals respond to each of the geometrical shapes.

We propose the following questions for our evaluation:

A. Perceived Safety - (Anxious - Relaxed):

The question covers an emotional description of what the shapes we have for the individual to see/select from. These adjectives are more specific beyond the environment how the individual feels about the situation they are in. This question may be very strong with the rounded shapes (semi-circle) in the individual's answer.

B. Perceived Safety - (Quiescent - Surprised):

This question is to focus on an individuals awareness around multi-robots and if they are caught off guard with their actions. It may not get as well responses due to the previous works concluding about the shapes already conducted on. If it is not of particular interest during the pilot study, we shall scrap this one out of the question pool. This question may be strongly associated with the random geometry shape.

C. Anchored Scales - Does not express emotions(-2) - Express emotion(+2):

This question is more of a straightforward and generic which I think could be one of the first questions asked to the individual. This could allow us to have more as a "controlled question" to allow us to see if the individual can actually feel something from the robot's geometry and not lie or inaccurately answer the rest of the questions poorly. This may be associated with the square geometry becoming neutral amongst the other shapes in the experiment.

D. Likeability - (Dislike - Like):

This question is generic as well, but it doesn't produce a specific emotion in which someone may not have the appeal in answering it. Could be the best question to fully grasp on what the individual feels about the shapes. This may be associated with the geometry of the semi-circle (being liked) and triangle (being disliked).

E. Anchored Scales - Submissive(-2) - Dominant(+2):

The question is interesting because does only a couple robots give a strong presence amongst the individual? We could ask the individual how they feel about a three robot configuration triangle compared to a five robot configuration and see if there is a definite distinction.

F. Perceived Safety - (Agitated - Calm):

This is covering more the environment which the individual feels to be in. A confounding factor to this question may vary depending on the time the robot is in the presence of the individual.

Ex: Being in a library the environment is calm; however, it may be stressful because someone is studying for a final exam.

G. Anchored Scales - Aloof(-2) - Belonging(+2):

I think this would be an interesting one because it is associated with a group of things. With robots moving around together we can get a response out of this which can vary depending on the geometry shape. Could get very interesting responses from the random shape.

VI. CONCLUSIONS

We will fill the conclusion once we obtain results from our pilot study.

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