Swarm Robotics Project

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1 Introduction

This project utilized decentralize algorithms to perform the following tasks:

1. Make a square formation in the room;
2. Get all the robot out of the room and make a circle formation outside;
3. Move the purple ball on the purple square;
4. Move the red ball on the red square;
5. Get back into the room and make a diamond formation;

the following sections will delve into each controller in detail. The environment is shown in figure 1.

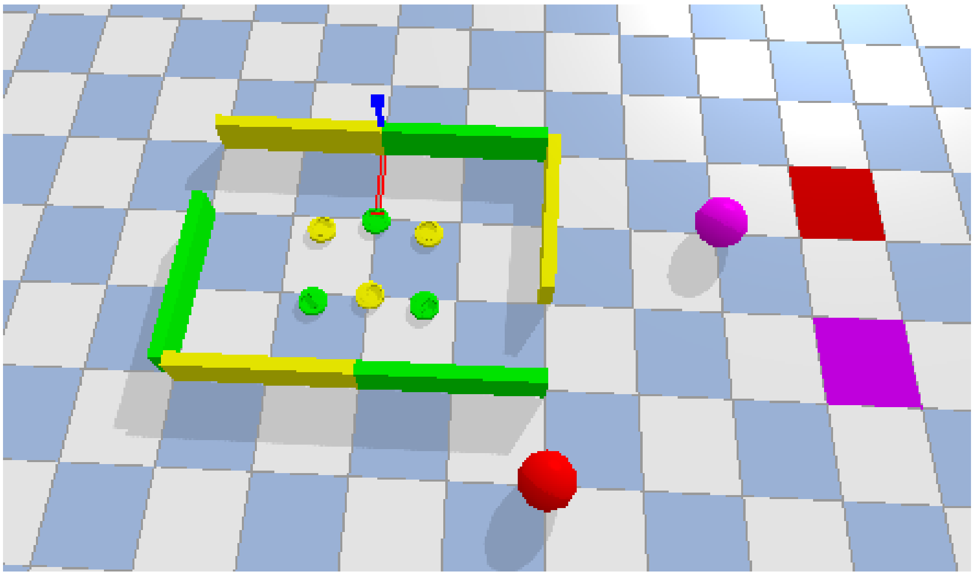

Figure 1: This image shows the environment of the task, the goal is to make certain formations and move the purple ball to the purple spot and move the red ball onto the red spot and return in the room.

2 Formation Control

To get a specific formation we can just utilize formation control techniques. However, here we need to consider losing connection due to increase in distances, thus we can use edge tensions to make sure the connection once established always exist. The edge tension is defined as,

$$\frac{\partial V_{ij}(\delta, x)}{\partial x_i} = \begin{cases} \dfrac{2\delta - \|l_{ij}\|}{(\delta - \|l_{ij}\|)^2}(x_i - x_j) & \text{if } (v_i, v_j) \text{ is an edge of the graph} \\ 0 & \text{otherwise} \end{cases}$$

if we let the control law be,

$$u_i = -\sum_{j \in \mathcal{N}_i} \frac{2\delta - \|l_{ij}\|}{(\delta - \|l_{ij}\|)^2}(x_i - x_j)$$

we have a consensus algorithm. Transforming it into a formation control algorithm we have the control law as,

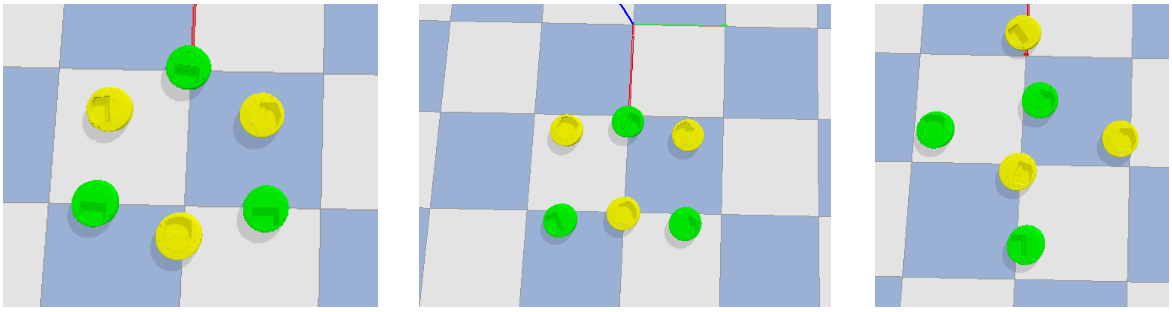

Figure 2: This images shows the three different formations as a result of the controller described in the formation control section. From the left to right we have the circle, square and diamond formation. Note that here there is a potential field for each of the robots for collision avoidance.

$$\dot{x}_i(t) = -\sum_{j \in N_{\mathcal{G}_d(i)}} \frac{2(\Delta - \|d_{ij}\|) - \|\ell_{ij}(t) - d_{ij}\|}{(\Delta - \|d_{ij}\| - \|\ell_{ij}(t) - d_{ij}\|)^2}(x_i(t) - x_j(t) - d_{ij})$$

with $d_{ij} = \tau_i - \tau_j$ for all i, j such that $\{v_i, v_j\} \in E_d$ is the desired translation vector between two vertices i and j, $\ell_{ij}(t) = x_i(t) - x_j(t)$ is the translation vector between two vertices i and j at time t and δ is the maximum connection length. This control law insures that the distance between connected robots would not exceed the connection limit Δ. We have the desired coordinates for each of the formations as,

$$\begin{aligned}
\text{Circle} &: \{(-0.25, \frac{\sqrt{3}}{4}), (-0.5, 0), (-0.25, \frac{\sqrt{3}}{4}), (0.25, -\frac{\sqrt{3}}{4}), (0.5, 0), (0.25, \frac{\sqrt{3}}{4})\} \\
\text{Square} &: \{(0, -0.5), (0, 0), (0, 0.5), (1, -0.5), (1, 0), (1, 0.5)\} \\
\text{Diamond} &: \{(0, 0), (\frac{2}{3}, 0), (\frac{4}{3}, 0), (2, 0), (1, 1), (1, -1)\}
\end{aligned}$$

the formations are shown in figure 2.

3 Moving with Potential Fields

In this project we require the robot to move in and out of room also towards the red and purple ball, to achieve this we can use potential fields. The potential field is defined as,

$$V = \begin{cases} \alpha(\ln(r) + \frac{d_0}{r}) & 0 < r < d_1 \\ \alpha(\ln(d_1) + \frac{d_0}{d_1}) & r \geq d_1 \end{cases}$$

and the force an agent experiences in the potential field is,

$$V' = \begin{cases} \alpha(\frac{1}{r} + \frac{d_0}{r^2}) & 0 < r < d_1 \\ 0 & r \geq d_1 \end{cases}$$

this ensures the agents move towards the center of the potential field while avoiding to collide with the center. The final configuration would be very likely that the agent ends up at a location where its distance with the center of the potential field is d_1.

Also we use a constant potential field to make the robots avoid collision with the wall, when the robot is within the proximity of the wall we have a potential field that rejects the robot. However, this requires tuning and my result shows that there still exist some collision with the wall.

4 Moving Balls

To move the balls I used formation control and by adding a uniform force on all of the robots we can move the formation towards the designated spot. When the controller switches from moving towards the ball to moving the ball an initial position is recorded and treated as the desired location for the formation. Usually when this location is calculated the agents surrounds the ball relatively tightly, therefore this formation forms a cage around the ball and by moving this cage the ball can be transported. However, in

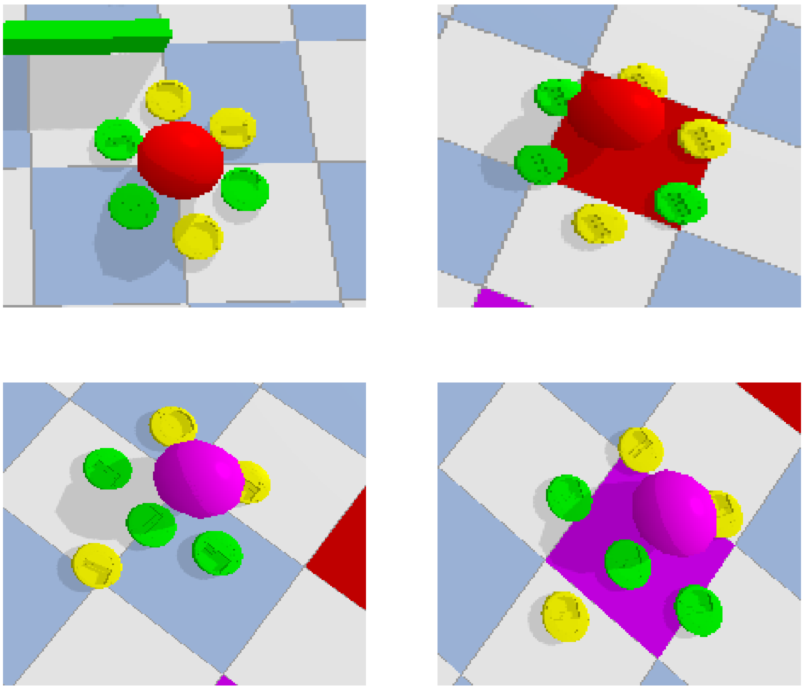

Figure 3: This images shows how the robots surround the ball and the final result of moving the ball on to the corresponding spot.

practice when moving this formation the distance between the balls tend to increase thus the ball might slip through when this occurs.

Note that when leaving the ball we want to avoid colliding with the ball, to achieve this we used a potential field that rejects the agents.

5 Discussion

Through this implementation we see that by using a set of decentralize algorithms we can enable a school of robots to accomplish complex tasks. There are many aspects of this implementation that can improved. This process uses a timer to switch between different controllers, however this should be done in a more decentralized methods.