# ECE 470: Lab 1.5
# Towers of Hanoi

Yutong Xie
NetID: yutongx6
Partner: Ananmay Jain
TA: Ben Walt
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## 1 Introduction

In lab 1.5, we expected to realize the tower of hanoi using the teach pendant. Tower of hanoi is an interesting mathematical game. There are totally three towers and each tower has three blocks. The goal is to move three blocks from one rod to another rod. There are some rules must be obeyed in the game.

- Only one block can be moved at a time.
- Blocks can only touch three locations.
- Lower-numbered block must be placed on top of a higher-number block like Fig 1 shows.

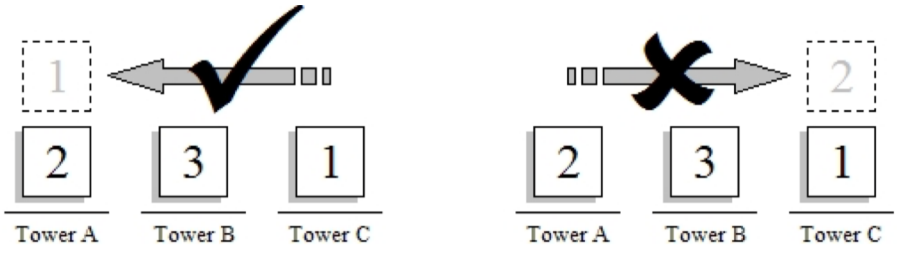


Figure 1: Solution for Tower of Hanoi with 3 blocks.

## 2 Method

To solve the Tower of Hanoi game, I prefer to split the blocks into two groups. In the lab, there are totally three blocks, block1, block2, and block3. We can set the top 2 blocks (two lower-numbered blocks) as group1 and the largest-numbered block as group2. Then, our goal is to move group2 to the destination and then move group1 to the destination. However, group 1 is placed above the group 2. Hence, we can move group1 to the third tower first, which I called "middle" here for convenience. After that, we can move group2 (block3) to the destination and move group1 from middle tower to destination. The question here is how to move group1 to middle tower. The solution is the same with

moving 3 blocks. We can divide group1 into two groups again, group1.1 and group 1.2 and execute the same operations. The solution is demonstrated clearly in the Fig 2.

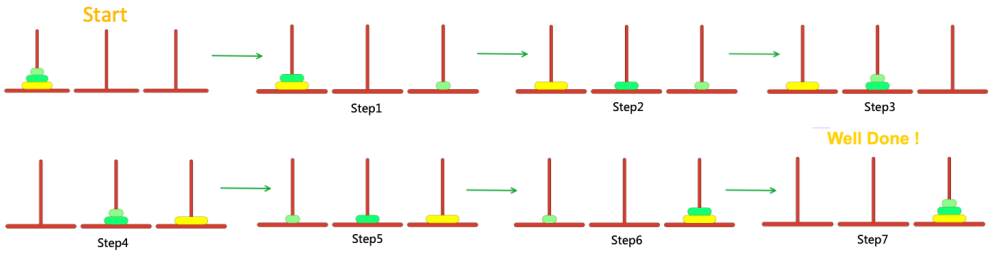


Figure 2: Examples of a legal and an illegal move.

Additionally, we have a circular move in our lab. **MoveP** is used for create a half circle movement. We use **MoveP** to move a block from tower1 to tower3. Meanwhile, we set a waypoint to restrict the path of our robotic arm as shown in Fig 3. What's more, we set the arm's orientation relative to the circle to unconstrained, which makes the arm more flexible.

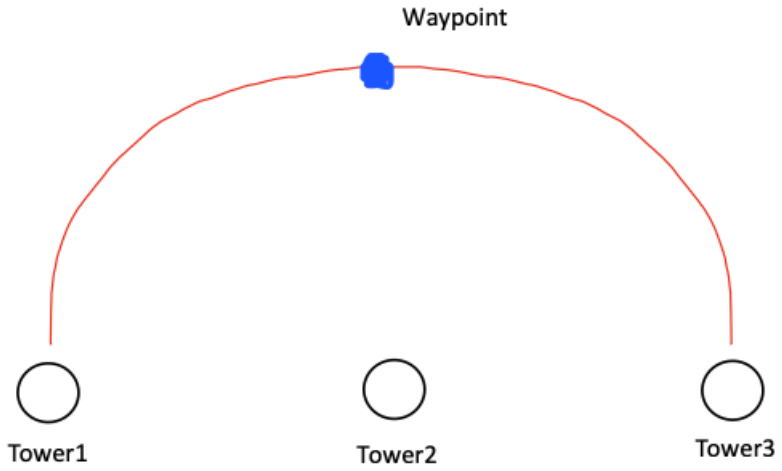


Figure 3: Implementation of half circle using MoveP.

## 3 Data and Results

We achieved our goal in 2 hours and succeed moving three blocks from one tower to another. Meanwhile, we make the block stack neatly by adjusting the orientation of robotic arm.

## 4 Conclusion

We complete the Hanoi game quickly, but it is a challenge for us to stack the blocks neatly. We try to use **MoveL** when UR3 pick up or put down the block. Hence, the block won't be rotate and keep the same orientation with the initial status. Also, we set the wrist of UR3 for all waypoint of three towers same and be vertical to the three towers as Fig 4 shows. Then all the block will be dropped

with same orientation. At the same time, I post the position data that we record for the UR3 in Fig 5 here for your reference.

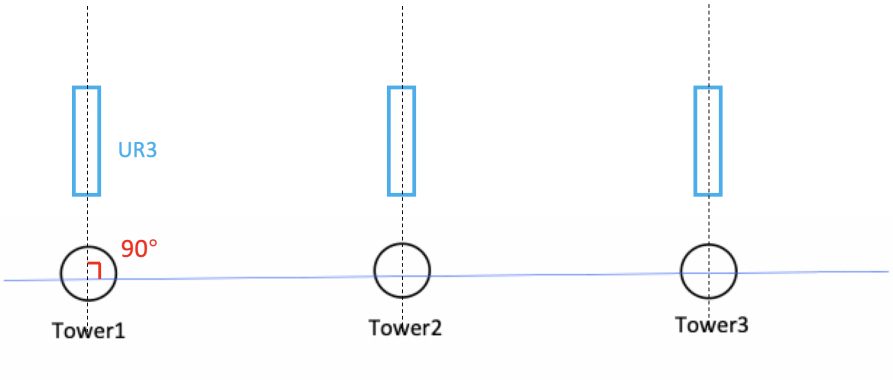


Figure 4: Pose of robotic arm relative to the tower.

| Position | Base | Shoulder | Elbow | Wrist1 | Wrist2 | Wrist3 |
|---|---|---|---|---|---|---|
| S1 | 160 | -57.49 | 99.5 | -135.92 | -90 | 70 |
| S2 | 160 | -52.04 | 99.5 | -138.04 | -90 | 70 |
| S3 | 160 | -45.9 | 99.5 | -145.66 | -90 | 70 |
| M1 | 171 | -56.39 | 96.35 | -131.36 | -90 | 85 |
| M2 | 171 | -51.81 | 98.32 | -137.63 | -90 | 85 |
| M3 | 171 | -45.29 | 99.14 | -146.09 | -90 | 85 |
| D1 | 183 | -52.73 | 89.41 | -126.34 | -90 | 96 |
| D2 | 183 | -47.56 | 91.92 | -135.3 | -90 | 96 |
| D3 | 183 | -43.13 | 92.74 | -139.37 | -90 | 96 |

Figure 5: Pose information about different joints.

In this lab, I figure out the different between **MoveJ, MoveL**, and **MoveP**, which can help me achieve different goals easily. **MoveJ** produces a curved path for the arm. It can make the arm move fast between waypoints, and it won't consider the path. **MoveL** moves the arm linearly between waypoints, which can keep the orientation of gripped objects. **MoveP** moves the arm linearly with constant speed with circular blends. The path can be adjusted by changing the radius of blend. The path becomes sharper when the radius is small, and the path turns smoother while the radius is large.

## References

[1] Tower of Hanoi. (2019, September 13). Retrieved from https://en.wikipedia.org/wiki/Tower_of_Hanoi

[2] Tower of Hanoi. (n.d.). Retrieved from https://www.mathsisfun.com/games/towerofhanoi.html