# Modular Arm Puzzle
## *Activity Sheet*

Please use this sheet to record your data from the Modular Arm Puzzle activity session.

***Materials Needed**: Modular Arm Puzzle Mat and Shapes.pdf (**printed at full scale**), pencil with eraser, scissors, optional: colored pencils or crayons.*

## Modular Robot Design with AI Background

What are some of the possible advantages of modular robots?

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How could machine learning help with modular robots?

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## Activity: Modular Arm Puzzle.

### Solve the Board!

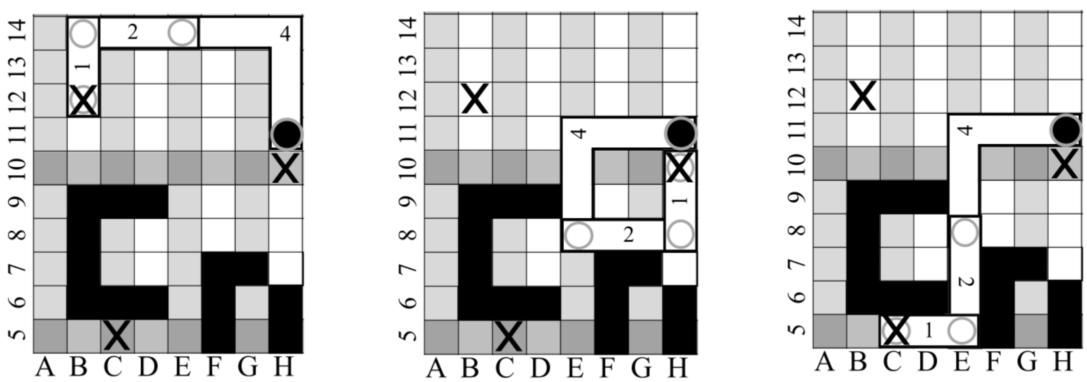
In the following activity, we play the role of the robot designer. Our goal is to select the modules (components and order) and the control (the joint angles between the modules) to reach a set of points.

### Game Rules

- No part of the modular arm can overlap with the obstacles (Areas shaded with black squares to form the letters “C, M, & U”)
- Modular arm parts must connect at the circular “joints”, but are otherwise unable to overlap. Only one connection per joint is allowed.
- The first joint on the first module must connect to the starting point, the filled circle in the center.
- The last joint on the last module must connect to the goal.
- Each module, obstacle, and marker must be correctly aligned with the grid.
- All pieces must be fully on the board, and aligned with the grid.

- To solve a goal point, the final joint (circle at the last space) must be located at that point. To solve the set, the same modular arm must reach all of the points listed.
- The sequence of modules used within a single set of goal points must be the same, but the orientation (representing the angle of the joints) of the joints can vary.

Here is an example, showing the bottom left section of the grid. The task here, described in terms of the goal locations that the tip of the modular arm must reach, can be encoded as **C5, B12, H10.**




The solution shown here is Module (M) 4, then type 2, then type 1, or in a shorter encoding, as **4-2-1.**

*Directions:*
For each goal point in the set, use a pencil to lightly draw an X on the spots to mark that the modular arm should reach. Then, when you are finished with that set, erase those marks with the pencil.

With these rules in mind, try to solve the following goal point sets, using the same arm to reach all points listed for a single task:

Task 1: C8
Task 2: C15, D16
Task 3: I4, G4, I12

List the solutions you found to the tasks.

1) ______________________________ 2) ______________________________

3) ______________________________

What makes the problem hard? What is your process, and what factors do you consider, when solving it?

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There may be multiple solutions to a puzzle. If so, what would be tie-breakers making some solutions better than others?

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## Solve Another Person's Puzzle!

Using the puzzle board components, create your own puzzle, and record it in the same syntax as above. At the same time, record the solution to this puzzle.

*Puzzle Solving Strategy:*

1. Note that a puzzle is not considered valid unless it comes with at least one valid solution!

2. Think about it first! Don't list random points, because that may not yield a solution!

3. One way to ensure that you are making a valid puzzle is by using the "forward" problem:
    a. Take a combination of parts and see where it can reach.
    b. Then, pass the "inverse" problem to your neighbor, and see if they can solve it!

List the tasks you made, and their solutions.

Task 1:____________________ Solution 1: ____________________

Task 2:____________________ Solution 2: ____________________

List the tasks your neighbors gave to you, and the solutions you found.

Task 1:____________________ Solution 1: ____________________

Task 2:____________________ Solution 2: ____________________

What strategies did you use to create your puzzles? Did those strategies help in decoding the puzzles given to you by your neighbors?

Are all points on the grid reachable by some modular arm made from components we provided, labelled 1, 2, 2, 3, 4? How can you tell if a point is reachable or not?

Does having more points to reach necessarily make the problem harder or easier to solve? Why could this be the case?

## Conclusions

Where else could modular robots be used?

What other methods, besides reinforcement learning, might be applicable to the problem of modular robot design?