Solving a Simple Maze

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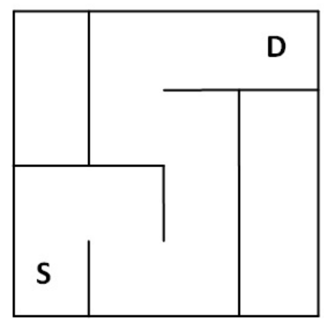
Lesson Focus

Lesson focuses on algorithmic thinking and programming. Make the students aware of the beauty of simple algorithms and their implementation in real fun games.

Lesson Synopsis

The activity involves the design of an algorithm for solving a 4x4 simple maze. The problem statement is just to design an algorithm and implement them using flow chart. If the background of students permits the use of basic programming, implementing the algorithm in a preferred programming language is recommended.



The students shall be given card or similar material to design a simple 4x4 maze as shown in the figure. The source and destination will be as shown in the figure (denoted by S and D respectively). They will be asked to find the route manually first. It will be followed by a discussion on what logic they have used for finding the route. They can list the conclusions derived from the discussion. Based on the conclusions, the students are asked to create an algorithm, in simple terms a 'step by step procedure', to solve the maze.

Advanced Level: If the algorithm is verified for the given maze, the students can go forward with the implementation of the same on a preferred programming language. This will make use of basic concepts of two dimensional arrays, loops, and conditional statements. Moreover, they will be able to enjoy the real fun in solving the maze, with their basic programming skill.

Age Levels

14-18. It is preferred that students have basic knowledge of algorithms and programming.

Objectives

- Learn how to systematically analyze a problem in such a way that an algorithm can be derived to solve it
- Learn about the usage of such algorithms to solve real problems.
- Learn about applications of such algorithms to get started with the world of robotics algorithms, artificial intelligence, and so on.

Anticipated Learner Outcomes

As a result of this lesson, students should have an understanding of:

- The design of simple algorithms to solve problems
- The importance of teamwork to come up with efficient and fast solutions for real problems
- The various pathways the students can explore related to algorithms. (eg: artificial intelligence, robotics algorithms etc)

Lesson Activities

Students design a simple maze as shown in figure (given in the synopsis). They will solve the maze, and will then list the assumptions and steps in arriving at the solution of the maze. This data will act as the input to developing a generalized solution to the maze, and thus the students will be able to describe the algorithm. Implementation of the algorithm in a programming language and exploration of the areas in which such algorithms may be used will be left to students as future (optional) task. Working as a team of two or three, will be effective and useful for the students not only in terms of work efficiency, but also on developing teamwork skills.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Worksheets (attached)
- Student Resource Sheets (attached)

Internet Connections

- A video of micromouse/maze solving robots, can be shown to students. For eg:
  - http://www.youtube.com/watch?v=xrF4v28AOlc
  - http://www.youtube.com/watch?v=H5F1nfFgBdI

Recommended Reading

- http://en.wikipedia.org/wiki/Maze_solving_algorithm.
- http://www.astrolog.org/labyrnth/algrithm.htm#solve

Optional Writing Activity

ead the Wikipedia page on maze solving algorithms and the Astrolog page on types of mazes and write a summary of the different approaches. Pick one of the approaches and list its strengths in terms of criteria such as complexity (simple is better) and speed (faster is better).

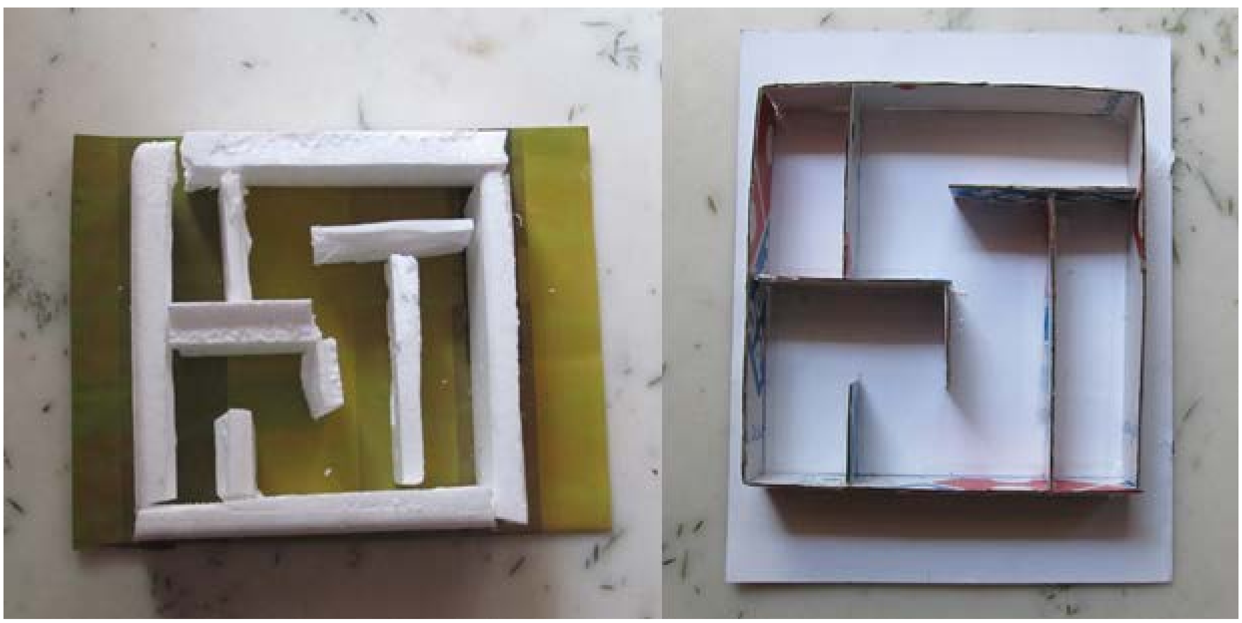
Solving a Simple Maze

For Teachers:
Teacher Resources

◆ Materials

- Card to act as a base on which to build the maze.
- Polystyrene balsa or card sufficient to build walls of a 4x4 maze as shown in the figure given in the synopsis. (Cardboard from the pizza box is an ideal option). The maze can have the dimension of 30cm (12 inch) square and 5cm (2 inches) in height. Specific dimensions are left to the teacher/organizer based on the availability of materials and room space available for the activity.
- Scissors/craft knife and glue/adhesive tape for building the maze
- A pen
- Copies of Student worksheet(one per group)
- Copies of the Maze Figure. (one per student)

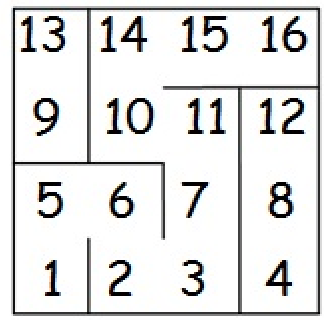
◆ Procedure



1. To set the scene, the students can be shown any video of micromouse/maze solving robot. Many suitable videos are available from YouTube. It is better if the videos are selected in advance and downloaded in case of internet connectivity problems.
2. Students should be given an introduction to the world of maze solving robots using the link given in the student resources. (Each student can be given a copy of the student resources sheet.)
3. Allow them get think about what makes the robots actually drive towards its destination by its own in a step by step fashion. This will introduce them to the understanding of algorithms and their role in the play.
4. The students can now start designing their maze. It is advised that they prepare the maze already shown in the figure (given in synopsis) for easy reference. This is

a simple maze without any loops or dead ends, which make the algorithms more complex. A copy of the maze diagram can be given to each group at this point of time.

5. Let them get started building the maze. First of all, on the cardboard to be used as platform, the students can draw an outline of the maze using the pencil and scale. Make sure that the dimensions are decided beforehand.
6.
    a. If cardboard is used for the walls, sellotape is the best option to fit them on the platform. However, it is good to keep this option left to the students, as they can come up with simpler and effective ideas.
    b. A maze with the walls made of thermocol is shown on the left side of the figure above. On the right, the wall is made out of cardboard. It is advised to reduce the height of the wall (around 1 inch), if cardboard are used.
7. Once they are done with building the maze. Using the sketch pen, they can mark the source and destination with letters 'S and 'D' respectively.
8. For simplicity, ask the students to number each cell using the sketch pen.
    a. The numbering can be done starting from Source with '1', moving along the right direction (along the row), and then again for the next row. It is as shown in figure. The figure can be shown to students in the screen, or a copy can be given to each group.
    b. The destination will have the value '16'.



9. Now, they can assume a robot (or even a real mouse!!) to be driven to 'destination' (denoted as 'D' or numbered as '16').
10. Ask them to find the path to the destination from source.
   They can note down the sequence of numbers denoting the cell the mouse has to go through, in order to reach the destination.
11. It's the time to raise the question on what made them arrive at such a list. Of course, the solution is pretty obvious for everybody, but thinking about the solution from the point of view of 'mouse' may be a little tricky. Let the group members discuss among themselves on what are the criteria/rules they have applied while arriving at such a solution, and let them take down the method the mouse should adopt in completing its mission.
12. A simple solution would look like this
    a. Assumptions: The mouse knows the numbers of each cell beforehand, and it knows the destination number to be reached.
    b. Starting from source, the mouse checks which path is open, looking at its right, front and left. It finds out the open path, goes to the next cell.
    c. Once it reaches the next cell, it checks if the cell value is equal to 16. If not, it will again do the path finding: looking at its right, front and left. (Note: the maze designed here is such that, there is only one pathway available from each cell, and it leads surely to the destination. In advanced cases, this might not be the case).
    d. Moving to the next cell, the above step is repeated.
    e. Once the cell vale matches with the destination number the mouse is looking for, it can stop, as the mission is completed.
13. If the students find difficulty in arriving at a solution, the teachers can help them out, giving the hints based on the steps described above, or thinking of more innovative solutions. This is left up to the teacher.

14. Once the students are clear about the step by step procedure, it's time to give them more about an 'introduction to algorithms'. It is just to convince them that whatever they have done (figuring out a step by step procedure and listing it out systematically), is nothing but algorithm design.
15. As a further activity, students can be encouraged to change the maze from the standard design given above to one of their own choosing, although with the same numbering and source and destination. Encourage them to think about any modifications their algorithms will require for the new maze. Some groups are likely to included dead ends or loops in their mazes, perhaps inadvertently. Dead ends in particular will complicate the algorithm since the algorithm will need to keep a record of the previous path. When there is only one route with no dead ends, only the previous cell need be recorded. Encourage the groups to share their results, so that groups with simpler mazes get to try their algorithms on more complex mazes, and adjust their algorithms accordingly.

◆ Time Needed

- 30-45 minutes can be given until building the maze.
- 60-90 minutes can be given for the rest of the task.
- The total activity can be organized for 2 hours.

Student Resource:

◆ It has been so many years since the challenge of maze solving robots came up. So many people in the past developed and demonstrated various models for the same. If you think the basic problem statement, you will be reminded of your childhood days where you were challenged to help a mouse find its route towards the destination, in a maze. The maze got complicated structure as you grew up!!!... So, have you ever imagined a real scenario, where you could make a mouse intelligent enough to solve the maze by its own? As technology evolved further such that intelligent robots can be developed, this problem has got its own place. That is how micromouse has become a standard problem statement. You can go back home and search for the problem statement, or even you can search in YouTube for videos, where people demonstrate their own bots solving the maze. Hey!! It's not only about solving the maze, but to solve it in the shortest possible time... Oh!! Yes, the problem gets complicated as you grow up.. But, to get started with the world of 'artificial intelligence and robotics', let’s think of a simple maze and move towards the ultimate mission. You may forget about the hardware part. There is something, which doesn't have any limit; it's our imagination, our way of thinking towards solving a problem. Yes!! It’s all about software development. Software development for such activities is merely based on algorithms. By the way, what is an algorithm?? It is nothing but 'step by step' procedure in completing a mission. So, are you ready to tackle the problem?

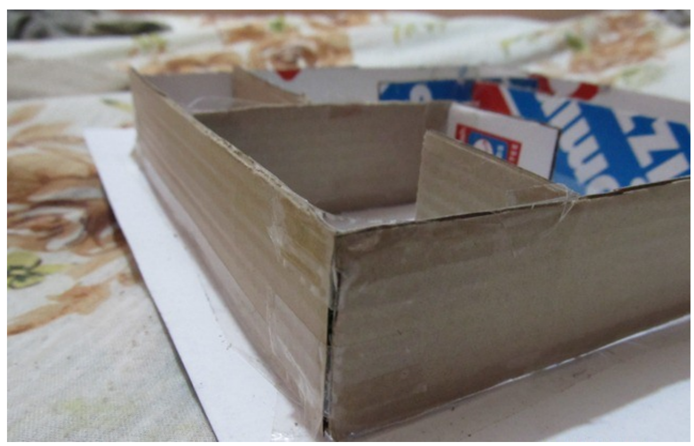
Solving a Simple Maze

Student Worksheet:
Design your own maze and solve it..

◆ You are working as a team of engineers who have been given the challenge to design a maze using the materials given to you, and then solve it. By this time, you might have already seen what a maze looks like, and some interesting maze solving robots. Before jumping into the real game, let's get started with building the maze. As you have seen, the maze consists of a platform and walls fitted onto it. Once you build your own maze with the dimensions suggested by your teacher, you will have to solve the maze – coming up with a step by step procedure you can give to the robot such that it can travel from source to destination. The maze has sixteen cells. The source is at the left bottom cell of the maze and the destination is at the right top of the maze.

◆ Planning
As a team, discuss among yourselves how to go about building the maze. You will have to decide what all materials you need. You can get them from your teacher. You may return materials, exchange materials with other teams. Consult with your teacher, if you need any clarification or doubts at this stage.

◆ Building
Take the material you use for the platform, say, the cardboard. Using the pencil or sketch pen, draw a layout of the maze on the platform. Share materials with other teams to build your maze. This is team work and it is important that you discuss among your team members and enjoy the spirit of working in a team. Share your thoughts and share your work. Listen to your friends, and help them out. Be sure to watch how other teams have designed their maze and how different the mazes are, compared to yours.



◆ Solving
Now it's time to start solving the maze. Take down the path in terms of the cell numbers, through which a mouse (a robot) has to travel to the reach the destination from the source. Now, think what made you arrive at your solution. Describe the logic behind your solution. Discuss among your friends and write it down.

It's important to think of the solution in terms of numbers. You can see the whole maze, and think about how to get from the source to the destination. However, you are much smarter than the robot. The robot cannot see the destination or understand the whole maze – the robot just knows the number of its current position and the numbers of the neighboring squares it can move to.

This is the real problem, how do you describe the solution to the robot? The robot doesn't know how to solve the maze. It only knows the source number is 1, and destination number is 16. So you have to give the robot a set of instructions such that the robot reaches the destination. Take down the instructions; consult your teacher for verification.

When you are doing this, think about how your solution would work if the maze was constructed differently. It is easy to design a solution if you know the maze beforehand, and simple tell the robot the moves it requires. However, can you come up with a solution that would work no matter what the pattern of the maze was? Can you think of ways of testing your solution?

◆ Evaluation

Use this worksheet to evaluate your team's results in this lesson.

1. Did you succeed in building the maze based on the figure given to you? If not, why?

2. Did you succeed in arriving at the solution for the maze? In other words, were you able to give the robot proper 'instructions' such that it could reach the destination? If not, why?

3. Did you negotiate any material trades with other teams? How did that process work for you?

4. Once you started building the maze, did you decide to change materials or add more materials?

5. Do you think that engineers have to stick to their original plan during the building stage? Why?

6. Do you think that the “building” stage helped you visualize the problem very clearly? If yes, how did it help you in solving the problem?

7. If you were working alone, would you have been able to complete the project easier? Explain.

8. Based on this activity, what do you think of algorithm development? Explain.

Teacher Resource: Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆ Principles and Standards for School Mathematics

As a result of activities, all students should develop

Geometry Standard

- Specify locations and describe spatial relationships using coordinate geometry and other representational systems
- Use visualization, spatial reasoning, and geometric modeling to solve problems

Problem Solving Standard

- Apply and adapt a variety of appropriate strategies to solve problems.
- Solve problems that arise in mathematics and in other contexts.

Representation

- Use representations to model and interpret physical, social and mathematical phenomena

◆Common Core State Standards for School Mathematics Grades 3-8 (ages 8-14)

Operations & Algebraic Thinking

- Generate and analyze patterns.
  - CCSS.Math.Content.4.OA.C.5 Generate a number or shape pattern that follows a given rule. Identify apparent features of the pattern that were not explicit in the rule itself. For example, given the rule “Add 3” and the starting number 1, generate terms in the resulting sequence and observe that the terms appear to alternate between odd and even numbers. Explain informally why the numbers will continue to alternate in this way.

◆ Standards for Technological Literacy – All Ages

The Nature of Technology

- Standard 2: Students will develop an understanding of the core concepts of technology.

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Teacher Resource:
Alignment to Curriculum Frameworks

◆CSTA K-12 Computer Science Standards Grades 6-9 (ages 11-14)

5. 2 Level 2: Computer Science and Community (L2)

- Computational Thinking (CT)
  3. Define an algorithm as a sequence of instructions that can be processed by a computer.
  6. Describe and analyze a sequence of instructions being followed (e.g., describe a character's behavior in a video game as driven by rules and algorithms).
  14. Examine connections between elements of mathematics and computer science including binary numbers, logic, sets and functions.
- Collaboration (CL)
  2. Collaboratively design, develop, publish, and present products (e.g., videos, podcasts, websites) using technology resources that demonstrate and communicate curriculum concepts.
  3. Collaborate with peers, experts, and others using collaborative practices such as pair programming, working in project teams, and participating in group active learning activities.
  4. Exhibit dispositions necessary for collaboration: providing useful feedback, integrating feedback, understanding and accepting multiple perspectives, socialization.
- Collaboration (CL)
  3. Collaborate with peers, experts, and others using collaborative practices such as pair programming, working in project teams, and participating in group active learning activities.
- Computing Practice & Programming (CPP)
  4. Demonstrate an understanding of algorithms and their practical application.