AI Search: Lions and Gazelles

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Lesson Focus

This is an introduction to Artificial Intelligence (AI) 'state-space search.' The entertaining story line provides necessary background justifying the classic rules. Students will write and perform a skit that solves the problem using pre-made paper props, as they explore the concept of state representation. This is followed by an informal analysis of state-space, state representations, depth- and breadth-first search, and shortest path.

Age Levels

Recommended for ages 11 – 13
Also appropriate for ages 8 – 10

Objectives *(of the lesson)*

Introduce students to:

1. Approaches to problem solving using classic puzzles
2. Using state-space representations to solve a problem
3. Informally comparing depth- and breadth-first search, and finding the shortest path

Anticipated Learner Outcomes

Students will be able to:

- Find a solution to one of the classic 'river crossing' puzzles
- Learn how to create a state-space search
- Describe the advantages of depth- versus breadth-first search to find a solution and shortest path

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Recommended Reading and Non-Computer Manipulative

- River Crossing 2 Game, by Think Fun
- Artificial Intelligence: The Basics, Kevin Warwick, Routledge, 2011

Optional Writing Activity

- This activity introduces river-crossing puzzles that can be solved through state-space search. Invent your own river-crossing story: include the puzzle descriptions and the solution.

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For Teachers:
Teacher Resources

- **Lesson Objectives**
  - Provide models for systematic problem solving using state-space search
  - Engage students in cooperative solution finding
- **Materials**
  - Sufficient copies of the animal images provided below to allow all students in the class to participate
  - Blue painters tape to create the edges of a river
  - An object that can be used for a 'tree branch', or a real branch
  - Pencils and paper for note taking
- **Procedure**

Session 1:

Prepare ahead or have the students assemble the animal tags that appear below. Prepare ahead or have the students set up two river banks by laying down blue painters tape (or masking tape) in two parallel, two yard-long strips, approximately one yard apart. Divide the students into puzzle solving groups. Each group consists of seven students: three will be lions, three will be gazelles, and one will be a narrator and note taker. If you can't form groups of exactly seven, assign other roles as needed: narrator, note taker, director, prop manager, etc. If you have theater experience, use theater production concepts to provide distinct roles for all of the students.

Explain the puzzle rules to the students:

> Three lions and three gazelles meet on one side of a river. All of them need to cross to the other side of the river. The current is too strong for any of them to swim across alone. None of the animals can cross without gripping a tree branch to help them float. A single branch lies on their side of the river. Only one or two animals at the most can use the branch at one time to get across, or they will sink. At least one animal must grip the branch to get it across (it can't simply be tossed back). If more lions than gazelles are on one side of the river, the lions will eat the gazelles. The animals holding onto the branch count toward those who will attack or be eaten when the branch is on either riverbank.

Explain to the students that they will be putting on a skit that demonstrates how all of the animals can cross the river safely. Worksheet 1 provides guidance. Have the groups find a solution to the puzzle using whatever strategy they can. (Please discourage them from gripping the 'branch' in their teeth. It is sufficient to simply hold onto it.) When they think they have a solution, have them demonstrate it to you, the judge. You can also assign judging to students. All groups will be asked to perform their skit for the others in the last 15 minutes of the hour. For those who can't find a solution, have them perform a skit where the lions eat the gazelles. (But don't tell them that is an option until the end, or no one will try to solve the problem. The dead-end (fail) state is far more fun than the success state!)

Wrap up the theater experience with a discussion of how they were able (or not able) to come up with a solution. Ask questions such as 'Was there more than one solution?', 'Is there a best solution?', 'How did you figure out the solution?'

If there is time, introduce some of the other puzzles in the Internet Resources above, using materials you have available such as the 'Think Fun' toy listed in Recommended Reading, online versions of the game, or using found pieces for the other classic puzzles. Have the students read the Science News article listed above, or explain those puzzles to them.

Session 2:

State-Space Search

Select one of the student groups to present the solutions again to remind everyone about the nature of the puzzle and how they solved it. The following is re-enforced in the resources for students and Worksheet 2.

A state-space is, essentially, a diagram of how a problem can be described as the paths from a start-state to a goal state, with possibly dead-ends and loops. (If they play video games, they may have a sense for this.)

Explain that a 'state' is a description, (a notation or representation) of what you need to keep track of in the puzzles (e.g. where the lions and gazelles are, and where the branch is).

Explain how state change rules describe how one state goes to another. For example "a lion grips the branch", "a gazelle lets go of the branch", "the branch is on the starting bank of the river". It is important that each group identify all of the necessary rules.

Using Worksheet 2, have groups of 2 – 4 students fill out the state diagram for lions and gazelles. Have them identify 'dead states' where the gazelles get eaten. Make sure they label (using any notation that works for them), the rules that transition between states.

When most of the students have completed the diagram, have a discussion about whether everyone found the same solution, how they filled out the diagram, and how did they decide which state to expand next. If appropriate, discuss the differences between depth- and breadth-first solutions.

- Depth-first: given a state, pick a rule, apply it to create a new state, and then apply a rule to that state. If it isn't a dead end, back up the path and explore another rule.

- Breadth-first: given a state, apply all possible rules for that state to create all of the possible next states. Mark dead-ends. Expand all possible states that are not dead-ends.

Solution Analysis

If your students have not looked at the Internet resources that briefly tell them about the "Fox, Rabbit, Cabbage" puzzle, but don't take the time to solve it.

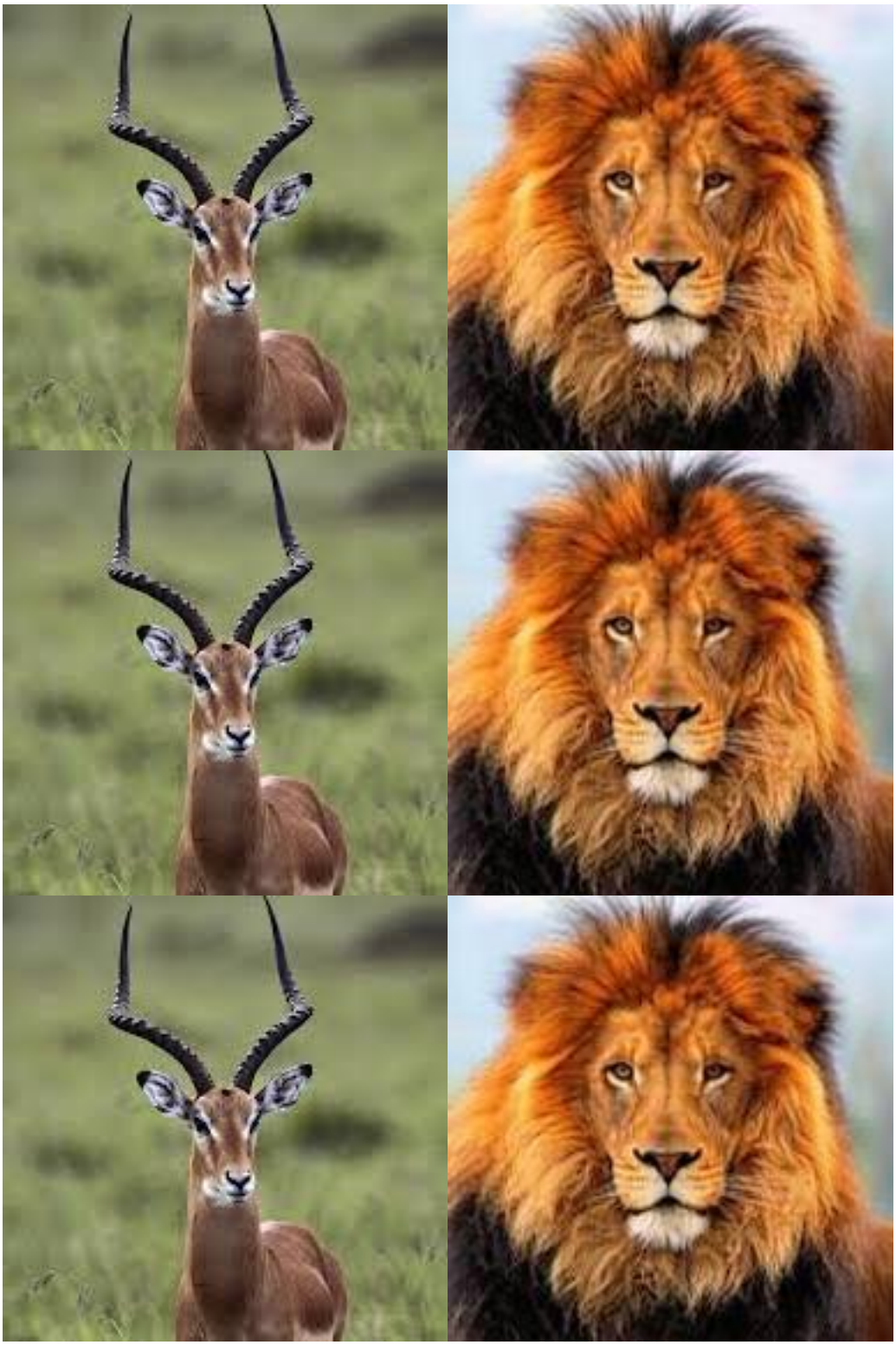
Middle school students have strong opinions. Discuss as much of the following as you can.

- Is there more than one solution?
- Is there a 'best' solution, and if so what is it and why is it best?
- What about the other kinds of problems (e.g. Fox, Rabbit, Cabbage). Are they really the same or different and why?
- What other kinds of puzzles have the same kind of structure?

Time Needed

- 2 sessions of at most 1 hour each. Can be done in one 2 hour session.

Print copies of this page sufficient for each skit ensemble. Cut and glue to heavy weight backing (or print on heavy weight paper). Punch holes in the upper left and right corners and thread yarn to make a necklace for the players.



Lion: http://vignette4.wikia.nocookie.net/animalcrossing/images/e/e3/Lion-013-2048x2048.jpg/revision/latest?cb=20130406213028
Gazelle: http://fullhdpictures.com/gazelle-wallpapers.html/android-gazelle-wallpapers

AI Search: Lions and Gazelles

Student Resource:

Session 1:

Artificial Intelligence (AI) has roots in simple puzzle solving. You may be familiar with AI in movies and video games, and have heard that it is used in Internet search; to genome mapping and creating genetically modified food. Computer Scientists who are AI researcher often start with simple puzzles because it helps them focus on how to *represent* the important parts of a problem, and how to create *algorithms* or *rules of logic* to solve a problem. The data that an AI program manipulates is called the 'state.' The algorithm is often called 'search.'

In the first half of this activity you will create skits to understand the solution to a basic math problem that involves crossing a river. The reason AI researchers love this particular puzzle is that it sometimes requires undoing what you've already done to solve the problem. Your job is to create a skit that successfully gets all of the animals across the river. Here is the story:

> Three lions and three gazelles meet on one side of a river. All of them need to cross to the other side of the river. The current is too strong for any of them to swim across alone. None of the animals can cross without gripping a tree branch to help them float. A single branch lies on their side of the river. Only one or two animals at the most can use the branch at one time to get across, or they will sink. At least one animal must grip the branch to get it across (it can't simply be tossed back). If more lions than gazelles are on one side of the river, the lions will eat the gazelles. The animals holding onto the branch count toward those who will attack or be eaten when the branch is on either riverbank.

Worksheet 1 helps you create the skit that you will perform at the end of the first session.

Session 2:

Your skit gives you insight into the problem, but didn't give you a way to describe to others how to get to the solution. You may have used trial and error, or had to decide what to do at each step. AI researchers try to find ways to instruct computers on how to figure out a solution. The researchers do not solve the problem. The computer program they write solves the problem. In the 1950s and 1960 a simple strategy called *state-space search* was created. Here is some vocabulary:

State-space: Is a diagram of how a problem can be described as the paths from a start state to a goal state, with possibly dead-ends and loops. Sometimes the state-space is thought of as all of the possible states, even ones that that can't be reached from other states.

State (or state description): Is a way of using the least amount of information needed to keep track of a problem. In the "Lions and Gazelles" puzzle this would be which riverbank the branch is on, and how many lions and gazelles are on each bank.

State change rules: Every state-space has rules to get you from one state to the next possible states. For example, "a lion grips the branch", "gazelle lets go of the branch", "the branch is moved across the river".

Depth first search: Given a state, pick a rule, apply it to create a new state, then, apply a rule to that state. If it is a dead end, back up the path and explore another rule.

Breadth first search: Given a state, apply all possible rules for that state to create all of the possible next states. Mark dead-ends. Expand all possible states that are not dead-ends.

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Student Worksheet 1
The Skit:

Create your stage: using materials given to you, create the two edges of the stream. Make sure all of your players know how to grab onto and let go of the prop that is your tree branch.

The Players:

Lion 1: _____ **Gazelle 1:** _____

Lion 2: _____ **Gazelle 2:** _____

Lion 3: _____ **Gazelle 3:** _____

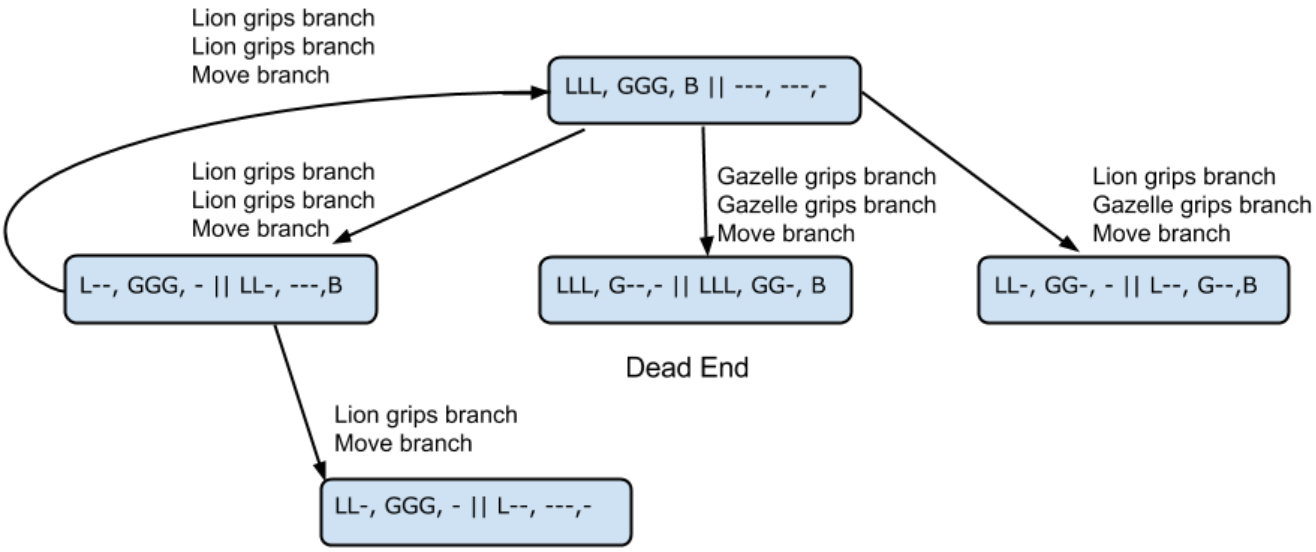
Production Crew: (who else has a role, and what is it?)

_____

Script Instructions: Using the space below write a ***draft*** of your script that moves all the Lions and Gazelles across the river. Rehearse your script so that everyone knows what to do and when. If you have time, use a computer or tablet to write up your script with stage directions.

Student Worksheet 2
State-Space Search:

Please refer to the student resource page for definitions. The diagram shows the start of a state-space for the "Lions and Gazelles" problem with a possible way to describe states. Your job is to (1) come up with a notation that is easier for you to write, but doesn't lose any information, (2) add missing rules, (3) using your clearer notation, create a 'reasonably' complete state-space, including dead ends and reverse moves. Reverse moves occur when you go back to a previous state, undoing your forward progress. Identify your start state and goal state(s).



State notation: LLL, GGG, B|| ---,---,-
This means there are 3 **L**ions and 3 **G**azelles on the left bank with the tree **B**ranch, and nothing on the right bank that is important to the puzzle.

Some rules: Lion grips branch, Gazelle lets go of branch, move branch across river.
Hints:

1) Notice that two or three rules are applied before drawing the next state. You could expand out the intermediate states, but it gets tedious. A good state space diagram captures just the essential information with creating clutter.
2) A reversing rule is shown. These may move you back more than one state!
3) Remember that your job is to find any, and perhaps all, of the possible solutions.

Questions:

1) As you created a state-space diagram, did you use depth- or breadth-first search?
2) One strategy is guaranteed to find the best solution. Which one is it?
3) When you solved the puzzle for your skit, did you use breadth- or depth-first search, or another combination?

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For Teachers: Alignment to Curriculum Frameworks

Note: All lesson plans in this series are aligned to the Computer Science Teachers Association K-12 Computer Science Standards, and if applicable also the U.S. Common Core State Standards for Mathematics, the U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics, the International Technology Education Association's Standards for Technological Literacy, the U.S. National Science Education Standards and the U.S. Next Generation Science Standards.

◆National Science Education Standards Grades K-4 (ages 4-9)

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- Understanding about science and technology

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- Understandings about science and technology

◆Next Generation Science Standards & Practices Grades 3-5 (ages 8-11)

Practice 2: Generating and Using Models

- Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.

Practice 6: Constructing Explanations and Designing Solutions

- Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem

Practice 7: Engaging in Argument from Evidence

- Construct and/or support an argument with evidence, data, and/or a model.

◆ Principles and Standards for School Mathematics

Problem Solving Standards

- build new mathematical knowledge through problem solving

Communication Standards

- Communicate their mathematical thinking coherently and clearly to peers, teachers and others

Representations

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

◆Common Core State Practices & Standards for School Mathematics (all ages)

- CCSS.MATH.PRACTICE.MP1 Make sense of problems and persevere in solving them.
- CCSS.MATH.PRACTICE.MP4 Model with mathematics.

◆ Standards for Technological Literacy - all ages

Nature of Technology

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

The Designed World

- Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies

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For Teachers:
Alignment to Curriculum Frameworks

◆CSTA K-12 Computer Science Standards Grades 3-6 (ages 8-11)

5.1 Level 1: Computer Science and Me (L1)

- Computational Thinking (CT)
  4. Describe how a simulation can be used to solve a problem.
- Collaboration (CL)
  3. Identify ways that teamwork and collaboration can support problem solving and innovation.

◆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.

  4. Evaluate ways that different algorithms may be used to solve the same problem.

  5. Act out searching and sorting algorithms.
- 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.