Building the Haystack and Finding the Needle:
Creating and Searching Matrices

Summary
In this lesson, students will use MATLAB and learn to create algorithms that populate matrices with numbers that meet specified criteria. They will also learn to search matrices and pull out desired information.

Engineering Connection
Matrices are a useful and powerful way to organize and manipulate numbers and are used in a variety of engineering contexts. MATLAB is a popular mathematical software package that is built on matrix math. In neuroscience research, matrices are used to store information about retinal structure and matrix math is used to determine the responses of retinal cells to different inputs. In this way models of the eye can be built that will provide insight into how the retina works.

Contents

Related Curriculum
- Algebra 2—Matrices
- Algorithms
- Computer Programming

Educational Standards
- New York Math 9-12 A2.PS.6 Use a variety of strategies to extend solution methods to other problems 2005
- New York Math 9-12 A2.PS.7 Work in collaboration with others to propose, critique, evaluate, and value alternative approaches to problem solving 2005
- New York Math 9-12 A2.PS.5 Choose an effective approach to solve a problem from a variety of strategies (numeric, graphic, algebraic)

☑ New York Math 9-12 Students will understand meanings of operations and procedures, and how they relate to one another.

Learning Objectives

1. Understand how matrix indices are used to move through a matrix.
2. Practice developing algorithms to automate the solution to a mathematical problem.
3. Practice testing and revising computer instructions that implement a specific algorithm.

Introduction/Motivation

During the summer, I conducted research attempting to understand how the retina in the eye processes the visual information it receives. To do this, I read about how the eye works and then attempted to build a mathematical model of it in the computer. Any model of the eye needs to represent where the individual cells are located and how they relate to each other. Since matrices are useful ways of organizing and manipulating mathematical information, we used them to represent what types of cells are located where. Once all the locations and connections are known, we can use math to represent how they talk to each other.

The retina has two main sensors: rods for detecting light levels (black and white) and cones for detecting colors. There are three types of cones, each responding to a particular color: red, green, or blue. These sensors are called photoreceptors. They are arrayed in a 2-dimensional sheet in a special arrangement. There are lots of cones in the middle, which we use for our focused, high-detail seeing; and there are lots of lots of rods around the periphery for night vision and motion detection. For our model, we had to program the computer to "build" the retina by deciding what type of sensor should be in each location. An added issue is that cones are 10x bigger than rods, so you also have to figure out how they all fit together. To do this, you have to understand how to move around a matrix and put into it the information you want that meets your needs.

So today we want to extend our knowledge of matrices by using indices to build matrices that have the properties we desire.

Lesson Outline

- Creating Matrices
  - Indexing Matrices: 2D, 3D, and 4D
  - Using "for" loops to move through a matrix
  - Declaring an empty matrix.
  - Guided Exercise: filling a matrix with ones.
  - Placing specific values in specific elements.
- Searching Matrices
  - Finding non-zero numbers
  - Guided Exercise: Storing the location and values of non-zero numbers

Activities

1. Fill a matrix with ones

2. Fill a matrix sequentially
3. Fill a matrix with sequential diagonals
4. Place a value in the center of the matrix
5. Fill a matrix with the distance of each element from the center element
6. Fill a matrix with concentric squares/rectangles of numbers
7. Fill a matrix with concentric rings of numbers
8. Fill a matrix with a sequential square spiral of numbers

Lesson Background and Concepts for Teachers

Brush up on matrix arithmetic by reading the chapter in an Algebra 2 text.
Do introductory exercises in MATLAB for manipulating the content of matrices.

Vocabulary and Definitions

Matrix—a rectilinear array of numbers
Element—one entry in a matrix
Indices—the "address" of a particular element
Dimension—the number of numbers needed to specify a "location"
2D, 3D, 4D—flat space, volume space, and hyper-space
For loop—a function that does a task a certain number of times
Algorithm—a process that solves a problem

Lesson Closure

During this unit we explored how to control the contents of a matrix to meet our specific needs. How might this be used to build a photoreceptor array? How might matrices be used to keep track of other real-world information? Wonderful ideas. Enjoy your weekend.

Assessment

Pre-Lesson: Brainstarter utilizing 2D matrix size and indices
Post-Intro: Guided practice during lesson
Post-Lesson: Group activities
Summary Assessment: Individual matrix algorithm activity

Lesson Extension

Exploring the MATLAB model of retina structure and function

Contributors

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Supporting Program

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