Matrix Implementation In Java

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April 23 2019

1 Description

This capstone combines my experience in Computer Science with my coursework in MATH285: Matrix Algebra. To demonstrate and practice what I learned in MATH285, I created an implementation of Matrices using the Java programming language. The general intent while creating this implementation was to create a reusable Java package for representing a Matrix or many Matrices. Particular focus was put on challenging myself to write my program almost exclusively from the lessons and documentation provided by MATH285, and to write code to perform similarly to how I did the coursework.

The project consists primarily of creating a general usage matrix package, but a secondary matrix tester package was also created to demonstrate the matrix package being used to complete coursework.

The matrix package consists of the primary Matrix class, and a secondary MatrixTools class. The Matrix class represents the data in a matrix, and all of the operations that can be done with matrices. The MatrixTools class is an optional secondary class to provide a different interface. This class was mainly created to provide static methods for performing matrix operations using parameters, should that type of interface be preferred. Particular care was given to create a Matrix package that could be used by others. This involved creating methods to allow the user to check if a particular operation is possible before doing the operation.

1.1 Matrix Class Features

- Creating matrices

- Getting indices
- Setting indices
- Checking dimensions
- Row operations
- Matrix operations
- Gaussian elimination
- Gauss-Jordan elimination
- Matrix inversion
- Finding determinants of matrices
- LU decomposition
- Finding rank and nullity of matrices
- Checking Matrices for compatibility with certain operations

The additional matrixTester package consists of example programs that use the Matrix package I created to reproduce work that was done in MATH285.

1.2 MatrixTester Features

- Perform basic Matrix operations
- Check to see if a certain vector spans a set of vectors
- Check a set of vectors for linear independence
- Simplify a system of equations
- Use Markov Chains to find probability

2 Physical, Social, and Development Environment

This project was done alone on various different computers both on and off campus. Most work was done in the computer science lab or the library. Occasionally, work was done on a home system. All work was done in the Eclipse development environment, and version control was maintained through Github.

3 Work With Others

All code was done alone, however I received advice from Dr. Matthews, Dr. Beck, and Dr. Belanger. The advice received from Dr. Matthews and Dr. Beck concerned general structure of the program, such as where to put Matrix operations. The advice received from Dr. Belanger consisted of help with the topics in MATH285, such as strategies for performing LU decomposition.

4 Hardware and Software Platform

Work was done both on Windows and Linux systems. All code was written using the Eclipse Development Environment.

5 Communications Skills

Often I would communicate with Dr. Belanger over how to accomplish different problems from MATH285. I would also update him on what I had accomplished. Since Dr. Belanger is not familiar with programming, I had the opportunity to explain the computer science aspect to him. For example, I would have to explain how parameters and returning variables work when describing situations where output may vary.

6 Useful CS Courses

The implementation of Matrices turned out to be fairly simple, though the original plan was to break the project into several classes. The most helpful course was CS260, as most of the complex Java conventions were learned there. CS181 was also helpful, as it was where most of my knowledge of Javadoc comes from. CS370 also helped me learn how to use Git for version control, and discussions with Dr. Beck influenced my design so that my project would properly follow the object-oriented paradigm when creating methods for matrix operations.

7 Useful Non-CS Courses

The only outside course that was useful was MATH285, as the project consisted of recreating nearly all of the work done in this course. I was able to use documents from the course as a reference when creating the project. I also talked with the professor about different strategies for solving different problems from the course.

8 Three Things I Learned

One thing I learned from this project was a novel way to copy matrices. Since matrices are a simple data representation consisting only of numbers and are used for mathematical purposes, math can be used for copying. The initial values in every index of a matrix in this project are zeroes. Since I can add matrices together, I can create a copy of a matrix by initializing a matrix of the same size, and adding the original matrix to it. While this is a novel way to copy a matrix, it isn't worthwhile to use, and is more computationally expensive to perform. The same amount of loop iterations is performed in addition, while also requiring addition to be made.

Another thing I learned was a more comprehensive understanding of the identity matrix. When discussing ways to use matrices to perform row operations, I wondered what the values in a matrix would have to be in order to perform the proper row operation when multiplied by another matrix. I realized that this is what the values in an identity matrix do: they represent which rows were changed from the original matrix.

The last thing I learned was an understanding of how the span and linear dependence of vectors can be used to analyze a system of equations. A system of equations converted to a matrix ca be analyzed for span and linear dependence. If the last vector of a matrix spans the other vectors, and the vectors are linearly independent, the system of equations has exactly one solution. If the last vector spans the other vectors, but the vectors are linearly dependant, the system of equations has infinitely many solutions. If the last vector doesn't span the other vectors, than the system has no solutions.

9 A Problem and a Solution

The most challenging thing to implement in my project was implementing LU decomposition of a matrix. Originally, the problem seemed too complex to code the same way as I work it by hand, and I searched online for algorithms. I found Doolittle's method to LU decomposition, however, this method didn't work for every matrix. Anytime pivoting was needed, the decomposition would fail. Most solutions that used row swapping seemed too complex, and used an additional permutation matrix to represent row swapping. I was worried about handling matrices that didn't need row swapping, and therefore didn't need an additional matrix. Ultimately, with the help of my MATH285 professor, I realized that even matrices that don't use row swaps still had a valid permutation matrix. I was now able to look over the lecture notes for this problem and determine a solution for LU decomposition.

10 Final Result

Unfortunately, this project didn't turn out nearly as complex as I assumed it would be. I assumed that different types of operations on a matrix would require their own class. However, when I tried to put these operations into their own class, I used static methods to implement the operations, and ultimately violated the object-oriented nature of this project. I provided an additional class that demonstrates the original idea I had, and to provide a different way to perform matrix operations. It is certainly possible to break the Matrix down into objects to represent certain sets of operations from within the Matrix, but I opted to keep everything as I created it.

Another thing I wasn't comfortable with was the large amount of code reusage. Much of the coursework done in MATH285 consist of some form of Gaussian or Gauss-Jordan elimination (Such as inverting a matrix, or finding the LU decomposition). However, extra steps are typically taken in the middle of the elimination algorithm. This resulted in code that mostly looked the same, but varied in the middle. It may be possible to break the elimination into pieces, so that most of the same code can be used, and vary only where it needs to. A strategy pattern may be a useful for breaking the problem up, but finding a clean solution may prove challenging.

One of the best parts of this project, however, came out of this code reusage. Many complex methods could either directly use other previously created methods to do most of the work, or reuse the code itself. Any time a problem used some form of elimination, I had most of the algorithm already created and ready to go. It was very satisfying to find that the work I had done would help solve later problems. It also demonstrates just how important Gaussian elimination and Gauss-Jordan elimination are to working with matrices.

The final benefit from this project was an increased understanding MATH285 coursework. In order to recreate coursework in code, comprehensive knowledge of the coursework was necessary. I learned more about how specific parts of a matrix work, and how they work with other portions of coursework. Attempting to convert the coursework into code improved my understanding of the subject.