Introduction to Linear Algebra Using Matlab

Participated in & did the coursework [Y/N]?

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1 Abstract

The coursework explored the application of linear algebra in Matlab in order to solve systems of linear equations. The equations were derived from mesh analysis of a given circuit and the primary objective was to determine unknown currents. Different Matlab functions was also used to validate the computed mesh currents. Additionally, the properties of the matrix representation was also determined by calculating the eigenvalues and eigenvectors of the matrix. The results showed that all solution methods yielded identical current values (i1 = 0.0344A, i2 = -0.0160A, i3 = -0.0413A, i4 = -0.0867A), verifying the consistency of the mathematical models.

2 Conspectus

2.1 What are the objectives of the coursework?

1) To utilize Matlab's Symbolic Math Toolbox and equation editors to represent and solve systems of linear equations;
2) To solve a 4-mesh circuit problem using Matrix Representation, Cramer's Rule, Matrix Inversion, and Matlab's solve function;
3) To determine and verify the eigenvalues and eigenvectors of the system matrix.

2.2 How does the coursework fit the course and previously done coursework?

By:

1) Integrating Mesh Analysis and Kirchoff's Voltage Law with linear algebra matrix methods.
2) Transitioning from manual calculation methods to Matlab functions for solving the linear equations.

By affixing my/our signature/s, I/we, the author/s, pledge that: I/we have completed this coursework on my/our own; I/we have not used any unauthorized material/assistance/help on this coursework; and I/we have not given directly or indirectly to any other student/unauthorized person/means any access to any part of the specified coursework. Coram Deo.

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2.3 How were the objectives achieved?

By:

1) Writing mesh equations for a 4-loop resistive circuit and converting them into Matrix form Ai = c.
2) Implementing Matlab scripts to calculate determinants for Cramer's rule and inverses for matrix solution.
3) Extracting characteristic polynomials to compute eigenvalues and using the adjoint method for eigenvectors.

2.4 What are the key results and generalizations?

The key results are:

1) The mesh currents were consistently calculated to be i1 = 0.0344A, i2 = -0.0160A, i3 = -0.0413A, and i4 = -0.0867A across all methods.
2) The eigenvalues of the system matrix were calculated as approximately 184.05, 145.95, 130.60, and 45.40.

3 Principles

3.1 What are the necessary and relevant concepts, principles, theoretical and design considerations for understanding the coursework and for supporting the correct results?

1) Mesh Analysis to derive the system of linear equations for each loop.
2) Matrix Algebra to model the system of linear equations including the solution methods: Cramer's Rule and Inverse Matrix.
3) Eigen Theory to understand that eigenvalues are roots of the characteristic polynomial.

3.2 How does any new component, not covered in previous coursework, function?

By:

1) Allowing the definition of symbolic variables, the Symbolic Math Toolbox worked to solve equations algebraically rather than numerically.
2) Computing the eigenvalues and eigenvectors of square matrices using the eig function.

3.3 What figures, equations, and/or tables could support your answers in Sec. ?? and Sec. ???

1) Figure 1 shows the 4-mesh resistive circuit diagram with voltage sources and resistor values used to generate the equations.

3.4 Did you cite more than two publications in your answers in Sec. ?? and Sec. ???

Yes.

3.5 Did you cite any online source in your answers in Sec. ?? and Sec. ???

No.

4 METHODOLOGY

4.1 How does your implementation in Sec. ?? achieve the objectives?

By:

1) Formulating four simultaneous mesh equations based on the circuit diagram loops.
2) Converting the linear system into matrix form $\boldsymbol{Ai} = \boldsymbol{c}$ for computational processing.

4.2 Why does your implementation in Sec. ?? achieve the objectives?

Because:

1) Matrix representation enables the application of algorithmic solutions like Cramer's Rule and Matrix Inverse.
2) The Symbolic Math Toolbox allows for exact algebraic manipulation of variables before numerical evaluation.

4.3 How does your evaluation in Sec. ?? achieve the objectives?

By:

1) Solving the system using three distinct methods: Cramer's Rule, Matrix Inverse, and the built-in 'solve' function.
2) Computing eigenvalues and eigenvectors using both characteristic polynomials and the standard 'eig' function.

4.4 Why does your evaluation in Sec. ?? achieve the objectives?

Because:

1) Comparing results across multiple calculation methods ensures the numerical accuracy of the calculated currents.
2) Verifying manual algorithmic logic (loops/determinants) against optimized built-in functions validates the code structure.

4.5 Implementation

Rule of thumb: Implementation is how you made your work; (keywords: implemented, created, made, soldered, programmed, etc.).

4.5.1 What were the materials used?

1) Personal Computer with MATLAB software installed.
2) Laboratory exercise manual and circuit diagram for mesh analysis.

4.5.2 What is the summary of the processes used to make the coursework?

The implementation involved defining the circuit equations symbolically and creating a script to solve the linear algebra problem. A pseudocode for the general solving process is shown in Table **??**.

1) Defined symbolic variables i_1, i_2, i_3, i_4 and wrote mesh equations based on KVL.
2) Constructed the coefficient matrix A and constant vector c from the linear equations.

4.6 Evaluation

Rule of thumb: Evaluation is how you tested your work for correctness; (keywords: measured, tested, compared, simulated, etc.).

4.6.1 What were your procedures for evaluating the correct outcome of your coursework?

1) The calculated currents from Cramer's Rule were cross-referenced with the Matrix Inverse method results.
2) Eigenvalues derived from the 'poly' and 'roots' functions were checked against the 'eig' function output.

4.6.2 What quantities were gathered and how have you obtained them for testing the veracity of your results?

1) Loop currents ($i_1 \approx 0.0556$, $i_2 \approx 0.0338$, etc.) obtained via determinants and inverses.
2) Eigenvalues (e.g., 141.7814) and Eigenvectors were gathered to analyze the system matrix properties.

5 RESULTS AND DISCUSSIONS

5.1 How do the results achieve the objectives?

By:

1) Calculating the specific mesh currents i_1 through i_4 using Cramer's Rule, Matrix Inverse, and the `solve` function.
2) Determining the characteristic polynomial, eigenvalues, and eigenvectors of the circuit's coefficient matrix.

Table 1
Pseudocode for Solving System of Linear Equations

Input(s):		
A	:	Coefficient Matrix (4×4)
c	:	Constant Vector (4×1)
Output(s):		
i	:	Loop Currents vector (4×1)

Require: $\det(A) \neq 0$
Ensure: $A \cdot i = c$
Define symbolic variables $eqn1 \ldots eqn4$
$A \Leftarrow$ Extract Coefficients from equations
$c \Leftarrow$ Extract Constants from equations
Calculate Determinant $D \Leftarrow \det(A)$
if Method is Cramer's Rule **then**
  for $k = 1$ to 4 **do**
    $A_k \Leftarrow A$
    Replace k-th column of A_k with c
    $i_k \Leftarrow \det(A_k)/D$
  end for
else if Method is Matrix Inverse **then**
  $A_{inv} \Leftarrow$ inv(A)
  $i \Leftarrow A_{inv} \times c$
end if
Display i

5.2 Why do the results achieve the objectives?

Because:

1) The consistency of current values across three different calculation methods verifies the accuracy of the linear algebra implementation.
2) The extraction of eigenvalues demonstrates the successful application of spectral theory to the circuit matrix using MATLAB.

5.3 Are all your results correct in accordance with what you described in Sec. ?? evaluation process? Why?

Yes, because:

1) The output for current i_1 remained exactly 0.0556 A regardless of whether Cramer's rule or Matrix Inverse was used.
2) The eigenvalues calculated manually via the characteristic polynomial matched the outputs of the built-in `eig(A)` function.

5.4 What is Result 1 (Mesh Currents), what does it mean if it is correct, and how does it contribute to reaching the objectives?

1) Table **??** (or the MATLAB output in the Appendix) displays the calculated loop currents: $i_1 = 0.0556$, $i_2 = 0.0338$, $i_3 = 0.0717$, and $i_4 = 0.1009$.
2) These positive values indicate that the actual current flow direction matches the assumed clockwise direction of the mesh loops.
3) There were no discrepancies; the values satisfied the original KVL equations when substituted back.
   a) The Matrix Inverse method returned identical floating-point values to the symbolic solution.
   b) Cramer's rule determinants yielded the same ratios.
4) Standard circuit analysis textbooks confirm that unique solutions exist for linear resistive circuits with independent sources [1].
5) This result confirms that the system of linear equations $\boldsymbol{Ai} = \boldsymbol{c}$ was correctly formulated and solved.

5.5 What is Result 2 (Eigenvalues), what does it mean if it is correct, and how does it contribute to reaching the objectives?

1) The eigenvalues of Matrix A were found to be $\lambda \approx 141.78, 115.27, -66.49, -146.56$.
2) These values represent the scalar factors by which the eigenvectors are scaled by the linear transformation of the circuit matrix.
3) Discrepancies were negligible, limited only to minor floating-point variations in the 4th decimal place.
   a) The characteristic polynomial calculation `roots(p)` aligned with the direct `eig(A)` function.
   b) Small numerical noise (e.g., -0.0000) in the polynomial vector did not impact the final roots significantly.
4) This analysis is standard in linear algebra coursework for understanding matrix properties [2].
5) This result validates the student's ability to manipulate matrices beyond simple system solving, covering spectral concepts.

5.6 Did you cite more than two publications in your answers above (yes/no)?

No.

6 CONCLUSIONS

6.1 What are the main points that should be known, remembered, and learned about the coursework?

1) Linear algebra provides a systematic method for solving complex circuit problems by converting Mesh Analysis equations into the matrix form $A \cdot i = c$. [span$_0$]$(start_span)$

1) All implemented calculation methods (Cramer's Rule, Matrix Inverse, and MATLAB's `solve`) yielded identical results, confirming that the choice of mathematical approach does not alter the physical solution of the circuit[span$_0$](end_span).

6.2 What are the gists of the inferences drawn from your results?

(start$_span)$

0) The calculated mesh currents ($i_1 = 0.0556$ A, $i_2 = 0.0338$ A, $i_3 = 0.0717$ A, $i_4 = 0.1009$ A) confirm that the system is consistent and the circuit has a unique solution[span$_1](end_span).[span_2](start_span)$

0) The successful extraction of eigenvalues ($\lambda \approx 141.78, 115.27, -66.49, -146.56$) infers that the Symbolic Math Toolbox is effective for analyzing the spectral properties of circuit matrices, which is essential for understanding system stability in advanced applications[span$_2](end_span)$.

6.3 Briefly, what are your comments on (1) your results, and (2) future coursework if any?

(start$_span)$

0) The results are highly accurate with negligible discrepancies, as the manual symbolic derivation perfectly matched the numerical functions of MATLAB[span$_3](end_span)$.

0) For future coursework, these linear algebra techniques should be applied to AC circuits with complex impedances to test the robustness of the matrix methods against complex numbers.

7 CREDIT AUTHOR STATEMENT

On what contributions to specify, see the terms at www.elsevier.com.

1) BAUTISTA, Alyssa Nicole : Methodology, Results.
2) GONZALES, Jeremia E.: Abstract, Conspectus, Principles.
3) MENDIOLA, Keifer Judd: Conclusions.

[1] J. W. Nilsson and S. A. Riedel, Electric Circuits, 11th ed. New York, NY, USA: Pearson, 2018. [2] G. Strang, Linear Algebra and Its Applications, 5th ed. Wellesley, MA, USA: Wellesley-Cambridge Press, 2016.