1. **Course Code and Course Title**

   MATH 3806 Multivariate Statistical Methods (3,3,1)

2. **No. of Units**

   3

3. **Offering Department**

   Department of Mathematics

4. **Pre-Requisite**

   MATH2207 Linear Algebra I and one of the following: or MATH2005 Calculus, Probability, and Statistics for Computer Science or MATH2006 Calculus, Probability, and Statistics for Science or MATH2206 Probability and Statistics or MATH2216 Statistical Methods and Theory

5. **Co-Requisite / Anti-Requisite (if any)**

   Nil

6. **Aims & Objectives**

   To provide an understanding of the classical multivariate analysis. Very often, observations in the social, life and natural sciences are multidimensional or very high dimensional. This kind of data sets can be analyzed by techniques in multivariate analysis. With the help of statistical package, such as Matlab and R, students will learn how to treat real multivariate problems.

7. **Course Intended Learning Outcomes (CILOs)**

CILO	By the end of the course, students should be able to:	PILO Alignment
1	Apply the basic graph techniques to find useful information from multivariate data and understand statistical theory of multivariate normal distribution.	2
2	Apply projection technique to analyze multivariate data and extract useful information from multivariate data.	2
3	Manipulate the software MATLAB or R and figure graphs for multivariate data.	2,5
4	Write MATLAB or R program to calculate multivariate statistics and design and implement innovative multivariate data processing system for extracting special useful information from data.	4,5
5	Work effectively in a team and able to solve problems independently.	5

8. **Teaching & Learning Activities (TLAs)**

CILO No.	TLAs

1,2,3,4,5	**Lab tutorial** Instructor will guide students to study basic knowledge of MATLAB or R and to know how to write program by MATLAB or R in the on week's course held on computer lab.
1,2,3,4,5	**Lecture and tutorial** Instructor will present real multivariate dataset and analyze in class. Students will consolidate the knowledge through discussion within lectures/tutorials.
1,2,3,4,5	**In-class activity** Instructor will guide students to find some multivariate data from their practical real life and make modeling, analysis and interpretation for their collected data

9   **Assessment Methods (AMs)**

Type of Assessment Methods ABC	Weighting	CILOs to be Address	Description of Assessment Tasks
In-class exercise	20%	1,2,3,4,5	In-class exercise will be given to enable students to practice on basic multivariate statistical concepts, calculations, algorithms implementation, engage in problem-solving. Each of them allows the students to know what they do well and what they need to work harder on. It also allows the instructor to identify learning needs and problems.
Writing assignments	20%	1,2,3,4,5	Writing assignments with long questions are designed to allow the instructor to keep track of how well the students master the knowledge of multivariate statistical methods covered during different stages of the course. The questions of assignments include calculations with steps and explanations, proofs, guided questions etc.
Project	20%	1,2,3,4,5	The project is designed to achieve CILO 3-5 by facilitating students working in a team environment and independently to model multivariate dimensional data by statistical methods. This may involve, but not limited to, in class discussions of rigorous technical problems and their solutions.
Final Examination (2 Hours)	40%	1,2,3,4,5	Final Examination is designed to see how far students have achieved their intended learning outcomes especially in the Knowledge domain. Students should have a thorough understanding of the knowledge and apply them correctly in different context to do well in the exam.

10.   **Assessment Rubrics**

CILO: 1 Apply the basic graph techniques to find useful information from multivariate data and understand statistical theory of multivariate normal distribution.

Criteria	Excellent	Good	Satisfactory	Marginal Pass	Fail
Application	Insightful and accurate application of the main basic graph techniques to find useful information from multivariate data with detailed consideration of the requirements and contextual factors.	Appropriate and accurate application of some of the basic graph techniques to find useful information from multivariate data with some consideration of the requirements and contextual factors.	Reasonably accurate application of a few basic graph techniques to find useful information from multivariate data with some consideration of the requirements and contextual factors.	Attempt in application of the basic graph techniques to find useful information from multivariate data with limited consideration of the requirements and contextual factors.	Inappropriate application of basic graph techniques to find useful information from multivariate data with no consideration of the requirements and contextual factors.

CILO: 2 Apply projection technique to analyze multivariate data and extract useful information from multivariate data.

Criteria	Excellent	Good	Satisfactory	Marginal Pass	Fail
Application	Insightful and accurate application of the main projection technique to analyze multivariate data with detailed consideration of the requirements and contextual factors.	Appropriate and accurate application of some of the projection technique to analyze multivariate data with some consideration of the requirements and contextual factors.	Reasonably accurate application of a few projection techniques to analyze multivariate data with some consideration of the requirements and contextual factors.	Attempt in application of the projection technique to analyze multivariate data with limited consideration of the requirements and contextual factors.	Inappropriate application of projection technique to analyze multivariate data with no consideration of the requirements and contextual factors.

CILO: 3 Manipulate the software MATLAB or R and figure graphs for multivariate data.

Criteria	Excellent	Good	Satisfactory	Marginal Pass	Fail
Manipulation	Insightful and accurate manipulation of the main software MATLAB and able to figure graphs for multivariate data with detailed consideration of the requirements and contextual factors.	Appropriate and accurate manipulation of some of the software MATLAB and able to figure graphs for multivariate data with some consideration of the requirements and contextual factors.	Reasonably accurate manipulation of a few software MATLAB and able to figure graphs for multivariate data with some consideration of the requirements and contextual factors.	Attempt in manipulation of the software MATLAB and able to figure graphs for multivariate data with limited consideration of the requirements and contextual factors.	Inappropriate manipulation of software MATLAB and able to figure graphs for multivariate data with no consideration of the requirements and contextual factors.

CILO: 4 Write MATLAB or R program to calculate multivariate statistics and design and implement innovative multivariate data processing system for extracting special useful information from data.

Criteria	Excellent	Good	Satisfactory	Marginal Pass	Fail
Execution	Sophisticated execution of MATLAB program with accuracy, reasoning and thorough consideration of assumptions, demonstrating high level of understanding.	Appropriate execution of some MATLAB program with considerable accuracy, reasoning and consideration of assumptions.	Reasonable execution of a few MATLAB program with some accuracy, reasoning and consideration of assumptions.	Attempt in execution of MATLAB program with limited accuracy, reasoning and consideration of assumptions.	Inappropriate execution of MATLAB program with no accuracy, reasoning or consideration of assumptions.

CILO: 5 Work effectively in a team and able to solve problems independently.

Criteria	Excellent	Good	Satisfactory	Marginal Pass	Fail
Solution	Thorough and elegant solution of problems with valid discussions, justifications, verifications, and appraisals of the underlying logic, mechanisms, theories, and relationships among elements.	Appropriate solution of problems with some valid discussions, justifications, verifications and appraisals of the underlying logic, mechanisms, theories, and relationships among elements.	Reasonable solution of problems with a few valid discussions, justifications, verifications and appraisals of the underlying logic, mechanisms, theories, and relationships among elements.	Attempt in solving the problems with limited discussions, justifications, verifications and appraisals of the underlying logic, mechanisms, theories, and relationships among elements.	Inappropriate solution of problems with no discussion, justification, verification or appraisal of the underlying logic, mechanisms, theories, or relationships among elements.

11. **Course Intended Learning Outcomes and Weighting**

Content	CILO No.	Teaching (in hours)	Tutorial (in hours)
I. Introduction and Matrix Algebra	1,2	6	2
II. Multivariate Normal Distribution and Its Sampling Theory	1,3	8	3
III. Tests of Hypotheses on Means and Covariance Matrices	1,3,4	10	3
IV. Multivariate Methods in Multivariate Analysis	1,2,3,4	15	5

12. **Textbooks / Recommended Remarks**

Textbook

1. Lecture notes prepared by the instructor

References

1. R.A. Johnson and P.W. Wichern, Applied Multivariate Statistical Analysis, 6th Ed., Prentice -Hall International Book Company, 2002.
2. J. Han and M. Kamber, Data Mining: Concepts and Techniques, The Morgan Kaufmann Publishers, 2001.
3. Daniel Zelterman, (2015), Applied Multivariate Statistics with R, Springer.
4. Bryan F. J. Manly and Jorge A. Navarro Alberto (2017). Multivariate Statistical Methods, A Primer. (Fourth Edition) CRC Press.

Software

1. MATLAB or R

13. **Course Content**

	Topics	Hours
I	Introduction and Matrix Algebra	6
	A Introduction to multivariate analysis and data mining	
	B Basic statistics of a data set	
	C Data displays and graphical representations	
	D Matrix algebra	
II	Multivariate Normal Distribution and Its Sampling Theory	8
	A Random vector and its distribution	
	B Moments of multivariate distributions	
	C Multivariate normal distribution	
	D Matrix normal distribution	
	E Maximum likelihood estimation	
	F Properties of estimators	
III	Tests of Hypotheses on Means and Covariance Matrices	10
	A From univariate to multivariate problems	
	B Tests of hypotheses on means and the T^2-statistic	
	C Two samples problem	
	D Testing equality of several means	
	E Some tests on covariance matrices	
IV	Multivariate Methods in Multivariate Analysis	15
	A Principal component analysis	
	B Factor analysis	
	C Canonical correlation analysis	
	D Classification	

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