



بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ



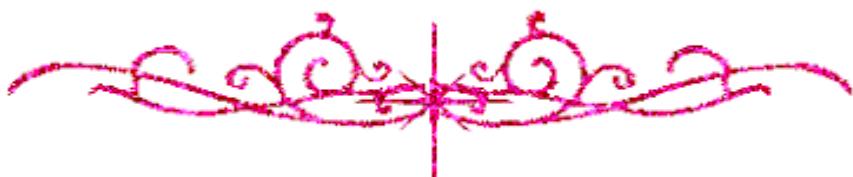
SALWA AKL



شبكة المعلومات الجامعية
@ ASUNET

شبكة المعلومات الجامعية

التوثيق الالكتروني والميكروفيلم



SALWA AKL



جامعة عين شمس

التوثيق الإلكتروني والميكروفيلم

قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها
على هذه الأقراص المدمجة قد أعدت دون أية تغيرات



يجب أن

تحفظ هذه الأقراص المدمجة بعيداً عن الغبار



SALWA AKL



بعض الوثائق

الأصلية تالفة



SALWA AKL



شبكة المعلومات الجامعية
@ ASUNET

بالرسالة صفحات

سالوة أكل



SALWA AKL

**Zagazig University,
Benha Branch
Faculty of commerce
Department of statistics
Mathematics and insurance**

B17323

**EXTENSIONS OF THE EXPECTATION
- MAXIMIZATION (EM) ALGORITHM
USING A BAYSIAN APPROACH**

BY

MERVAT MAHDY RAMADAN

9.7.1

Supervised By

PROF.

ABDUL FATAH MOHAMED AHMED KANDIL

Vice Dean for Graduate Studies
Chairman, Department of Statistics,
Mathematics and Insurance
Faculty of Commerce
Zagazig University
Benha Branch

PROF.

ABDUL HAID NABIH AHMED

Department of Mathematical Statistics
The Institute of Statistical Studies and
Research – Cairo University

A THESIS

*Submitted To The Statistics, Mathematic and Insurance,
Department Faculty of Commerce Zagazig University, Benha Branch, In
Partial Fulfillment of The Requirements For
Degree of Master of Statistics*

2005

APPROVED SHEET

EXTENSIONS OF THE EXPECTATION-MAXIMIZATION (EM) ALGORITHM BY A BAYSIAN APPROACH

BY

MERVAT MAHDY RAMADAN

This thesis is submitted as a requirement of the degree of M.Sc
of Statistics to the Faculty of Commerce, Benha University.

This thesis has been approved by:

Prof. Ahmed Kamel Emam

Prof. Abd Elfatah Mohamed Kandel

Prof. Abd Hadi Nabeah Ahmed

Prof. Atef Mohamed Abd Elmonem

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

﴿وَقُلْ أَعْمَلُوا فَسَيَرِي اللَّهُ عَمَلَكُمْ وَرَسُولُهُ وَالْمُؤْمِنُونَ وَسَرِدُونَ إِلَى

عَالِمِ الْغَيْبِ وَالشَّهَادَةِ فَيُنَبِّئُكُمْ بِمَا كُنْتُمْ تَعْمَلُونَ﴾

صدق الله العظيم

"سورة التوبه - آية ١٠٥"

ACKNOWLEDGEMENT

I am grateful to my professors; *Professor Abdul Fatah Mohamed Ahmed Kandil, and professor Abdul Hadi Nabih Ahmed*, for stimulating my interest in research, for always being available, and for their valuable contributions throughout the research effort. Without their guidance, insight, encouragement, and willingness to work long hours with me, this thesis would not have been possible.

I wish to thank my professors at the faculty of Commerce, Benha University, who supported me throughout the course work of this thesis. Moreover, I wish to express my sincere appreciation to my family, my mother, my father, my sisters and my brothers whose support and encouragement were vital to the achievement of this thesis.

CONTENTS

Items	Page
List of Tables.....	iii
List of Figures	iv
List of Abbreviations.....	v
Chapter:	
I. Introduction and Summary.....	1
II. Definition of Missing Data.....	3
2.1. Introduction.	3
2.2. Examples of Missing Data.....	4
2.3 Patterns of Missing Data	4
2.3.1 Univariate Sample with Missing Data.....	4
2.3.2 Monotone Pattern with X More Observed than Y.....	5
2.3.3 Univariate Missing Data	6
2.3.4 Monotone (nested) Missing Data.....	7
2.3.5 Unidentified Parameters of Missing Data.....	7
2.3.6 General Patterns of Missing Data.....	8
2.4 Nature of Missing Data.....	8
2.4.1 Missing Completely At Random MCAR).....	8
2.4.2 Missing At Random (MAR).....	9
2.4.3 Not Missing At Random(NMAR).....	9
2.5 Handling Missing Data.....	10
2.5.1 Procedures Based on Completely Recorded Units.....	11
2.5.2 Imputation – Based Procedures.....	11
2.5.3 Model – Based Procedure	12
III. Expectation -Maximization (EM) Algorithm	15
3.1 Introduction	15
3.1.1 Maximum Likelihood Estimation.....	15
3.1.2 EM Algorithm : Incomplete Data Structure.....	17
3.2. Basic Theory of the EM Algorithm.....	19
3.2.1 The E – and M – Steps.....	20
3.2.2 Convergence of EM Algorithm.....	23
3.2.3 Convergence Rate of EM Algorithm	24
3.2.4 Generalized EM Algorithm (GEM).....	27
3.2.5 Properties of the EM Algorithm.....	28
3.3 Examples of the EM Algorithm.....	29
3.3.1 Univariate Normal Sample.....	29
3.3.2 Linear Regression with Missing Values Confined to the Endogenous Variable.....	33
3.3.3 Sample from Multinomial Population.....	38
3.3.4 Sample from Binomial / Poisson Mixture.....	46
3.4 Stopping Criteria	54

3.4.1 The Relative Improvement of the Log Likelihood.....	54
3.4.2 Maximum Relative Difference in the Parameters.....	55
3.4.3 Gradient Function.....	55
3.4.4 Aitken Acceleration.....	56
3.4.5 Example: Mixture Exponential Distribution.....	56
IV. Speeding Up EM Algorithm	70
4.1 Introduction.....	70
4.2 ECM Algorithm	71
4.3 The PX-EM Algorithm.....	73
4.3.1 Introduction	73
4.3.2 Formal Definition of PX-EM.....	74
4.3.3 Rate of Convergence of PX-EM.....	77
4.3.4 The PX-EM Step as Covariance Adjustment.....	81
4.4 Examples.....	82
4.4.1 ECM Example.....	82
4.4.2 PX-EM Example.....	84
4.4.3 General Mixed Model Example	87
V. EM Algorithm for Bayesian Inference.....	97
5.1 Bayes Theorem.....	97
5.2 EM for Bayes Estimation.....	102
5.3 Examples.....	106
5.3.1 Univariate Normal Sample.....	106
5.3.2 Multinomial Population.....	110
5.3.3 Mixture Population.....	116
References.....	130
Arabic Summary	

LIST OF TABLES

Items	Page
Chapter (2):	
Table (2.1): Missing Data Handling Software Options.....	14
Chapter (3):	
Table (3.1): Data for Example (3.3.2).....	37
Table (3.2): Convergence of Linear Regression with Missing Values.....	38
Table(3.3): Convergence of Sampling from Multinomial Population.....	43
Table (3.4): Data of Sample from Binomial / Poisson Mixture.....	46
Table (3.5): Convergence of Data of Sample from Binomial/Poisson Mixture.....	51
Table (3.6): Data for 2 Finite Exponential Mixture.....	58
Table (3.7): Result of All Criterion.....	59
Table (3.8): The Final of Result of Two Initial Values.....	60
Chapter (4):	
Table (4.1): Convergence of PX – EM.....	86
Chapter (5):	
Table (5.1): Comprises Comparison Between ML and Bayesian Estimation for EM Algorithm.....	109
Table (5.2): Comprises Comparison Estimation Between ML and Bayesian Estimation for Multinomial Population.....	113
Table (5.3): Computation of $\xi^{(1)}$	122
Table (5.4): Computation of $\xi^{(2)}$	122
Table (5.5): Computation of $\xi^{(3)}$	122
Table (5.6): Computation of $\xi^{(4)}$	123
Table (5.7): Computation of $\xi^{(5)}$	123
Table (5.8): Computation of $\xi^{(6)}$	123
Table (5.9): Computation of $\xi^{(7)}$	124
Table (5.10): Computation of $\xi^{(8)}$	124
Table (5.11): Computation of $\xi^{(9)}$	124
Table (5.12): Computation of $\xi^{(10)}$	125
Table (5.13): Computation of $\xi^{(11)}$	125
Table (5.14): Computation of $\xi^{(12)}$	125

Table (5.15): Computation of $\xi^{(13)}$	125
Table (5.16): Computation of $\xi^{(14)}$	126
Table (5.17): Computation of $\xi^{(15)}$	126
Table (5.18): Computation of $\xi^{(16)}$	126
Table (5.19): Computation of $\xi^{(17)}$	126
Table (5.20): Computation of $\xi^{(18)}$	127
Table (5.21): Computation of $\xi^{(19)}$	127
Table (5.22): Convergence of Mixture Population Using Bayesian Estimation	128
Table (5.23): Comprises Comparison Estimation Between ML and Bayesian Estimation for Mixture Population	129

LIST OF FIGURES

Items	Page
Chapter (2):	
Figure (2.1): Univariate Sample with Missing Data	5
Figure (2.2): Monotone Pattern with X More Observed Than Y.....	5
Figure (2.3): Univariate Missing Data.....	6
Figure (2.4): Monotone (Nested) Missing Data	7
Figure(2.5): Unidentified Parameters of Missing Data.....	7
Figure (2.6): General Pattern of Missing Data.....	8
*Chapter (3):	
Figure (3.1): Convergence of Parameter-1	53
Figure (3.2): Convergence of Parameter -2	53
Figure (3.3): The History of Certain Convergence Criteria for the First Set of Initial Values.....	64
Figure (3.4): The History of the Parameters and the Log Likelihood for the First Data Set.....	65
Figure (3.5): The History of Certain Convergence Criteria for the Second Set of Initial Values.....	66
Figure (3.6): The History of the Parameters and the Log Likelihood for the Second Data Set.....	67
Figure (3.7): The History of the Log Likelihood and the Projected Log Likelihood Using the Aitken Acceleration Method.....	68
Figure (3.8): The History of the Values C in Aitkin Acceleration.....	69

LIST OF ABBREVIATIONS

AC	: Available – Case Method
AECM	: Alternating Expectation Conditional Maximization algorithm
CC	: The complete Case Analysis
CM	: Conditional Maximization
ECM	: Expectation – Conditional Maximization
ECME	: Expectation – Conditional Maximization Either
EM	: Expectation-Maximization
E-PX	: Expectation step for Parameter Expansion
E-step	: Expectation Step
GEM	: Generalized EM
MAR	: Missing At Random
MCAR	: Missing Completely At Random
MI	: Multiple Imputations
ML	: Maximization Likelihood
MLE	: Maximization Likelihood Estimation
M-PX	: Maximization step for Parameter Expansion
M-step	: Maximization Step
NMAR	: Not Missing At Random
N-R	: Newton – Raphson
PX-EM	: Parameter Expansion to accelerate EM
SAGE	: The Space Alternating Generalized