SOME CONTRIBUTIONS TO ESTIMATION
IN
ADVANCED TIME SERIES MODELS - VARMA AND BSM

CHI-KIN CHOW

A thesis submitted in partial fulfillment of the requirements for the degree of Postgraduate Studies Committee for the degree of Master of Philosophy

October 1991

Hong Kong Baptist College
Some Contributions to Estimation
in
Advanced Time Series Models - VARMA and BSM

by

CHI-KIN CHOW

Abstract

Maximum likelihood (ML) estimation, by means of the Kalman filter and state space models, has been widely used in time series analysis. In practice, many time series models can be cast in state space forms. In this thesis, two well-known models, VARMA and BSM, are considered. In the process of getting final ML estimates, good initial guesses are usually required. Two fast algorithms, the modified Splitid algorithm (MSP) and the accelerated EM algorithm, are proposed in this thesis for VARMA and BSM respectively. The results indicate that the performances of the algorithms are better than the original ones. Once initial guesses are obtained by these new algorithms, the likelihood function can then be maximized by some nonlinear optimization methods. Since the number of parameters involved in VARMA is usually very large, a new large-scale optimization algorithm, truncated Newton method with nonmonotone line search technique, is suggested. For BSM, the parameters usually must satisfy some constraints. Thus, a new optimization algorithm, the SNTO method, which is suitable in this case, is introduced. Numerical results show that the truncated Newton method is efficient for problems with large number of parameters. On the other hand, the SNTO method is particularly useful for multi-modal functions. In addition, a parallel version of SNTO is presented in this thesis, in order to show the abilities of parallel algorithms in optimization problems. Real-life data are fitted by different models, including VARMA and BSM. Corresponding forecasting results are recorded. The results show that both VARMA and BSM are adequate for forecasting. Further developments, including parallel algorithms in optimization and Kalman filtering, and some new approaches in state space modeling are suggested.
# Content

## 1. Introduction
1.1 Introduction 1

## 2. State Space Time Series Models
2.1 Introduction 6
2.2 State Space Model and Kalman Filtering
   2.2.1 State Space Model 7
   2.2.2 Kalman Filtering 8
   2.2.3 Fixed Interval Smoothing 11
2.3 Vector ARMA (VARMA)
   2.3.1 Identification 12
   2.3.2 Estimation 14
   2.3.3 Diagnostic Checking 16
2.4 Basic Structural Model (BSM)
   2.4.1 Some Extensions of BSM 18
2.5 Model Evaluations in VARMA and BSM 21

## 3. Estimation in VARMA and BSM
3.1 Introduction 24
3.2 Estimation in VARMA
   3.2.1 Sum of Squares approach (SS) 24
   3.2.2 Split Algorithm (SP) 25
   3.2.3 Modified Split Algorithm (MSP) 27
3.3 Estimation in BSM
   3.3.1 EM Algorithm 29
   3.3.2 Accelerated EM Algorithm 31
3.4 Information Matrix 32
3.5 Examples 33

## 4. New Optimization Methods
4.1 Introduction 40
4.2 Truncated Newton Method
   4.2.1 Truncated Newton Algorithm (TN) 41
   4.2.2 Nonmonotone Line Search Algorithm (NL) 43
   4.2.3 Truncated Newton Method with Nonmonotone Line Search (TNNL) 43
4.3 SNTO method
   4.3.1 SNTO Algorithm 45
   4.3.2 Parallel SNTO 47
4.4 Numerical Experiments 49
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.</td>
<td>Real Life Examples</td>
<td>56</td>
</tr>
<tr>
<td>5.1</td>
<td>Introduction</td>
<td>56</td>
</tr>
<tr>
<td>5.2</td>
<td>Real Life Examples</td>
<td>57</td>
</tr>
<tr>
<td>5.2.1</td>
<td>BSM of Hourly Temperature</td>
<td>57</td>
</tr>
<tr>
<td>5.2.2</td>
<td>VARMA model of Temperature and Wind Speed</td>
<td>65</td>
</tr>
<tr>
<td>5.2.3</td>
<td>Multivariate BSM of Dollar/Yen and Gold Price</td>
<td>69</td>
</tr>
<tr>
<td>5.3</td>
<td>Conclusions</td>
<td>75</td>
</tr>
<tr>
<td>6.</td>
<td>Conclusion</td>
<td>77</td>
</tr>
<tr>
<td>6.1</td>
<td>Summary</td>
<td>77</td>
</tr>
<tr>
<td>6.2</td>
<td>Further Developments</td>
<td>78</td>
</tr>
</tbody>
</table>

References 81

Vita 87