Contents

List of Tables ix
List of Figures x
List of Symbols xv

1. Introduction
   1.1 Background 1
   1.2 Systems for Seafloor Classification 7
   1.3 Limitations of Available Systems 10
   1.4 Research Objectives 12
   1.5 Outline of the Thesis 14

2. Pre-Processing Methodology
   2.1 Experimental Area 16
   2.2 Acoustic Data 17
      2.2.1 Characteristics of Reson Navitronics NS-420 18
      2.2.2 Data Acquisition 18
      2.2.3 Pre-Processing of Echo Envelopes 20
         2.2.3.1 Bottom Detection 20
         2.2.3.2 Echo Alignment 22
         2.2.3.3 Echo Average 23
         2.2.3.4 Echo Compensation 24
   2.3 Ground-Truth 28

3. A Concise Review on Acoustic Models
   3.1 Theoretical Background 32
      3.1.1 Reflection and Transmission 33
      3.1.2 Acoustic Scattering 35
      3.1.3 Interaction of Acoustic Waves with Seafloor 38
      3.1.4 Transmission Losses 39
# Contents

3.2 Models for Characterization of Seafloor

3.2.1 Empirical Models

3.2.2 Theoretical Models

## 4. Model-Based Estimation of Seafloor Sediment Parameters

4.1 Introduction

4.2 Temporal Backscatter Model

4.2.1 Mathematical Background

4.2.2 Geo-acoustic Parameters

4.3 Sensitivity Analysis

4.3.1 Influence of Mean Grain Size

4.3.2 Influence of Roughness Spectrum Parameters

4.3.3 Influence of Sediment Volume Scattering Parameter

4.3.4 Influence of Pulse Duration

4.3.5 Influence of Geo-Acoustic Parameters

4.4 Estimation of Seafloor Parameters

4.4.1 Three-Dimensional Inversion Scheme

4.4.2 One-Dimensional Search Algorithm

4.4.3 Simulated Annealing with Downhill Simplex Method

4.4.4 Four-Dimensional Inversion Approach

4.5 Inversion Results and Discussion

4.5.1 Mean Grain Size

4.5.2 Roughness Spectrum Parameters

4.5.3 Sediment Volume Scattering Parameter

4.6 Discussion on Roughness Spectrum Parameters

4.7 Conclusions

## 5. Echo Features Analysis

5.1 Overview

5.2 Echo Features

5.2.1 Backscatter Strength
5.2.2 Statistical Features
5.2.3 Spectral Features
5.2.4 Hausdroff Dimension
5.3 Background of Principal Component Analysis
5.4 Background of Cluster Analysis
5.4.1 Fuzzy C-Means Cluster Algorithm
5.5 Results and Discussion
5.5.1 Principal Component Analysis
5.5.2 Fuzzy C-Means Cluster Analysis
5.6 Conclusions

6. Neural Networks Based Selection of Echo Features

6.1 Introduction
   6.1.1 ANN Terminologies
       6.1.1.1 Weight
       6.1.1.2 Activation Function
       6.1.1.3 Bias
       6.1.1.4 Threshold
       6.1.1.5 Training
   6.1.2 Fundamental Model of Artificial Neural Network
   6.1.3 Perceptrons
   6.1.4 Network Architectures

6.2 Backpropagation Network
   6.2.1 Backpropagation Training Algorithms
       6.2.1.1 Gradient Descent Method
       6.2.1.2 Levenberg-Marquardt Algorithm
       6.2.1.3 Resilient Backpropagation Algorithm
   6.2.2 Performance of a Neural Network

6.3 MLP Networks Based Features Selection
   6.3.1 Pre-Processing of Input Data
   6.3.2 Methodology
   6.3.3 Results and Discussion
   6.3.4 Conclusions
7. Hybrid Approach for Classification of Seafloor Sediments

7.1 Introduction

7.2 Unsupervised and Supervised Learning Methods
7.2.1 Self Organizing Map
7.2.2 Learning Vector Quantization

7.3 Proposed Hybrid Approach
7.3.1 Estimation of Number of Cluster Centers
7.3.2 Simulation Study
7.3.3 FCM Based Selection of Echo Features

7.4 Comparison of Results
7.4.1 Comparison with Ground-Truth
7.4.2 Comparison with SOM-LVQ1 Hybrid Approach
7.4.2.1 Methodology
7.4.2.2 Results and Discussion
7.4.3 Comparisons with Other Methods

7.5 Conclusions

8. Concluding Remarks

8.1 Conclusions
8.2 Practical Utility
8.3 Future Work

Publications

Bibliography