

Fuzzy Data Analysis Methodology for the Assessment of Value of Information in the Oil and Gas Industry

Martin Vilela, Gbenga Oluyemi and Andrei Petrovski
Robert Gordon University
Sir Ian Wood Building, Garthdee Road, Aberdeen, AB10 7QB
Scotland, UK
{m.j.vilela-ibarra, g.f.oluyemi, a.petrovski}@rgu.ac.uk

Abstract— To manage uncertainty in reservoir development projects, the Value of Information is one of the main factors on which the decision is based to determine whether it is necessary to acquire additional data. However, subsurface data is not always precise and is characterized by a certain level of fuzziness. In this paper, a model is formulated to assess the Value of Information in the oil and gas industry in cases where the data proposed to be acquired is imprecise. The methodology is based on the use of fuzzy data modelling and analysis aimed at providing decision support for oil field developers. An oilfield from North Africa is used as a case study to show how the methodology works. This work shows how the analysis can be utilized to reach financial decisions on the necessity of additional data acquisition.

Keywords— Fuzzy modelling, Value of Information, Uncertainty and Risk, Decision analysis and support, Oil and Gas Industry application.

I. INTRODUCTION

Decision making is a central process in any business; in particular, the Oil and Gas Industry makes decisions routinely which could impact the business on short, medium or long terms. A key element for making consistent and robust decisions is to use a prescriptive method to assess each alternative option [1] and [2]; the need for using such methods is even greater when the variables concerning the decision carry uncertainties.

Over the past years, numerical techniques for model-based optimisation, parameter estimation and decision making related to subsurface hydrocarbon reservoirs have developed rapidly. It has also become possible to acquire detailed reservoir information through utilisation of well-based sensors and the usage of advanced measurement methods. Many of the newly introduced technologies, however, come at a significant cost, and the assessment of associated Value of Information (VoI) becomes increasingly important, especially at the field development and planning phases [3].

The development of offshore and onshore fields is considered a high-risk operation, involving considerable investment in complex uncertain scenarios. During the development phase, various sources of uncertainties may coexist: (1) geological uncertainties, associated with recoverable reserves and flow characteristics; (2) operational uncertainties,

related to production system availability; and (3) economic uncertainties, such as oil price, capital expenditures and operational expenditures [4].

Three main approaches to managing uncertainty have been identified [4]: (1) acquiring information to reduce geological uncertainty; (2) adding flexibility to the production system, allowing for contingencies to be put in place at a cost; and (3) defining a robust strategy able to cope with the range of possible scenarios.

This study focuses on the first and third approaches, and the type of decisions explored in this paper are those associated with data acquisition, specifically, data acquisition in the context of subsurface evaluations. In the subsurface domain, variables defining the reservoir and its production are only partially known and uncertainty is present in all evaluations. Imprecise values of these variables produce uncertainty in the reservoir production forecast, which makes it difficult to assess the financial benefits of developing the field or even decide whether to perform tasks to optimize hydrocarbon production. The uncertainty in the project outcome poses the risk of financial losses, which need to be avoided.

In most cases, data can be acquired to better understand the uncertainties and hopefully to reduce them; however, the value of acquiring data is not measured by uncertainty reduction *per se*, but by the reduction of risk and by an increased project value.

The works of [5], [6] and [7] made pioneering contributions in the field of decision-making for data acquisition; subsequently, more research and applications, such as [8] and [9], amongst others, expanded the scope of the subject and provided more robustness to the methodology. The VoI method is rooted in the broader field of Decision Analysis [1].

Due to the importance of reservoir characterization, various methods for acquiring reliable reservoir properties have been proposed, including computation intelligence and machine learning methods – artificial neural networks (ANN) in particular, which have shown great characterization potential by inferring reservoir properties from well log data [10]. Some machine learning methods take into consideration the Value of Information, to assist in dealing with uncertainties [4].

Fuzzy Data Analysis

Reinhard Viertl

A red circular graphic with a gradient, appearing as a semi-circle or a partial circle, located to the right of the author's name.

Fuzzy Data Analysis:

Fuzzy Data Analysis Hans Bandemer, Wolfgang Näther, 2012-12-06 Fuzzy data such as marks scores verbal evaluations imprecise observations experts opinions and grey tone pictures are quite common In Fuzzy Data Analysis the authors collect their recent results providing the reader with ideas approaches and methods for processing such data when looking for sub structures in knowledge bases for an evaluation of functional relationship e g in order to specify diagnostic or control systems The modelling presented uses ideas from fuzzy set theory and the suggested methods solve problems usually tackled by data analysis if the data are real numbers Fuzzy Data Analysis is self contained and is addressed to mathematicians oriented towards applications and to practitioners in any field of application who have some background in mathematics and statistics

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Statistical Methods for Fuzzy Data Reinhard Viertl, 2011-01-25 Statistical data are not always precise numbers or vectors or categories Real data are frequently what is called fuzzy Examples where this fuzziness is obvious are quality of life data environmental biological medical sociological and economics data Also the results of measurements can be best described by using fuzzy numbers and fuzzy vectors respectively Statistical analysis methods have to be adapted for the analysis of fuzzy data In this book the foundations of the description of fuzzy data are explained including methods on how to obtain the characterizing function of fuzzy measurement results Furthermore statistical methods are then generalized to the analysis of fuzzy data and fuzzy a priori information Key Features Provides basic methods for the mathematical description of fuzzy data as well as statistical methods that can be used to analyze fuzzy data Describes methods of increasing importance with applications in areas such as environmental statistics and social science Complements the theory with exercises and solutions and is illustrated throughout with diagrams and examples Explores areas such quantitative description of data uncertainty and mathematical description of fuzzy data This work is aimed at statisticians working with fuzzy logic engineering statisticians finance researchers and environmental statisticians It is written for readers who are familiar with elementary stochastic models and basic statistical methods

Statistical Modeling, Analysis and Management of Fuzzy Data Carlo Bertoluzza, Maria A. Gil, Dan A. Ralescu, 2012-11-02 Statistical Modeling Analysis and Management of Fuzzy Data or SMFD for short is an important contribution to a better understanding

of a basic issue an issue which has been controversial and still is though to a lesser degree In substance the issue is are fuzziness and randomness distinct or coextensive facets of uncertainty Are the theories of fuzziness and randomness competitive or complementary In SMFD these and related issues are addressed with rigor authority and insight by prominent contributors drawn in the main from probability theory fuzzy set theory and data analysis communities First a historical perspective The almost simultaneous births close to half a century ago of statistically based information theory and cybernetics were two major events which marked the beginning of the steep ascent of probability theory and statistics in visibility influence and importance I was a student when information theory and cybernetics were born and what is etched in my memory are the fascinating lectures by Shannon and Wiener in which they sketched their visions of the coming era of machine intelligence and automation of reasoning and decision processes What I heard in those lectures inspired one of my first papers 1950 An Extension of Wiener's Theory of Prediction and led to my life long interest in probability theory and its applications to information processing decision analysis and control

Fuzzy data analysis, 1993 Fundamentals of Statistics with Fuzzy Data Hung T. Nguyen, Berlin Wu, 2006-03-20 This book presents basic aspects for a theory of statistics with fuzzy data together with a set of practical applications Theories of fuzzy logic and of random closed sets are used as basic ingredients in building statistical concepts and procedures in the context of imprecise data including coarse data analysis The book aims at motivating statisticians to examine fuzzy statistics to enlarge the domain of applicability of statistics in general

A Statistical Approach to Fuzzy Data Analysis Larry Wayne Lewis, 1981 *Fuzzy Cluster Analysis* Frank Höppner, Frank Klawonn, Rudolf Kruse, Thomas Runkler, 1999-07-09 Provides a timely and important introduction to fuzzy cluster analysis its methods and areas of application systematically describing different fuzzy clustering techniques so the user may choose methods appropriate for his problem It provides a very thorough overview of the subject and covers classification image recognition data analysis and rule generation The application examples are highly relevant and illustrative and the use of the techniques are justified and well thought out Features include Sections on inducing fuzzy if then rules by fuzzy clustering and non alternating optimization fuzzy clustering algorithms Discussion of solid fuzzy clustering techniques like the fuzzy c means the Gustafson Kessel and the Gath and Geva algorithm for classification problems Focus on linear and shell clustering techniques used for detecting contours in image analysis Accompanying software and data sets pertaining to the examples presented enabling the reader to learn through experimentation Examination of the difficulties involved in evaluating the results of fuzzy cluster analysis and of determining the number of clusters with analysis of global and local validity measures This is one of the most comprehensive books on fuzzy clustering and will be welcomed by computer scientists engineers and mathematicians in industry and research who are concerned with different methods data analysis pattern recognition or image processing It will also give graduate students in computer science mathematics or statistics a valuable overview

Computational Intelligence - Volume I Hisao

Ishibuchi,2015-12-30 Computational intelligence is a component of Encyclopedia of Technology Information and Systems Management Resources in the global Encyclopedia of Life Support Systems EOLSS which is an integrated compendium of twenty one Encyclopedias Computational intelligence is a rapidly growing research field including a wide variety of problem solving techniques inspired by nature Traditionally computational intelligence consists of three major research areas Neural Networks Fuzzy Systems and Evolutionary Computation Neural networks are mathematical models inspired by brains Neural networks have massively parallel network structures with many neurons and weighted connections Whereas each neuron has a simple input output relation a neural network with many neurons can realize a highly non linear complicated mapping Connection weights between neurons can be adjusted in an automated manner by a learning algorithm to realize a non linear mapping required in a particular application task Fuzzy systems are mathematical models proposed to handle inherent fuzziness in natural language For example it is very difficult to mathematically define the meaning of cold in everyday conversations such as It is cold today and Can I have cold water The meaning of cold may be different in a different situation Even in the same situation a different person may have a different meaning Fuzzy systems offer a mathematical mechanism to handle inherent fuzziness in natural language As a result fuzzy systems have been successfully applied to real world problems by extracting linguistic knowledge from human experts in the form of fuzzy IF THEN rules Evolutionary computation includes various population based search algorithms inspired by evolution in nature Those algorithms usually have the following three mechanisms fitness evaluation to measure the quality of each solution selection to choose good solutions from the current population and variation operators to generate offspring from parents Evolutionary computation has high applicability to a wide range of optimization problems with different characteristics since it does not need any explicit mathematical formulations of objective functions For example simulation based fitness evaluation is often used in evolutionary design Subjective fitness evaluation by a human user is also often used in evolutionary art and music These volumes are aimed at the following five major target audiences University and College students Educators Professional practitioners Research personnel and Policy analysts managers and decision makers

Fuzzy Transforms for Image Processing and Data Analysis Ferdinando Di Martino,Salvatore Sessa,2020-04-22 This book analyzes techniques that use the direct and inverse fuzzy transform for image processing and data analysis The book is divided into two parts the first of which describes methods and techniques that use the bi dimensional fuzzy transform method in image analysis In turn the second describes approaches that use the multidimensional fuzzy transform method in data analysis An F transform in one variable is defined as an operator which transforms a continuous function f on the real interval a, b in an n dimensional vector by using n assigned fuzzy sets A_1, \dots, A_n which constitute a fuzzy partition of a, b Then an inverse F transform is defined in order to convert the n dimensional vector output in a continuous function that equals f up to an arbitrary quantity We may limit this concept to the finite case by defining the discrete F transform of a function f in one variable even if it is not known a priori A

simple extension of this concept to functions in two variables allows it to be used for the coding decoding and processing of images Moreover an extended version with multidimensional functions can be used to address a host of topics in data analysis including the analysis of large and very large datasets Over the past decade many researchers have proposed applications of fuzzy transform techniques for various image processing topics such as image coding decoding image reduction image segmentation image watermarking and image fusion and for such data analysis problems as regression analysis classification association rule extraction time series analysis forecasting and spatial data analysis The robustness ease of use and low computational complexity of fuzzy transforms make them a powerful fuzzy approximation tool suitable for many computer science applications This book presents methods and techniques based on the use of fuzzy transforms in various applications of image processing and data analysis including image segmentation image tamper detection forecasting and classification highlighting the benefits they offer compared with traditional methods Emphasis is placed on applications of fuzzy transforms to innovative problems such as massive data mining and image and video security in social networks based on the application of advanced fragile watermarking systems This book is aimed at researchers students computer scientists and IT developers to acquire the knowledge and skills necessary to apply and implement fuzzy transforms based techniques in image and data analysis applications

Data Engineering Olaf Wolkenhauer, 2004-04-07 Although data engineering is a multi disciplinary field with applications in control decision theory and the emerging hot area of bioinformatics there are no books on the market that make the subject accessible to non experts This book fills the gap in the field offering a clear user friendly introduction to the main theoretical and practical tools for analyzing complex systems An ftp site features the corresponding MATLAB and Mathematical tools and simulations Market Researchers in data management electrical engineering computer science and life sciences

Knowledge-Based Intelligent Information and Engineering Systems Bogdan Gabrys, Robert J. Howlett, 2006-09-27 The three volume set LNAI 4251 LNAI 4252 and LNAI 4253 constitutes the refereed proceedings of the 10th International Conference on Knowledge Based Intelligent Information and Engineering Systems KES 2006 held in Bournemouth UK in October 2006 The 480 revised papers presented were carefully reviewed and selected from about 1400 submissions The papers present a wealth of original research results from the field of intelligent information processing

A Guidebook for Integrated Ecological Assessments Mark E. Jensen, Patrick S. Bourgeron, 2012-09-07 Ecosystem management requires a planning and decision making process that places land use in its appropriate ecological context Because ecological assessments must be conducted at various spatial scales and across jurisdictional boundaries approaches to assessment must be compatible and consistent with each other A Guidebook for Integrated Ecological Assessment analyzes methods and provides standards and protocols for assessment and the integration of data

Case-Based Approximate Reasoning Eyke Hüllermeier, 2007-03-20 Making use of different frameworks of approximate reasoning and reasoning under uncertainty notably probabilistic and fuzzy set based techniques this book

develops formal models of the above inference principle which is fundamental to CBR The case based approximate reasoning methods thus obtained especially emphasize the heuristic nature of case based inference and aspects of uncertainty in CBR

Computational Intelligence Rudolf Kruse, Sanaz Mostaghim, Christian Borgelt, Christian Braune, Matthias Steinbrecher, 2022-03-26 This textbook provides a clear and logical introduction to the field covering the fundamental concepts algorithms and practical implementations behind efforts to develop systems that exhibit intelligent behavior in complex environments This enhanced third edition has been fully revised and expanded with new content on deep learning scalarization methods large scale optimization algorithms and collective decision making algorithms Features provides supplementary material at an associated website contains numerous classroom tested examples and definitions throughout the text presents useful insights into all that is necessary for the successful application of computational intelligence methods explains the theoretical background underpinning proposed solutions to common problems discusses in great detail the classical areas of artificial neural networks fuzzy systems and evolutionary algorithms reviews the latest developments in the field covering such topics as ant colony optimization and probabilistic graphical models *On Fuzziness* Rudolf

Seising, Enric Trillas, Claudio Moraga, Settimo Termini, 2013-01-12 The notion of Fuzziness stands as one of the really new concepts that have recently enriched the world of Science Science grows not only through technical and formal advances on one side and useful applications on the other side but also as consequence of the introduction and assimilation of new concepts in its corpus These in turn produce new developments and applications And this is what Fuzziness one of the few new concepts arisen in the XX Century has been doing so far This book aims at paying homage to Professor Lotfi A Zadeh the father of fuzzy logic and also at giving credit to his exceptional work and personality In a way this is reflected in the variety of contributions collected in the book In some of them the authors chose to speak of personal meetings with Lotfi in others they discussed how certain papers of Zadeh were able to open for them a new research horizon Some contributions documented results obtained from the author s after taking inspiration from a particular idea of Zadeh thus implicitly acknowledging him Finally there are contributions of several third generation fuzzysists or softies who were firstly led into the world of Fuzziness by a disciple of Lotfi Zadeh who following his example took care of opening for them a new road in science Rudolf Seising is Adjoint Researcher at the European Centre for Soft Computing in Mieres Asturias Spain Enric Trillas and Claudio Moraga are Emeritus Researchers at the European Centre for Soft Computing Mieres Asturias Spain Settimo Termini is Professor of Theoretical Computer Science at the University of Palermo Italy and Affiliated Researcher at the European Centre for Soft Computing Mieres Asturias Spain **Fuzzy Sets in Decision Analysis, Operations**

Research and Statistics Roman Slowiński, 2012-12-06 Fuzzy Sets in Decision Analysis Operations Research and Statistics includes chapters on fuzzy preference modeling multiple criteria analysis ranking and sorting methods group decision making and fuzzy game theory It also presents optimization techniques such as fuzzy linear and non linear programming

applications to graph problems and fuzzy combinatorial methods such as fuzzy dynamic programming In addition the book also accounts for advances in fuzzy data analysis fuzzy statistics and applications to reliability analysis These topics are covered within four parts Decision Making Mathematical Programming Statistics and Data Analysis and Reliability Maintenance and Replacement The scope and content of the book has resulted from multiple interactions between the editor of the volume the series editors the series advisory board and experts in each chapter area Each chapter was written by a well known researcher on the topic and reviewed by other experts in the area These expert reviewers sometimes became co authors because of the extent of their contribution to the chapter As a result twenty five authors from twelve countries and four continents were involved in the creation of the 13 chapters which enhances the international character of the project and gives an idea of how carefully the Handbook has been developed

Some Applications of Fuzzy Set Theory in Data

Analysis Hans Bandemer,1988

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Table of Contents Fuzzy Data Analysis

1. Understanding the eBook Fuzzy Data Analysis
 - The Rise of Digital Reading Fuzzy Data Analysis
 - Advantages of eBooks Over Traditional Books
2. Identifying Fuzzy Data Analysis
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Fuzzy Data Analysis
 - User-Friendly Interface
4. Exploring eBook Recommendations from Fuzzy Data Analysis
 - Personalized Recommendations
 - Fuzzy Data Analysis User Reviews and Ratings
 - Fuzzy Data Analysis and Bestseller Lists
5. Accessing Fuzzy Data Analysis Free and Paid eBooks
 - Fuzzy Data Analysis Public Domain eBooks
 - Fuzzy Data Analysis eBook Subscription Services

- Fuzzy Data Analysis Budget-Friendly Options
- 6. Navigating Fuzzy Data Analysis eBook Formats
 - ePub, PDF, MOBI, and More
 - Fuzzy Data Analysis Compatibility with Devices
 - Fuzzy Data Analysis Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Fuzzy Data Analysis
 - Highlighting and Note-Taking Fuzzy Data Analysis
 - Interactive Elements Fuzzy Data Analysis
- 8. Staying Engaged with Fuzzy Data Analysis
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Fuzzy Data Analysis
- 9. Balancing eBooks and Physical Books Fuzzy Data Analysis
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Fuzzy Data Analysis
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Fuzzy Data Analysis
 - Setting Reading Goals Fuzzy Data Analysis
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Fuzzy Data Analysis
 - Fact-Checking eBook Content of Fuzzy Data Analysis
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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