

# Computational Intelligence And Feature Selection

Assessing Feature Selection Methods and Their Performance in High Dimensional Classification Problems Computational Intelligence and Feature Selection Computational Methods of Feature Selection Spectral Feature Selection for Data Mining (Open Access) Subspace, Latent Structure and Feature Selection Understanding and Using Rough Set Based Feature Selection: Concepts, Techniques and Applications Feature Selection for High-Dimensional Data An Improved Feature Selection Method for Data Analytics Feature Selection for Knowledge Discovery and Data Mining Feature Selection and Extraction Recent Advances in Ensembles for Feature Selection Feature Selection Techniques for Classification and Clustering On Feature Selection Improving Feature Selection Techniques for Machine Learning Hybrid Methods in Feature Selection Information Gain Feature Selection Based on Feature Interactions Feature Engineering for Machine Learning and Data Analytics Feature Selection with a General Hybrid Algorithm Understanding and Using Rough Set Based Feature Selection: Concepts, Techniques and Applications Investigation of Extending Feature Selection Algorithms to Explicit Feature Selection in Kernel Space Surani Lakshima Mathara Arachchige Dona Richard Jensen Huan Liu Zheng Alan Zhao Craig Saunders Muhammad Summair Raza Verónica Bolón-Canedo Zhipeng Wang (le author) Huan Liu Swair Rajesh Shah Verónica Bolón-Canedo Ananya Gupta Andrew Y. Ng Feng Tan Senthamarai Kannan Subramanian Bangsheng Sui Guozhu Dong Jerffeson Teixeira de Souza Muhammad Summair Raza Qiaozhi Li

Assessing Feature Selection Methods and Their Performance in High Dimensional Classification Problems Computational Intelligence and Feature Selection Computational Methods of Feature Selection Spectral Feature Selection for Data Mining (Open Access) Subspace, Latent Structure and Feature Selection Understanding and Using Rough Set

Based Feature Selection: Concepts, Techniques and Applications Feature Selection for High-Dimensional Data An Improved Feature Selection Method for Data Analytics Feature Selection for Knowledge Discovery and Data Mining Feature Selection and Extraction Recent Advances in Ensembles for Feature Selection Feature Selection Techniques for Classification and Clustering On Feature Selection Improving Feature Selection Techniques for Machine Learning Hybrid Methods in Feature Selection Information Gain Feature Selection Based on Feature Interactions Feature Engineering for Machine Learning and Data Analytics Feature Selection with a General Hybrid Algorithm Understanding and Using Rough Set Based Feature Selection: Concepts, Techniques and Applications Investigation of Extending Feature Selection Algorithms to Explicit Feature Selection in Kernel Space *Surani Lakshima Mathara Arachchige Dona Richard Jensen Huan Liu Zheng Alan Zhao Craig Saunders Muhammad Summair Raza Verónica Bolón-Canedo Zhipeng Wang (le author) Huan Liu Swair Rajesh Shah Verónica Bolón-Canedo Ananya Gupta Andrew Y. Ng Feng Tan Senthamarai Kannan Subramanian Bangsheng Sui Guozhu Dong Jerffeson Teixeira de Souza Muhammad Summair Raza Qiaozhi Li*

high dimensional classification problems have gained increasing attention in machine learning and feature selection has become an essential step in executing machine learning algorithms identifying the smallest feature subset with the most informative features is the most crucial objective in feature selection first we propose an extended version of wrapper feature selection methods which selects a further smaller feature subset yet with similar performance secondly we examine four existing feature ordering techniques to find the most informative ordering mechanism using the results we suggest a better method by combining a sequential feature selection technique with the sum of absolute values of principal component loadings to get the most informative subset of features we further merge two different proposed approaches and compare the performance with the existing recursive feature elimination rfe by simulating data for several practical scenarios with a different number of informative features sample sizes and different imbalance rates we also use the synthetic minority oversampling

technique smote to analyze the behavior of the proposed approach our simulated results and application results show that the proposed methods outperform the original rfe by giving a reasonable increment or an insignificant reduction of f1 score on various data sets

the rough and fuzzy set approaches presented here open up many new frontiers for continued research and development computational intelligence and feature selection provides readers with the background and fundamental ideas behind feature selection fs with an emphasis on techniques based on rough and fuzzy sets for readers who are less familiar with the subject the book begins with an introduction to fuzzy set theory and fuzzy rough set theory building on this foundation the book provides a critical review of fs methods with particular emphasis on their current limitations program files implementing major algorithms together with the necessary instructions and datasets available on a related site coverage of the background and fundamental ideas behind fs a systematic presentation of the leading methods reviewed in a consistent algorithmic framework real world applications with worked examples that illustrate the power and efficacy of the fs approaches covered an investigation of the associated areas of fs including rule induction and clustering methods using hybridizations of fuzzy and rough set theories computational intelligence and feature selection is an ideal resource for advanced undergraduates postgraduates researchers and professional engineers however its straightforward presentation of the underlying concepts makes the book meaningful to specialists and nonspecialists alike

due to increasing demands for dimensionality reduction research on feature selection has deeply and widely expanded into many fields including computational statistics pattern recognition machine learning data mining and knowledge discovery highlighting current research issues computational methods of feature selection introduces the

spectral feature selection for data mining introduces a novel feature selection technique that establishes a general platform for studying existing feature selection algorithms

and developing new algorithms for emerging problems in real world applications this technique represents a unified framework for supervised unsupervised and semisupervise

this book constitutes the thoroughly refereed post proceedings of the pascal pattern analysis statistical modelling and computational learning statistical and optimization perspectives workshop on subspace latent structure and feature selection techniques slsfs 2005 the 9 revised full papers presented together with 5 invited papers reflect the key approaches that have been developed for subspace identification and feature selection using dimension reduction techniques subspace methods random projection methods among others

this book provides a comprehensive introduction to rough set based feature selection rough set theory first proposed by zdzislaw pawlak in 1982 continues to evolve concerned with the classification and analysis of imprecise or uncertain information and knowledge it has become a prominent tool for data analysis and enables the reader to systematically study all topics in rough set theory rst including preliminaries advanced concepts and feature selection using rst the book is supplemented with an rst based api library that can be used to implement several rst concepts and rst based feature selection algorithms the book provides an essential reference guide for students researchers and developers working in the areas of feature selection knowledge discovery and reasoning with uncertainty especially those who are working in rst and granular computing the primary audience of this book is the research community using rough set theory rst to perform feature selection fs on large scale datasets in various domains however any community interested in feature selection such as medical banking and finance can also benefit from the book this second edition also covers the dominance based rough set approach and fuzzy rough sets the dominance based rough set approach drsa is an extension of the conventional rough set approach and supports the preference order using the dominance principle in turn fuzzy rough sets are fuzzy generalizations of rough sets an api library for the drsa is

also provided with the second edition of the book

this book offers a coherent and comprehensive approach to feature subset selection in the scope of classification problems explaining the foundations real application problems and the challenges of feature selection for high dimensional data the authors first focus on the analysis and synthesis of feature selection algorithms presenting a comprehensive review of basic concepts and experimental results of the most well known algorithms they then address different real scenarios with high dimensional data showing the use of feature selection algorithms in different contexts with different requirements and information microarray data intrusion detection tear film lipid layer classification and cost based features the book then delves into the scenario of big dimension paying attention to important problems under high dimensional spaces such as scalability distributed processing and real time processing scenarios that open up new and interesting challenges for researchers the book is useful for practitioners researchers and graduate students in the areas of machine learning and data mining

feature selection is the process of choosing a significant subset of features from the given feature set for pattern recognition it can be treated as a pre step before constructing the machine learning model which could improve the prediction result by selecting the most significant features it would be easier to reduce the time of training reduce the complexity of the machine learning model avoid data overfitting and help the researcher to understand the source data most data types of features are either number or string and most of their distributions are either continuous or categorized however there exists a type of feature called a binary feature whereas the value is either 1 or 0 unfortunately there is less research work addressing the situation where the large portion of features are binary features inspired by some existing feature selection methods a new framework called fmc selector was represented which addresses specifically to select significant binary features from highly imbalanced datasets by combining the fisher linear discriminant analysis technique and the cross entropy concept together in our framework the fmc selector can be used to select the

most significant features from the given binary feature set we assess the performance and prediction results of fmc selector by comparing it with the other two most popular feature selection methods univariate importance ui and recursive feature elimination rfm the proposed framework showed better results than the benchmarks the new formula called mapping based cross entropy evaluation mce was derived from cross entropy which integrated mapping function to address the specific concerns for binary feature the introduced evaluation method called positive case prediction score pps could explore some additional information from imbalanced dataset where other existing methods were inadequate or not applicable

as computer power grows and data collection technologies advance a plethora of data is generated in almost every field where computers are used the computer generated data should be analyzed by computers without the aid of computing technologies it is certain that huge amounts of data collected will not ever be examined let alone be used to our advantages even with today's advanced computer technologies e.g. machine learning and data mining systems discovering knowledge from data can still be fiendishly hard due to the characteristics of the computer generated data taking its simplest form raw data are represented in feature values the size of a dataset can be measured in two dimensions number of features  $n$  and number of instances  $p$  both  $n$  and  $p$  can be enormously large this enormity may cause serious problems to many data mining systems feature selection is one of the long existing methods that deal with these problems its objective is to select a minimal subset of features according to some reasonable criteria so that the original task can be achieved equally well if not better by choosing a minimal subset of features irrelevant and redundant features are removed according to the criterion when  $n$  is reduced the data space shrinks and in a sense the data set is now a better representative of the whole data population if necessary the reduction of  $n$  can also give rise to the reduction of  $p$  by eliminating duplicates

feature selection is a very important process in statistics and machine learning it removes redundant and irrelevant features and selects the most useful set of features

from a given dataset this tends to improve generalization of machine learning algorithms and reduces training time feature selection is used to make the models more interpretable recently it has been also used to reduce bias of such models and ensure fairness of the outcome feature extraction is another dimensionality reduction process which finds a small set of features to approximate a given dataset unlike feature selection in extraction the resulting features can be arbitrary functions of the features in the original dataset there are fast algorithms to compute feature extraction but it doesn't provide the interpretability aspect of feature selection and it tends to be less effective than feature selection in making models generalize better one of the problems addressed in this dissertation is a hybrid problem which combines feature selection and extraction this hybrid problem is at least as hard as feature selection which is known to be np hard we show how simplistic sequential application of optimal selection and extraction does not provide an optimal solution for this problem we develop an algorithm to solve the hybrid problem optimally using methods inspired by the classic a search algorithm one of the most widely used feature extraction methods is the principal component analysis pca it is known to be very sensitive to the outliers in the data there have been various attempts in the literature to address this issue none promising an optimal solution to the problem we model this problem as a graph search problem and again apply our heuristic search framework to design an algorithm which solves this problem optimally we show that we compare favorably to the state of the art convex relaxation approach pca is closely tied to a very popular linear algebra problem called the eigenvalue problem the third part of the dissertation uses the eigenvalue problem and a variant of it known as the generalized eigenvalue problem to achieve the privacy of the user data today there are many companies which provide predictive models as services in order to use these services one needs to send one's data to such a service for prediction or inference it is possible that this data can be used to infer some confidential information about the data sender we design algorithms to apply transformations to this data so that the inference of the confidential information is prevented while the data can still be used to infer the desired information

this book offers a comprehensive overview of ensemble learning in the field of feature selection fs which consists of combining the output of multiple methods to obtain better results than any single method it reviews various techniques for combining partial results measuring diversity and evaluating ensemble performance with the advent of big data feature selection fs has become more necessary than ever to achieve dimensionality reduction with so many methods available it is difficult to choose the most appropriate one for a given setting thus making the ensemble paradigm an interesting alternative the authors first focus on the foundations of ensemble learning and classical approaches before diving into the specific aspects of ensembles for fs such as combining partial results measuring diversity and evaluating ensemble performance lastly the book shows examples of successful applications of ensembles for fs and introduces the new challenges that researchers now face as such the book offers a valuable guide for all practitioners researchers and graduate students in the areas of machine learning and data mining

there are several feature selection techniques that can be used for classification and clustering including wrapper methods these methods use a specific learning algorithm to evaluate the importance of each feature examples include forward selection and backward elimination filter methods these methods use a statistical test to evaluate the importance of each feature examples include chi squared test and mutual information embedded methods these methods use a learning algorithm that has built in feature selection capabilities examples include lasso and ridge regression in linear models hybrid methods these methods combine the strengths of wrapper and filter methods correlation based feature selection cfs this method uses correlation between features and the target variable to select the relevant features recursive feature elimination rfe this method recursively removing attributes and building a model on those attributes that remain it uses the model accuracy to identify which attributes and combination of attributes contribute the most to predicting the target attribute overall the choice of feature selection technique will depend on the specific problem and dataset at hand the

data mining tasks are often confronted with many challenges biggest being the large dimension of the datasets for successful data mining the most important criterion is the dimensionality reduction of the dataset the problem of dimensionality has imposed a very big challenge towards the efficiency of the data mining algorithms the data mining algorithms cannot handle these high dimensional data as they render the mining tasks intractable thus it becomes necessary to reduce the dimensionality of the data there are two methods of dimensionality reduction they are the feature selection and feature extraction methods bishop 1995 devijver and kittler 1982 fukunaga 1990 feature selection method reduce the dimensionality of the original feature space by selecting a subset of features without any transformation it preserves the physical interpretability of the selected features as in the original space feature extraction method reduce the dimensionality by linear transformation of the input features into a completely different space the linear transformation involved in feature extraction cause the features to be altered making their interpretation difficult features in the transformed space lose their physical interpretability and their original contribution becomes difficult to ascertain bishop 1995 the choice of the dimensionality reduction method is completely application specific and depends on the nature of the data feature selection is advantageous especially as features keep their original physical meaning because no transformation of data is made this may be important for a better problem understanding in some applications such as text mining and genetic analysis where only relevant information is analysed

as a commonly used technique in data preprocessing for machine learning feature selection identifies important features and removes irrelevant redundant or noise features to reduce the dimensionality of feature space it improves efficiency accuracy and comprehensibility of the models built by learning algorithms feature selection techniques have been widely employed in a variety of applications such as genomic analysis information retrieval and text categorization researchers have introduced many feature selection algorithms with different selection criteria however it has been

discovered that no single criterion is best for all applications we proposed a hybrid feature selection framework called based on genetic algorithms gas that employs a target learning algorithm to evaluate features a wrapper method we call it hybrid genetic feature selection hgfs framework the advantages of this approach include the ability to accommodate multiple feature selection criteria and find small subsets of features that perform well for the target algorithm the experiments on genomic data demonstrate that ours is a robust and effective approach that can find subsets of features with higher classification accuracy and or smaller size compared to each individual feature selection algorithm a common characteristic of text categorization tasks is multi label classification with a great number of features which makes wrapper methods time consuming and impractical we proposed a simple filter non wrapper approach called relation strength and frequency variance rsfv measure the basic idea is that informative features are those that are highly correlated with the class and distribute most differently among all classes the approach is compared with two well known feature selection methods in the experiments on two standard text corpora the experiments show that rsfv generate equal or better performance than the others in many cases

in recent years data have become increasingly larger in both number of instances and number of features in many applications this enormity may cause serious problems to many machine learning algorithms with respect to scalability and learning performance therefore feature selection is essential for the machine learning algorithms while handling high dimensional datasets many traditional search methods have shown promising results in a number of feature selection problems however as the number of features increases extremely most of these existing methods face the problem of intractable computational time since no single feature selection method could handle all requirements of feature selection in real world datasets hybrid methods presented here are the tested methods for effective feature selection one viable option is to apply a ranking feature selection method to obtain a manageable number of top ranked features

which could be further handled by traditional feature selection methods for further analysis

analyzing high dimensional data stands as a great challenge in machine learning in order to deal with the curse of dimensionality many effective and efficient feature selection algorithms have been developed recently however most feature selection algorithms assume independence of features they identify relevant features mainly on their individual high correlation with the target concept these algorithms can have good performance when the assumption of feature independence is true but they may perform poorly in domains where there exist feature interactions due to the existence of feature interactions a single feature with little correlation with the target concept can be in fact highly correlated when looked together with other features removal of these features can harm the performance of the classification model severely in this thesis we first present a general view of feature interaction we formally define feature interaction in terms of information theory we propose a practical algorithm to identify feature interactions and perform feature selection based on the identified feature interactions after that we compare the performance of our algorithm with some well known feature selection algorithms that assume feature independence by comparison we show that by taking feature interactions into account our feature selection algorithm can achieve better performance in datasets where interactions abound

feature engineering plays a vital role in big data analytics machine learning and data mining algorithms cannot work without data little can be achieved if there are few features to represent the underlying data objects and the quality of results of those algorithms largely depends on the quality of the available features feature engineering for machine learning and data analytics provides a comprehensive introduction to feature engineering including feature generation feature extraction feature transformation feature selection and feature analysis and evaluation the book presents key concepts methods examples and applications as well as chapters on feature engineering for major data types such as texts images sequences time series graphs

streaming data software engineering data twitter data and social media data it also contains generic feature generation approaches as well as methods for generating tried and tested hand crafted domain specific features the first chapter defines the concepts of features and feature engineering offers an overview of the book and provides pointers to topics not covered in this book the next six chapters are devoted to feature engineering including feature generation for specific data types the subsequent four chapters cover generic approaches for feature engineering namely feature selection feature transformation based feature engineering deep learning based feature engineering and pattern based feature generation and engineering the last three chapters discuss feature engineering for social bot detection software management and twitter based applications respectively this book can be used as a reference for data analysts big data scientists data preprocessing workers project managers project developers prediction modelers professors researchers graduate students and upper level undergraduate students it can also be used as the primary text for courses on feature engineering or as a supplement for courses on machine learning data mining and big data analytics

the book will provide 1 in depth explanation of rough set theory along with examples of the concepts 2 detailed discussion on idea of feature selection 3 details of various representative and state of the art feature selection techniques along with algorithmic explanations 4 critical review of state of the art rough set based feature selection methods covering strength and weaknesses of each 5 in depth investigation of various application areas using rough set based feature selection 6 complete library of rough set apis along with complexity analysis and detailed manual of using apis 7 program files of various representative feature selection algorithms along with explanation of each the book will be a complete and self sufficient source both for primary and secondary audience starting from basic concepts to state of the art implementation it will be a constant source of help both for practitioners and researchers book will provide in depth explanation of concepts supplemented with working examples to help

in practical implementation as far as practical implementation is concerned the researcher practitioner can fully concentrate on his her own work without any concern towards implementation of basic rst functionality providing complexity analysis along with full working programs will further simplify analysis and comparison of algorithms

feature selection methods play important roles in the area of machine learning being a part of preprocessing the technology of feature selection can select useful information from raw data a good feature selection method can significantly improve performance of a prediction model however most feature selection methods only work well with linear data although nonlinear data can be transformed into linear data by being projected into a high dimensional space the computation cost of calculating in high dimensional space is quite high kernel trick is a method in model training it reduces greatly the computational cost of calculating the inner product of high dimension data and thus is usually used to solve nonlinear problems however data in the high dimension space generated by kernel trick the so called kernel space are usually implicit therefore most feature selection methods cannot use kernel trick to process nonlinear data cao et al provided a new method that can explicitly select features in kernel space with limited additional cost by extending a famous margin based feature selection method relief inspired by their results we propose a method that transforms the original space to a so called explicit kernel space eks our method successfully extends and broadens the idea by cao et al with eks most traditional feature selection algorithms can use kernel trick to deal with real world data based on several tests with different types of data and algorithms the usefulness of eks is verified some of its properties are also presented and discussed

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