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Decision Making and Machine Learning Algorithms' Selection with Artificial Intelligent Rule-Based Expert System

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***Abstract*: Everybody is confronted daily with cluster of decisions that must be appropriately taken in the process of making accurate decision; individuals are faced with and most often fall prey to series of common biases, fallacies, and many other decision making odds. In determining which algorithm to apply for analysis (with machine learning algorithms/models) open to critical steps to be taken and also highly depend on many factors ranging from the type of problem at hand, the condition to choose a model and to the expected outcomes. The study looks at how artificial intelligent approach with expert system would be helpful in making timely decision on which type of algorithm(s) is/are capable to be applied and implemented to have desired results. The study also uses VisiRule software to model series of successful channels to arrive at a good decision making means. The use of VisiRule (Artificial Intelligent Based Expert System) was employed to give directional path ways to the selection of appropriate algorithms from supervised and unsupervised machine learning to different classification methods, regression methods, clustering approaches, dimensionality reduction methods, and association rules. The outcome of this study demonstrates the easy way through paths to select relevant and most appropriate model or algorithm that best fit the analysis at hand with detailed explanation of each alternative option. The use of VisiRule software has proven the easy way to achieve decision making problems without any codes requirement for such actions. Decision making challenges could be resolved by just implementing artificial intelligent rule-based expert system which require less time, coding free, and highly achievable accurate outcomes.**

***Keywords*: Decision Making, VisiRule, Artificial Intelligent, Rule-based System, Expert System**

I. INTRODUCTION

Decision making has been a carefully and procedural actions taken by every individual in the society. Researchers are increasingly investigating the conditions attached to application of models or algorithms and how to identify the most suitable existing algorithms/models for solving a problem. The decision making regarding selection of Algorithms/models is concerned with the kind of procedures or conditions available to apply an algorithm and selecting the best algorithm to solve a given problem [1]. Researchers of machine learning algorithms need methods that can help them to identify algorithm or their groupings (combinations) that achieve the potentially best performance. Selecting the best algorithm to solve a given problem has to do with having well conversant knowledge of conditions to select or use an algorithm/model and which one (Out of available algorithms) could give the required and optimal solution to the problem at hand and finally at what mode of operation to follow – Single or combined method [2].

A proliferation of algorithms/models exist, rooted in the fields of machine learning, statistics, pattern recognition, artificial intelligence, and database systems, which are used to perform different data analysis jobs on large volumes of data. The decision to take in order to recommend the most suitable algorithms has thus become rather challenging. Moreover, the problem is exacerbated by the fact that it is necessary to consider different combinations of parameter settings, or the constituents of composite methods such as ensembles [2].

It was observed that before a machine learning algorithm/model is trained, the researcher of a machine learning software tool or algorithm typically must manually select a machine learning algorithm and set one or more model parameters termed hyper-parameters. The algorithm and hyper - parameter values used can greatly impact the resulting model's performance, but their selection requires special expertise as well as many labor-intensive manual iterations. To make machine learning accessible to everyone interested to use them, with limited computing expertise, computer science researchers have proposed various automatic selection methods for algorithms and/or hyperparameter values for a given supervised machine learning problem [3].

The correct use of model evaluation, model selection, and algorithm selection techniques is vital in academic machine learning research as well as in many industrial settings [4]. Selecting the right algorithm is an important problem in computer science, because the algorithm often has to exploit the structure of the input to be efficient. So, solutions to the algorithm selection problem can inspire models of human strategy selection. Therefore, the algorithm selection problem as a special case of meta-reasoning and need to be tackled in a systematically approach manner [5]. Therefore, for explicit

presentation the paper is sectioned into: Introduction, machine learning divisions and explanations (Machine learning type, supervised learning, unsupervised learning, classification models, regression models, Dimension Reduction Techniques, association rules, clustering models - It covers Table-1 to Table-8 and figure-1), Application of Artificial Intelligent Rule-Based Expert System (VisiRule), Related literatures, Materials and methods, Analysis and results – It covers Figure-2 to Figure-8, Discussion and Conclusion

Table 1. Machine Learning Divisions And Explanations

Machine Learning Type	Meaning	Condition of use
Supervised learning	It can be used for those cases where we know the input as well as corresponding outputs.	Choose supervised learning when labeled data is available and the goal is to predict or classify future observations.
Unsupervised learning	It can be used for those cases where we have only data and no corresponding output data.	Choose unsupervised learning when label data is not available and the goal is to build strategies by identifying patterns or segments from the data.

Table 2. Supervised Learning Techniques

Supervised Learning	Meaning	Condition of use
Regression analysis	It is a supervised learning technique which helps in finding the correlation between variables and enables us to predict the continuous output variable based on the one or more predictor variables.	Choose regression analysis if you want to predict, forecast, model time series and determine the cause effect relationship between variables.
Classification algorithm	It is a supervised learning technique that is used to identify the category of new observations on the basis of training data.	Choose classification algorithm if the main goal is to identify the category of a given dataset and these algorithms are mainly used to predict the output for the categorical data.

Table 3. Unsupervised Learning Techniques

Unsupervised Learning	Meaning	Condition of use
Dimensionality reduction	It refers to techniques that reduce the number of input variables in a dataset. Dimensionality reduction works by projecting the data to a lower dimensional subspace which captures the "essence" of the data.	It is used when dealing with high dimensional data and it requires reduction for proper use
Clustering	It is an unsupervised machine learning method to identify and group similar data points in larger datasets without concern for the specific outcome.	Choose clustering when you want to classify data into structures that are more easily understood and manipulated.
Association Rules	Association rules are "if-then" statements that help to show the probability of relationships between data items, within large data sets in various types of databases.	Choose association rules when you want to find correlations and co-occurrences between data sets. They are ideally used to explain patterns in data from seemingly independent information repositories, such as relational databases and transactional databases.

Table 4. Classification Models Examples

Classification Models	Meaning and Condition of use
Multilayer Perceptron (Neural Network)	It is used to solve the classification problem for non-linear sets by employing hidden layers, whose neurons are not directly connected to the output. The additional hidden layers can be interpreted geometrically as additional hyper-planes, which enhance the separation capacity of the network.
Naïve Bayes	It is suitable for solving binary and multiclass prediction problems. Naïve Bayes is better suited for categorical input variables than numerical variables. It is more useful for making predictions and forecasting data based on historical results.
Decision tree	It is a supervised machine learning algorithm that can be used for both regression and classification problem statements. It divides the complete dataset into smaller subsets while at the same time an associated decision tree is incrementally developed. It is used when you want to make a decision about some kind of process such as "you want to choose between choice 1, choice 2 or choice 3"
K-Nearest Neighbor (KNN) algorithm	It is used for models that require high accuracy but do not require a human-readable model. KNN is an excellent baseline approach for recommending systems. KNN classifies the new data points based on the similarity measures like shape and colour and check a new object comes in with its similarity with the shape and colour.
Support Vector Machine (SVM)	It can be used for both classification and regression and for both linear and non-linear problems. It offers good accuracy and performs faster prediction with less memory usage. It uses a technique called the kernel trick to transform data and then based on these transformations to find an optimal boundary between the possible outputs. It is mostly used in cases where the number of dimensions is greater than the number of samples.
Random forest	It is used in a situation where we have a large dataset and interpretability is not a major concern. It combines multiple decision trees. It is used to solve regression and classification problems. It utilizes ensemble learning to combine many classifiers to provide solutions to complex problems. It works well with mixture of numerical and categorical features.
Stochastic Gradient	It is used for unconstrained optimization

Descent	problems. This algorithm is useful in cases where the optimal points cannot be found by equating the slope of the function to 0. It is an inexact but powerful technique. SGD is best used to find the model parameters that correspond to the best fit between predicted and actual outputs. SGD is an iterative method for optimizing an objective function with suitable smoothness properties.

Table 5. Regression Models Examples

Regression Models	Meaning and Condition of use
Linear regression	It is used when we want to predict the value of a variable based on the value of another variable. To another words, linear regression is used when we want to predict a continuous dependent variable from a number of independent variables.
Logistic regression	It is used when the dependent variable is categorical such as 1 or 0, true or false.
Ridge regression	It is used when multicollinearity is experienced in a dataset and when a dataset contains a higher number of predictor variables than the number of observations.
Lasso regression	It is used to obtain the subset of predictors that minimizes prediction error for a quantitative response variable. Lasso regression does this by imposing a constraint on the model parameters that causes regression co-efficients for some variables to shrink toward zero. It works well when there are a small number of significant parameters and the others close to zero i.e when only a few predictors actually influence the response.
Polynomial regression	It is generally used when the points in data are not captured by the linear regression model and linear regression fails to describe the best result clearly. It basically fit a wide range of curvature. It is used mainly when we have non-linear relationship between dependent and independent variables.
Bayesian linear regression	It is the using of probability distribution rather than point estimates. It is used to find not only the single "best" value of the model parameters, but to determine the posterior distribution for the model parameters. Bayesian linear regression allows a natural mechanism to survive insufficient data or poorly distributed data by formulating linear regression using probability distributors rather than point's estimates.
Elastic Net Regression	It is used when the variable form groups that contain highly correlated independent variables. It adds regularization penalties to the loss function during training. It combines features of elimination and coefficient reduction for lasso and ridge to improve your model's predictions.
Jackknife Regression	It is a method used to estimate the variance and bias of a large population. It is also used to evaluate the model performance using leave-one-out cross validation which means leaving one observation out of the calibration dataset, recalibrating the model and predicting the observation that was left out.
Stepwise regression	It is used when one has many variables and is interested in identifying a useful subset of the predictors. It is a way to build a model by adding or removing predictor variables usually via a series of F-tests or T-tests.

Table 6. Dimensionality Reduction Technique Examples

Dimension Reduction Techniques	Meaning and Condition of use
Principal Component Analysis	It is used mainly for variable which are strongly correlated, it is use to represent a multivariate datasets as smaller set of variables in order to observe trends, jumps, clusters and outliers. PCA does not work well with correlation co-efficient that are smaller than 0.3. So, it is used to reduce correlated observed variables to a smaller set of important independent composite variables.
Factor Analysis (FA)	It is used to describe variability among observed, correlated variables in terms of a potentially lower number of unobserved variables called factors. a. Exploratory Factor Analysis (EFA) is used when one needs to develop a hypothesis about relationship between variables. b. Confirmatory Factor Analysis (CFA) is used when one needs to test a hypothesis about the relationship between variables.

Table 7. Association Rule Examples

Association Rules	Meaning and Condition of use
Apriori Algorithm	It is used for mining frequent itemset and devising association rules from a transactional database. The parameters "Support" and "Confidence" are used. Support means frequency of occurrence while confidence is a conditional probability. It scans the original database multiples times to calculate the frequency of the item sets. In K-itemset it is better work for large datasets. It takes time and slow.
Eclat algorithm	It is used for small and medium datasets. It scans the currently generated dataset. This makes the algorithm fast and occupies less memory for processing.
Frequent Pattern Growth Algorithm (F-P Growth)	It is an improvement of apriori. It is used for finding frequent item set in a transaction database without candidate generation in the form of trees rather than the use of generation and testing strategy apriori.

Table 8. Clustering Models Examples

Clustering Models	Meaning and Condition of use
Hierarchical clustering also known as connectivity based clustering	It is used to build tree structures from data similarities in which it finds how the different sub-clusters relate to each other, and how far apart data points are in the form of a tree. It is very easy to understand and implement.
Partitioning clustering	It is also known as centroid-based on the characteristic and similarity of the data by specifying the number of partitions (K) of the data. Partitioning clustering decomposes a dataset into a set of disjoint cluster. Given a data set of N points, a partitioning method constraints K ($N \geq k$).
Distribution model based clustering	It is also known as expectation maximization clustering algorithm using Gaussian mixture model (GMM) is used in which the observed (multivariate) data is assumed to have been generated from a finite mixture of component models. Each component model is a probability distribution, typically a parametric multivariate distribution.
Density based clustering	It is also known as model based algorithm.

	Density based spatial clustering of application of noise- DBSCAN is used to find non-linear shapes structure based on the density.
Fuzzy C-means clustering	It is a set of clustering algorithm that is used when you are interested in clustering that provides one element of data or image belonging to two or more clusters. It works by allocating membership values to each image point correlated to each cluster center based on the distance between the cluster center and image point.

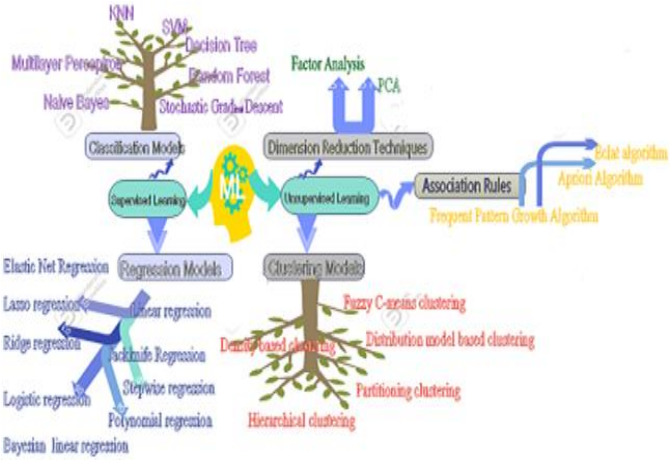

Figure 1: Relationship between machine learning algorithms

A. Application of Artificial Intelligent Rule-Based Expert System (VisiRule)

The use of artificial intelligent rule-based expert system is to make decision or selection without necessarily writing codes. Hence, artificial intelligent rule-based expert system software is always used as a decision supporting tool, in which the rules are basically and precisely presented using Logic Programming Model [6]. It is of great use to scholars in making a reasonable selection or decision in determining which algorithm to apply for analysis and critical conditions to be considered for the selections. Artificial intelligent rule-based expert system uses rules to mimic the behaviour of human experts; the rule can work either way: forward or backward (data-to-conclusion or conclusion-to-data). The use of the artificial intelligent rule-based expert system from literatures has proven its relevancies in various domains such as law, business, healthcare, insurance, education, transportation and many more. It helps to overcome many of the problems associated with text-based rules and decision tables [7]. Artificial intelligent rule-based expert system allows experts / researchers to concentrate on explaining and establishing the structure of the logic correctly using their chosen tools - those embedded materials that can assist researcher to accomplish his mission [8], [7]. According to [7] artificial intelligent rule-based expert system provides a drawing environment, which helps to draw decision charts, and it can be immediately executed and verified, or exported as graphical objects or as program text for embedding within larger computer processes and/or applications. The enhanced and additional features of the software include VisiRule Visualize, VisiRule Analytics and VisiRule AutoAudit [9]. Therefore, Artificial Intelligent rule-based expert serves as a guide for scholars/researchers to use in making good decision / selection regarding the type of models or algorithms fit their studies [6], [10]. VisiRule is application software that enables users to design and deliver rule-based expert systems using familiar graphical interfaces. Personal and business experts from different domains such as law, health sector, accountancy, education, engineering, will simply draw their knowledge using a dedicated point-and-click diagrams to specify the logic to assess user responses, and eventually define the various conclusions and outcomes. With the use of VisiRule software, experts no longer need to engage technical programmers to automate decision support systems – It is just a matter of understanding and organizing decision-making by experts themselves. So, VisiRule has online Artificial Intelligence System that offers rule-based workflow, decision tree analysis, process/workflow automation and many other features for users to implement in solving societal problems relating to making good and accurate decisions.

II. RELATED LITERATURES

The approach to selection of appropriate algorithms/models was viewed in two ways: the first aspect is looking at conditions to use an algorithm/model or combinations of algorithms/models and how possible for researcher to select the best algorithm/model to solve a kind of problem. Studies in the past contributed to this trend. The use of application software is a great opportunity to resolve the problem with artificial intelligent rule-based expert system via Visirule. This knowledge can help us to select the best algorithm for these instances. According to [1] algorithm selection techniques have achieved significant performance improvements. They unified and organized the vast literature according to criteria that determine algorithm selection systems in practice. The comprehensive classification of approaches identified and analyzed the different directions from which algorithm selection has been approached. Their paper contrasted and compared different methods for solving the problem as well as ways of using these solutions. Their study was closed by identifying directions of current and future research.

This survey presented by [2] looked into an overview of the contributions made in the area of algorithm selection problems. They presented different methods for solving the algorithm selection problem identifying some of the future research challenges in this domain. They further added that researchers have long ago recognized that it is difficult to identify a single best algorithm that will give the best performance across all problems. This is why later on many researchers have developed different approaches to addressing the algorithm selection problems. There are many approaches to addressing the algorithm selection problem; in connection to this, [11] claimed that machine learning is an established method of selecting algorithms to solve hard search problems.

The algorithm selection problem, as explained by [12] has attracted a great deal of attention, as it endeavours to select and apply the best algorithm(s) for a given task [13], [14]. The algorithm selection problem can be cast as a learning problem: the aim is to learn a model that captures the relationship between the properties of the datasets, or meta-data, and the algorithms, in particular their performance. This model can then be used to predict the most suitable algorithm for a given new dataset as viewed by [2].

[11] Conducted a study where they compared the performance of a large number of different machine learning techniques from different machine learning methodologies on five data sets of hard algorithm selection problems from the literature. They demonstrated that there is significant scope for improvement both compared with existing systems and in general. At the end, they gave clear recommendations as to which machine learning techniques were likely to achieve good performance in the context of algorithm selection problems. In particular, they showed that linear regression and alternating decision trees have a very high probability of achieving better performance than always selecting the single best algorithm. [3] researched on machine learning studies automatic algorithms that improve themselves through experience. Their paper reviewed methods, identified several of their limitations in the big biomedical data environment, and provided preliminary thoughts on how to address these limitations. The findings established a foundation for future research on automatically selecting algorithms and hyper-parameter values for analyzing big biomedical data.

[15] in their paper, they presented a machine learning-based approach to address models induced from algorithmic performance data can represent the knowledge of how algorithmic performance depends on some easy-to-compute problem instance characteristics. Using these models, they could estimate approximately whether an input instance was exactly solvable or not. Furthermore, when it was classified as exactly unsolvable, they could select the best approximate algorithm for it among a list of candidates. The results showed that the machine learning-based algorithm selection system could integrate both exact and inexact algorithms and provide the best overall performance comparing to any single candidate algorithm

[4] regarded machine learning as subfield of AI concerned with intelligent systems that learn. According to him, to understand machine learning, it is helpful to have a clear notion of intelligent systems. Therefore, their paper reviewed different techniques that could be used for each of the three subtasks and discussed the main advantages and disadvantages of each technique with references to theoretical and empirical studies. Common cross-validation techniques such as leave-one- out cross-validation and k-fold cross-validation were reviewed, the bias-variance trade-off for choosing k was discussed, and practical tips for the optimal choice of k were given based on empirical evidence

[5] applied theory to model how people choose between cognitive strategies and test its prediction in a behavioral experiment. They found out that people quickly learn to adaptively choose between cognitive strategies. People's choices in their experiment were consistent with the model used but inconsistent with previous theories of human strategy selection. Rational meta-reasoning appears to be a promising framework for reverse-engineering how people select between cognitive strategies and translating the results into better solutions to the algorithm selection problem. [16] carried out studies on the systematic literature review (SLR) that has been performed to get 20 studies (2012-2019) in the area of EDM. From these studies, 11 highly advanced machine learning models has been obtained and they have implemented them on 2 public student databases in order to predict their future outcomes. Feature extraction techniques were applied and then models have been trained based on the databases to get the required results. Results of different machine learning models were compared in order to find out the best model among them based on accuracy and F-measure. With these experiments, weak students can be easily identified and proper precautions can be taken in order to help them.

III. MATERIALS AND METHODS

The study employed the use of artificial intelligent rule-based expert system with Visirule software. Visirule software is designed for researchers as a decision supporting tool that the rules are basically and precisely presented without writing any simple code. The approach was based on the use of Logic Programming Model. The rule-based Expert system is of great use to researchers in making appropriate and relevant selection of machine learning algorithm suitable for statistical data analysis in researches [17]. It allows researchers to concentrate on explaining and establishing the structure of the logic correctly using their chosen tools - those embedded materials that can assist researcher to accomplish his mission [8], [7].

IV. ANALYSIS AND RESULTS

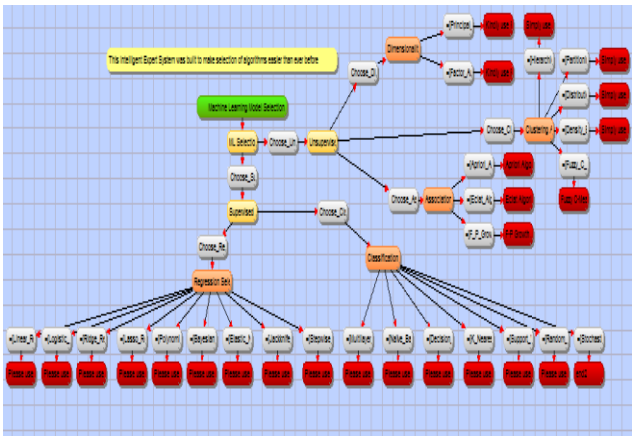

Figure 2: Complete VisiRule Tree Diagram

The figure 2 displays the condition to choose either supervised or unsupervised machine learning algorithm likewise it goes further to ask another question until the right decision is made on the suggestions provided by the software. The light yellow box was used as a comment that explained the purpose of the Tree diagram; the green box starts the Tree, the three Yellow boxes depicted single choice option type; five orange boxes stand for multiple choice option type; followed by thirty-three white boxes indicating the required options to be taken by the proceeding questions. At the end, twenty-six red boxes were used to give the expected outcome or conclusion.

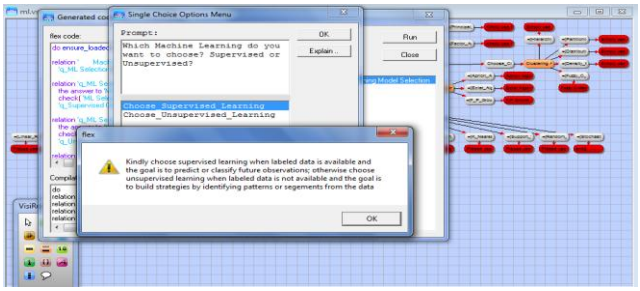

Figure 3: Supervised or unsupervised machine learning algorithms selection

The figure-3 prompts options to choose either supervised or unsupervised learning models with the explanation of the condition to choose the right and preferred options based on the problem to solve.

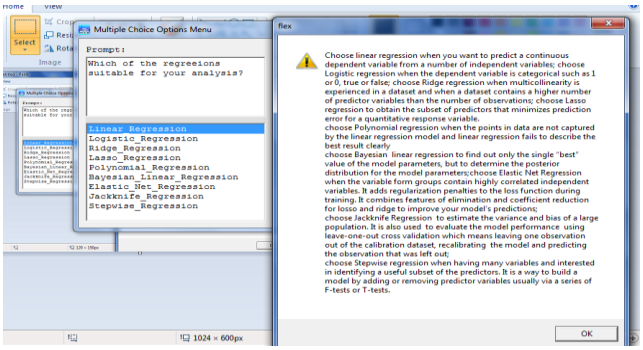

Figure 4: Regression types selection

The fourth figure (Figure 4) depicts the collection of regression analyses, from which the researcher would choose one. From figure 4, the details of each of the types are shown at right hand side with applicable conditions for their selection

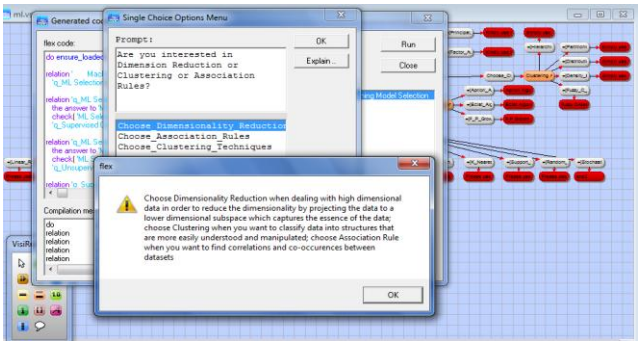

Figure 5: Dimensionality reduction selection

This figure-5 prompts the user the kind of dimensionality reduction technique or the type of association rules or clustering models to apply in solving the problem with explicit details of condition to choose the appropriate option

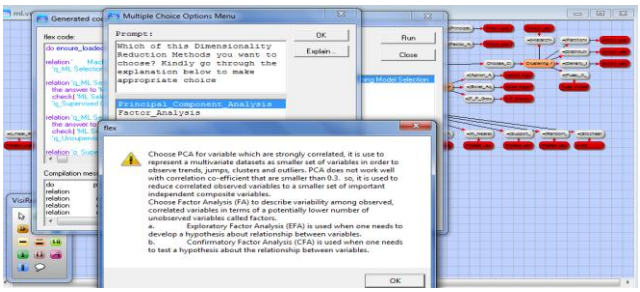

Figure 6: DRM selection conditions

Figure-6 shows selection of dimensionality reduction method that best fit the problem to solve. The figure is provided with explanation or condition to make the relevant choice.

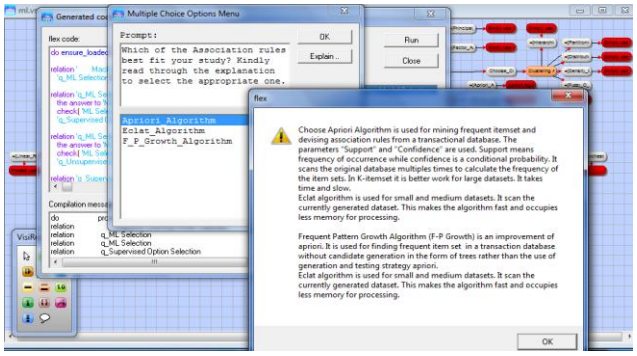

Figure 7: Association rules selection conditions

Figure-7 shows selection of association rules that best fit the problem to solve. The figure is provided with explanation or condition, at right-hand side, to make the relevant choice.

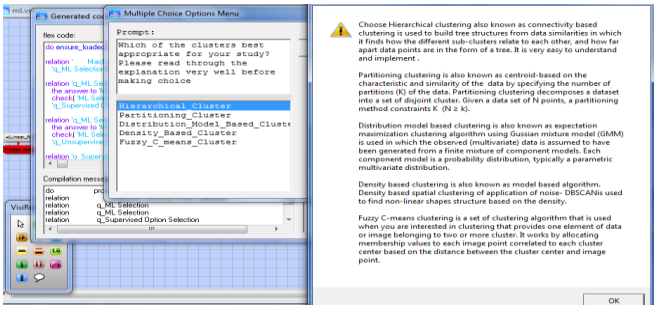

Figure 8: Clustering algorithms selection conditions

Finally, Figure-8 depicts selection of clustering algorithms that best suit the problem to solve. The figure also provided with explanations or conditions to make the relevant choice from the options available and displayed on the screen.

V. DISCUSSION

The use of the artificial intelligent rule-based expert system showed the easy way to determine which of the algorithm to use – based on the condition of its use. The figure 2 to 8

showed clearly the systematic procedures to best select the algorithms/model for further analysis and decision making. This approach is said to be useful and cost effective in decision making rather than manual selection method. The artificial intelligent rule-based expert system software as well does generate codes that can be exported to the web and other format like xls, xlsx, csv. The application of the Visirule covered the entire Machine Learning (ML) Algorithms/Models.

VI. CONCLUSION

For years, selecting the best algorithm/model to solve a given problem has been the subject of many studies. In this paper, researcher has been able to cover briefly the use of artificial intelligent rule-based expert system to select appropriate algorithm by first considering the conditions attached to the use and to select the best algorithm or group of algorithms that can perform better among others. Also, in this research paper, all machine learning algorithms/models, covering supervised and unsupervised learning models, were explained with conditions attached to each of the algorithms/models.

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