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IMPROVING BUSINESS RULES MANAGEMENT THROUGH THE APPLICATION OF ADAPTIVE BUSINESS INTELLIGENCE TECHNIQUE

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Abstract. Recently, swarm intelligence is becoming a powerful tool for optimizing operations of various businesses. Swarm intelligence is an artificial intelligence technique which study behavior of decentralized, self-organized systems. The goal of the authors of this paper is to elaborate swarm intelligence for business rules management improvement. The paper introduces the decision making model which is based on the application of Artificial Neural Networks (ANNs) and Particel Swarm Optimization (PSO) algorithm. In the proposed decision making model ANNs are applied in order to make the analysis of data and to calculate the decision. The training of ANNs is based on the application of PSO algorithm. The core idea of this algorithm application is to select the "global best" ANN for decision making and to adapt the weights of other ANNs towards the weights of the best network. The potentiality of PSO algorithm application for improving business rules management is shown in the case study.

Key words: Business Rules, Adaptive Business Intelligence, Decision Making Model, Artificial Neural Networks, Particle Swarm Optimization, Stock Markets.

1. Introduction

The continuing improvements of computer technologies make a big influence on each enterprise. Successful production and resources planning is crucial to the survival of enterprises in the increasingly competitive markets. Nowadays every complex and long-term information system has to deal with business rules [18]. However most of business rules management systems are focused on data gathering and production of detailed reports. As most managers now realize, there is a world difference between having good knowledge and detailed reports, and making smart decisions [17]. Enterprises need intelligent production and resource management systems in order to predict the performance and to provide short-term scheduling and control alternatives. The complexity and "noisiness" of markets cause difficulties in making real time analysis. For decision making, conventional tools are not powerful enough, thus more efficient information processing tools are required. This means that new computerized decision making tools have to be used in order to create powerful decision making systems. The use of artificial intelligence had made a big influence on decision making technologies and it was proved that efficient results can be obtained [5], [6]. In the comparison with conventional statistical tools, the main advantages of artificial intelligence tools are that they are able to learn to recognize patterns in the data set, they are flexible in changing environments and they can build models when more conventional approaches fail [6]. In comparison with statistical techniques, ANN makes less restrictive assumptions on the underlying distribution [4]. Another artificial intelligence tool, which already has shown promising results of its applications, is Swarm Intelligence (SI). It was proved that having complex systems a collection of individuals often solve a problem better than an individual - even an expert [2] , [5], [8], [16], [6]. For the decision making PSO algorithm is suitable as it allows making the search of the ”best” particle on a current time and making decisions, based on its performance. The application of ANN is quite common in business rules management systems. However, despite the optimistic view concerning the possibilities of ANN in financial forecasting [3], [9], investigations have shown that the average decision making quality was not sufficient using feed forward ANN and also ANN with pseudo input

variables (using principal component) [5].

The objective of this paper is to introduce adaptive business intelligence. The usefulness of this approach is shown by case study which is also presented in this paper. The paper presents the general idea of adaptive decision making model, which combines ANN and PSO algorithm. ANNs are used to make an analysis of historical data (e. g. stock changes data) and to form one step forward decision. While PSO algorithm is applied for the training of ANN. The paper is organized as follows: in Section 2 a brief overview of existing business management systems is presented. Section 2 is devoted for the presentation of evolutionary computation methods. Section 3 introduces the general idea of decision making model. Section 5 presents a case study on decision making model and its improvement by incorporation cluster analysis. The main conclusions of this work are presented in Section 6.

2. Business Rules Management systems

The fast growth of information technologies has direct influence on each organization. At the same time, that had influenced organizational networks, which became highly variable, and the environment of organizations, which is increasingly dynamic. To be competitive, organizations have to be able to react fast to the changes in the market, interpret non-standardized information which is needed for solving of problems, and beside that they have to be able to make fast decisions and change their management or infrastructure strategies if it is needed. However it is not so easy to solve complex business problems and come up with a right decision [10], [22]. Complex business problems have some special characteristics which makes solution difficult:

- Changing environment. It is difficult to solve problems which exist in a time-changing environment. It is very possible that the decision which was the right one today will not be the right one tomorrow.
- Large number of possible solutions. Sometimes the number of possible solutions can be so large that it is difficult to choose the best decision. At the same time, the search of the right decision can take too much time.
- Complexity of the problem. Solution of most of the problems has to satisfy many restrictions imposed by different regulations, laws, preferences etc. That makes the decision process even more difficult as it is not easy to find even one solution which would satisfy all the requirements.
- Larger number of objectives. Usually it happens that one solution is used to reach two objectives that work against each other. For example, many companies want to minimize time and cost of work. To allow business managers effectively control these tradeoffs, such problems may require an entire set of solutions (rather than just a single solution).
- Incomplete information or logical data gaps. Such gaps occure when the user gives incomplete information about the material processes and material input and output flows [11]. Decision making becomes more complex when necessary data are missing.
- Noisy data. Noisy data, that contains rounded figures and estimates, bring uncertainty in decision making process.
- Uncertain data. Quite often data, which were collected by company, might be not reliable.

All the problems mentioned above make business rules management process more complicated as selection of some rule for decision making becomes more complicate. That makes researchers to look for possible business management systems improvements. While creating an expert system more attention is given to artificial intelligence tools and evolutionary computation algorithms. Many IT professionals see the gap between development of expert systems and real life processes [13]. The observations have shown that most existing expert systems are rigid. That makes more difficulties when the need of changing decision making criteria in the systems appears. Also it was noticed that in existing systems there is needed quite a long business changes implementation time. That makes decision process more complicated and quite a big amount of decisions are unaddressed. While creating enterprise decision management systems, most enterprises want to automate and improve decisions across the enterprise. Such systems allow enterprises to make more targeted and profitable decisions. Having such systems, such decisions can be made as many times as it is needed. At the same time it leaves agility and makes enterprise to be able to adapt to the market situation "on-the-fly". However, all above mentioned factors, like rapid market changes, incomplete information etc. make decision process more complicated. Also, decision making becomes fuzzy, and clearly defined rules are not able to give the right decision on the right time.

Another problem which most managers face is that most of the systems are focused on three things: (1) data gathering, (2) data transformation into information and into knowledge and (3) easy to use graphical interface for display of knowledge and reports. In

Figure 1 in oval "a", there is presented process which is common for traditional business intelligence systems [17].

In most of the cases knowledge is assumed to be the most important issue and that is why it is named as a final objective (see Figure 1, oval "a"). However the practice is showing that knowledge is not longer enough. Manager working in the company can know many details about their customers, they can see many graphs which were drawn according to the data they have collected during several years, but still they will not know what decision to make. All the knowledge in the world will not guarantee the right or best decision [17]. In order to eliminate a gap between having the right knowledge and making the right decision we are introducing decision making model which is based on the idea of adaptive business intelligence. Differently from traditional systems (which are transforming data into knowledge), we offer to apply our proposed model for decision making, which is based on prediction and optimizations. The main idea of adaptive business intelligence is presented in Figure 1, oval "b". As it can be seen from Figure 1 (oval "b"), adaptive business intelligence includes prediction and optimizations techniques which are used to build self-learning decision systems. Another important thing about such systems is adaptability. Adaptability is a vital component of any intelligent system. In order to increase business rules management though the application of adaptive business intelligence we introduce decision making model which is based on application of ANN and PSO algorithm. More detailed presentation of PSO algorithm and business rules improvement through the application of proposed model is presented in Section 3. Some rules engines like BlazeAdvisor, adapt predictive analytics rule based application in order to give the users an opportunity to increase companies insight, decision making precision gives companies the ability to handle decision complexity [21]. However, despite the optimistic view concerning the possibilities of ANN in decision making process, our investigations have showed, that the average decision making (prediction) quality was not efficient using feed forward ANN and also ANN with pseudo input variables (using principal component).

3. Introduction to Evolutionary Computing Methods

Evolutionary computing is the emulation of the process of natural selection in a search procedure [8]. Evolutionary computing is the collective name for a range of problem–solving techniques based on the principles of biological evolution, such as natural selection and genetic inheritance [7]. Evolutionary computing is based on the model of natural evolution. Here an evolution is understood as an optimization process, where the aim is to improve the ability of individuals to survive. In a natural evolution the survival is achieved through reproduction. A new individual is reproduced from parents and it gets genetic material from parents. If individual gets good genes it has all the possibilities to survive. Otherwise individuals are weak and most of them probably lose the battle to survive. The first step in evolutionary computing is the modelling of population of individuals. Each individual is referred to as a chromosome. A chromosome defines/describes the features of individual. For each generation individuals compete to reproduce an offspring [8]. An individual who has better survival capabilities has more chances to reproduce. A new individual (offspring) is generated combining parental features. Such a procedure is referred to as the crossover. The possibility to survive is measured by fitness function which reflects the objectives and constraints of the problem to be solved.

An evolutionary algorithm is a generic term used to indicate any population-based metaheuristic optimization algorithm that uses mechanisms inspired by biological evolution, such as reproduction, mutation and recombination. Evolutionary algorithms are search algorithms, used to find solution to a given problem. Due to their random nature, these algorithms are not guaranteed to find an optimal solution for any problem, but they will often find a good solution if one exists. The evolutionary algorithms are constructed of the following components:

- **Solutions are represented as chromosomes.** In the case of evolutionary algorithm a population of individuals is created, where each individual presents a solution for the presented problem. Each individual from the populations has its own characteristics. Individuals' characteristics are represented by a chromosome or genome. At the same time, each chromosome represents a point in a search area. The subparts of chromosome are called genes. One gene is responsible for one characteristic of an individual. In terms of optimization, a gene represents one parameter of the optimization problem [8].
- **The survival possibilities are evaluated using fitness function.** As has been mentioned above, each chromosome represents a potential problem solution. The fitness function is used in order to evaluate the optimality of a solutions so that a particular

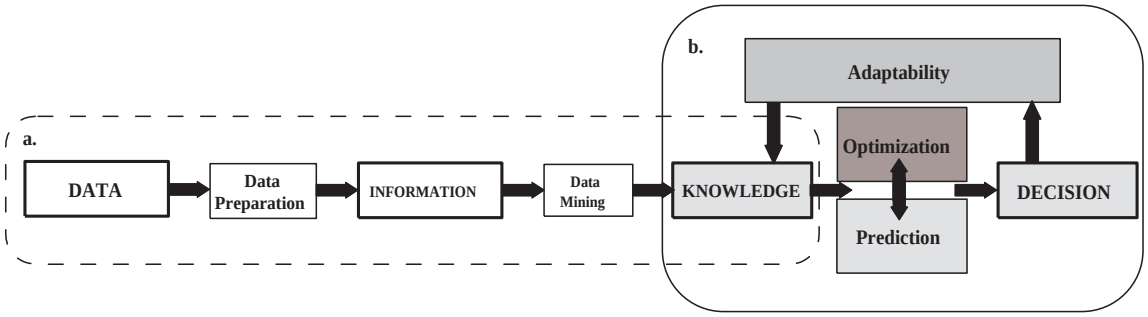

Figure 1. Adaptive Business Intelligence

particle may be ranked against all the other particles.

- **Initialization of the initial population.** One of the most important tasks is to generate the initial population. The simplest way to do that is to make it randomly. If there is some prior information available, heuristics can be used to bias the initial population toward potentially good solutions. The size of population has great influence on the calculation time and accuracy. If the population is big, it covers a bigger area of search space and a better accuracy can be reached. However, in that case it is very possible that time complexity per generation is increased.
- **Selection operators.** After each new generation of algorithm a new set of individuals is reproduced. The new generation is formed through application of three operators: cross–over, mutation and elitism. The aim of the selection operators is to emphasize better solutions within a population [8].
- **Reproduction operators.** These operators are responsible for the creation of a new individual from selected individuals. This is done through cross–over (a new individual is made by combining genes of parents) or mutation (a new individual is made through random change of genes in a chromosome). Reproduction operators are used to make an individual for a new generation. It can also happen that new individuals will be replaced with their parents. This happens in the case when the fitness of a newly created individual is better than that of its parents.

The termination of evolutionary algorithm is usually based on achieving a population member with some specified fitness or on having run the algorithm for a given number of generations. The below presented Figure 2 shows how the solution is made using evolutionary algorithm.

As it can be seen from Figure 2, the first step is the definition of the problem. When the problem is known, the population of individuals is initialized (each individual represents a possible solution for the presented problem). Evolutionary algorithms operate on a population of potential solutions applying the principle of survival of the fittest to produce better and better approximations to a solution. At each generation, a new set of approximations is created by the process of selecting individuals according to their level of fitness in the problem domain an breeding them together using operators borrowed from natural genetics. Evolutionary algorithms model natural processes, such as selection, recombination, mutation. Using these operators, after some number of generations the solution is reached.

4. Decision Making Model Based on Application of Particle Swarm Optimization Algorithm and Artificial Neural Networks

The general idea of decision making model is based on the application of artificial neural networks and particle swarm optimization algorithm for improvement of business rules management. The efficiency of this model is presented through its application to stock markets. Market dynamics is basically affected by individual behavior, since individuals determine the value of an asset. The influence which is made by individual on the price of an asset is determined by his/her willingness to pay some amount of money for it. On the other hand, not only individuals acting in the market have influence on the asset price. An asset also has its own intrinsic value; a minimum price an individual is willing to sell it for. While deciding what price to pay for an asset an individual first of all will look how much knowledge or information he/she has about that asset. An individual will take

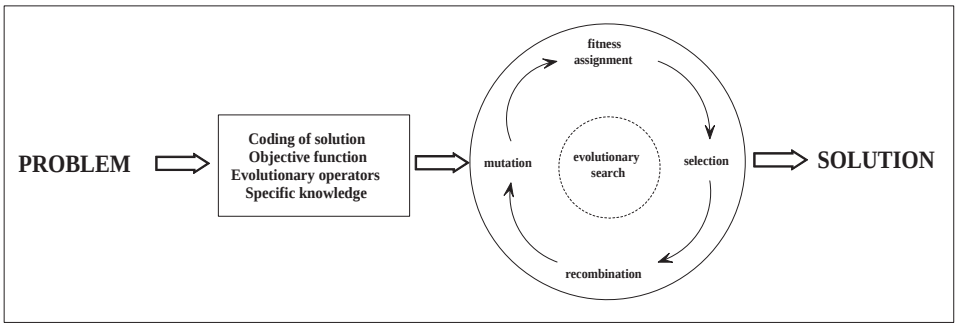

Figure 2. Problem Solution Using Evolutionary Algorithm

into account past, present and possible future information on that asset. Future information can be expectations of individual or market participant. The information technologies let the users find various types of information on the Internet. Information technologies have increased the availability of data. It is quite simple to get information about any particular company, its annual or quarterly reports or other information concerning the performance of the company. It is possible to retrieve recent financial ratios and historical ratios. Also, it is enough of data on stock option prices. Many researchers who work with stock prices' predictions and possess historical stock returns try to find patterns in them to get an extra edge while trading in financial markets. For that usually they try to apply technical analysis. Although it is generally assumed that past performance does not guarantee future performance. Another type of information which has a big effect of stock prices is different kind of announcements on upcoming events. Such information may affect specific stock or group of assets of some companies. The influence of such announcements as macroeconomic news has a great influence as well. In an IMF Working paper by Funke and Matsuda [9] several empirical studies, such as S. Hardouvelis [12], Li and Hu [15] and Sun and Tong [20] are cited to give an evidence that stocks are sensitive to news either of financial or macroeconomic nature. Because of such a big amount of information and factors which influence financial markets, the prediction of the financial markets changes becomes even more difficult task. Until now the researchers have proposed a big number of various tools. These tools are based on the application of different techniques: regression methods, artificial neural networks, genetic algorithms etc. However, as it was already mentioned above, these techniques do not ensure good performance of decision making methods in specific situations, especially in such ones when the environment is changing rapidly and is too noisy. The need for more advanced tool is obvious. A lot of research has been made and many systems have been created for the forecasting of stock markets. Currently a lot of research has been made on the application of computational intelligence tools for decision making in stock markets. The application of ANN is very common in financial markets as well. Yet, our investigations have shown that the average prediction quality was not efficient while using feed-forward ANN as well as ANN with pseudo- input variables. In order to improve the performance of existing decision making system we have developed an innovative decision support system which is based on the applications of artificial neural networks and particle swarm optimization algorithm. The main goal of our introduced algorithm was to create a tool that could be used in decision support systems (e. g. investment, credit management [1] etc.) and which could help to make decisions in environments with constantly changing parameters. Neural networks are universal function approximators that can map any nonlinear function. As such flexible function approximations, they are powerful methods for pattern recognition, classification and forecasting. Neural networks are less sensitive to error term assumptions and they can tolerate noise, chaotic components and heavy tails better that most other methods do. Other advantages include greater fault due to a large number of interconnected processing elements that can be "trained" to learn new patterns. The key idea of the proposed decision making method is to use artificial intelligence tools and through that application to promote the decision making process in dynamically changing environments. Apart from the application of artificial neural networks, we propose to use one of evolutionary computation algorithms, i. e. particle swarm optimization algorithm. PSO algorithm is one of the swarm intelligence algorithms. There are not so many examples of its application but it had been proven that its application can give very promising results. In the proposed decision making

method the artificial neural networks are presented as particles and particle swarm optimization algorithm is proposed to be used to find the values of artificial neural network input weights. The general idea of the decision making method is presented in Figure 3.

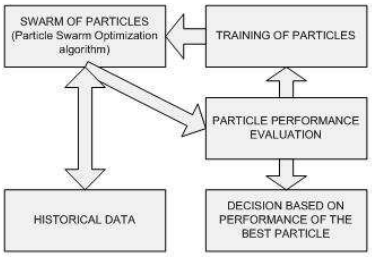

Figure 3. General Idea of Decision Making Model

As it can be seen from Figure 3 there are 5 main parts of the decision making method: historical stock returns data, swarm of particles, particles performance evaluation, training of particles and formation of portfolio. For one day forward decision making, the method is using historical stock returns. The stock returns data are passed to the swarm of particles. The particles make analysis of the data and make some conclusions about the purchase of the stocks depending on the analysis' results. Each particle makes its own analysis and makes its own decisions. When the decisions of the particles are known, an evaluation of each particle performance is made. The evaluation of particle performance is made through the application of particle swarm optimization algorithm. There are three main principles in particle swarm optimization algorithm:

- Evaluation of particles performance;
- Comparison of particle performance;
- Imitation.

The evaluation of particles performance is made in order to know if the particle is "attractive" or "repulsive". Without evaluation or particle performance the learning process can not occur as the particle can not select which environment feature attract and which repel. The comparison of particles performance is needed in order to compare themselves with other existing particles (neighbors) and imitate only those neighbors who are superior to themselves. The imitation process in this case is the central to the acquisition and maintenance of mental abilities. In the presented general idea picture, evaluation of the performance of each particle is made in the following way: knowing what decision was made by the particle an analysis of its decision through the comparison with real data is made. If the decision of some particle was close to the real situation in the market, and the biggest profit could be achieved following the decision of that particle, it means that the particle has shown the best performance on that day. The best performance means that the particle has managed to make the decision which is close to the real situation. When the particle which has shown the best performance is known, all other particles are slightly moved towards the performance of the best one. In contrast to the genetic algorithms, in a case of particle swarm optimization algorithm application, the particles which have shown the worst performance are not excluded from the population. Thus it is possible that in case of crucial environment changes these particles can show the best performance and make decisions which will allow avoiding big loss. The business rule can be written in the following way:

$$\text{expertise} = \text{getSwarmReccomendation(XWf)} \quad (1)$$

where X - observable values of some phenomenon, W - method parameters, and f- swarm experts. The algorithm implementing getSwarmReccomendation is divided into the following main steps:

1. Calculate investment recommendations of each "expert":

$$Y_i = f_i(X, W) \quad (2)$$

2. Evaluate the performance of each expert (possible profit of expert in the case when the expert would have been chosen for the past window days):

$$J_i = \sum_{t=day-n}^{day} P_i(Y_i(t)) \quad (3)$$

where $P_i(Y_i(t))$ is profit at time t of expert i

3. Find the winner expert win with the best performance:

$$win = argmax_i(J_i) \quad (4)$$

4. Inform all experts about the best expert win - share its experience among each other. Update W.

5. Invest into phenomenon recommended by the winner expert.

For example, this could be done by using the following simplified business rule, which makes a decision to invest or not based on the swarm recommendation:

if $getSwarmReccomendation(X, W, f) > 0.5$
then Buy
else $Sell$

Here we assume that $f = ANN$, where ANN is artificial neural network, X - variation of observable

phenomenon values and W - weights of neural networks. Knowing X values and having initially randomly generated W values, it is easy to calculate recommendations Y_i, where $i = 1, ..., k$. When the recommendations are known, the function (artificial neural network) f_{win}, which gives the best performance at current time is selected. This function is used for the decision making. Other experts are updated based on knowledge of the winner. Compared to other existing solutions, the developed decision making method has the advantage as it is very flexible. It could be applied in all noisy environments and environments with lots of continuously changing parameters. The proposed research is very perspective, as far as computational intelligence is an important and rapidly developing area of applied science, with a lot of challenging problems and innovating solutions.

5. Experimental Investigations

All the experimental investigations were run using daily stock returns of 350 stocks. These stocks were selected from SP500 index group. The data set represents daily stock returns for 12 years (01/Oct/91–01/Oct/03). For all experimental investigations we consider the variations of market close prices. For that, we are using market orders, as it allows simulate the buy action of stocks at the market closing time. While choosing the stocks for experimental investigations, an essential role was given to the liquidity ratio as it is correlated with the transaction fees while buying or selling the stocks. The method realization could be run having different groups of stocks (like SP500, Down Jones, DAX etc.), indices or other groups of securities.

5.1. Particle swarm optimization algorithm incorporating cluster analysis

Our previous research [19] have shown that the proposed decision making model can give valuable results. It was proved that, while using the proposed decision making model, the conservative investment strategy is outperformed and 5-10 times higher profit can be achieved. However, experimental investigations have shown that there are quite big deviations of the proposed decision making model results and that could cause quite big looses if trader enters market not in the right time. In order to reduce deviation of the results and traders risk further investigations on decision making model were made. In order to propose any improvement we have decided to explore the movement of particle during the decision making and training processes. It was noticed that after some number of iterations, particles in the particle swarm are seen to cluster in one or several regions. That shows the presents of optima. The relatively good performance of individuals causes them to attract their neighbors, who improve their own performance while moving toward the optimal regions. These results have shown that it would be worth to investigate if the distribution of particles in the search space could be used for an improvement of particle trajectories. For further experimental investigations the change of proposed decision making model was made and instead of using one particle for decision making and training of other particle we decided to identify clusters of particles in the search space and use the centers of clusters as substitutes for the bests. This improvement of PSO algorithm first was presented by Kennedy [14]. To find the cluster, we have selected the number of individuals as proposed cluster centers. While having cluster centers, we were calculating the distance of all other individuals from the centers in order to assign all individuals to the nearest cluster center. After that, the mean point for each cluster was calculated. The steps were repeated three times. Such a number of iterations was selected as the previous observations have shown that little change typically occurred after three iterations. In each iteration of the algorithm, identified cluster centers were used as substitutes for the individual best particle. In Table 1 the average results are presented. The average performance (profit estimation (%)) and standard deviation of each case are presented.

Table 1. Model Performance Evaluation (Different Number of Clusters)

	5 clusters	10 clusters	35 clusters
Profit estimation % and standard deviation	0.315 (dev.=0.05)	0.304 (dev.=0.06)	0.328 (dev.=0.07)

Our previous research have shown that the performance of decision making model gives better results than it could be achieved in the case of conservative investment. Having decision making model where one particle is used for decision making and training of other particles, in the best case we have got that the average profit estimation (%) is 0.245. The data presented in Table 1 shows that results are significantly better while using cluster center compare to the result when decision was made based on the individual particle's previous best position. Based on these experimental investigations, it can be suggested that the average performance of the decision making model can be improved by changing decision making on individuals previous best positions to decision making based on clusters centers. These preliminary

results should not be taken as a final decision to use cluster analyzed decision making model instead of the standard one, but they do point to a potentially useful research direction.

6. Conclusions

Business rules and their management are widely discussed by researchers and companies. The analysis of business rules management shows that data complexity, noisiness of environment changes, data incompleteness make that process more complicated and brings fuzziness into it. It was proved that all these factors make to look for more advanced business rule management solutions. In this paper there was presented the general idea of decision making model based adaptive business intelligence. The main idea of the proposed decision making model is that it incorporates ANN and PSO algorithms. The model was applied in order to make one-step forward decision considering historical data of daily stock returns. The presented case study, where the proposed decision making model was applied for decision making in stock markets, have shown that the promising results could be achieved. Experimental investigations using PSO where decisions are made using cluster centers instead of individual's previous best positions have shown that better results, in comparison to regular PSO application case, can be achieved. More research has to be done to explore how to combine regular PSO and reverse PSO to get even better results of decision making model.

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