

# Intelligent Techniques in Decision Making: A Survey

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## Abstract

**Background/Objectives:** With the idea of enhancing the capability and effectiveness of decision making while dealing complex problems and under uncertain environments, this article provides an insight to the leading intelligent techniques that could be employed to enrich the decision-making process. **Methods/Statistical Analysis:** Leading techniques like expert system, artificial neural network, fuzzy system, evolutionary computing, rough set, data mining and intelligent agent are being investigated in this review for analyzing the data so as to take a prudent decision making. **Findings:** However, one technique does not fit for all problem domains, hence basing on the complexity and to underlying data; it has been found as which technique could be employed for a particular problem to elicit the desired knowledge out of it. **Application/Improvements:** This study can be helpful for designing an intelligent decision system which can be tailored for the organizations basing on their domain and nature of data. However, a hybrid intelligent technique could be proposed which could handle the decision making process in an extremely efficient manner.

**Keywords:** Artificial Intelligence, Decision Support System, Fuzzy System, Intelligent Techniques, Neural Network, Rough Set

## 1. Introduction

As the data are being generated with an unprecedented rate, the organizations find it quite difficult to reason and extract usefulness of data. In this scenario, the decision making process become complicated especially for a large organization where huge data from disparate sources are originated. Even though many statistical tools and techniques are available, however their scope is limited as they cannot handle uncertainty aspect of the data. To this end, many intelligent techniques are being developed which are found more suitable for extracting information<sup>1</sup>.

Decision making is a human pursuit that involves cognitive capabilities such as learning, reasoning, critical thinking and many more. In order to overhaul the cognitive limitations of human being, Intelligent Decision System (IDS) can be viewed as a tool which well assists the decision makers in their effort. IDS work upon the principle of intelligent techniques at its kernel. It is highly favored in large organizations where knowledge workers and managers heavily rely on this tool<sup>2</sup>.

The fusion of Artificial Intelligence (AI) with Decision Support Systems (DSSs) has helped in widening the window of current research and application in information processing and analysis. As a result, the systems are smarter, quite efficient, adaptable, and better able to aid human decision making. While AI aims to mimic human behavior in limited ways, DSSs attempt to help humans make the best choice among a set of possible choices given explicit or implied criteria.

## 2. Intelligent Techniques

The combination of AI and DSSs provides formidable new computational assistance to humans that extend their capabilities in routine and complex stressful environments. Decision support system empowered with intelligence, and their domain expertise have been profoundly studied by many researchers, starting from Simon<sup>3</sup> followed by Sprague et al. <sup>4</sup>, and exemplified by Turban et al.<sup>5</sup> in their comprehensive analysis of tools and techniques for incorporating intelligence into DSS. Figure

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1 represents Simon's four phase of decision making. The strong presence of artificial intelligence has been perceived in most of the modern applications. Whether it is Supply-Chain Management (SCM), or Customer Relationship Management (CRM) or Business Intelligence (BI) systems, they use some form of intelligent techniques at their core for key decision making.

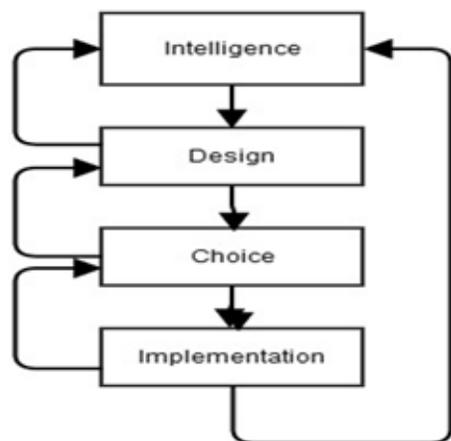


Figure 1. Simon's four phase of Decision making.

Intelligent techniques are useful for analyzing data and providing forecasts, quantifying uncertainty, readily providing information and suggesting the course of action. Figure 2 emphasizes how decision making is influenced by a diverse range of intelligent techniques.

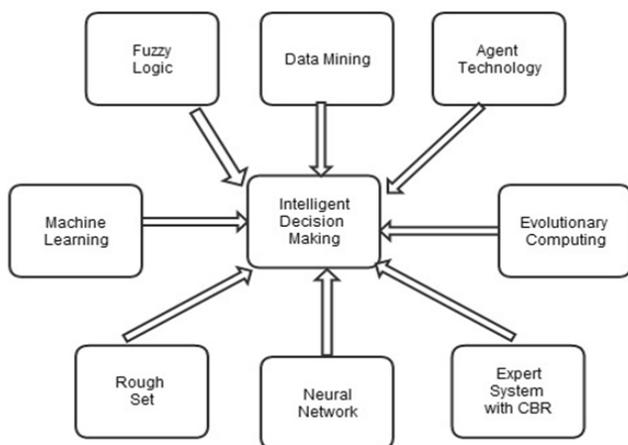


Figure 2. Intelligent techniques in decision making.

### 3. Expert System

Expert system is also able to automatically collect, transmit and analyze data for detailed analysis. Several expert system e.g. MYCIN<sup>6</sup>, PROSPECTOR<sup>7</sup> adopt

uncertainty management approach also. Most of the expert systems are rule-based and few works on the principle of case based reasoning. Health condition monitoring and associated services greatly benefit from the application of Case Based Reasoning (CBR)<sup>8</sup>. However, this system can well handle the complexity of biomedicine, can interact and communicate with multiple systems in clinical settings. The application of CBR in decision making in integrating with web 2.0 has been studied by He et al.<sup>9</sup>.

### 4. Artificial Neural Network

Neural network technique is mainly inspired by human nervous system. Like human being, Artificial Neural Network (ANN) is trained to perform the complex functions like pattern recognition, classification, speaker identification, etc. Learning is the basis of ANNs which feature seems not be practiced in other intelligent techniques. Success and failure of an ANN are dependent on the types of learning and rate of learning. The network can produce a specific output from a set of inputs. This can be achieved gradually as basing on the intermediate output, connection weights are adjusted so that the final output converges towards desired output. The main advantage of ANN over the traditional program is that they are able to address a problem that does not have an algorithmic solution.

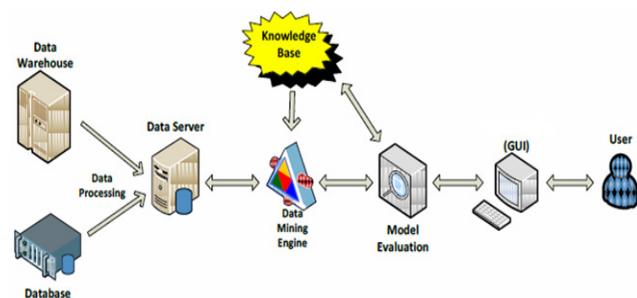
Table 1. ANN application domain

Application Field	Sub-field	Examples
Healthcare	Clinical diagnosis	Cervical cancer, breast cancer, brain disorder
	Image analysis	Radiographies,
	Signal analysis	MRI,CT ScanECG
Financial	Forecasting	Stock market price, GDP,
	Prediction	Bankruptcy Credit card fraudulent activity, loan defaulter, customer for target marketing
Bioinformatics	Protein sequencing	Amino acid
Image Processing	Image compression and decompression	JPEG, MPEG
Pattern Recognition	Speech recognition	Google voicemail
	Character recognition	Arabic text

In decision-making, there are several scenarios where neural networks has been applied<sup>10,11,12</sup>. Furthermore, complex mathematical problems are fairly represented using neural network notations<sup>13</sup>. After all, it has become a popular decision-making tool in financial domain<sup>14,15</sup>. The Table 1 represents ANN is a decision support tool in various areas and applications.

## 5. Data Mining

Evolution of data mining probably attributed to a time when data is abundant but information is rare. The ever growing data become obsolete if it is not analyzed to extract useful information, hidden patterns and interesting association lying in it. Hence it contributes none towards organizational decision making. In order to make decision making effective, decision makers must be armed with all sorts of knowledge by elucidating it from the database. Data mining is used synonymously to knowledge discovery or knowledge extraction from the database. However, not all knowledge (or information) discovery tasks are data mining, such as querying from the database or using Internet search engine to find a specific web page. They are called as information retrieval. Information retrieval process uses the pre-defined information extraction rules whereas data mining uses fitting models to or finds the unknown relations between the data items. The common data mining tasks include classification, clustering, frequent pattern mining, association, prediction and forecasting<sup>16</sup>. A typical data mining process has been represented in Figure 3.



**Figure 3.** Data mining process (Hu 2012).

Data mining plays an important role in decision support systems. One of the functionality, association mining (market basket analysis) are mostly used in

marketing research to know the customer's buying habits so that supermarkets and online stores can be modeled accordingly.

E-commerce applications employs this technique for correlating their products and forecasting of sales. Major day-to-day decisions in banking are influenced by the discoveries of data mining, e.g. credit card fraudulent detection, risk involved in loans, mortgage lending, customer attrition analysis. Data mining has been used almost in all the data- centric applications. One of the fields which is greatly benefited from it is the web. Web data mining refers to the use of data mining process for extracting knowledge from web contents and services<sup>18</sup>. In addition to this, outcomes of opinion mining which refers to sentiment analysis of online users help the managers to structure their decision accordingly. Similarly spatial data mining analyzes and interprets astronomical big data for fetching information and corresponding decision making.

## 6. Fuzzy System

Most of the real-life data due to their source of origin or measurement or processing are uncertain, vague and imprecise. Out of an array of techniques, fuzzy system remains in a forefront in handling of uncertainty information<sup>19,20</sup>. Many intelligent techniques justify their worthiness in working with decision support system and expert system. However, a problem having subjective or linguistic information cannot be handled by an expert system. In this case, the qualitative information needs to be converted into quantitative or binary information. This is possible by using 'IF...THEN' rule in fuzzy logic and eventually it explores various cause and effect relationship by employing those rules. Hence fuzzy set especially used for decision making in the applications where the decision and risk management goes hand in hand. In addition to this, fuzzy logic is useful for analyzing risks that are not well understood.

Decision support systems using fuzzy modeling have been validated in many applications<sup>21</sup> particularly when applied to multi-criteria decision-making processes<sup>22</sup>. Few works in fuzzy decision support system for the selection of transportation projects which uses a multiple objectives' selection process has been reported. New-product development activities exploit fuzzy-logic-based

decision-making approaches to reduce the risk involved<sup>23, 24, 25</sup>. Furthermore, fuzzy logic is also used in knowledge discovery from a database which accounts for decision making<sup>26</sup>.

## 7. Evolutionary Computing

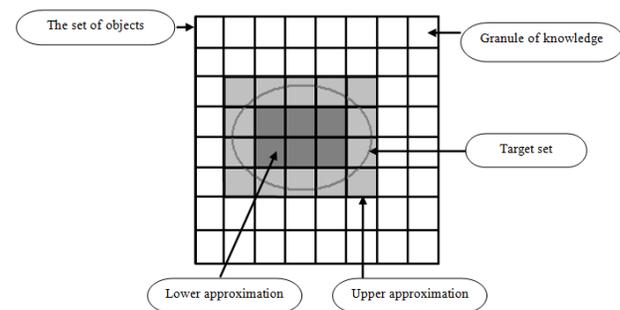
Evolutionary Computation (EC) is capable of addressing complex real-world problems involving randomness, complex nonlinear dynamics, and multimodal functions, which is beyond the scope of traditional algorithms. This area is inspired by the natural population genetics. GAs uses data as chromosomes that evolve through selection (random selection), cross-over (recombination to produce new chromosomes), and mutation operators. Finally, a fitness function is applied to select the best individuals. The process is repeated for a number of generations until the individual or group of individuals is reached that closely meet the desired condition. Decision-making models benefit from evolutionary computing in several important ways<sup>27</sup>:

1. Genetic algorithm is the manifestation of evolutionary optimization and widely been used in many applications<sup>28</sup>.
2. Decision-making processes usually take into account a number of criteria while evaluation and it is known as multi-criteria nature of the problem. Evolutionary techniques found effective while dealing those problems<sup>29</sup>.
3. GA generates near optimal solution quickly, which can be a better insight into the decision-making problem rather than waiting for optimal solutions, which require a long time<sup>30</sup>.
4. The origin of Genetic programming to evolve computer programs, logical expressions and mathematical models<sup>31, 32</sup>.

## 8. Rough Set Theory

Followed by theory of probability, fuzzy set theory, Rough Set Theory (RST), introduced by Pawlak<sup>33</sup> is a mathematical approach to deal with uncertain, vague and imperfect knowledge in an information system<sup>34</sup>. RST has an edge over others in uncertain data analysis because it does not need any prior or further information about data<sup>35, 36</sup>.

Rough set primarily are used in attribute selection problem and also used for classification tasks<sup>37</sup>. The power of rough set realized as given a set of values, it determines which are the elements definitely belongs and which are likely to belong e.g. lower and upper approximation<sup>38</sup>. It is graphically represented in Figure 4.



**Figure 4.** Rough set approximation (Pawlak 1982).

RST has been applied successfully while decision making in various fields. Decision rule can be extracted from attribute value table<sup>39, 40, 41</sup>. Also decision rules can be automatically extracted as performed from clinical data sets<sup>42</sup>. Most of these methods are based on generation of discernibility matrices and reducts. Decision-making based on rough set theory has been developed by Kusiak<sup>43</sup>. This approach was tested on a medical dataset for patients with lung abnormalities. Rough set along with soft set has been well used for decision making over an institutional data set<sup>44</sup>. Furthermore, multi-criterion decision making has been effectively accomplished in extending rough set technique over intuitionistic fuzzy approximation space<sup>45, 46</sup>. In addition to these, it also measures the uncertainty associated with an incomplete information system<sup>47</sup>.

## 9. Intelligent Agent

Artificial intelligence utilizing the power of cognitive science, programming which is quite close to capture the human behavior (object-oriented programming) and sensor data technique give rise to agent technology<sup>48, 49</sup>. An agent is a human or a system or an entity equipped with sensors and actuators<sup>50</sup>. An agent consists of architecture (hardware) and an agent program (software). Agent program implements agent functions, which map percept sequences to actions. An agent exhibiting some

form of intelligence in his action and thought is referred as an intelligent agent. The design of an intelligent agent involves development of an agent program and embedding the program into compatible hardware to run the agent program.

Intelligent agents have the following capabilities:

- Can communicate and interact with other agents
- Tend to be goal-oriented
- Do have skills to offer services
- Can generate autonomous behavior

Human centric agents are substitute for human as they quickly adept to the changing environment and automate accordingly. These are candidates for human-like reasoning and decision making. Human-agent-teaming is the area where human being is a part of the system and interacts with the agent lively so that decision making could be simpler. Intelligent agents are found to be applicable in following domains

- Industrial applications - Manufacturing, process control, air traffic control
- Medical applications - Patient care, health care
- Web - Information filtering, information gathering, e-commerce
- Entertainment - Games, Theatre

The next paradigm of software system is undoubtedly building the automatic intelligent agent, and it is quietly realized starting from a device, smart phone and supposing many more in a smart city.

## 10. Conclusion

Artificial intelligence approach can enhance human decision making through the use of intelligent decision support systems. To that end, this article presents background information on human decision making and identifies key techniques that contribute towards the intelligent decision-making process. Techniques used in such systems include case based reasoning, fuzzy logic, ANNs, evolutionary computing, data mining, machine learning, intelligent agents and rough computing models. However intelligent decision making is not widespread due to several constraints. Hence comprehensive research needs to be done in this sphere keeping an eye towards developing hybrid techniques that could be employed for decision making.

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