

## **Internet Applications with Fuzzy Logic and Neural Networks: A Survey**

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### **Abstract**

Many internet applications need to deal with large amount of data collected from non-technical users and is imprecise and incomplete in nature. Well structured rules are hardly available in general applications and the nature and the pattern of the users can never be fully accounted. Soft computing techniques like fuzzy logic and neural network are ideal for coping with this type of problems. We survey recent internet applications using these techniques from 2003 to present and summarize the applications in several categories. The survey finds these soft computing techniques are suitable for internet applications.

### **1. Introduction**

Internet applications are also commonly known as Web applications. We shall refer to them interchangeably in this paper. The World Wide Web (or the "Web") is a system of interlinked, hypertext documents that runs over the Internet. With a Web browser, a user views Web pages that may contain text, images, and other multimedia and navigates between them using hyperlinks. The Web was created around 1990 by Tim Berners-Lee and Robert Cailliau working at CERN in Geneva, Switzerland. (137) Since then, we see an ever growing number of applications that range from eCommerce to information search.

Typical Web applications are characterized by large amount of data that is growing in size and categories on a daily basis. Unlike other engineering problems where the issues and the size of the problem remain fairly constant, web applications present a new challenge to researchers. As of 2005, it is estimated that there are more than 11 billion web pages and the number is expected to be even higher and keep on growing today(138). How to effectively retrieve information from the web and guide users through this maze like information jungle can hardly be handled with few ad hoc rules. Business transaction over the internet has evolved from the B2B(Business-to-business), B2C(Business-to-consumer), to the current C2C(Consumer-to-consumer) protocol due the emerging P2P popularity. eCommerce has new issues to deal with, ranging from personalized recommendation to product recommendation. From the web deployment perspective, how to classify internet users and their usage pattern is a must in ensuring proper content is being delivered to the right user. Other related applications that will find soft computing techniques useful include network routing, internet traffic classification, and internet video game. We begin by presenting an overview of fuzzy logic and neural networks techniques and how they can be useful in internet applications. Web information retrieval and eCommerce are two of the most important internet applications and we describe how fuzzy logic and neural network are useful in such applications in section 3. In section 4, classification and clustering problems in internet applications are presented together with solutions using neurofuzzy methodologies. Miscellaneous categories, including network routing, internet video game, internet medical, etc., are presented in section 5. The promise of soft computing techniques for open issues in internet applications is presented in the conclusion.

## **2. Fuzzy Logic and Neural Networks for Internet applications**

### **2.1. Fuzzy Logic**

The ability to model imprecise and qualitative knowledge and handle uncertainty are distinguished characteristics of fuzzy sets. Fuzzy logic is capable of addressing approximate or vague notions that are inherent in many information retrieval (IR) tasks. For the top internet application, i.e., internet search engines, users typically are not domain expert and therefore cannot articulate the search with the

intended keywords as inputs to search engines. Fuzzy search engines are a natural solution to this challenge.

In eCommerce and many other internet applications, they system needs to translate users' qualitative preference of product and personal profile into relevant quantitative variables for best match or personalization. Relating linguistic variable to numeric variable is a must in such designs and Fuzzy logic is ideal for this requirement. Figure 1 illustrates how a quantitative price value can be associated to, typically multiple, qualitative variables to be used in eCommerce and other internet application rule engines. The ever growing number of data and data types online inevitably leads to duplicated information in many internet applications. Treating information in a non-crisp way in fuzzy logic makes it ideal for such scenario.

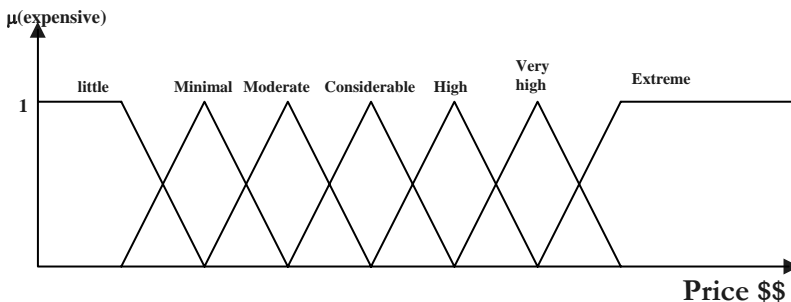


Figure 1 Relating numeric values to linguistic variables in rule engine

Classifying web pages has become an important and challenging jobs. This is due to the fact that web pages are growing in number and typically contain unstructured or vague information. One other challenge is the possibility of duplicated or seemingly related web pages. Fuzzy models can be used to represent information that are seemingly related so that meaningful and useful relationships between webpage and internet information can be established. Despite a growing trend in automating internet applications in a crisp way, numerous real life applications can hardly be represented in such manner without scarifying the usability. This is typical in translating linguistic domain and rule sets to internet solution engine. Fuzzy sets are inherently suitable for coping with linguistic domain knowledge and producing more interpretable internet solutions. The role of fuzzy sets in different internet applications is categorized in sections 3-5.

## 2.2. Neural Networks

Neural networks were earlier thought to be unsuitable for deduction because of their inherent black-box nature. This is, however, its strength as well. No information in symbolic form is needed to train the neural network for subsequent classification and/or deduction beyond its domain of training. There has also been active research aimed at extracting the embedded knowledge in trained networks in the form of symbolic rules. This serves to identify the attributes that are needed in performing classification. Many internet applications that need to be classified do not have explicit symbolic rules. One example of such is the internet user classification problem where abundant data is available although no explicit rules can be easily formed. Unlike fuzzy sets, the main use of neural nets in internet applications are in the area of rule extraction and clustering. Lately, game players demand a more realistic and changing environment and they are no longer satisfied to play in situations generated from preset rules or a variation of such. The adaptive ability of neural network to react to new situations and generalize training sets is an ideal match to extend internet games beyond the traditional settings and can help to create a new generation of games that adapt to different play styles.

### 3. Information retrieval and eCommerce applications

Information retrieval over the internet has always been the key application of internet. It is a challenging problem as the data structure is typically not available to the information seeker. Much of the work has focused on how to do a more effective search as well as mining web pages. The need to recover information from system with no clear structure is an ideal task for neural network. Use of fuzzy semantic to extend the search scope for a better result has also been conducted. eCommerce has been the main interest of internet applications and various new techniques have been researched in recent years to solve emerging problems like automated help in finance process, personalized product recommendation and self-guided shopping process. Numerous neural network and fuzzy logic based designed have shown to be helpful in all these eCommerce processes.

#### 3.1. Web content mining and search

As one of the important fields in data mining, Web mining refers to the use of data mining techniques to retrieve, extract and evaluate information from Web documents and services. Web mining typically addresses semi-structured or unstructured data, e.g., Web and log files, and are often represented by imprecise or incomplete information. This implies that neural networks are a useful instrument to mine knowledge from such data. We have seen the use of neural network in web page mining problem and the result appears to be promising though higher precision rate is still not quite attainable (16, 17, 128, 131). An approach in Figure 2 using RBF( Radial Basis Function) neural network for classification is more efficient than other available classifiers. When testing with 1000 Web pages from several popular web sites, RBF neural network can classify Web documents into five categories – News, Sports, IT, Education, Other - with 80 percent accuracy and has 10 percent higher than BP ( Back Propagation ) model.

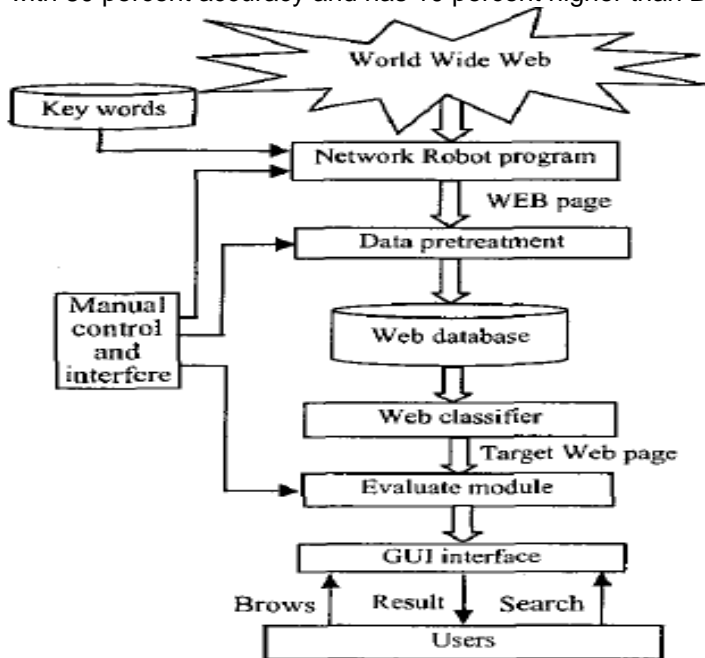


Figure 2 Web Classification Mining System Model based on RBF neural network (17)

Fuzzy logic was used in web mining because fuzzy logic is an ideal tool to handle approximate or vague notions that are inherent in many information retrieval (IR) tasks (23, 29, 30, 47, 71, 81, 96, 97, 115, 126). Most of the search engines search for data in their databases by using the exact words in the user query. Due to the fact that more users cannot articulate the search with the intended keywords, search engines fail to return the desired results from time to time. It is found that the user usually skims only through the first page of the search results; hence, it becomes crucial to output the best possible result to the user through their individual perspective. Fuzzy and Neural Network aided search engine can provide more relevant result to the users' query.(3, 18, 20, 36, 45, 54, 62, 66, 77, 106, 119, 129). It is especially true

when the semantics is taken into design consideration. This is a natural consequence as more relevant information is being extracted added to this process through the generalization feature of fuzzy logic and neural network. Fuzzy logic uses fuzzy rules to tracks the users and makes the decision about their interests. Neural network, once trained, can be used in making an optimal search result. The objective is to retrieve documents that satisfy a given query subject to a specific topic.

Figure 3 represents a search engine architecture utilizing fuzzy logic in interpreting the semantic of the search keywords. Here this search engine enhances the search with fuzzy linguistic search (FLS) or the Fuzzy Numeric Semantics (FNS) search modules. The Fuzzy linguistic search would extend the search to semantically related words based on the keywords entered in the user query. The FNS search technique searches for data that are contain keywords semantically related through the fuzzy linguistic-to-numeric mapping in the chosen application domain. Take for example, the search for high vitamin A foods is translated into a search on food that has over certain International Units of Vitamin A. This increases the efficiency of the search engine by as much as 50% in many cases.

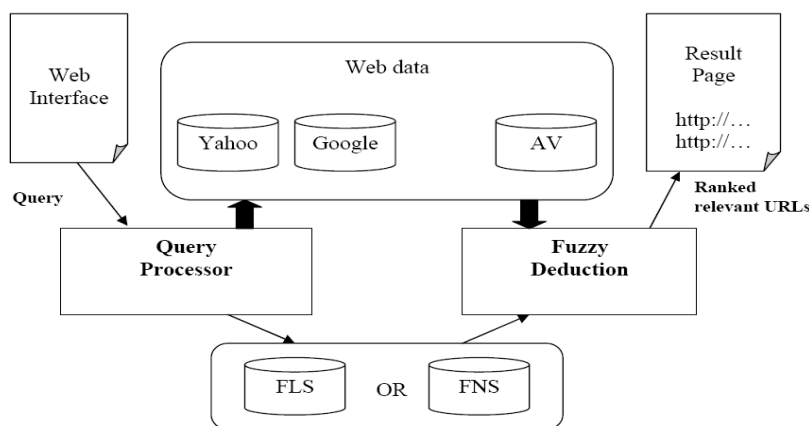


Figure 3 Perception-based search engine with fuzzy semantic (20)

Although fuzzy logic and neural network have been used extensively in various web applications, numerous areas remain open for researchers to bring these soft computing methodologies to solve other matching problems. This list includes:

- a) using fuzzy logic to provide frequency mapping and an explanation in search engines.
- b) enhancing search engines with fuzzy logic to reliably engage in searches for ideas or concepts which extend beyond mere word or word combination matches.
- c) improving existing search engine performance with fuzzy logic.
- d) using neural networks to resolve the failure of linear-sequential logic. systems to determine if the information being asked for does NOT exist in the databases which are available.
- e) using fuzzy logic to facilitate a more useful and efficient tagging system.
- f) applying fuzzy logic to current indexing schemes to enable search engine functions to operate semantically, particularly with respect to the various kinds of learning objects commonly archived in meta-databases, such as those extensively used in distance learning applications.

With the linguistic reasoning and the potential capability to deduce similarity among objects, it is expected that fuzzy logic will be able to offer promising solution to most, if not all, of the above open issues in the near future.

### 3.2. eCommerce

In banking and financial industry management of accounts and information involves heavy reliance on the use of networked computerized data systems. In AEC (Architecture, Engineering and Construction) projects, a large number of members have to work together on design and production of complex products. These team members may be geographically dispersed. Hence computer supported

collaborative work is important in the design process. IT tools are needed that enable collaboration among the team members. Risk assessment is an important area in such complex projects. It is often carried out individually by the various disciplines involved in the project. It is important to have tools available which will enable risk assessment to be undertaken collaboratively. Neural network and fuzzy logic can be used to help assess the risks and correlate information from a variety of technological and database sources to identify suspicious account activity (2, 32, 48, 55, 99, 123, 124).

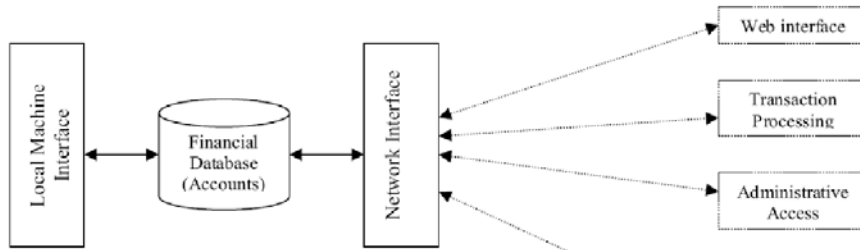


Figure 4: Access Mechanisms to Account (2)

In a typical finance process, the system needs quickly recognize underlying complex patterns in data and use them to assign risk levels to particular sets of transactions and activities observed in the environment of a financial institution. The scheme like that illustrated in Figure 4 proposes an activity monitoring and analysis tool based on the ability of neural networks. These systems are major sources of information that can be used in the identification and prevention of financial fraud like illegal/unauthorized transfer of funds by external and internal entities.

Finding a matching product among large product space and satisfying buyer's preferences is one of the essential activities in e-commerce. In online market, a customer specifies his/her product specifications while purchasing a product. At the same time, the customer wants to have the information about the popularity of the product. Neural network and fuzzy logic can be used to compare and rank the products based on customer's own preferences and on the information from the internet about the products.( 7, 14, 19, 25, 26, 34, 49, 51, 56, 61, 63, 68, 75, 78, 87, 100, 101, 102, 110, 122, 134).

Many consumers purchase multi-functional products according to their individual preferences. Consumers are normally aware of their basic needs, but often have little or no idea of product types, functions, usage and terminology with important information. Figure 5 presents a method to translate customer needs into applicable alternative combinations for the products of customers' desire. The theory of the analytic hierarchy process is utilized to evaluate the importance of customer needs, which are generally rated and described by qualitative expressions. When customers make a purchase for a multi-functional product, customers are normally aware of their basic needs but often have little idea of types, function, usage and terminology of the desired product. A fuzzy inference model is employed to establish the relationship between customer needs and alternatives for a multi-functional product. This product customization evaluation model is established for a product consisting of multi-features and their corresponding alternatives. By means of fuzzy inference rules, consumer needs can be translated into ideal combination of alternatives. Furthermore, fuzzy numeric variables are used here to quantify linguistic variables as well as the intensity of consumer's needs. Also, the weight of customer needs can be obtained using the analytic hierarchy process (AHP) with the help of fuzzy membership functions.

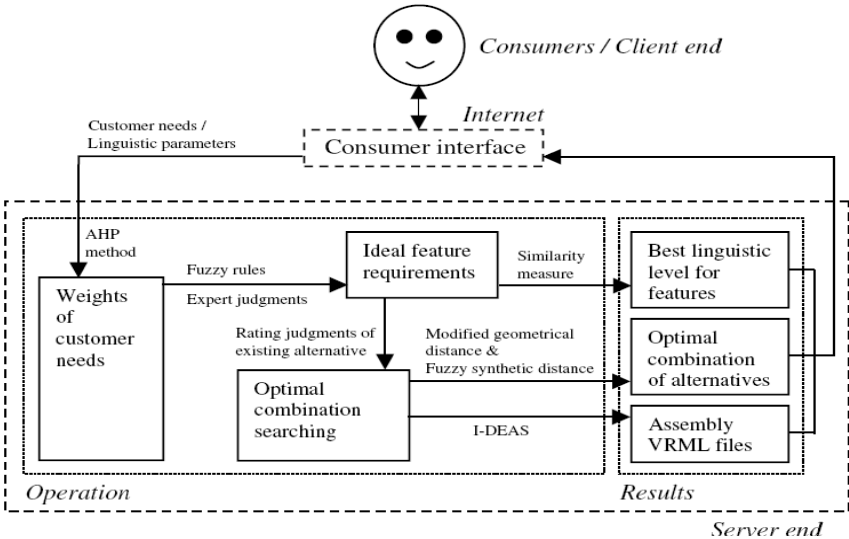


Figure 5: Analytic Hierarchy Process with fuzzy inference (49)

#### 4. Classification of web data and users

##### 4.1. Internet user classification

Internet traffic engineering and network management can greatly benefit from a reliable classification of internet users. The potential of different artificial Neural Network and fuzzy logic models for classifying Internet users based on their hourly traffic profile can be advantageous in various traffic engineering tasks and help in the selection of suitable trafficking plans (12, 83, 84, 88, 105, 109).

Figure 6 shows that logs from the web server can provide clues about the users of the website and that these logs could be used to gather information about the behavior of the users. These behavior attributes could be used to classify the different users and tailor the website based on these classifications. Although other methods succeed in grouping users according to their diverse Web interests, they lack the ability to adapt to changes in those interests over time. Adaptive resonance theory (ART1) offers an unsupervised clustering approach that adapts to change in users' access patterns over time without losing earlier information.

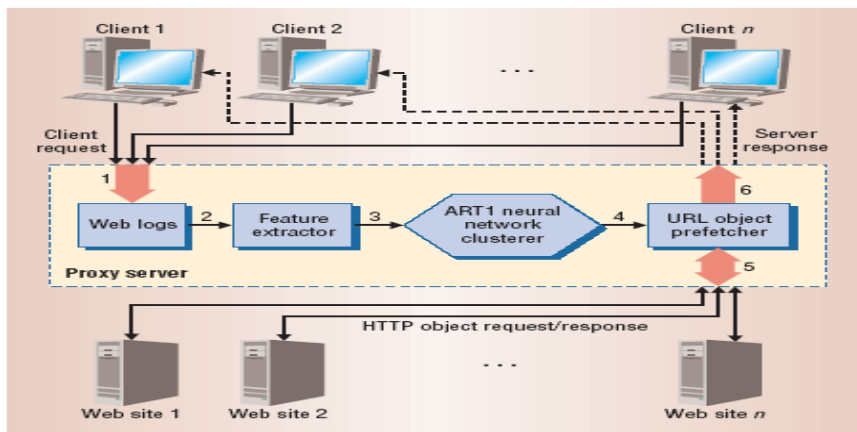


Figure 6: ART1-based clustering and prefetching architecture (105)

##### 4.2. Webpage classification and recommendation

Web documents that are either partially or completely duplicated in content are easily found on the Internet these days. These documents not only create redundant information on the Web, which take

longer to filter unique information and cause additional storage space, but also degrade the efficiency of Web information retrieval. Neural network and fuzzy logic can be used to detect similar HTML documents on the internet (93, 113, 127).

Figure 7 shows how blocks of texts in the HTML document is parsed and broken down into hierarchical contents based on the location of the blocks in the document. By using predefined fuzzy clusters, feature vectors of similar documents are used to find the similarity.

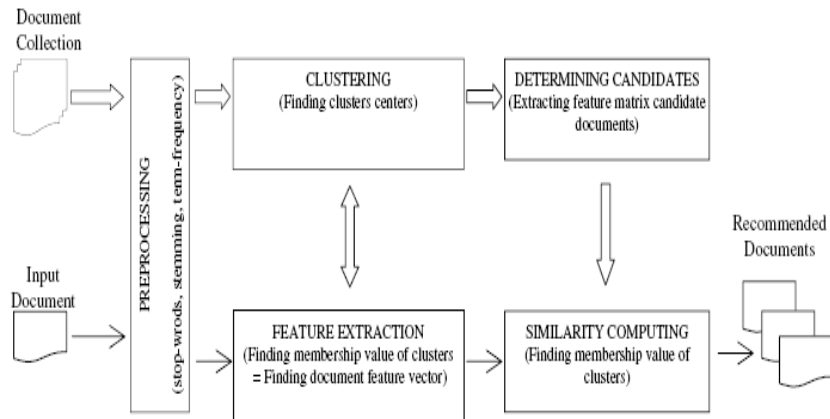


Figure 7 Webpage classification system architecture (93)

The Google's page rank algorithm and most of the other page ranking algorithms are designed to serve general purpose search engines. A ranking system that uses neural network and fuzzy logic to design a page ranking system is capable of doing a customized ranking. This customized ranking system intends to adapt neural network model to make it particularly suited for page ranking problem. The system allows automatic customization based on training examples or particular needs of the user (11, 33, 37, 38, 39). Figure 8 shows Graph Neural Networks (GNN) model that is capable of processing different types of graphs. Here, the Web is considered as a graph with each nodes denote pages and arcs denote hyperlinks. Web page ranking algorithm is fundamental algorithm for search engines. This helps to provide web page rank. This rank helps to sort out web pages returned in response to user queries. The main underlying idea of this approach is that the concept of "page importance" is not absolute but depends on the particular needs of a search engine or a user.

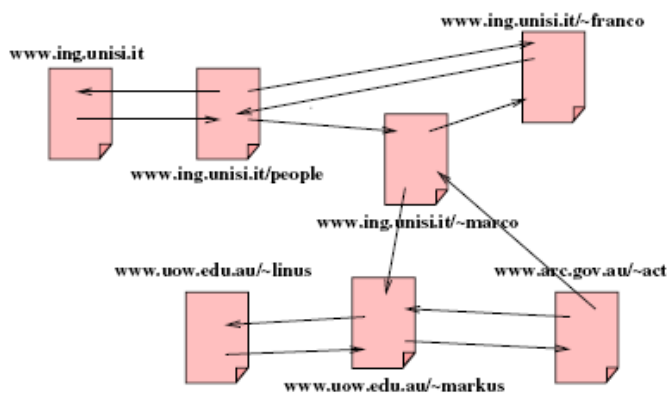
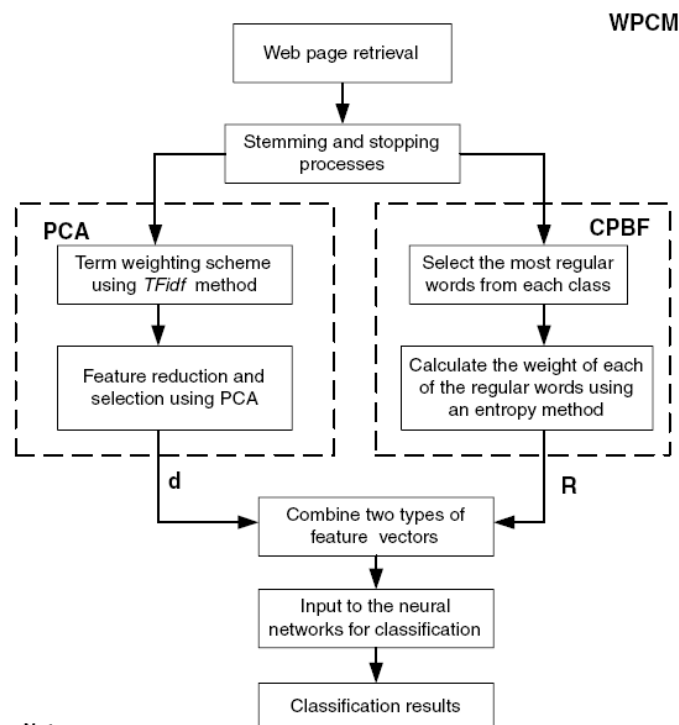


Figure 8 Graph Neural Networks (GNN) model. (39)

The Web information age has brought about a dramatic increase in the sheer amount of information. Hence, not surprisingly, there may be overwhelming information when searching and browsing the WWW. One of the most promising and potent remedy against this is personalization. Personalization aims to customize the interactions on a website depending on the user's explicit and/or implicit interests and desires. Web personalization has become more of a necessity than an option. One of the most successful examples of personalization comes in the form of web recommendation systems using neural network and fuzzy logic (23, 82, 86).

Website classification is popular in the information processing areas. The World Wide Web (WWW) is an information resource, whose full potential may not be realized unless its content is adequately organized and described. This applies not only to the vast network of web pages, but also users' personal repositories of web page bookmarks. However, due to the natures of immense size and dynamic content of the web, manual categorization is not a practical solution to this problem. There is a clear need for automated classification of web content. However it is difficult to increase the accuracy of website classification due to the diversity in the web pages' content. Neural network and fuzzy logic can be used to filtering the data on the web for classification (6, 5, 9, 21, 31, 40, 44, 46, 53, 57, 60, 64, 72, 91, 92, 103, 104, 107, 121, 125).

Figure 9 show the process of classifying a news web page using the web page classification method (WPCM) consists of web news retrieval process, stemming and stopping processes, feature reduction process using web classification process using error back-propagation neural networks. The average results of classifications base on WPCM are 87.82%. Although the WPCM approach provides an improvement of the classification results, the time taken to classify the web news page is significantly longer than other approaches.



**Note:**

**d** is a feature vectors from the PCA

**R** is a feature vectors from the CPBF

Figure 9 Web page classification using WPCM (107)

## 5. Other applications

### 5.1. Video Game

The market of video games is getting bigger and bigger throughout the recent years and it has become a facet of many people's lives. This market continues to expand as of now. In addition to its big player base, video games carry perhaps the least risk to human life of any real-world applications. They make an excellent test bed for techniques in artificial intelligence and machine learning. Machine learning is one of the most compelling and yet least exploited technology in the video game industry. This technology using neural network and fuzzy logic can greatly enhance video games, make video games more interesting and realistic, and to build entirely new genres (22, 58, 70, 73, 114). Figure 10 describes a novel game built around a real-time enhancement of the NeuroEvolution of Augmenting Topologies method (NEAT). Real-time NEAT (rtNEAT) is able to complexity neural networks as the game is played, making it possible for agents to evolve increasingly sophisticated behaviors in real time. Robot game agents (represented as small circles) are depicted playing a game in the large box. Every few ticks, two high-fitness robots are selected to produce an offspring that replaces another of lower fitness. This cycle of replacement operates continually throughout the game, creating a constant turnover of new behaviors.

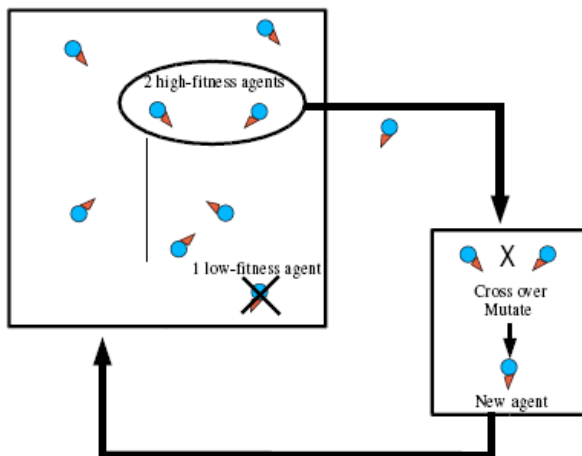


Figure 10 The main replacement cycle in rtNEAT (58)

### 5.2. Internet traffic Identification

Internet traffic identification is an important tool for network management. It allows operators to better predict future traffic matrices and demands, security personnel to detect anomalous behavior, and researchers to develop more realistic traffic models. A sophisticated Bayesian trained neural network is able to classify flows, based on header-derived statistics and no port or host (IP address) information, with up to 99% accuracy for data trained and tested on the same day, and 95% accuracy for data trained and tested eight months apart(10). Further, the neural network produces a probability distribution over the classes for a given flow. By providing high accuracies without access to packet payloads or sophisticated traffic processing this technique offers good results as a low-overhead method with potential for real-time implementation (4, 10, 13, 24, 35, 59, 67, 85, 108, 116, 130).

### 5.3. Miscellaneous

Ontology is the conceptualization of a domain into a human understandable, machine-readable format consisting of entities, attributes, relationships, axioms. It is used as a standard knowledge representation for the semantic web. However, the conceptual formalism supported by typical ontology may not be sufficient to represent uncertainty information commonly found in many application domains due to the

lack of clear-cut boundaries between concepts of the domains. To tackle this type of problems, one possible solution is to incorporate Fuzzy Logic into ontology to handle uncertainty data. Traditionally, fuzzy ontology is generated and used in text retrieval and search engines. However, the manual generation of fuzzy ontology from a predefined concept is difficult and tedious task that often requires expert interpretation. So, automatic generation of concept hierarchy and fuzzy ontology from uncertainty data of a domain is highly desirable. Fuzzy ontology can be incorporated to ontology to represent the uncertainty of the information. In order to tackle this problem fuzzy logic researchers propose a solution for that is known as the Fuzzy ontology generation framework which is basically used for automatic generation of Fuzzy Ontology of uncertainty information (15, 117, 118, 133).

The volume of e-mail that we get is constantly growing. We are spending more and more time filtering e-mails and organizing them into folders in order to facilitate retrieval when necessary. The rate of unsolicited (spam) e-mail is also rapidly increasing. It may vary significantly in content, from get-rich and selling items, to offensive e-mails and pornographic sites. Most modern e-mail software packages provide some form of programmable filtering, typically in the form of rules that organize mail into folders or dispose of spam mail based on keywords detected in the header or body. However, most users avoid the customizing software. In addition, manually constructing robust rules is difficult as users are constantly creating, deleting and reorganizing their folders. Even if the folders remain the same, the nature of the e-mails within the folder may well drift over time. The characteristics of the spam e-mail also change over time. Hence, the rules must be constantly tuned by the user. That is not only time consuming but also error-prone. A system that can automatically learn how to classify e-mails into a set of folders and filter spam e-mails is highly desirable. Neural network and fuzzy logic can be successfully used for automated e-mail filing into mailboxes and spam mail filtering (27, 90, 135). In (135) the success of filtering rates of neural network is 96.2% which is much better than the Bayesian method at 91.72%.

Rapid development of Internet technologies, remotely accessing and operating medical applications, ubiquitously, is becoming increasingly possible. So the virtual medical advice may be planned for the future, using an internet link and a fuzzy logic algorithm to replace the "doctor-patient" direct relations. But in this type of application, uncertainty can arise at various levels, and that can be solved using fuzzy logic algorithm. So we address the representation of uncertainty and the decision process through the use of fuzzy algorithms, in order to replace a medical consultation (1, 28, 52, 69).

Facial expressions contribute fifty five percent towards the meaning of a human interaction. Understanding facial expressions is an important requirement in the development of human computer interaction systems. Facial expressions are qualitative and cannot be expressed in terms of a mathematical model. A system framework that uses fuzzy logic to recognize facial expressions in video sequences can be useful for this purpose. Given a video as input, the system uses image processing techniques to determine MPEG4 Facial Animation Parameters (FAPs). A fuzzy rule base interprets a set of FAPs to constitute a particular facial expression (74, 76, 80, 136).

## **6. Conclusion**

We see a growing interest in using fuzzy logic and neural network for solving internet applications in the past 5 years. The inherent capability of neuro-fuzzy techniques in handling vague, large-scale, and unstructured data is an ideal match for internet related problems. Earlier research tends to focus on how to extract needed information from unstructured internet data. Lately, we have seen the use of neuro-fuzzy methodologies in building a structure web. Semantic web is one example of such. The notion of a structure web can be made more realistic when the concept of fuzzy logic is employed since web data tend to be fuzzy in nature. We expect to see an integration of soft computing techniques in Semantic web methodologies in the near future. Genetic algorithm for internet application should also become more popular as internet applications get larger in scale.

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