# Recent Patents on Computational Intelligence

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**Abstract:** The field of computational intelligence is the successor of artificial intelligence. It combines elements of learning, evolution and fuzzy logic to create programs that can exhibit, to some degree, intelligent behaviour. The last few years have seen a growth in theoretical and practical developments in this field. This paper presents an extensive survey of the latest patents in the domain of computational intelligence. It discusses and summarises some of these latest developments in terms of patents. The patents are categorised by their domain of application: Artificial Neural Networks, Fuzzy Logic and Evolutionary Algorithms and further classified by the application area.

**Keywords:** computational intelligence, artificial intelligence, artificial neural network, fuzzy logic, evolutionary algorithm, genetic algorithm, patents.

**Short running title:** Computational Intelligence Patents

## 1 Introduction

Computational Intelligence (CI) combines learning (Artificial Neural Networks), evolution (Evolutionary Algorithms), and Fuzzy Logic, in order to create intelligent behaviour. During the past few years, the field has benefited from an increment on research bringing new applications and ideas that have been patented. Novel, state-of-the-art and interesting patents are discussed. A survey on these ideas and applications within the three key areas of computational intelligence is presented:

1) Artificial Neural Networks (ANN). They can be viewed as a computer system that is made up of several simple and highly interconnected artificial neurons. These neurons process information by their dynamic state response to inputs. They have the capacity of learning in either supervised (from examples) or unsupervised mode. They can either be used for function approximation, classification problems or clustering [1].

2) Fuzzy Logic (FS). This is a simple rule-based If-Then_Else approach for modelling. It provides a way for making decisions based on vague, imprecise or missing information extending crisp logic to allow truth to hold to degrees rather than binary values [2, 3].

3) Evolutionary Algorithms (EA). This technique is a random guided search process for very challenging problems that have large and complex search spaces. It is inspired from biological evolutionary mechanisms such as reproduction and mutation to create a population of solutions to a problem, which evolve over generations to produce near optimal solutions that solve sufficiently problems. A fitness function evaluates how good every individual is (solutions to the problem) and the better solutions have a stronger chance of reproducing in to the next generation [4]. Other methods of reproduction include genetic operators such as crossover and mutation.

Many recent current applications of CI techniques for solving real world problems can be found in [5, 6, 7]. A patent is a legal document that entitles the creator/holder the right to prevent anyone from using or selling the invention.

This paper is divided in five sections. Section two discusses patents developed in the area of Artificial Neural Networks. Section three the presents some of the patents that use Fuzzy Logic. Section four explores patents developed in the field of Evolutionary Algorithms. An overview of the patents is presented in section five. Current and future developments are noted in section six.

## 2 Artificial Neural Networks

The field of artificial neural networks stagnated in the 1960$^{s}$ after it was proved that the Perceptron single layer neural network ([8]) was not capable of solving non linearly separable problems ([9]). It was not until 30 years later that the backpropagation ([10]) algorithm was proposed. This algorithm is capable of handling non linearly separable data with the aid of a hidden intermediate layer between the input and the output layers. Since the emergence of this method there has been an increase in research in this field. In this section, a

survey of recent ANN patents is arranged according to their applied and theoretical nature.

## 2.1 Applied

### 2.1.1 *Networking*

Network security encompasses a broad range of areas and a plethora of applications that aim to enhance and further tighten security protocols and measures. Such a method, devised by [11], focuses on authenticating operators of devices such as computers, ATMs etc. Authentication involves two processes: monitoring the user's operation of a keyboard (enrolment) and then comparing the enrolment data with features of the login attempt. The ability of ANNs to correctly classify samples that hold quantities of variation is crucial to this application since this reduces the chance of rejecting a valid user who mistypes login details. The learning vector quantisation neural network is chosen for its small storage requirements and trained with authentic users and failed login attempts.

### 2.1.2 *Business Intelligence*

Artificial neural networks are important to companies because they can model relationships and form predictions for challenging business models where traditional statistical methods struggle

A method for evaluating customer value to guide loyalty and retention schemes was patented by [12]. Many resources can be inefficiently utilised by adopting the same approach for loyalty and retention schemes to all customers, regardless of their potential revenue generation for a business. Deciding on which customers are more valuable to a business, in terms of revenue, allows marketing techniques to be identified. A hazard function provides a probability of a customer's termination of service which assists with determining when the customer is likely to terminate a contract, usually towards the end. Customer lifetime value is a measure for profit generating potential of a customer that is intended for identifying high-value customers. A multilayer feed-forward neural network is trained to model a hazard function which outputs a customer's hazard value and at a particular period during a contract. A set of hazard functions are generated and k-means clustering is applied to identify patterns in hazard functions between customers.

### 2.1.3 *Server / Database*

An artificial neural network to monitor real time performance of a database was developed by [13]. This approach overcomes adaptability issues with existing solutions that employ static rules. The performance is classified with an ANN and if the performance breaches a defined limit, a human operator is informed by email or similar means. Databases form a critical component of many businesses where many users, often customers, require simultaneous access. This method is able to monitor the dynamic behaviour of a database by updating the artificial neural network with the back-propagation algorithm. An example of a network input consists of data such as user connection information, IO utilization and CPU utilization of each of the users.

### 2.1.4 *Engineering*

A method for detecting usage anomalies in electrical devices which verifies if the device is under normal operation was developed by [14]. This has been invented for Matsushita Electric Works, Japan and an example apparatus that is demonstrated is an air conditioner. Acoustic and vibration sensors monitor the device and provide data that describes the operation. The signal data is then processed to identify key characteristics of a devices' operation. These characteristics are fed into a pair of unsupervised competitive learning neural networks with identical topologies. Each neural network performs the same function; they produce judgement values to determine the normality of device operation. The neural network operates in one of two modes: training or checking. The training mode learns the characteristics of the signals and the checking mode classifies the signals, thus checking for anomalies. By incorporating a switching unit, the pair of artificial neural networks are able to change modes according to the judgement result and evaluation criteria. When operation degradation occurs the artificial neural network's modes are switched to compensate for time-varying operation. For example, an air condition has very different operating characteristics during summer and winter. Misjudgements are avoided hence strengthening the reliability of classifications.

The problem of minimising power consumption of mobile devices, particularly mobile phones was tackled by [15]. Mobile phones operate in various modes during different operations (communication, idle etc.), which have dissimilar power requirements. An artificial neural network is trained to model an operator's behaviour from samples of mobile phone events. Events are recorded against time segments, for example, a phone call is received at 4am. The mobile phone is able to predict the operator's usage behavioural and configure the phone's power saving parameters according to their behaviour profile. If the operator's behaviour changes significantly

then small alterations are applied and the network is retrained.

#### 2.1.5 *Medicine*

An ANN for the diagnosis and prognosis of diseases from conditions and also to verify diseases from biological samples was developed by [16]. An artificial neural network has a single input layer that accommodates patient conditions and biological samples. A hidden layer defines rule bases for the diagnosis and identification of diseases. This method adopts an evolving connectionist system (ECOS) to form an evolving fuzzy neural network program. The ECOS component of this method aims to adapt the rule base according to the correlation between the different input types.

The problem of deriving the most effective pressure for continuous positive airway pressure (CPAP) treatment of obstructive sleep apnoea was tackled by [17]. The effects of this condition are pauses in breathing during sleep. Determining the most effective configuration of CPAP involves running an overnight test on patients, which is time consuming and laborious. Artificial neural networks are the most suitable method here because of the non-linearity of the problem and the complex behavioural processes.

#### 2.1.6 *Environmental*

This encompasses patents applied within ocean environments and also geology.

A method for predicting water clarity at varying depths in oceans was patented by [18]. This is intended for a variety of ocean applications that do not depend on upon satellite imagery or dynamic climatology models. The method uses an artificial neural network that is trained with water measurements: temperature, salinity, tidal information, water depth, and sediment data to produce an output of the water clarity, which is measured as optical attenuation. A gradient search technique is used to reduce the mean square error between of clarity measurements. The artificial neural network utilises an additional algorithm that incorporates satellite imagery when the sky is clear.

An ANN for electromagnetic geophysical surveying was used by [19]. An electric or magnetic field is transmitted into the earth's subsurface and the electric and/or magnetic fields generated as a result from this are measured at the surface. An initial model of the earth's subsurface is known and updated by inversion processing of the resultant electric/magnetic fields. The aim of modelling of features such as the spatial distribution of resistivity is to enhance the prediction and identification of oil and gas fields as well as modelling them. The method for inversion processing uses an artificial neural network to classify the responses which assists in improving the initial model of the subsurface.

#### 2.1.5 *Other*

An application of an ANN for odour discrimination using binary spiking neural network was patent by [20]. The ANN is part of an electronic nose system that includes olfactory pattern classification capable to handle many sensor inputs in a noise environment while recognising a large number of potential odours. The spiking neural network processes a large quantity of inputs from a chemical sensor array and distinguishes between different odours.

### 2.2 Theoretical

A method for evolving an ANN is described in [21]. A generic method is proposed that uses a genetic algorithm to evolve characteristics of an artificial neural network, such as an indirect mapping of the topology.

## 3 Fuzzy Logic

Fuzzy Logic has being used in many control applications ranging from break systems to washing machines. The most commonly used is type one, but current trends involve a more refined type two [22, 23]. Patents on applied and theoretical work are revised in this section.

### 3.1 Applied

#### 3.1.1 *Networking*

A method for tracking employees' locations via mobile phones for the purposes of: personnel verification monitoring of arrival/departure times of field based employees etc. was devised by [24]. An algorithm that is coined the term 'fuzzy logic algorithm' calculates the degree of probability that individual is the assigned employee in a verified location. The 'fuzzy logic algorithm' is described throughout the patent in a manner that suggests that fuzzy logic is analogous to probability – this is a misconception. The inputs to this algorithm are the individual's location (GPS), signature of recipient and service provider and a video/picture of the recipient.

A method for tackling the problem of denial of service and distributed denial of service HTTP "page" flood attacks was proposed by [25]. An attack is identified as an anomaly and prevented by filtering the attack. An

anomaly detection engine learns traffic parameters of a normal system that is not under attack. During operation the traffic parameters are analysed by the detection engine and their correspondence with historical parameters are checked. A combination of fuzzy logic and statistical thresholds are used. The detection engine is able to tune itself according to the normal traffic behaviour. This is achieved by recreating the input membership functions according to the continuous base lines every hour.

Fuzzy logic as well as forward chaining inference engines are used by [26] for intrusion detection systems. Information is gathered from sensors throughout the network and are analysed to provide a threat rating, which is then used by an alert system. This is a particularly well suited technique for intrusion detection because the rule base can be adapted very quickly, which is especially useful in highly dynamic environment where new techniques are discovered daily.

A method for an intrusion detection system that is based on fuzzy logic has been patented in [27]. This is aimed towards directed diffusion-based sensor networks and it works by analysing information from sensor nodes. The intention is to prevent and cope with damage caused by intrusions by analysing the characteristics of the network.

#### 3.1.2 *Business Intelligence*

Yahoo Inc. applied fuzzy logic to forecast and predict the performance of on-line advertisements [28]. A detailed method for determining the fuzzy sets is presented. A ranking score is calculated for an advertisement and a mapping between the advertisement and the query is assigned. Analytics are retrieved from the associated query and advertisement and used to construct a fuzzy set. An average forecasted advertising metric value is produced from the ranking score and the analytics data.

A method for monitoring status and performance indicators of information technology, such as percentage of CPU and low-level hardware up to enterprise level applications and their relation to business processes and business services was developed by [29]. Visual feedback is used to alert users. A phased multi colour display shows indicator status and monitored object status coloured by a scheme. This scheme is determined by applying fuzzy logic to the raw monitored indicator values and derived or propagated status attributes and by triggering events derived from fuzzy logic based analysis of raw measured indicator values and derived or propagated status attributes and raw events raised outside the apparatus.

A system for delivery assets based upon on the recipient's interests, for example, selecting an advertisement for a user of set top box on a cable network was developed by [30]. The system learns from user inputs to develop evidence that can characterize multiple users of the user equipment device audience. The system then processes current user inputs to match a current user to one of the identified users of that user equipment device audience. Fuzzy logic is used to improve development of the user characterizations, as well as matching of the current user to those developed characterizations.

#### 3.1.3 *Server / Database*

A method for autonomously tuning the number of threads in application server at runtime was developed by [31]. A system dynamically monitors and measures behaviours of an application server. These measures are fed into a fuzzy control model. The results derived from the fuzzy control model are then used to adaptively tune the number of threads in the application server. The process is continually executed in a feedback-loop manner providing continuous optimal performance.

Another database related patent using fuzzy logic was developed in [32]. The authors propose a method of improving the information search speed. Information is matched against records in a database by using fuzzy matching. The process comprises extracting characteristics from the sample, and using those extracted characteristics as indexes to address a lookup table. Each row within the lookup table points to an individual record occurrence list which contain details of not only the stored records from which the given characteristic can be extracted, but also those records having an extracted characteristic which are within a defined proximity to the said characteristic. Characteristics are extracted from the sample record, and a given stored record is identified as being a possible match with the sample if it appears in a required number of record occurrence lists.

#### 3.1.4 *Engineering*

Fuzzy logic is utilised in [33] to control an RF amplifier and associated tuner for continuous self-optimization and automatic load matching. The patent claims that the system is capable of at least doubling the battery life of a battery-powered transmitter.

A fuzzy logic based method for diagnosing malfunctions on a charge motion control valve coupled to an intake manifold of an internal combustion engine is discussed on [34]. The method includes: commanding the valve to at least one of close and open; determining a pressure range using fuzzy logic based on a mass of air flowing into the intake manifold and a temperature of the air flowing into the intake manifold; determining a change in absolute pressure of the intake manifold; comparing the change in absolute pressure to the pressure range; and diagnosing a malfunction of the valve when the change in absolute pressure is within the pressure range.

#### 3.1.5 *Other*

A method for searching text in data files has been proposed in [35]. The method facilitates the search of commonly found text in two text files. The method comprises a preliminary step of preparing at least the first file by (a) dividing the first file into a series of data packets having a predetermined size, and identifying packet addresses in the file, (b) combining each packet address with a digital signature that defines one of three fuzzy logic states, namely true, false and indeterminate. This is the result of a combinatorial computation on data from said file; where after said method comprises performing an actual search for a common extract by (c) comparing the fuzzy logic states combined with each packet address of the first file with fuzzy logic states determined on the basis of data from the second file, and (d) removing from the common extract search the respective address pairs from the first and second files that have the respective logic states true and false or false and true, and retaining the other address pairs that identify data packets that may comprise the common extract.

An email classification system using fuzzy logic was proposed in [36]. Emails are classified by generating a fuzzy membership function based on calculated weighted factors related to the persons identified in the "From;", "To:" and "cc:" fields of the email together with the persons identified in emails already present in the folders of the user's email system. A fuzzy membership function is used to allocate the email to the folder whose emails most frequently identify the persons identified in the email in question, in the roles specified for those persons in the email in question, and based on the distribution of those persons among folders.

### 3.2 Theoretical

A fuzzy logic system for processing type-2 fuzzy logic sets was proposed in [37]. The system comprises a fuzzification module for receiving an input, a rules module for storing rules to be applied to the input to generate fuzzified data, a processing stage for processing the output from the fuzzification module to generate processed data: and a defuzzification module for generating a crisp output value from the processed data. The rules module has fuzzy sets, each fuzzy set having an associated first multi-dimensional geometric object which has a surface formed of one or more connected planar polygons. The processing stage generates, from the fuzzified data, a model of a further multi-dimensional geometric object comprised of a number of planar surfaces having one or more connected planar polygons. The further multi-dimensional geometric object has a geometric centre; and the defuzzification module is arranged to determine the geometric centre of the further multi-dimensional geometric object. The crisp output value comprises the geometric centre of the further multi-dimensional geometric object. This type of logic system could be used in devices such as washing machines, camcorders, lifts and in chemical plants and expert systems.

## 4 Evolutionary Algorithms

### 4.1 Applied

#### 4.1.1 *Networking*

A genetic algorithm was used by [38] to provide a system to allow network service-to-device mapping. The services are mapped onto best-suited smart items selected from a plurality of smart items of a sensor network. As part of the mapping, a deployment of the services onto the smart items is initiated. A sorted repair structure which indicates an ordering of services in accordance with a hierarchy of services based on a composition of services for one or more devices of a sensor network is determined. One or more derived generation structures are determined based on a genetic algorithm applied to the sorted repair structure. A service is mapped onto at least one device of the sensor network, based on one of the derived generation structures. As a result, users can achieve a desired result faster even when executing the deployment remotely or automatically.

Disclosed is a method and devise for analysing and predicting errors occurring in a broadcasting system is presented in [39]. The method analyses errors generated periodically in the broadcasting system and it predicts the occurrence dates of future errors, thereby preventing the errors from occurring. The method is composed of several elements including:

a-) an error data analysis step of analysing error data for errors occurring in the broadcasting system.

b-) a function derivation step of deriving a prediction model function by extracting error factors from the error data analysed in the error data analysis step.

c-) a function completion step of completing the prediction model function through a genetic algorithm using the error data generated for a given period of time, based on the prediction model function derived in the function derivation step.

d-) a prediction verification step of correcting a prediction error by verifying the completed prediction model function.

e-) a prediction step of predicting a specific type of error occurring in the broadcasting system through the prediction model function completed in the function completion step and the prediction verification step.

#### 4.1.2 *Business Intelligence*

A method to minimise the costs of technical and business processes was proposed in [40]. These processes are comprised of resources and tasks requiring resources. The optimization uses the best assignment of resources to tasks to minimise the costs. The authors use a genetic algorithm search agent to improve a population of possible assignments, each represented by a single variable length chromosome, where the chromosome upon which the genetic algorithm operates is a direct encoding of possible resource to task assignments and order. To manage the enlarged search space, this method uses the genetic algorithm with substring crossover to evolve the population towards better solutions. The assignments generated by this method satisfy all constraints.

#### 4.1.3 *Server / Database*

A genetic algorithm based method that can receive a set of candidate predictive data mining model templates and repeatedly transform them based on templates in the set and historical data was developed in [41]. A predictive data mining model can be selected based on how well the model meets an objective function. The genetic algorithm is used to search a space of predictive data mining model building parameters to determine an optimal predictive data mining model based on a score function corresponding to, for example, the accuracy of the selected predictive data mining model.

#### 4.1.4 *Engineering*

An intelligent 3D fixture design method, which can solve interference problems between each work piece, tool and fixture module to design optimal types, specifications and layouts of the fixture system was proposed in [42]. The design method is based on a parametric solid model of 3D CAD software, which uses a space vector to determine if interference exists, and the interference position of such, between the solid models of work pieces, tools and fixture modules. The method uses a genetic algorithm to search type and its design shape and position parameters of each fixture modules. This allows for the design of an optimal fixture system and related specification and layout.

A genetic algorithm is used in [43] for obtaining an optimum value of a plurality of gain values used in a brake liquid pressure control device for controlling a liquid pressure of a liquid pressure brake. An ensemble is constituted by a plurality of individuals (gain curve) existing in certain generation. The individual includes a plurality of genes (gain value). In the plurality of individuals constituting the ensemble, evaluation is performed regarding each of the genes and evaluation is performed regarding each of the individuals. An intersection object individual and an elite individual are selected based on each evaluation of the individuals. By these intersections or the like, the gene of the intersection object individual is changed and the individual is changed and transferred to the next generation. After a plurality of generations, non uniformity between the individuals is reduced and the optimum individual (gain aggregate) is obtained.

#### 4.1.5 *Other*

A global predictive monitoring system for a manufacturing facility using genetic algorithms is proposed in [44]. The system can be used in an integrated circuit (IC) device fabrication facility to monitor processing of semiconductor wafers. The system may include deployment of a swarm of individually separate agents running in computers in the facility. Each agent comprises a genetic algorithm and uses several neural networks for computation. Each agent may be configured to receive a limited set of inputs, such as defective machine data and WIP information, and calculate a risk from the inputs. A risk may be a value indicative of a production yield. Each agent may also generate a quality value indicative of a reliability of the risk value. New agents may be generated from the initial population of agents. Outputs from the agents may be collected and used to calculate projections indicative of a trend of the production yield.

### 4.2 Theoretical

A quantum based method for performing selection, crossover and mutation operations according to a genetic algorithm is proposed in [45]. Entanglement vectors generated by the entanglement operator of the quantum algorithm are processed by a wise controller implementing a genetic algorithm, before being input to the interference operator. This algorithm can be

implemented with a hardware quantum gate or with a software computer program running on a computer. It can also be used in a method for controlling a process and a relative control device of a process which is more robust, requires very little initial information about dynamic behaviour of control objects in design process of intelligent control system, or random noise insensitive (invariant) in measurement system and in control feedback loop.

An evolutionary optimisation method is proposed in [46]. In a first step, an initial population of individuals is set up and an original fitness function is applied. Then the offspring individuals having a high evaluated quality value as parents are selected. In a third step, the parents are reproduced to create a plurality of offspring individuals. The quality of the offspring individuals is evaluated by means of a fitness function, wherein selectively the original or an approximate fitness function is used. Finally, the method goes back to the selection step until a termination condition is met. The step of evaluating the quality of the offspring individuals consists in grouping all offspring individuals in clusters, selecting for each cluster one or a plurality of offspring individuals, resulting in altogether 3/4 selected offspring individuals, evaluating the 3/4 selected offspring individuals by means of the original fitness function, and evaluating the remaining - 3/4 offspring individuals by means of the approximate fitness function.

An algorithm development environment for solving a class of combinatorial optimisation problems is provided in [47]. Many practical real-life applications can be formulated as combinatorial optimisation problems. Over the years, there have been many well-known algorithms proposed to solve these problems. The effort in customising algorithms to fulfil a particular domain-specific application is still significant. Furthermore, conventional approaches towards codes generation and modification are tedious and thus inefficient. To address the need for rapid generation of algorithms that are efficient in solving a given class of real-life problems, embodiments of the present invention encompasses a hierarchical tree structure for managing a procedure modules library. Based on the preferred management and object-oriented design concept, users configure and generate a genetic algorithm via an intuitive graphical user interface. The goal seeking approach of customisation of the generated genetic algorithm can be easily carried out for solving various optimisation problems. This way, the efficiency of algorithm development is enhanced significantly.

A series of methods for performing genetic algorithm-based feature selection are provided in [48]. In certain embodiments, the methods include steps of applying multiple data splitting patterns to a learning data set to build multiple classifiers to obtain at least one classification result; integrating the at least one classification result from the multiple classifiers to obtain an integrated accuracy result; and outputting the integrated accuracy result to a genetic algorithm as a fitness value for a candidate feature subset, in which genetic algorithm-based feature selection is performed.

# 5. Overview

This section provides a summary of recent patents in the field of computational intelligence reviewed in this survey paper which are recapitulated in tables 1, 2 and 3. The different patents are organised by domain: artificial neural networks, fuzzy logic and evolutionary algorithms. Within these domains, they are farther categorised by: application or theoretical, country of origin and year of publication. Application areas included networking, databases, businesses, medicine, environment, control, optimisation and classification.

As it can be seen in table 1, 91% of the artificial neural network patents reviewed were application based and only 8% were theoretical ones. The vast majority of them were published in the US. This represents 50% of the patents reviewed were US based. Only 25% of them were published in Asia, and 25% in the EU. Most of them were published in 2008. This indicates a growth in the number of patents in the field.

Table 2 shows a similar pattern than the one in table 1 with 92% of the patents reviewed being application based against 8% of them being theoretical. Again, 50% of the patents were developed in the US with a total of 35% of them coming from the EU. The number of patents for 2007 and 2008 are pretty much the same which shows a stable pace.

A much more varied output can be seen over patents involving evolutionary algorithms in terms of theory and application. Application related patents represent 63% against 37% for theoretical ones of the reviewed patents. Only 18% of the patents were developed in the US against 36% in the EU and 45% in Asia.

| Ref | Type | Area | Country | Year |
|---|---|---|---|---|
| [11] | Applied | Network | GB | 2007 |
| [12] | Applied | Business | US | 2008 |
| [13] | Applied | Database | HK | 2008 |
| [14] | Applied | Engineering | JP | 2008 |
| [15] | Applied | Engineering | US | 2008 |
| [16] | Applied | Medicine | NZ | 2008 |
| [17] | Applied | Medicine | US | 2008 |
| [18] | Applied | Environment | US | 2006 |
| [19] | Applied | Environment | US | 2008 |
| [20] | Applied | Other | US | 2008 |
| [21] | Theory | Optimisation | HU | 2008 |

*Table 1: Artificial Neural Network based patents*

| Ref | Type | Area | Country | Year |
|---|---|---|---|---|
| [24] | Applied | Network | US | 2007 |
| [25] | Applied | Network | IL | 2008 |
| [26] | Applied | Network | US | 2007 |
| [27] | Applied | Network | KR | 2008 |
| [28] | Applied | Business | US | 2007 |
| [29] | Applied | Business | US | 2007 |
| [30] | Applied | Business | US | 2008 |
| [31] | Applied | Database | AU | 2008 |
| [32] | Applied | Database | GB | 2008 |
| [33] | Applied | Engineering | US | 2008 |
| [34] | Applied | Engineering | US | 2007 |
| [35] | Applied | Other | FR | 2007 |
| [36] | Applied | Other | EG | 2008 |
| [37] | Theory | Type 2 | GB | 2008 |

*Table 2: Fuzzy Logic based patents*

| Ref | Type | Area | Country | Year |
|---|---|---|---|---|
| [38] | Applied | Network | DE | 2007 |
| [39] | Applied | Network | KR | 2008 |
| [40] | Applied | Business | US | 2007 |
| [41] | Applied | Database | IN | 2008 |
| [42] | Applied | Engineering | TW | 2008 |
| [43] | Applied | Engineering | JP | 2007 |
| [44] | Applied | Other | FR | 2008 |
| [45] | Theory | Control | IT/RU | 2006 |
| [46] | Theory | Optimisation | DE | 2005 |
| [47] | Theory | Optimisation | SG/US | 2007 |
| [48] | Theory | Classification | US | 2008 |

*Table 3: Evolutionary Algorithm based patents*

# 6. Current & Future Developments

The nature of the various CI techniques can be seen from the application areas. Fuzzy logic is commonly used for business and networking applications where the level of uncertainty is high. ANNs have a broad application area since they are able to model many complex processes present in the world. The trend in applications of evolutionary algorithms varies with little consistency. Despite their traditional applicability to problems of design and optimisation there are few patents that are imaginative and creative.

Future developments are envisaged to lie in the areas of high powered distributed computing, telecommunications/networking. Multi-core technology is becoming increasing more affordable and available, which opens up many new application areas that may have been previously unobtainable. Continual evolution of telecommunication protocols and infrastructure is likely to see a steady rate of patent publications. The arms race in the computer security world, especially networking, is not saturated and will continue to provide scope for new patents.

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