Chapter 1
Intelligent Decision Making Techniques in Quality Management: A Literature Review

Cengiz Kahraman and Seda Yanık

Abstract Intelligent techniques present optimum or suboptimal solutions to complex problems, which cannot be solved by the classical mathematical programming techniques. The aim of this chapter is to review the intelligent decision making literature in order to reveal their usage in quality problems. We first classify the intelligent techniques and then present graphical illustrations to show the status of these techniques in the solutions of quality problems. These graphs display the publishing frequencies of the intelligent quality management papers with respect to their countries, universities, journals, authors, types (whether it is a conference paper, book chapter, journal 1 paper, etc.)

Keywords Intelligent techniques · Quality management · Quality control · Tabu search · Fuzzy sets · Swarm optimization · Genetic algorithm · Ant colony optimization · Neural networks · Simulated annealing

1.1 Introduction

Traditionally quality is defined as the fitness for use. As the marketplace evolved, a modern view of quality stated that quality is inversely proportional to variability (Montgomery 2012). Quality control and improvement efforts aim to control the variability in order to ensure a continuous specific quality level. To this end, one of the most effective tools is statistical process control (SPC) which uses the approach of probability and statistics. The main aim of SPC is to monitor and minimize process variations. Statistical process control (SPC) is very useful in maintaining an acceptable and stable level of some quality characteristics (Guh 2003). SPC helps to first draw conclusions about the populations (or processes) by statistical inference process.

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Then, we decide diagnosing if the process is the deviated and take corrective actions if necessary.

The tools of quality management help us to draw the reasoning in order to make decisions for maintaining the quality. Intelligent decision making is defined as the computer-based artifacts performing human decision making task. Two main aspects of decision-making, diagnosis and look-ahead, may be adopted by the intelligent techniques such as expert systems, case-based reasoning, fuzzy set, rough set theories, neural networks (NNs) and optimization/evolutionary algorithms (Pomerol 1997). Intelligent systems either observe how people make the decision in the task at hand and reproduce the process in the machine or help to represent knowledge and reasoning (Pomerol 1997; Simon 1969, Newell and Simon 1972).

The advance of computer integrated manufacturing allowed automatic implementation of quality control tasks. The advanced data-collection systems (e.g. the machine vision system and scanning laser system) increased the rate and number of data input while decreasing the data collection costs. Quality problems commonly involve multivariate data that are not easy to model and/or optimize. Hence, computer-coded logic and algorithms are developed for the data analysis and decision making in quality control. Intelligent methods are extensively used for decision making in quality control together with data collection and analysis. Knowledge discovery with quality data has been achieved by various data mining techniques such association, clustering. On the other hand, decision-making tasks such as the description of product and process quality, prediction of quality, classification of quality and parameter optimization are achieved by intelligent techniques (Köksal et al. 2011). Fuzzy logic is used to capture the uncertainty and imprecision for the description of product and process quality. Rule-based experts systems provide a logical, symbolic approach for reasoning while neural networks use numeric and associative processing to mimic models of biological systems (Guh 2003). Both techniques help to predict or classify the quality. Evolutionary algorithms imitate the evolution process for the optimization of parameters in the quality control applications.

The aim of this chapter is to classify the intelligent techniques and to review their usage in the solution of complex quality problems. It provides an excellent review which summarizes the present status of quality problems solved by intelligent techniques.

The rest of the chapter is organized as follows. Section 1.2 classifies intelligent techniques. Section 1.3 presents a classification of literature of intelligent techniques in quality problems. Section 1.4 gives the results of literature review by some graphical illustrations. Section 1.5 concludes the chapter with future directions.

1.2 Intelligent Techniques

In this section, we introduce the intelligent decision making techniques which are used in the quality management literature.

1.2.1 Particle Swarm Optimization

Particle swarm optimization method is inspired from the social behaviour of biological swarm systems such as the movement of organisms in a bird flock or fish school. PSO method was developed originally by Kennedy and Eberhart (1995). It is a population-based computational method which achieves optimization by iteratively improving the candidate solutions. Particles, which are candidate solutions, form a population. The particles of the population are located in the search space according to the particle's position and velocity and the current optimum particles. The particles communicate either directly or indirectly with one another for search directions. As a result, the swarm is directed to the best solution. PSO has been used as an effective metaheuristic technique for various problem types of different applications. Some applications of the use of PSO method for different areas are reviewed as follows.

Image compression is an important tool which allows effective resource use. However, the quality of the compressed image should be assessed accurately. Optimal quantization tables which determine the compression ratio and the quality of the decoded images are selected using PSO method (Ma and Zhang 2013). A multi-objective model which also presents different trade-offs between image compression and quality is developed in their study. Real-time self tuning of autonomous microgrid operations of typical distributed generation units is needed for optimal power control strategy.

The parameter design problem for the lighting performance of a specific type of LED includes the settings of the geometric parameters and the refractive properties of the materials. Hsu (2012) proposed a hybrid approach for the selection of optimal design parameters using genetic programming (GP), Taguchi quality loss functions, and particle swarm optimization. The methodology helps to identify the key quality characteristics of a LED and outperforms the traditional Taguchi method in solving this multi-response parameter design problem.

Particle Swarm Optimization (PSO) is applied for real-time self-tuning of the power control parameters such as voltage and frequency regulation, and power sharing by Al-Saedi et al. (2012). The developed controller is shown to be effective to improve the quality of power supply of the microgrid.

The fuzzy logic and particle swarm optimization (PSO) method are also employed for the power quality by Hooshmand and Enshaee (2010). The single and combined power quality disturbances are aimed to be detected and classified using the proposed approach. The signals are used to identify the power quality disturbances which are derived from the Fourier and wavelet transforms of the signal. Fuzzy rule-based system which is oriented with a PSO algorithm is developed to classify the type of the disturbances. The PSO algorithm is used to provide optimized values for the parameters of the membership functions of the fuzzy rule-based systems used for detection and classification.

In construction applications, quality is closely interrelated with the time and cost. The objective is in such settings is minimizing the cost and time while maximizing the quality. The optimal combination of construction methods is chosen by fuzzy-multi-objective particle swarm optimization in the study of Zhang and Xing (2010). The imprecise or vague data related to quality is represented by fuzzy numbers. The proposed methodology presents the solution for time–cost–quality trade off problem of selected construction methods.

Shirani et al. (2015) introduced a hybrid algorithm, specifically designed to work with optimized decision tree with particle swarm optimization (PSO-DT), for the prediction of Soil physical quality indicators (i.e., air capacity, AC; plant-available water capacity, PAWC; and relative field capacity, RFC). The potential power of using the PSO-DT algorithm in setting up a framework for identifying the most determinant parameters affecting the physical quality of agricultural soils in a semiarid region of Iran is also investigated.

1.2.2 Genetic Algorithms

Genetic Algorithms (GAs) are heuristic procedures that use the principles of evolutionary algorithms. The methodology of Genetic algorithms have been developed by Holland (1975) and applied extensively to various types of optimization problems. GAs are inspired from the biological process of natural selection and the survival of the fittest. A pool of solutions defined as a population of chromosomes and a search process is achieved by generations of crossovers. Improvement is aimed to be obtained by selecting the competitive chromosomes that weed out poor solutions and carry over the genetic material to the offspring. At each iteration, the competitive solutions are recombined with other solutions to obtain hopefully better solutions in terms of objective function value or the “fitness” value. The resulting better solutions are then used to replace inferior solutions in the population. For further details on Genetic Algorithms, the interested reader is referred to the study by Reeves (2003).

Genetic algorithms have been mainly used for the calibration of model parameters which aim commonly to predict or classify quality and to search for the optimal design of quality detection and monitoring systems. Examples of studies from the literature are reviewed as follows.

The efficiency of electrical devices is highly related to harmonic occurrence in the inverters. Linear equations which are functions of the switching angles are needed to be solved to eliminate harmonics. Tutkun (2010) developed a hybrid genetic algorithm method based on the refinement of the genetic algorithms results through the Newton–Raphson method to simultaneously solve such non-linear equations.

In power systems, maintaining the quality is important and various methods have been studied to achieve power quality. One of the most common power disturbances is due to voltage sag which is a decrease in voltage or current at the power frequency for short durations. To obtain information related to voltage sags, power quality monitoring system are implemented in power supply networks. GAs have been used to find the optimal number and location of monitored sites to minimize the number of monitors and to reduce monitoring costs without missing essential voltage sag information (Gupta et al. 2014). Kazemi et al. (2013) have offered to use GAs to determine the optimal number and placement of power quality monitors (PQMs) in power systems. Specifically, a GA was developed to evaluate the optimum number of allocated monitors, which is defined as the minimum difference between the Mallow's Cp value and the number of variables used in the multivariable regression model for estimating the unmonitored buses. Mallow's Cp is a statistical criterion for selecting among many alternative subset regressions.

Selection of optimal number and location of quality monitoring sites is also a problem of water quality assurance. Park et al. (2006) used a genetic algorithm (GA) and a geographic information system (GIS) for the design of an effective water quality monitoring network in a large river system. Fitness functions were defined with five criteria: representativeness of a river system, compliance with water quality standards, supervision of water use, surveillance of pollution sources and examination of water quality changes. GIS data was used for obtaining the fitness levels.

Ng and Perera (2003) developed a GA to optimise model parameters of river water quality models. Then, Pelletier et al. (2006) has used a GA to find the combination of kinetic rate parameters and constants that results in a best fit for a model application compared with observed data. They modelled the relation between kinetics and the water quality in streams and rivers. Preis and Ostfeld (2008) also aimed to predict flow and water quality load in watersheds. They have used extensive data and employed a data driven modelling approach. The methodology included a coupled model tree–genetic algorithm scheme. The model tree predicted flow and water quality constituents while the genetic algorithm was employed for calibrating the model tree parameters.

Advances in the electronic systems and machine learning allow the uses of devices used for the detection of quality. Shi et al. (2013) used GAs to select and optimize the effective sensors of electronic nose which is aimed to contribute the modeling of production areas and tree species.

Artificial intelligence techniques are commonly used to detect quality. An application on the classification of the cotton yarn quality is presented by Amin (2013). A hybrid technique involving Artificial Neural Network (ANN) and genetic algorithm (GA) is developed. GA is used to find the optimal values of the input chromosomes (input attributes of the ANN) which maximize the nonlinear exponential function of the output node of ANN. Rules for classification are derived using the optimum chromosomes.

Chou et al. (2010) proposes a virtual metrology (VM) system for real-time quality measurement of wafers and detection of the performance degradation of machines in manufacturing of semiconductor and thin-film transistor liquid crystal display. Support vector machines model is used for detection and a GA is developed for the training/learning of support vector machine (SVM) model.

An application for the identification of materials at mines is presented by Chatterjee and Bhattacherjee (2011). They developed an image analysis-based method which efficiently and cost effectively determines the quality parameters of material at mines. A GA was designed to reduce the dimensions of the image features effectively. Then the features are modelled using neural networks against the actual grade values of the samples generated by chemical analysis.

Parameters related to manufacturing process are selected to for achieving high quality for more than one quality characteristics. Su and Chiang (2003) applied a neural–genetic algorithm to select these parameters. the neural network is used to formulate a fitness function for predicting the value of the response based on the parameter settings. GA then takes the fitness function from the trained neural network to search for the optimal parameter combination.

Castellini et al. (2015) presented an adaptive illumination system for image quality enhancement in vision-based quality control systems. In particular, a spatial modulation of illumination intensity was proposed in order to improve image quality, thus compensating for different target scattering properties, local reflections and fluctuations of ambient light.

1.2.3 *Fuzzy Sets*

Fuzzy sets are the basic concept supporting the fuzzy set theory. The main research fields in the fuzzy set theory are fuzzy sets, fuzzy logic, and fuzzy measure. Fuzzy reasoning or approximate reasoning is an application of fuzzy logic to knowledge processing. Fuzzy control is an application of fuzzy reasoning to control devices. One feature of FSs is the ability to realize a complex nonlinear input–output relation as a synthesis of multiple simple input–output relations.

The fuzzy set theory has been used in several intelligent technologies by today ranging from control, automation technology, robotics, image processing, pattern recognition, medical diagnosis etc. Some examples are

- A major application area is automotive industry. Fuzzy control has been applied to control automatic transmission system, suspension system, engine system, climate system and antilock brake system.
- Another example is washing machines that adjust their washing strategy based on sensed dirt level, fabric type, load size and water level.
- Fuzzy logic has been used to enhance processing of digital image and signals. Autofocus, auto-zoom, auto-white balancing and auto-exposure systems of cameras.
- Electrophotography process of photocopying machines has been improved. The image quality has been improved by better toner supply control based on fuzzy control.
- Some other successful applications are hand written language recognition and voice recognition.

Fuzzy logic and fuzzy set theory have been successfully applied to handle imperfect, vague, and imprecise information. Nevertheless, to handle vague and imprecise information whereby two or more sources of vagueness appear simultaneously, the modeling tools of ordinary fuzzy sets are limited. For this reason, different generalizations and extensions of fuzzy sets have been introduced (Rodriguez et al. 2012): Type-2 fuzzy sets, nonstationary fuzzy sets, intuitionistic fuzzy sets, fuzzy multisets, and hesitant fuzzy sets.

Fuzzy logic has been extensively used in quality measurement and control problems in the literature. Some of the recently published works are as follows: Yuen (2014) proposes a hybrid framework of Fuzzy Cognitive Network Process, Aggregative Grading Clustering, and Quality Function Deployment (F-CNP-AGC-QFD) for the criteria evaluation and analysis in QFD. The fuzzy QFD enables rating flexibility for the expert judgment to handle uncertainty. The Fuzzy Cognitive Network Process (FCNP) is used for the evaluation of the criteria weights.

An et al. (2014) introduce a fuzzy rough set to perform attribute reduction. Then, an attribute recognition theoretical model and entropy method are combined to assess water quality in the Harbin reach of the Songhuajiang River in China. A dataset consisting of ten parameters is collected from January to October in 2012. Fuzzy rough set is applied to reduce the ten parameters to four parameters.

Li et al. (2014) study the problem of multiple attribute decision making in which the decision making information values are triangular fuzzy numbers and a relative entropy decision making method for software quality evaluation is proposed. Then, according to the concept of the relative entropy, the relative closeness degree is defined to determine the ranking order of all alternatives by calculating the relative entropy to both the fuzzy positive-ideal solution (FPIS) and fuzzy negative-ideal solution (FNIS) simultaneously.

Ghorbani et al. (2014) provides a new method to categorize and select distributors for supply chain management. After determining criteria according to the service quality dimensions as a novel innovation, the fuzzy adaptive resonance theory (ART) algorithm is utilized to categorize distributors according to their similarity. Then, AHP and fuzzy TOPSIS are utilized to arrange distributors in their relative category.

Hsu (2015) integrated the fuzzy analytic network process and fuzzy VIKOR method in a fuzzy multi-criteria decision-making model to provide a complete process to diagnose managerial strategies to reduce customer gaps in service quality efficiently.

Wei et al. (2015) improved fuzzy comprehensive evaluation (FCE) by importing trustworthy degree to it and proposed an automatic hotel service quality assessment method using the improved FCE, which can automatically get more trustworthy evaluation from a large amount of less trustworthy online comments. Then, the causal relations among evaluation indexes were mined from online comments to build the fuzzy cognitive map for the hotel service quality, which was useful to unfold the problematic areas of hotel service quality, and recommended more economical solutions for improving the service quality.

1.2.4 Ant Colony Optimization

Ant Colony Optimization (ACO) is a metaheuristic approach for solving hard combinatorial optimization problems. Ant colony optimization (ACO) algorithm based on the foraging behaviour of ants has been first introduced by Dorigo and Gambardella (1997). The basic idea of ACO is to imitate the cooperative behavior of ant colonies. When searching for food, ants initially explore the area surrounding their nest in a random manner. As soon as an ant finds a food source, it evaluates it and carries some food back to the nest. During the return trip, the ant deposits a pheromone trail on the ground. The pheromone deposited, the amount of which may depend on the quantity and quality of the food, guides other ants to the food source (Socha and Dorigo 2008). Quantity of pheromone on the arc is decreased in time due to evaporating. Each ant decides to a path or way according to the quantity of pheromone which has been leaved by other ants. More pheromone trail consists in short path than long path. Because the ants drop pheromones every time they bring food, shorter paths are more likely to be stronger, hence optimizing the solution. The first ACO algorithm developed was the ant system (AS) (Dorigo 1992), and since then several improvement of the AS have been devised (Gambardella and Dorigo 1995, 1996; Stützle and Hoos 2000).

Bhaskara Murthy and Prabhakar Rao (2015) focused on the application of ACO with optimized link state routing protocol to improve quality of service in Mobile Ad Hoc Network, a dynamic multi-hop wireless network. Simulation results show that the proposed routing enhances the performance of the network.

1.2.5 Bee Colony Optimization

Artificial bee colony (ABC) algorithm was proposed by Karaboga (2005). Bee Colony Optimization (BCO) algorithm imitates the procedure of collective food search of honeybees. The initial search for the food is executed by a group of bees which inform their remaining bees in the hive about the location quantity and the quality of the food they have explored. A bee carrying out random search is called a scout. Moreover, the scout bees which will lead the followers also try to attract follower bees from the hive by a dance behaviour named as waggle dance. During the waggle dance, the quantity of the food is also given to the followers. Besides, it is known that the quality food is an important factor for strong commitment among the bees. The foraging bees under the lead of the explorer bee leave the hive and collect the food in the explored area. The collected food is returned back to the hive. As the bees collect the food, they return back to the hive to store the food. Then, those bees may choose one of the following options to go through: (i) it may continue to collect food at the same location under its previous leader; (ii) it may choose to build up its own team and try to attract followers to join its team (iii) they may separate from the leader bee and become an uncommitted bee. The exploration of new areas and food collection processes continuously take place.

The bee colony optimization algorithms are a newly developed swarm intelligence technique. Its application has mainly focused on job shop scheduling, location and transportation modelling as well as control theory (Davidović et al. 2011; Taheri et al. 2013; Ngamroo 2012). This newly proposed method provides a potential approach for the quality related intelligent decision making. Chen et al. (2015) firstly carried out a sensitivity analysis of a water quality model using the Monte Carlo method. Then, two hybrid swarm intelligence algorithms were proposed to identify the parameters of the model based on the artificial bee colony and quantum-behaved particle swarm algorithms. One hybrid strategy is to use sequential framework, and the other is to use parallel adaptive cooperative evolving. The results of sensitivity analysis reveal that the average velocity and area of the river section are well identified, and the longitudinal dispersion coefficient is difficult to identify.

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1.2.6 Neural Networks

Neural networks are computational models which are inspired by the connected neurons of the nervous system. The network structure takes the inputs, then weighs and transforms them by predetermined functions, finally determines the output(s) through neurons. Using the principles of human brain processes, artificial neural networks achieve learning from experiences and present the use of these experiences via parallel processing units (i.e. neurons). The learning process takes place in the network and stored as weights among the connections of the neurons.

ANNs are commonly used for machine learning, data classification, generalization, feature extraction, optimization, data completion and pattern recognition. The fundamental property of ANNs is to process data and make decisions using the weights acquired from the learning phase.

Salehi et al. (2012) proposes a model consisting of two models which are effective in recognition of unnatural control chart patterns. The first model is a support vector machine (SVM)-classifier which recognizes the mean and variance shift. The second model consists of two neural networks for mean and variance to detect the magnitude of the shifts. Ebrahimzadeh et al. (2011) develops an intelligent method for recognition of the common types of control chart pattern.

Similarly the method includes two modules: clustering module uses a combination of the modified imperialist competitive algorithm (MICA) and the K-means algorithm whereas classifier module includes a neural network for determining the pattern type. Cheng and Cheng (2011) aims to recognize the bivariate process variance shifts using neural networks. They have explored the networks design factors window size, number of training examples, sample size, training algorithm with respect to the performance of the neural network, in terms of the ARL and run length distribution. Wu and Yu (2010) propose a network ensemble model to identify the mean and variance shifts in correlated processes and show that this model performs better than single NNs. Hosseinifard et al. (2011) proposes to use artificial neural networks to detect and classify the shifts in linear profiles which are defined as relation between a response variable and one or more explanatory variables. Velo et al. (2013) compared the performance of alkalinity level prediction of cruise ships using ANN and multilinear regression. Then the alkalinity estimation is used for quality control of measurements. Lopez-Lineros et al. (2014) developed a non-linear autoregressive neural network for the quality control of raw river stage data. Kesharaju et al. (2014) develop a ultrasonic sensor based neural network to identify defects in ceramic components. Neural network approach is used for the classification of defects.

Kadiyala and Kumar (2015) presented a methodology that combines the use of univariate time series and back propagation neural network (widely used ANN) methods in the development and evaluation of IAQ models for the monitored contaminants of carbon dioxide and carbon monoxide inside a public transportation bus using available software.

1.2.7 Simulated Annealing

Simulated annealing (SA) methods are the methods proposed for the problem of finding, numerically, a point of the global minimum of a function defined on a subset of a k-dimensional Euclidean space. The motivation of the methods lies in the physical process of annealing, in which a solid is heated to a liquid state and, when cooled sufficiently slowly, takes up the configuration with minimal inner energy. Metropolis et al. (1953) described this process mathematically. SA uses this mathematical description for the minimization of other functions than the energy. The first results published by Kirpatrick et al. (1983), German and German (1984), Cerny (1985),

SA algorithm is a technique to find a good solution of an optimization problem using a random variation of the current solution. A worse variation is accepted as the new solution with a probability that decreases as the computation proceeds. The slower the cooling schedule, or rate of decrease, the more likely the algorithm is to find an optimal or near-optimal solution (Xinchao 2011).

1.2.8 Tabu Search

The word tabu (or taboo) comes from Tongan, a language of Polynesia, where it was used by the aborigines of Tonga island to indicate things that cannot be touched because they are sacred. According to Webster's Dictionary, the word now also means "a prohibition imposed by social custom as a protective measure" or of something "banned as constituting a risk."

Difficulty in optimization problems encountered in practical settings such as telecommunications, logistics, financial planning, transportation and production has motivated in development of optimization techniques. Tabu search (TS) is a higher level heuristic algorithm for solving combinatorial optimization problems. It is an iterative improvement procedure that starts form an initial solution and attempts to determine a better solution.

1.2.9 Swarm Intelligence

Social insects work without supervision. In fact, their teamwork is largely self-organized, and coordination arises from the different interactions among individuals in the colony. Although these interactions might be primitive (one ant merely following the trail left by another, for instance), taken together they result in efficient solutions to difficult problems (such as finding the shortest route to a food source among myriad possible paths). The collective behaviour that emerges from a group of social insects has been dubbed swarm intelligence (Bonabeau and Meyer, 2001). SI indicates a recent computational and behavioural metaphor for solving distributed problems that originally took its inspiration from the biological examples provided by social insects (ants, termites, bees, wasps) and by swarming, flocking, herding behaviours in vertebrates.

1.2.10 Differential Evolution

Differential evolution (DE) is introduced by Storn and Price in 1996. DE is known as population-based optimisation algorithm similar to GAs using similar operators; crossover, mutation and selection. According to Karaboğa and Ökdem (2004), the main difference in constructing better solutions is that genetic algorithms rely on crossover while DE relies on mutation operation. This main operation is based on the differences of randomly sampled pairs of solutions in the population. DE algorithm uses mutation operation as a search mechanism and selection operation to direct the search toward the prospective regions in the search space. In addition to this, the DE algorithm uses a non-uniform crossover which can take child vector parameters from one parent more often than it does from others. By using the components of the existing population members to construct trial vectors, the recombination (crossover) operator efficiently shuffles information about successful combinations, enabling the search for a better solution space. An optimization task consisting of D parameters can be represented by a D-dimensional vector. In DE, a population of NP solution vectors is randomly created at the start. This population is successfully improved by applying mutation, crossover and selection operators.

Zhang et al. (2015) proposed a new method for water quality evaluation integrated self-adaptive differential evolution algorithm and extreme learning machine namely SADEELM algorithm to overcome the limitation of extreme learning machine, which not only can solve the problem of complicated non-linear relationship between influencing factors and the grade of water quality, but also can well perform in water quality evaluation.

1.3 Some Quality Problem Areas Solved by Intelligent Techniques

Table 1.1 presents a classification of more than 50 papers from the literature including the used intelligent methods, aims of the studies, and the application areas of the related methods. As it can be seen from Table 1.1, Either only one of the intelligent techniques or integrated intelligent techniques are used for the solutions of quality problems.

1.4 Graphical Analyses of Literature Review

In this section, the results of literature review are given by some graphical illustrations. Figure 1.1 illustrates the publication frequencies of papers with respect to the years, indicating a positive trend. The years 2012 and 2013 have the largest frequencies that intelligent techniques are used for quality problems in the papers.

Figure 1.2 shows the journals most publishing papers on quality problems with intelligent techniques. Applied Mechanics and Materials take the first rank in the recent years.

Figure 1.3 ranks the universities that *intelligent quality* based papers come from. Technische Universitat Wien and Chongqing University takes the first and second ranks, respectively.

Figure 1.4 ranks the countries that *intelligent quality* based papers come from. China and US take the first and second ranks, respectively.

Table 1.1 Examples of quality problem areas solved by intelligent techniques

Authors	Method	Aim	Problem area
Ma and Zhang (2013)	PSO	Quality prediction/classification	Power control
Al-Saedi et al. (2012)	PSO	Design parameter optimization	Power control
Hooshmand and Enshaee (2010)	PSO-fuzzy logic	Quality prediction/classification	Power control
Zhang and Xing (2010)	PSO-fuzzy logic	Quality prediction/classification	Construction
Hsu (2012)	PSO-Genetic programming	Design parameter optimization	Lighting performance of LEDs
Tutkun (2010)	GA	Quality prediction/classification	Electrical devices
Gupta et al. (2014)	GA	optimal number and location of quality monitoring	Power systems
Kazemi et al. (2013)	GA	optimal number and location of quality monitoring	Power systems
Park et al. (2006)	GA	optimal number and location of quality monitoring	Water quality assurance
Ng and Perera (2003)	GA	Design parameter optimization	Water quality assurance
Pelletier et al. (2006)	GA	Design parameter optimization	Water quality assurance
Preis and Ostfeld (2008)	GA	Quality prediction/classification	Water quality assurance
Shi et al. (2013)	GA	Quality prediction/classification	Electronic nose used for detecting tree production Areas
Amin (2013)	ANN-GA	Quality prediction/classification	Cotton yarn quality
Chou et al. (2010)	SVM-GA	Quality prediction/classification	Manufacturing of semiconductor and thin-film transistor liquid crystal display
Chatterjee and Bhattacherjee (2011)	GA-ANN	Quality prediction/classification	Mining
Su and Chiang (2003)	GA-ANN	Design parameter optimization	Multivariate quality at manufacturing
Lopez-Lineros et al. (2014)	ANN	Quality prediction/classification	River stage data validation
Salehi et al. (2012)	ANN-SVM	Pattern recognition	Multivariate process control
Cheng and Cheng (2011)	ANN	Quality prediction/classification	Multivariate process control

(continued)

Table 1.1 (continued)

Authors	Method	Aim	Problem area
Ebrahimzadeh et al. (2011)	ANN	Pattern recognition	Multivariate process control
Wu and Yu (2010)	ANN	Pattern recognition	Multivariate process control
Kesharaju et al. (2014)	ANN	Quality prediction/classification	Ceramics
Hosseinifard et al. (2011)	ANN	Quality prediction/classification	Multivariate process control
Velo et al. (2013)	ANN	Quality prediction/classification	
Yuen (2014)	Fuzzy logic	Cloud software product development	Quality function deployment
An et al. (2014)	Fuzzy logic	Attribute reduction	Water quality assessment
Li et al. (2014)	Fuzzy logic	Relative entropy decision making	Software quality evaluation
Ghorbani et al. (2014)	Fuzzy logic	Distributor categorization	Supply chain management
Valavi and Pramod (2015)	Fuzzy logic	Determination of weightages	Maintenance quality function deployment
Liu et al. (2015)	Fuzzy logic	Service quality analysis	Certification and inspection industry
Azar and Vybihal (2011)	ACO	Optimization of service quality prediction accuracy	Software quality evaluation
Neagoe et al. (2010)	ACO	Wine quality assessment	Data mining
Dhurandher et al. (2009)	ACO	Optimization of quality of service security	Wireless sensor networks
Ning and Wang (2009)	ACO	Construction quality maximization	Construction project management
Tong et al. (2012)	SA	Laser cutting quality control	Laser applications
Abdullah and Othman (2014)	SA	Optimization of quality of service	Job scheduling
Kulkarni and Babu (2005)	SA	Product quality optimization	Continuous casting system
Soliman et al. (2004)	SA	Power systems quality analysis	Harmonics and frequency evaluation
Garcia-Martinez et al. (2012)	TS	Voltage minimization	Network expansion
Rahim and Shakil (2011)	TS	Optimization of quality control parameters	Economic production and Quality control

(continued)

Table 1.1 (continued)

Authors	Method	Aim	Problem area
Mukherjee and Ray (2007)	TS	Grinding process optimization	Process functional approximation
Umapathi and Ramaraj (2014)	SI	Quality of service improvement	Wireless mobile hosts
Zhang et al. (2014)	SI	Swarm intelligence optimization	Quality assessment
Machado et al. (2013)	SI	Texture analysis	Material quality assessment
Goudarzi (2012)	SI	Solution improvement for delivering digital video	Multi-hop wireless networks
Sagar Reddy and Varadarajan (2011)	SI	Quality of service improvement	Mobile communication systems
Lv et al. (2014)	DE	Water quality prediction	Regional ecological and water management
Sathya Narayanan and Suribabu (2014)	DE	Multi-objective time-cost-quality optimization	Construction project
Biswal et al. (2012)	DE	Classification of power quality data	Automatic disturbance pattern classification
Zheng et al. (2009)	DE	Urban living quality examination	Urbanization and income growth

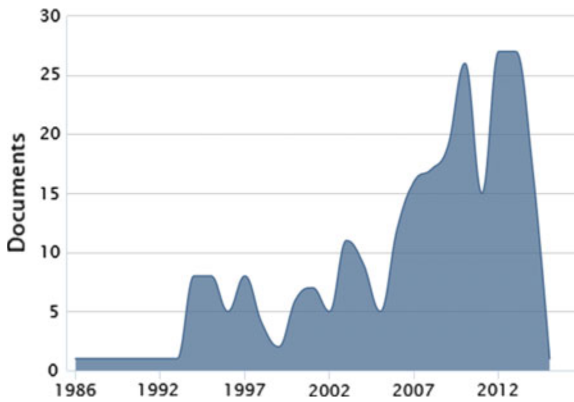

Fig. 1.1 Publication frequencies with respect to the years

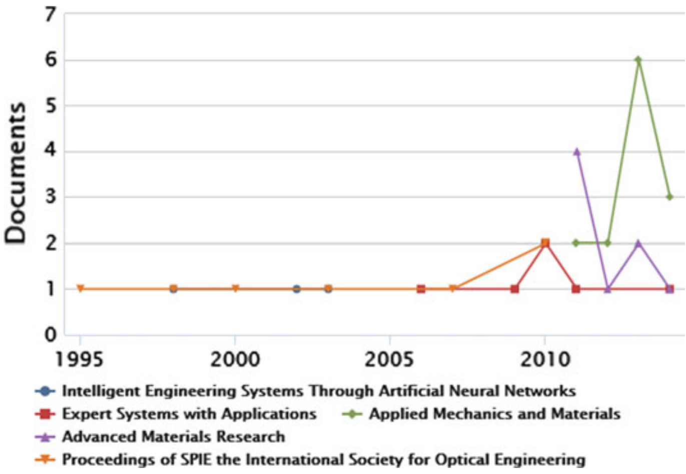

Fig. 1.2 The journals most publishing *intelligent quality* based papers

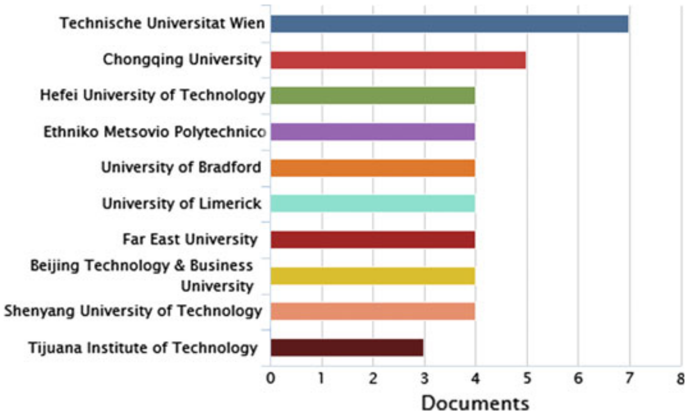

Fig. 1.3 The universities most publishing *intelligent quality* based papers

Figure 1.5 shows the distribution of the published intelligent quality based papers by their document types. Conference papers and journal papers take the first and second ranks, respectively.

Figure 1.6 shows the distribution of intelligent quality papers by their subject areas. Engineering and computer sciences take the first and second ranks, respectively.

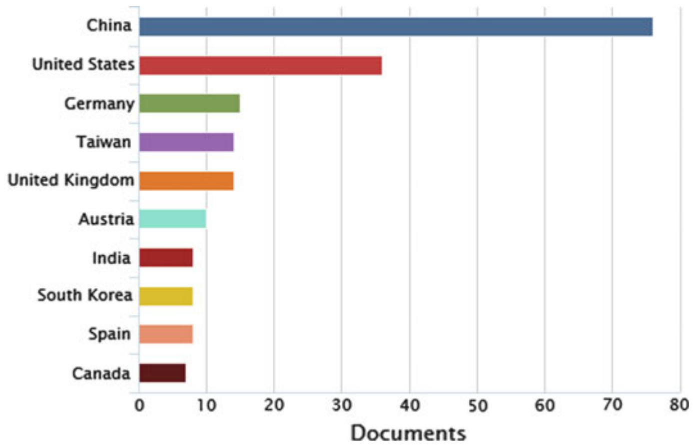

Fig. 1.4 *Intelligent quality* based papers by the countries

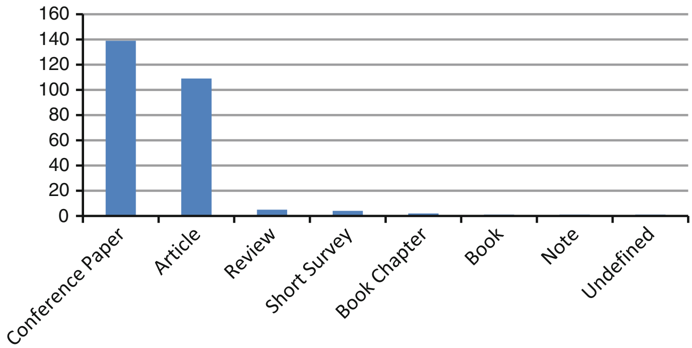

Fig. 1.5 Distribution of intelligent quality based papers by their document types

1.5 Conclusion and Future Trends

Complex quality problems are hard to solve by using classical optimization techniques which guarantee to find an optimal solution and to prove its optimality. Instead, intelligent techniques that may sacrifice the guarantee of finding optimal solutions for the sake of getting good solutions in a limited time have been introduced in this chapter. The quality problems solved by intelligent techniques in the literature are mostly related to power control and systems, water quality assurance, multivariate process control, software quality, and wireless networks. There is a significant increasing trend in the number of papers on quality problems using intelligence techniques after the year 2010. The subject area with the largest

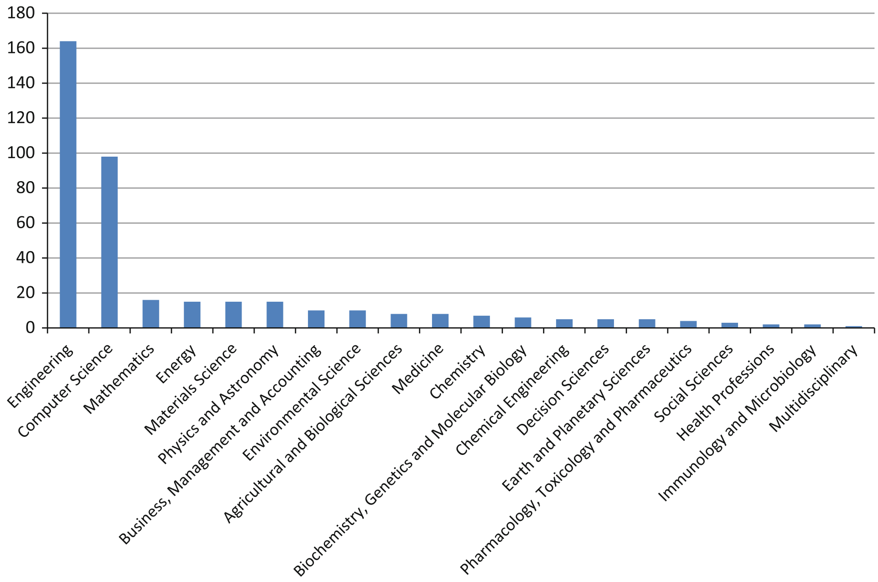

Fig. 1.6 The distribution of intelligent quality papers by their subject areas

frequency using intelligent techniques for quality problems is engineering sciences. Computer sciences then follow it. It can be concluded that researchers seem to more deal with intelligent techniques in the future as the complexity of the quality problems increases.

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