Review of Artificial Intelligence Applications in Garment Manufacturing

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Abstract Nowadays, apparel manufacturing enterprises are confronted with ever-increasing global competition and unpredictable demand fluctuations. These pressures compel manufacturers to continuously improve the performance of their production process in order to deliver the finished product within the most approximate period of time and the lowest production cost. However, consistent and optimal solutions are difficult to obtain under a fuzzy and dynamic manufacturing environment. Therefore, in response to the need for new approaches, a large (and continually increasing) number of efforts have sought to investigate and exploit the use of AI techniques in a variety of industrial applications. This chapter provides a systematic review of contemporary research articles related to the application of AI techniques in garment manufacturing. The research issues are classified into three categories, including production planning, control, and scheduling; garment quality control and inspection; and garment quality evaluation. The challenges facing adoption of AI technologies in garment industry are discussed.

Keywords Artificial intelligence · Garment manufacturing · Decision making Survey

1 Introduction

The garment industry is one of the most important sectors of the economy in terms of investment, revenue, trade, and employment generation all over the world. It is highly segmented and produces a wide variety of clothing and fashion products that change frequently with changes in style and season. The garment manufacturing involves many processing steps, beginning with order receiving and ending with dispatching shipment of the finished garments. Based on the present apparel industry,

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these processing steps can be categorized as pre-production, production, and post-production processes. The pre-production processes include sampling, sourcing of raw material, cost analysis, and approving the proposed product. The production processes include cutting and sewing. The postproduction processes include thread trimming, pressing, checking, folding, packing, and shipment inspection. Each step of these processes has its own set of considerations and requirements that should be addressed and completed before moving to the next phase. This makes the whole apparel manufacturing process incredibly complex and overwhelming to understand and manage.

Indeed, apparel companies have to deal with a global and very competitive environment which is characterized by rapid changes, short life-cycle products, high volatility, low predictability, tremendous product varieties, short production lead times, increasing customer demand, and rising labor costs. In such circumstances, industrial manufacturers constantly face complex and critical decisions. Traditionally, statistical regression methods have been widely used to solve decision problems, since they are easy to develop and implemented. However, they have the limitations of that they cannot handle complex nonlinear relationships with so many variables. Therefore, artificial intelligence (AI) techniques have been proposed as an alternative approach for modeling such complex relationships.

AI is the branch of computer science that is concerned with making computers behave like human beings. It deals with intelligent behavior which involves learning, reasoning, perception, communication, and interaction with complex environments (Adeli 2003). Many tools are used in AI including artificial neural networks (ANN), genetic algorithms (GA), fuzzy set theory, expert systems, machine learning. In the recent years, these techniques have attracted much attention of researchers and practitioners in the apparel manufacturing industry and have been applied successfully to solve a wide variety of decision-making problems such as production planning (Wong et al. 2014; Guo et al. 2013), cut-order planning (Bouziri and M'hallah 2007; Wong and Leung 2008), marker making (Huang 2013; Ozel and Kayar 2008), line balancing (Chen et al. 2002; Guo et al. 2006), sewing automation (Silva et al. 2004; Carvalho et al. 2010), inspection decisions (Zhang et al. 2011). Numerous research studies have shown that AI techniques have the potential of providing superior solutions over classical approaches (Guo et al. 2011).

This chapter aims to review current applications of artificial intelligence in garment manufacturing over last two decades. Based on the literature reviews, the challenges encountered by AI techniques used in the clothing industry will be discussed. The remainder of this review is structured as follows. The forthcoming three sections include review of applications of AI techniques in production planning, control, and scheduling, in garment quality inspection, and in garment quality evaluation. Afterward, challenges facing adoption of AI techniques in the garment industry will be discussed in the fifth section. Finally, conclusions will be given in the last section.

2 Applications of AI to Production Planning, Control, and Scheduling

Production planning, control, and scheduling is one of the most important aspects of garment industry which plays a vital role in coordination of the flow of materials and information between customers and suppliers and the business determining the product value stream. It manages the flow of material, the utilization of employee and equipment, and it responds to customer expectations. However, this process is prone to numerous disturbances which make it difficult to attain effectiveness of the actions taken. Therefore, the application of artificial intelligence techniques in all areas of production planning and control will make it possible to manage the knowledge in the area and enable improvement in the degree to which the customers' expectations will be met.

In this section, we will present a selection of the most significant applications of artificial intelligence techniques in some areas of the production planning and scheduling domain, including production order scheduling, cut-order planning, marker making, spreading and cutting schedules, line balancing, and machine layout design.

2.1 Production Order Scheduling

In the fashion industry, order scheduling is a key decision-making process which focuses on the assignment of production orders to appropriate production lines. However, in the most real-world apparel manufacturing environments, this process can be frequently disrupted through production difficulties and absenteeism. As a result, the pre-established order schedules are shifted very often after the production starts, which may lead to decreased production efficiency. Therefore, robust optimization approaches for production scheduling have gained increasing attention. In this way, Tang et al. (2017) investigated robust order scheduling problems in the fashion industry with the aid of a multi-objective evolutionary algorithm called non-dominated sorting adaptive differential evolution (NSJADE), by taking into account the pre-production events and the uncertainties in the daily production quantity. The NSJADE was utilized to search the order schedules in the fashion industry that achieve the following three objectives: (1) the schedules can minimize the total pre-production event clashes of all orders; (2) the schedules can minimize the total tardiness of all orders; (3) the schedules are not sensitive to variation of the daily production quantity during the process of real production. The observation from the experiments showed that the pre-production events and the existence of uncertainties in the daily production quantity heavily affect the order scheduling. Also, it was found that robust order schedules can be shifted less often after the production starts than non-robust ones, which saves labor cost and enhances the production efficiency. The authors underlined that with the help of robust order schedules, planners can pay close attention to the unfinished pre-production events as early as possible, negotiate earlier with the customers who place the orders about the delay in delivery, or arrange operators to work extra hours for these orders. In the same way, Guo et al. (2013) inspected a multi-objective order allocation planning problem in make-to-order manufacturing with the consideration of various real-world production features. To tackle this problem, they developed a novel hybrid intelligent optimization model, integrating a multi-objective memetic optimization process, a Monte Carlo simulation technique, and a heuristic pruning technique. The experimental results showed that the proposed model can effectively solve the investigated problem by providing effective production decision-making solutions. Wong et al. (2014) investigated a real-world production planning problem, multi-objective-order allocation, with the consideration of multiple plants and multiple production departments. They developed an intelligent and real-time multi-objective decision-making model to provide timely and effective solutions for this problem, by integrating RFID technology with intelligent optimization techniques. In this model, the RFID technology was used to collect real-time production data. Furthermore, a novel $(\mu/\rho+\lambda)$-evolution strategy process with self-adaptive population size and novel recombination operation was proposed and integrated with effective non-dominated sorting and pruning techniques to generate Pareto optimal production planning solutions. The obtained results showed that the proposed model can effectively solve the investigated problem by providing production planning solutions superior to industrial solutions.

Wong and Chan (2001) proposed an effective genetic algorithm approach incorporated with “earliness” and “tardiness” production scheduling and planning method to plan the clothing manufacturing process. In addition, a segmentation strategy was developed to divide the production planning period to overcome the problem of chromosome selection in GA. The experimental results demonstrated the effectiveness of the proposed method in the clothing manufacturing process. Mok et al. (2013) developed intelligent apparel production planning algorithms that allocate job orders to suitable sewing units to ensure the effective utilization of production capacity and on-time completion of all job orders. The intelligent planning algorithms were based on group technology and genetic algorithms and can be used for labor-intensive operation planning. The proposed algorithms have been shown to be able to substantially improve planning quality. The authors pointed out that these planning algorithms are currently used by apparel manufacturers in Hong Kong as part of their routine planning operations.

2.2 Cut-Order Planning

Cut-order planning (COP) is the problem of planning the fabric cut for a set of apparel orders. COP occurs for each order to be produced and is the starting point in the manufacture of the order. It seeks to minimize the total manufacturing costs by developing feasible cutting order plans with respect to material, machine, and labor. However, the COP process is a dynamic function that must respond to ever-changing status of many critical factors such as sales, inventory levels, raw materials, and labor and equipment availability. The variety of sizes, styles, fabrics, and colors induces significant complexity in this problem (Cooklin et al. 2006). Thus, effective optimization of COP solutions requires the use of advanced techniques derived from artificial intelligence. In this way, Wong and Leung (2008) proposed a genetic optimized decision-making model using adaptive evolutionary strategies in order to assist the production management of the apparel industry in the decision-making process of cut-order planning. The experimental results showed that the proposed method can reduce both the material costs and the production of additional garments while satisfying time constraints set by downstream sewing department. Bouziri and M'hallah (2007) investigated the cut-order planning problem using a new hybrid heuristic called "genetic annealing." This heuristic combined the advantages of population-based approaches (genetic algorithms) with those of local search (simulated annealing). The stopping criterion of this combined algorithm is to stop if the best current solution is not improved for three consecutive iterations. The obtained results demonstrated the validity and effectiveness of the proposed approach.

Abeysooriya and Fernando (2012a) presented a canonical genetic algorithm approach to solve the problem of cut-order planning generation. The proposed GA was implemented to maximize the number of garments in the cut templates generated in the COP, by searching optimized size ratios of the cut templates. Experimental results indicated that the proposed method can yield better solutions compared to the available methodologies of generating cut-order plans available in apparel industry. In another study (Abeysooriya and Fernando 2012b), the authors highlighted that adjoining conventional heuristic approaches with genetic algorithm accomplished an efficient searching of cut-order planning solutions.

2.3 Marker Making

Marker making is a critical process in the fabric-cutting room, in which pattern pieces of different sizes and styles of a garment are laid out on a sheet of paper, known as the marker paper, with fixed width and arbitrary length in order to achieve the highest fabric utilization (marker efficiency). One cutting order may require several markers to achieve optimal efficiency. Marker efficiency is determined by the percentage of the total fabric that is actually used in garment parts and depends on how tightly the pattern pieces fit together within the marker. The area in between the pattern pieces, which is not used by garment parts, is waste. The minimization of this waste is crucial to the reduction of production costs (Dumishllari and Guxho 2016). In fact, higher material utilization is of particular interest to garment industry, since a small percentage improvement in fabric efficiency can result in many savings. Thus, in order to optimize fabric utilization and achieve higher marker efficiency, increased attention is directed toward meta-heuristic methods, such as GA and particle swarm optimization algorithm, which are able to search the space searching intelligently (Hopper and Turton 2001). In this way, Vorasitchai and Madarasmi

(2003) investigated the pattern layout optimization problem using genetic algorithm in order to minimize fabric wastage in garment production industry. It was found that the proposed algorithm can improve the efficiency of almost all production quality markers, shirts, trousers, and other garments. Huang (2013) reported that optimized particle swarm algorithm can achieve ideal material utilization. M'hallah and Bouziri (2016) combined COP and marker making into a single problem, which was solved using constructive heuristics and three meta-heuristics: a stochastic local improvement method, global improvement method, and hybrid approach. These approaches were designed to enclose the behavior of expert markers and to limit the computation time. The obtained results provided computational proof of the benefits that industry can rip by integrating COP problem with marker making problem.

Wong and Leung (2009) proposed a methodology that hybridizes a heuristic packing (HP) approach based on grid approximation with an integer representation-based $(\mu + \lambda)$ evolutionary strategy (ES) in order to obtain an efficient layout of garment patterns so as to optimize the fabric utilization. The grid approximation provided two advantages over the geometric representation: The first one is that there is no need to introduce additional routines in order to identify enclosed areas in patterns, and the second is that it is easier to detect any overlap. The results showed that the proposed methodology provides an effective means by which to increase the marker efficiency. In another study, Wong et al. (2013a) developed a packing approach that integrates a grid approximation-based representation, a learning vector quantization neural network, a heuristic placement strategy, and an integer representation-based $(\mu + \lambda)$-evolutionary strategy to obtain efficient placement of irregular objects. The results were compared with those obtained by a genetic algorithm-based packing approach and those generated from industrial practice, demonstrating the effectiveness of the proposed approach.

Estimating the optimum cutting time directly affects the enterprise's cost, profit, product competition ability, and economic benefits. Ozel and Kayar (2008) designed a multilayer perceptron neural network to estimate the marker making cutting time based on marking lengths, the number of fabric layers, cutting blade speed, number of sizes, marking lengths, and cutting time. The network training was performed using the error back-propagation algorithm. It was found that the designed network exhibited satisfactory performance.

Hence, it can be drawn that the optimization of marker making process using artificial intelligence techniques can not only reduce the staff's working strength, but also greatly improve the material utilization ratio and the producing speed, leading to considerable economic benefits to garment manufacturing enterprises.

2.4 Fabric Spreading and Cutting Schedules

Fabric spreading is a preparatory operation for cutting that consists of laying plies of fabric one on top of the other in a predetermined direction on the cutting table to form a fabric lay. The composition of each spread, i.e., the number of plies for each color, is obtained from cut-order plan. Once spreading is done, garment panels are needed to be cut. Marker prepared according to the cut-order plan is plotted on a marker sheet, and it is laid on top of the fabric lay, to act as the reference for cutting. Cutter should follow the outline of the panels plotted on the marker sheet to cut the required cut panels from the fabric lay. Cutting out the patterns through all plies creates a set of bundles of garment pieces, and several such lays may be required to satisfy all demands (Rose and Shier 2007).

Scheduling of spreading and cutting demands labor cost minimization, faster throughput, greater accuracy, higher fabric utilization and correct cut-piece fulfillment. The problem consists of determining the lowest cost spreading and cutting schedule for garments of different styles, colors, and sizes, subjected to physical constraints of cutting table length and cutting knife height as well as business constraints of required demand for each stock-keeping unit (SKU) (Nascimento et al. 2010). In most cases, planning and scheduling of cutting process is decided by the managers based on the experience they gained by handling previous orders, so the systematic and effective functioning of the process is diminished. Furthermore, this subjective nature would not guarantee the optimal planning and scheduling of the process (Wong 2003). Moreover, in apparel manufacturing process, some dynamic factors which occur internally and externally will make the schedule complicated creating a harder problem to solve (Wong et al. 2005a, b). Therefore, effective scheduling is essential to accommodate higher production performances and low production costs. Recent advances in computing technology, especially in the area of computational intelligence, can be used to handle this problem. Among the different computational techniques, genetic algorithms are particularly suitable. A major feature of GA is the ability to take care of a variety of objective functions. Patrick et al. (2000) reported that optimal roll planning can be worked out by using genetic algorithm approach. They underlined that it is possible to save a considerable amount of fabric when the best roll planning is used for the production. Wong et al. (2005a) proposed a genetic algorithms approach to optimize both the cut-piece requirements and the makespan of the conventional fabric-cutting departments using manual spreading and cutting methods. It was found that both the makespan and cut-piece fulfillment rates were improved and that the latter was improved significantly. In another paper, Wong et al. (2005b) showed that the makespan and the influence caused by the change of schedule could be minimized by using a real-time GA-based segmentation rescheduling approach.

Wong et al. (2006a, b) used genetic algorithms and fuzzy set theory to generate just-in-time fabric-cutting schedules in a dynamic and fuzzy environment. It was found that the genetically optimized schedules improved the internal satisfaction of downstream production departments and reduced the production costs simultaneously. Mok et al. (2007) proposed a fuzzification scheme to fuzzify the static standard time so as to incorporate some uncertainties, in terms of both job-specific and human-related factors, into the fabric-cutting scheduling problem. They also proposed a genetic optimization procedure to search for fault-tolerant schedules using genetic algorithms, such that makespan and scheduling uncertainties were minimized. Experimental results indicated that the genetically optimized fault-tolerant schedules not only improved the operation performance but also minimized the scheduling risks.

2.5 Assembly-Line Balancing

An assembly line consists of a number of workstations which are arranged along a material handling system, in order to obtain a sequence of finished product types. The work pieces are moved from station to station, and at each one, certain operations are performed in view of some constraints. The first primary constraint is the cycle time which corresponds to the maximum available time for the production of any work piece at any workstation. In addition to cycle time, precedence relationships, which specify the order in which tasks must be performed in the assembly process, are the other primary constraints (Eryuruk et al. 2008). Moreover, tasks are assigned to operators depending on the constraints of different labor skill levels. Inappropriate workstations assignment will lead to the increase of labor cost, work in process (WIP), cycle time, and poor throughput.

The assembly-line balancing (ALB) problem consists of assigning tasks to an ordered sequence of workstations so that each workstation has no more than can be done in the workstation cycle time, and so that the unassigned (that is, idle) time across all workstations is minimized. Task allocation is based on the objective of minimizing the workflow among the operators, reducing the throughput time as well as the work in progress, and thus increasing the productivity. Each operator then carries out operations properly, and the work flow is synchronized. ALB problems that occur in real-world situations are dynamic and are fraught with various sources of uncertainties such as the performance of workers and the breakdown of machinery. Thus, several investigations using soft computing methods have been carried out in an effort to improve the productivity and efficiency of assembly lines in the clothing industry. Among these techniques, GA method has received much attention and has been applied successfully to many optimization problems. One of the earliest applications of GA to the clothing industry was carried out by Chan et al. (1998), who applied their method to an assembly system manufacturing men's shirts. The authors tried to improve the line efficiency by minimizing the time spent in assembly-line balance planning. They also included the various skill levels of workers as problem-specific information to solve a 41-task ALB problem. The results showed that the performance of genetic algorithm was much better than the performance of the greedy algorithm, which performed optimization by proceeding to a series of alternatives and assigned the most skillful worker to each task. Chen et al. (2002) presented a hybrid genetic algorithm approach for assembly-line planning problems involving various objectives, such as minimizing cycle time, maximizing workload smoothness, minimizing the frequency of tool change, minimizing the number of tools and machines used, and minimizing the complexity of assembly sequences. They classified the assembly-line planning problems into line balancing, tooling, and scheduling problems. The proposed method was improved by including heuristic solutions into initial population and developing a self-tuning method to correct infeasible chromosomes. Experimental results indicated that the proposed method can efficiently yield many alternative assembly plans to support the design and operation of a flexible assembly system. Guo et al. (2006) developed a genetic optimization method capable of dealing with a garment assembly line producing multiple products. Its performance was verified through experimentation using empirical data. Wong et al. (2006a, b, 2013b) developed a line balancing technique using genetic algorithms for optimizing the assignment of operatives in an assembly line. They also investigated the impact of different levels of skill inventory on the assembly makespan in order to find out the optimal number of task skills an operative should possess in the apparel assembly process. In a practical case study application, the algorithm was shown to be efficient. Results also indicated that there was a margin of diminishing returns in terms of worker training, in that workers who could perform more than three sewing operations brought little benefit in terms of line balance (Wong et al. 2006a, b). Yolmeh and Kianfar (2012) designed an efficient GA to solve setup assembly-line balancing problem. To determine the assignment of tasks to stations, the algorithm was hybridized using a dynamic programming procedure. Using dynamic programming, at any time a chromosome could be converted to an optimal solution. The computational results showed that the proposed GA outperforms all of the algorithms presented to solve assembly-line balancing problems so far. Unal et al. (2009) developed a heuristic algorithm for line balancing and evaluated its effectiveness under different line configurations using simulation. It was found that U-type line configuration is more advantageous compared to straight-line configuration according to both mean throughput per worker and also mean workstation utilization values. The authors highlighted that the proposed simulation-based line balancing approach can be used in all types of garment production.

The above-mentioned publications illustrate the potential of GAs to address the garment industry assembly-line balancing problems. However, one limitation of GA is that it cannot easily incorporate problem-specific information. If better solutions can be achieved by including this type of information, it may be advantageous to enhance GA in this manner. Brown and Sumichrast (2005) indicated that grouping genetic algorithms (GGA), firstly proposed by Falkenauer (1993), were more efficient for solving grouping problems than the standard GA. Hence, some researchers investigate the use of these tools to handle ALB problems in garment manufacturing. Chen et al. (2012) developed a GGA to solve the ALB problem of sewing lines with different labor skill levels in garment industry. The developed GGA could allocate workload among machines as evenly as possible for different labor skill levels, so the mean absolute deviations (MAD) could be minimized. The computational results revealed that GGA outperformed GA in both simple and complex problems by 13.81% and 8.81%, respectively (Chen et al. 2009). The authors highlighted that production managers could use the research results to quickly design sewing lines and achieve higher labor utilization rates and higher throughput levels. Chen et al. (2014) employed GGA in order to solve the line balancing problem in terms of minimizing the number of workstations for a given cycle time (the type I ALB problem). The efficiency of the developed heuristic was verified using empirical data from a sportswear factory combined with computational experiments. The authors stated that their arrived at algorithm could be of great aid to production managers interested in reducing cycle times and increasing labor utilization.

2.6 Machine Layout Design

Machine layout or flow line design involves determining the relative positions of machines (i.e., the layout) in facilities where a given product is manufactured. The layout design is key concern to organize operations in such a way as to maximize resource usage and overall system throughput. It generally depends on the products' variety and the production volumes (Islam et al. 2014). Indeed, change of machine layout is often required for small quantity and diversified orders in the apparel manufacturing industry. Hence, facility layout design is a continuous iterative process based upon the changing constraints of dynamic environment (Naik and Kallurkar 2016). Poor layout can lead to inefficiency, inflexibility, large volumes of inventory and work in progress, high costs, and unhappy customers. Changing a layout can be expensive and difficult, so it is best to get it right first time. Thus, optimization of layout design has become very essential to improve operational efficiency and reduce the nonproductive time. Thereby, many efforts have been undertaken to develop new design models and procedures that account for uncertainty and variability in design parameters such as product mix, production volumes, and product life cycles, for complex manufacturing system analysis and rational decision making while handling.

Genetic algorithms have proven to be a valuable method for solving a variety of hard combinatorial optimization problems. Martens (2004) developed a pair of GAs based on two alternative integer programming (IP) models in an attempt to find quality solutions for a variety of large real-life layout cases in the fashion industry. The obtained results showed that the proposed GAs were able to find optimal or near-optimal solutions on small problem instances and that they were capable of solving large, real-life layout problem in the fashion industry in an acceptable amount of time. Lin (2009) addressed a single-row machine layout problem with the objective of minimizing moving distance for cut pieces in a U-shaped sewing line. They developed a hierarchical order-based genetic algorithm, which has been shown to be able to make random and global searches to determine the optimal solution for multiple sites simultaneously and also to find speedily the best order for machine layout, which shortens the pieces moving distance and enhances production efficiency. Ultutas and Islier (2015) developed a clonal selection-based algorithm to solve the dynamic facility layout problem in footwear industry. Several scenarios were generated by using the real-life data. The proposed algorithm has been implemented and tested, showing promising results.

From this analysis, it appears that accurate machine setup is a key factor for increasing productivity and that facility layout remains an open research issue.

3 Garment Quality Control and Inspection

Garment inspection is an important stage of quality control that still relies heavily on trained and experienced personnel checking semifinished and finished garments visually. This process alone is very time-consuming because of the variety of styles, sizes, and fabric used in the clothing. Another concern is the quality standardization which requires the inspection to be repetitive to achieve a certain satisfaction (Fung et al. 2011). However, manual inspection imposes limitations on identifying defects in terms of accuracy, consistency, and efficiency, as workers are subject to fatigue or boredom, and thus inaccurate, uncertain, and biased inspection results are often produced. To tackle these problems, it is necessary to set up an advanced inspection system for garment checking that can decrease or even eliminate the demand for manual inspection and increase product quality. In this way, artificial intelligence techniques can be explored to ensure reliable and accurate quality control in industrial apparel manufacturing.

In this section, we will present a survey of the main applications of AI techniques for quality control in garment manufacturing process.

3.1 Seam and Fabric Sewing Performance

In cut and sewn apparel products, seams are formed when two or more pieces of fabric are held together with stitches. Various seams can be obtained by combining different fabric-cutting, joining, and stitching parameters (Yildiz et al. 2013). As the seam is one of the basic requirements in the construction of apparel, seam quality has great significance in apparel products. The seam performance is affected by various fabric mechanical properties with a combination of their sewing parameters. Therefore, investigating the performance parameters' relations will help to get a better understanding of the sewing process.

Owing to the complex and nonlinear relationships between the above-mentioned factors, ANNs present an attractive alternative to conventional statistical predictive techniques. In this way, Gong and Chen (1999) have successfully used ANN to predict the making-up performance of fabrics during garment manufacture, based on their mechanical properties measured by the Kawabata Evaluation System (KES-F) system. The predicted making-up performances included laying-up, cutting, overall handling, inter-ply shifting, structural jamming, seam slippage, needle damage, seam pucker, ease of pressing, dimensional stability, and appearance retention. The authors highlighted that artificial neural networks are effective for predicting potential problems in clothing manufacturing. Patrick et al. (2007) predicted the sewing performance of fabrics from fabric composition, weave structure, yarn count, sewing thread properties, and fabric low-stress mechanical properties, using a three-layer back-propagation (BP) neural network, which consists of 21 input nodes, 21 hidden nodes, and 16 output nodes. The sewing performance included severity of seam pucker, severity of needle damage, distortion, and overfeeding. The predicted values of most fabrics were found to be in good agreement with the results of sewing tests carried out by domain experts. Hui and Ng (2005) investigated the use of extended normalized radial basis function (ENRBF) neural networks compared to traditional BP to predict the sewing performance of fabrics in apparel manufacturing. It was found that the ENRBF neural network had better predictability than the BP neural network and that both models provided better advice than the experts in some areas, when compared to actual sewing performance. In another study, Hui and Ng (2009) used an ANN technique based on a back-propagation algorithm with weight decay technique and multiple regression with common logarithm method to predict the seam performance of fifty commercial woven fabrics used for the manufacture of men’s and women’s outerwear based on seam puckering, seam flotation, and seam efficiency. The developed models were assessed by verifying mean square error (MSE) and correlation coefficient (R-value) of test data prediction. The results indicated that the ANN model performed better than multiple regressions and that the prediction errors of ANN were low despite the availability of only a small training data set. Thus, it can be concluded that ANN techniques could be emulated as human decision in the prediction of sewing performance of fabrics more effectively.

The prediction of seam strength is also very important because it affects both the functional and aesthetic performance of an apparel product in terms of durability and stability. Onal et al. (2009) studied the effect of fabric width, folding length of joint, seam design, and seam type on seam strength of webbings made from polyamide 6.6 which were used in parachute assemblies as reinforcing units for providing strength by using both Taguchi’s design of experiment (TDOE) as well as an ANN. It was found that the predictions given by ANN model were better in accuracy than those performed by TDOE. Yildiz et al. (2013) constructed multilayer perceptron and radial basis function (RBF) neural network models to predict the seam strength and elongation at break in poplin and gabardine woven fabrics based on stitch type, seam density, sewing needle type, and sewing yarn type. The experimental results showed that both models produced reliable estimates of seam strength and elongation at break. The authors underlined that with the help of ANN models, sewing parameters can be chosen to form an optimum sewing process, leading to cost and lead time reduction.

3.2 Sewing Automation Equipment

The knowledge and control of sewing machines is an important aspect to consider by apparel manufacturers in order to produce high-quality garments and improve production efficiency. However, due to the complexity of the sewing process itself, commercial machines are not yet fully controlled or monitored. The sewing parameters are still being adjusted by “trial and error” at the beginning of the operation, as average values (Silva et al. 2004). Therefore, automation equipment is the key to improving the quality of apparel products and enhances the critical machine functions. Thus, many research efforts have been undertaken to avoid empirical machine settings, reduce setup times, and improve sewing machine performance and flexibility. Barrett et al. (1996) developed a wavelet neural network-based online classifier of fabric type and number of plies for use on a sewing machine to improve stitch formation and seam quality. Needle penetration forces and presser foot forces were captured and decomposed using the wavelet transform. The wavelet-filtered needle force waveform was used as an input of the ANN. It was found that the wavelet ANN could correctly classify both fabric type and number of plies being sewn with 97.6% accuracy. The authors indicated that, given the ability to identify fabric/ply combinations online, the sewing machine can use predefined sewing parameters to automatically adjust the sewing machine settings. Carvalho et al. (2010) developed a combined proportional integral derivative (PID)/fuzzy logic controller to provide a reference and force offset adaptation to the number of plies and sewing speed. The proposed controller included a "teach-in" procedure to tune the controller's parameters while varying sewing speed and the force output independently. The authors highlighted that the control system is still somewhat limited due to the dynamic response of the actuator and that future developments in the field of actuators will certainly allow a further improvement of the feeding behavior. They also stated that their work is a very significant contribution to eliminate trial-and-error tuning of the sewing machine, toward a highly flexible and controlled operation. Guhr et al. (2004) designed a fuzzy logic controller to control the vertical movement of the presser foot of the overlock sewing machine, which has been shown to effectively improve the control performance by adapting the sewing parameters such as speed, number of plies, and type of fabric.

Koustoumpardis and Aspragathos (2003) proposed a hierarchical robot control system which includes a fuzzy decision mechanism combined with a neuro-controller to regulate the tensional force applied to the fabric during the robotized sewing process. The fuzzy logic decision mechanism utilized only qualitative knowledge concerning the properties of the fabrics, in order to determine the desired tensional force and the location of the robot hand on the fabric. A feed-forward NN controller regulated the fabric tension to achieve the desired value by determining the robot end effector velocity. The simulation results demonstrated the efficiency of the system as well as the robustness of the controller performance since the effects of the noise are negligible. In another study (Koustoumpardis and Aspragathos 2007), the authors implemented and tested the proposed system in a real robotized sewing environment for two fabric handling tasks: firstly for a robot guiding fabrics toward sewing and secondly for the cooperation of a robot with a human for handling fabrics. It was found that the robot demonstrated a satisfactory real-time response and that the neural network controller was more robust than a PID controller working under identical conditions. Zacharia et al. (2009) designed a robot control system based on visual servoing and fuzzy logic for handling fabrics lying on a work table. This system was enhanced using genetic-based and adaptive control. The experiments showed that the proposed robotic system was flexible enough to handle various fabrics and that it was robust in handling deformations that may change fabric's shape due to buckling (wrinkling and folding). The authors indicated that this framework does not cover all the aspects of robot handling of flexible materials, since there are still several related issues requiring solutions. To alleviate the computational burden of geometrical computations, Zacharia (2012) proposed an innovative approach based on a novel genetic-oriented clustering method and an adaptive neuro-fuzzy inference system (ANFIS) for robot handling pieces of fabrics with curved edges toward sewing. The experimental results showed that the proposed approach was effective and efficient in guiding the fabric toward the sewing needle, sewing it, and rotating it around the needle and that it was robust against fabric's deformations. Also, it was shown that the proposed method presented good results when applied to fabrics with curved edges of unknown curvatures. The authors highlighted that this approach is applicable to any piece of fabric with edges of arbitrary curvature and that the achieved accuracy is really promising for future use in industrial applications

Kim et al. (2004) constructed a nonlinear network model for a commercial sewing machine equipped with a brushless direct current (BLDC) motor. Based on the model, a two degrees-of-freedom (DOF) PID controller was designed to compensate the effects of disturbance without degrading tracking performance. According to the experimental results, the model has been shown to be a good approximation of the sewing machine and the proposed method demonstrated the effectiveness for a motion control system that requires high speed, robustness, and accuracy.

Fung et al. (2011) developed a novel and flexible 6-axis robotic hanger system with three DOFs which can move in the two-dimensional (2D) plane for the inspection of knitted garments with different styles, sizes, and cloth fabrics. This 3-DOF hanger consists of three groups of linkages (body link, shoulder link, and sleeve link) which were designed to satisfy the conditions of inspection of various garments. A fuzzy-tuned PID (FT-PID) control algorithm was employed to regulate the controller parameters automatically. The simulation and experimental results showed that FT-PID controller outperforms conventional PID controller and that it could provide efficient performance even when the force sensor output is contaminated with noise.

3.3 Assessing Seam Pucker

Seam pucker is still a primary concern in garment manufacturing. When the sewing parameters and material properties are not properly selected, puckering appears like a wave front along the seam line of a garment and damages its aesthetic value. This problem occurs immediately after seam construction or may develop after several washing and drying processes (Ukponmwan et al. 2000).

For quality garments, it is important to accurately evaluate seam pucker to better understand its causes and to ultimately eliminate it in the garment manufacturing process. The initial methods of seam pucker evaluation were based on subjective assessment; they suffered from the limitations of higher evaluation time, inconsistency among judges, and need for training; the results are not reliable. Therefore, different approaches to assess seam puckering objectively have been done in order to accurately rate the level of puckering in the sewn fabric. Among these approaches, artificial neural network, neuro-fuzzy logic, and machine learning methods look promising. Park and Kang (1997) presented an objective method for evaluating seam pucker in woven fabrics during garment manufacturing by using artificial neural networks. They showed that the neural networks evaluate seam pucker the same way as the AATCC standard rating of well-trained human experts. The authors highlighted that this method can be used to find good sewing parameters and suitable auxiliary materials, including sewing thread, interlining. In another studies, Park and Kang (1999a, b) developed a new quantitative method to evaluate seam pucker with five shape parameters using three-dimensional image analysis and neuro-fuzzy logic. The shape parameters included the number of wave generating points, the wave amplitudes, and the wavelengths on the line next to the seam and on the edge line. These parameters were not directly obtained from a simple analysis of the power spectra, but from fuzzy logic and neural networks in order to analyze power spectra in more detail and to produce shape parameters with the neuro-fuzzy algorithm. The authors pointed out that the new grading system can contribute to improved garment quality by identifying and solving seam pucker problems related to material properties as well sewing conditions. This method can be instrumental in better understanding the cause of seam pucker and eventually eliminating it in garment manufacturing plants (Park and Kang 1999c). Pavlinic et al. (2006) investigated the effect of fabric mechanical properties on the quality of seam appearance using machine learning methods including regression tree and k-nearest neighbors (K-NN). The obtained results indicated that the K-NN algorithm is more appropriate for the purpose than regression trees and that there is a high degree of correlation between the ranks of the attributes selected by the experts and those selected by the K-NN method. In addition, it was confirmed that fabric elasticity had the most prominent impact on seam puckering. In fact, it was found that seam puckering was more noticeable with inelastic fabrics, where the tension in warp and weft threads was higher than with elastic fabrics, due to the fact that they were pushed aside as each sewing needle penetration. The authors underlined that the proposed approach is of considerable importance in the process of designing high-quality garments and that it offers, apart from savings in the amount of the fabric to be used, clear criteria for the required fabric quality parameters.

Thus, the use of artificial intelligence techniques will be helpful for the manufacturers and customers to exactly evaluate the seam pucker and accordingly control the quality of apparels.

3.4 Detecting and Classifying Garments Defects

The main purpose of garment quality control is to identify the faults at the earliest possible steps for production of garments, and earlier the defects will be detected lesser will be the wastage of fabric, time, and money. However, identifying garment defects through visual inspection is not reliable. Therefore, automated defect detection and classification is required to enhance the product quality in order to meet both customer demands and to reduce the costs associated with off-quality. Hence, numerous approaches were proposed to address the problem of detecting defects in the fabric or garment (Mahajan et al. 2009; Ngan et al. 2011).

Neural networks are one of the fastest most flexible classifier used for fault detection due to their nonparametric nature and ability to describe complex decision regions. Bahlmann et al. (1999) proposed a NN-based system for an automated, vision-based quality control of textile seams with the aim to establish a standardized quality measure and to lower costs in manufacturing. The system could evaluate seam quality from grayvalue images. It consisted of a suitable image acquisition setup, an algorithm for locating the seam, a feature extraction stage, and a neural network of the self-organizing map type for feature classification. The obtained results showed that even with few but well-fashioned features good classification results could be obtained. The authors highlighted that the proposed system would be useful not just to objectify quality control of textile articles, but it can also provide a basis to perform online adjustment of sewing machine parameters to achieve smoother seams. Wong et al. (2009) presented a stitching and classification technique based on wavelet transform and BP neural network. Five classes of common stitching defect samples including pleats, puckers, tension, skipped-stitches, and hole were analyzed. The classification results demonstrated that the proposed method had high recognition accuracy in the detection and classification of stitching defects and that it exhibited better performance compared to wavelet-based methods. Yuen et al. (2009a) proposed a fabric stitching inspection method for knitted fabrics in which a segmented window technique was developed to segment images into three classes using a monochrome single-loop ribwork of knitted garment: (1) seams without sewing defects; (2) seams with pleated defects; and (3) seams with puckering defects caused by stitching faults. Nine characteristic variables were obtained from the segmented images and input into a BP neural network for classification and object recognition. The classification results demonstrated that the developed inspection method achieved high recognition accuracy and that it can provide decision support in defect classification (Yeun et al. 2009b). Also, it was proven that the classifier with nine characteristic variables outperformed those with five and seven variables and that the neural network technique using either BP or radial basis (RB) is effective for classifying the fabric stitching defects.

Kulkarni and Patil (2012) designed an automated garment identification and defect detection model based on texture feature, Gray-Level Co-occurrence Metrics (GLCM) and Probabilistic Neural Network (PNN). The texture features were used to detect garment defects, and these defects are classified by using PNN classifier. The experiment results showed that the proposed model is effective and suitable for online garment inspection and that PNN exhibited better detection accuracy compared with BP neural network.

In an automation inspection system for defect detection and classification, it is necessary to solve the problem of detecting small defects that locally break the homogeneity of a texture pattern and to classify different kinds of defects, including color value defects of fabrics. Zhang et al. (2011) developed a new intelligent and automated inspection model based on genetic algorithms and a modified Elman method neural network to detect and classify colored texture fabric defects that are also suitable for garment-stitching defects. The results demonstrated that the proposed inspecting model is more feasible and applicable in fabric defect detection and classification.

The main advantage of using an automated visual inspection system is that it does not suffer from limitations of humans, such as exhaustion, while offering the potential for robust defect detection, leading to reduced cost and time-wasting.

3.5 Dimensional Change Issue

Dimensional stability is regarded as being of primary importance to finished garments. A fabric or garment may exhibit shrinkage in some dimensions due to some relaxation process which enables the strains and distortions imposed on the fabric during manufacturing and processing to be released, allowing the fabric to take up a stable relaxed configuration (Kaulkanci and Kurumar 2015). Shrinkage is a combined effect of number of factors such as relaxation, finishing, dyeing, and effects of machinery (Kaur and Roy 2016). Garments made from fabrics without dimensional stability may change shape after laundering or dry-cleaning, which is undesirable for wearers. Kalkanci et al. (2017) investigate the use of a feed-forward back-propagation NN to estimate dimensional measure properties of T-shirts made up of single jersey and interlock fabrics. To that end, for each of the two fabric groups made up of different materials with three different densities either containing elastane or not, a total of 72 different types of T-shirts were manufactured. Knitted fabrics were processed through finishing operations in a garment controlled environment. Following the garment manufacturing process, dimensions of the ultimate product (T-shirt) were taken and recorded individually. The experimental results showed that the prediction of dimensional properties produced by the NN model was highly reliable ($R2 > 0.99$). The authors concluded that ANNs could successfully estimate dimensional changes in a garment and that they would eliminate additional operations to resolve the tension problem, thereby increasing productivity.

4 Garment Quality Evaluation

The garment shaped and manufactured so that it fits the 3D shape of the human body should meet the criteria of appearance quality and comfort in wearing. Indeed, consumer satisfaction with apparel products is influenced by physical as well as the psychological qualities of product. Hence, assessment of apparel product not only is limited to the functional aspects, but also includes the aesthetics.

In this section, we will present some applications of soft computing methods for evaluating clothing quality.

4.1 Clothing Sensory Comfort

Sensorial comfort is the sensation of how a fabric or garment feels when it is worn next to the skin. This feeling may be pleasant like smoothness or softness, or be unpleasant, if a textile is scratchy, too stiff, or clinging to a sweat-wetted skin (Nawaz et al. 2011). The most commonly used objective evaluation of this aspect of comfort is carried out by measuring the mechanical properties of apparel fabrics using the Kawabata Evaluation System (KES). However, the relationship between these properties and sensory data is so complex that traditional statistics cannot give accurate results. Thus, AI techniques such as NN and fuzzy logic can provide an attractive alternative to predict clothing sensory comfort. Wong et al. (2003) developed feed-forward BP neural network models to predict an overall comfort perception from ten individual sensory perceptions (clammy, clingy, damp, sticky, heavy, prickly, scratchy, fit, breathable, and thermal), which were rated by twenty-two professional athletes in a controlled laboratory. The obtained results showed a good agreement between predicted and actual clothing ratings. Also, it was shown that NN provided quick and flexible solutions with self-learning ability for such simulations compared with statistical modeling techniques.

Wong and Li (2004) investigated the process of human psychological perceptions of clothing-related sensations and comfort to develop an intellectual understanding of and methodology for predicting clothing comfort performance from fabric physical properties using different hybrid models. A series of running wear trial, which involved 8 sets of tight-fit garment and 28 subjects, was conducted in an environmentally controlled chamber. Thirty-three fabric physical property indexes were measured, and nine individual sensations (clammy, sticky, breathable, damp, heavy, prickly, scratchy, tight, and cool) and overall comfort were rated by the subjects during the running period. In the prediction of overall comfort ratings, fuzzy logic, linear model, and NN were employed separately in the different hybrid models. The obtained results showed that the model that integrates the three modeling techniques could generate the best predictions compared with other hybrid models. This finding was attributed to the fact that this model combines the strengths of NN (self-learning capability), fuzzy logic (fuzzy reasoning ability), and statistics (data reduction and information summation). The authors highlighted that fabric physical properties can be used to predict overall clothing comfort with the application of the hybrid predictive model that it can closely simulate human sensory perception and judgement processes. Wang et al. (2008) developed an expert system based on fuzzy logic to describe sensory on clothing in accordance with professional knowledge and consumer preference and showed that it could be applied for product designing and fashion trends tracing in garment industry.

4.2 *Clothing Thermal Properties*

The thermal comfort is related to the ability of fabric to maintain the temperature of skin through transfer of heat and perspiration generated within the human body. Nowadays, various consumers consider thermal comfort as one of the most significant attributes when purchasing apparel products. The thermal properties of fabrics have been objectively and subjectively evaluated by several techniques (Pamuk 2008). However, owing to nonlinear relationship of different fibers, yarn and fabric parameters with thermal properties, difficulty arises in the statistical modeling. Therefore, it becomes difficult to study the effect of some parameters without varying the other parameters. Thereby, advanced techniques such as fuzzy logic and ANN look promising. Wang et al. (2005) presented a fuzzy system to predict the subjective perceptions of thermal comfort on the basis of simulated results of thermal and moisture sensations, in which dampness and coolness sensations were considered to be two main factors that would affect the final, clothing thermal comfort perception. The membership functions of these, as well as inference rules, were established through data collected from questionnaires in a series of wear trials carried out in a climate chamber. The experiments were then simulated again by specifying experimental conditions, human physiological activity level, as well as the textile material used. During the simulation, the following information was calculated: dynamic temperature and moisture concentration distribution of the human-clothing-environment system, the firing rate of the thermal receptors, the perceptions of dampness and coolness due to the contact of clothing, and the overall perception of clothing thermal comfort. It was found that the simulation results agreed well with the experimental results. Luo et al. (2007) developed a fuzzy NN thermal comfort model for evaluating the apparel thermal function in a dynamical and non-uniform environment, which was determined by the wearer's local and overall thermal sensations using physiological parameters including core and local body part temperatures and the rates of temperature changes. The test results for simulation data verified the reliability of this human-like approach. Al-Rashidi et al. (2015) used an ANN to predict the thermal insulation values of children's school wear in Kuwait classrooms. The obtained results showed that ANN was able to give more accurate prediction of the clothing thermal insulation values than regression equation and standard tables methods. The weight of each variable in the neural network structure was used to estimate the relative importance of each variable on the clothing thermal insulation prediction, and results indicated that the weight of the cloths had the most pronounced effect on the thermal insulation value. The authors indicated that the findings of their study give evidence about the applicability of the new ANN model to predict the thermal insulation of different children's clothing ensembles.

4.3 Garment Appearance Quality

Garment appearance is an important factor in determining clothes aesthetic aspect. Fabric's mechanical properties have prominent influence on fabric behavior during garment manufacturing and final product shaping (Mousazadegan et al. 2013). Formability of the fabrics in particular garment manufacturing processes and the stability of the newly created form directly impact garment appearance quality. Furthermore, an important role in ensuring the quality of the garment made is played by the additional factors, such as drape. These factors cannot be measured, but can be evaluated employing subjective grades, visual by nature. However, the subjective method does not offer engineering assessment of garment quality. Thus, with increasing market requirements, it is necessary to develop objective methods to evaluate fabric appearance quality. Pavlinic and Gersak (2009) presented an intelligent system for predicting garment appearance quality, based on studying the interactions between the parameters of fabric mechanical and physical properties, as measurable values, and the grade of garment appearance quality, i.e., the grade of each individual garment appearance factor, expressed by descriptive subjective grades. The factors of garment appearance quality were determined on the basis of the elements for obtaining proper drape, i.e., garment yield, achieving 3D shape, garment fit, the quality of the seams made, and the quality of garment appearance as a whole. A group of semiskilled evaluators and a group of experts in the field of garment engineering were doing the evaluation. The method of nearest neighbor k-NN was used to design the prediction model, showing better accuracy than regression trees. The authors highlighted that the developed intelligent system is of a particular applicative importance, as it can be used in engineering predictions and designing high-quality garments, while at the same time it offers important data on the quality requirements of particular parameters of fabric mechanical and physical properties, necessary to obtain the required garment appearance. They also outlined that this system represents a necessary objective technology of measuring and evaluating garment appearance quality, since the existing conventional methods of subjectively evaluating garment appearance quality should be replaced by a new knowledge-based engineering method.

Over the years, predicting fabric behavior during garment manufacturing process was considered by researchers in order to reduce manufacturing problems and achieve high-quality products. Xue et al. (2016) developed an ANFIS predictive model to study the relations between fabric formability and the mechanical properties for the end-use of men's suits. Based on the integration of NN and fuzzy inference, the proposed model has proven to be capable of producing results of higher predictive precision and better interpretability as compared with classical methods. The authors highlighted that the results obtained from their research are believed to be valuable for suit manufacturers and researchers who are working on the translation between fabric physical properties and the desired silhouette of men's suits and, meanwhile, could be instructive for dealing with many other similar problems concerning data uncertainty and imprecision.

Drape simulation is a very challenging task. Fan et al. (2001) investigate the use of a fuzzy-neural network system to predict and display the drape image of garments made from different fabrics and styles. The basic logic was to find and display a drape image from a database that was very close to the actual drape image of the newly designed garment of the same style. The proposed system has been tested to be satisfactory with lady's dress made of a wide range of fabrics. The advantages of the approach included very fast computation, avoiding difficulty of taking into account the effects of accessories, seams, and styles on drape in conventional drape simulation, and if sufficient drape images are stored in the database, the predicted drape image can be very close to the actual one. A disadvantage was that only limited styles and changeable feature dimensions can be allowed in the approach.

5 Challenges Facing Adoption of AI Techniques in Clothing Industry

Published literature presented in this chapter show the potential of AI techniques for providing support in decision-making and problem-solving processes involved in garment manufacturing. Nevertheless, in spite of these advantages, clothing companies do not widely use these advanced techniques. This fact can be attributed to the followings challenges and limitations:

- The lack of data availability and limited sample sizes. In fact, current AI approaches require a lot of labeled data in order to achieve decent accuracy in their predictions. However, apparel enterprises lack sufficient training data that are labeled, since labeling often requires expensive human labor and much time, which means the solutions fall short. Thus, AI techniques need to evolve toward *Unsupervised Learning* models that do not require labeled data to train the AI models.
- The cost of incorporating artificial intelligence in daily operations is still very high, and further advancements in the technology might bring that down. However, the investment and resources required to produce intelligent machines that can perform complex human tasks may not be justified by the increased productivity or cost savings.
- Most of the previous studies focused on presenting an AI-based methodology to handle a specified problem, and only few papers have compared the performance of different AI techniques.
- The long computational time required for handling a large size of data set. Indeed, easy or traceable problems can be solved in polynomial time. However, intractable problems require times that are exponential functions of the problem size.
- The setting of parameters of an AI technique has a large effect on its performance. Due to the insufficiency of theoretical foundation of AI techniques, parameter setting usually depends on experience or the trial-and-error method in previous studies.

- The effects of changes in many processing variables in the manufacturing process of garments have not been fully quantified. This is an important task for the clothing industry to accomplish in the future.
- The decision-making problems in the apparel industry have many distinct features, such as more uncertainties and dynamic features, which increase the complexity of these problems. In previous studies, various practical features existing in the clothing industry such as machine breakdown, variable operator efficiencies, and operator absenteeism were not investigated.
- The lack of confidence in the fairness of an AI-based system will limit support for its use and likely preclude adoption, even if that adoption could provide significant benefits.
- The lack of insight into how these systems work in the first place. For example, neural networks are usually inscrutable to observers and act as a black box, which does not consider nor explain the underlying physical processes explicitly. Although we know how they are put together and the information that goes in them, the reasons why they come to certain decisions usually goes unexplained.
- Today's expert systems have no ability to learn from their experience. Except for simple classification systems, expert systems do not employ a learning component to construct parts of their knowledge bases from libraries of previously solved cases. However, learning capabilities are needed for intelligent systems that can remain useful in the face of changing environments or changing standards of expertise.
- AI interference in human roles can cost jobs for a considerable share of our manpower. Hence, critics might lobby against extended AI implementation.
- Cultural resistance to change also high on the list of practical challenges provided by respondents will be a tougher nut to crack for many apparel companies.

6 Conclusion

AI offers great potential for the engineering of garments since it is able to significantly reduce the product development process and lead to great savings. It becomes an excellent tool for decision makers to effectively plan and execute complex manufacturing tasks, rapidly identify and solve critical quality issues, and deliver products that satisfy unique customer requirements.

In this chapter, the research on applications of AI in garment manufacturing was examined and classified into three categories as production planning, control, and scheduling; garment quality control and inspection; and garment quality evaluation. The findings reveal that artificial neural networks, genetic algorithms, fuzzy logic, neuro-fuzzy systems, and machine learning methods are the most frequent AI tools used in the applications in garment manufacturing. Another noteworthy finding is that the research issues investigated in previous studies are limited: A number of problems have rarely been discussed or examined.

Furthermore, the industrial use of AI technologies in the clothing industry is still very limited. This is because important hurdles exist at various levels. Thus, the implementation of the AI techniques into the clothing industry requires a careful consideration of the various practical features existing in the clothing industry in order to ensure optimal solutions. In addition, the effects of various AI model parameters, such as parameters of ANN structures, on the performance of solutions should be investigated in order to provide definite methods to set these parameters for certain problems. Meanwhile, AI with all its challenges and opportunities is an inevitable part of our future. Therefore, both the AI researchers and the apparel industry experts need to work closely together in order to explore practical decision-making problems not yet investigated in the apparel industry and improve the efficiency of existing AI approaches.

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