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REVIEW

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Intelligent techniques and optimization algorithms in textile colour management: a systematic review of applications and prediction accuracy

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Abstract

Based on a selection of 101 articles published from 2013 to 2022, this study systematically reviews the application of intelligent techniques and optimization algorithms in textile colour management. Specifically, the study explores how these techniques have been applied to four subfields within textile colour management: colour matching and prediction, colour difference detection and assessment, colour recognition and segmentation, and dye solution concentration and decolourization. Following an introduction to intelligent techniques and optimization algorithms in textile colour management, the study describes the specific applications of these techniques in the field over the past decade. Descriptive statistics are used to analyse trends in the use of these techniques and optimization algorithms, and comparative performances indicate the effectiveness of the techniques and algorithms. The study finds that the primary intelligent techniques used in the field of textile colour management include artificial neural networks (ANN), support vector machines (SVM) such as SVM, LSSVM, LSSVR, SLSSVR, FWSVR, fuzzy logic (FL) and adaptive neuro-fuzzy inference systems (ANFIS), clustering algorithms (e.g., K-means, FCM, X-means algorithms), and extreme learning machines (ELM) such as ELM, OSLEM, KELM, RELM. The main optimization algorithms used include response surface methodology (RSM), genetic algorithms (GA), particle swarm optimization (PSO), and differential evolution (DE). Finally, the study proposes a comparison of the performance of intelligent techniques and optimization algorithms, summarizes the relevant research trends, and suggests future research opportunities and directions, besides stating the limitations of this paper.

Keywords: Intelligent techniques, Optimisation algorithms, Textile colour management, Performance comparison reference, Review

Introduction

To enhance prediction accuracy, intelligent techniques and optimization algorithms are employed to identify and classify patterns in data. Artificial Neural Networks (ANN), K-means clustering algorithms, and Adaptive Neuro-fuzzy Inference Systems

(ANFIS) are among the commonly used intelligent techniques (Almodarresi et al., 2013; Pan et al., 2013; Vasseghian & Dragoi, 2018). Likewise, a few examples of commonly used optimization algorithms are Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO) algorithm, and Genetic Algorithm (GA) (Aryafar et al., 2019; Chaouch et al., 2019a; Zhang & Yang, 2014). These techniques and algorithms can serve as effective alternative tools for identification, classification, and prediction in the domain of textile colour management (He et al., 2021; Liu et al., 2022).

In the field of textile colour management, there are numerous problems that need to be addressed, including colour matching and prediction, colour difference detection and assessment, colour recognition and segmentation, as well as dye solution concentration and decolourisation. These issues are complex and cannot be easily solved by simple linear regression models. However, application of intelligent techniques and optimisation algorithms can help enhance the efficiency of optimisation, identification, and prediction. This, in turn, reduces the number of repeated experiments, leading to better solutions to these problems. For instance, ANN is a type of intelligent technique that can make predictions without requiring a mathematical description of the phenomena involved in the process, thus requiring less time to develop models (Khataee et al., 2013). K-means clustering methods can analyse the colour segmentation of printed fabrics in different colour spaces by minimising the sum of the squared distances between all points and the cluster centroids (Pan et al., 2013). ANFIS can combine the learning capabilities of neural networks with the capabilities of fuzzy logic to generate improved predictions (Haji & Payvandy, 2020). Optimisation algorithms, such as ACO, are computationally efficient methods for obtaining good solutions to combinatorial optimisation problems (Chaouch et al., 2019a). Meanwhile, the PSO algorithm is capable of continuously searching the problem space by representing random answers in the search and optimal solution region (Aryafar et al., 2019). Additionally, a combination of neural networks can be used to find the optimal weights and biases, thereby improving the performance of artificial neural networks (Aryafar et al., 2019). Alternatively, GA is a search heuristic in artificial intelligence that mimics natural selection (Zhang & Yang, 2014).

In the field of textile colour management, the desired colour is achieved through dyeing, which involves addressing the challenges of colour matching and prediction. Specifically, an appropriate colour formulation needs to be developed to get the same colour as the given reference colour by predicting the dyes and their respective concentrations (Chaouch et al., 2022). Traditional methods typically rely on experience of practitioners or the Kubelka–Munk theorem, but the accuracy of colour matching is hindered by various factors such as fibres, yarns and finishing processes (Şahin et al., 2022). Thus, investigating the problem of colour matching and prediction through intelligent techniques and optimization algorithms is essential. Moreover, after dyeing, the quality of the fabric's colour serves as a significant indicator for product testing (Zhang & Zhou, 2022). Traditional colour classification methods involve manual classification by experienced and skilled workers, who are susceptible to visual fatigue and subjectivity (Zhang & Zhou, 2022). Therefore, intelligent techniques and optimization algorithms-based colour difference detection and assessment models have been developed to meet the requirements of automated production of dyed fabrics. Furthermore, with diversification of colours in clothing, the demand for printed fabrics with complex colour patterns has increased (Qian et al., 2022). In the production of fabrics, colour recognition and segmentation are indispensable steps (Qian et al., 2022). However, the traditional methods of colour recognition and segmentation are not only labour-intensive but also unstable (Qian et al., 2022). Therefore, research on colour recognition and segmentation of multicoloured fabrics based on intelligent techniques and optimization algorithms has been initiated. Finally, concerning the concentration and decolourization of dye solutions in textile wastewater, a combination of intelligent techniques and optimization algorithms can effectively optimize the modelling process, save time and experimental costs, and improve the efficiency of pollutants removal (Kothari et al., 2022).

However, there is a dearth of comprehensive and systematic reviews, in extant literature, of applications of intelligent techniques and optimization algorithms in the field of textile colour management. While previous reviews of applications of intelligent techniques have been scattered and focused on textile wastewater decolourization, textile supply chain, and textile manufacturing processes (He et al., 2021; Liu et al., 2022; Ngai et al., 2014), a comprehensive review of the existing literature is critical to inform applications of intelligent techniques and optimization algorithms in the field of textile colour management. This review focuses on the last decade, i.e., from 2013 to 2022, and considers research articles published in journals or conference articles on applications of intelligent technologies and optimization algorithms in textile colour management. The research articles were selected using an advanced search in Web of Science with the following keywords: "TS = (textile OR fabric) AND TS = (colour fading OR colour prediction OR colour management OR colour recipe OR fading) AND TS = (ANN OR neural network OR intelligent techniques OR algorithm OR intelligent)." After removing articles that were not relevant to the topic, we selected 101 articles. For classifying different issues related to the field of textile colour management, a subjective approach was employed. This approach relied mainly on the authors' judgment by designing sub-category headings and classifying each article according to their own opinions (Liu et al., 2022).

This paper presents a systematic review of previously published literature on applications of intelligent techniques and optimization algorithms in the field of textile colour management. The objectives of this review are as follows:

1. To describe specific applications of intelligent techniques and optimization algorithms in the field of textile colour management.
2. To analyse the current trends in the use of intelligent techniques and optimization algorithms in the field of textile colour management.
3. To summarize the relevant research trends and identify future research opportunities for application of intelligent techniques and optimization algorithms in the field of textile colour management.

Methods

Specific applications of intelligent techniques and optimisation algorithms in the field of textile colour management

After reviewing 101 research articles published in the last decade (2013–2022) in the field of textile colour management, a subjective approach was used to classify these articles into the following four categories: (1) colour matching and colour prediction; (2) colour difference detection and assessment; (3) colour recognition and colour segmentation; and (4) dye solution concentration and decolourisation. Specifically, we have identified specific applications of intelligent techniques and optimization algorithms in this field and categorized them as follows: colour matching and colour prediction (34 research articles); colour difference detection and assessment (15 research articles); colour recognition and colour segmentation (20 research articles); and dye solution concentration and decolourisation (32 research articles).

Colour matching and colour prediction

For colour matching and prediction, a variety of intelligent techniques and optimization algorithms are available. These include Artificial Neural Networks (ANN) and Recurrent Neural Networks (RNN), Fuzzy Logic (FL) and Adaptive Neuro-Fuzzy Inference Systems (ANFIS), Response Surface Methods (RSM) and Taguchi methods, Combinatorial Optimization (CO), Ant Colony Optimization (ACO), Genetic Algorithms (GA), Grey Wolf Optimization (GWO), PSO-FMINCON algorithms (PSO-FMIN), Multi-Objective Evolutionary Algorithms (MOEA), and Non-dominated Sorting Genetic Algorithm II (NSGAII). A total of 34 research articles related to colour matching and prediction published in the past decade have been compiled and are presented in Table 1, sorted by algorithms. Besides, a meticulous exploration of the technical nuances and applications of these methodologies will ensue, with the objective of elucidating their respective merits and limitations.

Firstly, ANNs have been substantiated as potent tools for conducting colour predictions and colourant prognostications (Almodarresi et al., 2013; Hasanzadeh et al., 2013). Specifically, ANNs can be trained to emulate the behaviours of professional colourists, thereby learning the relationships between colourants and specific colour coordinates (Almodarresi et al., 2013). Nonetheless, conventional ANNs may encounter difficulties in processing sequential data. To mitigate this issue, RNNs have been introduced (Zhang et al., 2021). RNNs permit data to be input in a sequential format and share weight matrices (Zhang et al., 2021). However, RNNs are not devoid of issues, such as determining the number of network layers (Zhang et al., 2021). To ameliorate these issues, researchers have introduced dense blocks and employed Long Short-Term Memory (LSTM) blocks to preclude information loss (Zhang et al., 2021). Both techniques have significantly enhanced the performance of RNNs.

In addition, fuzzy logic, emanating from the foundational fuzzy set theory, navigates through four pivotal components: the fuzzification interface, the knowledge base, decision logic, and defuzzification (Hossain et al., 2015). It mitigates uncertainties and imprecisions by employing fuzzy sets and operational rules of fuzzy mathematics. Nonetheless, selecting a judicious number of membership functions and parameters to

Table 1 Specific applications of intelligent techniques and optimisation algorithms in the field of colour matching and colour prediction

Intelligent techniques and optimisation algorithms	Research content	Prediction accuracy	References
ANN	This research investigated the ability of three reactive dyes (Levafix Red CA, Levafix Yellow CA, and Levafix Blue CA) to match colours on cotton fabrics	Approximately 80% of the test data had a mean colour difference [CMC(2:1)] of less than 1.5	Almodarresi et al. (2013)
	This research focused on modelling the colour properties of denim treated by lasers, and the grey scale (percentage of brightness) was found to have the greatest influence on colour characteristics of the laser-treated denim	ANN method provided more accurate predictions than the LR method	Hung et al. (2014)
	This research aimed to predict the colour of leather dyeing using trimodal values (X, Y, Z) for a given dye concentration	The ANN model had the potential to provide a better level of colour prediction than the traditional Kubelka–Munk model, with a lower colour difference of 0.78 compared to 2.65 using the Kubelka–Munk model	Jawahar et al. (2015)
	This research focused on solving the colour mismatch between the design display and the actual fabric using ANN. The colour systems used were the standard RGB and CIE colour systems, respectively	This method substantially enhanced the colour matching between the design and its printed version with all decision coefficients greater than 0.9	Hwang et al. (2015)
	This research proposed an ANN model to predict colour characteristics of 1005 cotton knitted fabrics engraved by lasers under different process conditions. DPI and pixel time were identified as the two main factors influencing the colour yields	The relative errors in the ANN model mostly ranged between 0 and 5%, which is a reasonable range	Kan and Song (2016)
	This research focused on predicting viscose fibre mixture colours using a traditional neural network and a combination of several small neural networks	The average colour difference between the actual and predicted mixture colours of the test set samples was close to 1.0, indicating a high level of accuracy. The study also found that a combination of several small neural networks performed better than a traditional neural network when there were few training examples	Hemingray and Westland (2016)
	These researchers designed a mixing method based on Kubelka–Munk + ANN that can model the process of mixing fibres of different colours to match a desired colour and predict the reflectance values of the mixture	The results of the study showed that the predictions made by the Kubelka–Munk + ANN method were found to be valid after a paired *t*-test	Furferi et al. (2016)
	This research focused on predicting concentration of dyes and silver nanoparticles on silk knitwear using an artificial neural network (ANN) approach	The ANN approach resulted in a correlation of 0.994, indicating that the dye and AgNPs concentration predictions were highly accurate	Nateri et al. (2017)
	This research aimed to develop a spectrophotometric algorithm for top-dyed melange yarns by predicting the weighted average spectrum using ANNs and making recipe predictions from the weighted average using constrained least squares	The sum of the squared errors in the prediction of weighted average reflectance is just 0.15%, and the average colour difference is 0.79 CMC (2:1) units for the actual samples according to the predictions of nine blind test targets, which demonstrates the ability and usefulness of the algorithm for precise colour prediction	Shen and Zhou (2017)

Table 1 (continued)

Intelligent techniques and optimisation algorithms	Research content	Prediction accuracy	References
	This research investigated the correlations between the input digital image pixels and the chromaticity parameters of the printed textile samples using a competitive neural network	The best prediction results were obtained with a correlation of 0.9671 and MSE of 0.0091	Hajipour and Shams-Nateri (2019)
	This research aimed to predict the colour of digital textile printing using a spectral representation model of the optimized RBF neural network	In the test colour samples, 90% spectral error was less than 0.04, and the average and maximum spectral error were 0.025 and 0.066 respectively. The 90% colour difference (DE2000) of the test colour samples was less than 2.8, with the maximum and average values being 8.5 and 1.89	Liu and Liang (2018)
	This research investigated the use of ANN to predict dyeing parameters for achieving the required colour and fastness of cotton dyeing	The standard deviation and standard error showed a close match of the input–output system and remained within the 95% confidence level, indicating that the ANN model was effective in predicting dyeing parameters	Chakraborty et al. (2019)
	This research focused on the development of a shade prediction system using ANNs to predict the colour change of finished samples	The developed model was found to be capable of predicting the colour change with over 90% accuracy, with MAEs of 0.6542, 0.5872, 0.5318, 0.4839 and 0.4707 for the delta colour coordinate value (Delta CIE L*a*b*C*h values) models respectively	Farooq et al. (2020)
	This research investigated the use of ANNs to predict the Delta CIE L*a*b*C*h values of finished samples for dyed knitted fabrics after application of softeners	The developed system was able to predict shade changes with greater than 90% accuracy, with mean absolute errors of 0.78, 0.71, 0.54, 0.37 and 0.33 for the Delta CIE L*a*b*C*h values of the finished samples, respectively	Farooq et al. (2021)
	This research investigated the use of an ANN method to predict the CIE L*a*b* values of yarns after the dyeing process	The differences between the actual and predicted values were within acceptable limits, with most of the predicted data deviating from the test data by less than 0.5	Şahin et al. (2022)
RNN	This research proposed an intelligent model to predict the dye recipe for cotton fabric dyeing using hyperspectral colour measurements and the RNN approach. The study included 343 uniformly dyed fabrics and 20 unevenly dyed fabrics with three different dyestuffs	The relative prediction errors for the three types of dyeing formulations were 3.40%, 2.70%, and 3.10%, indicating good prediction accuracy using the RNN approach	Zhang et al. (2021)
ANN and RSM	This research aimed to predict the colour intensity of hyperbranched polymers (HBPs) on fabrics after treatment using RSM and ANN models	The ANN model had a lower relative error of 1.67%, indicating greater accuracy than the RSM model, which had a relative error of 1.80%	Hasanzadeh et al. (2013)

Table 1 (continued)

Intelligent techniques and optimisation algorithms	Research content	Prediction accuracy	References
	This research investigated the modelling and optimization of conditions for blue pigments for reactive cotton dyeing by combining RSM and ANN methods	The R^2 between the predicted and actual values was 0.942, indicating a high level of correlation between predicted and actual values	Rosa et al. (2021)
ANN and ANFIS	This research investigated how plasma treatment parameters affect dyed samples' colour intensity and tested the effectiveness of ANN and ANFIS methods in predicting colour intensity	The proposed ANN and ANFIS methods provided accurate predictions with R^2 values of 0.986 and 0.997, respectively, with ANFIS having higher prediction accuracy	Haji and Payvandy (2020)
ANN and FL	This research focused on modelling the colour properties of viscose knitwear	For FL, the R^2, root mean square error (RMSE), and mean absolute error (MAE) were 0.977, 1.025, and 4.61%, respectively. For ANN, they were 0.992, 0.726, and 3.28%, respectively. Both FL and ANN accurately predicted the fabric colour strength, but ANN showed more accurate predictions than FL	Hossain et al. (2017)
Fuzzy Logic Expert System (FLES)	This research aimed to predict the colour intensity of blended knitwear made of viscose and lycra (95:5) using the FLES, and to identify the key factors that determine the colour intensity	The FLES model showed an average relative error of 3.80%, a correlation coefficient of 0.992, and a fit of 0.986 between the actual and predicted results from the fabric	Hossain et al. (2015)
	This research aimed to predict colour fastness of three types of cotton knitwear using an expert system based on fuzzy knowledge	The absolute error between the actual and predicted colour intensity of the knitted fabric was found to be less than 5%	Hossain et al., (2016a, 2016b)
Taguchi method	This research aimed to predict colour fastness of blended knitwear made of viscose and lycra using the Taguchi method. The Taguchi method was effective in optimizing and predicting colour fastness of the fabric	The mean absolute error (MAE) was 3.48%, and the coefficient of determination (R^2) was 0.88	Hossain et al., (2016a, 2016b)
ACO	This research aimed to use the ACO method to match the colours of direct dye mixtures for dyeing cotton fabrics and to select appropriate dyes and their concentrations in the dye bath to reproduce the desired shades	The proposed method showed good performance with mean values of theoretical and experimental colour differences being 0.3322 and 0.8075, respectively	Chaouch et al. (2019a)
	This research investigated the use of an ACO method for predicting the colour formulation of three reactive dyestuffs (CI Reactive Yellow 145, CI Reactive Red 238, and CI Reactive Blue 235)	The implemented algorithm provided satisfactory results resulting in minor colour differences, below 0.7, between the reference and reproduced colours	Chaouch et al. (2019b)
ACO and GA	This research aimed to predict colour formulations for three different reactive dyes using two optimization techniques: ACO and GA	The ACO was slightly more accurate than the GA, with a mean MSE of 0.0048 for ACO and 0.1299 for GA. The ACO is also more efficient in terms of computation time	Chaouch et al. (2022)

Table 1 (continued)

Intelligent techniques and optimisation algorithms	Research content	Prediction accuracy	References
SVM algorithm	This research aimed to classify dyes in coloured fibres using spectral imaging with a sparse logistic regression algorithm and SVM algorithm. First, the sparse logistic regression algorithm was employed to analyse the reflectance data of the dyed fibres so as to identify a number of discriminatory bands. Then, the SVM algorithm was used to classify the reflectance considering a selection of spectral bands	It was found that 9 selected bands in the shortwave infrared region, in the range of 1000–2500 nm, classified dyes approximately 97.4% accurately	Rahaman et al. (2020)
PSO-LSSVM	This research focused on estimating K/S values for cotton fabrics dyed with reactive dyes using PSO-LSSVM, with the inputs to the model consisting of dye concentration and process conditions	The R^2 between the experimental and predicted values were extremely close to 1, indicating a good fit between dye concentration, process factors, and K/S values for cotton fabrics	Yu et al. (2020)
	This research developed a computerized dye formulation prediction method for a single database of reactive dyes using a PSO-LSSVM model and evaluated its performance in predicting the CIE L*a*b* values for dyed fabrics	The predicted CIE L*a*b* values for dyed fabrics at dye concentrations from the PSO-LSSVM model showed a high correlation with the measured values of the cotton fabrics, with a correlation coefficient of 0.9945 for the PSO-LSSVM model	Yu et al. (2021)
GA	This research aimed to solve a new model for predicting colour formulation using mixtures of reactive and direct dyes	The proposed algorithm showed a small CMC colour difference between the target and reproduction colours, with mean values of 0.328 and 0.686, indicating high accuracy	Chaouch et al. (2020)
ANN, GA and FL	This research focused on modelling Madder's harmless dyeing of polyester fabrics using ANNs optimised by GA and FL. The study aimed to assess how each parameter affects colour power and to estimate the actual K/S values using ANN and FL models	Both the ANN and FL models were able to accurately predict the K/S values with mean absolute percentage errors (MAPEs) of 2.52 and 3.01, respectively	Haji and Vadood (2021)
MOGA and MOPSO algorithm	This research aimed to optimize the cotton dyeing process with reactive black 5 dye to achieve the maximum K/S value within a predefined range using MOGA and MOPSO algorithms	The results showed that both algorithms proved to be very useful computational tools	Boukouvalas et al. (2021)
ANN and optimization algorithms such as GA, PSO, GWO, FMINCON, and PSO-FMIN	This research investigated the prediction of colour coordinates of cellulose fabrics in binary dyeing with natural dyes using ANN and optimization algorithms such as GA, PSO, GWO, FMINCON, and PSO-FMIN	The results showed that ANN weighting using the PSO-FMIN algorithm has higher accuracy in predicting colour coordinates. For CIE L*a*b* coordinates, the outputs MSEs' were 2.02, 1.68, and 1.39, respectively	Vadood and Haji (2022a)
using GAs to optimize ANN and NSGAII's multi-objective optimization algorithm	This research aimed to estimate colour properties of polyester fabrics treated with natural dyes using GAs to optimize ANN and NSGAII multi-objective optimization algorithm	MAPEs of the ANN for predicting CIE L*a*b* values were 0.67, 1.29, and 1.27, respectively, indicating relatively high accuracy. The proposed method was also highly efficient in determining the colouration parameters to achieve the desired colours using a multi-objective optimization method	Vadood and Haji (2022b)

safeguard system accuracy whilst circumventing an escalation in complexity emerges as a formidable challenge (Hossain et al., 2015). In an extended discourse, the ANFIS model amalgamates concepts from fuzzy logic and neural networks, endeavouring to optimize the parameters of the fuzzy logic system through the exploitation of the learning capability intrinsic to neural networks (Haji & Payvandy, 2020).

Besides, the RSM proffers a methodological approach to ascertain the multivariate regression equation between the response variable and a set of design variables, facilitated through quantitative data (Hasanzadeh et al., 2013). In a parallel vein, the Taguchi method also furnishes a methodology to discern the optimal parameter combination by conducting a minimized quantity of experiments (Hossain et al., 2016a, 2016b). However, the Taguchi method encounters challenges, notably an incapacity to invariably determine the impact of interactions and a deficiency in ensuring the predictive accuracy of the model (Hossain et al., 2016a, 2016b).

Concomitantly, metaheuristic methodologies, exemplified by ACO and GWO, proffer mechanisms for procuring considerably propitious solutions to stringent Combinatorial Optimization (CO) dilemmas within an acceptable computational temporal framework (Chaouch et al., 2019a; Vadood & Haji, 2022a). The PSO-FMINCON amalgamated algorithm assimilates the merits of Particle Swarm Optimization and FMINCON, furnishing a more exhaustive optimization stratagem (Vadood & Haji, 2022a). Notwithstanding the incapacity of these algorithms to invariably assure the identification of the global optimum, their efficacy has been substantiated in an array of applications.

Subsequently, Multi-Objective Optimization Algorithms, notably the NSGAII, have manifested distinctive superiority in the domain of multi-attribute optimization (Vadood & Haji, 2022b). While such algorithms can engender a compendium of approximate Pareto optimal solutions, symbolizing the compensations amongst objective functions (Boukouvalas et al., 2021), the selection of one or several pragmatically implementable solutions from this ensemble necessitates judicious deliberation by decision-makers, contingent upon specific circumstances and predilections (Boukouvalas et al., 2021).

In summation, it is discernible that each technique and methodology harbours its idiosyncratic application scenarios and intrinsic limitations. The selection of a particular technology in practical applications hinges upon a plethora of factors: the objective intended for optimization, the type and quantum of data available, the permissible computational complexity, and the requisite precision in problem resolution, inter alia. Future research might judiciously explore the amalgamation, complementation, or flexible utilization of these methodologies, contingent upon the distinctive characteristics of the problem.

Colour difference detection and assessment

For colour difference detection and assessment, the available intelligent techniques are: Support Vector Machine (SVM) algorithm and Least-squares SVM (LSSVM), Support Vector Regression (SVR) and Least-squares SVR (LSSVR), the Random Vector Functional-link net (RVFL), the Extreme Learning Machine (ELM) and the Kernel ELM (KELM) and the Regularisation ELM (RELM) and the Online Sequential ELM (OSELM) learning algorithms. Optimisation algorithms are: Principal Components Analysis (PCA) methods and GA, Whale Optimisation Algorithm (WOA) and Grasshopper

Optimisation Algorithm (GOA), Sine and Cosine Algorithm (SCA) and Marine Predator Algorithm (MPA), Hunger Games Search (HGS), Takagi–Sugeno Fuzzy Neural Network (T–S FNN) and GM (1,1) grey theory models, Bagging strategies, Rotation Forest (RF), Differential Evolution (DE). Combinations of intelligent techniques and optimisation algorithms are: DE-GOA-KELM, SCA-MPA-RVFL, DPS-DE-RELM, GWO-HGS-RVFL algorithm, Bagging-PSO-ELM, RF-PSO-SLSSVR model. The 15 research articles related to colour difference detection and assessment published in the last decade are summarised in Table 2, sorted by algorithms. The elucidated intelligent techniques and optimisation algorithms furnish multifaceted solution strategies for the detection and assessment of chromatic disparities. Subsequent sections will delve into a more meticulous exploration, thoroughly scrutinizing the performance, merits, and constraints of an array of intelligent techniques and optimisation algorithms.

The SVM, a supervised learning methodology, primarily finds application in classification and regression issues (Zhang & Yang, 2014). SVM, along with its variant, LS-SVM, proffers a robust framework, addressing classification and regression dilemmas by harnessing the principle of structural risk minimization. Notably, the SVM operates on the principle of identifying a hyperplane, strategically maximizing the segregation of positive and negative instances (Zhang & Yang, 2014). Furthermore, LS-SVM, through the employment of equal constraints and quadratic error terms, avails a method that is computationally more expedient (Zhang & Yang, 2014). These attributes render SVM and its variants an optimal selection for addressing issues pertaining to colour discrepancies. Nonetheless, it warrants noting that the efficacy of these models is significantly contingent upon the selection of pertinent parameters, a process commonly entailing a complex cross-validation procedure.

Besides, methods based on neural networks, namely RVFL, ELM, and their variants, are to be contemplated. RVFL garners attention owing to its non-iterative training protocol, rapidity, and capacity to proffer predictive models (Liu & Yang, 2021). ELM and its variants, such as KELM and RELM, are distinguished by their straightforward architecture, swift learning velocities, and minimized parameter adjustments (Li et al., 2020; Zhou et al., 2021a, 2021b, 2019a, 2019b, 2019c). Specifically, the KELM amalgamates kernel methods with ELM, thereby enhancing performance (Li et al., 2020). Concurrently, the RELM and the OSELM respectively incorporate regularization parameters and online learning capabilities (Zhou et al.,). Nevertheless, a pervasive limitation resides in the stochastic determination of input weights and biases, potentially inducing performance instability, most notably within the online sequential variant, OSELM (Zhou et al., 2019a, 2019b, 2019c).

Turning to optimization algorithms, the PCA method is ubiquitously employed in feature extraction, celebrated for its capacity to diminish dimensions and isolate principal components (Zhang & Yang, 2014). The GA, simulating the process of natural selection, stands as a search optimization technique (Zhang & Yang, 2014). The WOA is underscored by its uncomplicated operation, scant parameter adjustments, and adeptness at evading local optima (Zhou et al., 2019a, 2019b, 2019c). The initial population configuration of the GOA may exert influence over convergence velocity and solution quality (Li et al., 2020). The SCA executes optimization searches via sine and cosine functions (Liu & Yang, 2021). However, the efficacy of these algorithms is profoundly contingent upon

Table 2 Specific applications of intelligent techniques and optimisation algorithms in the field of colour difference detection and assessment

Intelligent techniques and optimisation algorithms	Research content	Prediction accuracy	References
SVM, PCA and GA	This research focused on developing a colour difference evaluation model for dyed fabrics using SVM, in which the researchers used Principal Components Analysis to select several independent indicators from training and test data, and optimised its parameters through a GA	The proposed model was compared to the traditional Naive Bayesian algorithm and was found to provide a 9% improvement in prediction accuracy and a 0.0985 reduction in relative error	Zhang and Yang (2014)
Improved LSSVR algorithm and GM (1,1)	This research aimed to achieve colour constancy of textured textiles by combining an improved LSSVR algorithm and GM(1,1)	The results showed an increase in prediction accuracy was achieved when the improved LSSVR algorithm was combined with the improved GM(1,1) model	Zhang et al. (2017)
ANN	This research aimed to detect the colour difference of fabrics by extracting the colour eigenvalues of fabric images	The accuracy of the colour difference detection exceeded 93%	Li et al. (2015)
Bagging-PSO-ELM	This research aimed to develop an accurate light correction model for dyed fabrics by using a hybrid of an ensemble ELM mechanism based on Bagging and PSO, which is Bagging-PSO-ELM, to avoid light variations that can lead to severe colour difference evaluation errors	The results indicated that the best predictive performance can be obtained with Bagging-PSO-ELM	Zhou et al. (2016)
T–S FNN algorithm	This research focused on developing a mapping relationship between RGB space and CIE L*a*b* space using the T–S FNN algorithm to simplify the colour space conversion process. The block method was also used to identify colour differences in dyed fabrics with a wide range of viewing angles	The predicted results were in accordance with the spectrophotometer measurements, demonstrating the effectiveness and feasibility of the T–S FNN algorithm for the real-time colour detection process	Li et al. (2017)
DE-OSELM, SVR and ELM algorithms	This research proposed a DE-OSELM algorithm based on a rotating forest framework for solving textile colour correction	The developed algorithm reduced the mean squared error (MSE) by 10.3% and 7.8% compared to textile colour correction algorithms based on support vector regression (SVR) and extreme learning machine (ELM) algorithms, respectively, indicating strong robustness and excellent prediction capability	Zhou et al., (2019a, 2019b, 2019c)
DE-WOA-ELM (WOA optimized by the ELM of DE)	This research proposed a colour-difference classification approach using DE-WOA-ELM	The average classification precision of the dataset was enhanced by 2.15%, 11.06%, 12.11% and 0.47% in comparison with ELM, SVM, BPNN and KELM, respectively	Zhou et al., (2019a, 2019b, 2019c)

Table 2 (continued)

Intelligent techniques and optimisation algorithms	Research content	Prediction accuracy	References
RF-PSO-SLSSVR, RF, PSO, and SLSSVR	This research proposed an RF-based ensemble PSO and SLSSVR algorithm to improve the accuracy of light correction models. Artificial intelligence techniques used: Random Forest (RF), Particle Swarm Optimization (PSO), and Sparse Least Square Support Vector Regression (SLSSVR)	The RF-PSO-SLSSVR algorithm reduced the root mean square error (RMSE) of angular by 13.6% and 10.6% compared to the conventional SVR and ELM algorithms	Zhou et al., (2019a, 2019b, 2019c)
DE-GOA-KELM, which is a KELM using an improved GOA	This research investigated the classification of colour differences in dyed fabrics. Artificial intelligence techniques used: DE-GOA-KELM, which is a KELM using an improved GOA	The proposed DE-GOA-KELM model had an average classification accuracy of 98.89%, while the accuracy of the KELM was only 91.08%	Li et al. (2020)
Improved K-means algorithm	This research focused on developing a colour difference online detection algorithm for fabrics	The results showed that the developed algorithm was able to meet the real-time requirements of the system, and the detection speed increased from 0.2 to 0.8 m/s in line with the sampling	Xie et al. (2020)
YOLO (you only look once) convolutional neural network	This research proposed a real-time inspection system using the YOLO convolutional neural network to detect common defects and colour differences in warp-knitted fabrics	The proposed method performs well in real-time and is highly accurate, meeting the fabric inspection requirements of warp knitting factories	Xie et al. (2021)
The SCA-MPA-RVFL algorithm	This research evaluated the colour constancy of dyed fabrics by using the SCA-MPA-RVFL algorithm to eliminate the effect of light variation on the colour difference classification of dyed fabrics	The results of the study indicated that the SCA-MPA-RVFL algorithm was effective in restoring the images of dyed fabrics close to those under standard illumination, thus evaluating the colour constancy of dyed fabrics well	Liu and Yang (2021)
DPS-DE-RELM	This research proposed a new optimization technique called DPS-DE-RELM for developing colour difference classification models for dyed fabrics	The proposed method showed faster convergence, high classification accuracy, and robustness. The maximum classification accuracy achieved was 98.87%	Zhou et al., (2021a, 2021b)
FWSVR and PSO	This research proposed an approach for predicting recipes for factory dyeing	The results showed a small average colour difference between the desired colour and the re-created colour; the Mean Absolute Percentage Error (MAPE) in the predicted concentration was less than 5%	Li et al. (2022)
improving the HGS-optimized RVFL algorithm using GWO	This research aimed to classify the colour differences in dyed fabrics by improving the HGS-optimized RVFL algorithm using GWO	The results showed that the proposed algorithm had good stability and fast convergence	Zhang and Zhou (2022)

the selection of the initial population and parameter configurations, potentially catalyzing fluctuations in convergence velocity and the calibre of the final solution (Li et al., 2020; Zhou et al., 2019a, 2019b, 2019c).

The GM(1,1) grey prediction model distinctly characterizes itself by necessitating merely a minimal dataset for proficient modelling (Zhou et al., 2016). Conversely, Bagging, an ensemble learning methodology, efficaciously augments the performance of singular models (Zhou et al., 2016). The Rotating Forest (RF) is founded upon Random Forest and PCA (Zhou et al., 2019a, 2019b, 2019c).

Upon contemplation of the amalgamation of intelligent techniques and optimization algorithms, exemplified by DE-GOA-KELM and RF-PSO-SLSSVR, these methodologies comprehensively harness the merits of disparate algorithms, such as the expedited learning capability of KELM and the global search proficiency of GOA, in conjunction with the ensemble learning framework of RF and the parameter optimization prowess of PSO (Li et al., 2020; Zhou et al., 2019a, 2019b, 2019c; Zhou et al., 2019a, 2019b, 2019c; Zhou et al., 2019a, 2019b, 2019c). Such amalgamated methodologies strive to mitigate issues inherent in individual algorithms, such as parameter selection and local optima, whilst concurrently sustaining efficient learning and precise forecasting.

Discussions and comparative analyses pertaining to the performance, advantages, and limitations of these intelligent techniques and optimization algorithms elucidate that, within the pragmatic application domains of colour difference detection and evaluation, the selection and amalgamation of algorithms necessitate a foundation upon the inherent characteristics and prerequisites of specific issues and might necessitate subsequent algorithmic adjustments and optimizations. Prospective research endeavours, comprising the development and exploration of novel algorithms or algorithmic combinations and the investigation into the performance of varied algorithms upon disparate types of colour difference issues, will indeed present a direction of substantial value. Such endeavours will not only facilitate a more profound comprehension of the operational mechanisms inherent in various algorithms but also substantiate the development of more precise and efficient methodologies for colour difference detection and evaluation.

Colour recognition and colour segmentation

For colour recognition and colour segmentation, the available intelligent techniques and optimisation algorithms are the FCM algorithm, ANN, SVM, the K-means clustering algorithm and the X-means clustering algorithm, the Self-organising Map (SOM) and Node-Grown SOM (NGSOM), the Density Peaks Clustering (DPC) algorithm, the Efficient Dense Subspace Clustering (EDSC) algorithm, fuzzy region competition, and Fuzzy region-based segmentation (FRBS) approach. The 20 research articles related to colour recognition and colour segmentation published in the last decade are summarised in Table 3, sorted by algorithms. Subsequent sections will delve meticulously into the performance, advantages, and limitations of the aforementioned algorithms to facilitate a comprehensive comprehension of their practical applications and potential in colour recognition and segmentation.

In the realm of colour recognition and segmentation, clustering undoubtedly emerges as one of the pivotal steps (Pan et al., 2013). Among them, the unsupervised FCM

Table 3 Specific applications of intelligent techniques and optimisation algorithms in the field of colour recognition and colour segmentation

Intelligent techniques and optimisation algorithms	Research content	Prediction accuracy	References
FCM algorithm	This research implemented an FCM algorithm to detect the density of single-system fabrics	The maximum error in the detection results was 0.24%	Pan et al. (2013)
	This research proposed a novel FCM-based stepwise classification method for automatic recognition of colour yarn layout of single-system colour woven fabrics	The error of the preliminary automatic recognition was only 8.57% and 11.27%	Zhang, Pan, et al. (2015a)
	This research aimed to automatically detect the colour effects of fabric of dyed yarn, using a minimum repetition-based unit recognition algorithm	The FCM algorithm categorized the colour of all floats with an error rate of 18.75%	Zhang et al. (2015b)
	This research proposed an automatic analysis procedure for embroidery fabric images that includes colour analysis, pattern shape analysis, and texture analysis. In colour analysis, RGB images are pre-processed using wavelet transform and median filter, and then binary region segmentation is performed using the FCM clustering method, which can yield colour statistical values and colour features in terms of the number of colours	The proposed colour segmentation method is relatively more stable and can reduce the calculation time by 75% compared to the FCM and clustering validity index-based colour segmentation methods	Shih et al. (2016)
ANN	This research investigated the use of an ANN in a vision system to classify the colour fastness of woven fabrics	The vision system using ANN was able to identify the colour fastness of woven fabrics with 100% accuracy for red, purple, and yellow, 83.33% accuracy for green, and 91.67% accuracy for blue	Samsi et al. (2013)
Automatic Feedback Error Correction (AFEC algorithm)	This research developed an automatic feedback error correction colour-weave pattern recognition algorithm (AFEC algorithm) for automatic colour recognition of yarn-dyed fabrics	The X-means clustering algorithm achieved a false positive rate of about 1.33% in the classification of colours in the original image	Zhou et al. (2013)
A new unsupervised method	These researchers developed a new unsupervised method to detect colour regions that are prominent in images of yarn-dyed fabrics. The colour of the dominant colour region is correlated with the colour of the yarn through a probabilistic model. And it estimates the colour histogram of the main colour region based on the colour of the yarn in the image of the yarn-dyed fabric. A hierarchical segmentation structure is then designed to identify the dominant colour region within the image	The model processes a dominant colour region in images taken with macro and telephoto lenses in just 0.045 and 0.075 s, indicating suitability for industrial applications	Luo et al. (2013)
A grading algorithm based on rotationally invariant statistical features	This research focused on using image analysis techniques from the CIELAB colour model and a grading algorithm to describe the colour and automatically grade silk threads according to colour	The colour-sorting solution achieved an accuracy rate of 91%	Pal et al. (2013)

Table 3 (continued)

Intelligent techniques and optimisation algorithms	Research content	Prediction accuracy	References
An improved model based on multi-stage fuzzy region competition, and fuzzy region-based segmentation (FRBS) approach	This research proposed an improved model based on multi-stage fuzzy region competition for colour segmentation of colour images, and recoloured textile images with different colour themes to achieve automatic colour theming of textile images	Not specified	Han et al. (2013)
	This research proposes a new method that accurately divides colour regions for several types of fabrics using the CIELAB colour system and a fuzzy region-based segmentation (FRBS) approach	The FRBS approach outperformed traditional methods such as FCM clustering methods, Gustafson-Kessel clustering methods, expectation maximisation segmentation methods, traditional FRBS approaches as well as PCA-based fuzzy region competition methods	Zheng (2015)
	This research proposed an intelligent colour pattern recognition algorithm for yarn-dyed fabrics that uses a fuzzy region competition strategy in the classification of yarn colours	The extracted yarn colours are highly similar to those recognised by human vision, with a computation time of fewer than 15 s for the whole detection process	Zheng et al. (2019)
A colour clustering method based on a node classification correction method using adjacency information	This research aimed to classify the colours of nodes in the digital intelligent recognition of fabric weave patterns using a node classification correction method based on adjacency information	The study improved the accuracy of node classification by using the type and colour information of neighbouring nodes	Zhong et al. (2013)
K-means clustering method, X-mean clustering algorithm, improved watershed algorithm and improved K-means clustering method	This research focused on developing a new colour clustering algorithm based on the K-means clustering method to classify dyed yarns according to their colours in interlaced multicoloured dyed woven fabrics	The new method was found to be superior to the traditional approach in terms of accuracy and robustness	Zhang et al., (2015a, 2015b, 2015c)
	This research proposed an intelligent detection method based on image analysis to identify the colour and weaving patterns of yarn-dyed fabrics automatically	The experimental results showed that the proposed method was able to identify the colour of yarn-dyed fabrics very well	Li et al. (2019)
	This research proposes a new approach for colour segmentation and extraction of multicoloured yarn woven fabrics via a hyperspectral imaging system. The approach includes an improved watershed algorithm and an improved K-means clustering method to address the over-segmentation issue of the watershed algorithm	The proposed approach outperforms ordinary K-means, FCM, and DPC methods in the evaluation metrics of compactness and separateness, with an execution efficiency improvement of a minimum of 55%. The colour difference between the presented approach and the spectrophotometrically measured CMC (2:1) was between 0.60 and 0.88 units, indicating high accuracy of colour measurement	Zhang et al. (2020)

Table 3 (continued)

Intelligent techniques and optimisation algorithms	Research content	Prediction accuracy	References
NGSOM-based clustering algorithm	This research proposed an NGSOM-based clustering algorithm for intelligent colour classification of colour images and accurate delineation of regions of different colours for colour measurement	The proposed algorithm was found to have a better peak signal-to-noise ratio and higher time efficiency than some commonly used colour clustering algorithms	Ouyang et al. (2019)
SOM algorithm, DPC algorithm and EDSC algorithm	This research used a hyperspectral imaging system to determine optimum amounts of colour and merge clusters after multicolour measurements of printed fabrics by an algorithm that combines a SOM algorithm to determine the main clusters and a DPC algorithm	The approach efficiently identified the optimum amounts of colour for accurate colour segmentation of the printed fabric and required less execution time	Zhang et al. (2019)
	This research focused on developing an algorithm for colour segmentation of multicoloured porous printed fabrics using a combination of SOM Neural Network and EDSC algorithms. After pre-processing the fabric images, primary clustering was achieved by the SOM algorithm and then secondary clustering was performed by the EDSC algorithm. In the clustering process of the EDSC algorithm, the optimal silhouette coefficient is introduced to automatically determine the number of clustering centres. Finally, post-processing such as grey scale transformation, binarization and open operation eliminates the incorrect segmentation of edge colours, making the algorithm more suitable for industrial applications	The algorithm was found capable of accurately identifying colours of small regions and colour segment complex printed fabric images with an accuracy of 88.3%	Qian et al. (2022)
SVM	This research performed colour sorting of recycled waste textiles by the SVM classification method in a computer vision system	The classification accuracy for 466 textile samples was 96.57%	J. Zhou et al., (2021a, 2021b)
ANN and deep learning convolutional neural networks trained with the SVM method	This research focused on digital image analysis for colour matching of knitted cotton fabrics using ANN and deep learning convolutional neural networks	The ANN predicted three colours (blue, red and mauve) with correct classification rates of 82.37%, 83.16% and 89.25%, respectively. The deep learning convolutional network trained with the SVM method predicted 100%, 100%, and 100% of the three colours	Das and Wahi (2022)

algorithm is widely acclaimed as the most illustrious clustering method due to its capacity to iteratively update cluster centres and membership grades of data points, thereby positioning the cluster centres aptly within the dataset (Pan et al., 2013). Furthermore, FCM can be deployed to analyze the colour segmentation of printed fabrics within disparate colour spaces (Pan et al., 2013).

In contrast to FCM, the K-means clustering algorithm aspires to minimize the sum of squared distances between all data points and their respective cluster centres (Zhang et al., 2015a, 2015b, 2015c). Although both K-means and FCM algorithms exhibit particular merits, they are constricted by a predominant limitation, namely, the prerequisite knowledge of the number of clusters (Ouyang et al., 2019). Additionally, the X-means clustering algorithm, an extension of K-means, boasts a diminished time complexity, rendering it a significant temporal advantage when addressing problems of identical scale. For instance, the runtime of the FCM algorithm is at least 2.7 times that of X-means (Zhou et al., 2013).

The SOM, an unsupervised neural network technology, facilitates recognition or description within previously unencountered inputs (Ouyang et al., 2019). Despite the attainment of plausible colour segmentation outcomes utilizing a SOM with 10×10 nodes, the computational process typically proves to be time-intensive (Ouyang et al., 2019). To address this complication, the algorithm of Node Growing Self-Organizing Map (NGSOM) has been introduced, affording a reduction in processing time by up to eightfold without a compromise in accuracy (Ouyang et al., 2019).

Moreover, the DPC, a novel clustering algorithm underpinned by density, diverges from algorithms such as K-means by obviating the necessity to pre-determine the number of clustering centres (Zhang et al., 2019). This method furnishes a fresh perspective for data point classification and underscores the paramountcy of selecting clustering centres (Zhang et al., 2019).

Integration of SOM and EDSC for colour segmentation algorithms, through a bifurcated clustering approach—initially via SOM, followed by EDSC—augments the precision of segmentation considerably (Qian et al., 2022). The EDSC algorithm, inherently a subspace clustering method predicated on spectral clustering, deviates from traditional compressed sensing methods by emphasizing inter-data point connections, albeit necessitating manual input of clustering centre quantity (Qian et al., 2022).

In summation, diverse intelligent techniques and optimization algorithms each proffer unique advantages and limitations within the realms of colour segmentation and pattern recognition. The selection of an algorithm in practical applications hinges upon the specificity of task requirements and data characteristics. Future research endeavours to explore algorithms or methods capable of adaptively determining clustering centre quantity present a valuable trajectory.

Dye solution concentration and decolourisation

For dye solution concentration and decolourisation, the available intelligent techniques and optimisation algorithms are ANN, RSM, grey relational analysis (GRA), Taguchi methods, ANFIS, hSADE-NN (the ANN with a hybrid DE version), PSO algorithms, SVM, Random Forest. A summary of the 32 research articles related to dye solution concentration and decolourisation published over the last decade is given in Table 4, sorted

Table 4 Specific applications of intelligent techniques and optimisation algorithms in the field of dye solution concentration and decolourisation

Intelligent techniques and optimisation algorithms	Research content	Prediction accuracy	References
ANN	This research identified the optimal conditions for the decolourisation process of C.I. Direct Red 23 dye solution by investigating how operating parameters affect decolourisation performance	The achieved prediction performance was satisfactory with an R^2 value of 0.958	Khataee et al. (2013)
	This research investigated the prediction of optimal conditions for biodegradation of Remazol Brilliant Blue R dye using a MLP neural network	The optimal biodegradation conditions predicted by the MLP neural network resulted in a biodegradation index of 96%	Rosaa et al. (2013)
	This research focused on using ANNs, specifically by UV/H_2O_2, to remove chemical oxygen demand (COD) and colour from extracted wastewater from textiles	The neural model achieved a correlation coefficient of 99% for COD and 97% for colour	Yonar and Kilic (2014)
	This research evaluated the nZVI-Fenton process for reducing colour and COD from azo-dye textile wastewater using a regression model and an ANN	The ANN provided very accurate predictions with R^2 values ranging from 0.96 to 0.99, while the regression model provided predictions with R^2 values between 0.92 and 0.95	Yu et al. (2014)
	This research focused on modelling the coagulation process of chitosan extracted from spent shrimp shells for the treatment of reactive dye in an aqueous solution	R^2 between the estimated and observed outputs was 0.986 and the root mean square error (RMSE) was 2.951	Bui et al. (2016)
	This research focused on modelling and evaluating the electro-oxidation of wastewater containing CBSOL LE red wool dye	The regression coefficient between the training and target values was 0.995, indicating that the ANN model was trained accurately	Kaur et al. (2015)
	This research focused on predicting the removal of Disperse Blue 79 dye colour from water treatment residues using different ANNs	The R^2 values of the ANNs models were greater than 0.90, indicating a high level of accuracy in predicting the removal of Disperse Blue 79 dye from water treatment residues	Gadekar and Ahammed (2016)
	This research investigated the prediction of dye removal efficiency (colour and COD values) of Sunfix Red S3B in an aqueous solution during electrocoagulation	The low RMSE value (9.844%), MAE (13.776%) and high R^2 (0.836) validated the validity of the ANN model predictions	Manh (2016)
	This research extended an ANN to estimate the degradation efficiency of acid blue by martensitic nanoparticles of different sizes based on experimental results	The results showed suitable performance with $R^2 = 0.955$	Rahmani et al. (2016)
	This research investigated the use of heterogeneous sono-Fenton-like treatment to remove acid blue 92 and estimated its removal efficiency using an ANN	The correlation coefficient (R^2) was found to be 0.9836, based on experimental data, indicating a high level of accuracy in estimating the removal efficiency of acid blue 92 in the treatment process	Dindarsafa et al. (2017)

Table 4 (continued)

Intelligent techniques and optimisation algorithms	Research content	Prediction accuracy	References
	This research focused on predicting the removal efficiency of suspended matter and colour in real textile wastewater after chemical coagulation and sedimentation	The ANN models provided accurate predictions with R^2 ranging from 0.93 to 0.96 for both suspended matter and colour removal efficiency	Yu et al. (2017)
	This research involved the analysis and modelling of reactive grey BF-2R dyes using ANNs	The ANN model accurately predicted the experimental data, with a correlation exceeding 0.999	do Nascimento et al. (2018)
	This research aimed to develop a prediction model for treating dyes in wastewater by adding alum through electrocoagulation of a rotating anode, using regression analysis and an ANN model	The results showed that the ANN model performed better than the regression analysis method, and the R^2 value was 0.928, indicating a high level of accuracy	Taha et al. (2020)
	This research used ANN to predict parameters related to the plasma decolourisation of organic dyes [reactive orange 16 (RO 16), reactive blue 19 (RB 19), and direct red 28 (DR 28)] in wastewater. The oxidation was the key parameter for decolourisation performance of RO 16 and DR 28, while the argon flow rate was the main parameter for decolourisation of RB 19	ANN can be used to optimise the processing parameters to enhance removal efficiency	Mitrović et al. (2020)
	This research aimed to predict the removal efficiency of pollutants using $FeCl_3$ coagulant under different variables	The output results all had R^2 above 0.90, indicating high accuracy and the ability to simulate the coagulation process	Karam et al., (2020a, 2020b)
	This research focused on estimating the removal efficiency of coagulation and adsorption of iron/copper nanoparticles during textile wastewater treatment using ANNs	The R^2 value between the predicted and actual values exceeded 0.98, indicating high accuracy, and the ANN could be used with confidence to predict the removal efficiency of the target parameters	Mahmoud et al. (2021)
	This research aimed to optimize and predict the adsorbent on the reactive Pr Red Hegxl dye using factorial design methods and ANNs	The proposed model was able to reasonably predict the removal efficiency (%) with a model correlation coefficient R^2 greater than 0.97 and RMSE less than 0.0317	Yargic et al. (2021)
ANN and GA	This research focused on the use of an ANN model to optimize and predict the behaviour of an adsorption system for the removal of phenol red by Au-NP-AC and TiO_2-NP-AC loaded on activated carbon	The ANN model had a mean squared error (MSE) of 3.19×10^{-4} and 0.0022 for Au-NP-AC and TiO_2-NP-AC loaded on activated carbon, respectively, and fitted R^2 of 0.9962 and 0.9729, respectively, indicating that it could fit well with the removal efficiency of phenol red	Ghaedi et al. (2014)
RSM and GA	This research aimed to optimize the photocatalytic degradation of Basic Blue 41 (BB41) and Basic Red 46 (BR46) dyes using RSM and GA methods	The optimal conditions for the photocatalytic degradation of BB41 and BR46 were found to be 72.56% and 67.89% using RSM and 72.36% and 68.34% using GA, respectively. The values predicted by both methods closely matched the experimental values	Mahmoodi et al. (2017)

Table 4 (continued)

Intelligent techniques and optimisation algorithms	Research content	Prediction accuracy	References
ANFIS and GA	This research focused on estimating the dye and silver nanoparticle concentrations when treating silk fabrics with nanosilver using spectrophotometric colour matching	The ANFIS method outperformed the GA method in predicting the dye and AgNP concentrations, with MAE and RMSE values for the ANFIS method being 0.087 and 0.103 for the dye concentration, and 0.002 and 0.003 for the AgNP concentration	Nateri et al. (2019)
ANN and RSM	This research aimed to optimize the electrochemical degradation of synthetic wastewater containing reactive black 5 textile dye by using RSM and ANNs	The final neural network model showed an exponential R^2 of 0.982 and an MSE of 0.0146, indicating effective predictive performance. The optimized conditions resulted in complete colour removal and up to a 73.77% reduction in COD in a 180-min treatment process	Viana et al. (2018)
	This research conducted a comparative study of textile wastewater decolourisation using nano zerovalent iron, activated carbon, and green synthetic nano zerovalent iron, and utilized ANNs and RSM for modelling and prediction of the colour adsorption process	The ANN data matched the regression analysis results from the RSM optimization, indicating that both ANN and RSM models were able to predict and model the colour adsorption process	Karam et al., (2020a, 2020b)
	This research investigated the effectiveness of nanomaterial adsorbents for dye adsorption and the effect of operational parameters on it	The experimental colour removal rates matched the predicted values obtained by using RSM-ANN modelling	Thomas et al. (2021)
	This research investigated the optimization of the electrochemical oxidation process of textile wastewater at graphite electrodes using RSM and ANN techniques, with a focus on the influence of pH, time, and current on the process	The R^2 correlation coefficients of the RSM and ANN models for colour removal were 0.91 and 0.98, respectively, indicating a high level of accuracy in predicting colour removal during the electrochemical oxidation process	Saleh et al. (2021)
	This research aimed to predict and optimize the electrocoagulation process of cationic dyes using an ANN combined with an RSM	The R^2 of the model was close to 1, indicating that the process was successfully trained by the ANN and optimized by the RSM	Kothari et al. (2022)
RSM and GA-ANN methods	This research focused on modelling and optimizing the removal of azo dyes in the sono-Fenton process using RSM and GA-ANN methods	When conditions were optimal, the prediction errors of the hybrid GA-ANN and RSM were 0.002% and 3.225%, respectively	Baştürk and Alver (2019)
ANFIS and hSADE-NN	This research aimed to model and optimize the removal of acidic blue 193 by UV and persulfate processes	hSADE-NN had an MAE (Mean Absolute Error) of 3.61%, and ANFIS had an MAE of 5.18%, indicating good prediction results	Vasseghian and Dragoi (2018)
A grey-based Taguchi neural network approach	This research aimed to improve the optimum process conditions for acrylic fibre dyeing using a grey-based Taguchi neural network approach	The grey relationship rating was improved from 0.6630 to 0.7749 using the grey-based Taguchi ANN approach, resulting in an improvement of approximately 17%	Zeydan (2014)
Non-linear multiple regression and a hybrid ANN model based on PSO	This research focused on modelling and evaluating the pollutant sorption process in industrial wastewater using non-linear multiple regression and a hybrid ANN model based on PSO	The results showed that the non-linear regression and hybrid PSO-ANN models could effectively model the pollutant sorption process in industrial wastewater with an R^2 of 0.91	Aryafar et al. (2019)

Table 4 (continued)

Intelligent techniques and optimisation algorithms	Research content	Prediction accuracy	References
ANFIS, ANN, and polynomial regression	This research aimed to predict the dye concentration on AgNPs and AgNP-treated silk fabrics using ANFIS, ANN, and polynomial regression methods	The ANFIS system outperformed other methods, with a prediction error of 0.07% for the system	Nateri et al. (2021)
SVM, Random Forest	This research investigated the treatment of real textile wastewater using spinning disc technology and aimed to model the experiments	The best model in terms of regression correlation was the SVM model	Zaharia et al. (2021)
RSM, ANN, and ANFIS	This research investigated the removal efficiency of coagulant treatment of COD and colour from textile wastewater based on various conditions using RSM, ANN, and ANFIS models	The ANFIS model was found to be more suitable than ANN and RSM. The R^2 and MSE values for ANFIS were 0.9997 and 0.0003, respectively. The R^2 and MSE values for ANN were 0.9955 and 0.0845, respectively, and for RSM were 0.9474 and 1.0494, respectively	Nnaji et al. (2022)

by algorithms. The ensuing discussion proffers a comparative analysis of the efficacies of various intelligent techniques and optimization algorithms, coupled with a discourse on their respective merits and demerits.

Primarily, ANNs furnish a potent methodology for investigating optimal conditions pertinent to the decolourization process of textile dye solutions (Khataee et al., 2013; Rosaa et al., 2013). The ANNs exhibit substantial advantages, notably their capacity to obviate the necessity for a mathematical description of the implicated process phenomena, to curtail the temporal requirements for model development, and to predict under a paucity of empirical data (Khataee et al., 2013; Rosaa et al., 2013). Subsequently, ANFIS and neuro-evolutionary methods emerged as two methodologies rooted in ANNs (Vasseghian & Dragoi, 2018). ANFIS amalgamates ANN and Fuzzy Inference System (FIS), wherein the output of each rule constitutes a linear combination of input variables, and the ultimate output manifests as the weighted mean of the output of each rule (Vasseghian & Dragoi, 2018). The neuro-evolutionary methods, on the other hand, facilitate topology and parameter optimization by conjoining ANN and Differential Evolution (DE) (Vasseghian & Dragoi, 2018). DE possesses the capability to ascertain the optimal topology and parameter values of ANN (Vasseghian & Dragoi, 2018). Moreover, hSADE-NN, an ANN enveloping a hybrid DE version, epitomizes features including a rectified mutation mechanism, an adaptive program (intended for the automatic detection of optimal control parameters), and a local search program (Vasseghian & Dragoi, 2018). Additionally, the PSO algorithm, a paradigm of search and optimization, postulates that each particle symbolizes a potential solution within the search space (Aryafar et al., 2019). Through the perpetual update of the position of each particle, predicated upon the experience and comportment of the particle and its neighbouring entities, PSO demonstrates capability in conducting searches within the problem space (Aryafar et al., 2019). The integration of PSO and neural networks empowers the efficacious determination of optimal values for weights and biases, thereby amplifying the performance of ANN (Aryafar et al., 2019).

Furthermore, GRA represents a methodology for quantifying correlations among variables, distinguished by its capacity to handle incomplete, ambiguous, and imprecise information (Zeydan, 2014). By transforming complex relationships among multiple performance characteristics into grey relational grades, GRA furnishes a simplified assessment and solution (Zeydan, 2014). Nonetheless, a potential limitation of this method may reside in its reliance upon the quality and structure of the data. The Taguchi method minimizes variations in quality characteristics by utilizing the signal-to-noise ratio (S/N) and embodies a method of experimental design applicable to the optimization of products and processes (Hossain et al., 2016a, 2016b).

Upon holistically evaluating the advantages, and limitations of various algorithms and techniques, it becomes evident that a singular method struggles to exhibit optimal performance in all circumstances. Consequently, the selection or design of algorithms in practical applications necessitates a comprehensive consideration of the characteristics and demands of the problem. The amalgamation of diverse algorithms or techniques facilitates an enhanced resolution of issues and challenges encountered in the decolourization process of textile dye solutions.

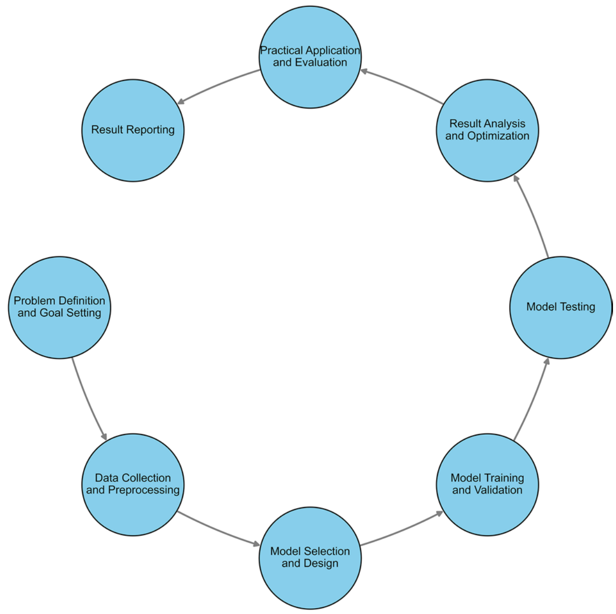

Fig. 1 General framework for applying intelligent techniques and optimization algorithms in textile colour management

Research framework in the domain of textile colour management

In the exploration of the aforementioned domain of textile colour management, a research procedural framework was summarised, which is dedicated to shepherding researchers from the phase of problem definition through to the stage of research findings reporting (Fig. 1).

The framework initially underscores the paramountcy of problem definition and objective delineation, mandating that researchers elucidate their core issues and research objectives at the inception of the project. The subsequent data collection and preprocessing phase emphasizes the acquisition and organization of data conducive to model development. Subsequently, the model selection and design phase necessitates that researchers, contingent upon the nature of the problem and characteristics of the data, select and devise suitable models. In the model training, validation, and testing phases, models are to be trained upon the data, followed by an evaluation of their performance and generalization capabilities through validation and test sets. The results analysis and optimization phase demands a thorough analysis of model outputs and, where requisite, model optimization. Once the model has undergone validation and is deemed reliable, it transitions into the actual application and evaluation phase, wherein it is deployed in a practical working environment and undergoes continuous performance assessment. Ultimately, the results reporting phase encompasses the organization and summarization of the entire research process and outcomes.

This universal procedural framework permits subdivision and applicability to four distinct sub-domains within textile colour management, each of which engages a multiplicity of intelligent techniques and optimization algorithms. For instance, in the realm of colour matching and prediction, a myriad of algorithms, inclusive but not limited to ANN, RNN, and FL, have been deployed to notable effect. In additional sectors, such as colour difference detection and evaluation, an assortment of algorithms, such as SVM, LS-SVM, and SVR, have been employed. The framework furnishes a lucid trajectory for research, enabling a direct comparison and subsequent enhancement of various intelligent techniques and optimization algorithms within each sub-domain, whilst concurrently availing opportunities for interdisciplinary research amongst the disparate sub-domains.

Performance evaluation of intelligent techniques and optimization algorithms

For the performance evaluation of intelligent techniques and optimization algorithms, researchers typically employ various metrics, including but not limited to MAE, MAPE, RMSE, and R^2 (Hossain et al., 2017; Li et al., 2022). The MAE primarily reflects the overall accuracy of the model and correlates closely with the consistency between model predictions and actual measurements. A model demonstrates high precision when the MAE approaches zero, indicating high consistency between predictions and actual measurements. Conversely, a larger MAE signals a requisite enhancement of model accuracy (Hossain et al., 2017). Distinctively, the Root Mean Square Error (RMSE) focuses on the comprehensive accuracy of the model. Unlike MAE, RMSE prioritizes situations with larger predictive errors, thereby capturing anomalies in predictions with heightened sensitivity (Hossain et al., 2017). Furthermore, the Mean Absolute Percentage Error (MAPE) assesses the model from a relative performance perspective, furnishing a measure of the relative size of the predictive error (Li et al., 2022). The Coefficient of Determination (R^2) constitutes another pivotal metric, primarily reflecting the degree to which the model fits the data. An R^2 value approaching 1 denotes a high correlation between model predictions and actual observations, while a lower R^2 may signify suboptimal data fitting by the model (Hossain et al., 2017).

In the integration of textile colour arrangement with intelligent technology and optimization algorithms, the evaluation of model performance should not be confined to a single metric. Although foundational metrics such as MAE and RMSE can provide an initial overview of performance, ensuring the practicality of the model in actual industrial applications necessitates considering additional critical factors, such as colour difference, computational efficiency, and stability.

The pertinence of colour discrepancy attains a pivotal stance within the domain of textile colour management. The CMC formula, ubiquitously embraced, stipulates a colour variance of 1.0 unit as the permissible zenith of tolerance (Farooq et al., 2021). Progressing further, the CIE2000 formula, contrived upon a novel dataset, not only inaugurates new evaluative components but also meticulously scrutinizes the intricate relationship intertwining chroma and hue, thereby rendering a more precise reflection of tangible visual perceptions (Sharma et al., 2005).

Moreover, amidst the juxtaposition of disparate algorithms or models, cognizance of the equilibrium between computational duration and model precision becomes imperative. An algorithm, in its quest for augmented computational efficacy, might relinquish a modicum of accuracy. In contrast, a model of elevated precision might necessitate an elongated computational timespan (Chaouch et al., 2022). Stability emerges as an indispensable element. To quantify this attribute, prevalent practices involve observing the output consistency of the model amidst diverse datasets or under assorted input

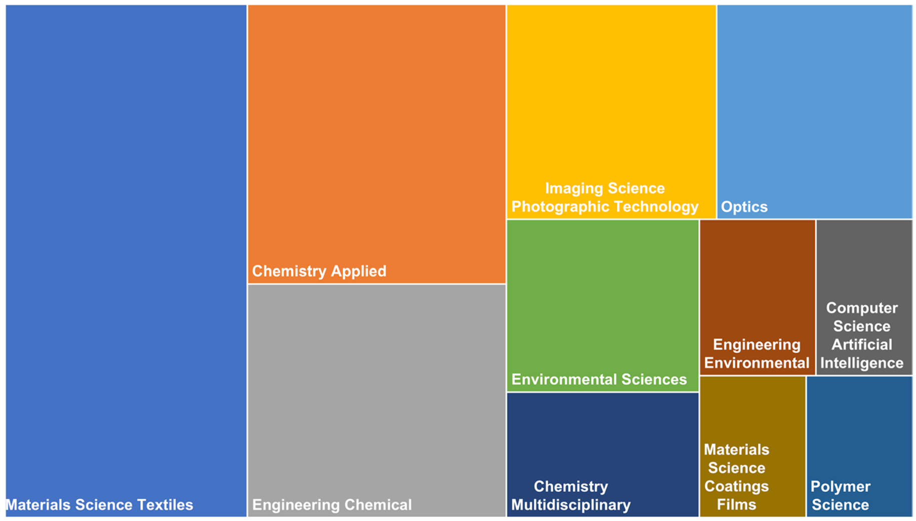

Fig. 2 Distribution of 101 research articles selected from the Web of Science Core Collection

perturbations. Should the algorithm yield highly coherent outputs under such conditions, it could be deemed to exhibit commendable stability (Zhang & Zhou, 2022).

In summation, an integrated evaluation system, amalgamating various metrics, indubitably facilitates a more encompassing and profound assessment of a model's overall performance, thereby furnishing researchers with lucid and comprehensive insights into its capabilities.

Results and Discussion

This section provides a descriptive statistical analysis and discussion of the 101 research articles that have been reviewed. The descriptive statistics and discussion encompass the following four sections: (1) distribution of research articles by journal; (2) distribution of research articles by year of publication and analysis of paper citations; (3) trend analysis of intelligent techniques and optimisation algorithms used in the field of textile colour management; and (4) comparison of performance of some intelligent techniques and optimisation algorithms applied in the field of textile colour management.

Distribution of research articles by journal

Figure 2 depicts the distribution of research articles among the ten domain journals. Among the 101 research articles chosen, 42 of them pertain to Materials Science Textiles (MST), accounting for 41.6% of the total. Additionally, 24 research articles belong to Chemistry Applied (CA) (23.8%) and 20 research articles belong to Engineering Chemical (EC) (19.8%). The data indicate that the selected research articles are primarily concentrated in the domains of MST, CA and EC, which are journals in the fields of textiles, chemistry and engineering, respectively.

Distribution of research articles by year of publication and analysis of paper citations

Figure 3 illustrates the distribution of research articles over the years, demonstrating that the number of published articles (on subjects of interest) tends to fluctuate over the

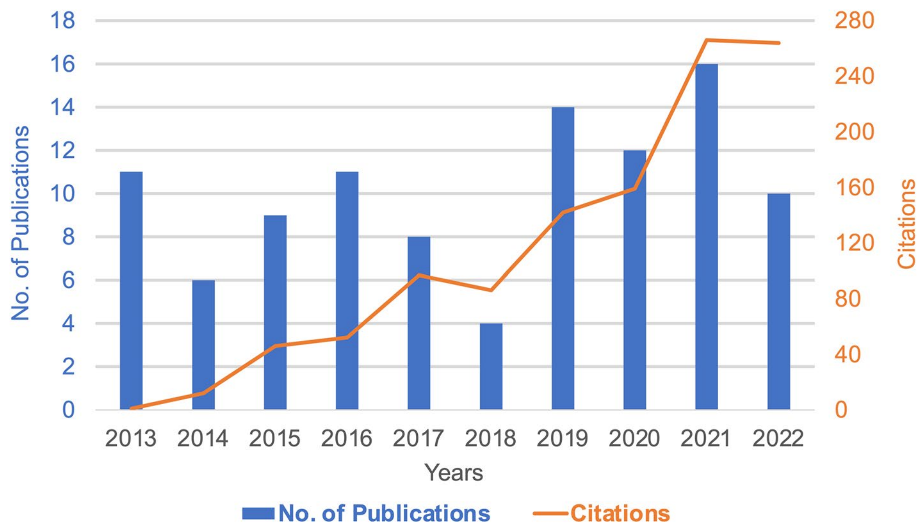

Fig. 3 Distribution of the 101 research articles by year of publication and change in the total number of citations per year of the publications

years. Notably, the total number of research articles published in the first 6 years (2013–2018) is 49, yielding an average of 8 research articles per year. In contrast, the total number of research articles published in the last 4 years is 52, with an average of 13 research articles published per year. This suggests the gradual proliferation and development of intelligent techniques and optimization algorithms in the realm of textile colour management. Additionally, Fig. 2 depicts the variations in the number of citations per year, indicating a transition from a relatively steady increase to a relatively rapid rise in citations per year as time progresses. The sum total of citations for the 101 selected research articles was 1126, averaging 11.15 citations per research article.

Trend analysis of intelligent techniques and optimisation algorithms used in the field of textile colour management

This section begins by describing specific intelligent techniques and optimization algorithms applied in each of the four areas: (1) colour matching and prediction; (2) colour difference detection and assessment; (3) colour recognition and segmentation; and (4) dye solution concentration and decolourization. It outlines an overview of the distribution of intelligent techniques and optimization algorithms used in the field of textile colour management during the last decade.

Figure 4 displays the main intelligent techniques used in colour matching and prediction research. ANN, FL and ANFIS have been the most commonly employed intelligent techniques, representing 64.7% and 14.7% of the 34 research articles on colour matching and prediction, respectively. The less frequently used intelligent techniques include SVM, LSSVM and RNN. The primary optimization algorithms applied in colour matching and prediction research were GA, PSO, PSO-FIMIN and ACO, accounting for 14.7%, 11.8%, and 8.8% of the 34 research articles on colour matching and prediction, respectively. Other optimization algorithms, such as MOEA, NSGAII, RSM, GWO and Taguchi's method, have been employed less frequently.

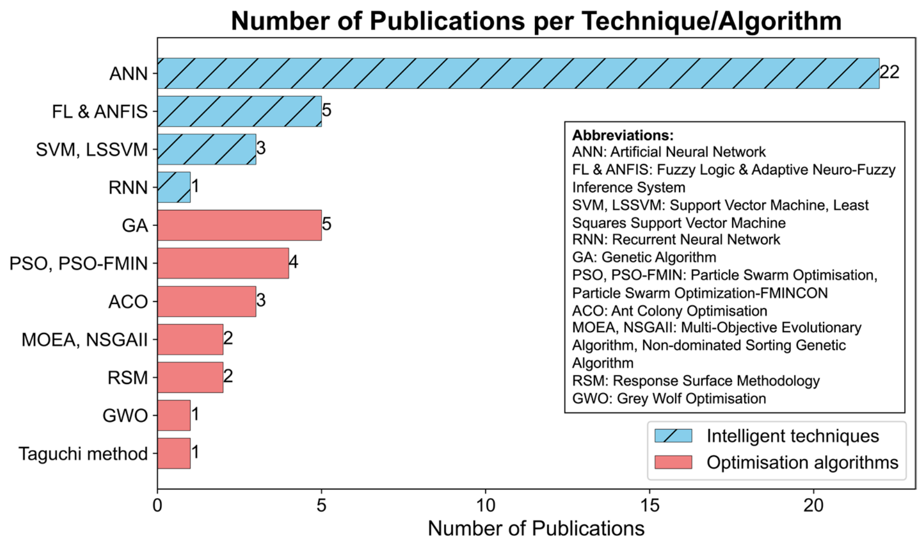

Fig. 4 Intelligent techniques and optimisation algorithms applied to colour matching and colour prediction in the last decade

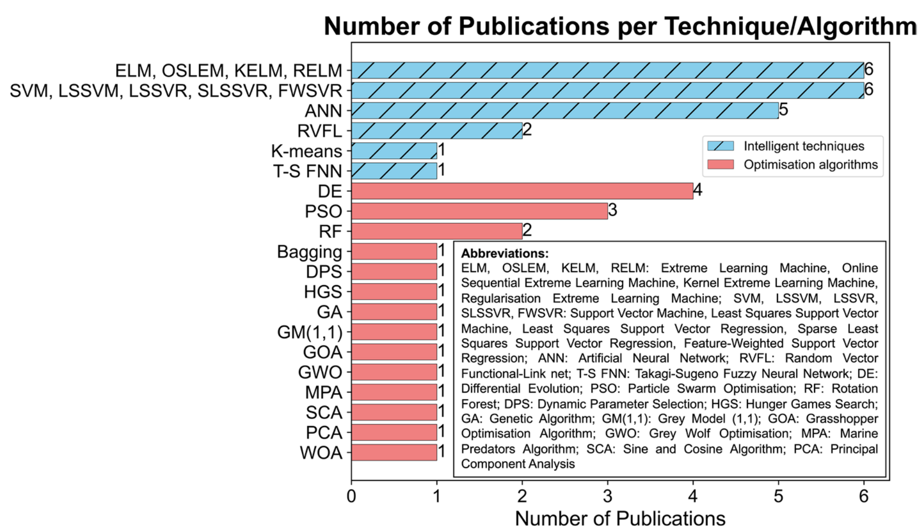

Fig. 5 Intelligent techniques and optimisation algorithms applied to colour difference detection and assessment in the last decade

Figure 5 displays the predominant intelligent techniques used for colour difference detection and assessment: (1) ELM (e.g., ELM, OSLEM, KELM, RELM); (2) SVM (e.g., SVM, LSSVM, LSSVR, SLSSVR, FWSVR); and (3) ANN, representing 40.0%, 40.0% and 33.3% respectively of the 15 research articles on colour difference detection and evaluation. RVFL, K-means algorithms, and T–S FNN have been used less frequently as intelligent techniques. The primary optimization algorithms applied for colour difference detection and assessment are DE, PSO, and RF, which represent 26.7%, 20.0%, and 13.3% respectively of the 15 research articles on colour difference detection and evaluation. respectively. The less frequently used optimization algorithms are Bagging, DPS, HGS, GA, GM(1,1), and GOA.

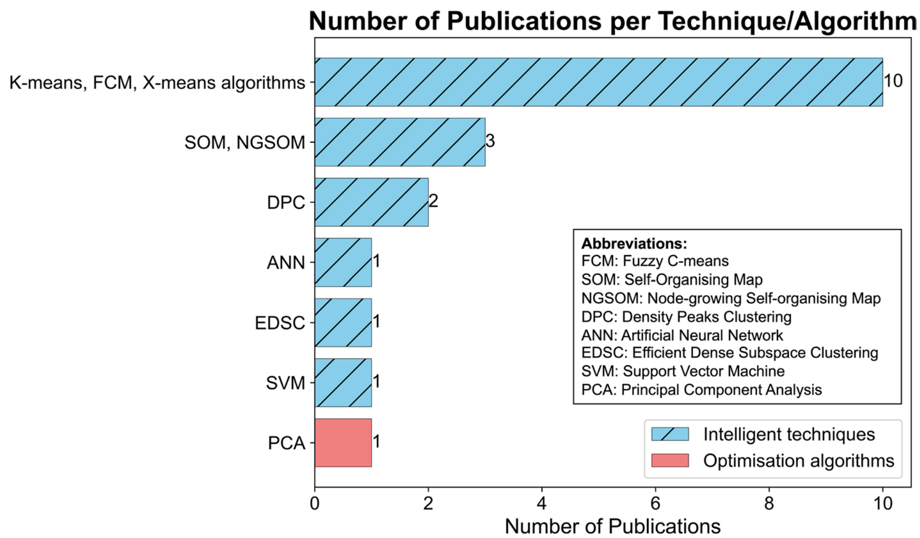

Fig. 6 Intelligent techniques and optimisation algorithms applied to colour recognition and colour segmentation in the last decade

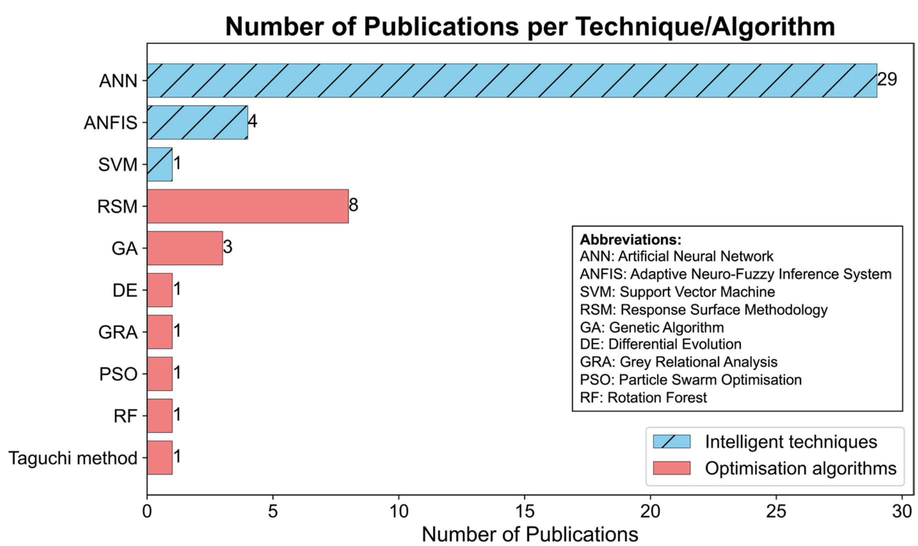

Fig. 7 Intelligent techniques and optimisation algorithms applied to dye solution concentration and decolourisation in the last decade

Figure 6 demonstrates that the principal intelligent techniques used for colour recognition and segmentation are clustering algorithms (e.g. K-means, FCM, X-means), SOM, NGSOM, and DPC, representing 50.0%, 15.0%, and 10.0% respectively of the 20 research articles on colour recognition and segmentation. ANN, EDSC, and SVM have been used less commonly as intelligent techniques. The main optimization algorithm applied for colour recognition and segmentation is PCA.

Figure 7 shows that the primary intelligent techniques employed in concentration and decolourization of dye solutions are ANN and ANFIS, accounting for 90.6% and 12.5% respectively, of the 32 research articles on the topic. SVM, on the other hand, has been employed less frequently. Regarding optimization algorithms, RSM and GA have been the primary techniques used in dye solution concentration and decolourization, while DE, GRA, PSO, RF, and Taguchi methods are less commonly applied.

In general, primary intelligent techniques implemented in textile colour management are (1) ANN; (2) SVM, including SVM, LSSVM, LSSVR, SLSSVR and FWSVR; (3) FL and ANFIS; (4) clustering algorithms, such as K-means, FCM, and X-means; and (5) ELM, such as ELM, OSELM, KELM and RELM. The less commonly used intelligent techniques include SOM, NGSOM, DPC, RVFL, EDSC, RNN and T–S FNN. In addition, the most frequently applied optimization algorithms are RSM, GA, PSO and DE in the selected 101 research articles. Other optimization algorithms, such as ACO, RF, GM (1,1), MOEA, NSGAII, PCA and Taguchi methods, have been used less frequently.

Performance comparison of some intelligent techniques and optimisation algorithms in the field of textile colour management

This section provides a comprehensive overview of the comparison of performances of various intelligent techniques and optimisation algorithms employed in the field of textile colour management. The comparison is based on their efficacy in tasks such as (1) colour matching and prediction; (2) colour difference detection and assessment; (3) colour recognition and segmentation; and (4) dye solution concentration and decolourisation.

Regarding colour matching and prediction, the ANN model exhibits superior predictive capabilities compared to the RSM model, as evidenced by Hasanzadeh et al. (2013), with a relative error of 1.7% for the ANN model, which is lower than the 1.8% relative error of the RSM model. Similarly, Hossain et al. (2017) and Haji and Vadood (2021) demonstrated that the ANN model provides higher accuracy in prediction than the FL model, with the ANN model achieving a higher R^2 (Hossain et al., 2017) and smaller RSE, MAE, and MAPE (Haji & Vadood, 2021; Hossain et al., 2017). Conversely, in Haji and Payvandy (2020), ANFIS yielded higher prediction accuracy than the ANN model, with the correlation coefficient of ANFIS being superior to that of the ANN model. Furthermore, in Vadood and Haji (2022a), using the PSO-FMIN algorithm to weight the ANN resulted in better prediction results than the BPNN, as indicated by a smaller MSE. Regarding optimisation algorithms, Chaouch et al. (2022) demonstrated that ACO can provide better predictions and higher computational efficiency than GA, as reflected by the lower mean MSE and shorter computational time required for ACO. Overall, it is important to note that different intelligent techniques may provide different levels of prediction accuracy, depending on various factors such as modulation methods, application contexts, and data structures.

Zhang and Yang (2014) used a GA-optimised SVM approach to construct an evaluation model that offers higher prediction accuracy and lower relative error than the conventional Naive Bayesian algorithm. This model provides a more reliable assessment of the quality of dyed fabrics. Similarly, Zhou et al., (2019a, 2019b, 2019c) revealed that DE-OSELM can provide superior prediction accuracy compared to the traditional textile colour correction models based on SVR and ELM algorithms. The models were also observed to exhibit better generalisation and robustness. Additionally, Zhou et al., (2019a, 2019b, 2019c) demonstrated that the DE-WOA-ELM model can yield a higher average classification accuracy than other methods, such as ELM, SVM, BPNN, and KELM, with an improvement ranging from 0.5 to 12.1%. In the study conducted by Zhou et al., (2019a, 2019b, 2019c), the RF-PSO-SLSSVR model was found to produce lower RMSE values compared to the traditional SVR and ELM algorithms. Li et al. (2020) also demonstrated that the DE-GOA-KELM method provides superior classification accuracy compared to the traditional KELM model, with an improvement of approximately 8%. Lastly, Zhou et al., (2021a, 2021b) showed that the DPS-DE-RELM model could achieve higher classification accuracy, faster convergence, and greater robustness than the conventional ELM model. From the aforementioned studies, it is evident that by combining intelligent techniques and optimisation algorithms, the prediction accuracy and robustness of traditional methods or single intelligent techniques can be enhanced.

Regarding colour recognition and segmentation, a number of studies have investigated the effectiveness of various clustering algorithms. Ouyang et al. (2019) found that the NGSOM clustering algorithm outperforms traditional SOM and FCM algorithms in terms of peak signal-to-noise ratio and time efficiency. Zhang et al. (2019) reported that the use of the DPC-SOM algorithm leads to superior predictions compared to traditional SOM, DPC, K-means, and FCM, and requires less time for execution. Additionally, Zhang et al. (2020) demonstrated that an improved version of the K-means algorithm yields higher execution efficiency than the standard K-means, FCM, and DPC algorithms. Finally, in a recent study, Das and Wahi (2022) showed that deep learning convolutional networks trained using SVM achieve higher classification accuracy than traditional BPNN. These results highlight the potential benefits of improving existing intelligent techniques or combining them with optimization algorithms to achieve better prediction accuracy or higher execution efficiency.

According to Mahmoodi et al. (2017), both RSM and GA displayed similar prediction accuracies in terms of dye solution concentration and decolourisation. Meanwhile, Vasseghian and Dragoi (2018) found that hSADE-NN demonstrated better prediction accuracy than ANFIS, resulting in a 1.5% increase in accuracy. In contrast, Nateri et al. (2019) reported that ANFIS outperforms GA, as indicated by lower MAE and MSE values and higher correlation coefficients obtained using the ANFIS model. Similarly, Baştürk and Alver (2019) found that optimising ANN using GA leads to lower prediction errors compared to the RSM model. Saleh et al. (2021) also reported higher correlation coefficients when using the ANN model compared to the RSM model. Meanwhile, Nateri et al. (2021) found that the ANFIS model produces fewer prediction errors than the ANN model. Zaharia et al. (2021) demonstrated that higher regression correlations could be achieved using the SVM model compared to the RF model. Lastly, Nnaji et al. (2022) found that, compared to ANN and RSM, the ANFIS model yields superior results with higher regression coefficients and smaller MSE. Overall, the papers cited above have indicated that the reference order for prediction accuracy ranges from high to low as hSADE-NN > ANFIS > ANN > RSM, ANFIS > GA, GA-ANN > RSM, and SVM > RF. However, it is important to note that different modulation methods and application contexts may produce different prediction accuracy results.

Future developments

Several future research directions are suggested in light of the descriptive statistics of the selected articles. Firstly, the number of research articles published on intelligent techniques and optimisation algorithms in the field of textile colour management over the last 10 years has fluctuated, with an upward trend each year, which indicates that the application of intelligent techniques and optimisation algorithms in the field of textile colour management is gradually becoming more popular and is growing fast. Thus, researchers may delve into these areas further.

Besides, when analysing the different intelligent techniques and optimisation algorithms used in the field of textile colour management, the most commonly used intelligent techniques are ANN, FL & ANFIS, clustering algorithms (e.g., K-means, FCM, X-means) and ELM (e.g. ELM, OSLEM, KELM, RELM), while the main optimisation algorithms used in the field of textile colour management are RSM, GA, PSO, DE. Furthermore, combining different intelligent techniques and optimisation algorithms or improving existing ones can provide higher prediction accuracy and faster execution efficiency than single or traditional intelligent techniques and optimisation algorithms. Therefore, future innovations may be directed at improving the existing intelligent techniques and experimenting with combinations of different intelligent techniques and optimisation algorithms to suit applications in the field of textile colour management, thus facilitating further enhancements in prediction accuracy and execution efficiency.

Furthermore, it is noteworthy that the application of intelligent techniques and optimization algorithms is not evenly distributed across the four sub-domains of the textile colour management field. For example, the traditional SVM is less frequently employed as an intelligent technique for dye solution concentration and decolourisation, whereas SVM is widely employed as an intelligent technique for colour difference detection and assessment. Furthermore, SVM has been further enhanced by LSSVM, LSSVR, SLSSVR, and FWSVR, which have the potential to provide superior prediction accuracy and faster execution efficiency. Thus, a promising future direction is to leverage the intelligent techniques and optimization algorithms presented in the four sub-domain papers to optimize the use of existing techniques and algorithms, thereby achieving improved prediction and faster convergence.

An additional innovation in the field of textile colour management could involve adapting a pre-existing algorithm via transfer learning techniques (Torrey & Shavlik, 2010). By doing so, this algorithm could be applied to other sub-domains within the field, leading to more advanced and accurate results. For instance, while ANNs are commonly used for colour matching and prediction, RNNs have shown the potential for providing more precise predictions. Thus, implementing RNNs in sub-domains where ANNs are typically used, such as colour difference detection and assessment, dye solution concentration, and decolourisation, may enhance prediction accuracy and overall efficiency.

Limitations

The present review has had some limitations concerning the selected papers. Firstly, it comprises a compilation of research articles retrieved from the Web of Science using certain keywords, focusing on the application of intelligent techniques and optimization algorithms in the field of textile colour management. This approach implies that there may be some omissions in the literature reviewed, given that the collected research articles are solely sourced from journals available in the Web of Science database, which is limited in terms of journal availability and may not cover all published research articles. Furthermore, the selection of keywords and the subsequent screening of articles performed by the authors are subjective and reliant on their own interpretation, which may also lead to some omissions. Additionally, the articles under review span from 2013 to 2022, encompassing a period of approximately 10 years, which may not provide a comprehensive outlook on the application of intelligent techniques and optimization algorithms in the field of textile colour management.

Despite the significance of intelligent techniques and optimization algorithms, their applications are limited by constraints imposed on the collection and description of research papers. For instance, due to spatial constraints, some techniques and algorithms are briefly discussed to impart a contextual understanding of their applications without providing exhaustive details. In evaluating the performance of these techniques and algorithms, results are solely derived from selected papers and are only intended for reference purposes. Predictive accuracy outcomes may differ depending on various factors, such as modulation techniques, application contexts, and data structures, necessitating further research by implementing these intelligent techniques and optimization algorithms.

Conclusions

Analysing 101 research articles from 2013 to 2022, this study comprehensively reviews the application of intelligent techniques and optimisation algorithms in textile colour management, encompassing (1) colour matching and prediction, (2) colour difference detection and assessment, (3) colour recognition and segmentation, and (4) dye solution concentration and decolourisation. The study identifies ANN, SVM and its enhancements, FL, ANFIS, clustering algorithms, and ELM, as well as optimization algorithms like RSM, GA, PSO, and DE, as widely used in this field. It finds that ANFIS often surpasses ANN and FL, ACO outperforms GA, hSADE-NN exceeds ANFIS, ANN, and RSM, and SVM is superior to RF, though results may vary based on the methods and data structures used.

Upon comprehensive analysis, the paper summarizes key research trends in intelligent technique and optimisation algorithm application in textile colour management and suggests future research could enhance existing methods, explore novel technique combinations, or leverage transfer learning to heighten prediction accuracy and optimisation efficiency.

Abbreviations

ACO Ant colony optimisation
ANFIS Adaptive neuro-fuzzy inference system
ANN Artificial neural network
ANOVA Analysis of variance
CO Combinatorial optimisation
COD Chemical oxygen demand
DE Differential evolution
DPC Density peaks clustering
DPS Dynamic parameter selection

DPS-DE	The differential evolution algorithm with dynamic parameter selection
EDSC	Efficient dense subspace clustering
ELM	Extreme learning machine
FCM	Fuzzy C-means
FL	Fuzzy logic
FMIN	FMINCON algorithm
FRBS	Fuzzy region-based segmentation
GA	Genetic algorithm
GOA	Grasshopper optimisation algorithm
GRA	Grey relational analysis
GWO	Gray Wolf optimisation
HGS	Hunger games search
hSADE-NN	Hybrid self-adaptive differential evolution with neural networks
IGOA	Improved grasshopper optimisation algorithm
KELM	Kernel extreme learning machine
LSTM	Long-short term memory
LSSVR	Least squares support vector regression
LSSVM	Least squares support vector machine
LR	Linear regression
MAE	Mean absolute error
MLP	Multilayer perceptron
MOEA	Multi-objective evolutionary algorithms
MOGA	Multi-objective genetic algorithm
MOPSO	Multi-objective particle swarm optimisation
MPA	Marine predators algorithm
NGSOM	Node-growing self-organizing map
NSGAII	Non-dominated sorting genetic algorithm
OAs	Orthogonal arrays
OSELM	Online sequential extreme learning machine
PCA	Principal component analysis
PSO	Particle swarm optimisation
PSO-FMIN	A combination of particle swarm optimisation and FMINCON
RELM	Regularisation extreme learning machine
RF	Rotation forest
RNN	Recurrent neural network
RSM	Response surface methodology
RMSE	Root mean square error
RVFL	Random vector functional-link net
R^2	Coefficient of determination
SCA	Sine and cosine algorithm
SOM	Self-organising map
SVM	Support vector machine
SVR	Support vector regression
S/N	Signal-to-noise
T–S FNN	Takagi–Sugeno fuzzy neural network
WOA	Whale optimisation algorithm

Author contributions

Conceptualization: SBL, CWK, KYL and YHL; Methodology: SBL and CWK; Investigation: SBL; Resources: SBL and CWK; Data curation: SBL; Writing—original draft preparation: SBL; Writing—review and editing: SBL, CWK, KYL and YHL; Visualization: SBL; Supervision: CWK, KYL and YHL; Project administration: CWK; Funding acquisition: CWK. All authors have read and approved the final version of the manuscript.

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Availability of data and materials

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Declarations

Competing interests

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