RPMME

Homepage: http://penerbit.uthm.edu.my/periodicals/index.php/rpmme
e-ISSN : 2773-4765

A Study in Development of Control Chart Pattern Recognition Scheme Based on Literature

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DOI: https://doi.org/10.30880/rpmme.2022.03.01.002
Received 15 Nov. 2021; Accepted 15 April 2022; Available online 30 July 2022

Abstract: Control chart pattern recognition (CCPR) is an important aspect in statistical process control (SPC). The abnormal patterns occurred in control charts can be related to specific assignable causes that have a negative impact on process stability. The recognizing of control chart pattern has provided a various developed approach over the years. In point of fact, numerous research studies literature with various development criteria and different approach trends have been published. Despite the abundance of research studies literature on the CCPR areas, there has been a difficulty to examine and analyze the development criteria and approach trends of CCPR schemes studies. Therefore, this study proposes a classification development criteria scheme for analyzed and classified the development criteria and trends in CCPR schemes research studies article. About 21 published research studies articles of CCPR schemes within 2011 – 2021 were analyzed and classified. The following are some of the study major findings. Firstly, most of the CCPR research studies still worked with the common development criteria and trends from previous decade. Secondly, some identification on implemented input representation and learning algorithm of researcher developed method. Moreover, the percentage of research studies for methods detecting the control chart pattern (CCPs) using support vector machine (SVM) is increasing. Next, there are some modifications on development of pattern recognizer model with an added feature. Furthermore, majority of the research studies performance criteria are using recognition accuracy, data mining based, and correct recognition ratio for performance measure. Generally, the common development criteria and trends are still widely used in the research of CCPR schemes and the other development criteria are expected to be implemented more in the future due to its promising contribution. Hence, this study will provide a summarized information that is useful for further development of CCPR schemes.

Keywords: Control Chat Pattern Recognition, Development Criteria, Research Studies Literature

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1. Introduction

Control charting is one of Statistical Process Control (SPC) tools that is widely implemented for Quality Control (QC) It was developed in 1924 by Shewhart and since then, it has been used to monitor methodology of process quality. SPC is the most important tool for manufacturing process control. A control chart is a useful way of finding the causes of variation in a process. The former type of variation is unavoidable and can only be minimized through management methods but cannot be thoroughly eliminated from the production process [1]. Another type is called special causes where common causes are unassignable and special causes are assignable. An unnatural pattern that occurs on the charts can lead to a certain assignable cause to the process production. Controlling the process variation and finding out the causes will be the most important aspect for recognize the various patterns in control charts. The chart recognizer role is important to detect the abnormal function in the process.

The process can be tracked and managed when a special cause variation occurs in the process with simple statistical process control (SPC) control chart patterns. There a six-basic type of control chart pattern that is normal, upward shift (US), downward shift (DS), upward trend (UT) or downward trend (DT), and cyclic. All patterns that different than normal patterns that being recognize as not functioning correctly and adjustment are required throughout the process. The reason of unnatural patterns happens is shift patterns indicate material, machine or operator adjustments, and trend patterns indicate wear of the tool. Voltage fluctuations in the power supply can be demonstrated by cyclic pattern [2]. The boundaries of the control chart patterns show the monitored manufacturing process that when the point is exceeded or the control chart displays unnatural pattern, it means the process is out of control. The use of appropriate specialized techniques can help a quality practitioner to identified the pattern easily.

A countless test and run test have been performed over the years to recognize of an unnatural pattern which the analysis of process data is still difficult due to pattern recognition tasks. Several developments of control chart pattern recognition methods have been made and the methods are separated into two categories that is expert system and machine learning. Generally, there are many researchers has developed and proposed approach for recognition a pattern of control chart, where the findings from the research have contributed to research studies related to control chart pattern recognition schemes and provided a various of proposed approach over the years.

However, there is a lack of literature providing a critical review on the issues associated to such advances since 2010. Therefore, there is a motivation to highlight research direction, as well as to present a summary of some updated issues in the development of ANN-based control chart pattern recognition schemes as being addressed by the frontiers in this area. Among others, the issues highlighted are highly related to input data and process patterns, input representation, recognizer design and training, and validation. Such issues could be useful for new researchers as a starting point to facilitate further improvement in this area. Therefore, this research aims to summarize the findings and classify the trends in development criteria of control chart pattern recognition schemes.

2. Methodology

In this study, the concept of finding a required articles based on proposed article criteria are divided into two sections for choose and verify the obtain articles that related to CCPR schemes research studies. The first section of this designed articles literature search is the articles are discovered by using a computerize search on an academic search engine such as Google scholar, Science direct, Scopus, and SpringerLink with search keyword use are control chart pattern recognition schemes, control chart pattern recognition, control chart pattern and control chart recognition. Next, the second section is limited the search articles only for journal articles and conference proceedings, which other form of publication such as books, and unpublished paper are not covered. The article year of publication is also limited to a 10 years period from the year of 2011 to year of 2021. The design process of articles literature search for obtained the articles is shown in figure 1

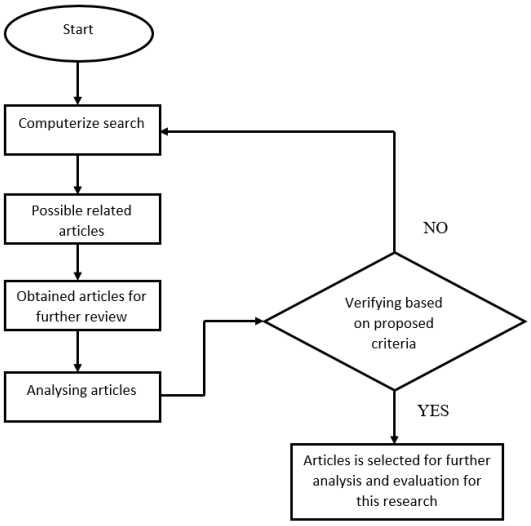

Figure 1: The design process of articles literature search flowchart

2.1 Proposed development criteria of CCPR schemes

In order to recognizing the development criteria, the articles will be analysis based on a classification development criteria that are designed after the selected articles and be carried out until this study is complete. The proposed classification development criteria consist a question that related to a development in a CCPR schemes and a possible answer for the question. The following question and possible answer of the proposed classification development criteria is shown in table 1.

Table 1: Question and possible answer of the proposed classification development criteria

Question	Possible answer
What are the types of control chart pattern used by researcher?	- Mean or variance shift pattern - Six basic unnatural patterns - Other specific unnatural pattern - Six basic and specific unnatural patterns
An expectation of the data model used by researcher?	- Real world data - Artificial data
What are the types of input representation used by researcher?	- Raw data based - Feature based - Raw data & feature based
What are the methods used by researcher for detecting the CCPs?	- Rule based - Artificial neural network: supervised and unsupervised - Support vector machine
What is the learning algorithm applied by researcher?	- Back propagation algorithm - Levenberg Marquardt algorithm - Kernel function algorithm - Other developed algorithm
What are types of pattern recognizer model implemented by researcher?	- Modification model - Traditional model
The performance criteria used by researcher for evaluating the purposed methods?	- No performance measures - Average run length - Other performance measure
What is the validation methods researcher used?	- No validation - Comparing with real case studies - Testing with real world data

3. Results and Discussion

3.1 Articles classifying according to the year of publication and the title of the journal

The number of articles that related to the pattern recognition schemes, which been collected from the year of 2011 to 2021 is shown in figure 4.1. From the 21 collected articles, the average number of published articles that related to the control chart pattern recognition topic is one journal per year. A distribution of the published articles is fluctuating throughout the year of 2011 to 2021. The pattern of the published articles could be influence by the potential of a time lag in editing and rechecking the submitted manuscripts as well as journal publication schedules, which it may result to the journal publish all at once in certain year.

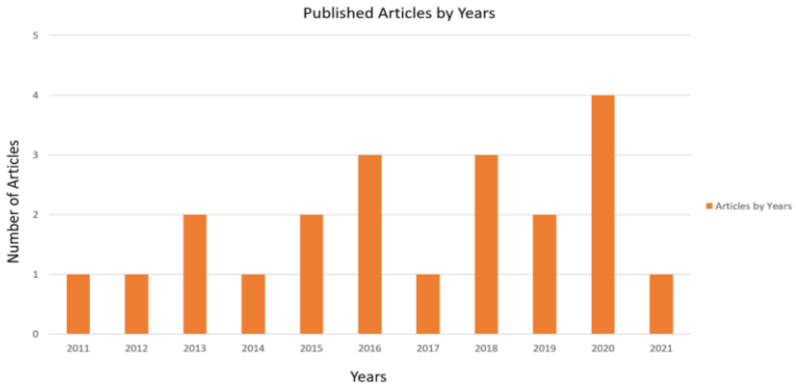

Figure 2: Number of published articles by years

3.2 Articles classifying according to the developed control chart scheme for pattern recognition

The 21 collected articles that related to the control chart pattern recognition have been reviewed according to the developed CCPR criteria for each article. A developed control chart pattern recognition criterion that has been identified is been summarized in the table 2, which the criteria presented a key tool in the research of CCPR schemes.

Table 2: Classification criteria of developed CCPR

Classification development criteria of CCPR	2011 – 2021 (21 articles)	Percentage (%)
Types of control chart pattern		
- Six basic control chart patterns	13	61.90
- More and specific control chart patterns	8	38.10
Data model		
- Real world data (actual data)	5	23.81
- Artificial data	16	76.19
Types of input representation		
- Raw data based	7	33.33
- Feature based	11	52.38
- Raw data & Feature based	3	14.29
Methods for detecting the CCPs		
- Rule based	0	0
- Support vector machine	11	47.83
- Artificial neural network:		
Supervised	12	52.17
Unsupervised	0	0
Learning algorithm		
Supervised ANN:		
- Back propagation algorithm (BPA)	6	26.09
- Levenberg Marquardt algorithm (LMA)	1	4.35
	1	4.35

- Broyden- Fletcher- Goldfarb-Shanno algorithm (BFGSA)	1	4.35
- Spikeprop algorithm (SPA)	3	13.04
- Bees algorithm (BA)		
Support Vector Machine:	11	47.83
- Kernel function		
Pattern recognizer model		
- Modification	9	42.86
- Traditional	12	57.14
Performance criteria		
- Average Run Length	1	4.76
- Other performance measure	20	95.24
Validation methods		
- Testing with real world data	5	23.81
- No validation	16	76.19

3.3 Types of control chart pattern

The types of control chart pattern can be categorized and identified into two sections, of which the first section is six basic control chart patterns and the other section is a more or specific control chart pattern that includes the six basic control chart patterns and other patterns such as systematic and stratification. According to figure 3, there are about 8 out of 21 reviewed articles with the percentage of 38.10 % that have used the systematic and stratification pattern with the six basic CCP for the control chart pattern recognition. The addition of the systematic and stratification pattern in the recognition by researchers are to make the system more comprehensive and reduce the number of abnormal causes. Based on review article written by Xu et al. [3] and A. Addeh, Khormali, et al. [4], the assignable causes of the systematic pattern are a point to point variation that occurs in a predictable manner, which the high point always follows a low point or the other way around and the stratification pattern is a situation of the data being plotted does not identifies the specific process and the data becomes more concentrated due to computational error. However, many researchers are still preferred to use the six basic control chart patterns in their studies for the control chart pattern recognition.

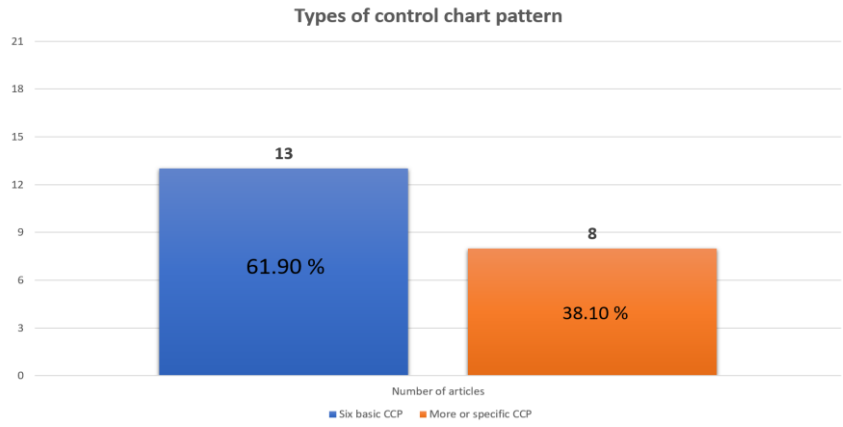

Figure 3: types of control chart pattern based on reviewed article

3.5 Data model

The data used in control chart pattern recognition for training and testing are classified in two major categories, which is artificial data and real-world data. Based on the reviewed data model in figure 4, there are about 16 from 21 written articles with a percentage of 76.19 % has used the artificial data for training and testing, which showed many researchers prefer to use the artificial data other than real world data. The artificial data is more preferred by researchers in control chart pattern recognition because the amount of real-world data is not readily available on a large scale, while training of a

recognizer requires a lot of data to be used to recognize a pattern. However, one of the researchers in the reviewed article has stated that the artificial data is limited and unable to recognize all the unnatural patterns in the real-world data in a simulation because different practical has different characteristics quality that very complex.

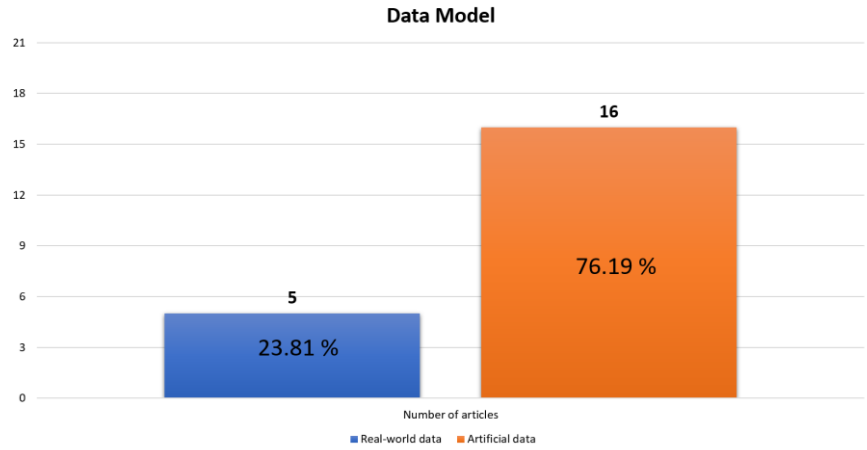

Figure 4: Data model based on reviewed article

The five reviewed articles that used the real-world data means all the five writers are able to obtain a sufficient amount of data from an industrial production process. According to table 3, most of the real-world data use by researcher is recognize in six basic control chart pattern such as normal, cyclic, upward & downward trend and upward & downward shift.

Table 3: Utilization of real-world data with recognition of control chart pattern

Author	Pattern	Data model
Fuqua & Razzaghi [5]	Normal, Cyclic, Upward & Downward Trend, Upward & Downward Shift	Real-world data
Khormali & Addeh [6]	Normal, Cyclic, Upward & Downward Trend, Upward & Downward Shift	Real-world data
Laosiritaworn & Bunjongjit [7]	Normal, Cyclic, Upward & Downward Trend, Upward & Downward Shift	Real-world data
J.Addeh et al. [8]	Normal, Cyclic, Upward & Downward Trend, Upward & Downward Shift	Real-world data
Ebrahimzadeh et al. [9]	Normal, Cyclic, Upward & Downward Trend, Upward & Downward Shift	Real-world data

3.6 Types of input representation approach

According to figure 5, the feature-based approach of input data in control chart pattern recognition has become one of the most used input representations over raw data in the years of 2011 to 2021. The number of reviewed articles that used the feature-based is 11 articles out of 21 articles with a percentage of 52.38%, which the reason behind this selection stated by writer is due to feature-based ability that can increase the pattern recognition accuracy and stability. Moreover, statistical feature and shape feature have a different approach of extracted the input data by using mathematical equation and geometric feature, which there is about two articles that written by Lu et al.[10] and De La Torre Gutierrez & Pham [11] consist only the shape featured and the other nine articles consist of two feature-based that is statistical and shape. The selection of feature based by researcher based on review article is shown in figure 6

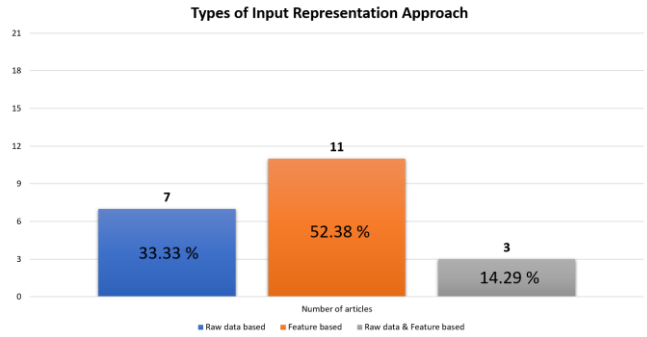

Figure 5: Types of input representation approach based on reviewed article

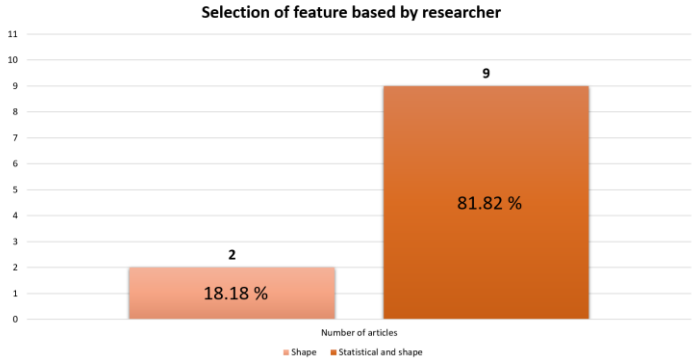

Figure 6: Selection of feature based by researcher based on reviewed article

Based on the 11 reviewed articles, there are about 8 reviewed articles has the similarity in geometric features that been used in the shape feature. Besides that, two of the articles written by J. Addeh et al. [8] and Ebrahimzadeh et al. [9] has proposed one shape feature known as the maximum value of variation in signal amplitude in a short time interval, which the feature is expected to be used for separating the pattern between shift and trend pattern. The other 3 reviewed article use a different types of shape features with the same proposed features as the eight features. Even though the shape features are different, the proposed is still the same as the eight features, which discriminate, distinguish and separate patterns of input data. The detail about all the eight geometric features including the proposed geometric feature is summarized in table 4.

Table 4: Summarized of eight geometric features and proposed geometric based on reviewed articles

Symbol	Feature	Detail
S	Slope	The slope of the least square line of the data that used to separate normal, cyclic and trend pattern.
NC1	Number of mean crossing	The number of points where the average line and the data pattern converge for differentiate normal, stratification and systematic pattern from cyclic, shift and trend pattern
NC2	Number of least-square line crossing	The number of points where the average line and the data pattern converge for separating natural and trend patterns from other pattern
AS	Average slope	An average slope of the line segment that used for separate trend pattern from other pattern.

SD	Slope difference	The difference between the least square line and the line segment that separate shift pattern from other pattern.
APML	Area between the pattern and the mean line	The area between the data graph and the mean line that separate stratification and other patterns.
APSL	Area between the pattern and least square line	The area between the data graph and least square line that separate cyclic and shift patterns from normal and trend patterns
ASS	Area between least square line and line segments	An area that trends pattern has a value about zero and shift pattern has its higher that the feature separate trend pattern from shift pattern.
MVSASTI	Maximum value of variation in signal amplitude in a short time interval	In both shift and trend trends, the overall variance of signal amplitude in a 60-second time interval is nearly equivalent that use for separate two pattern.

Furthermore, The most common statistical features that writer selected are mean, standard, deviation, skewness, and kurtosis in representing normal and non-normal samples for the abnormal control chart pattern. One of the writers stated that the common statistical features have an ability to effectively improve the accuracy of recognition patterns and this feature mostly classifies the data based on attribute and quantity characteristics. For extracting the data, the feature use by J. Addeh et al. [8], Chowdhury & Janan [12], Ebrahimzadeh et al. [9], Zhou et al. [13], M. Zhang & Cheng [14] and Zhao et al [15] are presented in the form of a mathematical equation, in which each statistical feature has a different equation and based on the reviewed article the equation is shown in table 5.

Table 5: The statistical feature mathematical equation based on the reviewed article

Feature	Equation	Detail
Mean	$\frac{\sum_{t=1}^{n} x_t}{n}$	Where x_t is the input (reference) vector and *n* are the total length of the observing window
Standard deviation (Std)	$\sqrt{\frac{\sum_{t=1}^{n}(x_t - mean)^2}{n}}$	Where x_t is the input (reference) vector, mean is the sample mean value and *n* are the total length of the observing window
Skewness	$\frac{\sum_{t=1}^{n}(x_t - mean)^3}{n(Std)^3}$	Where x_t is the input (reference) vector, mean is the sample mean value, Std is the sample standard deviation value and *n* are the total length of the observing window
Kurtosis	$\frac{\sum_{t=1}^{n}(x_t - mean)^4}{n(Std)^4}$	Where x_t is the input (reference) vector, mean is the sample mean value, Std is the sample standard deviation value and *n* are the total length of the observing window
Mean square value	$\frac{\sum_{t=1}^{n} {x_t}^2}{n}$	Where x_t is the input (reference) vector and *n* are the total length of the observing window
Autocorrelation		Where *x(t)* is the input (reference) vector of

	$\frac{[\,x(1) \times x(2) + \cdots + x(n-1) \times x(n)]}{n}$	process point and *n* are the total length of the observing window
Positive CUSUM	$C_n^+ = max[0, (\,x_t - mean) + C_{n-1}^+]$	Where mean is the sample mean value, *x(t)* is the input (reference) vector and *n* are the total length of the observing window
Negative CUSUM	$C_n^- = max[0, (mean - \,x_t) + C_{n-1}^-]$	Where mean is the sample mean value, *x(t)* is the input (reference) vector and *n* are the total length of the observing window

As shown in figure 5, there is a few writers that use raw data based as input representation for control chart pattern recognition input and it can be seen that selection on raw data based is lesser than feature based although the raw data-based approach is simpler than feature based. Based on the reviewed articles, a common pre – processing approach that has been used to transform the raw data samples is normalization, in which the data will range between a certain value and an equation will be used for obtaining the normalized data value. The normalization equation that has been used based on the reviewed articles is shown in table 6.

Table 6: The normalization equation based on reviewed articles

Pre – processing approach	Equation	Detail
Normalisation (De la Torre-Gutiérrez & Pham, 2019) [11]	$S_t = \frac{O_t - \underline{O}}{\widehat{\sigma_o}}$	Where $\underline{O}$ is the mean of the output, $\widehat{\sigma_o}$ is the standard deviation of the output and O_t represent the sample raw data.
Normalization (Laosiritaworn & Bunjongjit, 2013) [7]	$v' = \frac{v - min_A}{max_A - min_A}$	Where min_A and max_A is the minimum and maximum value of standardized data

Therefore, a combination of two input representation approach that consist of raw data based and feature based is also been used by a researcher. In general, comparative effectiveness research comparing raw data-based and feature-based techniques is starting to be selected as an input representation approach by few studies in order to analyse the recognizer model recognition accuracy performance from the two different input representations. So, the selection of the most useful features is a critical component of enhancing recognition accuracy.

3.7 Methods for detecting the control chart pattern

Based on table 7 and figure 7, There are three methods that been classify from the reviewed articles that have used this method for the research proposed in control chart pattern recognition. the number of research studies that adopted the rule-based method is zero in the year of 2011 to 2021. The zero approach in these methods are due to issue of recognition, which many of the reviewed articles has stated the fact about using this method may cause a problem of inaccurate recognition because of the statistical properties has difficult to obtain the identical statistical properties derived from some pattern with different classes. As a result, there are about 12 out of 21 reviewed articles with the percentage of 52.17% have use the artificial neural network methods for the research studies.

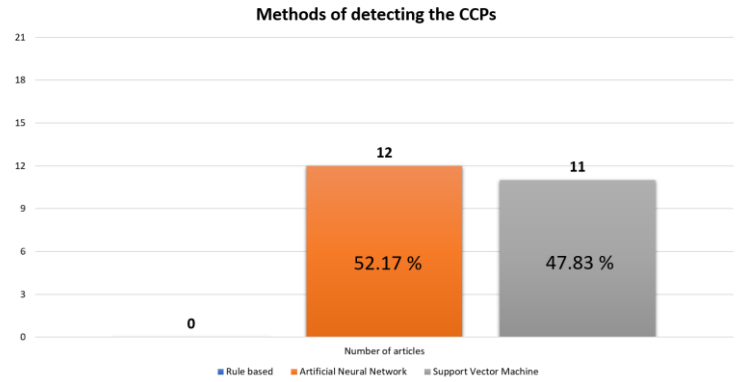

Figure 7: Methods of detecting the CCPs based on reviewed article

The capabilities of artificial neural network in the pattern recognition, which able to learning and self- organized make it the most selected method by writer on the reviewed article. For control chart pattern recognition, the artificial neural network consists of many varieties of structure and has two categories known as supervised and unsupervised.

Table 7: The ANN method and categories based on reviewed articles

Author	ANN method	Categories
Fuqua & Razzaghi [5]	Convolutional	Supervised
A. Addeh, Zarbakhsh, et al. [16]	Multilayer perceptron	Supervised
Laosiritaworn & Bunjongjit, [7]	Multilayer perceptron	Supervised
Xu et al. [3]	Convolutional	Supervised
J. Addeh et al. [8]	Multilayer perceptron	Supervised
A. Addeh, Khormali, et al. [4]	Radial basis function	Supervised
Zan et al. [17]	Convolutional	Supervised
De La Torre Gutierrez & Pham [11]	Probabilistic	Supervised
Zhang et al. [18]	Radial basis function	Supervised
Cheng et al. [14]	Multilayer perceptron	Supervised
Ebrahimzadeh et al. [9]	Multilayer perceptron	Supervised
Awadalla & Abdellatif Sadek [19]	Spiking	Supervised

This ANN methods become the key measure of utilization in pattern recognition due to its competence in handling noisy measurements, which no assumption is require about the statistical distribution of the monitored data and during a training phase, it learns to recognise patterns by observing example of patterns. Although this ANN methods have been the most method applied in detecting the control chart pattern it also have its own limitations.

Therefore, there is an improve and better method than the ANN that known as support vector machine. The impressive number of selections of support vector machine by writer on the reviewed articles is due to the method capability of structure risk minimization principles, which it has a better generalization power with a different solution than the ANN model. The implements empirical risk minimization in the ANN are purposed to reduce the error on the training data but the structural risk minimization in the SVM make the method can recognize the small sample that result a good use in the pattern recognition schemes.

Furthermore, the SVM accuracy recognition performance is depending of its selection of the kernel function and parameters such as cost parameter, slack variables and margin of hyper plane for finding an optimal linear separating hyperplane and maximizes the margin between two nearest data point in the two different classes of data. So, this method also has its limitations due to selection of kernel function, high algorithmic complexity, extensive memory requirements, and slow in the test phase. Although on the drawbacks, this method obtains a more accurate result than ANN method on the reviewed article.

3.8 Learning algorithm applied

For supervised ANN, the learning algorithm that been identified based on the reviewed article are about five learning algorithm that known as back propagation (BP), Levenberg – Marquadt (LM), Broyden Fletcher Goldfarb Shanno (BFGS), SpikeProp (SP) and bees. The most common learning algorithm selected by writer for supervised ANN are the back propagation, where there are about six reviewed articles with percentage of 26.09 % have used the algorithm is shown in figure 8. In the back propagation algorithm, the algorithm that been used on the reviewed articles are categorized into a few types that are recognized as root mean square propagation, resilient and adaptive. Based on reviewed article, Fuqua & Razzaghi [5] used the root mean square propagation type for the algorithm robust behaviour and programming compatibility, Ebrahimzadeh et al [9] used the resilient type for it function that can determine the position of the weight update by the sign of derivatives and J. Addeh et al. [8] used the adaptive type for it better convergent speed in finding an optimal weight.

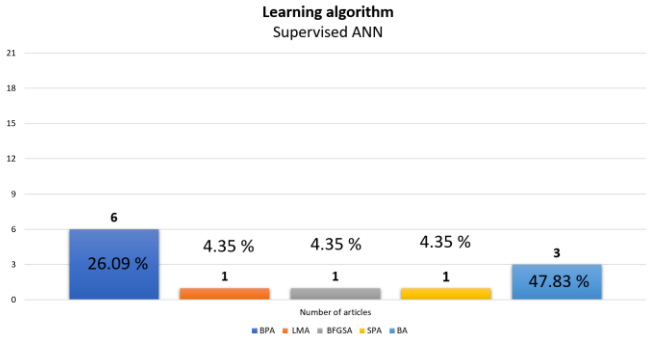

Figure 8: learning algorithm for supervised ANN based on reviewed article

For the bees algorithm, there is three reviewed article have used this algorithm in training for supervised ANN. The concept of this algorithm is based on honey bee foraging activity in finding the best solution for reduce the size of the input parameter and the number of primary functions, as well as increase the recognition model's training speed and efficiency. Based on A. Addeh, Khormali, et al. [4] and Zhang et al. [18] reviewed articles, a classifier that use a bees algorithm as learning algorithm have produce a better recognition accuracy rate than classifier with a common algorithm

Moreover, the LM and BFGS algorithm approximately have the same capability as the BP algorithm, which this algorithm has more robust performance and very fast convergence. Based on Awadalla & Abdellatif Sadek [19] reviewed articles, the SP algorithm are different than common algorithm, which this algorithm is an improved algorithm that can train the delay and time constant of each interaction and also the threshold of the neurons. Therefore, the studies based on these algorithms are limited due to lack of research studies to show it capabilities and performance to be use in the supervised ANN.

In the support vector machine, there are only one learning algorithm that have been used by writer, which the algorithm is known as kernel function. The combination of this algorithm with SVM are preferred by writer are due to its capability in overcome the issue on the input space in SVM, which finding an optimal linear separate hyperplane in all application data. According to De La Torre Gutierrez & Pham [11] reviewed articles, the recognition accuracy performance of this kernel function with SVM has a better performance than an ANN classifier with bees algorithm in recognized a pattern.

Furthermore, there is one reviewed article written by Zhou et al. [13] have used a combination of two kernel function for producing a hybrid kernel. This hybrid kernel created by the writer are to make an improve kernel than common kernel with an increase of the generalization ability and learning capacity in a classifier. Despite of the advantages and better performance of the kernel function with SVM, there are few problems that need to be outcome in order to achieve higher recognition accuracy, which the problem is deciding an optimal kernel function type and finding the parameter values for the training and testing. So, about 6 out of 11 writers on the reviewed article that have used the kernel function with SVM has proposed an addition algorithm to be implement in the SVM for assist in finding

the hyper parameter values to be apply. As shown in figure 9, the addition algorithm that been identified based on reviewed articles are bees algorithm (BA), cuckoo optimization algorithm (COA) and genetic algorithm (GA). The capability of GA in optimize the input feature set and hyper parameter simultaneously are the reason it become preferred algorithm by writer, which the BA and COA is only capable focusing in finding the optimum hyper parameter.

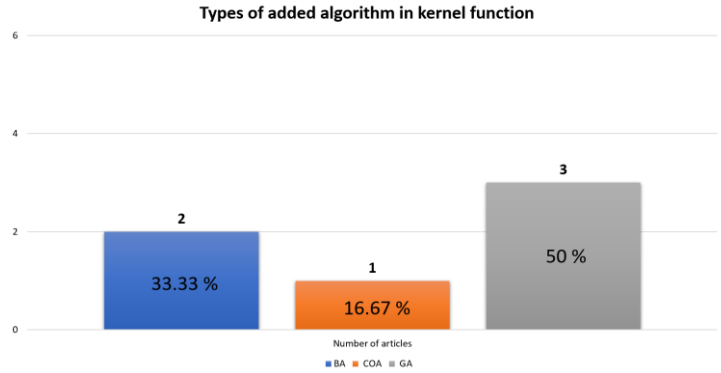

Figure 9: An identified added algorithm in kernel function based on reviewed article

Based on reviewed articles written by M. Zhang & Cheng [14], this genetic algorithm is a powerful tool in the area of global optimization due to its efficiency, robustness and parallel, which the algorithm will find a best combination parameter for classifier and also improve the recognition accuracy rate. Therefore, a SVM with a kernel function operate more efficiently and the recognition accuracy rate increase with an addition of an algorithm

3.9 Development of pattern recognizer model

Based on all the reviewed articles, most of the research studies are still focus on using a traditional concept for development of pattern recognizer model. However, there is few other research studies, which the writer has make a modification on the pattern recognizer model development by adding a new feature into the model. An identified of this development of pattern recognizer model are shown in figure 11. The writer innovation of the model is potentially open up a new version of an improve model to be create that can outcome the traditional model.

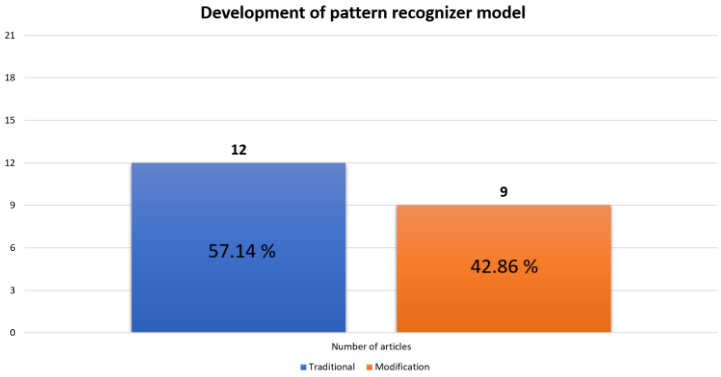

Figure 10: Development of pattern recognizer model based on reviewed article

Moreover, some of the modification feature use by writer are an existed feature that was combine with a classifier for overcome the deficiency of a traditional model, which a structure of the modification pattern recognizer model is shown in figure 11.

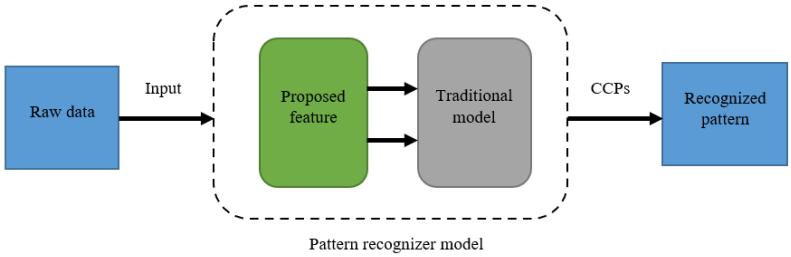

Figure 11: Structure of modification pattern recognizer model

Each of the feature in the modification model have a different improvement and contribution toward the classifier, where a detail of added feature effect in a modify model based on writer research studies are shown in table 9. The writer also has compared the modification model with traditional model on their research studies, which the most the modify model achieve a better recognition accuracy than traditional model and some of the modify model use a same learning algorithm as traditional model.

Table 9: Effect of added feature in modification model based on reviewed articles

Author	Modification model	Effect
Lu et al. [10] and M. Zhang & Cheng [14]	Multi – class SVM (MSVM)	• Improve the recognition accuracy for mixture CCPs. • Obtain more generalized performance of detecting the abnormal CCPs conditions under various machining environment.
Xanthopoulos & Razzaghi **[**20**]**, Zhou et al. **[**13**]**, and Khormali & Addeh [6]	Fuzzy clustering SVM (FSVM)	• Enhance the abnormal quality control data detection problems. • Reduces the impact of noise points on classification accuracy in the training process. • Extract new features and minimise the input data dimension.
Xu et al. [3] and Zan et al **[**17]	One dimensional convolutional neural network (1D CNN)	• Obtaining the ideal feature set from the raw data of the CCPs • Improve generalization ability
Zhao et al. **[**15**]**	Supervised locally linear embedding SVM (SLLE – SVM)	• Improve sample aggregation and mutual exclusion of diverse samples. • Estimate the embedding dimension and local parameters
Kao et al. [21]	Independent component analysis SVM (ICA – SVM)	• Able to obtain normal pattern and process disturbance that hidden in the process data.

3.10 Implemented performance criteria

Average run length (ARL) is commonly used as an effective and standard measure for evaluating the performance of a control chart. However, the number of reviewed articles based on the implemented performance criteria used by researcher, which shown in figure 12 that the most number and percentage are not using the ARL performance measure. The other implemented performance criteria that researcher have used for the control chart pattern recognition schemes are recognition accuracy performance measure, data mining-based measure and correct recognition ratio.

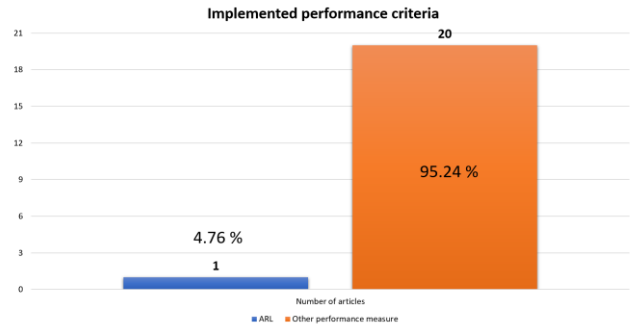

Figure 12: Implemented performance criteria based on reviewed article

The recognition accuracy performance measure determines the average value of the performance of the CCPs by using number of independent runs for finding the ideal optimization for possible highest performance. For the correct recognition ratio, this approach is designed to ratio the number of correctly classified patterns to the total number of test pattern and use as an estimation criterion performance, which it was used by Zan et al. [17] and Zhou et al. [13] in their research studies. Next, the data mining based measures used by Fuqua & Razzaghi [5] are based on confusion matrix that used a designed algorithm and applied for imbalanced data classification for the performance measure.

The selection of performance criteria by writer for their studies shown that the research studies with ARL performance measure are limited and no longer commonly use as measuring tools for estimate the classifier performance of a control chart, which this is maybe due to lack of standard interpretation and practically difficulties in the ARL performance measure.

3.11 Validation methods

In order to evaluate the validity of the proposed method of the research, additional experiments were performed after the simulation experiment and a different approach is been use for determine the purposed methods performance toward real application for validate the research findings. Based on the reviewed article, there are about 5 out of 21 reviewed articles with the percentage of 28.57 % shown in figure 13 have validated the purposed methods in the research studies. The validation of the purposed methods on the reviewed articles are based on industry production or manufacturing, which Fuqua & Razzaghi [5] and Xanthopoulos & Razzaghi [20] are using real dataset collected from wafer manufacturing industry that contains time series dataset samples.

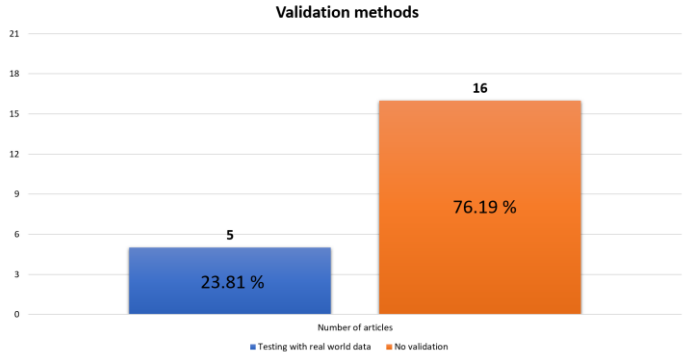

Figure 13: The validation methods based on reviewed article

This validation methods approach in a research studies can be one important aspect for researcher in order to verify their purposed methods performance, which by using only a computerized simulation result for verifying the methods performance may produce a different result than real dataset form a production environment. However, there is about 16 reviewed articles with no validation methods in

the research studies. This situation happen are maybe due to difficulty for obtaining the real dataset from industry and insufficient real dataset.

4. Conclusion

Despite the fact that the proposed classification development criteria have some drawbacks. However, this study able to provides some useful information about the present control chart pattern recognition research studies literature as well as some development for future studies. By analysing the information gather from the classification development criteria, there is some of development criteria for the CCPR is still in the common criteria area from previous decade. The implement of common criteria has developed as reference guideline based on previous research studies that help for further development in CCPR. Moreover, a trend has arisen in input representation and performance criteria, where most of the researcher has implement a feature-based input representation and used other performance measure. Besides that, the findings also discover other development criteria such as support vector machine and its learning algorithm, modification pattern recognizer model and specific control chart pattern. Each of the discover development criteria used by researcher shows that its contribution produces a positive result towards the CCPR schemes. Lastly, the findings of this study believe that the common criteria are still the most preferred development criteria to be used by researcher but the other development criteria also start to gain attention and it can be seen in the future that the common criteria will be replace due to its promising contribution in CCPR.

Acknowledgement

The authors would also like to thank the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia for its support.

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