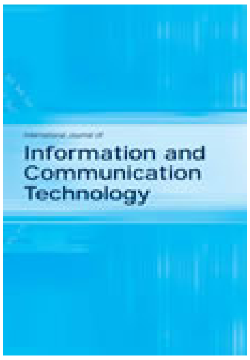

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Data analysis of digital teaching resources and interactive behaviour between teachers and students based on K-means algorithm

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Abstract: The focus of traditional research on teaching behaviour of teachers and students is mainly on identifying the expressions and behaviours of teachers and students, neglecting the analysis of interactive behaviour data between students and teachers. Effective recognition of teacher-student interaction behaviour through K-means algorithm, automatic recognition of classroom teacher-student behaviour using trained teacher and student behaviour recognition models, and analysis and statistics of paired and correlated teacher-student behaviour patterns in traditional classrooms through artificial intelligence technology, thereby promoting effective processing of teacher-student interaction behaviour data. Through experimental research, it has been verified that the method proposed in this article can accurately identify the interactive behaviour between teachers and students in smart teaching, effectively improving the effectiveness of teaching strategy formulation. Through research, it is known that combining intelligent algorithms for training and identifying teacher-student interaction behaviours is beneficial for improving educational and teaching modes, promoting teacher reflection, and promoting the development of educational and teaching informatisation reform towards a better path. In the future, continuous improvement can be made to the K-means algorithm to further promote the effective implementation of smart teaching.

Keywords: K-means algorithm; digitalisation; teaching resources; interactive behaviour.

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1 Introduction

At present, classroom teaching and learning behaviour analysis based on artificial intelligence technology mostly focuses on developing intelligent teaching behaviour recognition and analysis system tools, and these systems mostly use classroom speech information as the basis for recognition, while there is still a slight lack of analysis in classroom nonverbal behaviour. Research on classroom teaching behaviour theory focuses on exploring classroom teaching modes and teaching evaluation indicators, while quantitative and practical research on classroom teaching behaviour analysis theory is still relatively scarce. Due to the current situation where classroom teaching and learning behaviour analysis mostly uses manual observation to record and annotate classroom behaviour, it has caused great consumption of human and material resources, and is largely limited by the attention level and subjective consciousness of observers. This leads to the lack of guarantee for the objectivity and immediacy of the analysis process and results.

The research motivation of this article is to use artificial intelligence technology to reduce labour and time costs in teaching behaviour analysis, optimise classroom teaching modes, promote the development of educational informatisation, and cultivate more innovative talents for the country, which is an important research goal in the interdisciplinary field of contemporary education and computer science.

The focus of traditional research is mainly on identifying the expressions and behaviours of teachers and students, neglecting the analysis of interactive behaviour data between students and teachers. Therefore, in the context of smart teaching, it is necessary to combine intelligent analysis methods for improvement.

This article aims to effectively analyse the interactive teaching behaviour of teachers and students through intelligent methods, helping to effectively carry out the intelligent teaching process. K-means algorithm is used to effectively identify the interactive behaviour of teachers and students, and trained teacher and student behaviour recognition models are used for automatic recognition of classroom teacher and student behaviour. Artificial intelligence technology is used to analyse and statistically analyse the paired and correlated teacher-student behaviour patterns that appear in traditional classrooms, thus promoting the effective processing of data on teacher-student interaction behaviour and providing reliable data support for the formulation of subsequent teaching strategies.

This article continues the traditional research scope and upgrades the recognition of teacher-student behaviour. Starting from the perspective of teacher-student interaction, it combines intelligent training methods to improve the recognition effect of teacher-student interaction behaviour.

Compared with traditional teacher-student behaviour recognition, this article further improves the education mode and teaching data processing methods, finely improves the theory of classroom teaching and learning behaviour analysis, and fully utilises the advantages of artificial intelligence technology in the practical research of teaching behaviour analysis theory, which is conducive to improving the education and teaching mode and promoting teacher reflection, as well as promoting the development path of education and teaching informatisation reform towards a better development path.

The research on teacher-student classroom behaviour patterns based on skeleton information addresses the problems of incomplete evaluation standards, single evaluation subjects, and insufficient quantifiability in current classroom teaching behaviour analysis research. The main contribution of this article is to provide a more comprehensive, detailed, accurate, and objective analysis framework for classroom teaching behaviour analysis through big data analysis and computer vision technology, And using a combination of theory and practice to verify the effectiveness of the framework, it has important research significance and application value in intelligent analysis of student learning behaviour, accurate evaluation of student behaviour participation status, improvement of classroom teaching quality, promotion of teacher teaching reflection, and future construction of intelligent classrooms.

This paper combines K-means algorithm to analyse the digital teaching resources and the interactive behaviour between teachers and students, so as to improve the teaching interaction effect between teachers and students in colleges and universities and effectively promote the popularisation and development of intelligent teaching.

2 Related work

Classroom teaching is an interactive process between teachers' teaching activities and students' learning activities with teaching materials as the medium. Teacher-student interaction, as an indispensable part of classroom teaching, runs through the whole process of classroom teaching. Moreover, there is no classroom teaching without teacher-student interaction.

Analysis of user behaviour characteristics. Based on the behavioural characteristics of users in certain aspects, merge and study user groups with similar characteristics, and classify user behaviour patterns based on the behavioural characteristics of each dimension. Based on the behavioural characteristics of different aspects of users, study their behaviour patterns from the perspective of data and establish a user behaviour model. User learning monitoring and warning. User learning monitoring and warning refers to a real-time reminder mechanism that focuses on the learning dynamics of users at different stages of learning, provides appropriate warnings or reminders to users in a timely manner, and enables them to adjust their self-learning attitude and methods in a timely manner (Hromalik and Koszalka, 2018). Assist in teaching decision-making. By analysing the path, browsing order, and habits of users' online learning, combined with the order of course settings, user characteristics, and rules and information between user grades, the possible learning types of users are determined, in order to recommend suitable learning resources and set reasonable courses for users. Determine whether teaching methods and strategies are appropriate for different categories of users, in order to provide a basis for adjusting teaching methods and strategies (Cooper et al., 2019).

Interpersonal interaction is an indispensable form of interaction in classroom teaching, mainly reflected in verbal communication and nonverbal activities between teachers and students, as well as between students. For example, students can think and answer questions given by the teacher, and groups can communicate and discuss around the same learning topic. For this form of interaction that occurs between people, analysing the language of teachers and students, classroom teaching mode, and emotional atmosphere of classroom teaching. Compared to traditional classrooms, the introduction of modern equipment that promotes student learning and teacher-student interaction allows teachers and students to participate in both verbal and some nonverbal behaviours through technology. For example, teachers use electronic whiteboards to display and play teaching resources during the teaching process, or use software systems in smart classrooms to send and receive assignments for students and conduct learning situation analysis. So in a smart classroom environment, interpersonal interaction is all based on technology, and technology-based forms of interpersonal interaction will inevitably be carried out in more efficient, convenient, and diverse forms (Moorhouse and Wong, 2022).

Arnò et al. (2021) suggests that the term 'teaching interaction' should be used in the context of re teaching to distinguish between interactive behaviour in teaching and non teaching interaction. It is believed that "teaching interaction occurs between students and the teaching environment, including communication and interaction between teachers, students, and learning resources." There are three types of interactive subjects in the classroom: teachers, students, and student groups, and the interaction between these three types of subjects has generated five more categories. Greenhow et al. (2021) categorises teacher-student interaction in the classroom as teacher centred, student centred, and knowledge centred, and believes that 'classroom interaction' is to mobilise important elements in the classroom teaching process, closely adhere to teaching objectives, allow various teaching subjects to influence each other, form interaction, and view this process as dynamic. Bayanov et al. (2019) believes that teacher-student interaction is based on social interaction, and the social interaction behaviour between teachers and students arises from teaching activities. Teachers and students exhibit a series of interdependent behaviours and processes through classroom activities. The interactive behaviour between teachers and students is a dialogue activity that generates mutual influence in problem-solving activities through the use of modern educational technology in classroom teaching, based on equal relationships between teachers and students, in order to achieve teaching objectives.

The information technology-based interactive analysis coding system (ITIAS) proposed in Rapanta et al. (2020) adds student speech behaviour, refines 'silent' behaviour, and adds human technical interaction. However, its classification of technology is relatively general and cannot fully demonstrate the teaching interaction in a smart classroom environment, incorporated technology and environment into the interactive behaviour analysis system and proposed an interactive analysis coding system based on 'human technology environment'. Herodotou et al. (2019) proposes an interactive coding table for classroom teaching behaviour (OOTIAS) suitable for 1:1 digital teaching environments. However, this coding system only enriches the technical content and does not simplify or refine other aspects.

The smart classroom environment is a personalised learning environment supported by media devices and modern technology, and its essence is a highly interactive learning space. In the environment of a smart classroom, teachers can use technology to design teaching, explore educational laws, and develop information-based teaching abilities. However, the smart classroom environment is only used as a means and tool to assist teaching. In actual teaching operations, the smart classroom environment cannot be used to dominate teaching and the classroom. Instead, the course content knowledge should be combined with information technology to promote teaching, and technology should not be used for the sake of technology. This is the reverse of the cart before the horse. No matter what kind of classroom, improving teaching quality is always the core goal (Callo and Yazon, 2020). Fletcher et al. (2020) divides the interaction between people and technology in smart classrooms into two categories: teacher operated technology and student operated technology. Teacher operation technology mainly refers to the application of interactive electronic whiteboards, discussion assessments, e-books and other software and hardware in the classroom by teachers, and the use of media technology in teachers to carry out classroom teaching activities, such as playing resources and displaying student works. As long as students use mobile terminal devices to learn their operating skills, the general classroom is equipped with mobile terminals such as tablets, answering machines, and VR glasses. Students can use these devices to learn resources, answer questions, and interact with VR. Under this teaching platform, students' learning behaviour has undergone tremendous changes compared to traditional classrooms. In terms of the behaviour of students doing exercise questions, in the past, teachers sent students a question sheet or students completed classroom exercises on their own in exercise books. However, with the intervention of media technology, teachers directly sent the required exercises to students through the teacher's end, greatly increasing selectivity and flexibility. After students completed the homework, they can save and send it to the teacher, It can avoid losing homework or teachers being unable to collect and count each student's homework. Moreover, after class, teachers can analyse students' performance in the classroom based on their homework completion and provide corresponding personalised learning materials and plans to achieve individualised teaching (Reamer, 2019). Other classroom activities, such as student-student collaboration behaviour, can also be well carried out in a smart classroom environment (Priyadarshini and Bhaumik, 2020). Through the movable desks and chairs in the smart classroom, students can be divided into different task groups according to their needs. After completing a task together, students can display the results of each group's learning on the discussion side screen, and the evaluation methods are also diverse, including teacher evaluation, student self-evaluation There are various rating methods such as inter group evaluation and peer evaluation. In a smart classroom environment, the reasonable and correct application of media technology inevitably has advantages that are difficult to overcome in traditional classrooms (Okoye et al., 2021).

Giri and Dutta (2020) suggests that between students and students, with equality as the basic premise. Through language, eyes, gestures, or auxiliary tools, teachers and students influence each other in terms of ideas, concepts, emotions, attitudes, values, behaviours, knowledge, etc. Rahayu and Wirza (2020) suggests that classroom teacher-student interaction refers to the interaction or influence that occurs between teachers and students in a classroom teaching context, with a promoting or inhibitory effect. The classroom is the main place for education and teaching in schools. According to Aliyyah et al. (2020), teacher-student interaction in the classroom refers to the interaction between teachers and students with a certain social background, as well as between students and students, with equality as the basic premise. Through language, eyes, gestures, or auxiliary tools in classroom teaching, teachers and students influence each other in their thoughts, concepts, emotions, attitudes, values, behaviours, knowledge, and other aspects. Classroom teacher-student interaction includes teacher-student interaction, as it mainly emphasises that the process of teacher-student interaction occurs in the classroom, and teacher-student interaction can also occur during after-school campus activities and extracurricular activities (Caena and Redecker, 2019).

In real classroom teaching activities, the behaviour of teachers and students is often interrelated, rather than completely independent behaviour. The behaviour of teachers is mostly purposeful and aimed at guiding students to make corresponding reaction behaviours (Graham, 2019). For example, when teachers point to a slide, they aim to focus students' attention on the content of the slide, and students will react accordingly when they see the behaviour made by the teacher. Therefore, the behaviour of teachers and students often appears in pairs, this kind of behaviour between teachers and students accounts for a significant proportion in the actual classroom teaching process (Farooq and Soomro, 2018).

3 Model algorithm

3.1 Behaviour recognition algorithm

In order to realise the intelligent application of the teacher-student behaviour pattern proposed in this study in real classroom, it is necessary to train a teacher-student behaviour recognition model with excellent recognition effect.

The biggest difference between ST-GCN network and traditional skeleton-based behaviour recognition method is that it uses the locality and time dynamics of graph convolution to learn each part of information implicitly, and does not need to manually allocate human joint parts. Therefore, the design of this model is easier, and the effect of learning the skeleton action characteristics of human body is better. Figure 1 is a concrete structure of ST-GCN network (Khan et al., 2000).

Firstly, an undirected spatio-temporal graph $G = (V, E)$ with internal and inter-frame connections is constructed on a skeleton sequence containing N nodes and T frames, $V = \{v_{ti} | t = 1, \ldots, T, i = 1, \ldots, N\}$. Joints and edges in the same frame are connected, as shown in Figure 2.

Then, each node is connected to the same node in adjacent frames. This connection is naturally defined and does not require manual allocation. Therefore, this network structure can work on datasets with different numbers of joints or joint connections. Edge set E is composed of two subsets, and one subset represents the internal connection of skeleton on each frame, which is denoted as $E_s = \{v_{ti}v_{tj} | (i, j) \in H\}$, that is, spatial edge, where H represents a group of naturally connected human joints. Another subset is an intra-frame edge which is formed by connecting identical nodes in two adjacent frames, that is, a time-domain edge, which may be denoted as $E_F = \{v_{ti}v_{(t+1)i}\}$. For a particular joint i, all edges in E_F represent its trajectory with time. At this point, the skeleton topology of a video is established, in which the node information is (abscissa, ordinate, confidence) and the side information is (E_s, E_F).

Taking the traditional two-dimensional image convolution as an example.

Let the convolutional kernel size be expressed as $K \times K$, the input feature is represented as f_{in}, then the output value x can be represented as (Khan et al., 2022a):

$$f_{out}(x) = \sum_{h=1}^{K} \sum_{w=1}^{K} f_{in}\left(p(x, h, w)\right) \cdot w(h, w) \tag{1}$$

Figure 1 Structure diagram of ST-GCN network (see online version for colours)

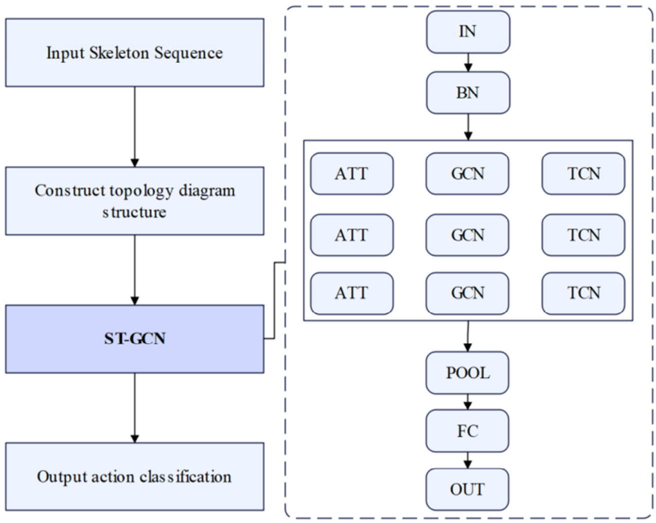
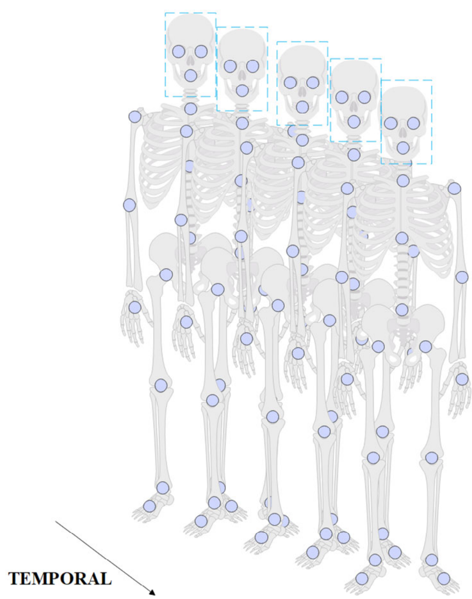


Figure 2 Space-time diagram of skeleton sequence (see online version for colours)



Among them, w is a weight function, p is a sampling function, which samples (h, w) around x pixels, and convolution operation is performed on adjacent pixels in the range, which can be expressed by equation (2).

$$p(x, h, w) = x + p'(h, w) \tag{2}$$

Extending the above equation to the fact that the input feature graph is located on the spatial graph V_t, the convolution operation on the graph can be defined. In the graph, the neighbourhood node set of node V_{ti} can be expressed as equation (3) (Khan et al., 2023).

$$B(v_{ti}) = \left\{ v_{ti} \left| d(v_{tj}, v_{ti}) \le D \right. \right\} \tag{3}$$

We set $D = 1$, that is, the first-order domain of joint nodes. $d(v_{tj}, v_{ti})$ is the shortest distance from v_{tj} to v_{ti}, so the sampling function can be expressed in the form of equation (4).

$$p(v_{ti}, v_{tj}) = v_{tj} \tag{4}$$

In the graph structure, a neighbouring domain $B(v_{ti})$ of a joint node V_{ti} is divided into a fixed k sub-sets, and each subset has a digital label. The weight function can be represented as equation (5) form (Khan et al., 2022b):

$$w(v_{ti}, v_{tj}) = w'(l_{ti}(v_{tj})) \tag{5}$$

The equation (1) is rewritten, and the generalised diagram convolution is as shown in the equation (6):

$$f_{out}(v_{tj}) = \sum_{v_{tj}} \frac{1}{Z_{ti}(v_{tj})} f_{in}(p(v_{ti}, v_{tj})) \cdot w(v_{ti}, v_{tj}) \tag{6}$$

Among them, the radical $Z_{ti}(v_{tj}) = |\{v_{tk}|l_{ti}(v_{tk}) = l_{ti}(v_{tj})\}|$ corresponds to the base of the subset, and this item is added to balance the contribution of different subsets to the output. When the equations (4) and (5) are brought into the equation (6), the airspace diagram is defined, as shown in the equation (7) (Khan et al., 2022c).

$$f_{out}(v_{tj}) = \sum_{v_{tj}} \frac{1}{Z_{ti}(v_{tj})} f_{in}(v_{tj}) \cdot w'(l_{ti}(v_{tj})) \tag{7}$$

As to extend the convolution of spatial graph to temporal and spatial domain. ST-GCN uses TCN. Then, the nodes connected in time domain can be added to the concept of neighbourhood, so that the convolution of spatial domain graph can be extended to time and space domain. Because the shape is fixed, the traditional convolution layer can be used to complete the time convolution operation. At this time, the neighbouring node of the node V_{ti} is shown in the equation (8).

$$B(v_{ti}) = \left\{ v_{qj} \left| d(v_{tj}, v_{ti}) \le K, |q - t| \le [\Gamma / 2] \right. \right\} \tag{8}$$

Among them, Γ is the size of the time domain convolution core. It can be seen from the upper equation that the definition of adjacent nodes is less than K at the spatial distance and less than $\Gamma/2$ at the front and back of the frame distance. That is, the time constraint is added to the definition of the space neighbourhood, as shown in Figure 3.

The sampling function of convolution operation of spatio-temporal graph is the same as that of convolution operation of spatial graph. The weight function only needs to redefine the mapping function of label grouping, and the rest are calculated in the same way. Then, the weight function of the convolution of the spatio-temporal graph is shown in equation (9).

$$lst\left(v_{qj}\right)=l_{ti}\left(v_{ti}\right)+\left(q-t+[\Gamma/2]\right)\times K \quad (9)$$

Among them, $l_{ti}(v_{ti})$ is the label mapping of a single frame situation at the node v_{ti}. From this, it clearly defines the convolutional operation on the structure of the structure. The way ST-GCN divides subsets is shown in Figure 4.

Figure 3 Schematic diagram of time constraint (see online version for colours)

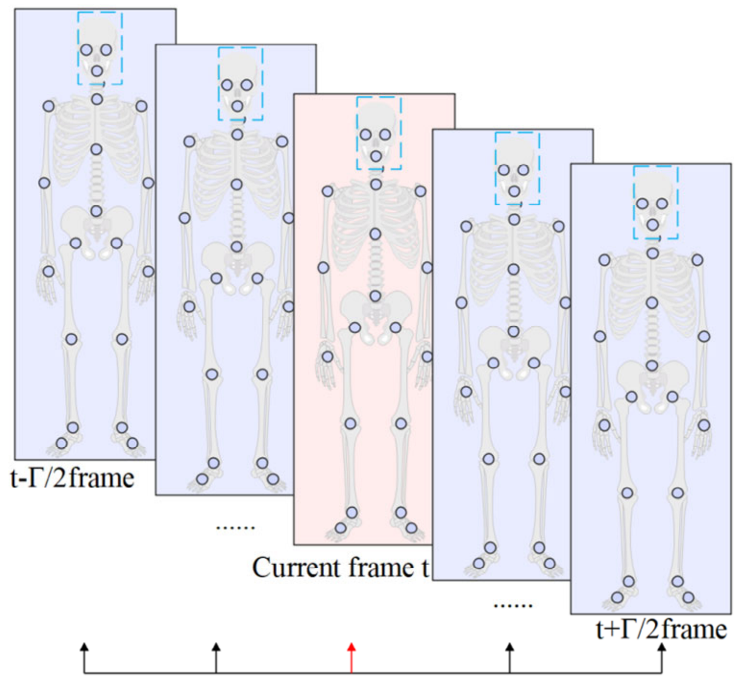
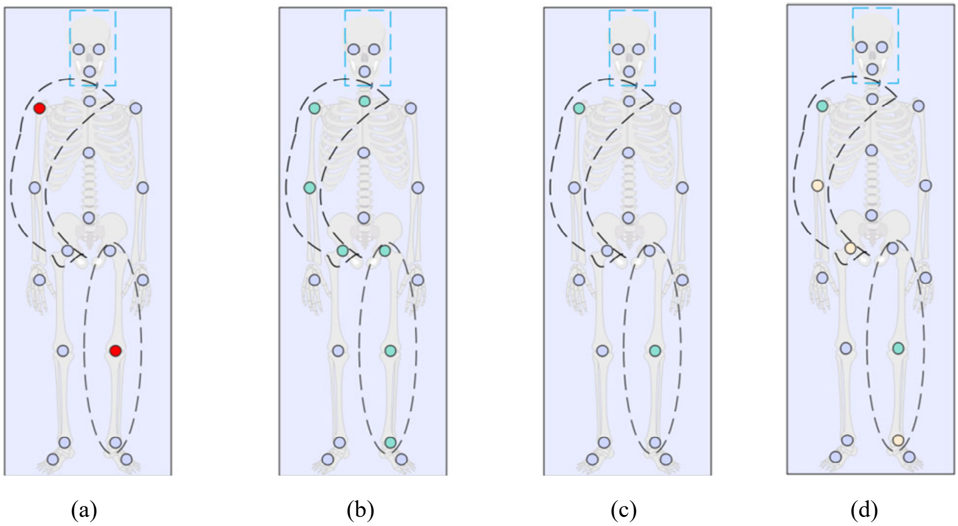


Figure 4(a) is an input single frame skeleton sample, where the blue dots represent joints and the red dashed coils represent the receiving domain of the filter. Figure 4(b) is the simplest and most direct partition strategy-uni-labelling, which has only one subset, that is, the whole neighbourhood set itself. However, this partition method has an obvious disadvantage, thus affecting the classification effect based on skeleton information. Figure 4(c) shows another partitioning strategy, distance partitioning, Figure 4(d) shows spatial configuration partitioning. In this case, for the convolution operation of a node, the weight matrix includes three weight vectors as shown in equation (10).

$$l_{ti}\left(v_{ti}\right)=\begin{cases}0 & IFr_j=r_i\\ 1 & IFr_j<r_i\\ 2 & IFr_j>r_i\end{cases} \quad (10)$$

Figure 4 Schematic diagram of the way of dividing subsets by ST-GCN (see online version for colours)



Among them, r_i represents that the centre of gravity in all frames is trained to the average distance of joint i. The internal connection of the internal joint of the single frame is represented by the adjacent matrix A and the self-connected unit matrix **I**. The ST-GCN that uses the first division strategy can be implemented with equation (11).

$$f_{out} = \Lambda^{-\frac{1}{2}}(A+I)\Lambda^{-\frac{1}{2}} f_{in} W \tag{11}$$

Among them, $\Lambda^{ii} = \sum_j (A^{ij} + I^{ij})$, and the weight matrix W is the sum of the weight vector of multiple output channels. The input feature diagram of ST-GCN can be expressed as the three dimensions (C, V, T). Among them, C represents the characteristics of the joint, V represents the number of joints, and T represents the number of key frames. The convolution is achieved by performing the standard two-dimensional convolution of 1 × Γ, and the amount of tensor obtained is multiplied with the standardised adjacent matrix $\Lambda^{-\frac{1}{2}}(A+I)\Lambda^{-\frac{1}{2}}$ in the second dimension. For the distance division and spatial configuration, it can also be implemented by the above methods, but the adjacent matrix is decomposed into several matrix A_j, where $A+I = \sum_j A_j$, and at this time ST-GCN can be written as a formula (12) form.

$$f_{out} = \sum \Lambda_j^{-\frac{1}{2}} A_j \Lambda_j^{-\frac{1}{2}} f_{in} W_j \tag{12}$$

Although people's joint nodes are in groups of movement when doing action, the importance of the same joint node in different actions should be different. Therefore, each layer of ST-GCN adds a learning mask M. That is, the $A + I$ in the formula (11) is replaced with the $(A + I) \otimes M$, and the A_j in the formula (12) is replaced with $A_j \otimes M$.

Among them, ⊗ means multiplying the elements between the two matrices, and the mask *m* is initialised to a full matrix. The mask will be based on the importance learning weight of the edge of each airspace in E_s, so as to adjust the characteristics of node characteristics to the contribution of its neighbouring nodes.

3.2 K-means algorithm

K-means algorithm is mainly divided according to the similarity or distance function between samples. The basic idea of K-means algorithm is to divide all the points to be clustered into different clusters through a given initial cluster centre and a limited number of iterations. Its Euclidean distance measurement formula is:

$$d(x_i, x_j) = \sqrt{\sum_{k=1}^{n} (x_{ik} - x_{jk})^2} \tag{13}$$

Among them, n is the number of vector attributes, x_i and x_j are two vectors in the dataset, and x_{ik} and x_{jk} are the k^{th} attributes of vectors x_i and x_j, respectively.

K-means algorithm is an important algorithm in clustering analysis, which is simple and easy to implement. Its main steps are as follows:

Step 1 The algorithm initialises the number of cluster centres K and the coordinates of K cluster centres.

Step 2 The algorithm calculates the distance between all the points to be clustered and each cluster centre, and divides the points to be clustered into the nearest cluster.

Step 3 The algorithm updates the cluster centre coordinates.

Step 4 The algorithm repeats steps 2 and 3 until the number of iterations is reached or the cluster centre coordinates do not change.

The advantages of the K-means algorithm are:

1. It is a fast, simple and effective method to solve clustering problems.
2. If the result cluster is compact and the difference between clusters is obvious, the clustering effect is better.

Although K-means algorithm is simple and easy to implement, it still has some shortcomings:

1. Selection of initial centroid coordinates. Generally speaking, the initial coordinates of the centre of mass should be given before the algorithm runs, and the coordinates are usually selected by random method. Because of the random uncertainty, the given coordinates often have a great influence on the clustering effect.
2. The choice of K value. The size of K represents the number of final clusters, and the clustering effect may lead to different results because of different K values.
3. Convergence of objective function. For different problems, it is necessary to construct a suitable objective function, so that the algorithm can effectively converge. If there is a big difference between clusters in the clustering results, and the members in the cluster are relatively concentrated, then K-means algorithm can often get better clustering results. However, there may be a situation, that is, the size,

density and shape of each cluster are very different, and K-means algorithm may not be able to cope with these situations, resulting in poor classification results.

Clustering analysis of behaviour activity information refers to dividing the same or similar behaviours into different categories by using a certain similarity measure according to the obtained data related to behaviour activities, such as location, time and activity status. According to the different research contents, it can be divided into individual behaviour clustering analysis and group behaviour clustering analysis, both of which can be analysed by using clustering algorithms in data mining. Clustering analysis of individual behaviour refers to clustering the behaviour of a single individual, and mining the behaviour rules or other valuable information of the individual. For example, according to the GPS information of individuals, the places where individuals often move can be clustered. In addition, cluster analysis of group behaviour refers to cluster analysis of a large number of individuals to deeply understand the behaviour of different individuals, divide them into different categories according to the similarity between individuals, and find out the behaviour rules of groups, so as to provide more effective and convenient services for personalised recommendation, marketing and other industries.

In general, K-means algorithm can do better clustering analysis, but K-means algorithm has the defect that the number and coordinates of initial clustering centres are difficult to determine. Therefore, aiming at the problems in K-means algorithm and the characteristics of behavioural activity data, this section improves K-means algorithm. In this paper, the adaptive clustering method based on clustering is adopted, and the improved algorithm is suitable for data with scattered distribution among clusters and compact distribution within clusters. The specific implementation flow of the algorithm is as follows:

Step 1 The algorithm samples data points, calculates the distance from each sample point to other sample points, and obtains the distance between the nearest and farthest points.

Step 2 The algorithm sets a variety of threshold radius in the nearest and farthest distance range.

Step 3 The algorithm selects a threshold radius, randomly selects an unmarked point *P* from the array as the centre point of a cluster, marks the point, and calculates the distance between the point *P* and other unmarked points in the array.

Step 4 If the distance between other points in the array and the point *P* is less than *T*, then these points belong to the cluster centred on the point *P*, and these points are marked.

Step 5 The algorithm repeats steps 2 through 3 until all the points in the array are marked.

Step 6 According to the number and coordinates of the initial clustering centres obtained by the pre-processing algorithm, the algorithm uses K-means algorithm to cluster. According to the flow of K-means algorithm, the coordinates of each clustering centre are iteratively updated to obtain clustering results.

Step 7 The algorithm repeats Step 3 through Step 6 until all threshold radii are executed once.

Step 8 The algorithm adopts the prototype-based cohesion evaluation method, evaluates the clustering results under different threshold radius, and obtains the natural number of clusters according to the inflection point in the cohesion curve. The aggregation measure function based on prototype is as follows, where C_i is each cluster centre, x is node data, and *dist* is Euclidean distance measure:

$$Cluster\ SSE = \sum_{x \cup C_i} dist\left(C_i, x\right)^2 \tag{14}$$

4 Models and experiments

4.1 Construction of model

With the development and advanced performance of deep learning methods in other computer vision tasks, RNN, CNN and GCN using skeleton data have begun to appear in large numbers. Figure 5 shows the general flow of deep learning behaviour recognition method based on 3D skeleton.

Table 1 Participation pattern of teacher-student behaviour

High level of participation	Teacher-student behaviour pattern pair	Low level of participation	Point to multimedia-reading
	Point to multimedia-look up		Point to multimedia-turn head
	Point to multimedia-writing		Writing on the blackboard-reading
	Writing on the blackboard-look up		Write on the blackboard-turn head
	Writing on the blackboard-writing		Demonstration-writing
	Demonstration-imitation		Demo-turn head
	Demo-look up		Patrol-look up
	Patrol-writing		Ask questions-look up
	Patrol-read		Ask questions-reading
	Patrol-turn head		
	Ask questions-raise hand		

Because the focus of this study is to explore the relationship between teacher and student behaviour and its influence on the analysis of students' behaviour participation, do not divide teachers' teaching behaviour and students' learning behaviour independently in the classification of classroom behaviour as in the previous teaching analysis framework, but divide teachers' and students' actions in the classroom into pairs according to the obvious relationship between teachers' and students' behaviours according to the participation level they represent, and form teacher-student behaviour pattern pairs. Table 1 describes in detail each teacher-student behaviour pattern pair and the participation level it represents.

Figure 5 General flowchart of behaviour recognition (see online version for colours)

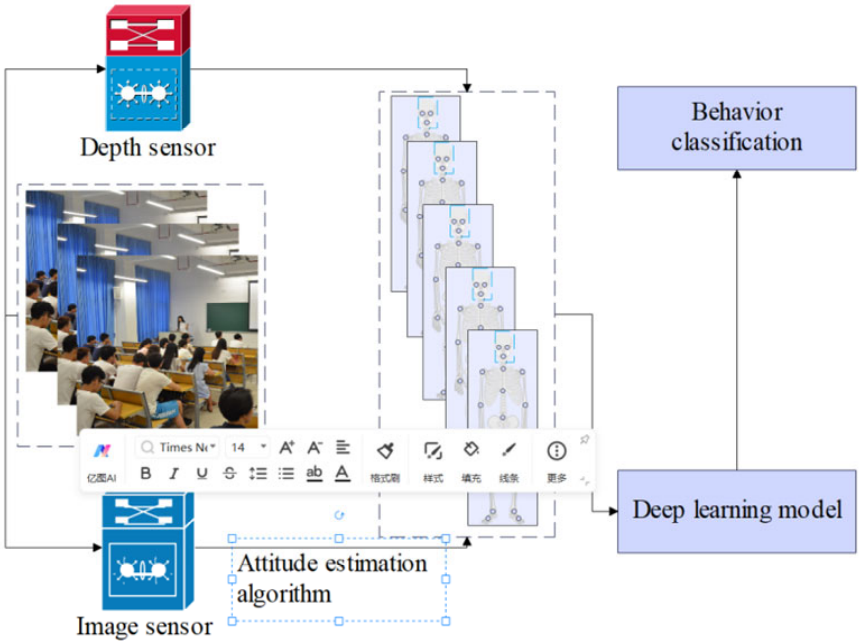
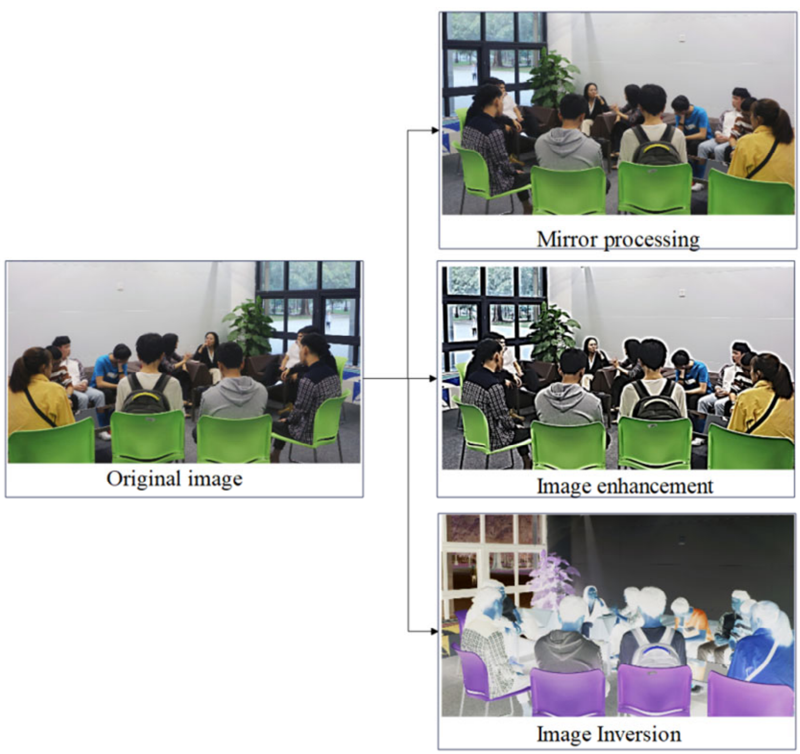


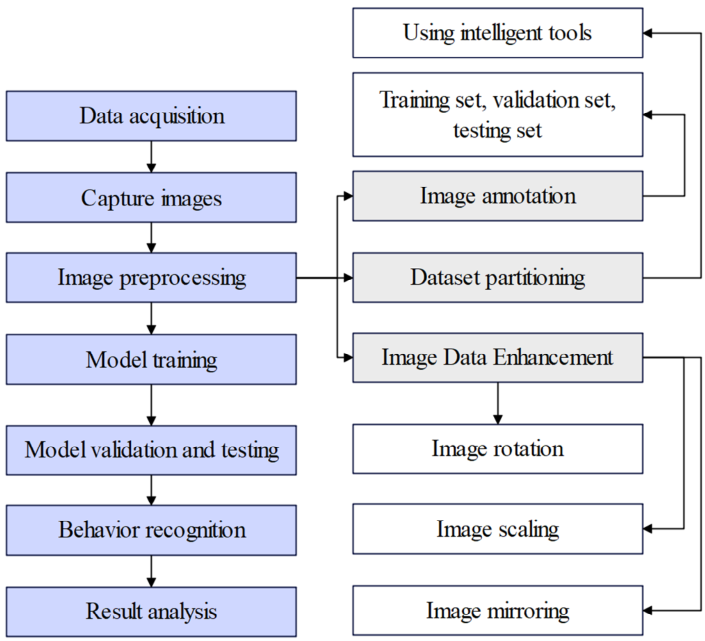
Figure 6 Renderings of data enhancement (see online version for colours)



Using the method of frame extraction, one image is extracted every 30 times, and the images at different times are randomly selected as the dataset of interactive behaviour recognition between students and teachers. The quality of the image in the dataset will significantly affect the training effect of the model. Therefore, it is necessary to clean the extracted image to remove the blurred image. Finally, LabelImg tool is used to label the interactive behaviour recognition dataset between students and teachers.

In order to avoid model over-fitting and enhance the robustness of the algorithm, this paper adopts off-line enhancement method, and randomly selects rotation, scaling and mirror image to enhance the data of the images in the training set. The enhanced sample of data is shown in Figure 6.

Figure 7 Overall flowchart of test (see online version for colours)

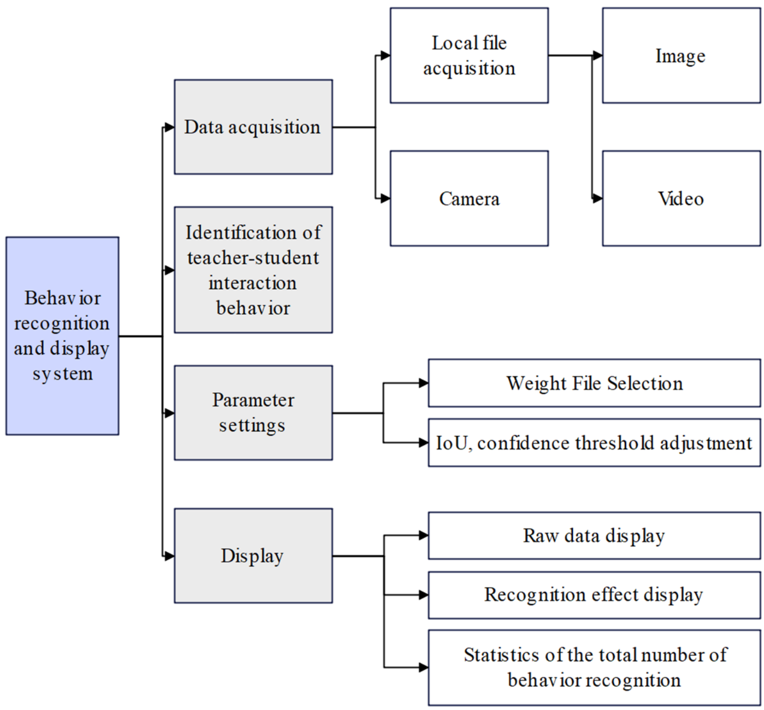


As shown in Figure 6, the original image is mirrored, rotated and scaled at the same time, which increases the diversity of the image. The overall flowchart of the test is shown in Figure 7.

As shown in Figure 7, the whole experiment firstly collects data to obtain the interactive behaviour images of students and teachers, and then pre-processes the images to prepare for model training. After training the model, the performance test and result analysis are carried out. The overall framework of the student-teacher interaction behaviour identification and statistics system is shown in Figure 8.

It mainly includes data acquisition, student-teacher interaction behaviour identification, parameter setting and display. The data acquisition part is used to select the main channels for data acquisition, including local file acquisition and camera call. The interactive behaviour recognition part of students and teachers recognises the data sent by the data acquisition part by calling the trained model, and makes statistics on the total duration of each behaviour in the current frame image. The parameter setting section includes weight file selection, IoU threshold, and confidence threshold adjustment, and the display section is a display of the original data, the recognition effect, and the duration of each behaviour recognised in the current frame image. The behaviour analysis data in this paper is mainly identified by the behaviour recognition algorithm mentioned in the second part, and processed by K-means algorithm.

Figure 8 Overall frame diagram of teacher-student interaction behaviour recognition and display system (see online version for colours)



The software system of this paper is divided into three parts. Among them, embedded devices mainly design the UI interface of LCD display screen, mobile APP design is mainly user login design and action display design to realise the real-time query of road condition information on the mobile phone side, and finally the software design on the server side is mainly to realise the video display and storage design. The design software used in this paper mainly uses PyQt, QT and Androidstudio to design three parts respectively. The overall process design of the software system is shown in Figure 9.

Considering the independence and computational efficiency of each module of the monitoring system, this design deploys the intelligent analysis module in the newly established server. Among them, the server and the original monitoring system are implemented by common C/S architecture. C/S architecture is usually set as a two-tier structure, the server is responsible for processing data, and the client is responsible for completing interactive tasks. The video information collected by the camera is first transmitted to the client in the video monitoring system, and then transmitted to the server through the LAN. The video information is intelligently analysed in the server, and the human actions in the video are classified and identified and the dangerous actions are warned. The basic topology diagram of the intelligent monitoring system is shown in Figure 10.

Figure 9 Overall block diagram of system software design (see online version for colours)

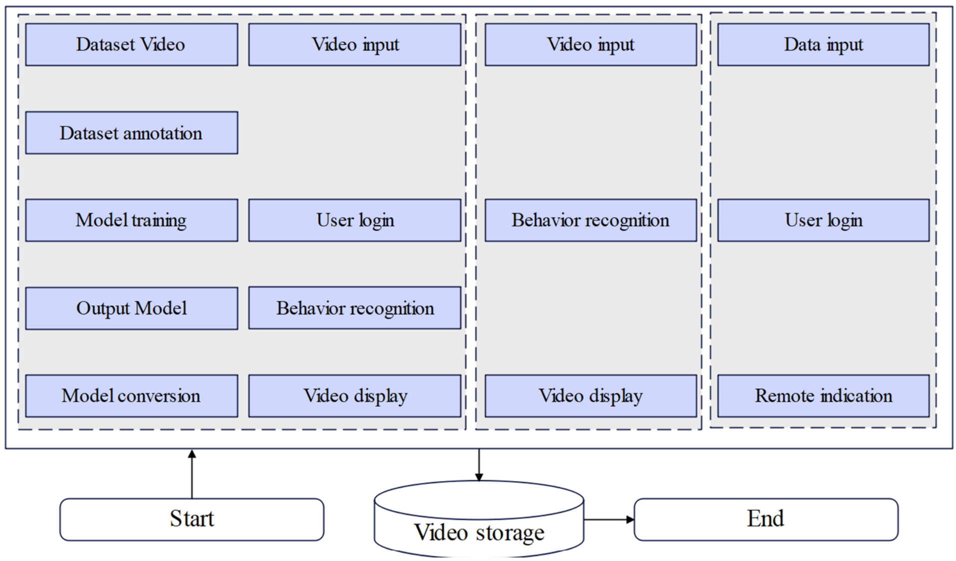
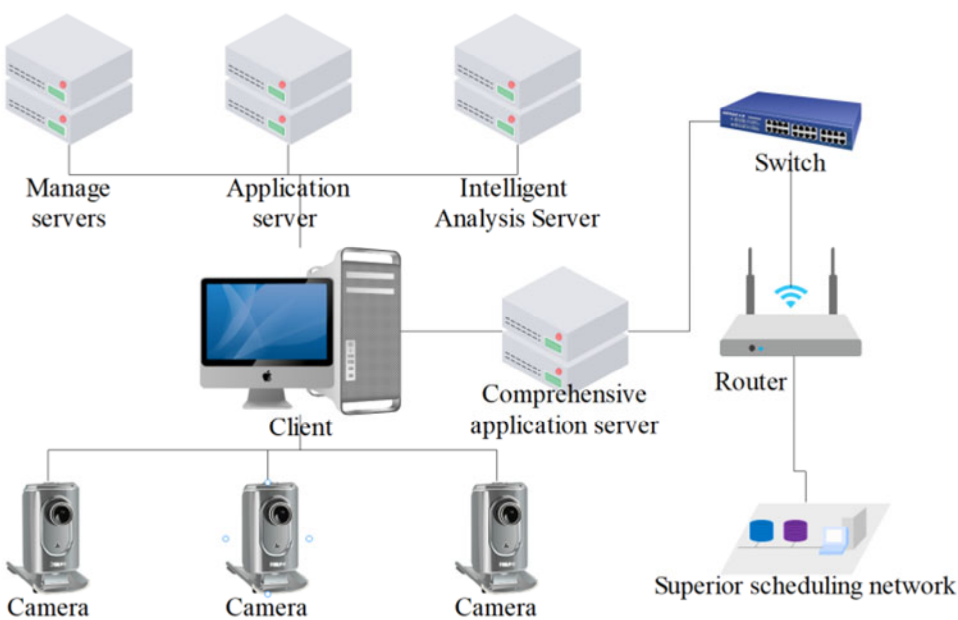


Figure 10 Topology diagram of system network

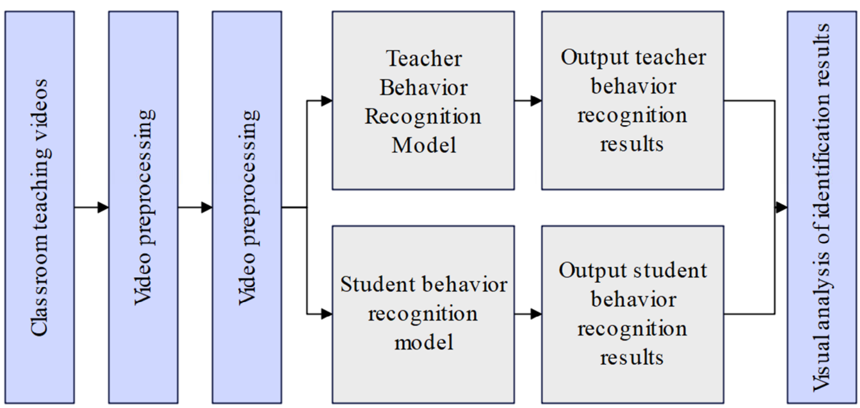


4.2 Experimental study

Compared to the previous research on teacher-student behaviour datasets in this field, a relatively large dataset of teacher-student classroom behaviour videos has been established, which includes five types of teacher behaviour and six types of student behaviour, each containing about 1,000 videos. And a video dataset containing real classroom teaching from various regions has also been established, which can be used for future intelligent analysis and research of video-based teaching. By conducting transfer learning on spatiotemporal graph convolutional networks, the temporal and spatial characteristics of video skeleton sequences were fully utilised, achieving better performance than other models on the teacher-student classroom behaviour dataset established in this paper.

All the experiments in this study are completed in Windows10 operating system and python3.7 environment. The deep learning framework used is Pytorch, the processor used is AMD R7-4800H with eight cores and 16 threads, the graphics card used is two NVIDIA GEFORCE RTX2080Ti with 32G video memory, and the code debugging is using Pycharm software. The process of applying the teacher-student behaviour participation mode proposed in this study to real classroom teaching video is shown in Figure 11.

Figure 11 The flowchart of experimental (see online version for colours)



In this paper, we collect the actual videos of classroom teaching for experimental analysis, identify the interactive behaviour between teachers and students through multiple groups of videos, and get the experimental results shown in Table 2.

From Table 2, it can be seen that the data analysis model of teacher-student interaction behaviour based on K-means algorithm proposed in this paper can play an important role in the recognition of classroom and student interaction behaviour characteristics. The algorithm model of this paper is to combine behaviour recognition algorithm with K-means algorithm for teacher-student interaction recognition. In order to verify the reliability of this method, the fusion algorithm is compared with Cramer algorithm and Apriori algorithm, mainly from three aspects: behaviour recognition accuracy (%), feature marking accuracy (%) and data processing speed (ms). Among them, behaviour recognition is the recognition of teacher-student interaction process, feature marking is the action marking of teacher-student interaction process, and data processing is to verify the processing speed of ten-minute teaching video. Finally, the experimental results shown in Table 3 are obtained.

Table 2 Test results of model experiment

	Teacher-student behaviours pattern pair	*Accuracy (%)*		*Point to multimedia-reading*	*Accuracy (%)*
High level of participation	Point to multimedia-look up	79.75	Low level of participation	Point to multimedia-turn head	86.25
	Point to multimedia-writing	84.45		Writing on the blackboard-reading	85.86
	Writing on the blackboard-look up	77.20		Write on the blackboard-turn head	87.67
	Writing on the blackboard-writing	85.03		Demonstration-writing	81.13
	Demonstration-imitation	87.90		Demo-turn head	83.30
	Demo-look up	80.15		Patrol-look up	83.13
	Patrol-writing	81.44		Ask questions-look up	79.55
	Patrol-read	78.40		Ask questions-reading	78.21
	Patrol-turn head	84.50		Point to multimedia-reading	86.36
	Ask questions-raise hand	76.88			

It can be seen from Table 3 that the fusion algorithm proposed in this paper has certain advantages in many aspects compared with the traditional algorithm, so the model proposed in this paper can play an important role in the interaction analysis between teachers and students.

Table 3 Comparison results of algorithms

	Behaviour recognition (%)	*Feature marking (%)*	*Data processing (ms)*
Fusion algorithm	83.32	80.23	253
Cramer algorithm	76.64	72.32	544
Apriori algorithm	73.54	71.54	476

To further verify the effectiveness of the system model in this article, the effectiveness was verified through teaching practice methods. An experimental study was conducted using a certain class in a university as an example. The teaching practice effectiveness of the system model in this article was evaluated using expert evaluation methods, and the experimental results are shown in Table 4.

Table 4 Evaluation of teaching practice

Number	*Evaluate*
1	88.56
2	92.55
3	91.21
4	91.82
5	88.26
6	91.32
7	92.45
8	88.67
9	90.97
10	91.80
11	89.06
12	89.14

Through teaching practice evaluation, it can be concluded that the data analysis of digital teaching resources and interactive behaviour between teachers and students based on K-means algorithm proposed in this article can play an important role in teaching practice.

5 Conclusions

The relationship between teachers' behaviour and students' behaviour is close and relatively complex, so teacher-student interaction behaviour, as the third perspective of classroom teaching behaviour research, has gradually aroused the interest of educators. Moreover, the quantitative analysis of teacher-student participation in classroom interaction is conducive to promoting teachers' reflection on teaching, improving teachers' classroom teaching level and stimulating students' enthusiasm and enthusiasm for classroom learning. This paper combines K-means algorithm to analyse the digital teaching resources and the interactive behaviour between teachers and students, so as to improve the teaching interaction effect between teachers and students in colleges and universities. The experimental research has verified that the K-means algorithm-based digital teaching resource data analysis model for teacher-student interaction behaviour proposed in this paper can play an important role in the recognition of classroom and student interaction behaviour characteristics. Compared with traditional teacher-student behaviour research models, the proposed model has improved accuracy in behaviour recognition (%), feature labelling accuracy (%), and data processing speed (ms) all three perspectives have obvious advantages. Therefore, the model proposed in this article can play an important role in the analysis of interaction between teachers and students. Further exploration of lighter video-based teacher-student behaviour recognition models and solving the problem of more character occlusion in teaching videos are also potential research directions in the future.

The classroom scenario targeted by this research institute is only traditional classrooms, and with the reform and development of modern education and teaching, many new classroom models are also prevalent in various places, such as flipped classrooms and efficient classrooms. The proportion of activities between teachers and students in the classroom has gradually changed. For these new classroom teaching models, a more comprehensive and systematic analysis framework needs to be developed to adapt to the diversified teacher-student behaviour patterns that appear in the new classroom; this study only categorises the patterns of nonverbal behaviour between teachers and students in the classroom, and the importance of other types of teacher-student behaviour in the classroom, such as verbal behaviour, cannot be ignored. When analysing certain teacher-student behaviours, verbal behaviour may be more intuitive and accurate. Therefore, the future multimodal framework for analysing teacher-student classroom behaviour still needs further improvement and refinement.

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1 2023 Guizhou Province Higher Education Teaching Content and Curriculum System Reform Project: Exploring the Path of Digital Empowerment for Business Teachers Curriculum Innovation – Taking Leadership as an Example, No. 2023226.

2 Guizhou Province Education Science Planning Project: Research on the Mechanism of 'Lying Flat Psychology' for College Students Based on Action Teaching Innovation (No. 2023B027).

3 Guizhou University of Commerce 2023 Campus level Education Reform Project: 'Leadership' Online and Offline Mixed First Class Course, ID: 2023XJYK05.

4 Ministry of Education's Collaborative Education Program for Industry and Education: Teacher Training for Leadership Course Based on Talent Development Strategy (No. 230805309283215).

5 Research Achievements of the Provincial Innovation Team on the Governance and Practice of Digital Business Ecology at Guizhou University of Commerce.

References

Aliyyah, R.R., Rachmadtullah, R., Samsudin, A., Syaodih, E., Nurtanto, M. and Tambunan, A.R.S. (2020) 'The perceptions of primary school teachers of online learning during the COVID-19 pandemic period: a case study in Indonesia', *Journal of Ethnic and Cultural Studies*, Vol. 7, No. 2, pp.90–109.

Arnò, S., Galassi, A., Tommasi, M., Saggino, A. and Vittorini, P. (2021) 'State-of-the-art of commercial proctoring systems and their use in academic online exams', *International Journal of Distance Education Technologies*, Vol. 19, No. 2, pp.55–76.

Bayanov, D.I., Novitskaya, L.Y., Panina, S.A., Paznikova, Z.I., Martynenko, E.V., Ilkevich, K.B. and Allalyev, R.M. (2019) 'Digital technology: risks or benefits in student training', *Journal of Environmental Treatment Techniques*, Vol. 7, No. 4, pp.659–663.

Caena, F. and Redecker, C. (2019) 'Aligning teacher competence frameworks to 21st century challenges: the case for the European digital competence framework for educators (Digcompedu)', *European Journal of Education*, Vol. 54, No. 3, pp.356–369.

Callo, E.C. and Yazon, A.D. (2020) 'Exploring the factors influencing the readiness of faculty and students on online teaching and learning as an alternative delivery mode for the new normal', *Universal Journal of Educational Research*, Vol. 8, No. 8, pp.3509–3518.

Cooper, G., Park, H., Nasr, Z., Thong, L.P. and Johnson, R. (2019) 'Using virtual reality in the classroom: preservice teachers' perceptions of its use as a teaching and learning tool', *Educational Media International*, Vol. 56, No. 1, pp.1–13.

Farooq, M.U. and Soomro, A.F. (2018) 'Teachers and technology: trends in English language teaching in Saudi Arabia', *International Journal of English Linguistics*, Vol. 8, No. 1, pp.10–19.

Fletcher, J., Everatt, J., Mackey, J. and Fickel, L.H. (2020) 'Digital technologies and innovative learning environments in schooling: a New Zealand experience', *New Zealand Journal of Educational Studies*, Vol. 55, No. 1, pp.91–112.

Giri, S. and Dutta, P. (2020) 'Identifying challenges and opportunities in teaching chemistry online in India amid COVID-19', *Journal of Chemical Education*, Vol. 98, No. 2, pp.694–699.

Graham, A. (2019) 'Benefits of online teaching for face-to-face teaching at historically black colleges and universities', *Online Learning*, Vol. 23, No. 1, pp.144–163.

Greenhow, C., Lewin, C. and Staudt Willet, K.B. (2021) 'The educational response to COVID-19 across two countries: a critical examination of initial digital pedagogy adoption', *Technology, Pedagogy and Education*, Vol. 30, No. 1, pp.7–25.

Herodotou, C., Hlosta, M., Boroowa, A., Rienties, B., Zdrahal, Z. and Mangafa, C. (2019) 'Empowering online teachers through predictive learning analytics', *British Journal of Educational Technology*, Vol. 650, No. 6, pp.3064–3079.

Hromalik, C.D. and Koszalka, T.A. (2018) 'Self-regulation of the use of digital resources in an online language learning course improves learning outcomes', *Distance Education*, Vol. 39, No. 4, pp.528–547.

Khan, A.A., Laghari, A.A., Gadekallu, T.R., Shaikh, Z.A., Javed, A.R., Rashid, M., Estrela, V.V. and Mikhaylov, A. (2000) 'A drone.based data management and optimization using metaheuristic algorithms and blockchain smart contracts in a secure fog environment', *Computers and Electrical Engineering*, Vol. 102, No. 3, p.108234.

Khan, A.A., Laghari, A.A., Li, P., Dootio, M.A. and Karim, S. (2023) 'The collaborative role of blockchain, artificial intelligence, and industrial internet of things in digitalization of small and medium-size enterprises', *Scientific Reports*, Vol. 13, No. 1, p.1656.

Khan, A.A., Laghari, A.A., Shaikh, Z.A. and Dacko, Z. (2022b) 'Pikiewicz and Sebastian Kot. 'Internet of things (IoT) security with blockchain technology: a state-of-the-art review'', *IEEE Access*, Vol. 1, No. 1, pp.16–26.

Khan, A.A., Shaikh, A.A. and Laghari, A.A. (2022c) 'IoT with multimedia investigation: a secure process of digital forensics chain-of-custody using blockchain Hyperledger Sawtooth', *Arabian Journal for Science and Engineering*, Vol. 1, No. 1, p.16.

Khan, A.A., Wagan, A.A., Laghari, A.A., Gilal, A.R., Aziz, I.A. and Talpura, B.A. (2022a) 'BIoMT: a state-of-the-art consortium serverless network architecture for healthcare system using blockchain smart contracts', *IEEE Access*, Vol. 10, No. 2, pp.78887–78898.

Moorhouse, B.L. and Wong, K.M. (2022) 'Blending asynchronous and synchronous digital technologies and instructional approaches to facilitate remote learning', *Journal of Computers in Education*, Vol. 9, No. 1, pp.51–70.

Okoye, K., Rodriguez-Tort, J.A., Escamilla, J. and Hosseini, S. (2021) 'Technology-mediated teaching and learning process: a conceptual study of educators' response amidst the COVID-19 pandemic', *Education and Information Technologies*, Vol. 26, No. 6, pp.7225–7257.

Priyadarshini, A. and Bhaumik, R. (2020) 'E-readiness of senior school learners to online learning transition amid COVID-19 lockdown', *Asian Journal of Distance Education*, Vol. 15, No. 1, pp.244–256.

Rahayu, R.P. and Wirza, Y. (2020) 'Teachers' perception of online learning during pandemic COVID-19', *Jurnal Penelitian Pendidikan*, Vol. 20, No. 3, pp.392–406.

Rapanta, C., Botturi, L., Goodyear, P., Guàrdia, L. and Koole, M. (2020) 'Online university teaching during and after the COVID-19 crisis: refocusing teacher presence and learning activity', *Postdigital Science and Education*, Vol. 2, No. 3, pp.923–945.

Reamer, F.G. (2019) 'Social work education in a digital world: technology standards for education and practice', *Journal of Social Work Education*, Vol. 55, No. 3, pp.420–432.