# Intelligent Clothing Design and Production Integrating CAD and Virtual Reality Technology

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**Abstract.** The full name of clothing CAD is computer-aided clothing design, which refers to the use of electronic computers to assist personnel in clothing design. It has higher efficiency, better quality, and more accurate positioning than traditional manual design. In addition, many clothing CAD systems have integrated intelligent technology, elevating traditional clothing design to the level of intelligent assisted design. This project initiated the application research of intelligent visual technology based on DL (deep learning) in ethnic clothing culture and pattern design. A pattern generative model based on DL is proposed. Our new model uses a two-layer LSTM (long- and short-term memory) network in the decoding part, and performs the required mapping through sufficient depth and nonlinear transformation, instead of placing a simple single hidden layer multilayer perceptron on the top of the decoder in the original language decoding model. Research has shown that the algorithm proposed in this paper greatly improves the pattern matching accuracy of four corner rotation changes, with an accuracy increase of 56.127%. From the perspective of the highest accuracy of a single pattern, the traditional algorithm has a maximum accuracy of only 70.066%, while for some ethnic patterns, the highest accuracy of the improved algorithm in this article can reach 100%. The language decoding model based on double-layer LSTM can perform more nonlinear transformations on image and language information, thereby improving the semantic expression ability of the generated description statements.

**Keywords:** Computer Aided Design; Deep learning; Intelligent vision technology; National costume; Pattern
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## 1 INTRODUCTION

Clothing CAD technology is a clothing design tool for clothing production and processing enterprises. It effectively enables clothing engineering technicians to design better and more market competitive fashion. Applying clothing design knowledge to the process of clothing design, achieving optimized and intelligent design while incorporating rich graphic processing functions. It is an inevitable trend to develop intelligent garment CAD technology for fashion design on the basis of general garment CAD technology mainly based on geometric modeling. Clothing CAD design refers to the process of using computer software and hardware to assist in designing clothing drawings. This technology is very important in clothing production and design, which can greatly improve efficiency and quality. A clothing CAD system generally consists of two parts: hardware and software. The hardware includes computers, scanners, printers, etc., while the software includes clothing design software and CAD drawing software. Abdulahimovna [1] discussed the clothing CAD system, which can help designers draw various patterns of clothing on computers.

CAD intelligent clothing refers to the process of using computer software and hardware to assist in designing clothing drawings. This technology is very important in clothing production and design, which can greatly improve efficiency and quality. A clothing CAD system generally consists of two parts: hardware and software. The hardware includes computers, scanners, printers, etc., while the software includes clothing design software and CAD drawing software. Clothing CAD management is a complex process that involves system design, development, implementation, operation, and maintenance. Only through careful management and practice can the normal operation of the clothing CAD system be ensured, and the efficiency and quality of clothing design and production be improved. Clothing CAD is a three-dimensional modeling and display technology based on virtual reality technology, which can convert planar two-dimensional clothing templates into three-dimensional clothing samples. This technology is also known as 3D visual stitching technology. A clothing CAD system generally consists of two parts: hardware and software. The hardware includes computers, scanners, printers, etc., while the software includes clothing design software and CAD drawing software. The clothing CAD system can help designers layout and size various parts of clothing, such as tops, pants, sleeves, etc., in order to make the production process more efficient. In short, clothing CAD design is an important clothing design technology that can greatly improve efficiency and quality, helping designers better complete clothing design and production.

## 2 RELATED WORK

Du et al. [2] conducted geometric optimization design of the product, effectively solving the theoretical and technical foundation of lightweight design in the manufacturing process. Meanwhile, due to the application of universal finite element analysis software in clothing design, many clothing problems have been solved. Horiba et al. [3] combined finite element analysis software with other clothing problem solving tools to effectively estimate clothing problems, including shear stress, heat conduction, pressure, temperature, etc. By combining different solving tools and software, the optimal method can be found to estimate clothing problems, and the impact of clothing structure and material characteristics on clothing performance can be better understood. Hu [4] proposed a design framework for a component-based intelligent clothing modeling CAD system. By dividing clothing into different components, each component becomes a relatively independent design unit. Huang [5] applied the psychological recognition system to clothing design and made algorithm improvements. By developing a clothing recognition structure system with different psychological electrical signals, the design and construction of intelligent clothing were carried out. Through the design research in this article, the test evaluation results were used to experience the effectiveness of clothing design. Lee et al. [6] established and optimized the manufacturing process of intelligent sports underwear using various automated machines. Li et al. [7] conducted clothing design development on the Internet and artificial intelligence. The study explores some challenges in design, raw materials, and supply chain management from the perspective of the clothing industry chain. Through personalized design of medical and clothing, it has analyzed the hot research areas of intelligent clothing. Lashin et al. [8] designed a fuzzy design system for artificial intelligence. The system sets fuzzy logic for different optimized stores by controlling influencing factors. Design through the color, lighting, and logo of the product, aiming to achieve more perfect customer optimization and logical setting. Linet et al. [9] conducted an open online graphic training access software, which showed that the basic development mode of CAD open software requires playback measurement tools and video editing. This study can help teachers who face challenges in accessing educational software for specific disciplines, guiding them on how to use affordable alternative software. Produce teaching materials such as screen projection for teaching CAD concepts, such as Coreldraw. The production of patterns is the beginning of the clothing design cycle. Pattern making is a mature technology that requires technical ability, flexibility in design interpretation, and a realistic understanding of clothing structure. Moniruzzaman and Oishe [10] designed and developed a technique called planar pattern design to construct various types of patterns. Ninga [11] elaborated on the current application status and the sorting in teacher work tasks, using typical clothing product types as carriers and enterprise actual tasks as carriers, using classroom teaching methods, emphasizing the consistency between students' learning and actual work. Starting from students' practical teaching. Panneerselvam and Prakash [12] perfectly edit the pattern outline according to the required shape in the graphic design of jacquard fabrics. The weaving markers that need to be applied should control long floats and avoid using them in places where there are no longer floats to maintain the perfect editing contour. In manual graphic design, the designer decides on the type of woven marker used to control the float and applies it to the selected part. Sayem [13] used computer programs to calculate the similarity between actual pants and virtual clothing. This can be achieved by using computer vision techniques such as calculating similarity matrices or Euclidean distances. Virtual 3D CLO (Computer Integrated Geometry Processing) programs can be used to compare the similarities between actual pants and virtual pants. Souza [14] aims to explore the application of intelligent technology in the clothing and accessories industry for people with disabilities. It describes the intelligent technologies in ves tiles devices aimed at helping patients recover through a systematic review of the database. Won and Lee [15] imported image data of actual and virtual pants into a computer. And use appropriate software to convert them into 3D geometric shapes. This can be achieved by using techniques such as triangular meshes or surface meshes. Xin et al. [16] conducted an analysis of the application of nanotechnology materials in textile and clothing. By further analyzing the market and consumption, safe and intelligent design of nanomaterials can be carried out. Its research aims to apply safety intelligence under nano clothing. Promote the innovative development of textile and clothing, further adapt to the new needs of the market and consumers, and play a positive role.

## 3 RESEARCH METHOD

### 3.1 Pattern Matching Algorithm for Clothing CAD Technology

Due to the rise of computer technology, a large number of ethnic clothing patterns have emerged on the internet, which are diverse and often unable to be classified. Using web crawler and other technologies can easily search and download images in the network, that is, the problem of obtaining national costume patterns in the network is easy to solve. How to extract patterns with unique meanings is particularly important. Especially after segmenting ethnic patterns, there will be many repetitive and flawed patterns. Extracting feature patterns using matching algorithms is an effective method.

Extracting pattern texture features for matching, as this feature has the characteristics of low dimensionality, good matching effect, and strong stability. The method of structure is that the pattern is composed of texture elements with a "repetitive" spatial organization structure and arrangement rules. Representative methods include syntactic texture description and digital morphology. SIFT (Scale Invariant Feature Transform) is a pattern feature descriptor. This descriptor describes the local features of the pattern, has scale invariance, and can detect key points of multi-scale patterns, playing an important role in pattern matching.

Gaussian blur, also known as Gaussian smoothing, is a pattern filter. It uses Gaussian function to calculate the blur template. The two-dimensional scale space of a pattern is defined as follows:

$$L(x,y,\sigma)=G(x,y,\sigma)*I(x,y) \quad (1)$$

$$G(x,y,\sigma)=\frac{1}{2\pi\sigma^2}e^{\frac{\left((x-m/2)^2+(y-n/2)^2\right)}{2\sigma^2}} \quad (2)$$

$L(x,y,\sigma)$ represents the scale space of the pattern, $G(x,y,\sigma)$ is a Gaussian function with variable scale, " * " is a convolution operator, and $(x,y)$ is the size of spatial coordinates that determines the smoothness of the pattern. The larger $\sigma$ is, the smoother the pattern is, and the smaller $\sigma$ is, the clearer the pattern is. The pyramid model is shown in Figure 1 below:

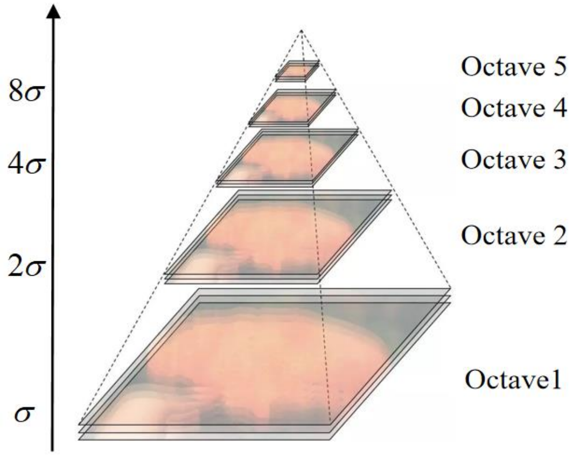


**Figure 1**: Gaussian pyramid model.

Because the second derivative Laplacian is very sensitive to image noise, it is usually not used directly. Instead, the influence of the second derivative Laplacian on the increase of image noise, such as Gaussian Laplacian, is alleviated by introducing Gaussian functions. The definition of Laplacian operator is shown in Formula (3):

$$\nabla^2 f(x,y)=\frac{\partial^2 f(x,y)}{\partial x^2}+\frac{\partial^2 f(x,y)}{\partial y^2} \quad (3)$$

Gauss Laplacian operator is defined as shown in formula (4):

$$\nabla^2 G(x,y)=\frac{\partial^2 G(x,x)}{\partial x^2}+\frac{\partial^2 G(x,x)}{\partial y^2}=\left[\frac{x^2+y^2-2\sigma^2}{\sigma^4}\right]e^{\frac{x^2+y^2}{2\sigma^2}} \quad (4)$$

The value $\sigma$ is the standard deviation of Gaussian function $G(x,y)$.

$$F(Z)=Z^2+C \quad (5)$$

$Z,C$ is plural here. Therefore, in the actual calculation and programming, the corresponding real part and imaginary part are used to replace $Z,C$ here.

At present, the clothing CAD system includes the following content: (1) Style design system: the application of clothing shape design and color. It mainly consists of functions such as line drawing, color pattern filling, effect polishing, and effect image printing and output. (2) The paper pattern structure design system refers to the design of clothing plane structure. The main process involves selecting design methods, determining specifications and standards, analyzing and calculating data, analyzing and determining structural elements, and designing and drawing paper patterns. (3) Template scaling system: also known as grading, push board, etc. The main process includes basic paper sample input, design of grading rules, and drawing of grading quantity input paper sample scaling diagram. (4) Layout diagram design system: connected to the automatic cutting bed system, providing an important basis for the subsequent process of cutting. The main process includes design of bed separation scheme, preprocessing of discharge data, selection of discharge scheme, and drawing of discharge diagram. Due to the limited number of texture features and fixed angle rotation transformations in clothing patterns, it is difficult to match the patterns. Therefore, this article proposes a further improvement plan to extract the main direction vector of the pattern shape context descriptor, and add rotation invariance to the algorithm through rotation matching of the direction vector to adapt to the matching application of ethnic patterns.

The required rotation angle of the pattern is determined by matching the pattern direction vector, and the matching cost is calculated after the pattern is rotated. Then, the matching results of the improved algorithm on the national ornamentation pattern database and the traditional shape database are shown. The matching process is shown in Figure 2.

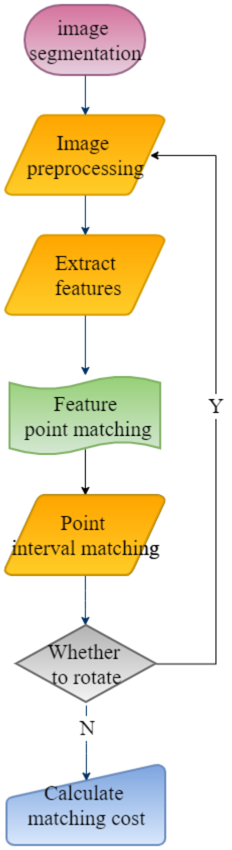


**Figure 2**: Matching method flow.

The unstable value of the extremum can be defined as: let the region $C_i$ be an extremum region, and $S(C_i)=(C_i,C_{i+1},\cdots,C_i+\Delta)$ is the branch node of the root node $C_i$. The unstable value of $C_i$ is defined as:

$$v(C_i)=\frac{|C_{i+\Delta}-C_i|}{|C_i|} \tag{5}$$

Where $|C_i|$ represents the number of pixels in $C_i$. If the unstable value of the extreme value area $C_i$ is smaller, that is, more stable, than that of its parent node $C_{i-1}$ and child node $C_{i+1}$, this extreme value area $C_i$ is called the maximum stable extreme value area.

In this paper, we choose the combination of energy, contrast and homogeneity as the rule. Energy, measured by ASM (AngularCondMoment), uses $C(i,j)$ itself as its own weight.

$$Energy=\sqrt{ASM}, ASM=\sum_{i=0}\sum_{j=0}C(i,j)^2 \tag{6}$$

The weights of contrast and homogeneity features are affected by the distance between pixels, such as formula (7).

$$Contrast=\sum_{i=0}\sum_{j=0}(i-j)^2C(i,j) \tag{7}$$

Among them, the more uniform the distribution of $C(i,j)$, the smaller the energy characteristic, and when all terms are equal, the characteristic value is the smallest.

The value in the initial direction vector is not 0 or 1, but the number of feature points in each interval. If all feature points are set to $P=120$, then the extracted direction vector is $O(11,4,130,0)$, and $O$ is shifted to get $O^{'}(0,0,0,1)$. It is necessary to calculate the Euclidean distance between $O$ and $Q_1,Q_2$ to judge the most appropriate direction vector. As shown in the following formula (8).

$$d=\sqrt{\sum(O-o)^2} \tag{8}$$

### 3.2 DL-Based Pattern Generation

The 3D clothing CAD system is used as a display and pattern design tool for clothing 3D. It mainly has the following functions: linking fabric models with objective test data, providing realistic fabric drape models. 3D to ZD flat unfolding algorithm and providing automatic plate making. Automatically push gears using a scaled manikin. Dressing technology combines traditional design patterns into clothing, which is then observed on a 3D mannequin. Utilizing personalized 3D human body models for customized clothing design, namely MTM technology for clothing. Figure 3 shows a typical CNN (Convolutional Neural Network) structure.

In that convolution lay, each feature graph has a convolution kernel with the same size, and each feature graph in the convolution layer is convolve on the feature graph input in the previous layer by different convolution kernels, then the correspond elements are multiplied and added, then an offset is added, and finally, the activation function is used to convert it into nonlinear output.

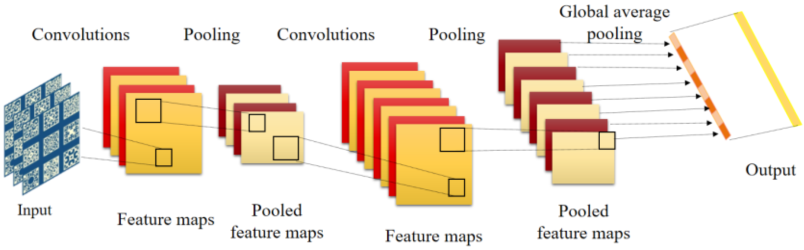


**Figure 3**: The basic structure of CNN.

CNN's output layer needs to classify images, so it needs classifiers. Common classifiers include Softmax and Sigmoid. The max function is calculated as formula (9).

$$p(i)=\frac{\exp\left(\theta_i^T x\right)}{\sum_{k=1}^{k}\exp\left(\theta_i^T x\right)} \tag{9}$$

In the original CAD image description generative model based on adaptive attention mechanism, we improved the language decoder because of the simple structure of the language decoder. Our new model uses a two-layer LSTM (short - and long-term memory) network in the decoding part. Perform the required mapping through sufficient depth and nonlinear transformation, instead of placing a simple single hidden layer multilayer perceptron on the top of the decoder in the original language decoding model. The network structure of the model proposed in this article is shown in Figure 4.

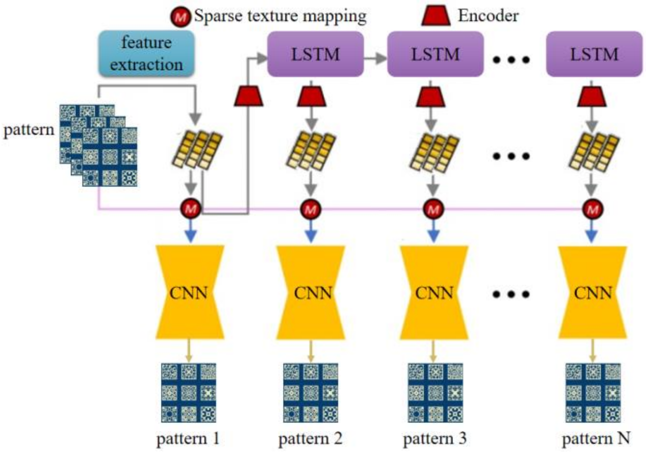


**Figure 4**: The network structure of the model.

The encoder is implemented by Transformer structure. Given a set of image features $I$ extracted from the input image, the permutation invariant coding of $X$ can be obtained by $self-attention$ used in Transformer:

$$self-attention(I)=attention(Q,K,V)=soft\max\left(\frac{QK^T}{\sqrt{d}}\right)V \tag{10}$$

$Q$ is the query vector, $\langle K,V\rangle$ is a set of corresponding data pairs; $d$ is the scaling factor.

There is no need to establish the graph structure relationship of words for iterative operation. Therefore, the generation description text model of this paper adopts TF-IDF to extract keywords, and the calculation formula is:

$$topic = TF\text{-}IDF\left(Y_{title}\right) \tag{11}$$

The two layers of LSTMs in the decoder are standard LSTM units, and the general formula for calculating the hidden layer state of lstm units is as follows:

$$h_t = LSTM\left(x_t, h_{t-1}\right) \tag{12}$$

Where $x_t$ represents the input of the LSTM unit at the current time $t$, and $h_{t-1}$ represents the hidden layer state of the LSTM unit at the previous time.

## 4 ANALYSIS AND DISCUSSION OF RESULTS

According to the requirements of virtual clothing design, clothing designers can use the 3D V Resign design system to directly translate or rotate along the y-axis or z-axis using the system's internal dialog box. Simultaneously utilizing the Opengl graphics library developed by SG I company, utilizing its graphics functionality and cross platform capabilities. By combining computer vision methods, read the three-dimensional lattice data of the human body from several existing images. Subsequently, the 3D human body model surface fitting function is utilized. By combining digital cameras, rotating platforms, and the rational application of dense lighting, a complete 3D human clothing design software model is constructed. The experimental environment of this paper is Intel(R)Core(TM)i5 CPU with 2GB memory. MATLAB is used to realize this algorithm. The images of ethnic patterns of six ethnic minorities were collected, and a data set of ethnic images with 1000 images was formed through data expansion, of which 800 were used as training sets and 200 were used as testing sets.

In order to recognize the characters in the scene, this model is trained for each type of characters on the picture to detect the potential character regions and select the region with the highest detection score as the character recognition result. The results are shown in Table 1 and Figure 5, and compared with LSTM method.

| *Category* | *LSTM* | *our* |
|---|---|---|
| Clear | 75.432 | 87.212 |
| Complex background | 83.251 | 83.549 |
| Multicolor character | 76.127 | 88.03 |
| Uneven illumination | 76.271 | 84.905 |
| Low contrast | 79.067 | 84.5 |
| Blurred | 78.232 | 86.131 |
| Severe deformation | 76.975 | 83.306 |

**Table 1**: Comparison of recognition rate.

The average recognition rate of this model on data sets is 85.3761%, that of LSTM is 77.9079%, and that of various characters is increased by 3.06%-10.18% respectively. Moreover, the influence of character classification on the recognition rate of this model is smaller than that of LSTM, especially for pictures with uneven illumination, which proves that the robustness of this model is stronger than that of LSTM. In order to better evaluate the recognition performance of this model, we evaluate the performance of the algorithm on data sets. The experimental results are shown in Figure 6.

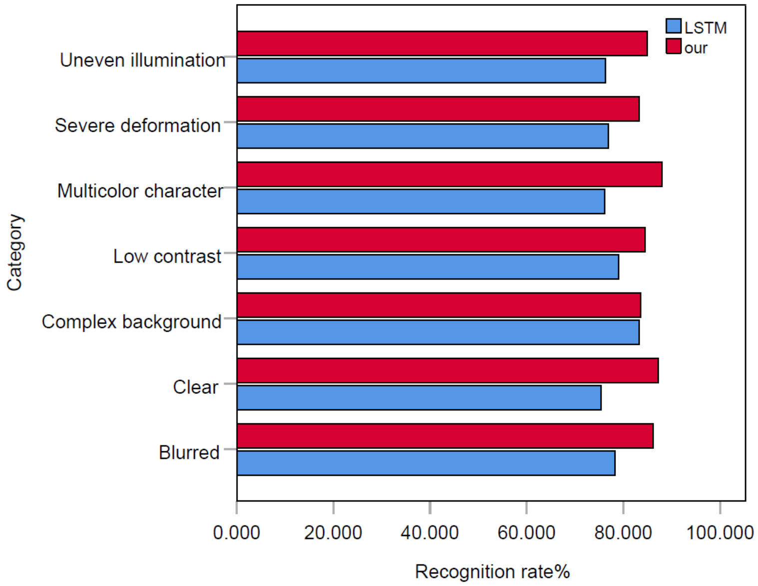


**Figure 5**: Comparative statistical chart of recognition rate.

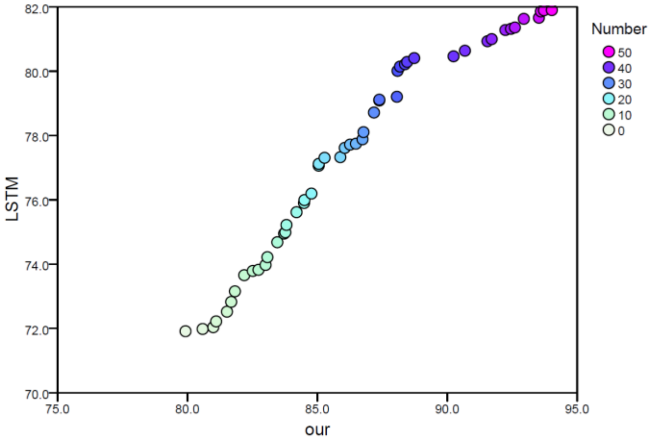


**Figure 6**: Character recognition rate of several days in different candidate areas.

The results show that the average recognition rate of this model on the data set increases by 3.15%, and with the increase of candidate character regions, this model can achieve a higher recognition rate than LSTM. Aiming at the dimensionality reduction of high-dimensional sparse coding descriptors, effective information is saved, and the recognition accuracy is improved. Compared with gradient features, sparse coding has stronger expressiveness to characters.

Time overhead is an angle to measure the algorithm, and the ideal algorithm is to reduce time overhead while pursuing high accuracy. For real-time recognition algorithms, time overhead is a very important aspect that needs to be optimized. Table 2 and Figure 7 show the time cost comparison of different algorithms.

| *Image* | *AlexNet* | *VGGNet* | *ResNet* | *LSTM* | *Our* |
|---|---|---|---|---|---|

| sample | | | | | |
|---|---|---|---|---|---|
| 1 | 2.629 | 2.61 | 5.188 | 4.495 | 0.864 |
| 2 | 1.485 | 3.492 | 3.717 | 4.98 | 0.975 |
| 3 | 3.384 | 2.83 | 2.71 | 3.506 | 0.612 |
| 4 | 3.748 | 3.269 | 3.776 | 4.031 | 1.292 |
| 5 | 1.863 | 3.813 | 3.329 | 2.788 | 1.098 |
| 6 | 2.543 | 2.282 | 3.286 | 2.79 | 0.665 |
| 7 | 1.812 | 3.673 | 4.995 | 4.473 | 0.884 |
| 8 | 1.686 | 2.921 | 4.563 | 3.569 | 1.397 |
| 9 | 2.728 | 2.361 | 5.013 | 2.597 | 0.76 |
| 10 | 2.2 | 2.481 | 4.336 | 4.202 | 1.251 |
| 11 | 3.552 | 4.123 | 3.627 | 3.623 | 1.077 |
| 12 | 2.948 | 3.941 | 4.986 | 4.267 | 0.89 |
| 13 | 3.49 | 2.284 | 4.416 | 5.104 | 0.666 |
| 14 | 3.025 | 3.665 | 3.755 | 4.599 | 0.484 |
| 15 | 1.734 | 2.435 | 2.686 | 3.894 | 0.915 |

**Table 2**: Time cost comparison (seconds).

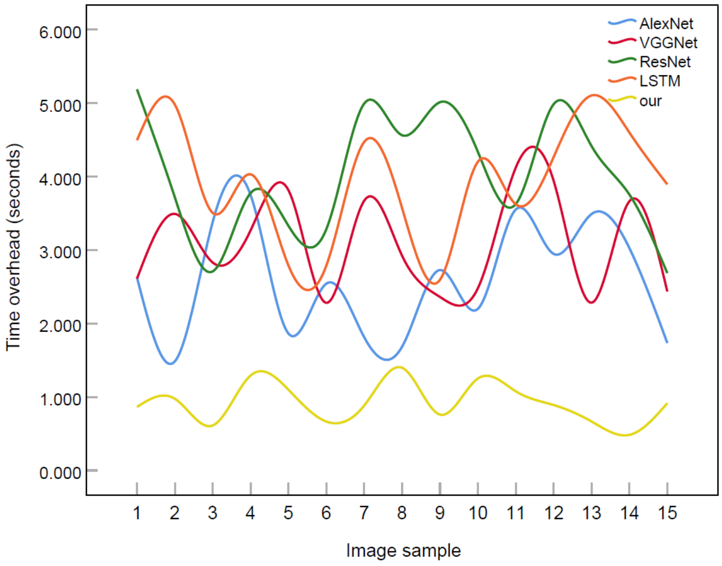


**Figure 7**: Time expenditure trend chart.

It can be seen that the time cost of this algorithm is the lowest, and the time cost of ResNet is the highest, which is about three times that of the former. Net ranked second, and VGGNet ranked third. Time overhead is directly related to the length of feature vector, and the longer the length, the greater the time overhead. In this paper, after extracting features and effectively fusing them, the algorithm adopts dimension reduction technology, which greatly reduces the time cost.

From the above matching results, it can be seen that the improved algorithm in this paper can basically find out the matching pattern with four angular rotations similar to the original pattern. The average accuracy rate of the whole national pattern search is shown in Figure 8 and Figure 9 below.

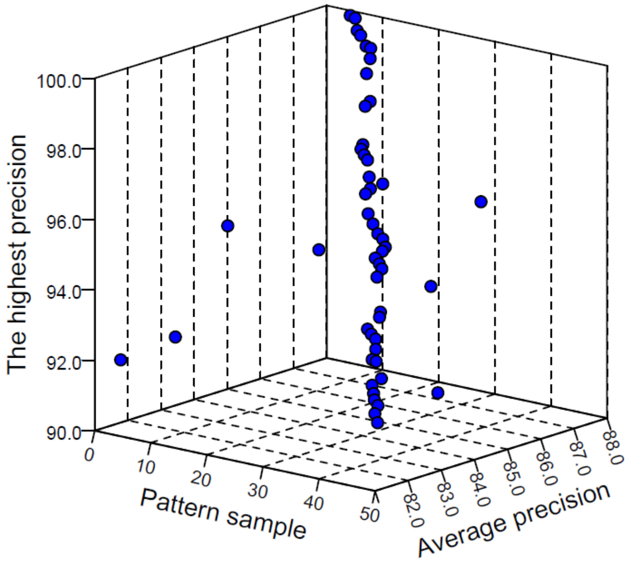


**Figure 8**: The algorithm in this paper matches the traditional dress primitives.

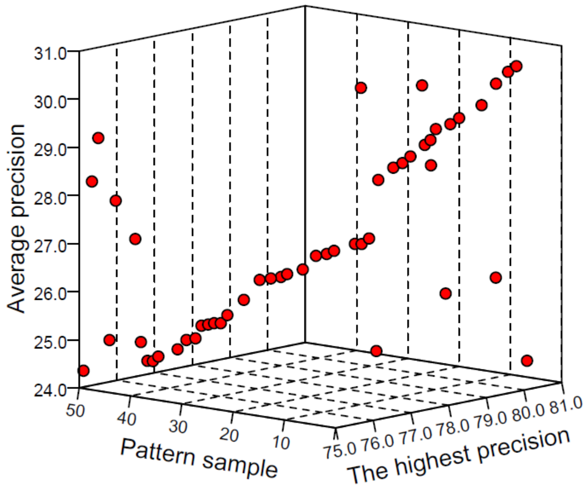


**Figure 9**: The traditional method matches the traditional dress primitives.

In this paper, the algorithm greatly improves the accuracy of pattern matching with four angular rotation changes, and the precision rate is increased by 56.127%. Good results have been achieved in the matching of national ornamentation patterns, which can match similar patterns that can't be found in traditional shape context methods due to rotation transformation.
From the highest precision of single pattern, the highest precision of the traditional algorithm is only 70.066%, while for some ethnic patterns, the highest precision of this improved algorithm can reach 100%.

We replace the image encoder in the Adaptive Attention model with the ResNet-101 network, and train it again. During the training, only the parameters of the sentence decoding model are trained, and the CNN part is not fine-tuned, so as to achieve fair comparison. Table 3 shows the comparative experimental results of Adaptive Attention model and our new model on ethnic image data sets.

| *Evaluation criteria* | *Adaptive Attention* | *our* |
|---|---|---|
| BLEU | 0.842 | 0.831 |
| METEOR | 0.9 | 0.95 |
| ROUGE | 0.975 | 1.483 |
| CIDEr | 1.413 | 1.65 |

**Table 3:** Comparative experimental results.

It can be seen that the performance of our improved model is better than that of the original Adaptive Attention model, which verifies the effectiveness of our double-layer LSTM language decoding model. The language decoding model based on double-layer LSTM can perform more nonlinear transformations on image information and language information, thus improving the semantic expression ability of the generated description sentences.

## 5 CONCLUSION

By utilizing 3D human body measurement technology and virtual reality technology, a fully sized and realistic human body model and clothing mannequin can be established in a computer. Designers can rotate the model from various angles and design the direction of light around the stage, creating an immersive feeling. This article proposes an application of DL intelligent vision computer-aided technology in clothing culture. Through network transmission, designers can use virtual reality technology to build 3D models for customers according to the size of their corresponding parts input by customers. And implement personalized design with human absence on its model. After virtual sewing with a computer and communicating with customers about the fitting effect through the internet, the entire design of the work is ultimately completed. In this article, the algorithm greatly improves the accuracy of pattern matching with changes in corner rotation, with an accuracy increase of 56.127%. Good results have been achieved in the matching of ethnic decorative patterns. From the perspective of the highest accuracy of a single pattern, the traditional algorithm has a maximum accuracy of only 70.066%, while for some ethnic patterns, the improved algorithm can achieve a maximum accuracy of 100%.

## 6 ACKNOWLEDGEMENTS

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