INDERSCIENCE PUBLISHERS
Linking academia, business and industry through research

International Journal of Signal and Imaging Systems Engineering

ISSN online: 1748-0701 - ISSN print: 1748-0698
https://www.inderscience.com/ijsise

Syntactic approach to reconstruct simple and complex medical images

Shilpa Rani, Kamlesh Lakhwani, Sandeep Kumar

DOI: 10.1504/IJSISE.2023.10059438

Article History:

Received:	13 October 2020
Accepted:	22 December 2021
Published online:	28 September 2023

Syntactic approach to reconstruct simple and complex medical images

Shilpa Rani*

Department of CSE,
Lovely Professional University,
Punjab, 144411, India

and

Department of CSE,
Neil Gogte Institute of Technology,
Hyderabad, 500039, India
Email: shilpachoudhary2020@gmail.com
*Corresponding author

Kamlesh Lakhwani

Department of CSE,
JECRC University,
Jaipur, 303905, India
Email: kamlesh.20980@lpu.co.in

Sandeep Kumar

Department of CSE,
Koneru Lakshmaiah Education Foundation,
Vaddeswaram, AP, 522302, India
Email: er.sandeepsahratia@gmail.com

Abstract: Most researchers find pattern recognition to be an interesting area to study. Objects that are different in shape, size, colour, and scale are easy to identify apart. Most of the available models for object recognition use a statistical approach, which works well if there is no noise in the image and the image is simple. However, this method fails if the pattern is more complicated, and there may be ambiguous results for complex pattern datasets. In that case, it would be better to use structural pattern recognition. We focused on the syntactic approach to describing the features as knowledge, which could make a big difference in theoretical computer science. Experiments have been performed on Brain MRI datasets and own dataset. To identify the performance of the reconstruction algorithm MAE, CPU time, and RMSE and iteration of the frame are calculated.

Keywords: pattern recognition; structural pattern recognition; picture description language; 2D images; knowledge vector; contour; syntactic pattern recognition.

Reference to this paper should be made as follows: Rani, S., Lakhwani, K. and Kumar, S. (2023) 'Syntactic approach to reconstruct simple and complex medical images', *Int. J. Signal and Imaging Systems Engineering*, Vol. 12, No. 4, pp.127–136.

Biographical notes: Shilpa Rani is presently working as an Assistant Professor in the Department of Computer Science and Engineering, Neil Gogte Institute of Technology, Hyderabad, India. She has a good Academics and Research experience in various areas of Computer Science. She is pursuing PhD from Lovely Professional University, Punjab. Her area of research includes image processing, IOT, and big data. She has filed successfully 12 National/International Patents. She has published 2 text books "Logical and Functional Programming", Ashirwad Publication, 2009–2010 and "Software Engineering", VAYU Education of India, 2011.

Kamlesh Lakhwani works as an Associate Professor in the Department of Computer Science and Engineering at Lovely Professional University, Punjab India. He has an excellent academic background and a rich experience of 13 + years as an academician and researcher in Asia.

He is certified by Google and Coursera for the demanding course "Architecting with Google Compute Engine". He has several awards to his credit such as *Best Research Paper Award and Research Appreciation Award* from Lovely Professional University Punjab India, *Topper* for course Cloud Computing by NPTEL.

Sandeep Kumar is presently working as a Professor, Department of CSE, Koneru Lakshmaiah Education Foundation, Vaddeswaram, AP, India. He has a good Academics and Research experience in various areas of Electronics and Communication. His area of research includes Embedded System; Image processing, Biometrics and Machine Learning. He has filed successfully 7 National and 1 International Patent. He has been invited 4 times being an expert in various colleges/university in India. He has published 70 research papers in various international/national journals.

1 Introduction

Different objects always surround the human being, and obviously, it is always an easy task for human eyes, but the same is not valid for the machines all the time. Building artificial intelligence to the machine to recognise the objects is not easy, and this problem always attracts researchers (Brady et al., 1988). Pattern recognition provides a solution for such problems where recognition or identification of the objects plays an important role. The different pattern recognition applications are data mining, biometric recognition systems, image processing, medical imaging, etc. (Jain et al., 2000).

Three basic steps (Jasmin and Rajan, 2013) need to follow to implement these applications, represented in Figure 1. The first step is preprocessing. Preprocessing is used for the removal of unwanted data, noise and to identify the missing values. This step could include feature scaling, getting the dataset, importing the library files, and splitting the data into training and testing datasets. The second step includes the extraction of features from the image. Feature vector should be extracted from the image to represent the whole image adequately. After that feature vector is analysed for the recognition purpose and at last, classification would be done. Classification is used to categorise the data into different classes according to the knowledge received through the training process. These are the three essential steps of any pattern recognition system. Other steps could be added according to the requirements of the application.

Figure 1 Basic steps of pattern recognition techniques (see online version for colours)

Different pattern recognition methods are available such as the Statistical method, structural method, NN techniques, template matching, etc. (Seema and Dass, 2012). All the techniques mentioned above have their pros and cons. The statistical method describes each pattern in terms of the feature vector. Features should be chosen so that it defines the whole image correctly. This method recognises the probabilistic nature of the image we process (Fazel and Chakrabartty, 2011; Devroye et al., 1996; Duda and Art, 1973). The system which is designed with statistical methods is noise insensitive. This system is a good choice if noise is present in the dataset. However, this method fails if patterns are more complex and there is a possibility of ambiguous results for complex pattern datasets. In that case, structural pattern recognition is more helpful. For a better understanding of complex patterns, patterns can be considered as a combination of sub-patterns (Fu, 1982; Pavlidis, 1977) and these complex and high dimensional patterns require complex grammars (Gips, 1975; Ota, 1975; Williams, 1975; Flasiński et al., 2014). This method can even deal with two-dimensional and three-dimensional image datasets.

The remaining paper is organised: Section 2 presented a literature survey. Section 3 explained about proposed architecture and methodology. Section 4 represents the results section. Conclusion and future work are discussed in Section 5.

2 Literature survey

In the last three decades, most researchers have worked on statistical pattern recognition and template matching methods based on related applications (Gonzalez and Woods, 2002), but less contribution was made in the structural pattern recognition field. The structural pattern recognition approach divides the complex patterns into sub-patterns and these sub-patterns can be further divided. This method can assign a pattern to the already defined class. This approach is useful for object recognition, natural language processing, and scene analysis (Tanaka, 1995; Rosenfeld and Kak, 1982; Memon et al., 2000). In the case of scene analysis mechanism, patterns will always be complex, and when these patterns are represented through features, then the size of the feature vector will be significant. In that case, assigning a specific class to each pattern is cumbersome. The syntactic pattern recognition technique can understand simple and complex patterns with the help of primitives and grammar rules. The effectiveness of these approaches always depends upon the recognition of simple and easy pattern primitives and identifying the relationship between these pattern primitives. Moshad and Ali (2001) presented a method for recognising digits written in Bengali. However, this approach was failed for the recognition of Bengali HCR. Rashid and Ali (1998) used a string matching method. The authors have used eight directional codes for converting the image into a feature vector. This approach was only designed for Bengali digits. Pal and Chaudhuri (1948) have also proposed a method for the recognition of Bengali numerals. This technique was able to recognise the numerals without thinning and normalisation operation. Khalfallah et al. (1992) have presented a visual pattern recognition method. Authors have used graphical symbols for the recognition of binary patterns. Sarker et al. (2019) have presented a new method for the QA system. To find the answer from a given text, authors have introduced the POS tagging and parsing technique Method proposed method outperformed for simple sentences. They may enhance the technique for complex and long sentences in the future. Quang et al. (Thang, 2012) have presented research on the A* algorithm for parsing techniques and proposed an HGM model based on the same algorithm. This method can replace the existing VMN, which was used to overcome the problem of Chomsky standard forms. The performance of HGM was better than VNM. For implementation purposes, they have used JAVA. In the future, researchers may use this method to implement text analysis of the Vietnamese language.

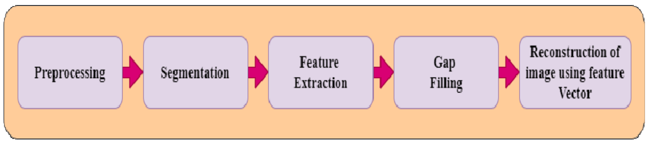
Mall and Jaiswal (2014) have mainly focused on the linguistic features of data-driven parsing and did some modifications in the CKY algorithm. They introduced a speech tagger to enhance the grammatical parts of the database and applied linguistic rules for better parsing results. This method has given accuracy of 91.4%, which is better than other existing methods. Ogiela and Tadeusiewicz (2000) presented the effectiveness of the syntactic approach in pattern recognition-based systems. The syntactic approach is used for extracting the features from the feature vector. Moreover, it is used to identify the shape and structure of the objects present in the image. If there is any abnormality in the object's shape, it can quickly identified. This would be helpful for the early diagnose of dangerous diseases like pancreatitis and uterus-related tumours.

As per our literature work, most of the authors used parsing techniques for linguistic systems and very little work has been done in this field. The highest accuracy which is achieved till now is still 91%. Many scopes are still available in this field. Ogiela and Tadeusiewicz (2000) have worked on medical images, which can be a game-changing method in the field of biomedical. The syntactic approach would be better in the field of object recognition (Kumar et al., 2021; Raja et al., 2020; Shilpa et al., 2012; Swathi and Rani, 2019; Jain et al., 2015; Ghai et al., 2020; Shilpa et al., 2020). We proposed a novel method to recognise the object from the 2D image based on that concept.

3 Proposed methodology

The potential problems with the method and their alternative approach for solving it has been discussed earlier. Based on the gap in the existing methods, a proposed method has been designed and developed, which could be a general approach to solving a more comprehensive range of pattern recognition problems. The proposed methodology is divided into three steps. The first step is preprocessing, in which noise is removed from the image and improves the image quality and then the features extraction technique is applied and represented in Figure 7. The Picture description language represents the feature vector and the feature vector consists of direction code and length code. There is a possibility that objects could be scattered in the image or many objects are present in the same image. The gap-filling algorithm is applied to identify the feature vector of all the objects, a novel approach to the proposed method and represented in Section 3.4. Now the obtained feature vector can be used to reconstruct the original image. The procedure of reconstructing the source image from the feature vector is described in Section 3.5. A detailed description is given in Figure 2.

Figure 2 Steps of proposed methodology(see online version for colours)



3.1 *Preprocessing*

The preprocessing technique removes the noise and unwanted data from the image. In the proposed method, median filtering is used to remove the noise from the image. The median filter sorts all the pixels in increasing order and then finds the median value. The median filter can preserve the shape and line structure of the image. In the proposed method 3×3 median filter is applied to the image, which means the window size is 3×3. An illustration of the median filter is represented in Figure 3.

Figure 3 Noise reduction with 3×3 median filtering(see online version for colours)

100	100	100	100	100
100	200	205	203	100
100	195	200	200	100
100	200	205	195	100
100	100	100	100	100

→

100	100	100	100	100
100	100	200	100	100
100	200	200	200	100
100	100	195	100	100
100	100	100	100	100

3.2 Segmentation

Image segmentation is a method of locating the object in the image, and it identifies the boundary of the image. The proposed method focuses on the shape of the image and the object should be highlighted from the image's background. In this step, the object's contour is identified from the image using the active contour method. The object's contour is a simple curve that joins all the boundary points with some colour or intensity value.

For the extraction of contour, we need to select the energy function. The energy function is consists of internal and external energy and image energy, which is represented in equation 1:

$$E_T = [E_{int} + {}_N E_{xt} + E_{img}]\mathrm{d}s \quad (1)$$

where E_T = Total energy, E_{int} = Internal energy, E_{ext} = External energy, E_{img} = Image energy, ds = distance between the control points.

Figures 4 and 5 represents the contour of the image after preprocessing and segmentation.

Figure 4 Binary image and its contour representation (see online version for colours)

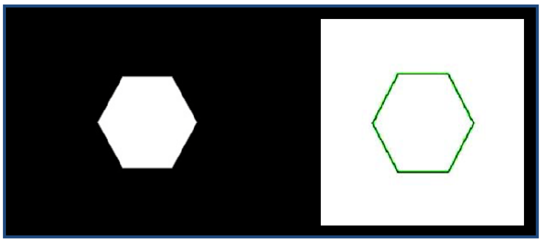
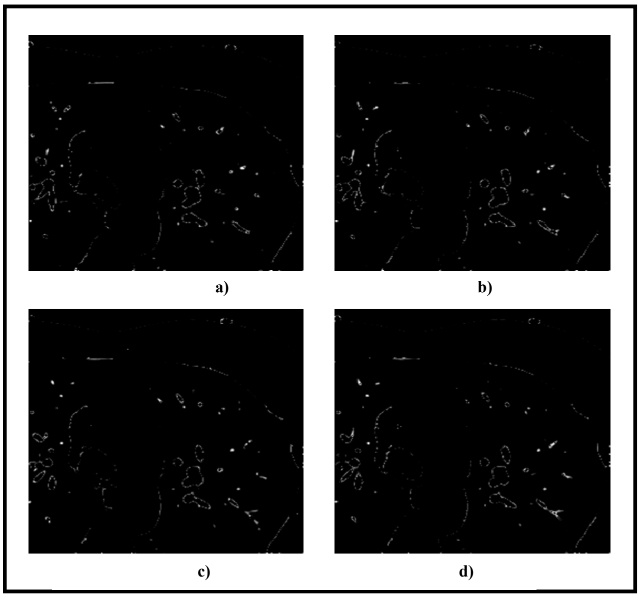


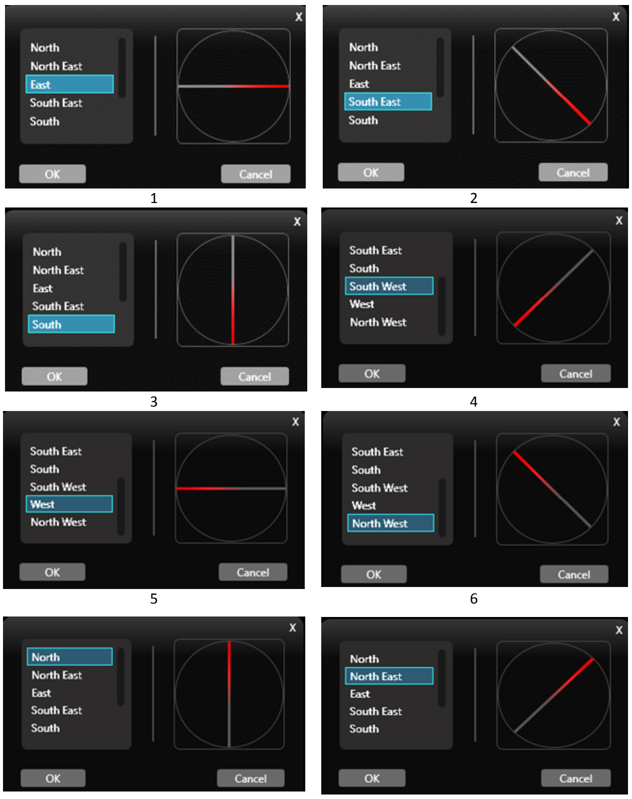
Figure 5 (a) Original image and (b) contour representation of the original image



3.3 Generation of feature vector

Extracting the features from the image is an essential step in object recognition. We used picture description language to represent the features in the proposed method. The contour of the image is an input for this step. The image contour is traced by pixel, starting from pixel position (1, 1) to find the initial foreground pixel (x_i, y_i) with the intensity value 1. This will identify the initial point of the first component present in the image and the proposed algorithm is written to find the next neighbour of the current pixel in all the preferred directions. Preference will be generally given to the right side of the pixel (from the current pixel). These eight directions are represented in Figure 6. The naming conventions of the preferred direction are Right(R), Down Right (DR), Down (D), Down Left (DL), Left (L), Up left (UL), Up (U), and Up Right (UR). This method prioritised the previously recognised direction over other preferred directions. The tracing of each pixel will continue until the algorithm finds any connected neighbour pixel to the current position (x, y) and will remove the already traced pixel. If there is no neighbour pixel, then the algorithm will display the knowledge vector of that component, and again algorithm will continue until it does not trace all the components present in the image. The final knowledge vector will be displayed if all the components are traced. This knowledge vector is nothing but a feature vector consisting of each component's direction and length code, and this knowledge vector will give the information that some objects are present in the image. The flow chart of the feature extraction method is represented in Figure 7.

Figure 6 Preferred directions for identification of neighbour pixel (see online version for colours)

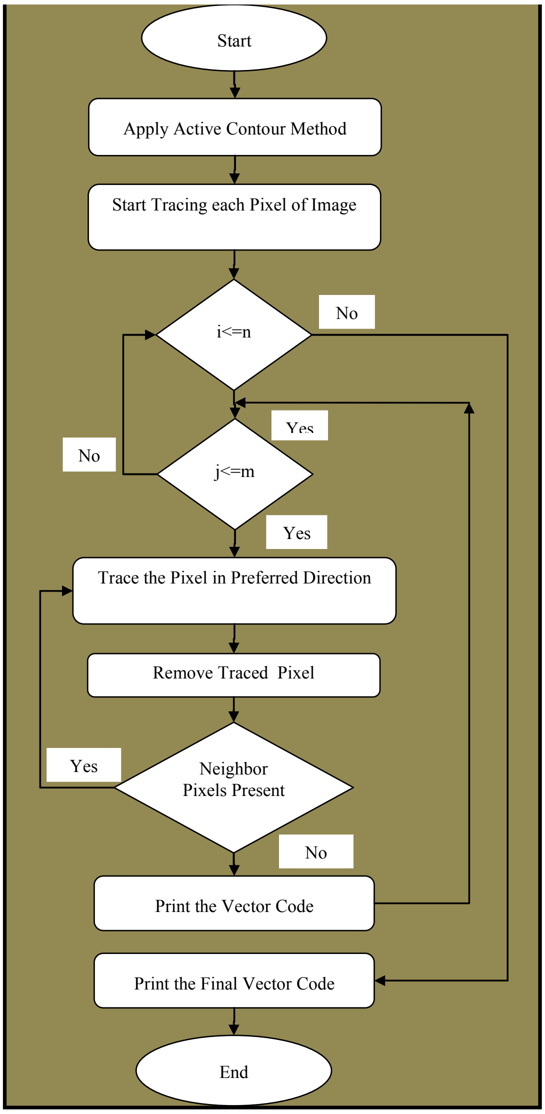


As discussed earlier, the knowledge vector consists of direction and length code. Direction code is nothing but a string of non-terminal elements separated by a ▫ (delimiter). The vector code of an arbitrary square can be represented in the following way:

<81, 81> *R*▫*D*▫*L*▫*U*▫*80▫80▫80▫79▫<82, 81>

Here * is the separator between direction code and length code. The predecessor of * is called direction code and the successor of * is known as length code. Vector code has four directions and other than U, all other directions have the same length because the scanned pixel is already removed. After the scan, the beginning point <81, 81> and the endpoint <82, 81> are removed from the image.

Figure 7 Flow chart of feature extraction method (see online version for colours)



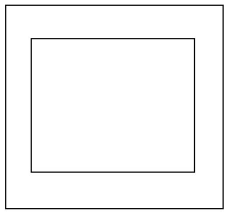
3.4 *Gap filling*

When the image pixel is scattered, it would be difficult to identify the components. To reduce the difficulty in identifying the object, we introduced a new algorithm used to fill the small gaps in the image and the algorithm is known as a gap-filling algorithm. If the nearest neighbour pixel is not present in the image, the algorithm will look forward in a preferred direction. If a pixel is present in the next level, the gap-filling algorithm connects the present pixel position to the next level to form connectivity that fills the gap between pixels. The algorithm is written below:

Figure 8 has two rectangles it means two components are present in the image and a pixel gap < 43,302>. Here we will use the gap-filling algorithm and obtain the knowledge vector after gap filling is:

Figure 8 Shape of rectangle

<42, 28>/R273*DR2*D235*L275*U236*/<43, 28>#



3.5 *Redrawing of the image using the feature vector*

In the proposed method, we have added the concept of redrawing an image using direction length code. Below we have represented the algorithm for redrawing the image feature vector.

Algorithm:

Step 1: Read the feature vector of an image.

Step 2: Mark the starting pixel point of the first component.

Step 3: Trace the pixels in all the directions present in DLC and the respective length of the pixel to 1.

Step 4: Repeat Steps 2 and 3 for all the components present in the DLC.

Step 5: The final plot gives the image of the input shape taken for DLC generation

4 Experiment setup and evaluation parameters

All the algorithms mentioned above are implemented in python using the Anaconda tool.

A GPU-based system with Windows-10 OS, RAM of 8 GB is used for experiments, and only one core is used for computation purposes.

4.1 *Dataset*

For evaluation of the proposed work, two datasets are used. The first dataset is the own dataset, a collection of 50 images and a combination of simple and complex images. Another dataset contains Brain MRI images for Brain tumour detection. This dataset contains 208 images and the dataset has been taken from Kaggle.

4.2 Evaluation parameters

The proposed model is evaluated using different parameters like Mean absolute error, CPU time, and RMS error is calculated for Noise sensitivity and blurring sensitivity.

- *Mean absolute error*: To calculate the mean absolute error, the following formula is used:

$$MAE = \frac{\sum_{x=0}^{X}\sum_{y=0}^{Y}\left|\mathrm{Re}_{xy} - Org_{xy}\right|}{XY} \quad (2)$$

Here, X, Y represents the dimension of the image, and *Org* and Re represent the original and reconstructed image. For every image error, it is calculated. The error is calculated in all eight directions, and an average is represented in the scatter graph.

- *CPU time*: CPU time is nothing but required to execute any instruction. Generally, it depends on the number of instructions and the type of instructions that we are executing. In the proposed method, we calculate the CPU time for reconstructing the image, i.e., how much time it takes to reconstruct the image from a given feature vector. To calculate the CPU time following formula is used:

$$CPU\ time = \frac{1}{\text{Performance of the Processor}} \quad (3)$$

For the computation purpose, only one core is used in the experiment.

- *RMS error*: RMS error is the standard method of calculating the model's error. It gives the difference between predicted and observed values. The formula is defined as follows:

$$RMSE = \sqrt{\sum_{i=1}^{n}\frac{(y_i' - y_i)^2}{n}} \quad (4)$$

where

y_1', y_2', …, y_n' is predicted value

$y_1, y_2, \ldots, y_n$ are observed values

n = No. of observation.

5 Results

For every image of the dataset, the algorithm provides the feature vector, and later another algorithm provides the reconstructed image that completely matches the original image with some exceptions of the pixels, which are not noticeable. To check the quality of the reconstructed image, the mean absolute error is calculated, which is used to check the difference between the original image and the reconstructed image. The average Mean absolute error is 0.126, which is lesser than the existing method (Waller et al., 2013). The other parameter of performance evaluation is CPU time and accuracy. Comparative analysis of MAE, CPU time, Number of iteration have been done for the proposed method on own dataset and Brain MRI dataset and shown in Tables 1 and 2. Table 3 shows the accuracy of the reconstruction algorithm, which shows that the reconstructed image is very close to the original image. The algorithm can redraw all the edges and structure of the image properly. In Table 3, we represented only a simple image, but the experiments have been done for complex images, but the feature vector's size is significant, so that representation would be problematic. For the reference purpose in Figure 12, we represented a complex original image and reconstructed image.

Table 1 Experimental results of the proposed method on brain MRI dataset and comparative analysis with existing methods

	MAE	*CPU time*	*Iteration*
Proposed method	0.127	10 ms	96 it/s
Waller et al. (2013)	0.130	–	–
Ye et al. (2010)	–	75.1 s	33 it/s
Ye et al. (2010)	–	18.6 s	7 it/s

Table 2 Experimental results of the proposed method on own dataset and comparative analysis with existing methods

	MAE	*CPU time*	*Iteration*
Proposed method	0.125	1 ms	2272 it/s
Waller et al. (2013)	0.130	–	–
Ye et al. (2010)	–	75.1 s	33 it/s
Ye et al. (2010)	–	18.6 s	7 it/s

Reconstruction of the image has been done under different circumstances. Noise is added into the original image and then reconstruction has been done and calculated the RMS error. Noise is added with standard deviation at the scale of 0–10%. In the same way, Blurriness' is added with the intensity of 0 to 1.5 pixels and then RMS error is calculated. Noise sensitivity and Blurriness sensitivity are calculated and represented in Figures 9 and 10.

Reconstruction of the image is always a difficult task in clinical research. Generally, it will take high computational time on a conventional personal computer. Reconstruction will take approximately 4 min for each frame (Ramirez et al., 2011). A GPU-based system is an excellent solution to this problem. In the proposed method, reconstruction is faster compared to existing techniques. In the proposed method, reconstruction of the simple image is done in 1 ms and the average iteration of the frame is 2272 it/s and in the same way for complex images, reconstruction of the image is done in 10 ms and average iteration of the frame is 96 it/s which is represented in Figure 11.

Table 3 Feature vector of basic shapes and reconstruction of the image using the feature vector

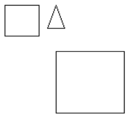
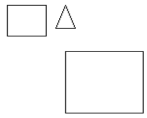
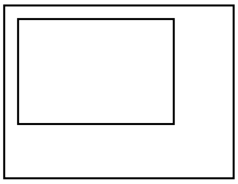
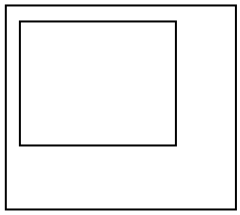
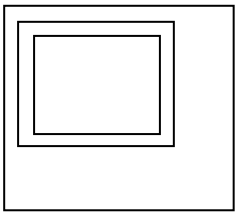
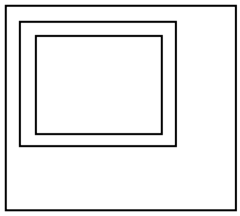
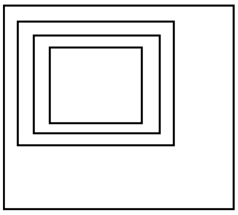
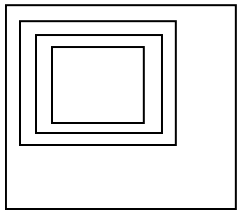
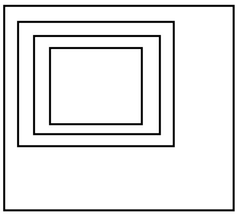
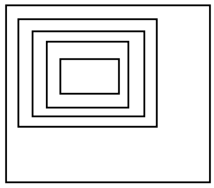
S. No.	*Original image*	*Feature vector*	*Reconstructed image*
1.		<21,21>R□D□L□U□*40□40□40□39□<22,21><21,81>1□1□2□1□2□1□2□1□2□1□2□1□2□1□2□1□2□1□2□1□2□1□1□20□1□1□2□1□2□1□2□1□2□1□2□1□2□1□2□1□2□1□2□1□2□<23,80><81,81>R□D□L□U□*80□80□80□79□<82,81>	
2.		<81,81>R□D□L□U□*80□80□80□79□<82,81>	
3.		<19,23>/R212*D223*L212*U222*/<20,23>#	
4.		<50,56>/R151*D159*L151*U158*/<51,56>#	
5.		<78,83>/R100*D104*L100*U103*/<79,83>#	
6.		<99,107>/R56*D58*L56*U57*/<100,107>#	

Figure 9 Calculation of RMS error with intensity of noise (see online version for colours)

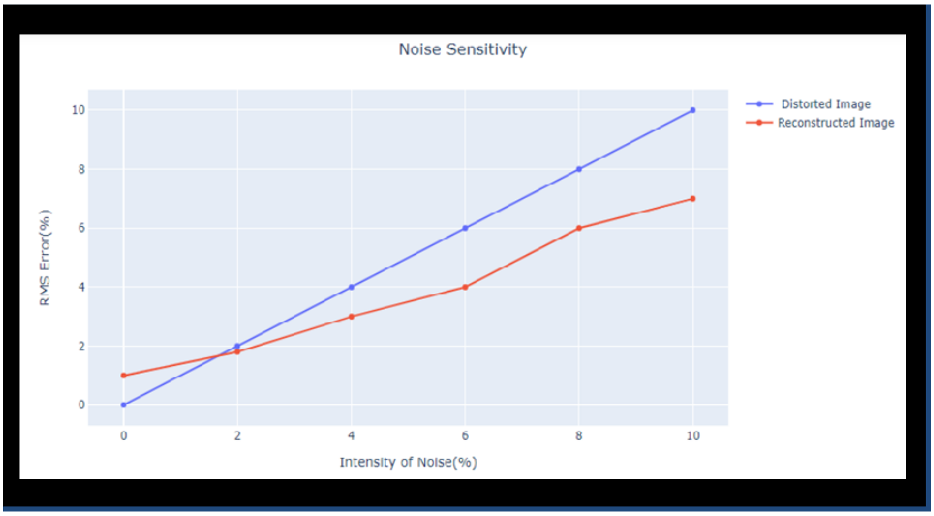


Figure 10 Calculation of RMS error with blurring sensitivity (see online version for colours)

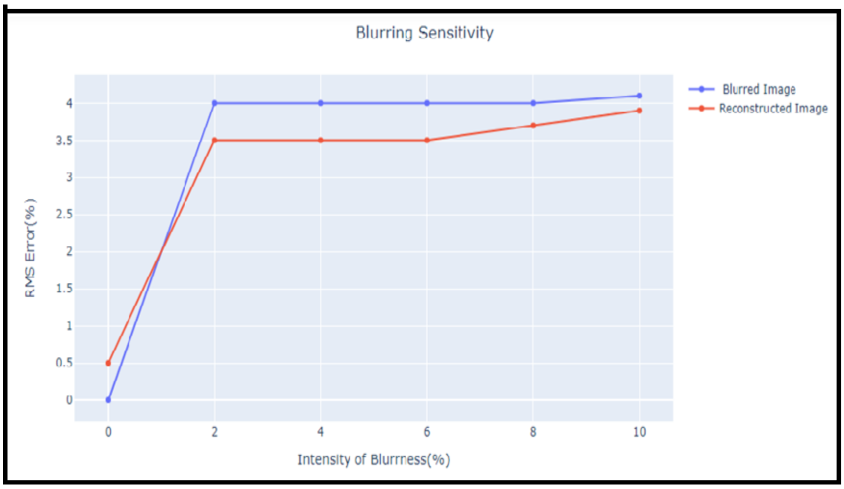


Figure 11 CPU time and average iteration of the frame for the proposed method (see online version for colours)

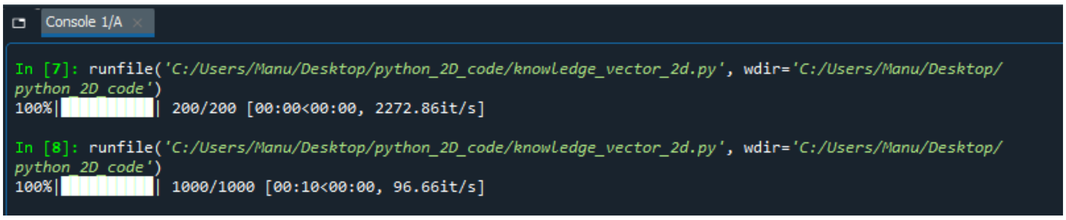
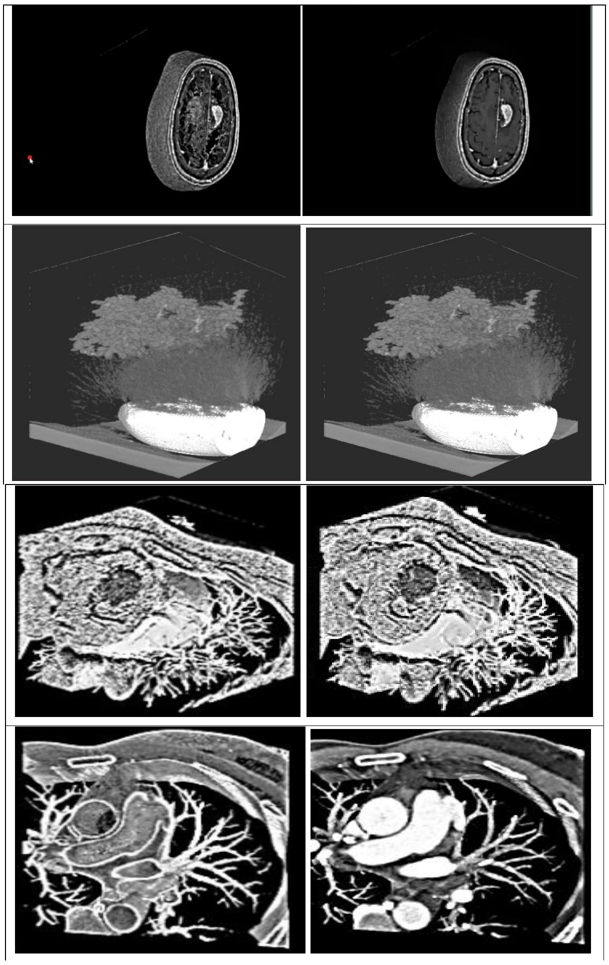


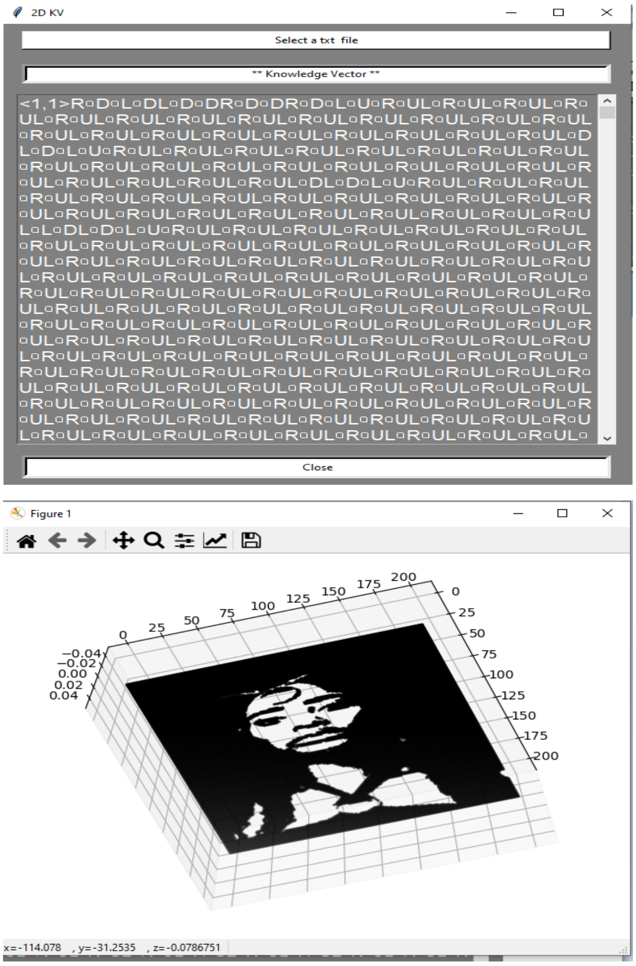
Figure 12 Original (Left) and reconstructed image (Right)



Figures 13 and 14 represents the GUI of the proposed Methodology. With the help of GUI, we can select any image from the dataset and create the knowledge vector of the given image and the knowledge vector can be saved in the text file. This is represented in Figure 13. In the same way, a text file consisting of a knowledge vector will be given as an input. The original image can be obtained, which is represented in Figure 14.

Figure 13 GUI for creating a knowledge vector from the input image

Figure 14 GUI of reconstruction of the image using knowledge vector (see online version for colours)



6 Conclusion and future scope

This paper proposed an algorithm for feature extraction and feature representation. Extraction and representation of the features have been done with the help of picture description language. This method can represent each pixel in a textual form referred to as a string, and further, we have proposed an algorithm that can convert the knowledge vector into an image called the reconstruction of an image using a feature vector. The results show the knowledge vector for basic shapes only, but we have also tested the algorithms for complex medical images, and the results are outperformed. In the future, we will perform normalisation to reduce the size of the knowledge vector, and we are planning to apply classifiers to classify different objects. In the future, the algorithm's performance can be evaluated on benchmark 2D and 3D datasets and this method could be a better solution for object recognition in 2D and 3D images.

References

Brady, J., Nandhakumar, N. and Aggarwal, J. (1988) 'Recent progress in recognition of objects from range data', *9th International Conference on Pattern Recognition*, Rome, Italy, pp.85–92.

Devroye, L., Gyorfi, L. and Lugosi, G. (1996) *A Probabilistic Theory of Pattern Recognition*, Springer-Verlag, Berlin.

Duda, R.O. and Art, P.E. (1973) *Pattern Classification and Scene Analysis*, John Wiley & Sons, New York.

Fazel, A. and Chakrabartty, S. (2011) 'An overview of statistical pattern recognition techniques for speaker verification', *IEEE Circuits and Systems, Magazine 2nd Quarter*, pp.61–81.

Flasiński, M. and Jurek, J. (2014) 'Fundamental methodological issues of syntactic pattern recognition', *Pattern Analysis and Applications*, Vol. 3, pp.465–480.

Fu, K.S. (1982) *Syntactic Pattern Recognition, and Applications*, Prentice-Hall, Englewood Cliffs, NJ.

Ghai, D., Gianey, H.K., Jain, A. and Uppal, R.S. (2020) 'Quantum and dual-tree complex wavelet transform-based image watermarking', *International Journal of Modern Physics B*, Vol. 34, pp.2050009.

Gips, J. (1975) *Shape Grammars and Their Uses*, Verlag, Basel and Stuttgart, Birkhauser.

Gonzalez, R.C. and Woods, R.E. (2002) *Digital Image Processing*, Addison-Wesley, New York.

Jain, A., Kumar, A. and Sharma, S. (2015) 'Comparative design and analysis of mesh, torus and ring NoC', *Procedia Computer Science*, Vol. 48, pp.330–337.

Jain, A.K., Duin, R.P.W. and Mao, J. (2000) 'Statistical pattern recognition: a review', *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 22, No. 1, January, pp.4–37.

Jasmin, G.D. and Rajan, E.G. (2013) 'Normalized vector codes for object recognition using artificial neural networks in the framework of picture description languages', *Global Journal of Computer Science and Technology*, Vol. 11, No. 1, pp.207–2018.

Khalfallah, H., Petriu, E.M. and Groen, F.C.A. (1992) 'Visual position recovery for an automated guided vehicle', *IEEE Trans. Instrum. Meas.*, Vol. 41, No. 6, December, pp.906–910.

Kumar, S., Singh, S. and Kumar, J. (2021) 'Face spoofing detection using improved SegNet architecture with a blur estimation technique', *International Journal of Biometrics*, Vol. 13, pp.131–149.

Mall, S. and Jaiswal, U.C. (2014) 'Resolving issues in parsing technique in machine translation from the Hindi language to English', *2014 International Conference on Computer and Communication Technology (ICCCT)*, IEEEv, Allahabad, India.

Memon, N., Neuhoff, D.L. and Shende, S. (2000) 'An analysis of some common scanning techniques for lossless image coding', *IEEE Trans. Image Process.*, Vol. 9, No. 11, pp.1837–1848, November.

Moshad, M.A.A. and Ali, M.M. (2001) 'Recognition of handwritten Bangla digits by intelligent regional search method', *Proc. Int. Conf. Comput. Inf. Tech.*, December, University of Dhaka, Bangladesh, pp.297–302.

Ogiela, M.R. and Tadeusiewicz, R. (2000) 'Application of syntactic methods of pattern recognition for data mining and knowledge discovery in medicine', *Data Mining and Knowledge Discovery: Theory, Tools, and Technology, II*, Vol. 4057, pp.308–318, International Society for Optics and Photonics.

Ota, P.A. (1975) 'Mosaic grammars', *Pattern Recognition*, Vol. 7, June, pp.11–13.

Pal, U. and Chaudhuri, B.B. (1948) 'Automatic recognition of unconstrained off-line Bangla handwritten numerals', in Tan, T, Shi, Y. and Gao, W. (Eds.): *Proc. Advances Multimodal Interfaces*, Vol. 1948, pp.371–378.

Pavlidis, T. (1977) *Structural Pattern Recognition*, Springer-Verlag, New York.

Raja, R., Kumar, S., Rani, S. and Ramya Laxmi, K. (2020) 'Lung segmentation and nodule detection in 3D medical images using convolution neural network', *Artificial Intelligence and Machine Learning in 2D/3D Medical Image Processing*, CRC Press, Boca Raton, Florida, USA, pp.179–188.

Ramirez, L., Prieto, C., Sing-Long, C., Uribe, S., Batchelor, P., Tejos, C. and Irarrazaval, P. (2011) 'TRIO a technique for reconstruction using intensity order: application to undersampled MRI', *IEEE Transactions on Medical Imaging*, Vol. 30, No. 8, pp.1566–1576.

Rashid, A.M. and Ali, M.M. (1998) 'On line recognition of handwritten characters using 1-dim, 1-dim DP approach', *Proc. Int. Conf. Comput. Inf. Tech.*, December, University of Dhaka, Bangladesh, pp.86–90.

Rosenfeld, A. and Kak, A.C. (1982) *Digital Picture Processing*, 2nd ed., Vol. 1/2.Academic, New York.

Sarker, J., Billah, M. and Al Mamun, M. (2019) 'Textual question answering for semantic parsing in natural language processing', *2019 1st International Conference on Advances in Science, Engineering and Robotics Technology* (*ICASERT*), IEEE, Dhaka, Bangladesh, pp.1–5.

Seema, A. and Dass, R. (2012) 'Pattern recognition techniques: a review', *International Journal of Computer Science and Telecommunications*, Vol. 3, No. 8, August, pp.25–29.

Shilpa, C., Lakhwani, K. and Agrwal, S. (2012) 'An efficient hybrid technique of feature extraction for facial expression recognition using AdaBoost classifier', *International Journal of Engineering Research and Technology*, Vol. 8, pp.1–8.

Shilpa, R., Lakhwani, K. and Kumar, S. (2020) 'Three-dimensional wireframe model of medical and complex images using cellular logic array processing techniques', *International Conference on Soft Computing and Pattern Recognition,* Springer, Cham, pp.196–207.

Swathi, A. and Rani, S. (2019) 'Intelligent fatigue detection by using ACS and by avoiding false alarms of fatigue detection', *Innovations in Computer Science and Engineering*, Springer, Singapore, pp.225–233.

Tanaka, E. (1995) 'Theoretical aspects of syntactic pattern-recognition', *Pattern Recognition.*, Vol. 28, No. 7, July, pp.1053–1061.

Thang, L.Q. (2012) 'A hierarchical graph method using in A* algorithm for Vietnamese parsing technique', *Proceedings of the 2012 International Conference on Asian Language Processing*, Hanoi, Vietnam, pp.25–28.

Waller, B.M., Nixon, M.S. and Carter, J.N. (2013) 'Image reconstruction from local binary patterns', *2013 International Conference on Signal-Image Technology and Internet-Based Systems*, IEEE, Kyoto, Japan, pp.118–1233.

Williams, K.L. (1975) 'A multidimensional approach to syntactic pattern recognition', *Pattern Recognition*, Vol. 7, September, pp.125–137.

Ye, X., Chen, Y. and Huang, F. (2010) 'Computational acceleration for MR image reconstruction in partially parallel imaging', *IEEE Transactions on Medical Imaging*, Vol. 30, No. 5, pp.1055–1063.