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A review of English language from the scanned document with the use of pattern recognition: Detailed study on recognition system

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Abstract
The technology of Document Analysis and Recognition, as a branch of pattern recognition, faces various practical demands in the real world, such as the digitization of books, newspapers, and archives, invoicing, and corporate documents. Pattern recognition and machine learning are among the most cutting-edge areas in software science. Statistical learning theory based neural network approaches and methodologies have recently come under more and more scrutiny. By utilizing the proper character recognition and segmentation modules for optical character recognition (OCR), it is essential to identify the document's language and printing style. In the field of pattern recognition, recognizing handwritten papers is a difficult problem. Algorithms and statistical models that computers use to complete a certain task without being explicitly focused on machine learning (ML). It is possible to utilize these algorithms for a variety of purposes, including data mining and image processing. It is easy to automate tasks by utilizing machine learning when an algorithm has learned how to deal with data. The purpose of this review article is to summarize and compare many well-known methodologies that are utilized at various phases of a pattern recognition system's development. After examining several strategies for pattern identification, it was determined that the most accurate method is optical character recognition (OCR). Optical character recognition (OCR) scanners, on the other hand, have a 99 percent accuracy rate. Diabetes Retinopathy (DR) also has the lowest accuracy, at just percent.

Keywords: pattern recognition, machine learning, document analysis recognition, optical character recognition, diabetes retinopathy

Introduction
As a foundational cognitive function, the ability to identify patterns offers a platform for higher-level judgments, which have been demonstrated to be critical for survival and evolution in difficult contexts. Pattern recognition, on the other hand, is an important aim for both artificial intelligence and machine learning, as the solution of several high-level intelligent issues is strongly reliant on the achievement of accurate patterns and automatic identification.

Many problems have had their accuracies greatly and swiftly improved at various points in time. For example, with a convolution neural network (CNN) on the MNIST (ten-class handwritten digit) data set, it is possible to obtain more than 99% accuracy without the use of typical hand-crafted features. Improved accuracy was seen on the further challenging task of Image Net 1000-class large-scale visual recognition over time.

All three implicit assumptions underlying most pattern recognition models-I.I.D., clean data, and closed-world assumptions-provide the basis for most pattern recognition models.

Assumptions like these are reasonable in a lab setting and reduce the difficulty of the issue, thus it was the cornerstone of most pattern identification standards. The implementation of prototypes developed using these theories will typically degrade dramatically in the real world since these assumptions are rarely met. Thus, to construct robust structures for real situations, it should violate these expectations and create new models and processes by rethinking the fundamentals of model identification.

Brief Impression of Pattern Recognition Methods
As displayed in Fig. 1, two-stage and end-to-end pattern recognition techniques are two of the most used ways to analyze data for patterns. Cascaded handcrafted feature interpretation and pattern categorization are common in conventional approaches. Raw data is transformed

into an arbitrary present area with the properties of inside-class density and between-class separability via feature representation.

To reduce within-class variation, preprocessing (such as eliminating noise and standardizing data) is first employed, followed by feature extraction, which is usually domain-specific. New configuration establishing difficulties necessitates the development of new features, and superior quality will lessen the strain on later classifier learning. This type of work could be discovered in various functions such as action recognition [6], gait recognition [7] and then iris recognition [8].

Pattern categorization, the next step after feature representation, is a significantly broader challenge. This phase is also well-established as statistical pattern identification [9], where several various problems are deemed from various perceptions. First, dimensionality decline [10] is commonly assumed to originate a lower-dimensional representation to enable successive categorization tasks. A discrete dimensionality reduction approach to feature selection is also an option. Classification models can then be applied following this step. Class-conditional density approximation and prior probability are both parts of the Bayes decision theory, which is the most fundamental approach. An artificial neural network is also commonly used for design categorization [11], with multilayer perceptron (MLP), polynomial networks, then radial basis function (RBF), and polynomial network. Methods based on a decision tree depict the categorization rule in the form of a tree [12]. Kernel methods, [13] which performs linear operations on greater or even infinite-dimensional space modified indirectly by a kernel mapping function, has been commonly employed to expand linear models to nonlinear ones, and the most representative way is SVM [14]. Predictions from numerous complementing models can be combined in ensemble methods to boost performance even further. Clustering [15] is generally used as an unsupervised strategy for pattern identification.

There are frequently several options for both including interpretation and classifier learning in two-stage approaches. In practice, distinct pattern recognition issues tend to have various optimal configurations based on their domain-specific experiences, making it difficult to forecast which combination is ideal. Obstinately, deep learning [16] methods learn the feature interpretation and classification together from the raw data, making them end-to-end. The learned characteristics and classifiers are more collaborative about the given task in this approach, which is more adaptable and discriminatory than two-stage systems.

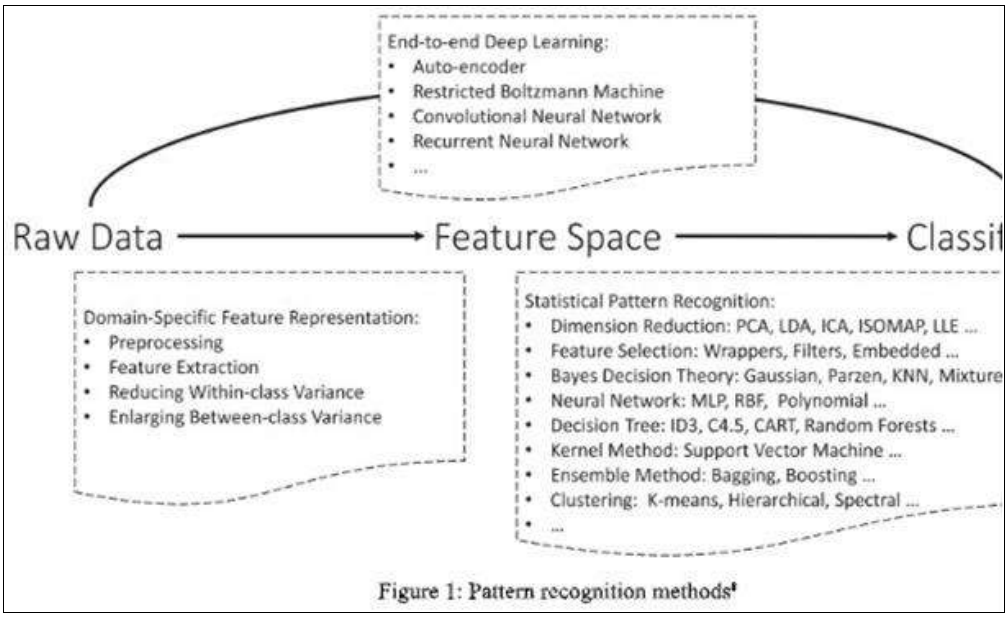

Fig 4: Reinforcement Learning [18].

Robustness in Pattern Recognition

To develop a model identification method, there should be several guidance examples and test examples where x is the studied model and y is the equivalent label (the hat on the icon is used to distinguish training and test examples). The principle of pattern identification is to learn the joint allocation or provisional distribution information and can be employed in more complex applications, such as image interpretation. They could use statistical classification or neural networks to solve the more difficult challenge of pattern recognition, for instance, the recognition of three-dimensional objects recognizes structural patterns [19].

Pattern Recognition System

A pattern recognition arrangement may be applied in several different ways thought of as a method that can handle actual and noisy data. The human expert's decision is the most important factor in determining whether or not the system's choice is correct [19].

The structure of the pattern recognition system

Three main stages make up a PR-based pattern-recognition system. The first step is to gather data, and the next two are to analyze and classify patterns found in that data. Data construction is the process of transforming raw data into a form that can be processed by computers. Data processing, such as feature extraction and data dimension compression, is the primary goal of pattern analysis when it comes to identifying patterns, pattern classification is all about using Data gained via pattern analysis. An integer label, such as "1"or "0," is the result of a classification PR problem, which assigns an item to a particular class [19]. The following is a list of the basic components of a PR system in figure 5.

Decision
Post-processing
Classification/regression/description
Pre-processing
Feature extraction
Pattern acquiring
Objects Figure 5. The composition of PR system [19].

Literature Survey
Pattern recognition and machine learning are used in the work to analyze language in scanned documents. The following are the explanations provided by various researchers and authors of related works:
Rabby *et al*., (2021) [22] explain that Bangladeshi is the world's most widely spoken language. To develop an OCR system, it is critical to identify execute character recognition and segmentation modules in a certain language and print style. Utilizing numerous deep learning models, the author suggested a novel technique for automatic identification of each document's language and printing style, including both printed and handwritten, in terms of a script (Bangla or English). Moreover, they could classify text as printed or handwritten, a classification challenge that obtained greater than 99 percent test accuracy at the character level. Additionally, under the suggested model, Only Bangla and English can now be detected, and there are only printed and handwritten forms of the written word that can be detected at the moment. But they are working to expand their detection capabilities to include more languages and writing styles such as letterpress characters and font families.
Wei *et al*., (2021) [23] stated that relaxometry based on nuclear magnetic resonance (NMR) is widely utilized in a variety of disciplines of research due to its advantages over metabolomics techniques, including ease of preparation, ease of use, and low price. However, there are no publications on metabolic mixes that can be evaluated by T2 relaxation curves, which are commonly used in metabolomics research such as determining their geographical origin and extracting features via Data mining and pattern recognition. The author would go through the data mining technique for relaxing metric data in that work (i.e., relaxometry learning). Analysis and a machine-learning method are the foundations of the approach, which is well-suited for studying relaxation curves.
Rani, N. Shobha., (2020) [24] suggested that the handwritten Kannada character identification based on Devanagari handwriting recognition technology can be used to impart knowledge. The enormous Devanagari recognition system data corpus will be used as training material to recognize traditional Kannada characters written by hand, albeit with a smaller database.VGG19 NET uses deep learning network architecture to transfer knowledge for recognition.
A hidden output layer, two tightly connected ones, and five blocks of hidden layers make up the VGG19 NET architecture. Each block has layers of convolution and a layer of maximum pooling except the block. A total of 92000 photos with 46 classes make up the Devanagari character set in the suggested classification framework, whereas the 81654 training pictures and 9401 testing photos total 188 classes with 200-500 sample images in each. VGG19 NET uses 1,23,654 data samples in its training. They employed 9401 samples with an accuracy of close to 90% for experiments with 188 classes made up of 40-100 samples apiece. 73.51 percent accuracy after 10 epochs of evaluation with the VGG19 NET, with a loss of 16.18 percent.
Alyoubi *et al*., (2020) [25] planned that Diabetic Retinopathy (DR) causes abnormalities in the retina that impede vision when they're not well planned. Due to the
irreversibility of DR, therapy can only sustain eyesight, not restore it. It is possible to drastically lower the risk of visual loss with early detection and treatment of DR. Ophthalmologists' use of DR retina fundus images for diagnosis is labor-intensive, expensive, and prone to error compared to computer-aided evaluation. Recently, deep learning has evolved as one of the most important technologies widely used approaches for optimization in a range of sectors, most notably medical picture analysis and classification. Convolutional neural networks (CNN) are becoming more extensively employed as a method for deep learning in medicinal copy processing due to their effectiveness. The analyses of recent ways of recognition that are state-of-the-art and categorization of Deep learning methods are used to DR fundus pictures. Table 1 summarizes the related work.
Wang *et al*., (2020) [26] planned that computers can now understand human languages through Natural Language Processing (NLP). An important function of natural language processing (NLP) is to segment words for deeper grammatical and semantic analysis. Multimodal neural networks (MNN) are suggested. There is a multilayer sub-neural network for each mode, and each one has its distinct structure. It is a tool for converting features from one model to another. An English word recognition system based on a network model approach is developed to address the problem word segmentation approaches cannot guarantee the long-term dependability of text semantics and extended training prediction time. Shortens network training and prediction times by utilizing the Conditional Random Field (CRF) model to annotate several phrases at once. Bi-direction Gated Recurrent Unit (BI-GRU). According to the results of the experiments, As it relates to word segmentation, however, this technique performs comparably to the BI LSTM-CRF model, however, the average estimated processing rapidity is 1.94 times quicker boosting word segmentation processing efficiency.
Paliwal *et al*., (2019) [27] analyzed that scanners and mobile phones are making it increasingly difficult to extract information from unstructured document pictures like receipts, insurance claim forms, and financial bills. Data extraction from photographs containing tabular sub-images presents a distinct set of challenges, compounding the difficulty of the task.
It involves accurately detecting identifying and extracting information from the rows and columns of the specified table in a picture. Detection of tables has come a long way, but extracting the data from them remains a challenge since it requires a more precise recognition of the table structure (rows and columns). There have been several previous attempts that used two different models to tackle the table detection and structure recognition issues. An end-to-end deep learning network for the identification and recognition of tables and structures is presented as Table Net. The approach relies on the interdependence between the two objectives of identifying tables and recognizing their structures to separate the table and column areas. International Conference on Document Analysis and

Recognition (ICDAR) 2013 and Marmot Table, two publicly available datasets, were used for these experiments and yielded. The suggested model and extraction technique produce state-of-the-art results.

Sánchez *et al*., (2019) [28] intended the handwritten text recognition to be utilized to access the worldwide collection of historical materials housed in archives and libraries. Automated Handwritten Text Recognition (HTR) can be a difficult problem to solve because Feature extraction, image processing, and document image analysis are among the sophisticated Pattern Recognition techniques. They must be used in conjunction with one another. This work provides the HTR benchmarks that increase in complexity from various perspectives, based on historical documents provided in English and German during the 2013 through 2017 ICFHR and ICAR conferences' open contest. There is a suggested system for each benchmark that improves upon the previous work that has been done under similar circumstances. The goal of the study is to set new standards and benchmarks for HTR technology progress by presenting fresh challenges and illuminating current state-of-the-art outcomes together with the datasets and all of the software tools necessary to build the most basic systems accessible for free.

Lu *et al*., (2019) [29] analyzed optical coherence tomography (OCT) as minimally invasive imaging technology. It may produce micrometer-resolution three dimensional pictures of retinal constructions. These pictures can aid in identifying virus-connected changes beneath the retinal surface, the existence of edema or fluid accumulation can impair vision, and are indicative of retinal vascular abnormalities.

The goal of the author is to present Multiclass Fluid detection (MFD) and segmentation in OCT pictures of the retina as a new framework. A neural network with all of its connections convolutional was trained to distinguish and classify by a graph cut technique, fluid pixels can be produced based on OCT pixel intensity and segmentation of the retinal layers. Random forest classification was used to identify and remove the incorrectly identified fluid areas from the segmented regions of fluid. The suggested framework takes first place in Segmentation difficulty in detecting (mean dice: 0.7667) (mean AUC: 1.00).

Rashid *et al*., (2018) [30] suggested that tables are a convenient way to express data structurally. Recognizing tables is critical for extracting the information from document images. Typically, current OCR algorithms deliver textual data extracted from tables without understanding the table's real structure. Recognizing the table structure is critical for deriving the content's contextual significance. Recognizing table structures in diverse texts is difficult because of the wide variety of table layouts. It becomes more difficult when there are no physical rulings on the table. In a model of a pre-trained neural network, the textual content of documents is categorized as a table or non-table elements. The system was trained on a portion of the photos for UW3 images and demonstrated greater than 97 percent table and non-table detection components on a test set.

Chen *et al*., (2015) [3] stated that OCR methods cannot be directly utilized. As far as Recognition systems are concerned, they are designed to work with only one language and a single orientation. Therefore, they could only handle those types of texts. Many non-character-based ways of recognition have been developed to address the issue. These approaches did not perform as well as more advanced OCR systems. As a result, it is preferable to identify the linguistic type and position before performing OCR. Moreover, it is quite difficult to extract consistent information for recognition. Since the forms of the letters in different languages are significantly confusing. Convolutional neural networks (CNN) have recently demonstrated remarkable effectiveness in pattern recognition tasks. As a result, CNN is an excellent choice for such demanding assignments. The author started a CNN to acknowledge text attributes. There is indeed a new sliding window voting method suggested to reduce the size of the network. The technique demonstrated a very high recognition rate in the experiments. The results validated the suggested strategy, which may also be used to develop a document interpretation system using OCR technology. There is a wide range of authors who used the technique and presented their discoveries, as can be seen in table 1.

Table 1: Summary of related work

S. no	Author's	Techniques	Outcome
1.	Rabby *et al*., (2021) [22]	Conventional neural network (CNN)	CNN was able to identify the document's characteristics. The new voting method with a sliding window reduces the size of the network while maximizing the use of the text line's content. The method achieved a very high success percentage in the tests.
2.	Wei *et al*., (2021 [23]	Optical character recognition (OCR)	Due to its ability to distinguish between handwritten and printed texts and the high degree of accuracy achieved in testing. Optical character recognition (OCR) is a critical component in character recognition and segmentation systems.
3.	Rani, N. Shobha., (2020) [24]	Optical character recognition (OCR)	OCR is employed to establish tables and extract data from document images by table recognition. Test sets yielded a 97% accuracy rate in the ability to distinguish between components on and off a table.
Understanding the context of the content requires an understanding of the table structure.			
4.	Alyoubi *et al*., (2020) [25]	Table Net and deep learning	Techniques are employed in the identification and recognition of tables and their structures. It comprises accurately detecting the tabular region inside a picture and then recognizing and extracting data from the selected table's rows and columns.
5.	Wang *et al*., (2020) [26]	NLP (Natural Language Processing)	An important function of natural language processing (NLP) is to segment words for deeper grammatical and semantic analysis. Tool for converting features from one model to another. There are issues with word segmentation processing.
6.	Paliwal *et al*.,	Handwritten Text	It is utilized to identify the textual material. They are aimed at becoming new challenges for HTR

	(2019) [27]	Recognition (HTR)	technologies to spur future innovation. Baseline systems are implemented by publicly available datasets and software tools.
7.	Sánchez *et al*., (2019) [28]	Deep Learning Network (DLN)	A novel model for handwritten Kannada character recognition is described that uses handwritten Kannada characters. The Devanagari handwritten recognition system's training data was used.
8.	Lu *et al*., (2019) [29]	Machine learning	Automated learning technique and analytic framework specifically designed to analyze relaxation curves.
9.	Rashid *et al*., (2018) [30]	Optical coherence tomography (OCT)	A graph-cut algorithm can extract the intensity of OCT pictures and retinal layer segmentation to produce 3D scans of retinal structures with micrometer resolution.
10.	Chen *et al*., (2015) [3]	Diabetic Retinopathy (DR)	In comparison to computer-aided diagnosis techniques, Doctors' manual inspections of DR retina fundus pictures are time-consuming, labor intensive, expensive, and prone to misdiagnosis.

Comparative Analysis

This section of the study offers a comparative analysis of the pattern recognition abilities of several deep learning approaches. It is the most a 99 percent success rate. First, OCR has an accuracy rate of 97%. Table 2 displays the accuracy comparison. Figure 6 provides a graph comparing widely used technique for recognizing the accuracy of the results: patterns. CNN Table Net, CNN Simple, Deep Learning Network (DLN), and Machine Learning (ML) are only a few of the approaches

Table 2: Comparison based on Accuracy 120% 100% 80% 60% 40% 20% 0% OCR [27] OCR [28] DLN [32] DR [35]

Technique	Accuracy (%)
OCR [24]	99%
OCR [32]	97%
DLN [25]	73.51%
DR [27]	94.5%

Conclusion and future scope

The author recommends a CNN model for the identification of orientation and document language. The Convolutional Neural Network (CNN) provides substantial improvement when used in conjunction with the handwritten document character recognition approach. To categorize document terms into a table or non-table categories, a neural network is trained on these contextual cues and then tested. The suggested framework investigated the difficulties associated with the classification of characters in the Devanagari Dataset Both the quality of the training data and the effectiveness of the machine learning procedures are necessary for a successful model. Additionally, machine learning methodologies were discussed to illustrate their applicability for a variety of real-world issues across a variety of major application fields. In the future, another method of improving the character segmentation model would be to move beyond a greedy search for the most likely solution. To implement a robust technique providing more accuracy and less error rate in the future.

References

1. Tanaka Hiroshi. X-BROT: Prototyping of compatibility testing tool for web application based on document analysis technology. In 2019 International Conference on Document Analysis and Recognition Workshops (ICDARW). IEEE. 2019;7:18-21.
2. Elsayed, Omnia, Khaled Mahar, Mohamed Kholief, Hatem A. Khater. Automatic detection of the pulmonary nodules from CT images. In 2015 SAI Intelligent Systems Conference (IntelliSys). IEEE, 2015, 742-746.
3. Javed Mohammed, Nagabhushan P, Bidyut B Chaudhuri. A review on document image analysis techniques directly in the compressed domain. Artificial Intelligence Review. 2018;50(4):539-568.
4. Saeed, Sana, Saeeda Naz, Muhammad Imran Razzak. An application of deep learning in character recognition: an overview. Handbook of Deep Learning Applications, 2019, 53-81.
5. Rajalakshmi M, Saranya P, Shanmugavadivu P. Pattern recognition-recognition of a handwritten document using convolutional neural networks. In 2019 IEEE International Conference on Intelligent Techniques in Control, Optimization and Signal Processing (INCOS). IEEE, 2019, 1-7.
6. Li Junchan, Yu Wang, Pengfei Wang, Qing Bai, Yan Gao, Hongjuan Zhang, *et al*. Pattern recognition for distributed optical fiber vibration sensing: A review. IEEE Sensors Journal, 2021.
7. Chen Li, Song Wang, Wei Fan, Jun Sun, Naoi Satoshi. Deep learning-based language and orientation recognition in document analysis. In 2015 13th International Conference on Document Analysis and Recognition (ICDAR), IEEE, 2015, 436-440.
8. Jebadurai, Jebaveerasingh, Immanuel Johnraja Jebadurai, Getzi Jeba Leelipushpam Paulraj, and Sushen Vallabh Vangeepuram. Handwritten Text Recognition and Conversion Using Convolutional Neural Network (CNN) Based Deep Learning Model. In 2021 Third International Conference on Inventive Research in Computing Applications (ICIRCA), IEEE, 2021, 1037-1042.
9. Valenzuela Sergio E, Juan B Calabrese, Josue Ortiz-Medina, Claudia N Sánchez. Convolutional neural networks for detection of hand-written drawings. In 2020 IEEE ANDESCON, IEEE, 2020, 1-5.
10. Berry Michael W, Azlinah Mohamed, Bee Wah Yap, eds. Supervised and unsupervised learning for data science. Springer Nature, 2019.
11. Sarker, Iqbal H. Ai-based modeling: Techniques, applications and research issues towards automation, intelligent and smart systems. SN Computer Science. 2022;3(2):1-20.
12. Sarker, Iqbal H. Machine learning: Algorithms, real-world applications, and research directions. *SN* Computer Science. 2021;2(3):1-21.
13. Alzubi, Jafar, Anand Nayyar, Akshi Kumar. Machine learning from theory to algorithms: an overview. In Journal of physics: 6 conference series. 2018;1142(1):012012. IOP Publishing.
14. Mahesh Batta. Machine learning algorithms-a review. International Journal of Science and Research (IJSR). [Internet]. 2020;9:381-386.
15. Singh Amanpreet, Narina Thakur, Aakanksha Sharma. A review of supervised machine learning algorithms. In 2016 3rd International Conference on Computing for

Sustainable Global Development (India Com). IEEE. 2016, 1310-1315.
16. Livieris, Ioannis E, Konstantina Drakopoulou, Vassilis Tampakas T, Tassos Mikropoulos A, Panagiotis Pintelas. Predicting secondary school students' performance utilizing a semi-supervised learning approach. J thenal of educational computing research. 2019;57(2):448-470.
17. Ray Susmita. A quick review of machine learning algorithms. In 2019 International conference on machine learning, big data, cloud and parallel computing (COMITCon). IEEE, 2019, 35-39.
18. Dhall, Devanshi, Ravinder Kaur, Mamta Juneja. Machine learning: a review of the algorithms and its applications. Proceedings of ICRIC. 2019 2020, 47-63.
19. Sharma, Priyanka, Manavjeet Kaur. Classification in pattern recognition: A review. International Journal of Advanced Research in Computer Science and Software Engineering, 2013, 3(4).
20. Martinez-Luengo, Maria, Athanasios Kolios, Lin Wang. Structural health monitoring of offshore wind turbines: A review through the Statistical Pattern Recognition Paradigm. Renewable and Sustainable Energy Reviews. 2016;64:91-105.
21. Silva, Jonathan A, Elaine R Faria, Rodrigo C Barros, Eduardo R Hruschka, André CPLF de Carvalho, *et al*. Data stream clustering: A survey. ACM Computing Surveys (CSUR). 2013;46(1):1-31.
22. Rabby AKM, Shahariar Azad, Md Majedul Islam, Nazmul Hasan, Jebun Nahar, Fuad Rahman. A Novel Deep Learning Character Level Solution to Detect Language and Printing Style from a Bilingual Scanned Document. In 2020 IEEE International Conference on Big Data (Big Data), IEEE, 2020, 5218-5226.
23. Wei, Feifei, Yuuri Tsuboi, Kengo Ito, Kenji Sakata, Jun Kikuchi. Relaxometric learning: A pattern recognition method for T2 relaxation curves based on machine learning supported by an analytical framework. BMC chemistry. 2021;15(1):1-8
24. Rani N Shobha, Subramani AC, Akshay Kumar, Pushpa BR. Deep learning network architecture based kannada handwritten character recognition. In 2020 Second International Conference on Inventive Research in Computing Applications (ICIRCA), IEEE, 2020, 213-220.
25. Alyoubi Wejdan L, Wafaa Shalash M, Maysoon Abulkhair F. Diabetic retinopathy detection through deep learning techniques: A review. Informatics in Medicine Unlocked. 2020;20:100377.
26. Wang, Dongyang, Junli Su, Hongbin Yu. Feature extraction and analysis of natural language processing for deep learning English language. IEEE Access. 2020;8:46335-46345.
27. Paliwal, Shubham Singh, Vishwanath D, Rohit Rahul, Monika Sharma, Lovekesh Vig. Tablenet: Deep learning model for end to-end table detection and tabular data extraction from scanned document images." In 2019 International Conference on Document Analysis and Recognition (ICDAR), IEEE, 2019, 128-133.
28. Sánchez, Joan Andreu, Verónica Romero, Alejandro H. Toselli, Mauricio Villegas, Enrique Vidal. A set of benchmarks for handwritten text recognition on historical documents. Pattern Recognition. 2019;94:122-134.
29. Donghuan Lu, Morgan Heisler, Sieun Lee, Gavin Weiguang Ding, Eduardo Navajas, Marinko V Sarunic, *et al*. Deep learning based multiclass retinal fluid segmentation and detection in optical coherence tomography images using a fully convolutional neural network. Medical image analysis. 2019;54:100-110.
30. Rashid, Sheikh Faisal, Abdullah Akmal, Muhammad Adnan, Ali Adnan Aslam, Andreas Dengel. Table recognition in heterogeneous documents using machine learning. In 2017 14th IAPR International conference on document analysis and recognition (ICDAR). IEEE, 2017;1:777-782.