

Review of handwritten document recognition strategies: Patent perspective

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One of the many computer-related topics being researched for digitization of handwritten data is handwritten document recognition. Because handwriting is beneficial for a variety of purposes, such as teaching, learning, generating proposals, architectures, etc., handwriting recognition is a passionately disputed topic. Text, symbols, mathematical equations, digits, and tables make up a handwritten document. This paper examines and summarises research handwritten document recognition disclosed through patents. This report searches, reviews, and analyses patent documents using patent databases such as Lens and Unified Patents. A patentometric review of 101 patent documents is presented in this paper. In terms of patent qualitative and quantitative patent indices, the study summarises and analyses outstanding patents. This article presents a thorough global patent study to assist academics and scientists in developing more efficient handwritten document recognition algorithms and systems.

Keywords: Handwritten document recognition, Patent perspective, Patentometric review, Handwritten symbol recognition, Handwritten digit recognition .

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1. Introduction

Because of the COVID-19 epidemic, education and commercial work are conducted electronically via the Internet (digital media). For better understanding and readability, online instruction necessitates the conversion of handwritten text, numbers, equations, diagrams, and other materials into digital form. The real-time presentation work produced with a stylus, while online teaching or

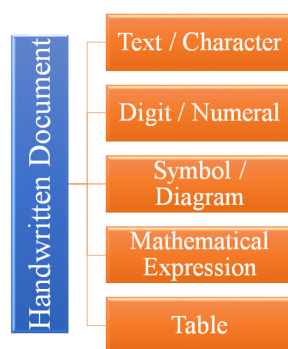


Figure 1

Various types of contents of handwritten document

presenting business proposals, must be transformed to digital form for the listeners' better understanding. Digital transformation of handwritten documents is necessary because it is not always easy to decipher everyone's writing.

According to M. A. P. Alonso et al. [5], handwriting has many logical advantages. Handwriting improves your capacity to concentrate on what you're writing. It helps with memory, information organisation, and prioritisation. Handwriting also helps with information comprehension and processing. Those who make notes by hand are better at answering conceptual questions than students who type notes [57]. Text, digits, mathematical expressions, diagrams, and tables are all types of contents of handwritten documents, as shown in Figure 1. Recognition of these types of content pursues different challenges and difficulties. According to the review, various patents have been granted on each phase individually, except for table recognition. Still, very few patents are granted on document recognition as a whole, with all types of contents addressed.

Handwritten document recognition has seen a surge in patent filings as a result of rapid advancements in innovation. The major goal of this study is to provide an in-depth examination of granted patents in recognition of all types of contents of handwritten documents. The study presents a thorough examination of critical facts and technological breakthroughs in handwritten document recognition. This research also includes a patentometric examination of patents filed for the recognition of handwritten documents. This review article provides researchers with a ready reference to patented research to help them decide on their research without duplication.

2. Patent Perspective

Handwritten document recognition (HDR) refers to the process of recognising the contents of a handwritten document and converting it to a digital format.

All contents, including text, diagrams, digits, mathematical expressions, and tables, must be identified from the handwritten document and converted to digital form. The

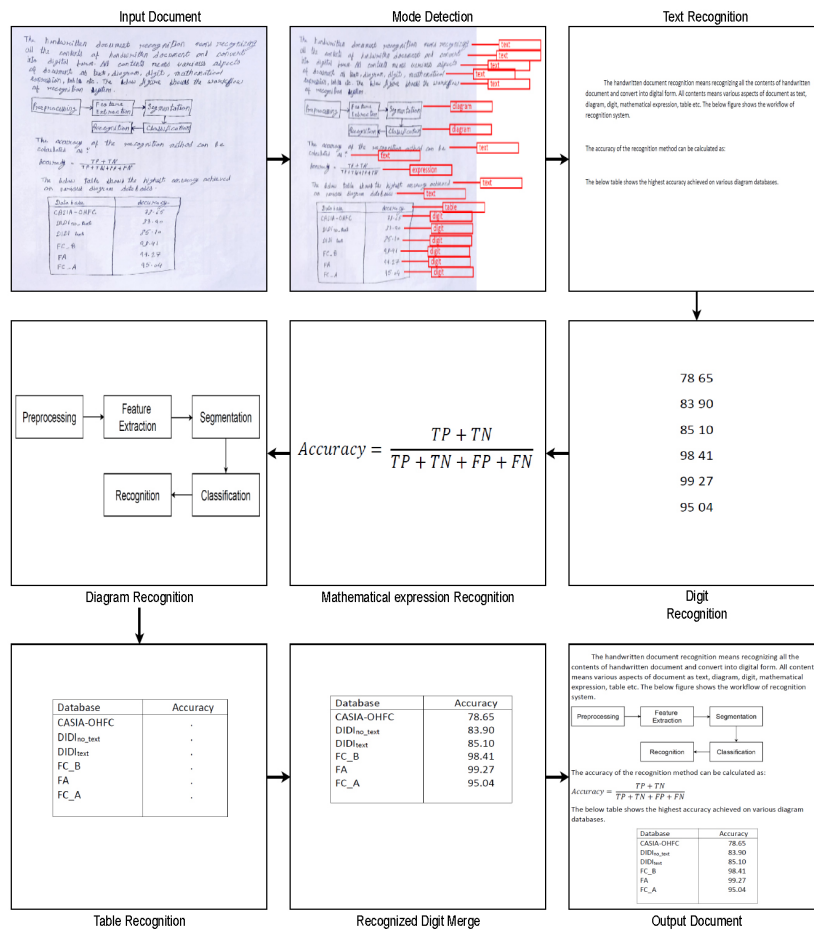


Figure 2

Image workflow of handwritten document recognition system

process of the HDR system is shown in Figure 2, where a handwritten document is given as input, and the system outputs the digitised form of the input document.

For various stages of HDR, a tremendous amount of research is being done to automate the entire process, reduce the complexity of the algorithms, and improve the efficiency of the systems. Finding novel or acceptable approaches for recognising various types of HDR content, as indicated in Figure 2, is one of the research fields. As a result, in order to give a novel solution, a complete knowledge and grasp of the existing state-of-the-art literature is required. From a patent standpoint, this review report provides a panoramic view of HDR stages. This paper examines the current state of patentable research in the types of contents of HDR in various nations throughout the world.

Insights into emerging technology trends can be gained via thorough patent research, goods, biz intelligence, and patent filing [16]. Patinformatics is a new field that entails

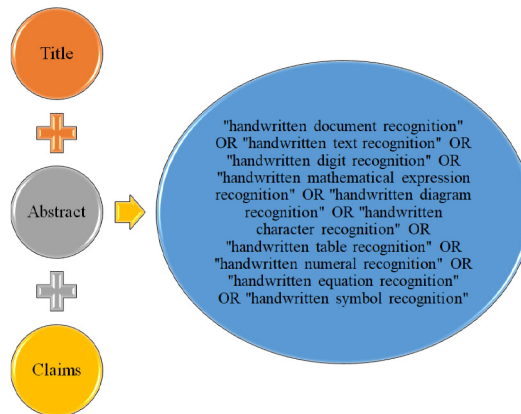


Figure 3

Fields and keywords used on <https://www.lens.org/> for patent search.

analysing patents using a variety of activities and tools to provide statistics, correlations, trends, and indices of patents [74, 56, 63]. Historically, there have been patent-related studies on areas like web-based advertising, the fisheries industry, dielectric materials, and breast cancer theranostics [15, 76, 23, 61]. Patent documents give techno-legal information pertaining to a particular innovation based on the geographical region/country. In this paper, the freely available patent databases such as Lens [60], Unified Patents and Google Patents [59] are used for review. The study includes patentometric information conceptual and technological analysis of the patent documents, and graphical depictions. The granted patents in various types of HDR contents are also summarised in this work.

An appropriate selection of a set of keywords is essential for searching the most relevant patent documents. Based on prior knowledge and considering the scope of the paper, the keywords used for the search are a combination containing all the HDR content types. The applied query and keywords used are shown in Figure 3 on the Lens Patent database (<https://www.lens.org/>). The search yielded 586 patent records with 447 simple and 437 extended families. The search result 476 patent applications, 101 granted patents, six search reports and three limited patent documents. The patentometric analysis is done on the 101 granted patents, and the most relevant patents are summarized along with the patent indices in the next section. A unified patent database is used to get information about the patent indices.

3. Patentometric Review

3.1 Preliminary Highlights

The patent document trend in Figure 4 shows that most patents were granted in 1999 and 2000, followed by 2008. However, after the drop in 2016, the Covid-19 pandemic resulted in an increase in patent grants in digitizing handwritten documents.

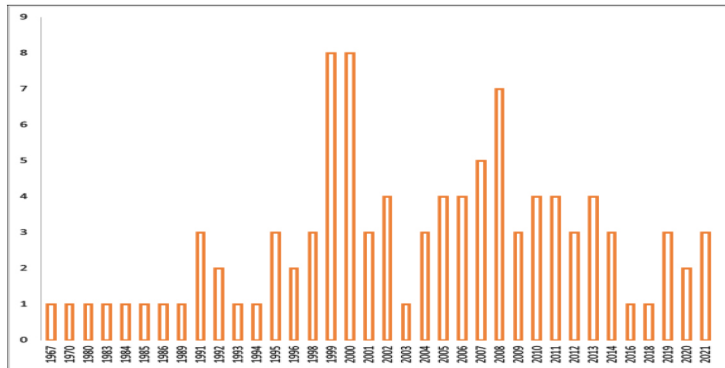


Figure 4
Patent trend over the years.

The legal status of granted patent documents in HDR, categorized by the owner's name, is considered for analysis and is shown in Figure 5. The figure shows that the Microsoft Technology Licensing LLC owner has the most granted and active patents. Most of the patents granted to the Microsoft Technology Licensing LLC owner fall into two categories: handwritten character recognition and handwritten mathematical expressions, recognition. Handwritten characters are recognized based on the allograph of handwriting style. For the recognition of handwritten mathematical expression, a path score is calculated for several symbol-relation pairs reflecting a symbol and its spatial relationship to a preceding symbol at each stroke. It is done by the creation of a symbol graph with nodes and linkages.

Figure 6 provides the distribution of patent documents according to their jurisdiction. The United States (US) has the most significant number of patents as most applicants and inventors are from the US. Patent rights and laws are only valid in the countries or regions where they are applied for or granted. The top ten US patent classification codes belong to

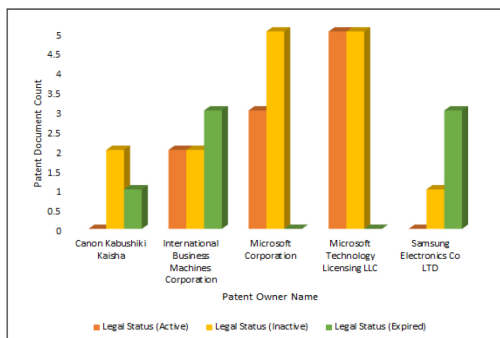


Figure 5
Legal status of granted patent documents in HDR.

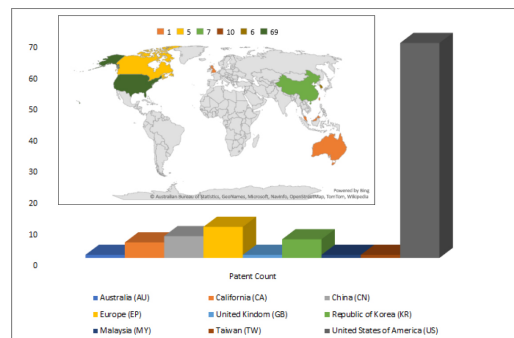


Figure 6
Mapping of patent documents based on jurisdiction.

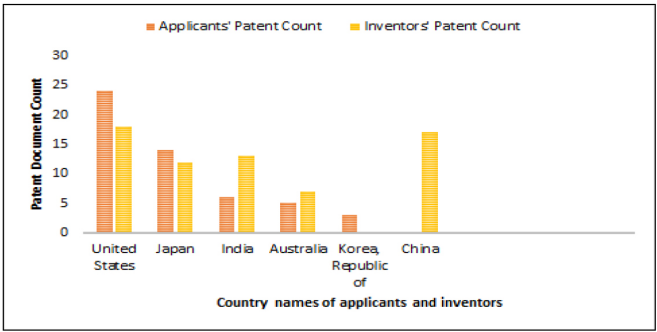


Figure 7

Patent documents based on Applicants and Inventors country

class 382-Image analysis with the highest number of patents belonging to expansion level 187-Online recognition of handwritten characters.

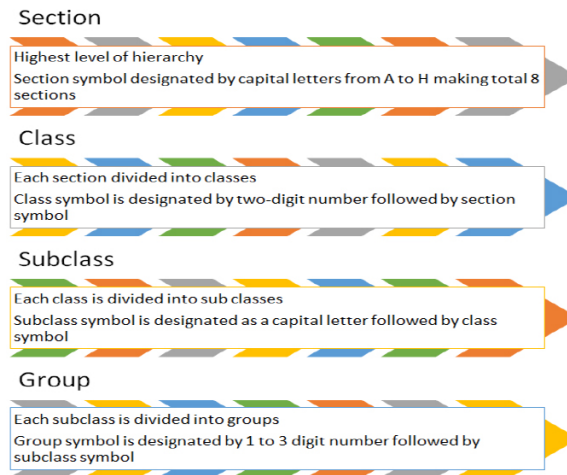
The patent contributions of applicants and inventors worldwide are depicted in Figure 7. For the research activity, inventors from various countries are participating and collaborating. The United States and Japan account for the majority of applicants and inventors. Researchers and scientists from developing nations must put more effort into contributing significantly.

3.2 Classification Schemes

There are three patent classification schemes, namely, the reformed version of international patent classification (IPC), cooperative patent classification (CPC) and United States classification (US). These categorization schemes use a separate set of classification codes/symbols for different technological domains, and patents are classified using these codes/symbols. As indicated in Table 1, the IPC is divided into eight sections, from A to H.

Table 1
IPC classification code sections

Section Symbol	Section Title
A	Human necessities
B	Performing operations; Transporting
C	Chemistry; Metallurgy
D	Textiles; Paper
E	Fixed constructions
F	Mechanical Engineering; Lighting; Heating; Weapons; Blasting
G	Physics
H	Electricity

**Figure 8****Classification symbols layout**

CPC along with the mentioned IPC sections has one more section Y. It belongs to general tagging of new technological developments. All patent offices across the world use the IPC. The symbols for classification are laid out, as seen in Figure 8.

The CPC scheme is jointly managed by the European and United States patent office. A new section Y, has been added to the CPC method for labelling new technological developments. The classification codes identify the research domains or areas, making it easier for researchers to find papers. The description of the top ten IPCR and CPC classification codes is shown in Table 2 and Table 3 respectively.

Table 2**Description of major IPCR classification code**

IPCR Classification Code	Document Count	Description
G06K9/62	44	Methods or arrangements for recognition using electronic means
G06K9/00	37	Methods or arrangements for reading or recognising printed or written characters or for recognising patterns
G06K9/22	36	Image acquisition using hand-held instruments
G06K9/46	18	Extraction of features or characteristics of the image
G06K9/68	13	Combination of image acquisition and preprocessing functions using sequential comparisons of the image signals with a plurality of reference

Contd...

G06F3/041	12	Digitisers
G06F3/033	10	Pointing devices replaced by user; Accessories therefor
G06K9/18	8	Detection or correction of errors using printed characters having additional code marks or containing code marks
G06F3/048	7	Interactive techniques on graphical user interfaces (GUI)
G06K9/24	6	Construction of the instrument

The majority of IPCR patent documents fall in the G06K9 and G06F3 categories. G06K9 category include the methodology for the recognition of handwritten or printed characters. G06F3 category include arrangement for passing input data and output data from processing to control unit.

Table 3
Description of major CPC classification code

CPC Classification Code	Document Count	Description
G06V30/1423	31	It generates handwriting-related sequences of location coordinates.
G06V30/10	23	Character recognition
G06V30/36	14	Matching; Classification
G06V30/373	13	Matching; Classification based on unique sample or subpattern
G06V30/347	11	Sampling; Contour coding; Stroke extraction
G06F3/04883	10	For inputting data by handwriting, e.g. gesture or text
G06V10/75	10	Organisation of the matching processes, e.g. simultaneous or sequential comparisons of image or video features; Coarse-fine approaches, e.g. multi-scale approaches; using context analysis; Selection of dictionaries
G06V30/333	8	Preprocessing; Feature extraction
G06K9/6255	6	Creating dictionaries and determining typical reference patterns
G06V10/12	6	Details of acquisition arrangements; Constructional details thereof

Most CPC patent documents fall in the G06V30 category, which includes methods for character recognition, recognising digital ink, and document-oriented image-based pattern recognition. Figure 9 and Figure 10 show the trends of IPCR and CPC groupings for granted patents in HDR published at different patent offices, respectively.

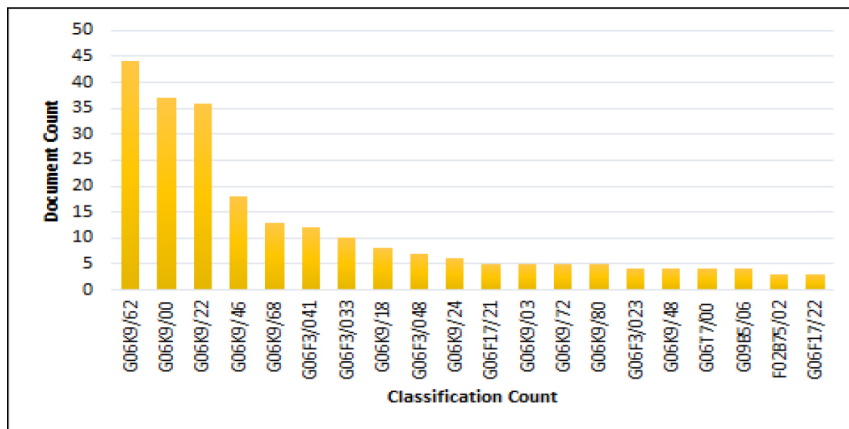


Figure 9

IPCR classification code along with document count.

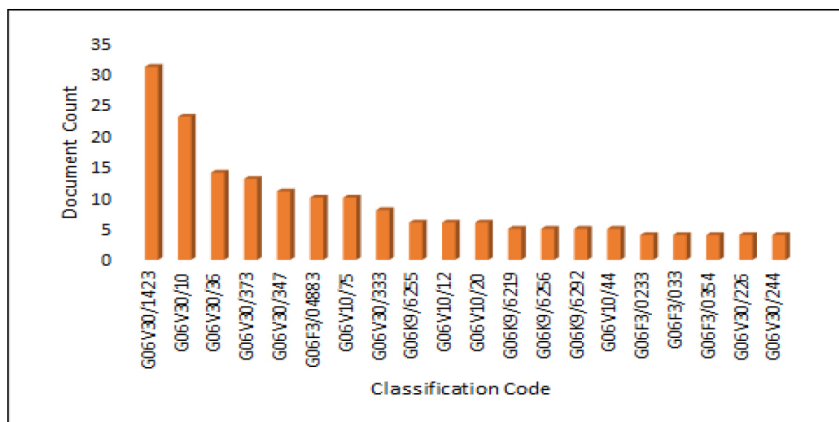


Figure 10

CPC classification code along with document count.

3.3 Citation Analysis

The cites patent count and the cited by patent count are two metrics used in citation analysis. The count of patent documents addressed by the patent in question, also called a backward citation, is the first metric. The granted patent documents in HDR having more than 20 cites patent count are listed in Table 4. The latest granted patent on handwritten character recognition by Z. Konrad et al. [41] cited 41 patents in their document. Their innovation is a technique for confirming the recognition of handwritten characters produced by a user, using an artificial neural network. Training the artificial neural network, collecting handwritten characters, and analysing the acquired characters were the steps taken for recognition purpose.

Table 4
Granted patent document with more than 20 cites patent count

Application Number	Publication Date	Title	Cites Patent Count
US 47987795 A [62]	03-04-2001	Handwritten keyboardless entry computer system	107
US 4229608 A [19]	09-12-2014	Handwritten character recognition interface	73
US 24210402 A [14]	13-04-2004	System and method of handwritten character recognition	50
US 89770301 A [38]	14-03-2006	Incorporating handwritten notations into an electronic document	48
US 201113204703 A [46]	02-10-2012	Handwritten character recognition system	45
US 201716765459 A [41]	02-11-2021	Method of handwritten character recognition confirmation	41
US 94180710 A [45]	30-08-2011	Handwritten character recognition	41
US 201715441194 A [80]	23-07-2019	Resolution-limited narrow CNN modules provide the basis of a convolutional neural network (CNN) system	37
US 11124805 A [79]	16-01-2007	Pen-based handwritten character recognition and storage system	33
US 75576301 A [78]	22-11-2005	Pen-based handwritten character recognition and storage system	32
US 30596805 A [1]	12-01-2010	Allograph based writer adaptation for handwritten character recognition	28
US 49216804 A [44]	15-04-2008	Methodology for decoding of handwritten characters	23
US 65720603 A [8]	10-08-2010	Methodology for recognition of character image	22

The amount of times the patent in consideration is mentioned by other patents in their document, also known as forward citations, is the second metric cited by patent count. Patent documents with more than 50 forward citations are shown in Table 5. The patent on a real time handwriting recognition system by A. N. Jourjine [31] is cited in 228 patent documents. It recognizes handwritten characters using input and point buffer with static and dynamic stroke features.

Table 5
Granted patent document cited by more than 50 patents

Application Number	Publication Date	Title	Cited by Patent Count
US 80037497 A [84]	22-09-1998	Method and apparatus for recognizing hand-written characters using a weighting dictionary	263
US 47682695 A [31]	23-11-1999	Real time handwriting recognition system	228
US 15578305 A [88]	04-11-2008	Analyzing tabular structures in expression recognition	197
US 33739382 A [68]	12-06-1984	Methods and apparatus for the automatic classification of patterns	188
US 2083898 A [35]	01-05-2001	Handwritten character recognition using multi-resolution models	164
US 29898999 A [52]	11-09-2001	Method and system of handwritten-character recognition	147
US 40741895 A [81]	19-05-1998	Car navigation system	130
US 89783686 A [67]	22-08-1989	Real time handwritten character input system	113
US 24987994 A [72]	30-04-1996	Handwritten character size determination apparatus based on character entry area	112
US 48463095 A [34]	19-10-1999	Character recognition system identification of scanned and real time handwritten characters	84
US 95128792 A [21]	14-06-1994	System for recognizing handwritten character strings containing overlapping and/or broken characters	84
US 67998891 A [29]	14-04-1992	Time delay neural network for printed and cursive handwritten character recognition	77
US 47987795 A [62]	03-04-2001	Handwritten keyboardless entry computer system	63
US 58036695 A [82]	13-07-1999	Handwritten character recognition apparatus with an improved feature of correction to stroke segmentation and method for correction to stroke segmentation for recognition of handwritten character	63
US 37008482 A [58]	22-01-1985	On-line character recognition using closed-loop detector	62
US 89770301 A [38]	14-03-2006	Incorporating handwritten notations into an electronic document	61
US 18936588 A [43]	15-10-1991	Method and apparatus for handwritten character recognition	60

Contd...

US 953398 A [71]	07-11-2000	Method and apparatus for on-line handwritten input character recognition and recording medium for executing the method	59
US 33883103 A [69]	08-05-2007	Handwriting information processing apparatus, handwriting information processing method, and storage medium having program stored therein for handwriting information processing	56
US 80113997 A [85]	05-02-2002	Handwritten character recognition apparatus and method using a clustering algorithm	56
US 42121189 A [50]	06-08-1991	Multi-scale recognizer for hand drawn strokes	56
US 29856689 A [65]	23-07-1991	On-line handwritten character recognition apparatus with non-ambiguity algorithm	55
US 58684390 A [9]	09-06-1992	Robust prototype establishment in an on-line handwriting recognition system	54

Backward citations aid in analysing the invention's fundamental cause and progress in that field. Forward citations, on the other hand, can be thought of as a sign of future inventions that will be valuable. Figure 11 shows the trend of forward and backward citation counts for the top patents based on both cites and cited by patent count.

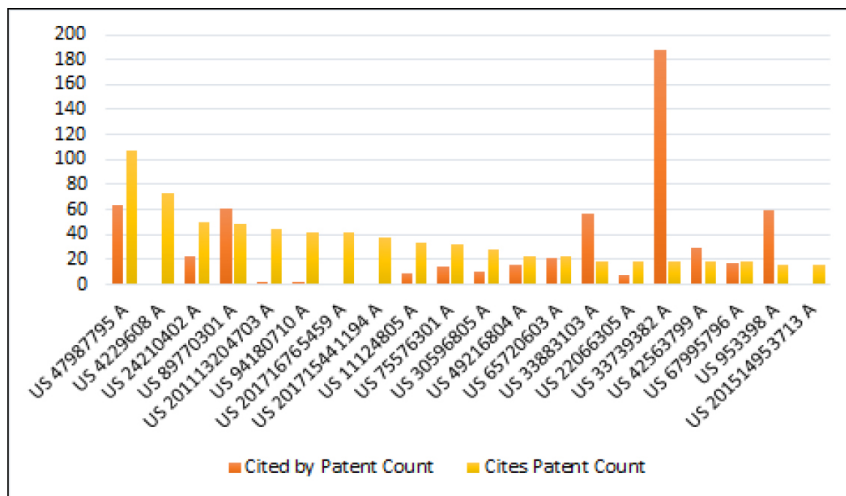


Figure 11

Trend of forward and backward citation counts for patent documents.

3.4 Patent Indices with Summary

Table 6 summarises the patents that have been granted recently i.e. from year 2011 onwards on the various types of contents of handwritten documents.

Table 6
Summary of granted patents on HDR types of contents with patent indices from year 2011

Publication Number	Publication Date	Title	Summary	Patent Indices
CA-3050025-C [6]	01-11-2021	Systems and methods for end-to-end handwritten text recognition using neural networks	To translate a handwritten text image to a sequence of characters corresponding to text included in the scanned handwritten text input image, the approach uses a deep Convolutional Neural Network (CNN) with an RNN (Recurrent Neural Network) based encoder and decoder unit.	APIX:A BRIX:D CITX:D PVIX:54.74 RNIX:54.22 SVIX:0.48
US-11164025-B2 [41]	01-11-2021	Method of handwritten character recognition confirmation	The current invention is a technique for confirming the recognition of handwritten characters produced by a user using an artificial neural network. Training the artificial neural network, collecting handwritten characters, and analysing the acquired characters were the steps taken.	APIX:A BRIX:C CITX:D PVIX:0 RNIX:-0.37 SVIX:0.37
US-10956727-B1 [7]	22-03-2021	Handwritten diagram recognition using deep learning models	A machine learning component gets a digitally encoded image containing a handwritten diagram and locates and classifies a number of objects inside it. The handwriting recognition component interprets one or more alphanumeric text strings, while the structure recognition component discovers connections between each symbol.	APIX:B BRIX:B CITX:D PVIX:0 RNIX:-0.37 SVIX:0.37
US-10671844-B2 [17]	01-06-2020	Handwritten text recognition	Based on an estimate of the direction of writing and the scale of each stroke, the subject technology determines a local orientation of the existing line group incorporating the new input stroke. It also uses the calculated location orientation to normalise the current line group, including the new input stroke.	APIX:AA BRIX:D CITX:D PVIX:50.07 RNIX:49.68 SVIX:0.37

Contd...

US-10360494-B2 [80]	22-07-2019	Convolutional neural network (CNN) system based on resolution-limited small-scale CNN modules	The use of resolution-limited small-scale CNN modules in a convolutional neural network (CNN) system is reported.	APIX:B BRIX:B CITX:D PVIX:67.48 RNIX:66.34 SVIX:1.11
US-10169670-B2 [18]	31-12-2018	Stroke extraction in free space	The use of a paired ring device to extract strokes in free space is described. It receives one or more photos from the ring device with which it is linked. The method uses one or more photos to feed into a character training model, which then transcribes the characters into a digital document.	APIX:A BRIX:D CITX:D PVIX:54.13 RNIX:53.37 SVIX:0.74
KR-1018403-58-B1 [27]	19-03-2018	Mathematics learning apparatus and method using handwritten mathematical expressions recognition	An apparatus and method for learning mathematics utilising handwritten formula recognition are disclosed, in which a learner can practise solving a math problem and fix an incorrect solution process without the assistance of a teacher.	APIX: BRIX: CITX:D PVIX:42.53 RNIX:41.99 SVIX:0.52
US-9432526-B2 [53]	29-08-2016	Image forming system, image forming apparatus, remote control apparatus, and recording medium for displaying an input screen	A display unit, a communication unit, and a display control unit were created for a remote control device.	APIX:B BRIX:D CITX:D PVIX:54.75 RNIX:54.18 SVIX:0.57
US-8908973-B2 [19]	08-12-2014	Handwritten character recognition interface	Methods, systems, and devices for entering text and a handwriting area on a touch-sensitive display of a device are given, as well as computer program products.	APIX:B BRIX:A CITX:C PVIX:69.8 RNIX:69.48 SVIX:0.32
US-8494277-B2 [12]	22-07-2013	Handwritten character recognition based on frequency variations in characters	A handwritten character recognizer based on black and white pixel image.	APIX:D BRIX:C CITX:D PVIX:56.64 RNIX:56.43 SVIX:0.22

Contd...

US-8363947-B2 [13]	28-01-2013	Handwritten character recognition based on frequency variations in characters	For recognising cursive and non-cursive handwriting, there is a technique, system, and computer programme product. Capturing a handwritten character as a pixel picture, and comparing the pixel ratio for each segment are all part of the innovation.	APIX:C BRIX:B CITX:D PVIX:56.64 RNIX:56.43 SVIX:0.22
US-8290274-B2 [66]	15-10-2012	Method for handwritten character recognition, system for handwritten character recognition, program for handwritten character recognition and storing medium	Handwritten character recognition based on polygonal approximation.	APIX:B BRIX:B CITX:C PVIX:58.79 RNIX:58.63 SVIX:0.17
US-8280168-B2 [46]	01-10-2012	Handwritten character recognition system	The innovation is a character classification system. It includes a CPU and an input device for accepting a handwritten input character. The processor is set up to associate each character model with an output character and define a model-specific segmentation strategy for that output character and its associated segment model for each character model.	APIX:C BRIX:C CITX:C PVIX:61.09 RNIX:60.02 SVIX:1.08
CN-101331-476-B [10]	10-07-2012	System and method for handwritten character recognition	The claimed situation count number gives a machine and/or a way that allows studying and/or spotting a handwritten character. A personalization aspect can educate a classifier primarily based totally on an allograph associated with a handwriting fashion to offer handwriting popularity.	APIX:C BRIX:AA CITX:C PVIX:72.4 RNIX:70.47 SVIX:1.94
US-8009914-B2 [45]	29-08-2011	Handwritten character recognition	The invention is a method for classifying a handwritten input character. The use of character models is employed. The input character is deconstructed into segments using each of the character models, and the segments are assessed against the segment model of the relevant character model to provide a score indicating how well the segments adhere to the segment model.	APIX:C BRIX:D CITX:C PVIX:61.09 RNIX:60.02 SVIX:1.08

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US-7929767-B2 [55]	18-04-2011	Analyzing subordinate sub-expressions in expression recognition	A technology to spot and input handwritten equation directly in laptop through supplying a part of a multi-direction framework. A dedication can be made whether or not an expression shape candidate is legitimate and legitimate expression shape applicants can be saved in a parse tree.	APIX:A BRIX:C CITX:C PVIX:68.08 RNIX:67.87 SVIX:0.22
US-7885456-B2 [86]	07-02-2011	Symbol graph generation in handwritten mathematical expression recognition	From the start to the last stroke in the sequence, a forward pass through a sequence of strokes indicating a handwritten equation is done. A path score is calculated for a number of symbol-relation pairs that each reflect a symbol and its spatial relationship to a preceding symbol at each stroke. It is created a symbol graph with nodes and linkages.	APIX:B BRIX:B CITX:C PVIX:0 RNIX:0 SVIX:0

Different patent indexes, such as the advanced patent index (APIX), broadness index (BRIX), citation index (CITX), portfolio value index (PVIX), renew index (RNIX), and save index (SVIX), are used to determine the qualitative and quantitative measure of patents. The patents are arranged in chronological order by publication date. APIX, BRIX, and CITX are examples of qualitative indexes. APIX is a metric for patent validity that estimates the likelihood of a patent's survival based on previous rulings. Online handwritten text recognition works on the strokes. The innovation by R. S. Dixon et al. [17] detects the local orientation based on the direction and scale of strokes, which is the first and most essential step in recognising of handwritten text. Hence, it has the highest APIX grade AA. BRIX is a metric that measures how broad a patent is based on the uniqueness of its claims. The highest BRIX grade AA is achieved by the granted patent author A. A. Abdulkader et al. [3], published in 2019 for handwritten character recognition because their claims are based on allograph data, allograph component and allograph neural network classifier. CITX uses the number of forward citations to rate patents. PVIX is a metric for the value of a patent portfolio. PVIX is influenced by patent family, market, and reputation. The patent value of a family (PVIX) is calculated by multiplying the total outstanding fees for a family (SVIX) by RNIX. The granted patent on allograph-based writer adaptation for handwritten character recognition, by A. A. Abdulkader et al. [3, 2], has the highest PVIX 72.4, SVIX 1.94 and RNIX 70.47. As allograph technology for character recognition is very reputed in the market.

The review shows that the highest qualitative and quantitative measure is achieved by handwritten character recognition using an allograph mechanism. The first patent on an allograph-based technique was granted in 2010 [1]. That means that the methodology

or innovation from the earlier work can also be referred to to proceed with the current research. Hence the innovation done before 2011 has equal importance. That's why the previous patents are again categorized into two groups based on publication year, one from the year 2001 to year 2010 and another year before 2001. Table 7 summarises the patents published between 2001 and 2010, and Table 8 summarises those published before 2001.

Table 7
Summary of granted patents on HDR types of contents with patent indices from year 2001 to 2011

Publication Number	Publication Date	Title	Summary	Patent Indices
US-7773808-B2 [8]	09-08-2010	Apparatus and method for recognizing a character image from an image screen	A method and apparatus are described for storing document information on a mobile terminal equipped with a camera. The camera captures an image of a document, which is displayed. A character image is recognised from the displayed document image and translated into character data in response to a document "RECOGNIZE" key input.	APIX:C BRIX:C CITX:C PVIX:0 RNIX:0 SVIX:0
CN-100587-660-C [77]	02-02-2010	Method and device for forecasting and discriminating hand-written characters	Innovation for recognition of handwritten characters using a prediction algorithm. It includes the following steps: initially user writes a certain number of handwriting points of character; a handwriting character recognizer recognises the written handwriting points of character; and the obtained recognition result information is used to process the forecast prediction recognition.	APIX: BRIX: CITX:C PVIX:61.72 RNIX:61.44 SVIX:0.29
US-7646913-B2 [1]	11-01-2010	Allograph based writer adaptation for handwritten character recognition	The claimed issue count affords a gadget and/or a way that allows reading and/or spotting a handwritten character. A personalization thing can teach a classifier primarily based totally on an allograph associated with a handwriting fashion to offer handwriting reputation for the as a minimum one handwritten character.	APIX:C BRIX:AA CITX:C PVIX:72.4 RNIX:70.47 SVIX:1.94

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CA-2617416-C [32]	28-09-2009	Character recognition system identification of scanned and real time handwritten characters	Innovation, for recognition of handwritten character, containing document scanner and a stylus and digitising tablet that allows a user to enter handwritten characters in real time.	APIX: BRIX: CITX:C PVIX:0 RNIX:0 SVIX:0
US-7561737-B2 [87]	13-07-2009	Mathematical expression recognition	A multi-path framework is characterised as a technique for identifying and inputting handwritten mathematical statements into a computer.	APIX:B BRIX:B CITX:C PVIX:68.16 RNIX:68.17 SVIX:0
US-7561739-B2 [54]	13-07-2009	Analyzing scripts and determining characters in expression recognition	Receiving symbols correlating to handwritten mathematical expression entry strokes, recognising subscript and/or superscript structures, and selecting a character for each symbol of the set are all part of a technique for analysing a handwritten mathematical expression. Based on the collection of symbols, a graph of vertices and edges and edges can be built, and the graph can be searched to find optimum candidates.	APIX:A BRIX:B CITX:C PVIX:0 RNIX:0 SVIX:0
US-7447360-B2 [88]	03-11-2008	Analyzing tabular structures in expression recognition	The tabular structure analysis component of the multi-path framework is meant to determine tabulated structures, such as those described by parentheses, within handwritten mathematical equations. Determining if a symbol representing input strokes belongs to a tabular structure associated with a mathematical expression is part of a method to determine tabular structures in a handwritten mathematical expression.	APIX:B BRIX:A CITX:B PVIX:0 RNIX:0 SVIX:0
US-7412391-B2 [37]	11-08-2008	User interface design apparatus and method	A person interface layout equipment which reduces the weight related to enter operation through an creator is provided. When a speech reputation grammar along with a semantic shape producing rule is acquired, at the least one semantic shape is extracted from the semantic shape.	APIX:C BRIX:A CITX:B PVIX:0 RNIX:0 SVIX:0

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CA-2194491-C [33]	02-06-2008	Character recognition system identification of scanned and real time handwritten characters	An image processor attached to the document scanner for handwritten character recognition. The ordered pattern arrays contain sparsely ordered co - ordinate arrays of skeletal image.	APIX:A BRIX:D CITX:B PVIX:61.48 RNIX:61.5 SVIX:0
CN-100385454-C [11]	30-04-2008	Method and apparatus for scaling handwritten character input for handwritten character recognition	The innovation presented a data processing system that scales handwritten input stroke. The scaling is done on the basis of input area.	APIX:C BRIX:A CITX:B PVIX:80.89 RNIX:80.47 SVIX:0.4
US-7359551-B2 [44]	14-04-2008	Method and apparatus for decoding handwritten characters	Disclosed is a technique of appearing written individual recognition, consisting of sequentially evaluating a given enter individual with one in all a sequence of saved individual fashions. The step of evaluating in addition includes, decomposing the given enter individual into one or extra segments.	APIX:C BRIX:C CITX:B PVIX:61.09 RNIX:60.02 SVIX:1.08
US-7266236-B2 [39]	03-09-2007	Accelerated handwritten symbol recognition in a pen based tablet computer	A method and equipment for recognition of handwritten symbol are described in the invention. Using special purpose hardware, handwritten symbols are converted into machine readable characters in one implementation. A recognition processing unit (RPU) performs feature extraction and recognition in one version of the special purpose hardware.	APIX:D BRIX:AA CITX:B PVIX:0 RNIX:0 SVIX:0
US-7263211-B2 [25]	27-08-2007	Information processing apparatus and method, computer-readable memory, and program	An statistics processing equipment for detection of sampling price.	APIX:B BRIX:A CITX:B PVIX:0 RNIX:0 SVIX:0
US-7215815-B2 [69]	07-05-2007	Handwriting information processing apparatus	A invention for processing of handwritten information based on co-ordinate value and strokes.	APIX:C BRIX:D CITX:B PVIX:0 RNIX:0 SVIX:0

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US-7200267-B1 [30]	02-04-2007	Handwriting recognition with mixtures of bayesian networks	The invention uses a combination of Bayesian networks to recognise handwriting. A mixed Bayesian network (MBN) is made up of multiple hypothesis-specific Bayesian networks (HSBNs) with hidden and observable variables. Each HSBN constructs a world model based on the assumption that the important external hidden variable is in one of its states.	APIX:D BRIX:AA CITX:B PVIX:0 RNIX:0 SVIX:0
US-7164793-B2 [79]	15-01-2007	Pen-based handwritten character recognition and storage system	The current invention relates to an improved system and method for detecting, recognising, and storing handwriting as it is written by a pen-sized and shaped device. Both an engaged feedback circuit and a character recognition mechanism are used in the invention to divide detected input into character components.	APIX:C BRIX:B CITX:B PVIX:0 RNIX:0 SVIX:0
US-7013029-B2 [38]	13-03-2006	Incorporating handwritten notations into an electronic document	The processor is configured to get hold of information related to a handwritten notation carried out to a broadcast web page and an digital photograph of a place of the published model of the web page close to the notation, to perceive a corresponding passage withinside the digital model of the web page and to create an digital notation primarily based at the acquired information and related to the corresponding passage.	APIX:B BRIX:A CITX:A PVIX:0 RNIX:0 SVIX:0
US-6970581-B2 [24]	28-11-2005	Information processing apparatus and method, computer-readable memory, and program	The statistics processing equipment affords particular individual handwriting or signature even though the individual popularity entered the usage of digitizers having exclusive processing rates.	APIX:C BRIX:B CITX:AA PVIX:0 RNIX:0 SVIX:0
US-6968083-B2 [78]	21-11-2005	Pen-based handwritten character recognition and storage system	The current invention is directed to an improved system and method for detecting, recognising, and storing handwriting as it is written by a pen-sized and shaped device. Both an active feedback network and a character recognition mechanism are used in the invention to divide detected input into character components.	APIX:C BRIX:B CITX:AA PVIX:0 RNIX:0 SVIX:0

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US-6950555-B2 [4]	26-09-2005	Holistic-analytical recognition of handwritten text	The analytical recognition module cuts the picture of the input string of characters into individual character images using segmentation assumptions from the segmented character feature sets. An analytical answer list with a plurality of word or phrase answers generated via a plurality of character images for the various segmentation assumptions.	APIX:C BRIX:C CITX:AA PVIX:70.05 RNIX:69.75 SVIX:0.24
US-6931153-B2 [28]	15-08-2005	Handwritten character recognition apparatus	A character string input area of a handwritten character recognition equipment is of a size that allows the user to hand create a plurality of character thereon using a stylus. For each stroke that makes up the handwritten character string, a coordinate detection unit extracts a coordinate string. An input complete judgement unit evaluates a handwritten character string that comes before it.	APIX:C BRIX:D CITX:AA PVIX:67.2 RNIX:67.22 SVIX:0
US-6804817-B1 [64]	11-10-2004	Information-object designation system	An information-object classification system in which two character strings are compared, one expressive of a name of each of the information objects stored in an information processing system and the other based on externally inputted information, and when a match of the two character strings is detected, an event for the information object whose name is expressed by the matching character string is started.	APIX:C BRIX:AA CITX:A PVIX:0 RNIX:0 SVIX:0
US-6721452-B2 [14]	12-04-2004	System and method of handwritten character recognition	An "activity"-based system and technique for on-line character recognition that uses less code or data memory, is alphabet-independent, and can be trained by just typing the alphabet once.	APIX:C BRIX:B CITX:A PVIX:0 RNIX:0 SVIX:0

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US-6477274-B1 [40]	04-11-2002	Handwritten character recognition devices and electronic devices incorporating same	An analog/digital converter receives and translates a series of analogue voltage signals generated by a user activating one or more touch switches during a handwriting stroke into a series of digital values. A processor processes the sequence of digital values in conjunction with a handwriting recognition algorithm, recognises the alphanumeric characters that correspond to the user's handwriting strokes, and then displays the detected alphanumeric characters inside the display.	APIX:D BRIX:A CITX:A PVIX:49.25 RNIX:49.04 SVIX:0.23
US-6401067-B2 [48]	03-06-2002	System and method for providing user-directed constraints for handwriting recognition	A information popularity machine and technique which permits a consumer to pick out among a "default popularity" and "confined popularity". A popularity engine makes use of predetermined default popularity parameters to decode information.	APIX:C BRIX:A CITX:A PVIX:0 RNIX:0 SVIX:0
US-6345119-B1 [85]	04-02-2002	Handwritten character recognition apparatus and method using a clustering algorithm	For a plurality of handwritten characters extracted from an enter image, a person class for every person is first decided via way of means of a person popularity method. Second, consistent with a clustering method, similarity stages of person-bureaucracy amongst extracted characters are decided.	APIX:B BRIX:C CITX:A PVIX:0 RNIX:-0.04 SVIX:0.04
US-6289124-B1 [52]	10-09-2001	Method and system of handwritten-character recognition	An imagined stroke is used to link the finishing point of every actual stroke of an inputted handwritten character to the starting place of the succeeding actual stroke to construct a single line in the present character recognition method. The point of a single line turn, as well as the direction and angle of the turn at that place, are then specified using a feature level.	APIX:D BRIX:AA CITX:B PVIX:62.26 RNIX:62.17 SVIX:0.07

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US-6226403-B1 [35]	30-04-2001	Handwritten character recognition using multi-resolution models	A garage medium having saved thereon a fixed of instructions, which whilst loaded right into a microprocessor, reasons the microprocessor to extract strokes from a plurality of characters, derive a pre-described range of stroke fashions primarily based totally at the strokes extracted from the plurality of person and constitute the plurality of characters as sequences of stroke fashions.	APIX:B BRIX:AA CITX:B PVIX:75.43 RNIX:75.41 SVIX:0
US-6212297-B1 [62]	02-04-2001	Handwritten keyboardless entry computer system	A keyboardless entry computer system features a transparent input screen that creates positional information when contacted by a stylus, as well as a display screen situated physically below the input screen so that a displayed character can be viewed below it. The system consists of a computer that has been configured to assemble positional data into Strokes, calculate Stroke characteristics, and then compare Stroke characteristics to those recorded in a database in order to detect the symbol drawn by the stylus.	APIX:D BRIX:AA CITX:B PVIX:0 RNIX:0 SVIX:0

Table 8

Summary of granted patents on HDR types of contents with patent indices before year 2001

Publication Number	Publication Date	Title	Summary	Patent Indices
US-6160914-A [51]	11-12-2000	Handwritten character verification method and apparatus therefor	Verification of handwritten character based on coordinate information and pressure information.	APIX:C BRIX:D CITX:C PVIX:0 RNIX:0 SVIX:0
US-6144764-A [71]	06-11-2000	Method and apparatus for on-line handwritten input character recognition and recording medium for executing the method	Recognition of handwritten characters using strokes, their transition and start to end point of stroke.	APIX:C BRIX:A CITX:C PVIX:0 RNIX:0 SVIX:0

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TW-409213-B [20]	20-10-2000	Method and device for handwritten character recognition	A handwritten character recognizing device (100) and method for handwritten character recognition improves the accuracy of conventional character recognizers by using a post-processor (130)	APIX: BRIX: CITX:C PVIX:0 RNIX:0 SVIX:0
KR-100233193-B1 [83]	30-11-1999	Handwritten character recognition apparatus with an improved feature of correction to stroke segmentation	The present invention is directed to recognizing the positional relationship between the frame delimiting the previously written stroke and the newly written stroke. identify a predetermined type for changing the divided portion; and a method of changing the divided portion of one or more strokes constituting any one of a character and a symbol by changing the divided portion according to the change-indicating stroke.	APIX:B BRIX:D CITX:D PVIX:0 RNIX:-0.03 SVIX:0.03
US-5991441-A [31]	22-11-1999	Real time handwriting recognition system	A handwritten character recognizer that recognizes handwritten character using input and point buffer.	APIX:C BRIX:C CITX:D PVIX:0 RNIX:0 SVIX:0
US-5982928-A [36]	08-11-1999	Character recognizing apparatus and method of controlling the same	A system consisting of a plurality of terminals connected through communication is sometimes used to acquire information input from the terminals to a host terminal. Alternatively, the host terminal concentratively manages the character recognizing methods and dictionaries of all the terminals and performs character recognition. and edit/arrange the information in the host terminal	APIX:C BRIX:C CITX:D PVIX:0 RNIX:-0.03 SVIX:0.03
US-5812697-A [84]	21-09-1998	Method and apparatus for recognizing handwritten characters using a weighting dictionary	A method of recognizing handwritten characters. A recognition dictionary is prepared including a plurality of characters and corresponding character clusters.	APIX:C BRIX:C CITX:D PVIX:0 RNIX:0 SVIX:0

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US-5745599-A [70]	27-04-1998	Character recognition method	The innovation recognizes handwritten character based on segmentation of neighbouring points connected by a line.	APIX:B BRIX:D CITX:D PVIX:0 RNIX:0 SVIX:0
US-5426711-A [42]	19-06-1995	Online handwritten character recognition	An online handwritten character recognition system that uses simple processing of a small number of operations to narrow down candidates for handwritten character identification rapidly and reliably.	APIX:D BRIX:D CITX:D PVIX:0 RNIX:0 SVIX:0
US-5420939-A [22]	29-05-1995	Method and apparatus for a focal neuron system	An image input layer with a plurality of input neurons, an input layer with a plurality of output neurons, and a plurality of focal neurons positioned between the image input layer and the input layer make up a focal neuron system. A maximum and minimum boundary is set for each dimension of the image array. A focal neuron is chosen based on the maximum and minimum boundaries to provide proper scaling and translation of the topic image from the image layer to the input layer for each dimension. On the surface of the brain, each excited neuron	APIX:D BRIX:D CITX:D PVIX:0 RNIX:0 SVIX:0
KR-9500055-33-B1 [26]	24-05-1995	On-line character recognizing system	On-line handwritten character recognition is the focus of the system. It compensates for a sample point omission and modifies a transformed and written character correctly using handwriting tendencies. It consists of: I a tablet input part(1); (ii) a preprocessing part(2) normalising a character to a certain size; (iii) a feature extraction part(3) calculating a whole length, a start point, and an end point of a stroke; (iv) a stroke recognition part(4) finally recognising a defined stroke; (v) a character recognition part(5) recognising an initial sound, a middle sound, and an end sound.	APIX: BRIX: CITX:D PVIX:0 RNIX:0 SVIX:0

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US-5321768-A [21]	13-06-1994	System for recognizing handwritten character strings containing overlapping and/or broken characters	The invention removes punctuation and noise and performs joining and splitting of characters. The process is repeated if any unrecognised characters remain in the string. The joining and splitting operations are repeated until the string's remaining characters are either identified or declared to be unrecognisable.	APIX:D BRIX:B CITX:D PVIX:0 RNIX:0 SVIX:0
US-5237628-A [47]	16-08-1993	System and method for automatic optical data entry	The invention provides a system and method for automatically processing machine printed forms that have been filled out by hand. A manual data entry step is not required with the novel system and method. Each form is digitally imaged using a scanner or other equipment. An optical recognition engine scans each form's digital picture using an algorithm that can distinguish machine printed characters but not handwritten characters to locate the fields in the digital image by locating the machine printed field IDs. An offline method for recognising handwritten characters	APIX:D BRIX:C CITX:D PVIX:0 RNIX:0 SVIX:0
US-5105468-A [29]	13-04-1992	Time delay neural network for printed and cursive handwritten character recognition	A time delay neural network is defined by feature detection layers limited for extracting features and subsampling a sequence of feature vectors input to the feature detection layer in question. Information referring to connecting segments between the end point of one stroke and the beginning point of another stroke are examples of additional information.	APIX:C BRIX:A CITX:D PVIX:0 RNIX:0 SVIX:0
US-5058182-A [43]	14-10-1991	Method and apparatus for handwritten character recognition	For the recognition of written characters, a method and apparatus are provided. This method entails raster scanning the written character to detect stroke-based properties, as well as extracting the character's vertical and horizontal strokes.	APIX:C BRIX:A CITX:D PVIX:0 RNIX:0 SVIX:0

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US-5038382-A [50]	05-08-1991	Multi-scale recognizer for hand drawn strokes	In angle filters, a known hand drawn stroke is serially sampled at several scales to get n filtered known strokes at n different scales. The unknown hand drawn stroke is identified as the same as the known hand drawn stroke.	APIX:D BRIX:C CITX:D PVIX:0 RNIX:0 SVIX:0
US-4607386-A [73]	18-08-1986	Handwritten character recognition device	A handwritten character recognition device comprises a feature point circuit for recognizing a character with using three feature points for a continuous stroke connecting a first stroke and second strokes. Even if the stroke number may be irregularly changed, the inputted character can be recognized without a necessity of storing information for the irregularly changed strokes.	APIX:C BRIX:C CITX:D PVIX:0 RNIX:0 SVIX:0
US-4495646-A [58]	21-01-1985	On-line character recognition using closed-loop detector	A unique "closed-loop" type detector is used in an online handwritten character recognition system. The detector detects the writing element's movement across the writing surface and is limited in its ability to generate strings of directions travelled by requiring the detector to move only between neighbouring directions.	APIX:C BRIX:AA CITX:D PVIX:0 RNIX:0 SVIX:0
US-4454610-A [68]	11-06-1984	Methods and apparatus for the automatic classification of patterns	Methods and apparatus for the automatic classification of patterns are disclosed in which the intensity or gray level values of selected pixels of digital images of functions of position-invariant transforms.	APIX:C BRIX:B CITX:D PVIX:0 RNIX:0 SVIX:0
CA-1070020-A [49]	14-01-1980	Method and apparatus for recognizing handwritten characters in an optical acter recognition machine	Handwritten character recognition is facilitated in an optical character recognition machine by electronically scaling-down the size of received characters, both in height and width, to normalized dimensions. Recognition of the character is effected by decoding the test results.	APIX: BRIX: CITX:D PVIX:0 RNIX:0 SVIX:0

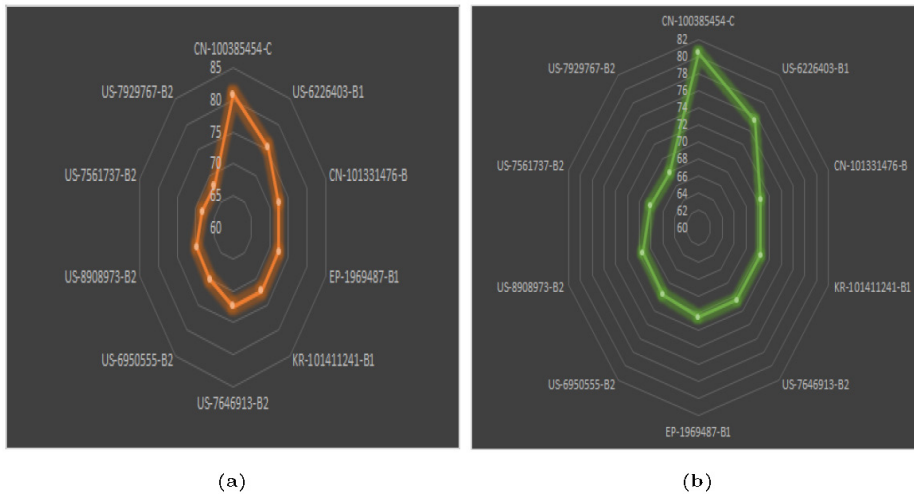


Figure 12
Top 10 patents (a) Based on PVIX; (b) Based on RNIX

Figure 12 depicts graphs for the PVIX and RNIX quantitative measures for the top ten granted patents to date, respectively. The highest PVIX 80.89 and RNIX 80.47 is achieved by Y.-F. Chen and J. Dunsmoir [11] granted patent. The patent's legal status remains active as the innovation scales the input strokes. The stroke parameters are scaled in the data processing system innovated by the applicants to increase the recognition rate of handwritten characters.

4. Conclusion

The review reveals that handwritten document recognition is an emerging research area. Worldwide spread and consistent growth after the COVID-19 pandemic indicate the research potential in handwritten document digitization. Along with recognition of text, symbols, digits, etc., researchers also focus on the creation of a device which will convert the stylus written input on one screen to digitized output displayed on a parallel screen. For character recognition, the most recommended methods are a combination of CNN and RNN encoder and decoder units. Most of the research is carried out in English only, with only a few contributions made in other languages especially languages in India. In comparison to poor countries, developed countries make a large contribution. Recognition of handwritten tables is one of the research fields need to be explored. According to the Ethnologue Language Catalogue of the World, India ranks fourth in terms of the number of languages spoken. In India, there are various languages in which regional scripts are written, such as Hindi, Marathi, Bengali, Urdu, Punjabi, etc. It needs to be converted to digital form to store these scripts for future generations.

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