

Document details

[< Back to results](#) | 1 of 1

[Export](#) [Download](#) [Print](#) [E-mail](#) [Save to PDF](#) [Add to List](#) [More... >](#)

[Full Text](#) [View at Publisher](#)

IETE Journal of Research
Volume 64, Issue 2, 4 March 2018, Pages 176-194

Convolutional Neural Network Training incorporating Rotation - Based Generated Patterns and Handwritten Numeral Recognition of Major Indian Scripts (Article)

Akhand, M.A.H.^a [✉](#), Ahmed, M.^a [✉](#), Rahman, M.M.H.^b [✉](#), Islam, M.M.^c [✉](#)

^aDepartment of Computer Science and Engineering, Khulna University of Engineering & Technology, Khulna, Bangladesh

^bDepartment of Computer Science, KICT, International Islamic University, Selangor, Malaysia

^cDepartment of Computer Science and Engineering, Bangladesh University of Engineering & Technology, Dhaka, Bangladesh

Abstract

[View references \(36\)](#)

Handwritten numeral recognition has gained much interest in recent times because of its diverse application potentials. Bangla and Hindi are the two major languages in Indian subcontinent and a large number of population in vast land scape uses Bangla and Devnagari numeral scripts of these two languages. Well-performed handwritten numeral recognition system for Bangla and Devnagari is challenging because of similar shaped numerals in both scripts; few numerals differ from their similar ones with a very few variation even in printed form. In this study, convolutional neural network (CNN) based two different methods have been investigated for better recognition of Bangla and Devnagari handwritten numerals. Both the methods use rotation-based generated patterns along with ordinary patterns to train CNN but in two different modes. In multiple CNN case, three different training sets (one with ordinary patterns and two with clockwise and anti-clockwise rotation-based generated patterns) are prepared; three different CNNs are trained individually with each of these training sets; and their decisions are combined for final system decision. On the other hand, in the case of single CNN, combination of above three training sets is used to train one CNN. A moderated pre-processing is also employed while generating patterns from the scanned images. The proposed methods have been tested on prominent benchmark handwritten numeral datasets and have achieved remarkable recognition accuracies. The achieved recognition accuracies are found better than reported recognition accuracies of prominent existing methods; and such outperformance mounted proposed methods as better recognition systems. Moreover, CNN's performance improvement due to use of generated patterns has also been clearly identified from the presented experimental results. © 2018 IETE.

Author keywords

- Convolutional neural network
- Handwritten numeral recognition
- Image pre-processing
- Pattern generation

Indexed keywords


- Engineering controlled terms:
- Clocks
- Convolution
- Image processing
- Neural networks

- Compendex keywords
- Convolutional neural network
- Diverse applications
- Handwritten numeral recognition
- Handwritten numeral recognition systems
- Image preprocessing
- Indian subcontinents
- Pattern Generation
- Recognition accuracy

- Engineering main heading:
- Character recognition

Metrics [View all metrics >](#)

1	Citation in Scopus
4.05	Field-Weighted Citation Impact



PlumX Metrics [View all metrics >](#)

Usage, Captures, Mentions, Social Media and Citations beyond Scopus.

Cited by 1 document

Noisy image classification using hybrid deep learning methods
Roy, S.S. , Ahmed, M. , Akhand, M.A.H.
(2018) *Journal of Information and Communication Technology*

[View details of this citation](#)

Inform me when this document is cited in Scopus:

[Set citation alert >](#)

[Set citation feed >](#)

Related documents

Multiple Convolutional Neural Network Training for Bangla Handwritten Numeral Recognition
Akhand, M.A.H. , Ahmed, M. , Rahman, M.M.H.
(2016) *Proceedings - 6th International Conference on Computer and Communication Engineering: Innovative Technologies to Serve Humanity, ICCCE 2016*

Convolutional neural network training with artificial pattern for Bangla handwritten numeral recognition
Akhand, M.A.H. , Ahmed, M. , Rahman, M.M.H.
(2016) *2016 5th International Conference on Informatics,*

ISSN: 03772063
Source Type: Journal
Original language: English

DOI: 10.1080/03772063.2017.1351322
Document Type: Article
Publisher: Taylor and Francis Ltd

Stacked auto encoder training
incorporating printed text data
for handwritten bangla numeral
recognition

Ahmed, M. , Paul, A.K. , Akhand,
M.A.H.
(2017) *19th International
Conference on Computer and
Information Technology, ICCIT
2016*

View all related documents based
on references

Find more related documents in
Scopus based on:

Authors > Keywords >

References (36)

[View in search results format >](#)

☐ All ☐ Export ☐ Print ☐ E-mail ☐ Save to PDF ☐ Create bibliography

- ☐ 1 Plamondon, R., Srihari, S.N.
On-line and off-line handwriting recognition: A comprehensive survey
(2000) *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 22 (1), pp. 63-84. Cited 1495 times.
doi: 10.1109/34.824821
[View at Publisher](#)

- ☐ 2 Pal, U., Chaudhuri, B.B., Belaid, A.
A complete system for bangla handwritten numeral recognition
(2006) *IETE Journal of Research*, 52 (1), pp. 27-34. Cited 19 times.
doi: 10.1080/03772063.2006.11416437
[View at Publisher](#)

- ☐ 3 Lecun, Y., Bengio, Y.
Pattern recognition and neural networks
(1995) *neural Networks*. Cited 2 times.
Arbib M.A., (ed), Cambridge: MIT Press, and," in, Ed

- ☐ 4 LeCun, Y., Bottou, L., Bengio, Y., Haffner, P.
Gradient-based learning applied to document recognition
(1998) *Proceedings of the IEEE*, 86 (11), pp. 2278-2323. Cited 6274 times.
doi: 10.1109/5.726791
[View at Publisher](#)

- ☐ 5 Lecun, Y., Bengio, Y., Hinton, G.
Deep learning
(2015) *Nature*, 521 (7553), pp. 436-444. Cited 3726 times.
<http://www.nature.com/nature/index.html>
doi: 10.1038/nature14539
[View at Publisher](#)

- ☐ 6 Bhattacharya, U., Chaudhuri, B.B.
(2009) *Offline Handwritten Bangla and Devanagari Numeral Databases*
Kolkata: Computer Vision and Pattern Recognition Unit, Indian Statistical Institute, and,. Available
<http://www.isical.ac.in/~ujjwal/download/database.html>

-
- 7 Basu, D.K., Nasipuri, M., Kundu, M., Basu, S., Das, N., Sarkar, R., Mollah, A.F., (...), Saha, S.
(2011) *CMATERdb 3.1.1 & CMATERdb 3.2.1: Handwritten Bangla and Devanagari Numeral Databases*
Kolkata: Center for Microprocessor Application for Training Education and Research, Jadavpur University,
and,. Available
<http://code.google.com/p/cmaterdb/>
-
- 8 Bhattacharya, U., Chaudhuri, B.B.
Handwritten numeral databases of Indian scripts and multistage recognition of mixed numerals

(2009) *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 31 (3), pp. 444-457. Cited 129 times.
doi: 10.1109/TPAMI.2008.88

View at Publisher
-
- 9 Bashar, M.R., Hasan, M.A.F.M.R., Hossain, M.A., Das, D.
Handwritten Bangla numerical digit recognition using histogram technique
(2004) *Asian Journal of Information Technology*, 3, pp. 611-615. Cited 8 times.
-
- 10 Basu, S., Das, N., Sarkar, R., Kundu, M., Nasipuri, M., Basu, D.K.
An MLP based approach for recognition of handwritten 'Bangla' numerals

(2005) *Proceedings of the 2nd Indian International Conference on Artificial Intelligence, IICAI 2005*, pp. 407-417. Cited 15 times.
ISBN: 0972741216; 978-097274121-7
-
- 11 Basu, S., Sarkar, R., Das, N., Kundu, M., Nasipuri, M., Basu, D.K.
Handwritten Bangla digit recognition using classifier combination through DS technique

(2005) *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 3776 LNCS, pp. 236-241. Cited 19 times.
ISBN: 3540305068; 978-354030506-4
doi: 10.1007/11590316_32

View at Publisher
-
- 12 Khan, M.M.R., Rahman, S.M.A., Alam, M.M.
Bangla handwritten digits recognition using evolutionary artificial neural networks
(2004) *Proc. of the 7th International Conference on Computer and Information Technology (ICCIT 2004)*. Cited 9 times.
Dhaka, Bangladesh: 26–28 December, and, ” in
-
- 13 Wen, Y., Lu, Y., Shi, P.
Handwritten Bangla numeral recognition system and its application to postal automation

(2007) *Pattern Recognition*, 40 (1), pp. 99-107. Cited 63 times.
doi: 10.1016/j.patcog.2006.07.001

View at Publisher
-

- 14 Das, N., Sarkar, R., Basu, S., Kundu, M., Nasipuri, M., Basu, D.K.
A genetic algorithm based region sampling for selection of local features in handwritten digit recognition application
(2012) *Applied Soft Computing Journal*, 12 (5), pp. 1592-1606. Cited 43 times.
http://www.elsevier.com/aps/findingjournaldescription.cws_home/621920/description#description
doi: 10.1016/j.asoc.2011.11.030
[View at Publisher](#)
-

- 15 Wen, Y., He, L.
A classifier for Bangla handwritten numeral recognition
(2012) *Expert Systems with Applications*, 39 (1), pp. 948-953. Cited 17 times.
doi: 10.1016/j.eswa.2011.07.092
[View at Publisher](#)
-

- 16 Nasir, M.K., Uddin, M.S.
Hand written Bangla numerals recognition for automated postal system
(2013) *IOSR J. Comput. Eng.*, 8 (6), pp. 43-48. Cited 10 times.
-

- 17 Singh, P.K., Das, S., Sarkar, R., Nasipuri, M.
Recognition of handwritten indic script numerals using mojetta transform
(2017) *Advances in Intelligent Systems and Computing*, 458, pp. 459-466. Cited 3 times.
<http://www.springer.com/series/11156>
ISBN: 978-981102034-6
doi: 10.1007/978-981-10-2035-3_47
[View at Publisher](#)
-

- 18 Singh, P.K., Sarkar, R., Nasipuri, M.
A study of moment based features on handwritten digit recognition
(2016) *Appl. Computat. Intell. Soft Comput.*, pp. 1-17. Cited 3 times.
Article ID: 2796863, and
-

- 19 Akhand, M.A.H., Ahmed, M., Hafizur Rahman, M.M.
Convolutional neural network based handwritten Bengali and Bengali-English mixed numeral recognition
(2016) *Int. J. Image Graph. Signal Process*, 8 (9), pp. 40-50. Cited 3 times.
-

- 20 Chowdhury, A.M.S., Rahman, M.S.
Towards optimal convolutional neural network parameters for Bengali handwritten numerals recognition
(2016) *19th International Conference on Computer and Information Technology, ICCIT 2016*, art. no. 7860237, pp. 431-436.
ISBN: 978-150904089-6
doi: 10.1109/ICCITECHN.2016.7860237
[View at Publisher](#)
-

- ☐ 21 Shopon, M., Mohammed, N., Abedin, M.A.
Bangla handwritten digit recognition using autoencoder and deep convolutional neural network
(2016) *IWCI 2016 - 2016 International Workshop on Computational Intelligence*, art. no. 7860340, pp. 64-68. Cited 2 times.
ISBN: 978-150905768-9
doi: 10.1109/IWCI.2016.7860340
[View at Publisher](#)
-

- ☐ 22 Bajaj, R., Dey, L., Chaudhury, S.
Devnagari numeral recognition by combining decision of multiple connectionist classifiers
(2002) *Sadhana - Academy Proceedings in Engineering Sciences*, 27 (PART 1), pp. 59-72. Cited 54 times.
<http://www.springer.com/engineering/journal/12046>
doi: 10.1007/BF02703312
[View at Publisher](#)
-

- ☐ 23 Shrivastava, S.K., Gharde, S.S.
Support vector machine for handwritten Devanagari numeral recognition
(2010) *Int. J. Comput. Appl.*, 7 (11), pp. 9-14. Cited 14 times.
-

- ☐ 24 Singh, P., Tyagi, N.
Radial basis function for handwritten Devanagari numeral recognition
(2011) *Int. J. Adv. Comput. Sci. Appl.*, 2 (5), pp. 126-129.
-

- ☐ 25 Kumar, R., Ravulakollu, K.K.
Offline handwritten Devnagari digit recognition
(2014) *ARPJ Journal of Engineering and Applied Sciences*, 9 (2), pp. 109-115. Cited 4 times.
http://www.arpnjournals.com/jeas/research_papers/rp_2014/jeas_0214_1006.pdf
-

- ☐ 26 Kumar, R., Ravulakollu, K.K.
Handwritten devnagari digit recognition: Benchmarking on new dataset
(2014) *Journal of Theoretical and Applied Information Technology*, 60 (3), pp. 543-555. Cited 6 times.
<http://www.jatit.org/volumes/Vol60No3/11Vol60No3.pdf>
-

- ☐ 27 Singh, P., Verma, A., Chaudhari, N.S.
Devanagri handwritten numeral recognition using feature selection approach
(2014) *Int. J. Intell. Syst Appl.*, 6 (12), pp. 40-47. Cited 4 times.
-

- ☐ 28 Singh, P., Verma, A., Chaudhari, N.
Feature selection based classifier combination approach for handwritten Devanagari numeral recognition
(2015) *Sadhana - Academy Proceedings in Engineering Sciences*, 40 (6), pp. 1701-1714. Cited 3 times.
<http://www.springer.com/engineering/journal/12046>
doi: 10.1007/s12046-015-0419-x
[View at Publisher](#)
-

-
- 29 Goyal, M., Garg, N.K.
Handwritten Devanagari numeral recognition using structural and statistical features
(2014) *Int. J. Emerg. Technol. Comput. Appl. Sci.*, 9, pp. 324-329.
-
- 30 Arya, S., Chhabra, I., Lehal, G.S.
Recognition of Devnagari numerals using gabor filter

(2015) *Indian Journal of Science and Technology*, 8 (27), art. no. IPL0583. Cited 7 times.
<http://www.indjst.org/index.php/indjst/article/view/81856>
doi: 10.17485/ijst/2015/v8i27/81856

View at Publisher
-
- 31 Prabhanjan, S., Dinesh, R.
Handwritten Devanagari characters and numeral recognition using multi-region uniform local binary pattern

(2016) *International Journal of Multimedia and Ubiquitous Engineering*, 11 (3), pp. 387-398.
http://www.sersc.org/journals/IJMUE/vol11_no3_2016/37.pdf
doi: 10.14257/ijmue.2016.11.3.37

View at Publisher
-
- 32 Akhand, M.A.H., Ahmed, M., Rahman, M.M.H.
Convolutional neural network training with artificial pattern for Bangla handwritten numeral recognition

(2016) *2016 5th International Conference on Informatics, Electronics and Vision, ICIEV 2016*, art. no. 7760077, pp. 625-630. Cited 4 times.
ISBN: 978-150901269-5
doi: 10.1109/ICIEV.2016.7760077

View at Publisher
-
- 33 Rahman, M.M., Akhand, M.A.H., Islam, S., Shill, P.C., Hafizur Rahman, M.M.
Bangla handwritten character recognition using convolutional neural network
(2005) *Int J. Image Graphics Signal Process.*, 7 (3), pp. 42-49. Cited 10 times.
-
- 34 Melville, P., Mooney, R.J.
Creating diversity in ensembles using artificial data

(2005) *Information Fusion*, 6 (1), pp. 99-111. Cited 165 times.
doi: 10.1016/j.inffus.2004.04.001

View at Publisher
-
- 35 Akhand, M.A.H., Murase, K.
Ensembles of neural networks based on the alteration of input feature values

(2012) *International Journal of Neural Systems*, 22 (1), pp. 77-87. Cited 25 times.
doi: 10.1142/S0129065712003079

View at Publisher
-

□ 36 Palm, R.B.
DeepLearnToolbox
(2012) *GitHub*
in,. Available
<https://github.com/rasmusbergpalm/DeepLearnToolbox/>

© Copyright 2018 Elsevier B.V., All rights reserved.

< Back to results | 1 of 1

^ Top of page

About Scopus

- What is Scopus
- Content coverage
- Scopus blog
- Scopus API
- Privacy matters

Language

- 日本語に切り替える
- 切换到简体中文
- 切换到繁體中文
- Русский язык

Customer Service

- Help
- Contact us

ELSEVIER

Terms and conditions Privacy policy

Copyright © 2018 Elsevier B.V. All rights reserved. Scopus® is a registered trademark of Elsevier B.V.

Cookies are set by this site. To decline them or learn more, visit our Cookies page.

RELX Group™