A
Dissertation
On

# HANDWRITTEN DIGIT CLASSIFICATION USING DEEP LEARNING

Submitted in partial fulfilment of the requirements

For the award of the degree of

## MASTER OF TECHNOLOGY

## IN

## SOFTWARE ENGINEERING

By

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# CERTIFICATE

This is to certify that the project report entitled **"HANDWRITTEN DIGIT CLASSIFICATION USING DEEP LEARNING"** is a bona fide record of work carried out by Karan Kumar (2K13/SWE/06) under my guidance and supervision, during the academic session 2013-2015 in partial fulfilment of the requirement for the degree of Master of Technology in Software Engineering from Delhi Technological University, Delhi.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

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# ABSTRACT

Abstract Representation of data is identified as a very important concept before applying any classification technique as it helps to make sense of data (images, videos etc.) and learn features. However training a single layer linear or non linear classifier has serious limitations considering the vastness of variability in data. The variability can be expressed in terms of handwriting of a person, pre-processing of images in the problem domain of classifying handwritten digits. Selection of features/latent factors therefore becomes an important aspect of classification since they are able to represent more abstract concepts related to data and each one can be provided a unique significance value. We have compared various approaches and their variations to generate an optima set of features which can be used for the classification problem of handwritten digits. Restricted Boltzmann machines(RBM) which form the baseline for deep learning are used to discover latent factors which then feed forward to higher level RBM's or classifiers. The classifiers studied in the research include Linear Mapping, Radial Basis Function Neural Network, and Backpropagation and up-down algorithm. Results from all variations in RBM parameters and classifiers are observed and discussed. We have compared our results with other related works and it is found that the maximum accuracy achieved is 97.7%

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# ABBREVIATIONS USED

| | |
|---|---|
| RBM | Restricted Boltzmann machine |
| DRBM | Discriminative Restricted Boltzmann machine |
| DBM | Deep Boltzmann Machines |
| DBN | Deep Belief Nets |
| DNN | Deep Neural Networks |
| BP | Back Propagation |
| RBFNN | Radial Basis Function Neural Network |
| FA | Factor Analysis |
| RBF | Radial Basis Function |
| PDAs | Personal Digital Assistants |
| BBRBM | Bernoulli- Bernoulli RBM |
| GBRBM | Gaussian-Bernoulli RBM |
| MRF | Markov Random Field |
| MCMC | Markov chain Monte Carlo |
| MLP | Multilayer Preceptor model |
| ML | Machine Learning |
| HMM | Hidden Markov Models |
| CRF | Conditional Random Fields |
| SVMs | Support Vector Machines |
| CD | Contrastive Divergence |
| w.r.t. | With respect to |
| i.e. | That is |