# Improving Neural Networks by Preventing Co-adaptation of Feature Detectors

G. E. Hinton, N. Srivastava, A. Krizhevsky, I. Sutskever and R. R. Salakhutdinov (2012)

# Problem in a nutshell

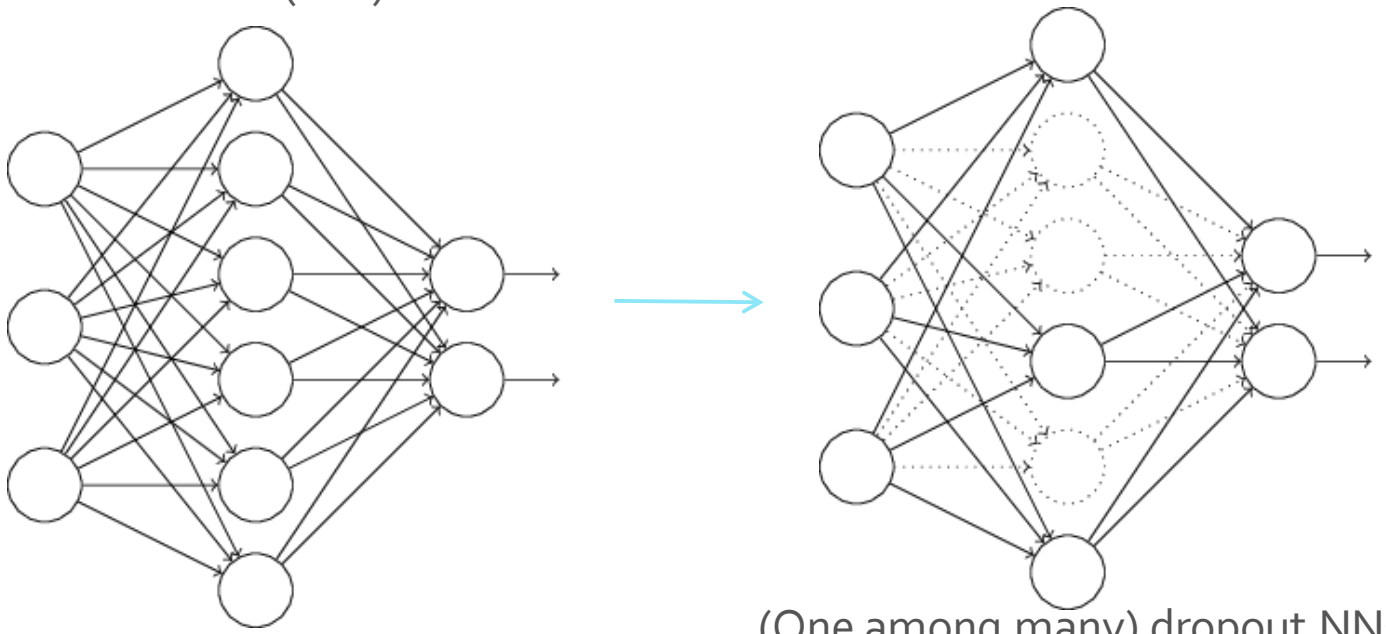
- Training a large feed-forward neural network using a small dataset may result in an "overfit" model

# (One) Existing solution

- Model Averaging
  - Instead of using one(large) NN, use many different(large) NNs to classify or predict
  - Test data on each model
  - To obtain the final output, combine individual model outputs(predictions) via averaging or voting scheme
  - But, training and testing on multiple large NNs becomes computationally expensive

# Proposed solution

- Model Averaging using "dropout"
  - Instead of using one large NN, use many dropout (smaller) NNs to classify or predict
  - Test data on (one) "mean network"



(One among many) dropout NNs

# Proposed solution in detail

## Training

- For each training instance (mini-batch)
  - Create a dropout NN by omitting random 50% hidden and/or 20% input units
  - Renormalize weight vector(W) when it exceeds the upper bound on L2 norm of W
  - After each epoch, increment the learning rate by a factor of 0.998

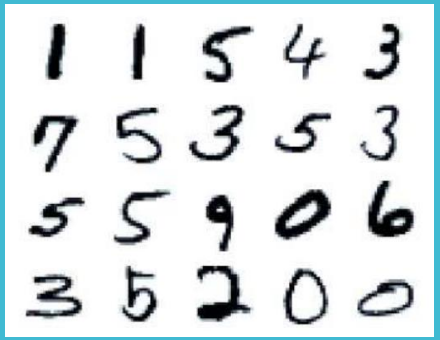
## Testing

- Create a "mean network"
  - In the initial NN(with all hidden units), reduce all outgoing weights by a factor of 0.5
  - Log likelihood estimate is guaranteed to be higher than each individual network*

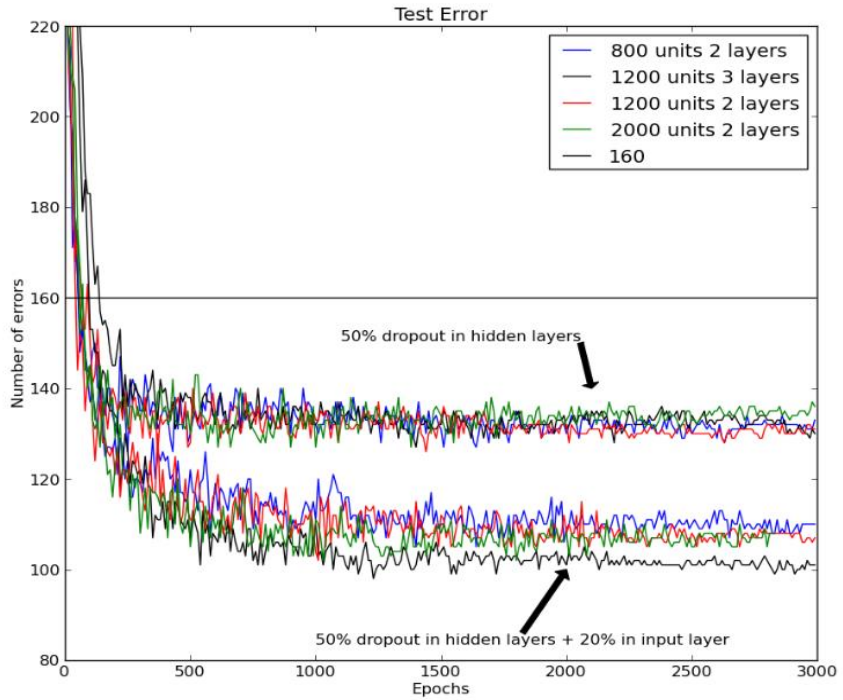
# Experiments and Results I

MNIST dataset

(60000 train, 20000 test)



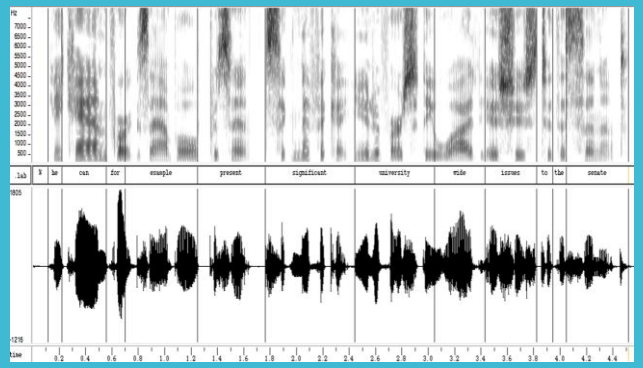
- "Dropout" training using different feed-forward NN architectures
- "Dropout" fine-tuning on deep belief nets and deep Boltzmann machines
  - #Units in each hidden layer – 500, 1000
  - #Errors reduced from 95 to 79 after 50% dropout in DBM; from 118 to 92 in DBN



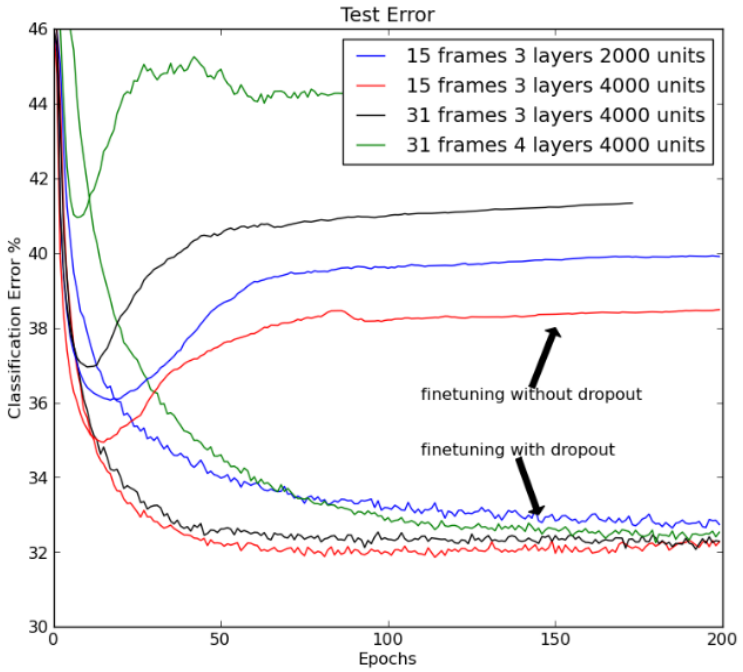
# Experiments and Results II

TIMIT dataset

(630 speakers - 10 word sentence)



- "Dropout" training using NN architectures
  - #Units in input layer – 15,31; output layer – 10
- "Dropout" fine-tuning vs Standard backpropagation fine-tuning



# Experiments and Results III

Reuters Corpus Volume I

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Delegates to the three day Congress will be considering 26
resolutions concerning various issues, including the future
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and eradication program, the NPPC said. A large
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- 804,414 text documents - 103 different topics
- 50 classes with 402,738 documents
- Random split of data into two halves for training and testing
- Utilize 2000 most frequent words to represent documents
- Standard backpropagation NN error rate reduced from 31.7% to 29.63% with 50% dropout

# Experiments and Results IV

CIFAR-10 dataset

- 50000 train – 10000 test (tiny) 32x32 images
- 10 output classes
- State-of-the-art -18.5% error rate
- CNN without dropout - 16.6% error rate
  - 3 convolutional layers
  - 3 max-pooling layers
- CNN with dropout - 15.6% error rate
  - 50% dropout on last hidden layer

# Experiments and Results V

IMAGENET dataset

- Millions of high-resolution images resized to 256x256 inputs
- 1000 classes with 1000 examples each
- State-of-the-art - 47.7% error rate
- CNN without dropout – 48.6% error rate
  - 5 convolutional layers
  - 3 max-pooling layers after 1st, 2nd and 5th layers
- CNN with 50% dropout – 42.4% error rate
  - 2 more hidden layers before the output layer

# Summary

- Proposed "dropout" technique solved the problem of overfitting
- Implementation to test generalization performance
- Improved accuracy in popular speech recognition, natural language processing and object recognition datasets compared to standard backpropagation techniques without dropout.



Image credits: lifehacker.com

# Reducing the Dimensionality of Data with Neural Networks

G. E. Hinton and R. R. Salaktudinov(2006)

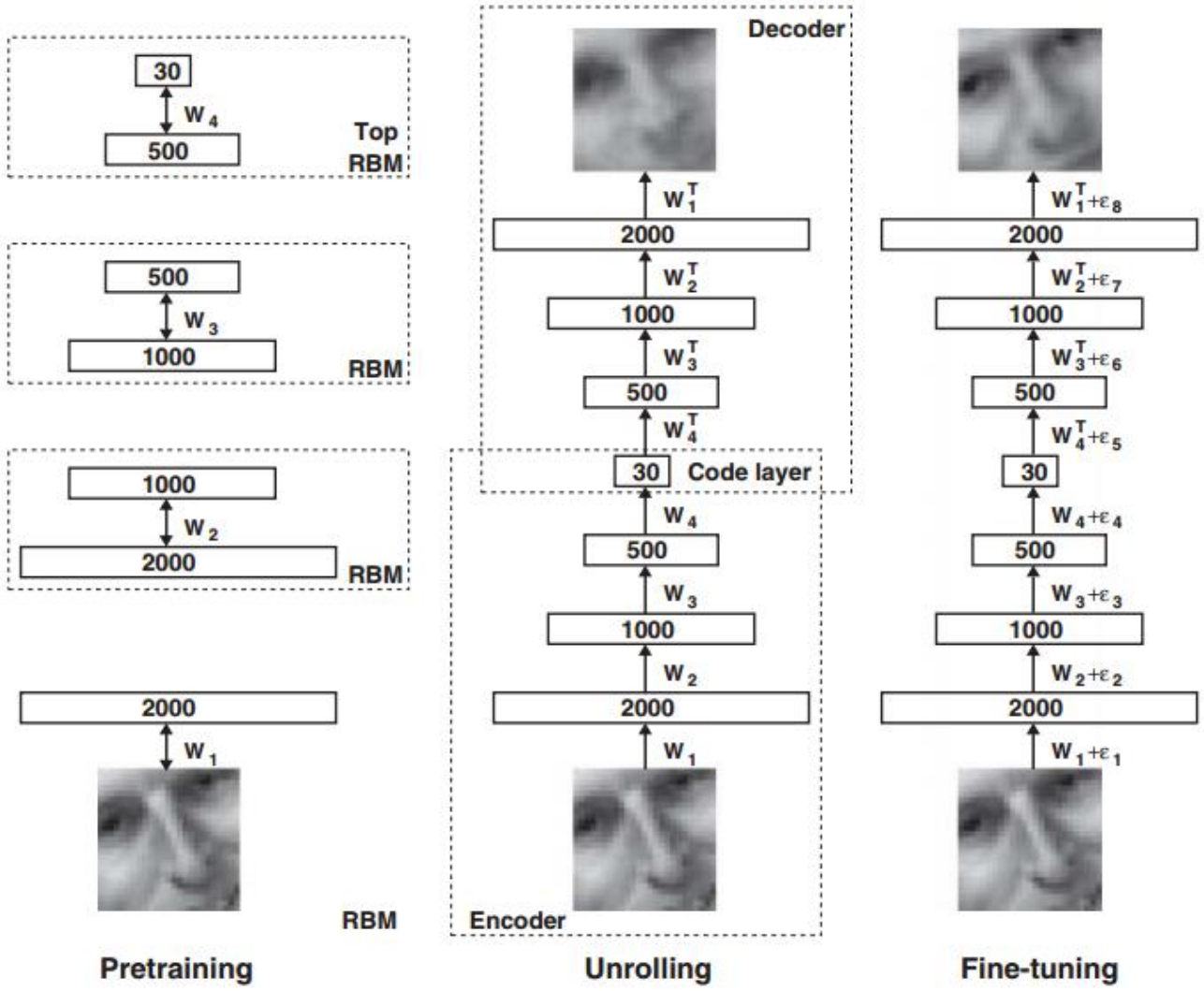
# Problem in a nutshell

- High dimensional data and large NNs
- Dimensionality reduction usually done using
  - Principal Component Analysis(PCA) for images
  - Latent Semantic Analysis(LSA) for documents(words)
- Autoencoders can be used
- But, how to find out "good" initial weights

# Proposed solution

- Pretraining
  - Learn a stack of restricted Boltzmann machines (RBMs)
  - Each RBM has only one layer of feature detectors
  - Each RBM's learned feature activations used as "data" for training the next RBM in the stack
- Unrolling
  - Create a deep autoencoder by "un-rolling" the RBMs
- Fine-tuning (weights)
  - Identify weights via backpropagation of error derivatives

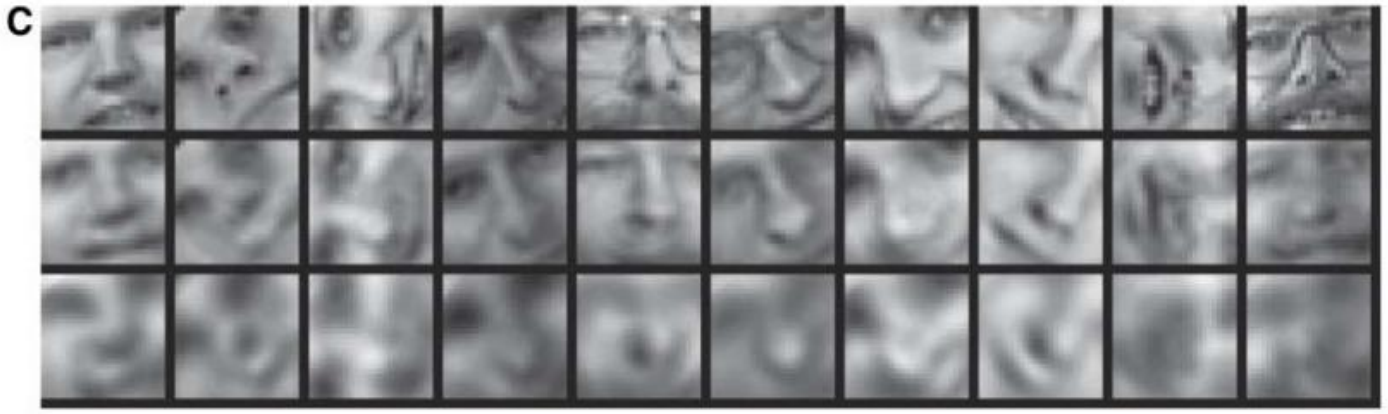
# Proposed solution(visual)



# Experiments and Results I

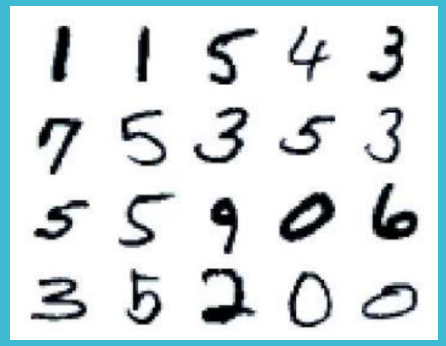
OLIVETTI dataset

- 30-dimensional 625-2000-1000-500-30 autoencoder(2nd row)
- 30- dimensional PCA(3rd row)
- Reconstructed images



# Experiments and Results II

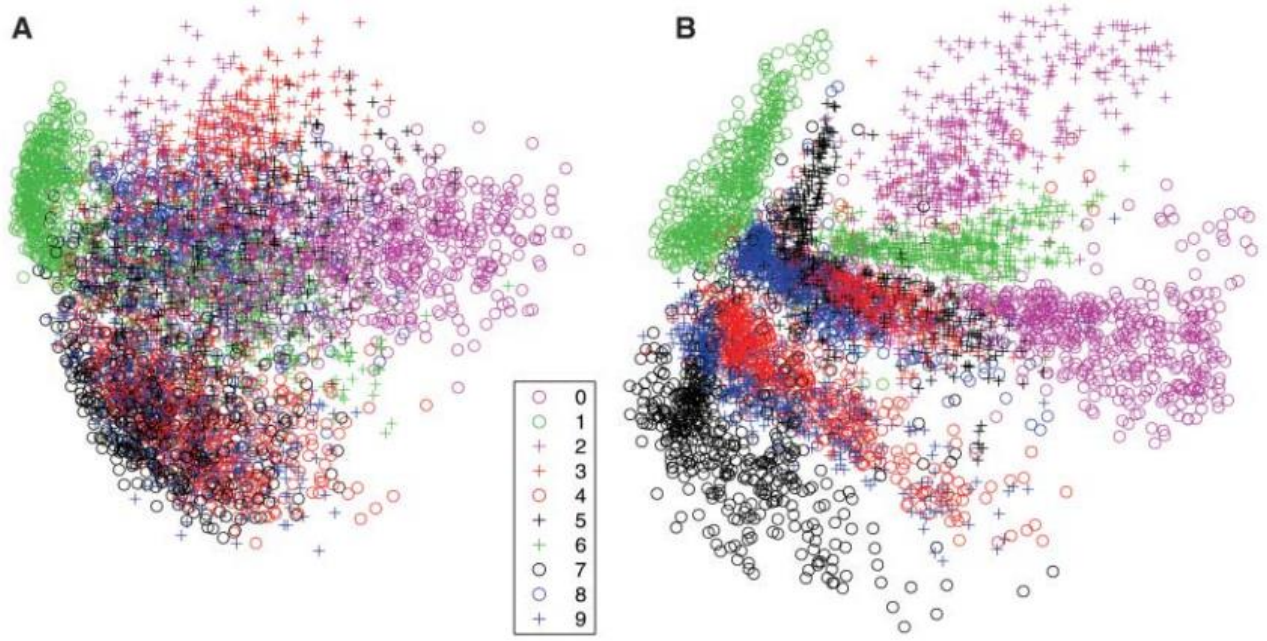
MNIST dataset



- 2-dimensional codes for 500 digits of each of the 10 classes

A) PCA

B) 784-1000-500-250-30 autoencoder



# Experiments and Results III

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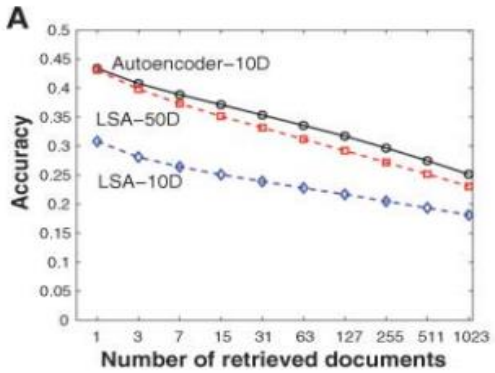
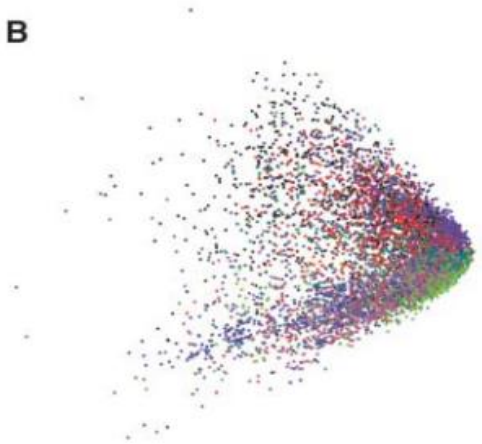
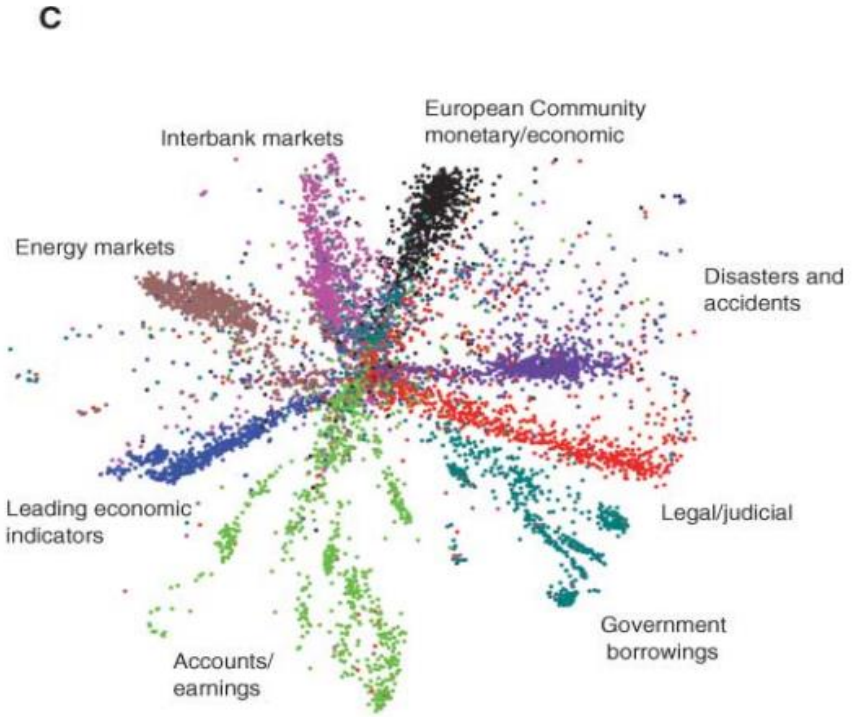
- 2-dimensional codes for 804,414 newswire stories

B) Latent Semantic Analysis (LSA)

C) 2000-500-250-125-10 autoencoder



# Summary

- Proposed pre-training methodology for autoencoders that removes unimportant variations in input data
- Implemented the same and achieved optimal results
- Outperformed standard dimensionality reduction techniques(PCA, LSA) on popular image recognition and natural language processing datasets



Image credits: lifehacker.com

# References


- Hinton, G.E. and Salakhutdinov, R.R., 2006. Reducing the dimensionality of data with neural networks. *science*, *313*(5786), pp.504-507.
- Hinton, G.E., Srivastava, N., Krizhevsky, A., Sutskever, I. and Salakhutdinov, R.R., 2012. Improving neural networks by preventing co-adaptation of feature detectors. *arXiv preprint arXiv:1207.0580*.