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# Denoising Gated Boltzmann Machines

#### Charlie Tang

Centre for Theoretical Neuroscience University of Waterloo

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## Introduction

- Visual recognition in the real world is noisy (occlusions, shadows, etc...)
- For discriminative classifiers, we can only improve recognition by adding examples to the training set or play with model architecture
- RBM and DBM are generative models, we should use them to denoise *before* recognition

Introduction

Approach

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## **MNIST** Recognition With Noise



Figure: Standard DBN is not robust when facing noise during recognition.

Introduction

Approach

## (Tang & Eliasmith, ICML '10)

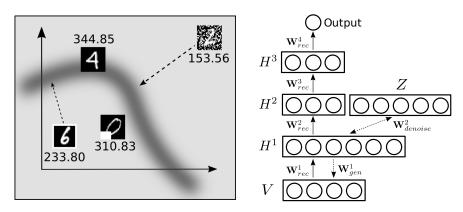


Figure: Network with attentional feedback modulation.

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## Results

#### Table: Summary of recognition results

Network	clean	border	block	random
After denoising	1.24%	1.29%	19.09%	3.83%
Trained w/ noise	1.61%	1.77%	8.39%	6.64%

- Denoising algorithm is computationally expensive, complicated
- Top-down and bottom-up inputs are combined in an rather ad hoc way

Approach

## A Better Denoising BM

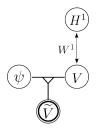


Figure: "Denoising gated Boltzmann machine".

- Adding  $\tilde{v}$  layer allows a buffer between noisy input  $(\tilde{v})$  and clean images (v)
- Use  $\psi$  to explain the noise and occlusion
- Top down modulation of  $\psi$  can help denoising
- Denoising is easy by running Gibbs sampling on conditional  $p(\mathbf{v}|\tilde{\mathbf{v}})$

## DGBM Energy

$$E(\mathbf{v}, \tilde{\mathbf{v}}, \psi, \mathbf{h}^{1}) = -\mathbf{b}^{\mathsf{T}}\mathbf{v} - \mathbf{c}^{\mathsf{T}}\mathbf{h}^{1} - \mathbf{v}^{\mathsf{T}}W^{1}\mathbf{h}^{1} - \mathbf{a}^{\mathsf{T}}\psi + \sum_{i}\gamma_{i}\psi_{i}\log(1 + \eta_{i}(v_{i} - \tilde{v}_{i})^{2}))$$

Noise likelihood:

- let  $d_i = |v_i \tilde{v}_i|$
- $p(d_i|\psi_i=1)\propto (1+\eta_i d_i^2)^{-\gamma_i}$
- $p(d_i|\psi_i=0)\propto constant$

Learning:

- max  $\frac{1}{N} \log p(\mathbf{v}, \mathbf{\tilde{v}}, \psi)$  using Persistent CD
- +ve phase samples  $p(\mathbf{h}|\mathbf{v})$
- -ve phase samples  $p(\mathbf{h}|\mathbf{v})$  and  $p(\mathbf{v}, \mathbf{\tilde{v}}, \psi|\mathbf{h})$

## DGBM Learning

v	vtilde	psi
0000000000	00400266000	0101010101010101010
1 Z 2 1 1 7 7 3 1 7	1240072741972	
8222222222	2222222222	2222222X22
33333333333	3333133558	22232232
4444444444	33333333333 577947234773	无法使某人 化乙基乙基乙基
555555555	1255556555	
<b>66666666</b>	6666666666	
7777777777	1977.1947.1927.1947.2727.27	7.767.77.1.101.57.477
8888888888	2888 38818	
99999999999	9.9.19.9.79 9 9 9 9	CONTRACTOR STATES AND A SAME
10 v	to utilitie	fo pri
fp_v		fp_psi
1371619640	2571629690	fp_psi
		lp_pei
93716 <b>156</b> 40 951 <b>87</b> 37 <b>0</b> 7 <b>4</b> 1 <b>7</b> 05719171	2371679690 2178237259 1785719757	12_pi
2 S 7 I 6 7 9 6 9 0 2 J 7 8 3 7 7 7 7 7 7 7 8 5 7 1 9 7 7 7 5 2 8 9 7 7 2 4 2 8	2371479640 2570337259 7725719757 5839272438	(p_psi
2 S 7 I 6 7 9 6 9 0 2 S 7 0 3 7 0 7 4 1 7 0 5 7 1 9 7 7 S 8 9 9 7 7 2 4 2 8 7 5 9 F 3 1 0 8 2 3	2371679690 2178237259 1785719757	Ip_psi   0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0   0 0 0 0 0 0 0 0 0 0
7   1   6   7   6   9   0     8   5   7   8   7   7   7   7   7     1   7   3   7   1   9   1   7   7   7     5   8   9   7   7   2   4   8   8     7   5   9   6   3   1   0   8   2   3     0   #   3   9   6   6   3   2   9	2371479640 2570337259 7725719757 5839272438	Image: constraint of the state of the s
7 8 7 1 6 7 6 4 0   8 5 1 8 7 7 7 7   1 7 3 5 1 9 7 7 7   5 8 9 7 7 4 8   7 5 9 6 3 1 0 8 2   7 5 9 6 3 1 0 8 2 3   0 4 3 9 6 6 3 2 3   0 4 4 7 5 4 6 3 2 3	2371479640 25702937029 720571977 5239272438 7595310323 043766323 044756739	Ip_psi     Image: Strate
7   8   7   1   6   7   6   4   0     9   5   1   8   7   7   7   7   7     1   7   3   5   7   1   9   1   7   1     5   9   8   9   7   7   2   4   2   8     7   5   9   6   7   7   7   4   2   8     7   5   9   6   6   3   2   3   0   4   3   4   4   6   6   3   2   3   0   4   3   4   6   6   3   2   3   0   4   3   4   3   4   3   5   3   0   1   3   8   7   5   4   3   3   5   3   3   3   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5   5 <td< td=""><td>2371479690 25716737029 7705719771 593972429 7595310323 0459666323 045967773823 59001382764</td><td>Ip_psi   Ip_psi     Image: Image:</td></td<>	2371479690 25716737029 7705719771 593972429 7595310323 0459666323 045967773823 59001382764	Ip_psi   Ip_psi     Image:
7 8 7 1 6 7 6 4 0   8 5 1 8 7 7 7 7   1 7 3 5 1 9 7 7 7   5 8 9 7 7 4 8   7 5 9 6 3 1 0 8 2   7 5 9 6 3 1 0 8 2 3   0 4 3 9 6 6 3 2 3   0 4 4 7 5 4 6 3 2 3	2371479640 25702937029 720571977 5239272438 7595310323 043766323 044756739	Ip_psi     Image:

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