Spatiotemporal Sequence Memory for Prediction using Deep Sparse Coding

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Brain is an advanced prediction machine

• Prediction is intelligence framed by understanding – Jeff Hawkins
• Brain is doing active inference, predictive coding - Karl Friston
• Prediction is the essence of intelligence - Yann LeCun

• Prediction happens in multiple places within the brain – Breska, Ivry (2018)
• Neurons in the visual system became predictive over time – Georg Keller (2017)
Sparse Coding

Original

Reconstruction

\( \Phi T(\vec{u}) \)
Sparse Coding

\[ \hat{I} \approx \Phi T(\tilde{u}) \]
Sparse Coding

\[ E = \frac{1}{2} \left\| \hat{I} - \{ \Phi T(\hat{u}) \} \right\|_2^2 + \lambda \| T(\hat{u}) \|_1 \]
Locally Competitive Algorithm (LCA) - Rozell et al. 2008

• Dynamical sparse solver
• Neurons are leaky integrators driven by feedforward input
• Lateral inhibition by other neurons in the population
• Learning the dictionary is through Hebbian like learning rules
Deep Sparse Coding
Deep Sparse Coding

![](image)
Deep Sparse Coding
Deep Sparse Coding

I''

V1''

D1

V2

V1'

D2

V1

D1

I

Deep Sparse Coding

I'

V2

D2

V1

D1

I
Deep Sparse Coding

I' → V2 → V1 → I

D1

D2
Deep Sparse Coding

Multimodal Associations
- Image and Image
- Image and Audio
Deep Sparse Coding

Multimodal Associations
Image and Image
Image and Audio
Any number of modalities or...
Spatiotemporal architecture
How is this predictive?
Test Data

- Reconfigurable high bay
- Controllable lighting, we can test in both poor and good lighting
- Large room enables viewing at a distance
8x8 convolutional kernels
5 frames
256 dictionary elements
Reconstruct the future
Spiking LCA dynamics on a Loihi predecessor

Intense but very brief period of competition

Much faster convergence on a neuromorphic architecture
Future and Conclusion

• We predict that we will be look at implementations of our framework on neuromorphic hardware
• We have shown the ability to hallucinate the future, quantify prediction error
• We are only utilizing an unsupervised reconstruction

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Questions
Future Reconstruction Error
Top-down Feedback
Top-down Feedback

V1 -> D1

V2 -> D2

I'