

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



Original

$$\overbrace{\vec{I}}$$



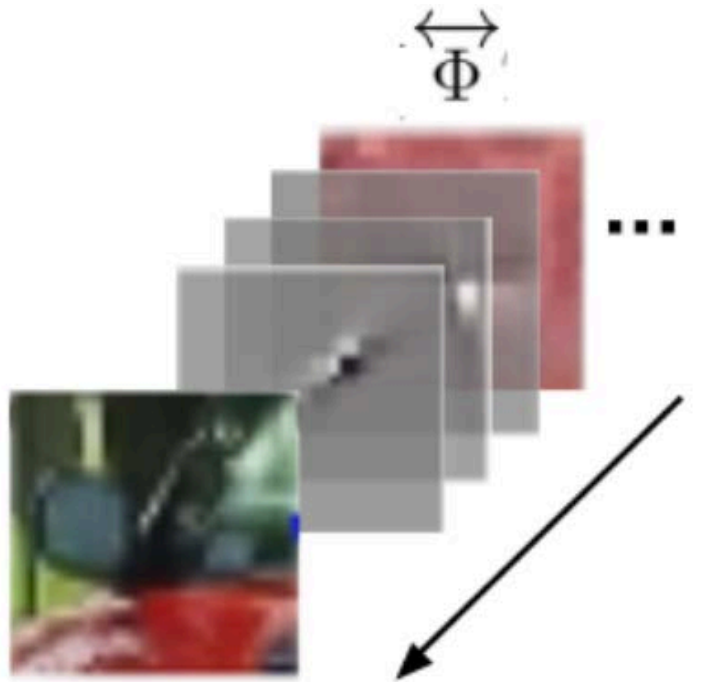
Reconstruction



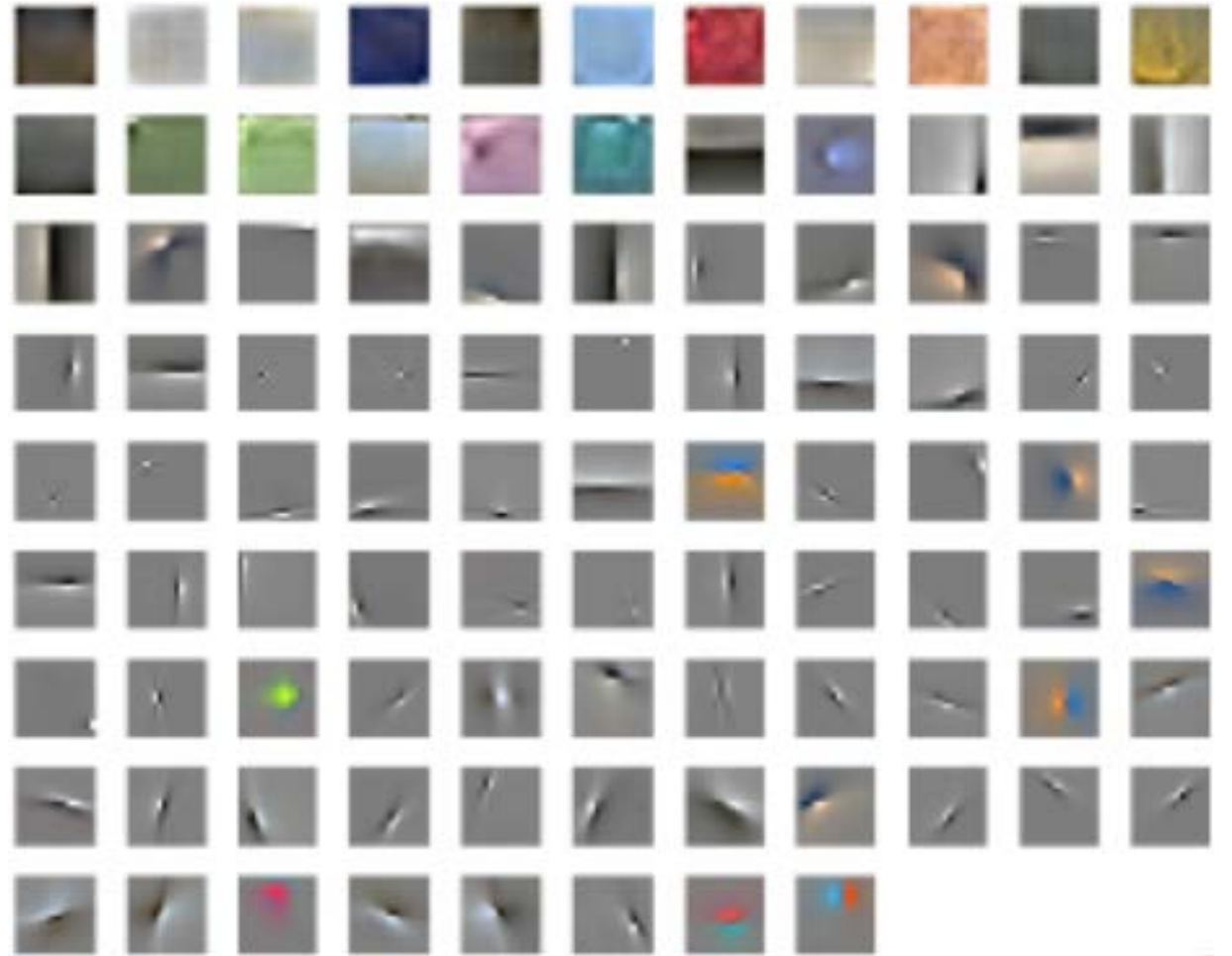
Reconstruction

$$\overbrace{\Phi T(\vec{u})}$$

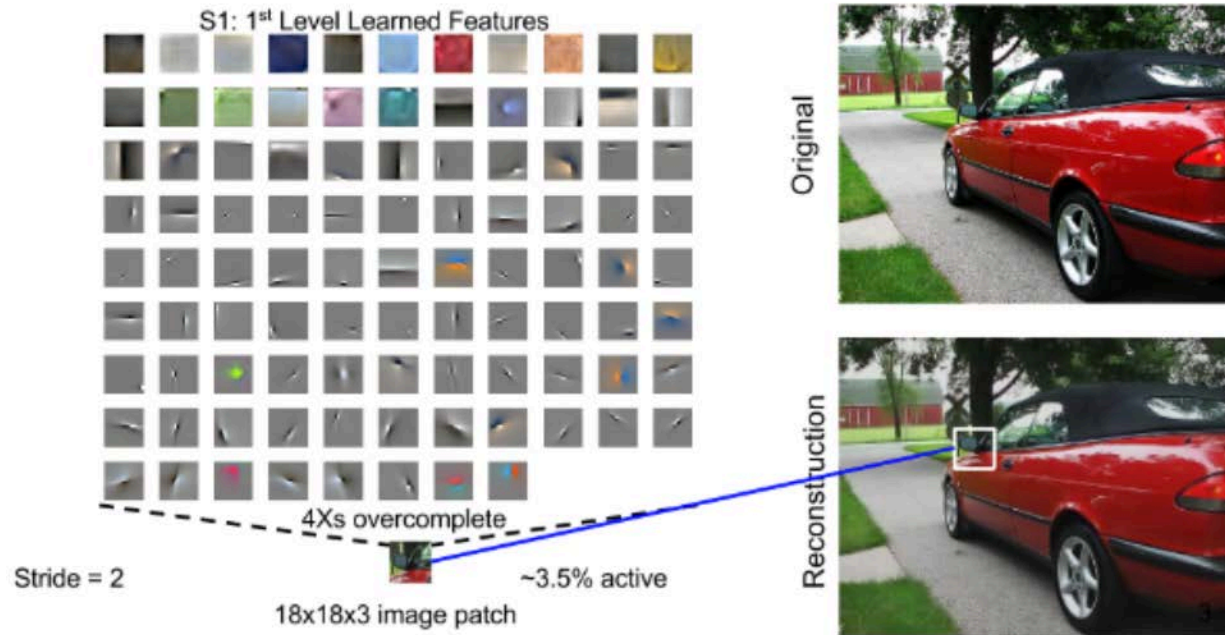
Sparse Coding



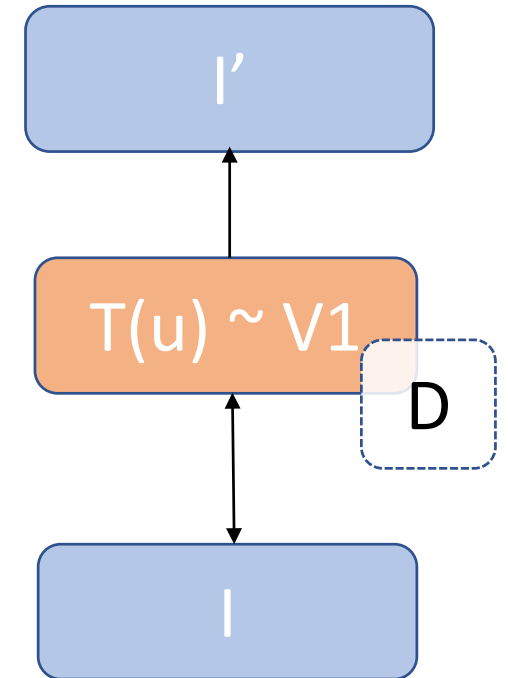
$$\text{Original } \underbrace{\vec{I}} \approx \underbrace{\Phi}_{\text{Reconstruction}} T(\vec{u})$$



Sparse Coding



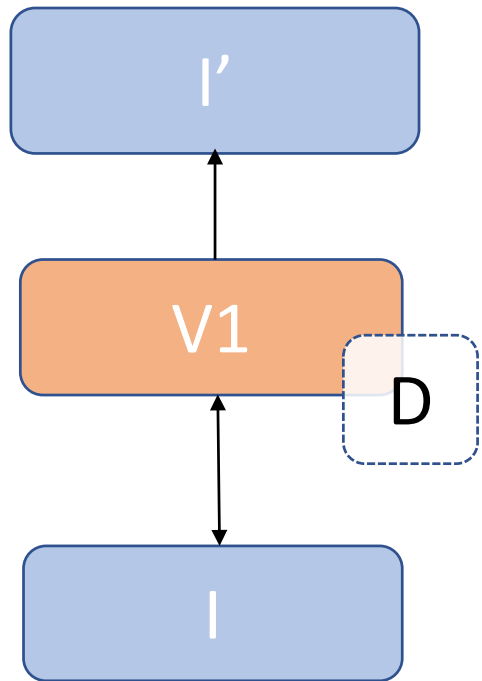
$$E = \frac{1}{2} \underbrace{\|\vec{I} - \{\Phi \vec{u}\}\|_2^2}_{\text{Reconstruction Term}} + \underbrace{\lambda \|\vec{u}\|_1}_{\text{Sparsity Term}}$$



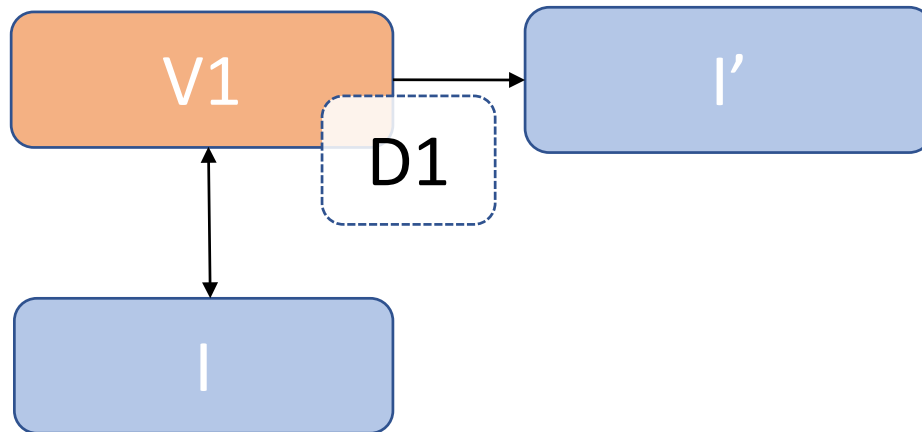
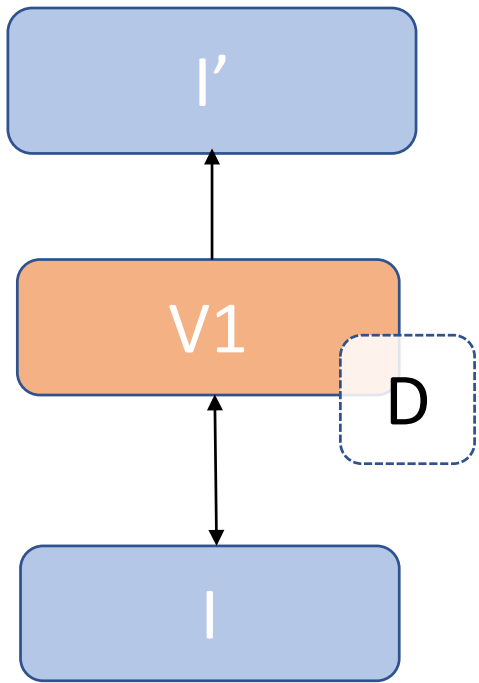
Locally Competitive Algorithm (LCA) - Rozell et al. 2008

- 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

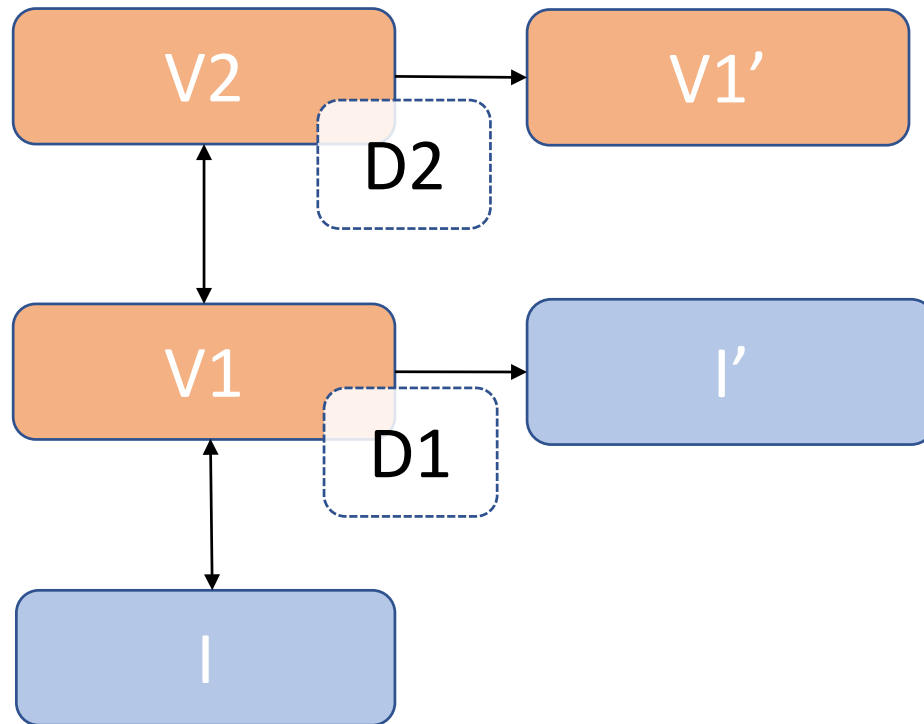
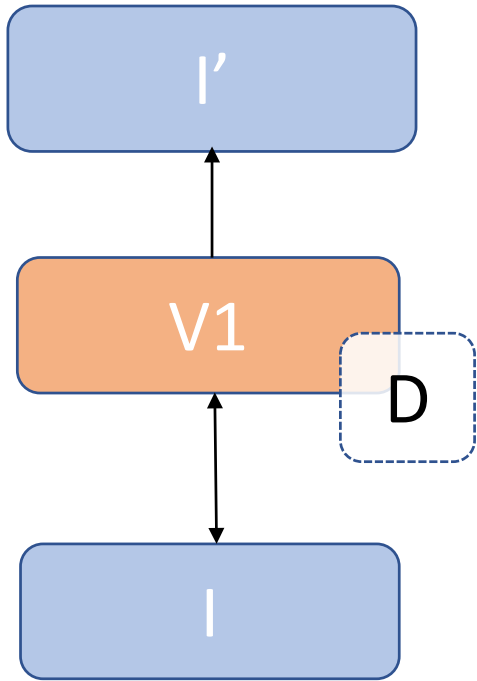
Deep Sparse Coding



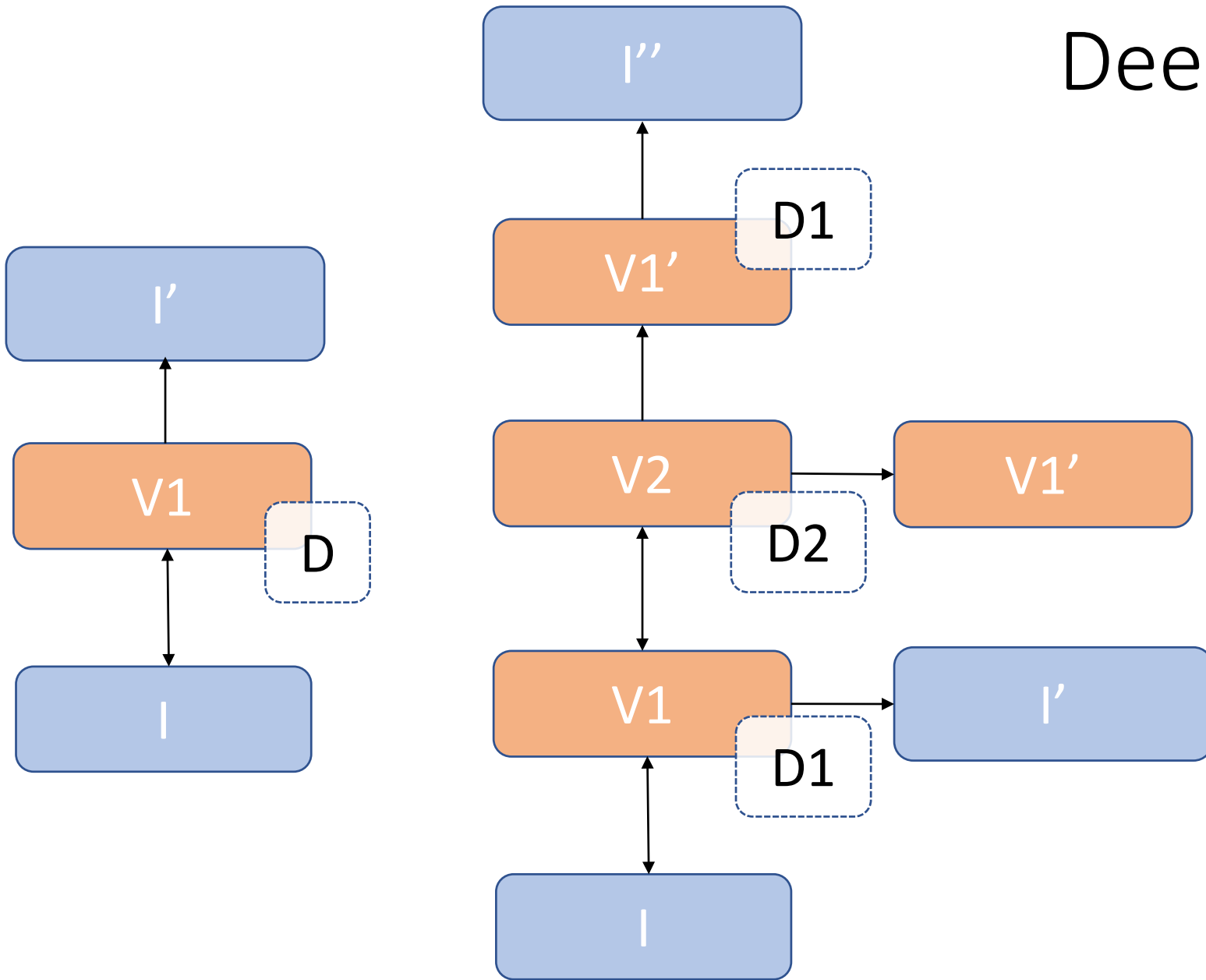
Deep Sparse Coding



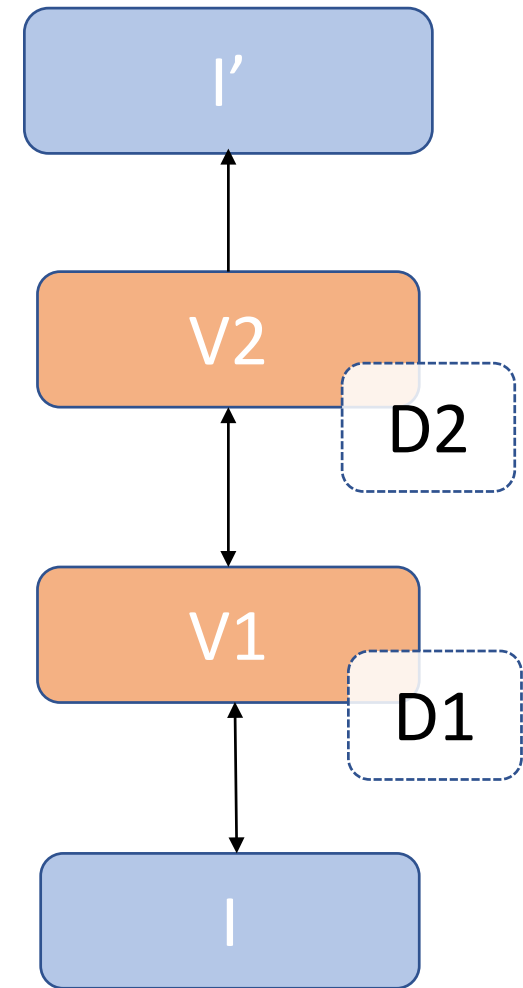
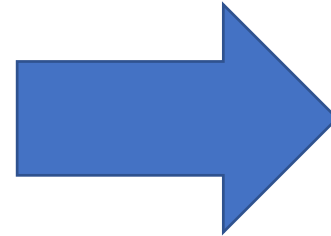
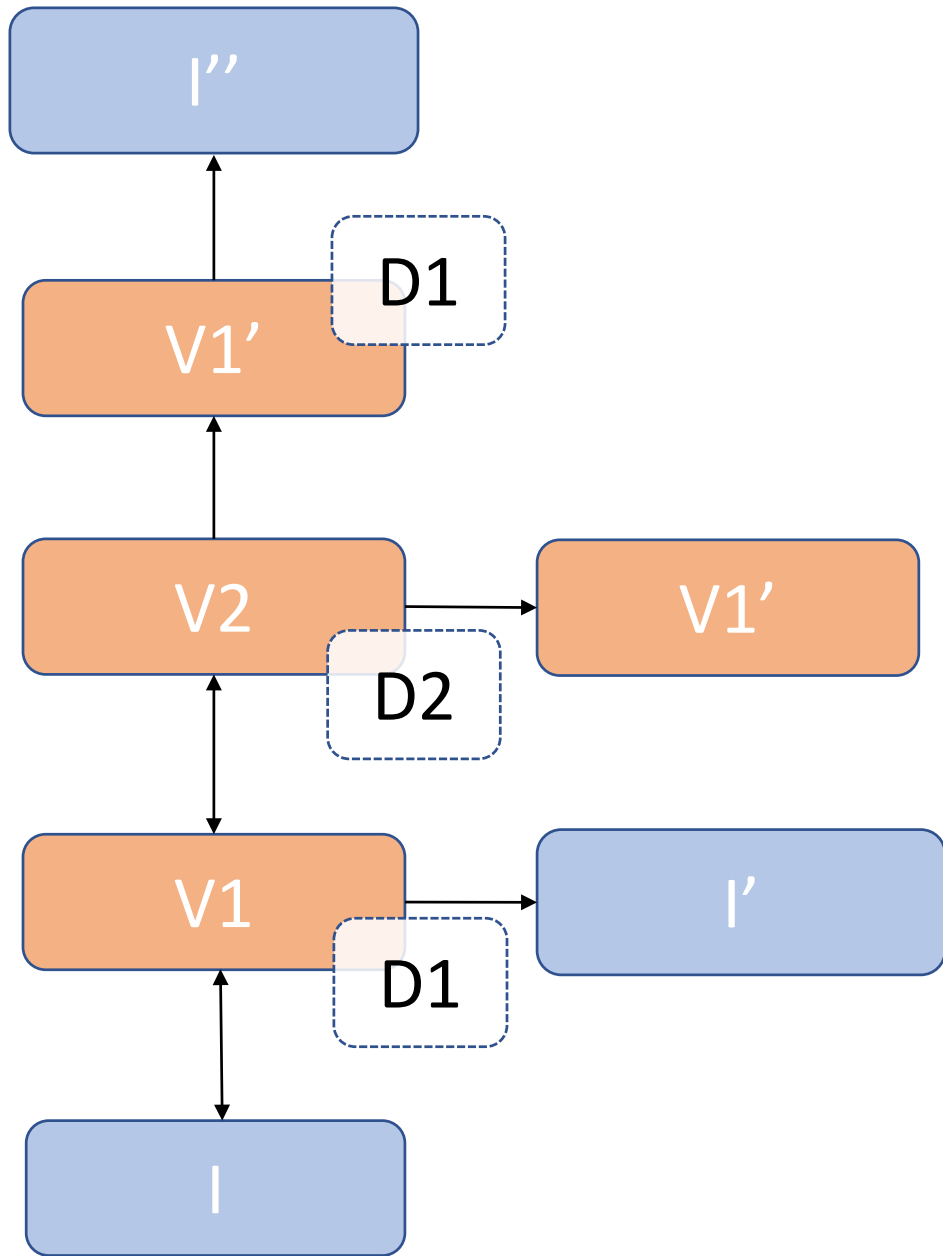
Deep Sparse Coding



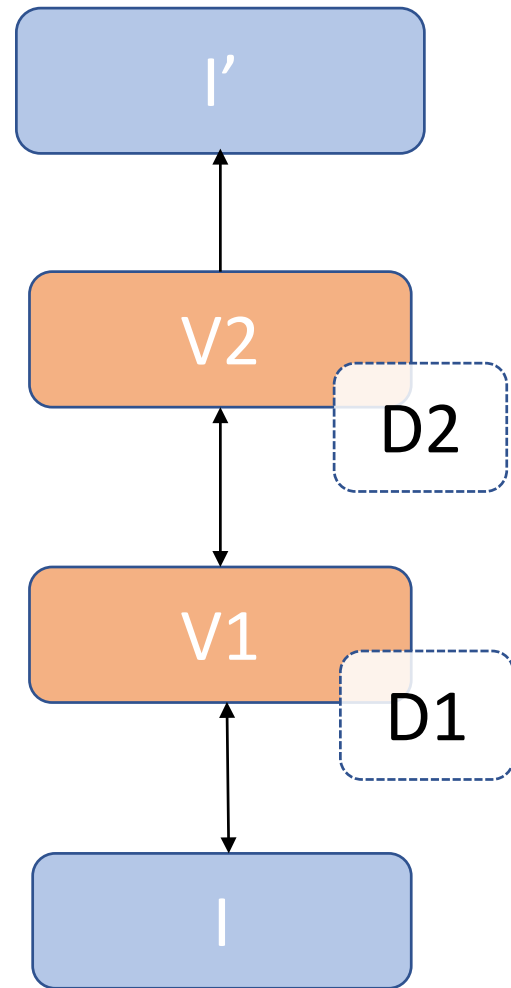
Deep Sparse Coding



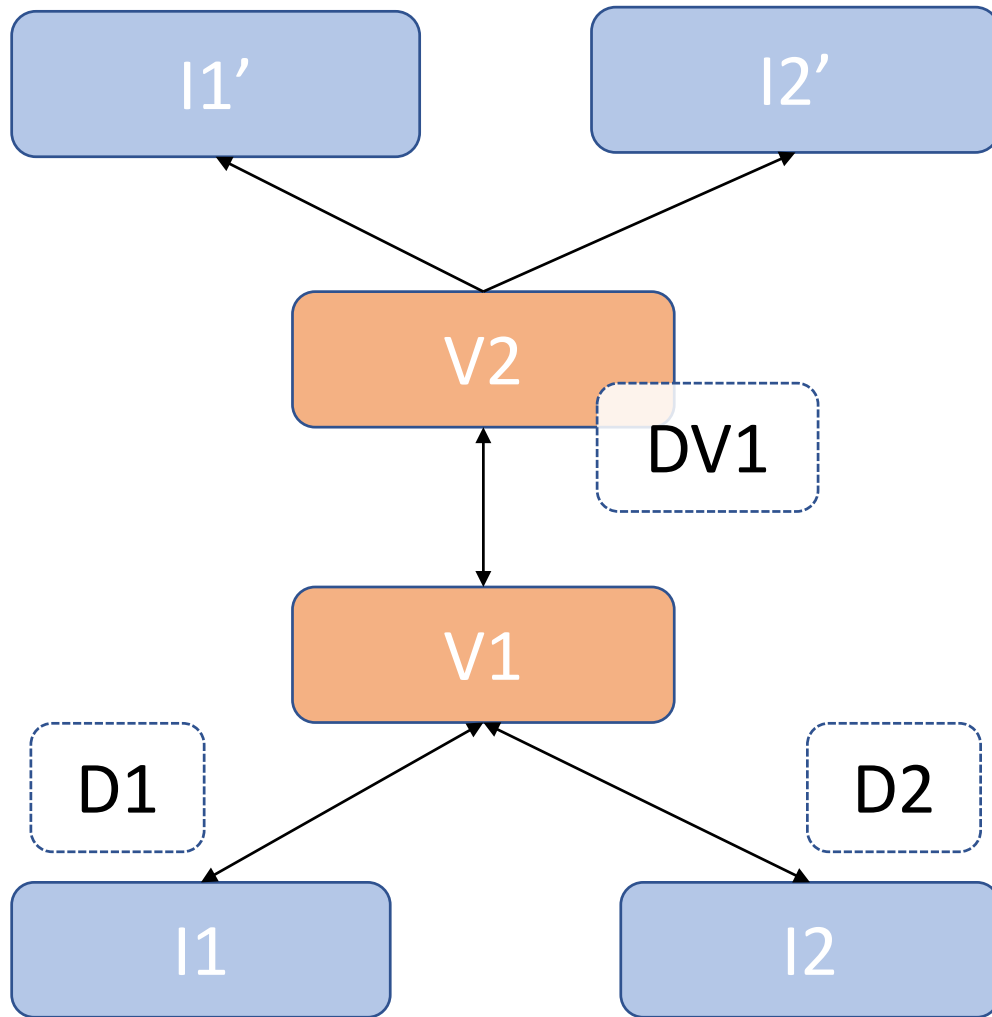
Deep Sparse Coding



Deep Sparse Coding

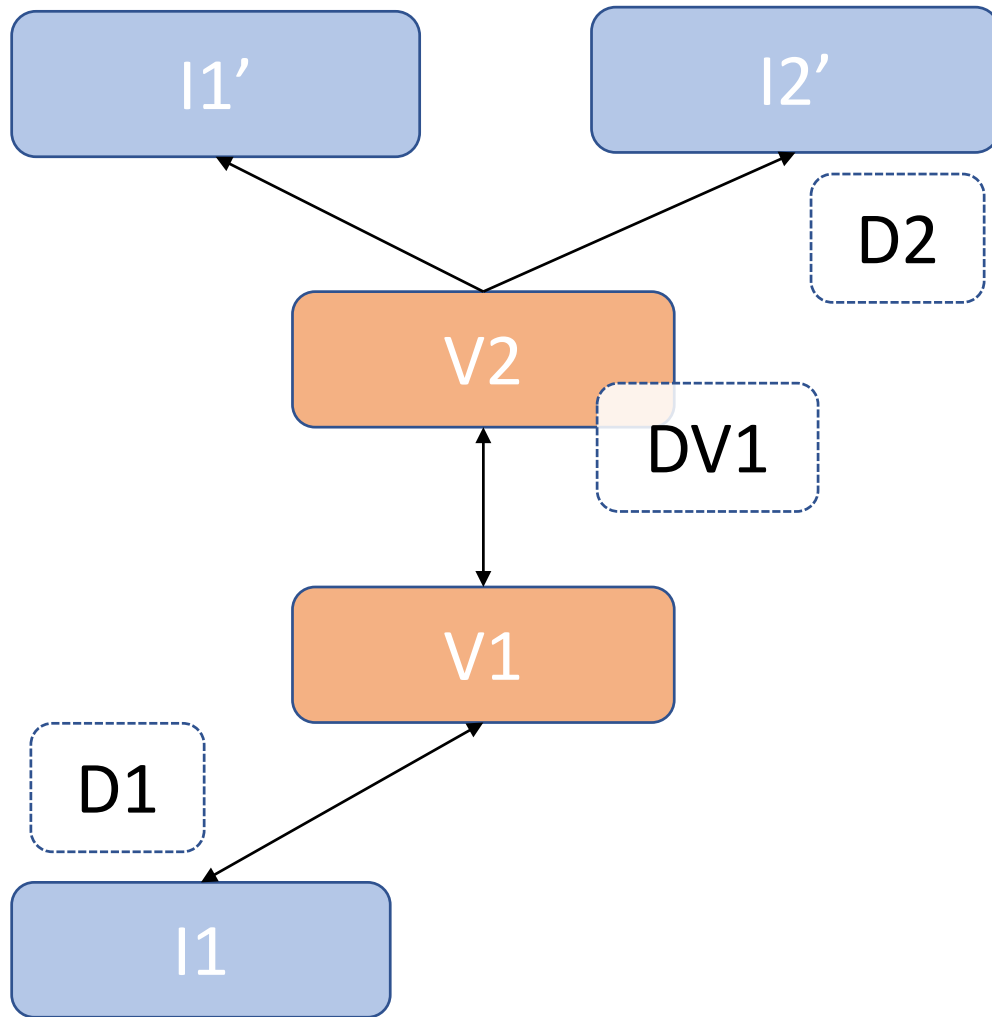


Deep Sparse Coding



Multimodal Associations
Image and Image
Image and Audio

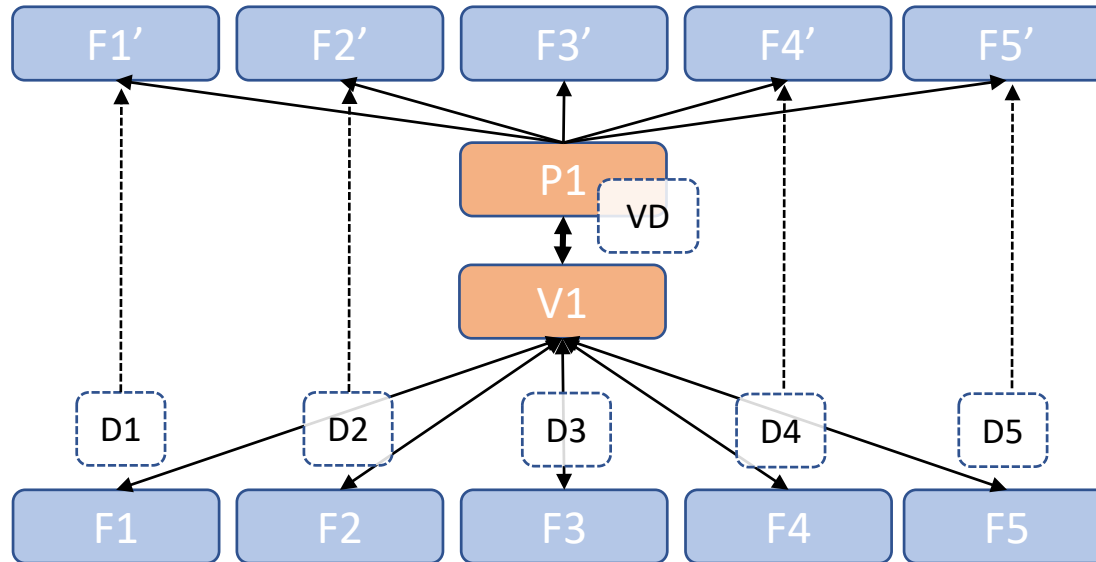
Deep Sparse Coding



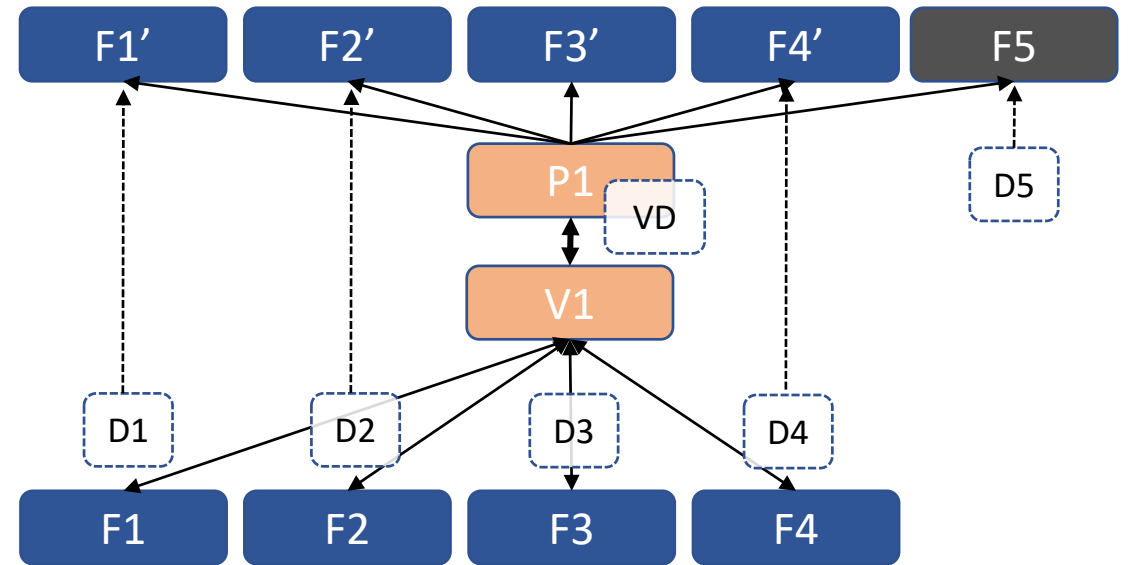
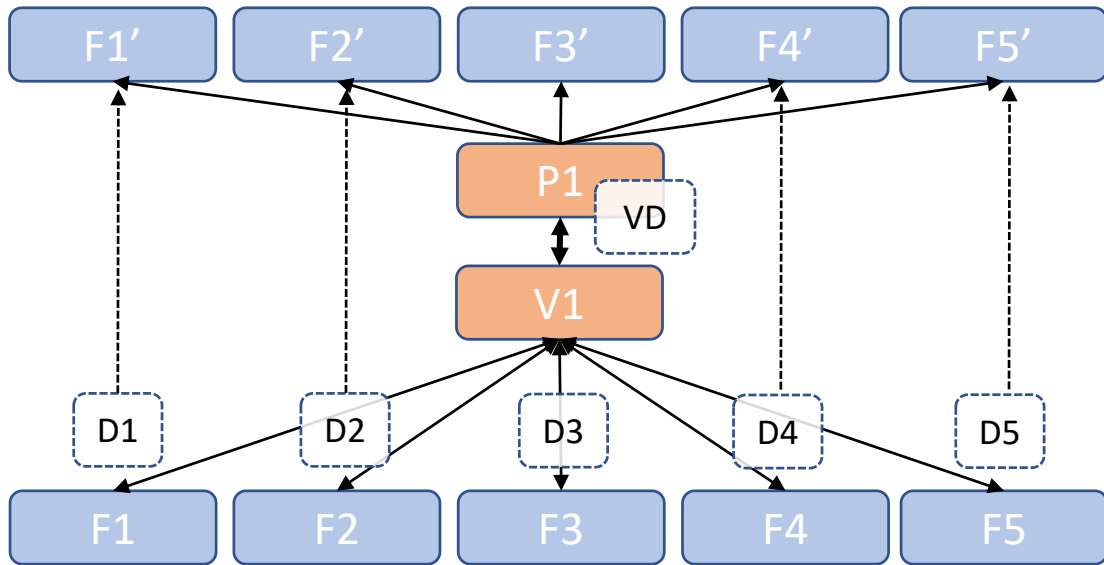
Multimodal Associations
Image and Image
Image and Audio

Any number of modalities or...

Spatiotemporal architecture

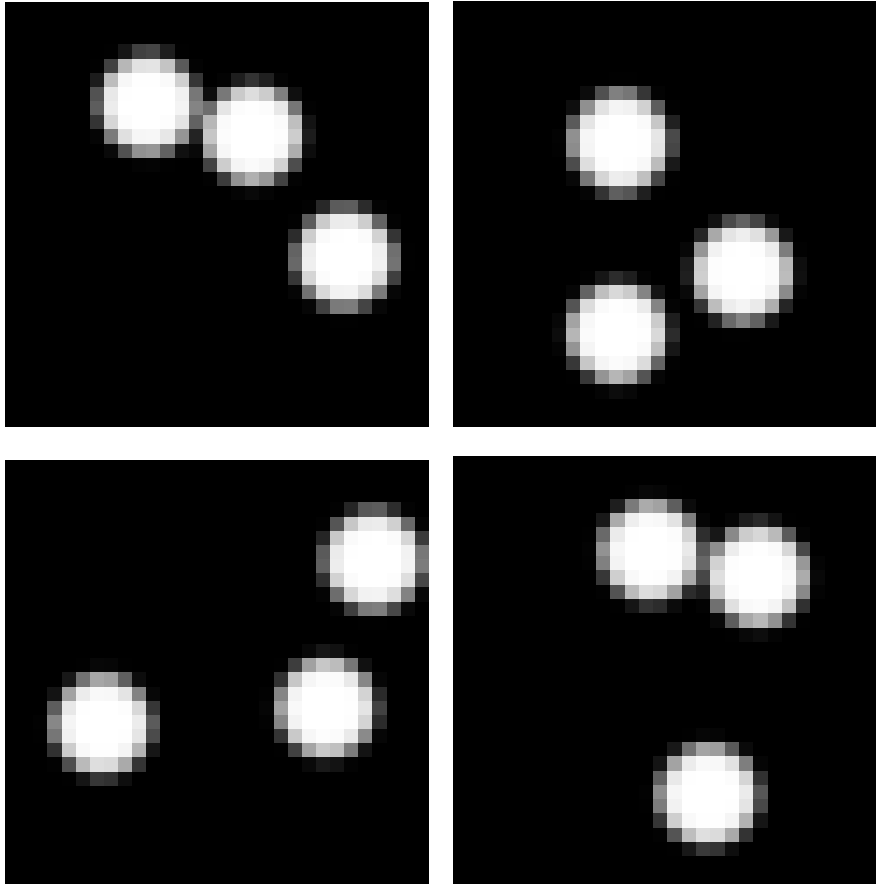


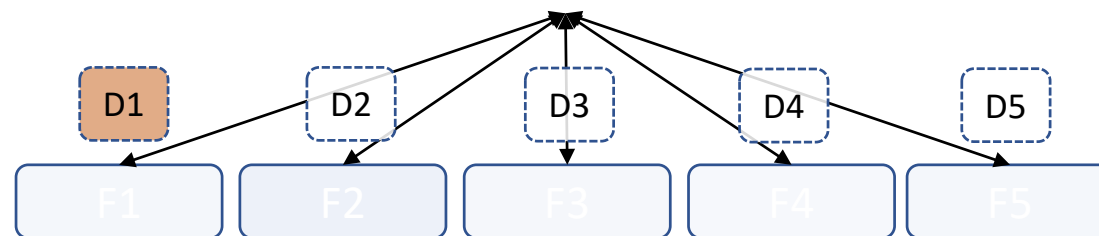
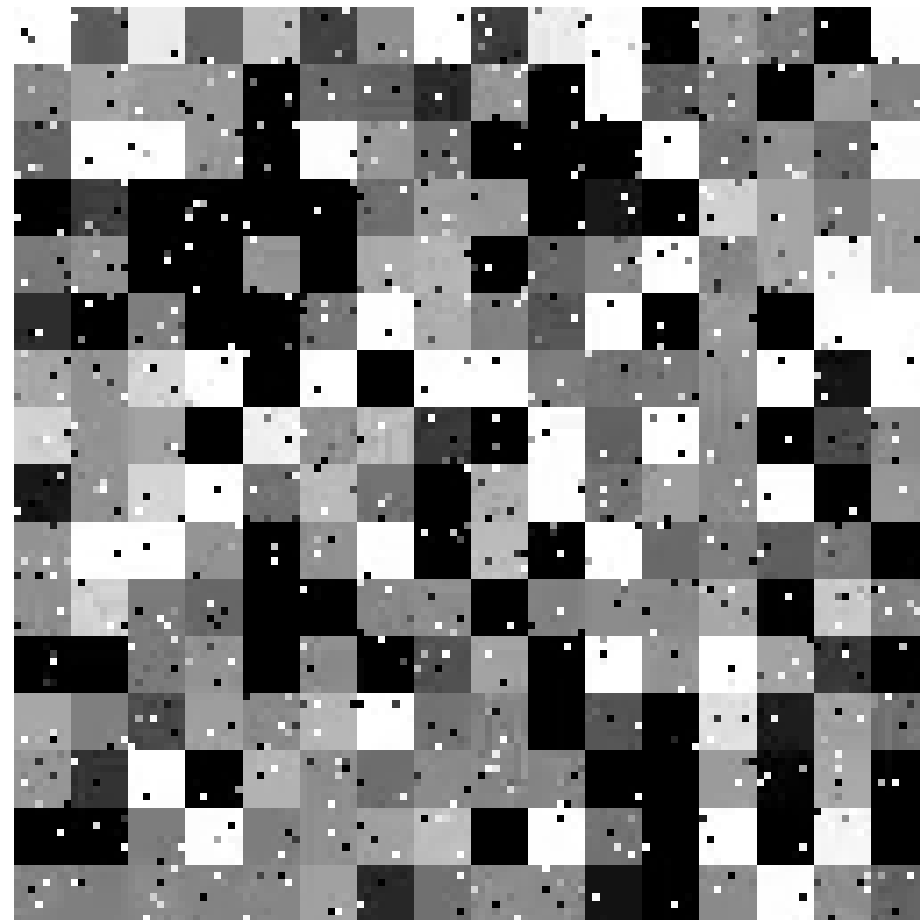
How is this predictive?

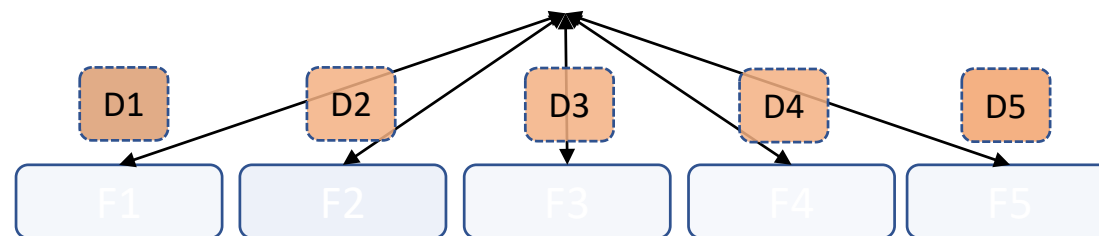
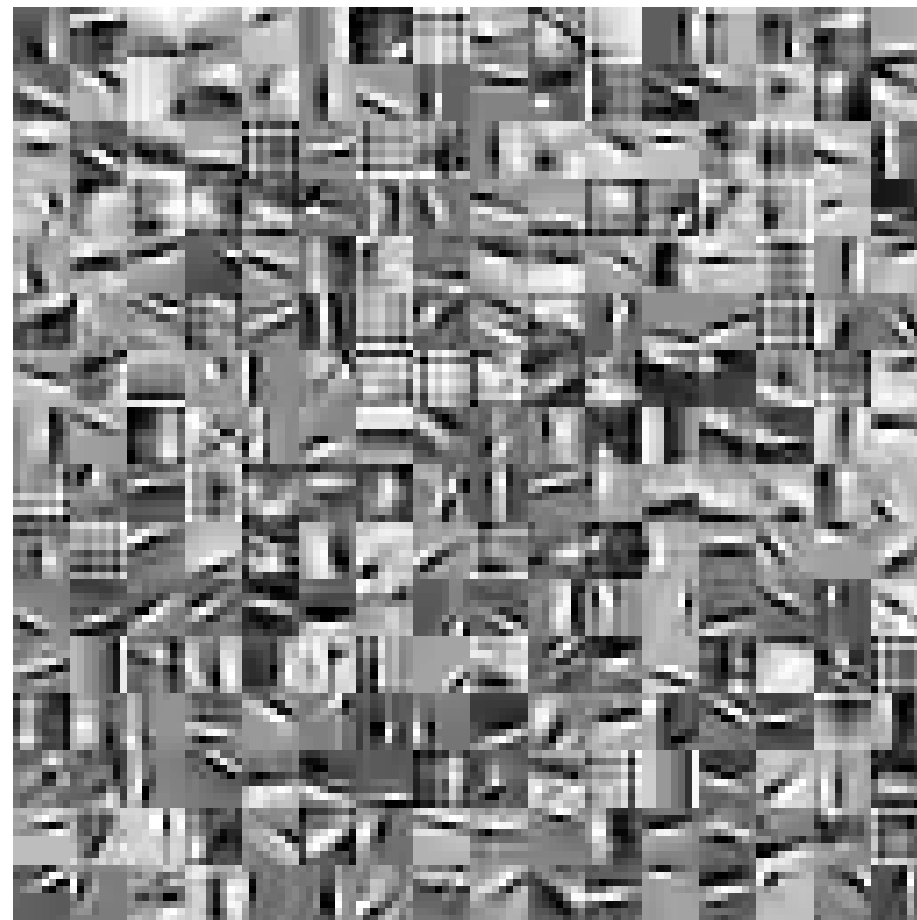


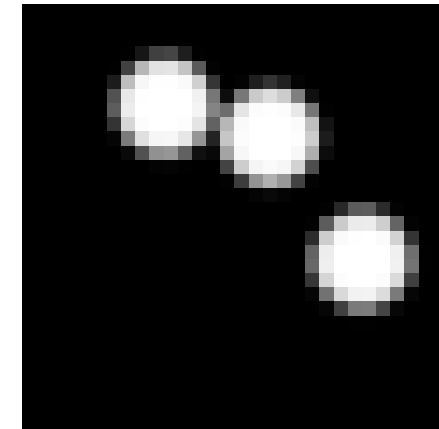
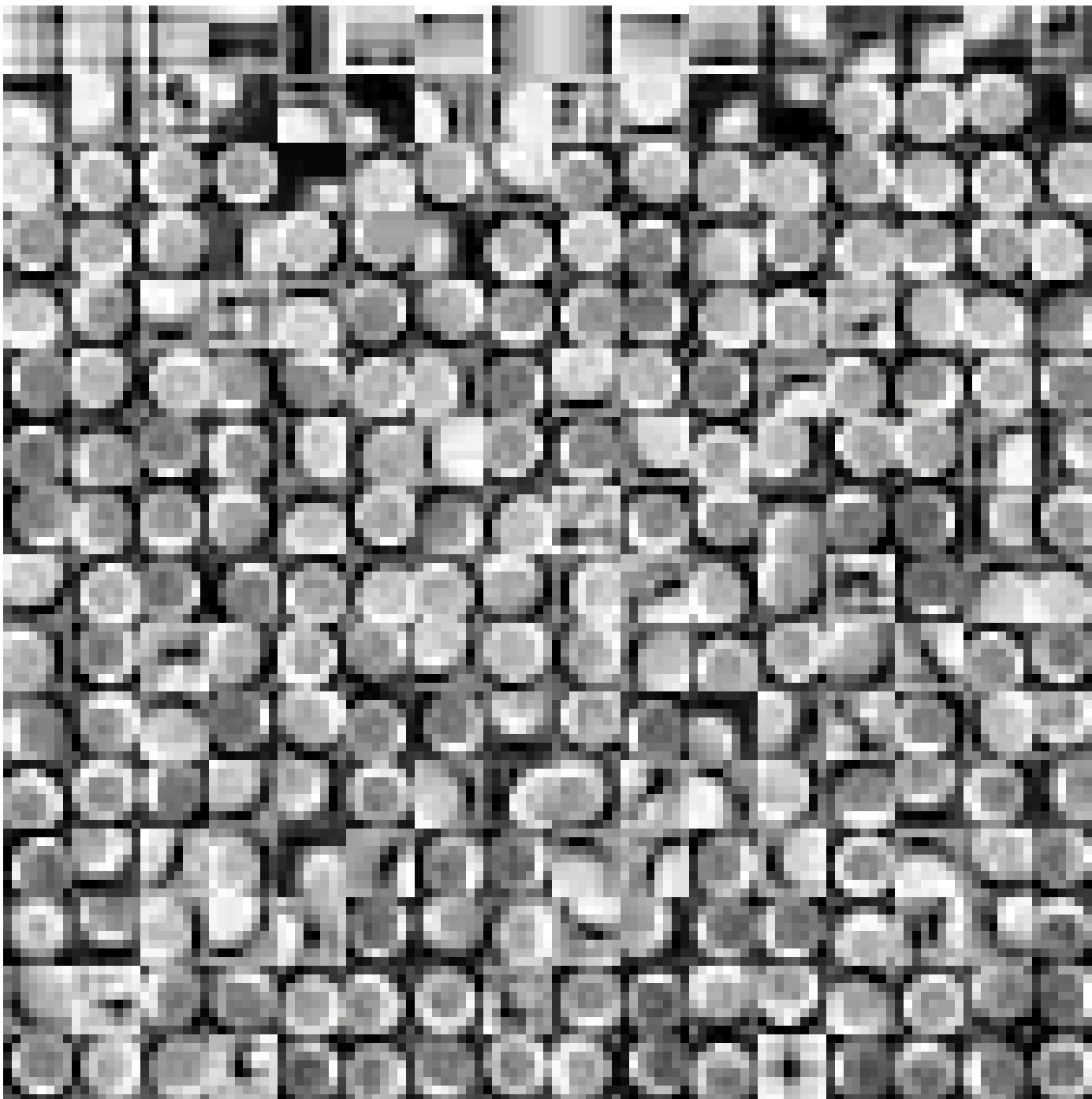
Test Data

- Reconfigurable high bay
 - Controllable lighting, we can test in both poor and good lighting
 - Large room enables viewing at a distance



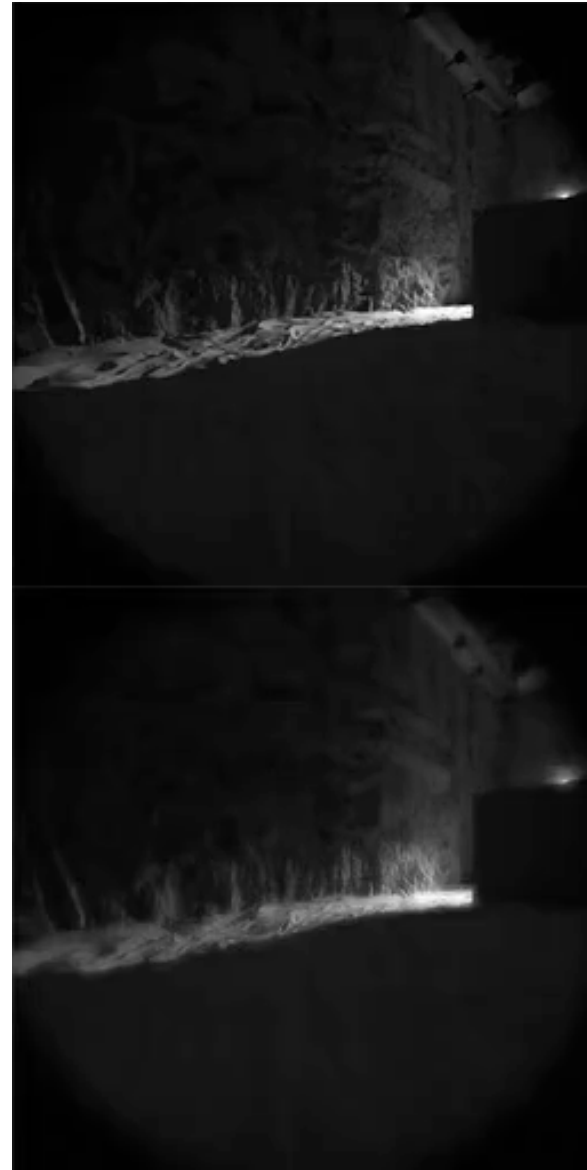




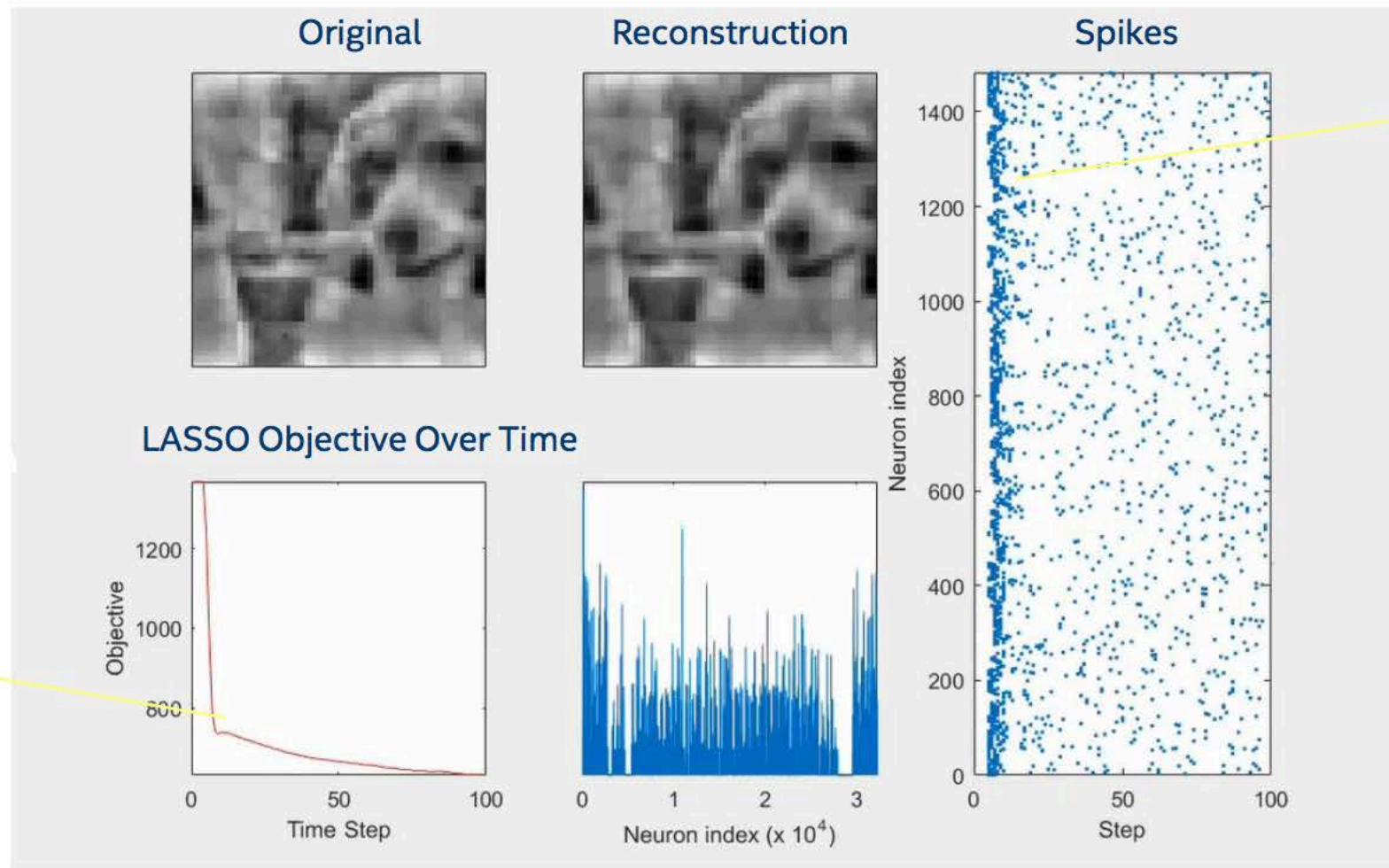


8x8 convolutional kernels
5 frames
256 dictionary elements

Reconstruct the future



Spiking LCA dynamics on a Loihi predecessor



Intense but very brief period of competition

Much faster convergence on a neuromorphic architecture

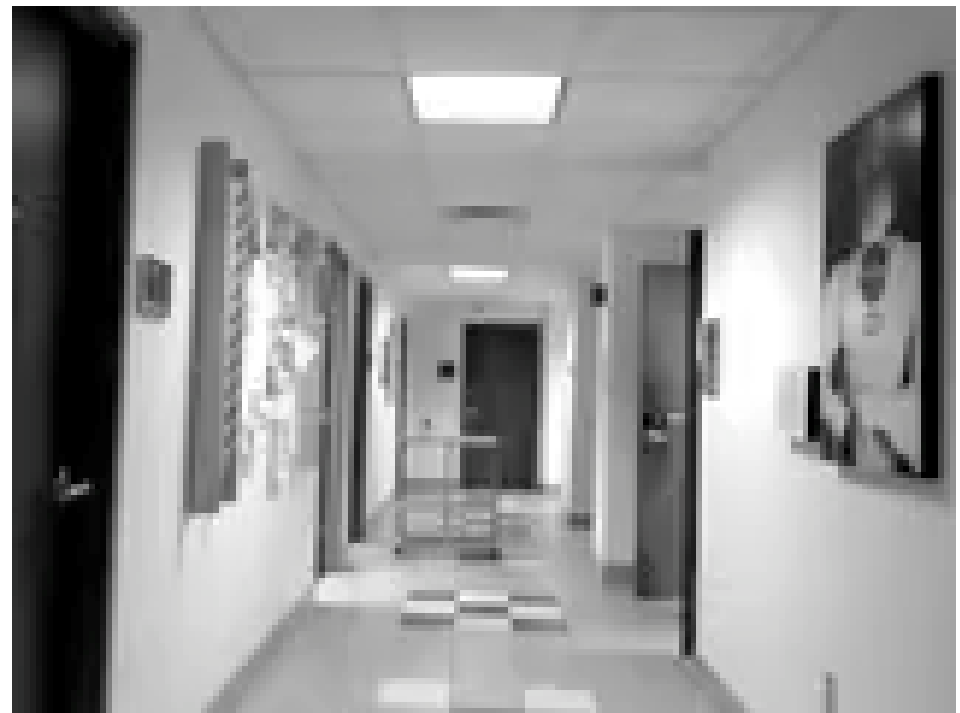
Future and Conclusion

- 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

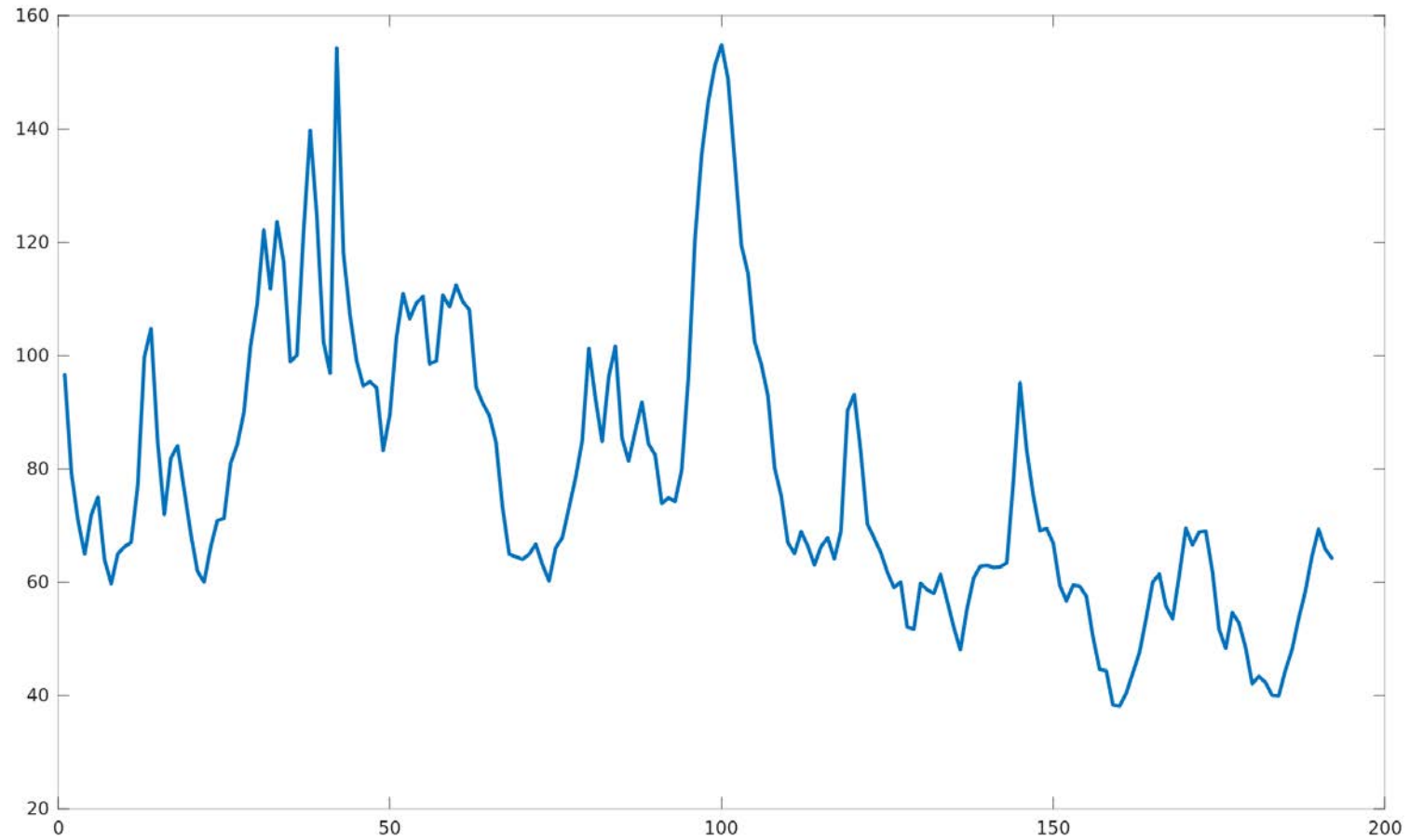
Acknowledgements

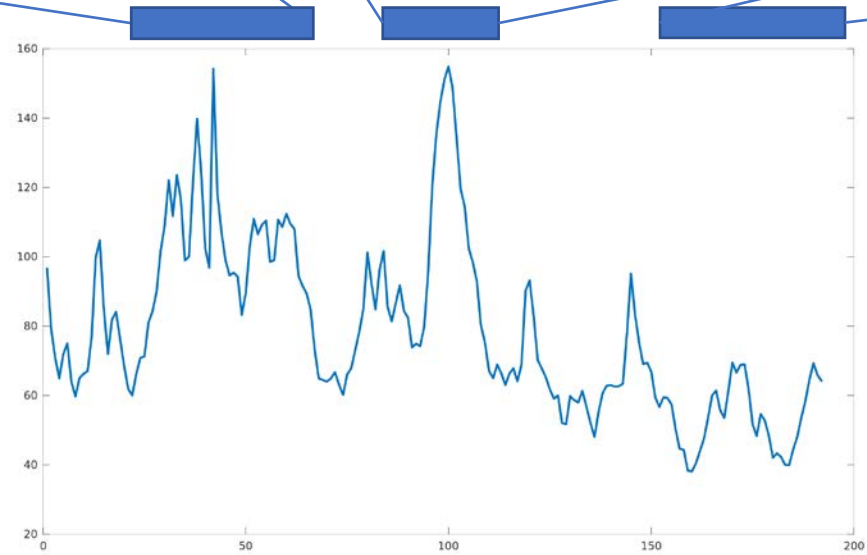
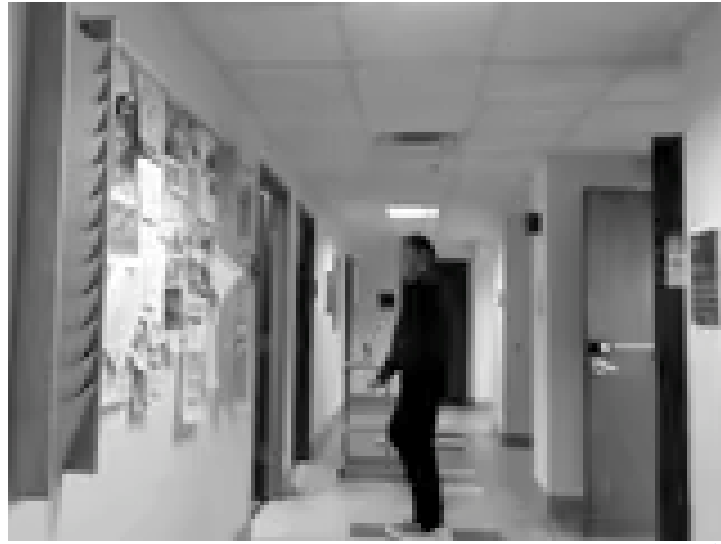
- Department of Energy Visiting Faculty Award
- Office of Naval Research Visiting Faculty Award
- Intel Corporation and INRC
- National Science Foundation

Questions

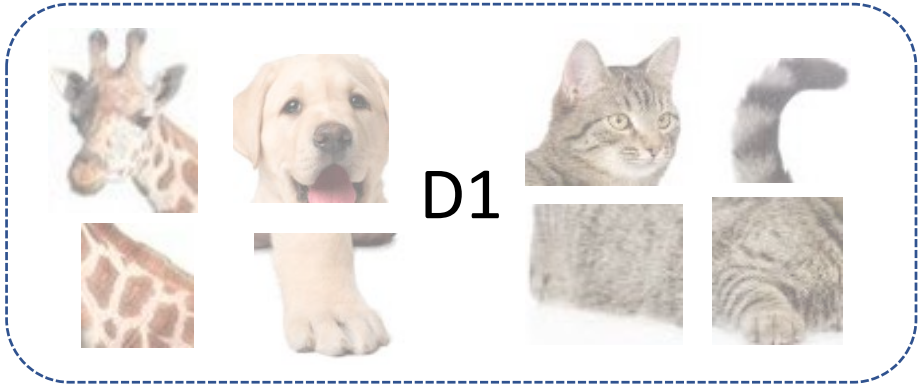
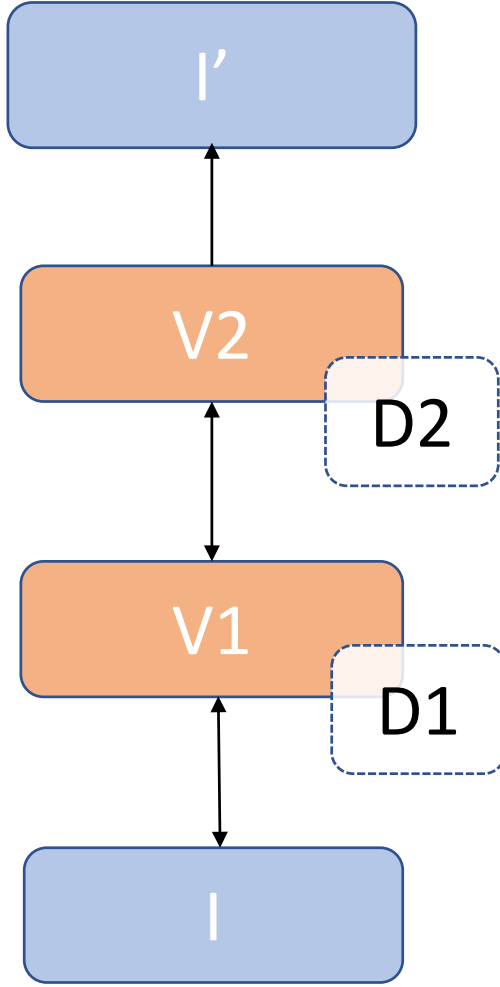


Future Reconstruction Error





Top-down Feedback



Top-down Feedback

