Motivation and Goal
Understanding why certain receptive field properties get selected for the encoding of behaviorally-relevant latent variables (e.g., binocular disparity, motion) is a focus of visual neuroscience research. Here, using i) a natural stereo-image database with groundtruth disparity information at each pixel and ii) a nonlinear-linear-nonlinear subunit modeling framework, we examine how natural (external) stimulus variability and biologically-plausible (internal) response noise determines the binocular receptive field properties that are most useful for encoding binocular disparity in natural scenes. We demonstrate a functional advantage for non-orthogonal receptive fields, and show how the encoding fidelity of different receptive field properties changes with various stimulus properties.

Method
Nonlinear-linear-nonlinear subunit model
Examples of Binocular Receptive Field
Orthogonal and non-orthogonal receptive fields are examined.

Binocular Visual input
Luminance Image
Disparity Image
Disparity contrast

Examples of Binocular Receptive Field
1 cpd 2 cpd 4 cpd 8 cpd

Joint Response of two model simple cells

Fisher information:
\[ J(f) = E \left( \frac{1}{\pi} \log \left| \mathbf{R} \right| \right) \]

Summary statistics of model simple cell responses
Narrowband normalization gaussianizes simple-cell response distribution.

Joint response
Encoding fidelity

Effect of External Variability on Encoding Fidelity
Stimulus disparity and disparity contrast jointly determine which spatial frequencies are most useful to encode. The most useful spatial frequencies define the most useful subspace to encode.

Effect of Internal Noise on Encoding Fidelity
Non-uniform encoding fidelity within a subspace in the presence of internal noise.

Conclusion
External variability (stimulus disparity and external variability) determines the usefulness of different encoding subspaces. The most useful preferred SF decreases with stimulus disparity but increases with disparity contrast.

Encoding fidelity within each subspace is non-uniform when internal noise is introduced. Non-orthogonal receptive field pairs confer a coding advantage when encoding binocular disparity from natural stimuli in presence of internal noise.