Two-Dimensional Phase Unwrapping Using Neural Networks

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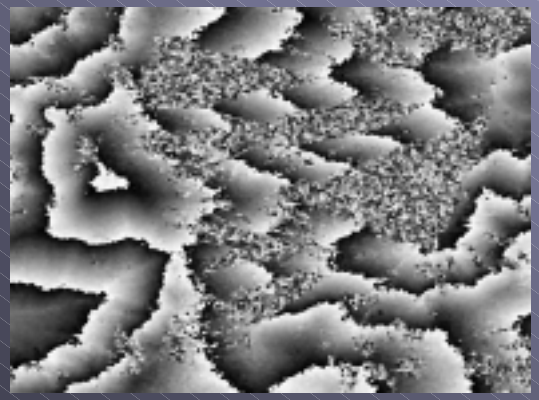
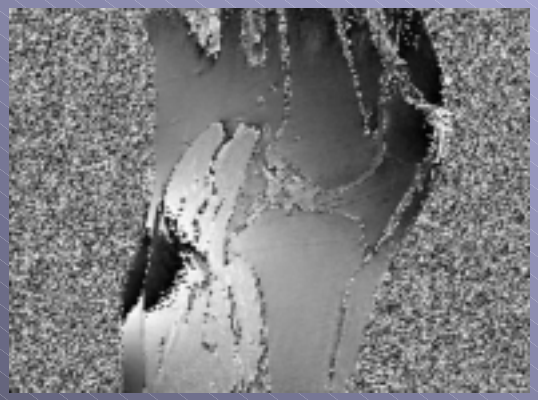
Phase-Based Imaging Methods

Synthetic Aperture Radar



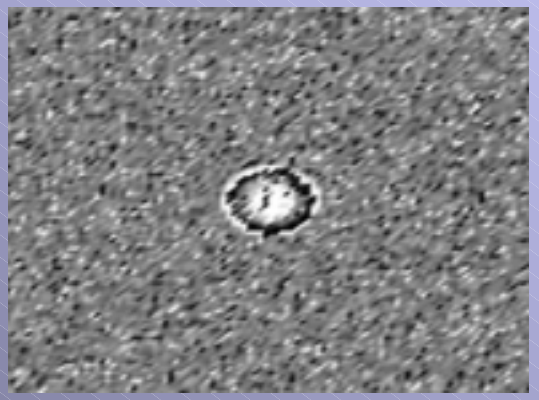
Mountains

Magnetic Resonance Imaging



Knee

Optical Doppler Tomography



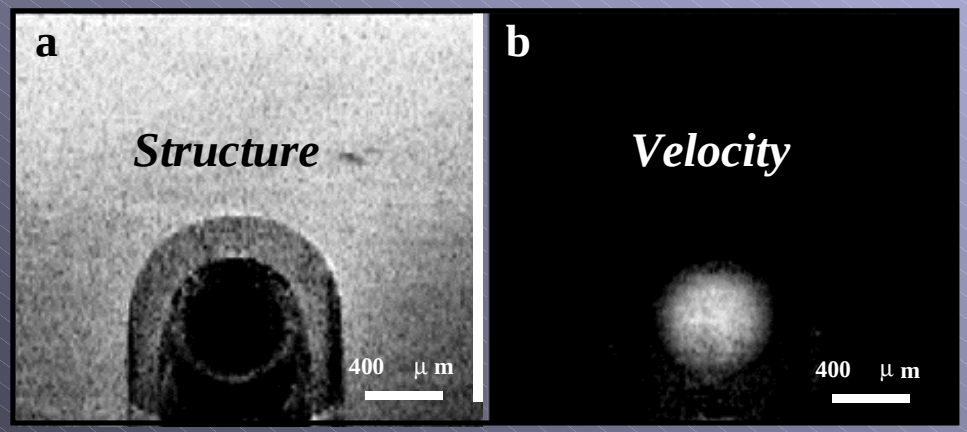
Blood Vessel

Optical Doppler Tomography (ODT)

- Uses lasers to image skin tissue
- Obtains two images
  - Structure: proportional to amplitude
  - Velocity: proportional to phase

Surface

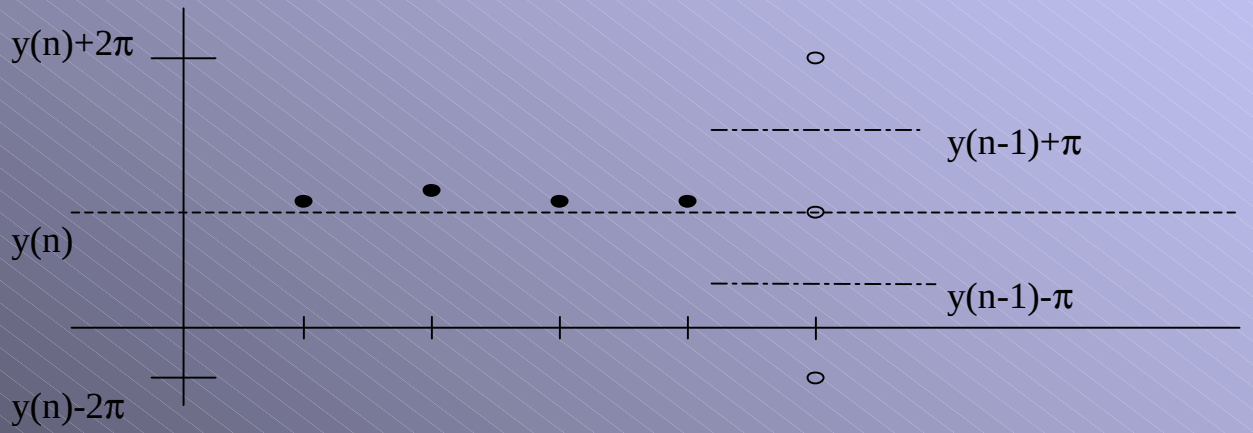
Depth



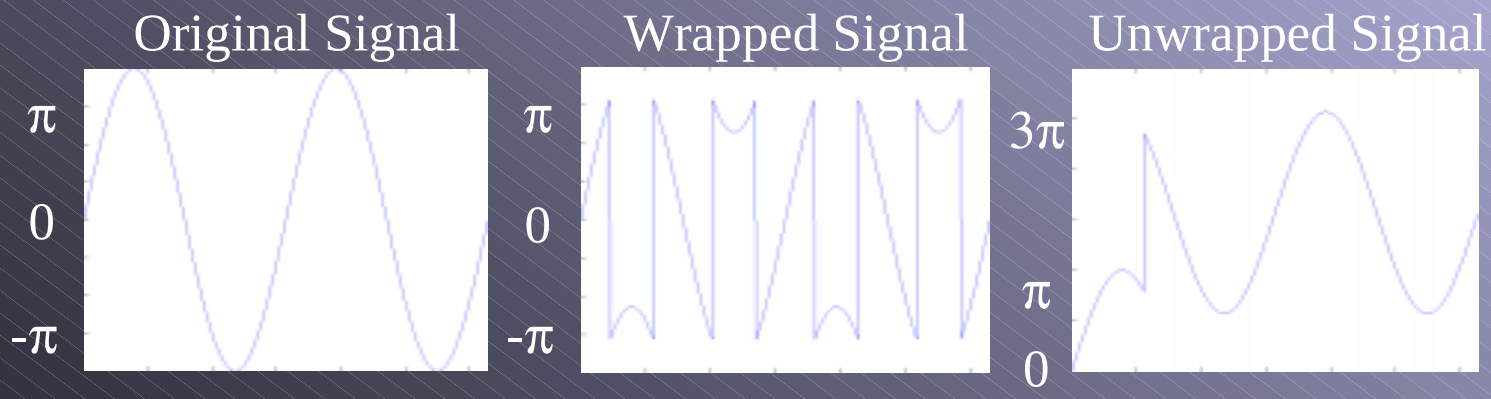
OCT images of
polystyrene microspheres

1-D Phase Unwrapping

- Use information from neighboring pixels

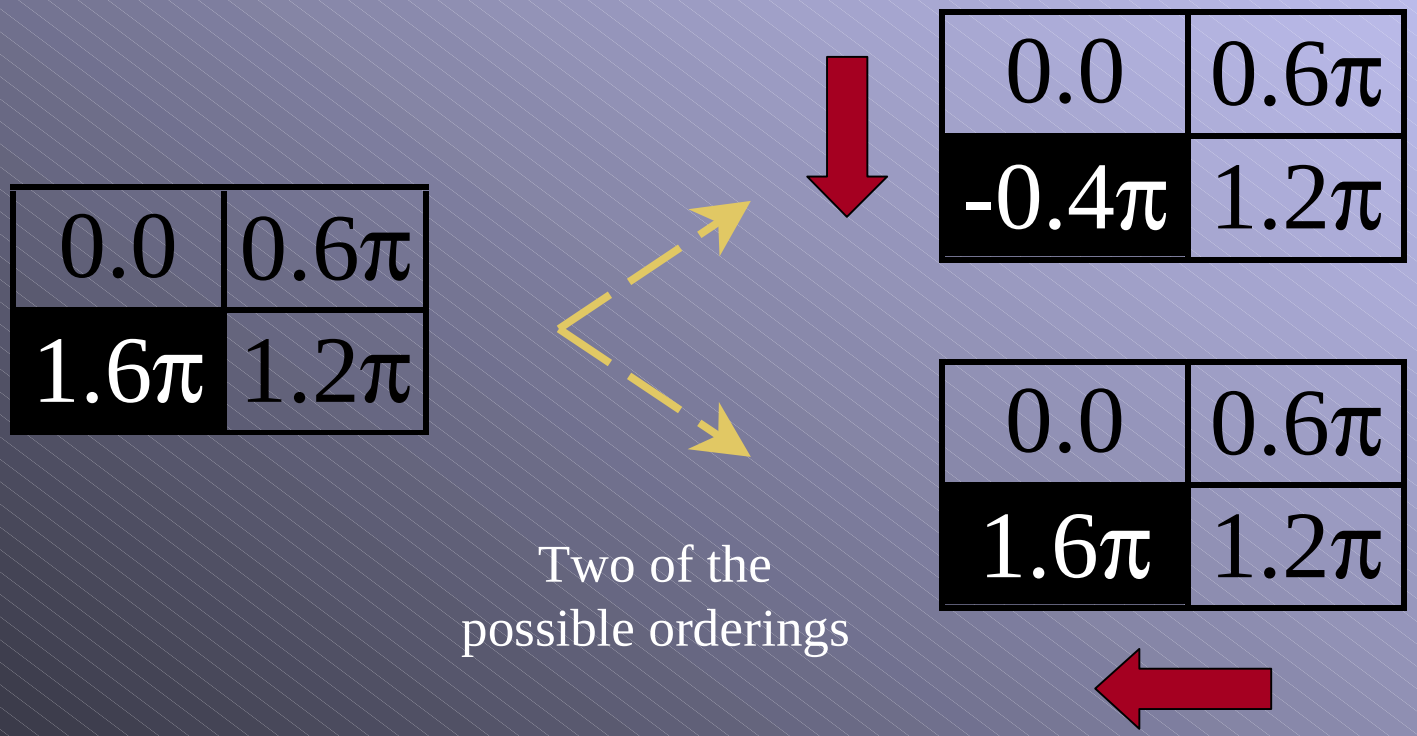


- Errors propagate



2-D Phase Unwrapping

- Possible to use second dimension to recover
- Residues: conflicts in different dimensions

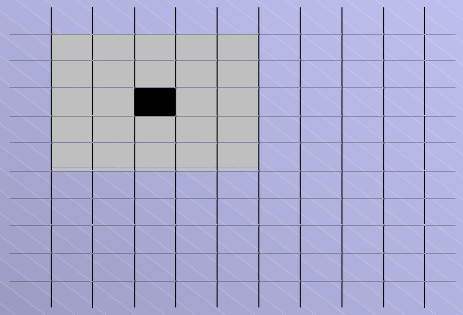


Why Neural Networks?

- Fast unwrapping of ODT velocity images
  - 10 100×100 images per second
  - Global optimization methods impractical
  - Fast local methods necessary
- Learn features in ODT velocity images of skin tissue
  - Sparse images
  - All blood flow follows parabolic law
- Goal: Train neural networks to detect phase jumps in ODT phase images

Phase Jump Detector

- Feedforward multilayer perceptron network
- Wrapped values of 5×5 neighborhood of pixels as inputs to network
- Three outputs for the current pixel
  - Positive jump of 2π
  - No jump of 2π
  - Negative jump of 2π
- Non-iterative, pixel parallel computation



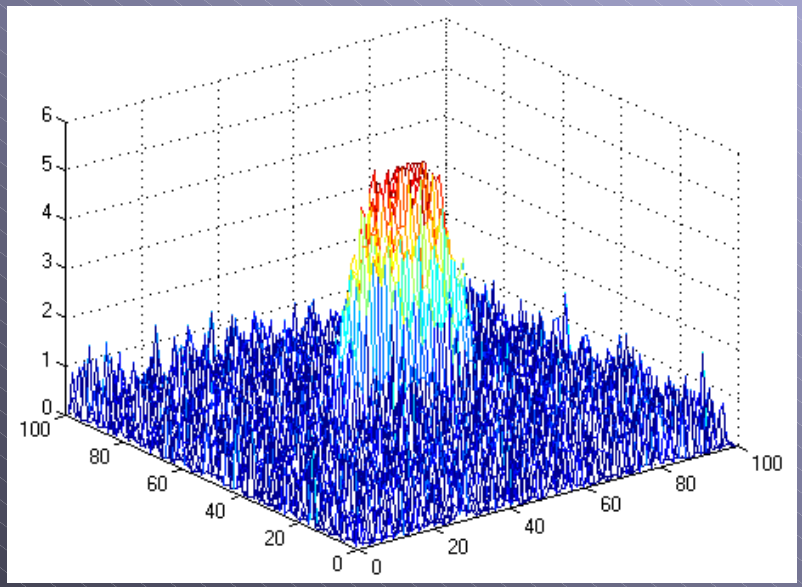
Neighboring pixels

Current pixel

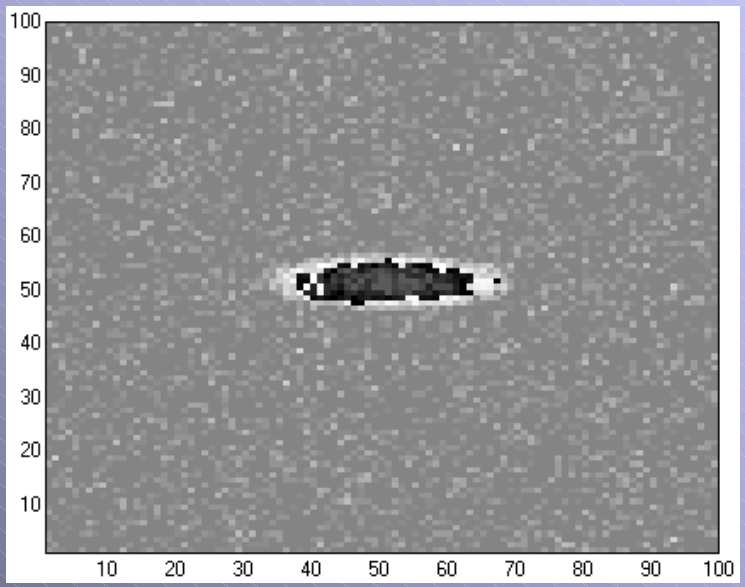
Phase Jump Detector

- Neural network parameters
  - 25 input neurons (5×5 image block)
  - 5 hidden neurons
  - 3 output neurons
- Training of neural network
  - Train using 90 simulated ODT images with conjugate-gradient method
  - Validate with 10 simulated ODT images
  - Simulated images have variety of vessel sizes and shapes
- Tested on 100 simulated ODT images

Simulated Image



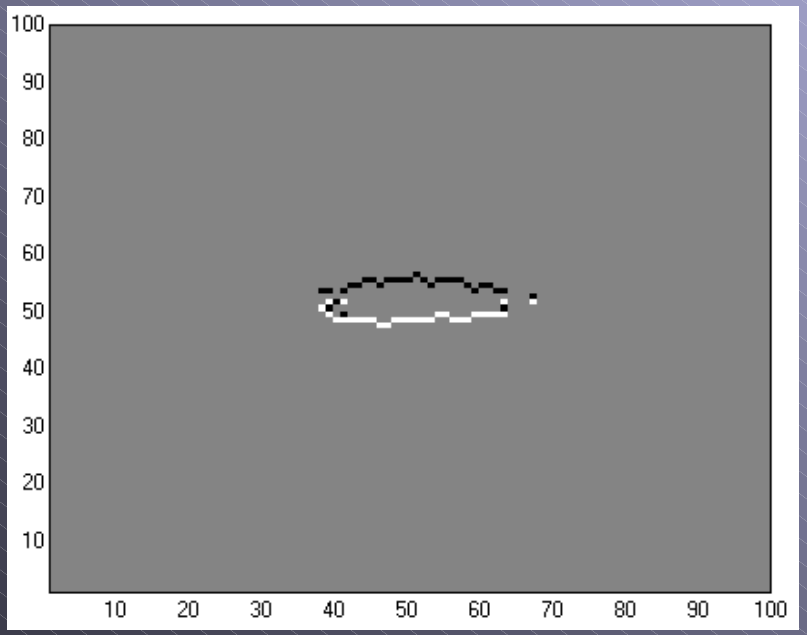
Simulated flow in a blood vessel without wrapping



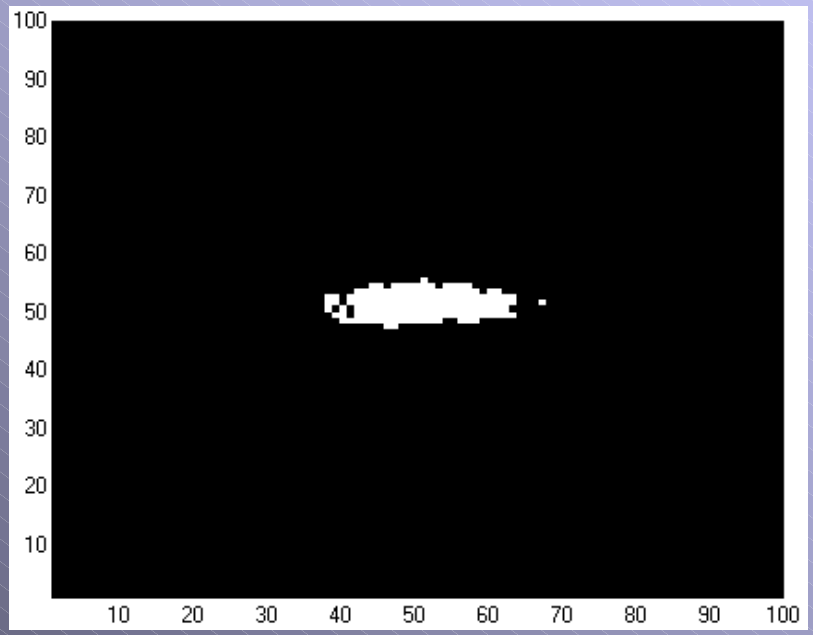
Simulated flow in a blood vessel after wrapping

Phase Jump Detection

- Unwrap along columns
  - Top pixel is always zero since no movement at edge of skin
  - At positive (negative) jump, add (subtract) 2π to rest of column



Location of positive (black) and negative (white) phase jumps



Pixels in the range [π, 3π)

Confusion Matrix

Classified

Actual		Positive	No Jump	Negative
	Positive	0.89	0.11	0
	No Jump	0.0004	0.9988	0.0008
	Negative	0	0.09	0.91