Signal And Image Deconvolution Using Neural Networks

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Results from a selection of blind deconvolution problems with varying point-spread functions are presented.

Blind deconvolution is a computational technique that permits the recovery of a signal or image that has been transformed in an unknown manner due to the imperfect resolution of the measuring process. A common application is the recovery of an improved image given a blurry photograph.

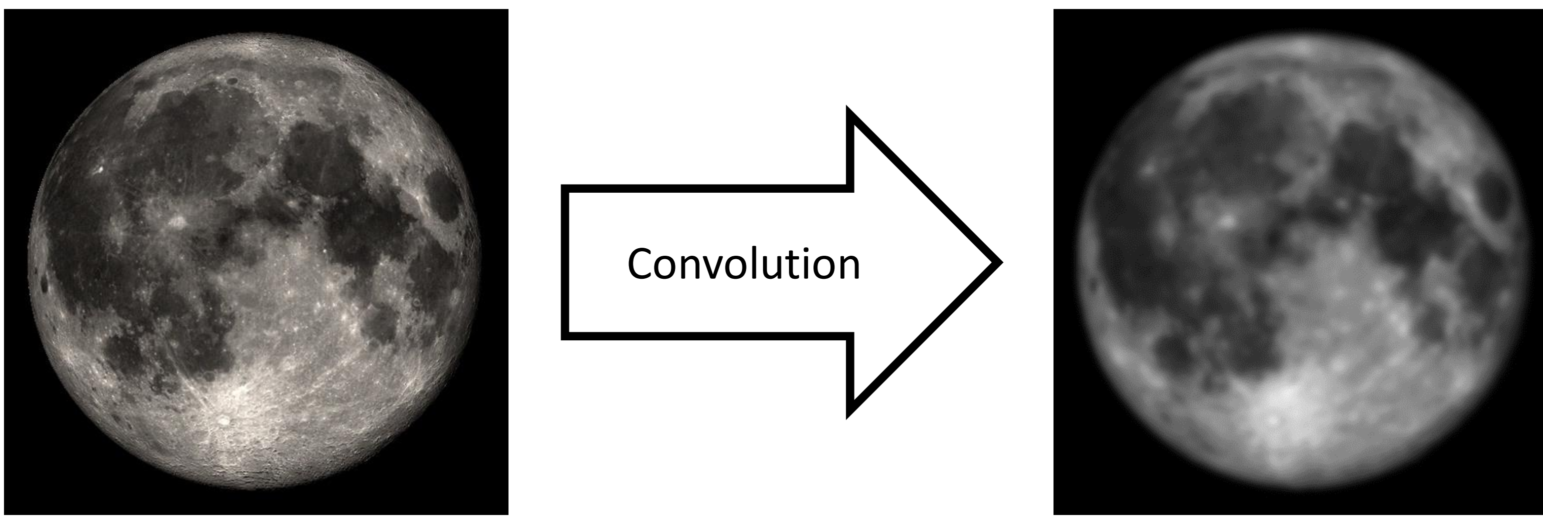
The difficulty of solving this problem arises not only because the extent of blur is unknown (hence, the term blind), but also because the blur may vary across the field of view.

The ability of artificial neural networks to infer a function from observations is exploited to provide a solution to this problem. Neural networks can learn the complex transformations needed for blind deconvolution problems with varying point-spread functions. This technique is useful in applications where sufficient training data exists in the form of matched pairs of source and target signals.

Some possible applications of this method are in the areas of seismology, astronomy, microscopy, fluorescence spectral imaging, and medical imaging.

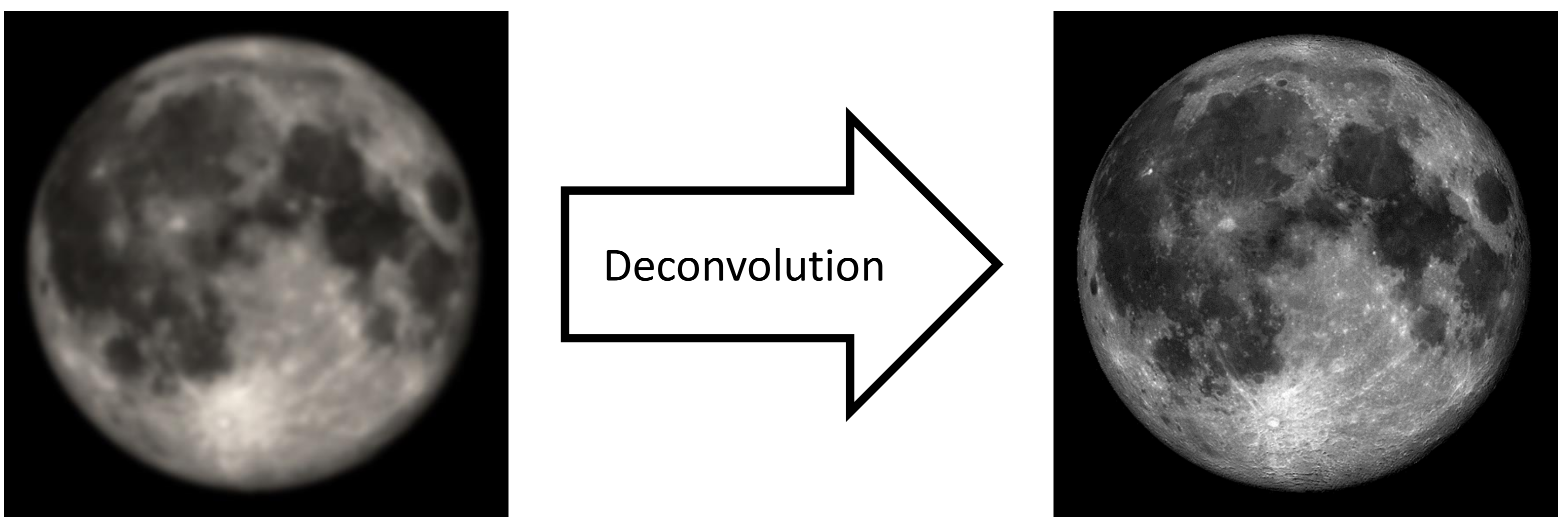
What is convolution?

In signal and image processing, convolution refers to the distortion introduced by limitations inherent in real measuring instruments or processes.



What is deconvolution?

Deconvolution refers to the computational process of recovering the original signal or image from given degraded observations.



Why is deconvolution difficult?

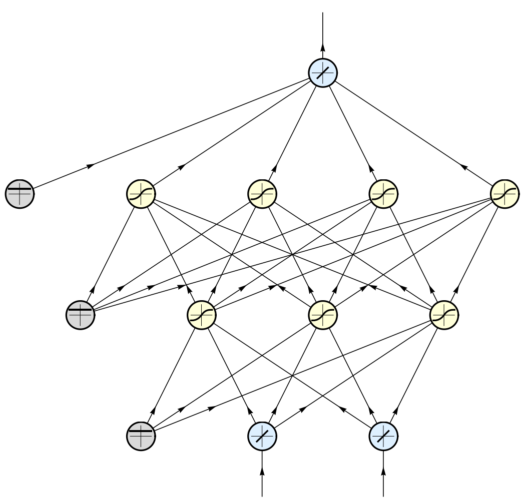
- The exact way by which the measuring device transforms the input to output (point-spread function, PSF) is often unknown.
- Even if the transformation is known, the process of undoing the transformation amplifies noise, often rendering the result useless.
- The point-spread function may be varying in space and/or time.
- The degradations introduced by the measuring device may involve nonlinearities due to saturation and quantization.

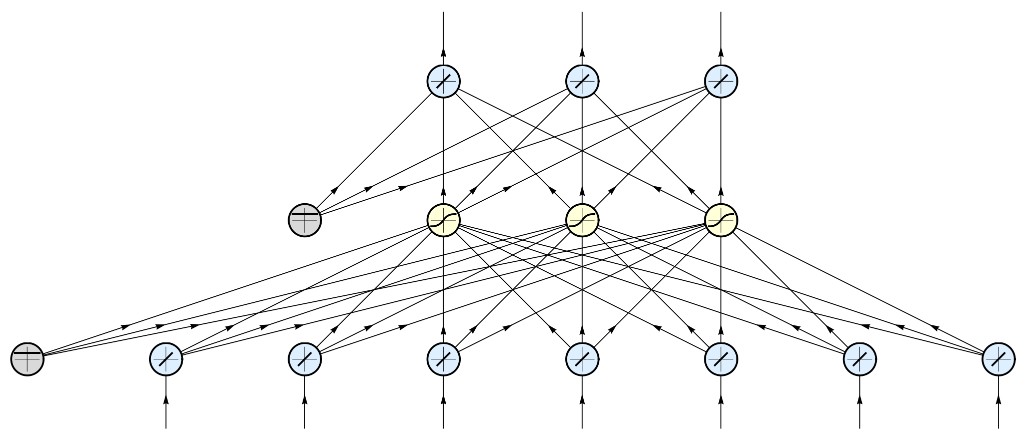
What is new in this work?

- Application of proprietary neural networks.
- The method allows the use of point-spread function (PSF) estimates, if available.
- The method handles varying blur and some amount of nonlinearities.

What is a neural network?

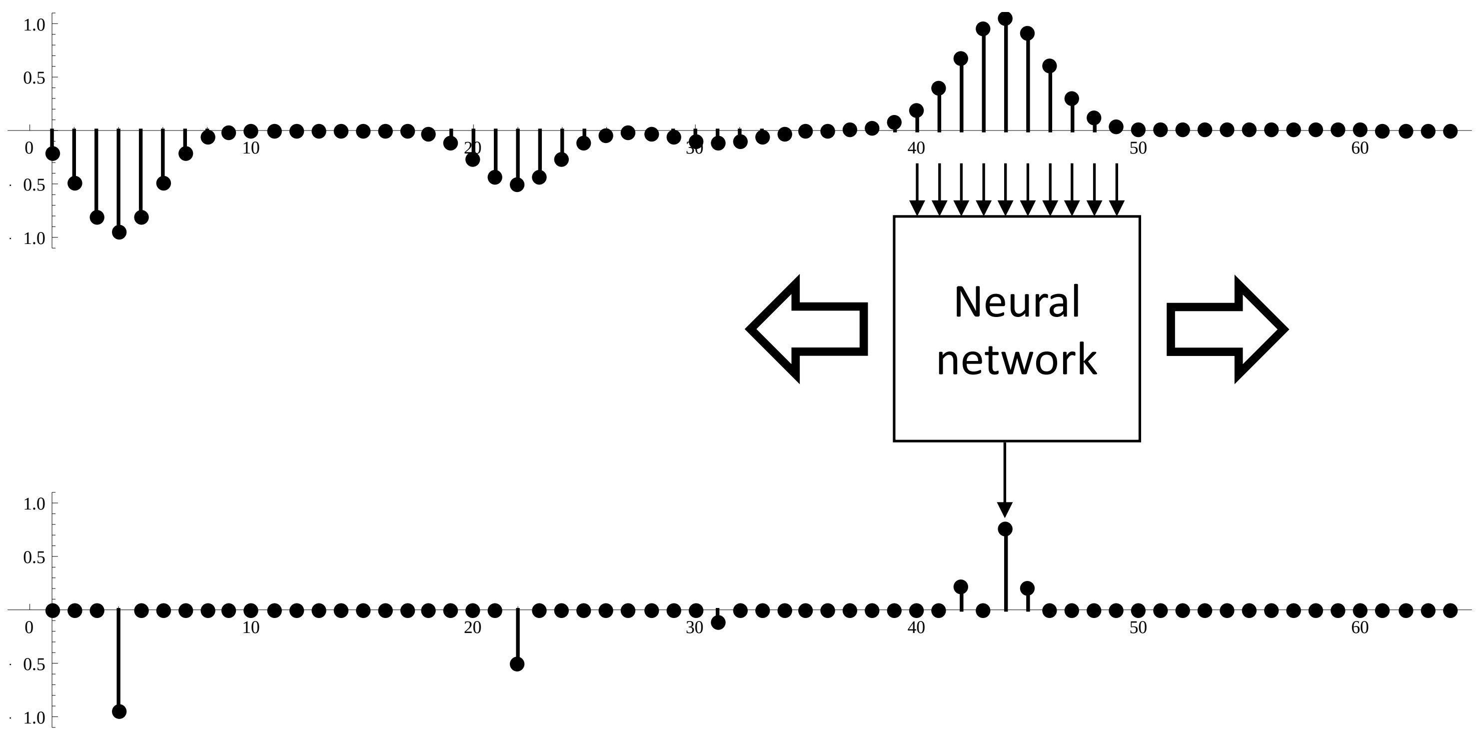
A neural network is a classic pattern recognition tool for learning input-output associations. Between the input and output, a neural network consists of fixed linear, nonlinear and summation units. Typically, a neural network of a chosen configuration is trained by searching for the optimal combination of weights that approximate a prescribed input-output training set.





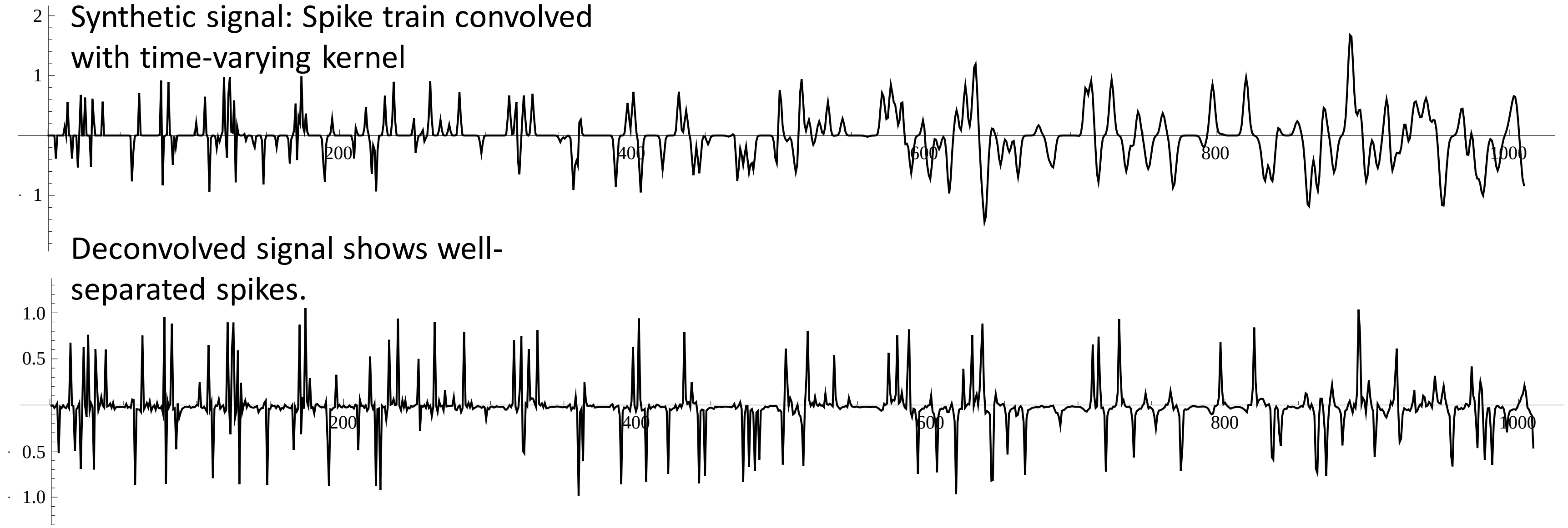
How can a neural network be used to perform deconvolution?

1. Obtain a large training database of input signals and the corresponding idealized output. If it is not practical to build this database by actual measurements, use a mathematical model to simulate the measurement process.
2. Choose a practically feasible architecture and train the network.
3. Check the correctness of deconvolution on a separate testing database.



Results

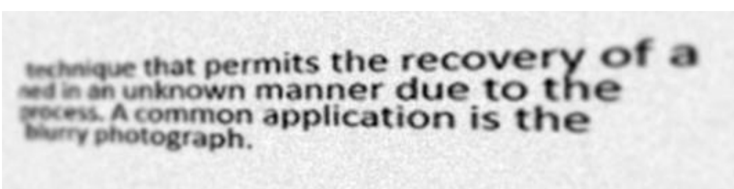
Numerical Demonstration 1:



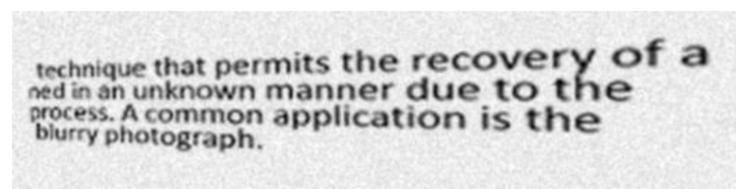
Synthetic signal: Spike train convolved with time-varying kernel

Deconvolved signal shows well-separated spikes.

Numerical Demonstration 2:



Actual off-side photograph of text on computer screen.



Deconvolved image shows uniform resolution and restored focus.

Applications

- Potential applications to signal / image restoration, resolution improvement, and noise reduction in seismology, astronomy, microscopy, fluorescence spectral imaging, and medical imaging.
- I welcome opportunities to discuss applying this or related techniques to your problem. shashi@numericinsight.com

Selected References

1. T. E. Bishop, S. D. Babacan, B. Amizic, A. K. Katsaggelos, T. Chan, and R. Molina, "Blind image deconvolution: Problem formulation and existing approaches," in Blind Image Deconvolution: Theory and Applications, P. Campisi and K. Egiazarian, Eds. Boca Raton, FL: CRC, ch. 1, 2007
2. M. Nørgaard, O. Ravn, N. K. Poulsen and L. K. Hansen. "Neural Networks for Modelling and Control of Dynamic Systems," London, U.K.:Springer-Verlag, 2000.
3. R. O. Duda , P. E. Hart, and D. G. Stork, *Pattern Classification,* New York: Wiley-Interscience, 2000.