

# Measuring the Distance Between Images and Image Uncertainty Using Wavelet Decompositions and the Earth Mover's Distance

Yunfan Tang<sup>1</sup> and Roy E. Welsch<sup>2,3</sup>

<sup>1</sup>The University of Hong Kong, Hong Kong, China

<sup>2</sup>Massachusetts Institute of Technology, Cambridge, MA, USA,

<sup>3</sup>Corresponding Author: Roy Welsch, email: rwelsch@mit.edu

## Abstract

Most users of statistics are aware of the fact that a different sample from the same population can lead to different sample statistics and often use confidence intervals, margins of error, etc. to show this. However, many users of statistics accept plots and images at face value and pay little attention to showing non-statisticians how they (or the implicit visual models associated with them) might vary from sample to sample. In this paper we discuss ways to measure the distance between images using wavelet decompositions and the Earth Mover's Distance along with various ways to find five image summaries (like five number summaries) to allow quick comparison of central and extreme images. We also consider various ways to model image uncertainty by examining how one might bootstrap image residuals after the wavelet structure has been removed. Since there is always some structure left in the residuals, we face many of the same problems (but with more complexity) that are faced when bootstrapping time series residuals after building a time series model (sieve bootstrap). We demonstrate our techniques on a series of fMRI brain images.

Keywords: bootstrap, fMRI, image decomposition and uncertainty, visualization,