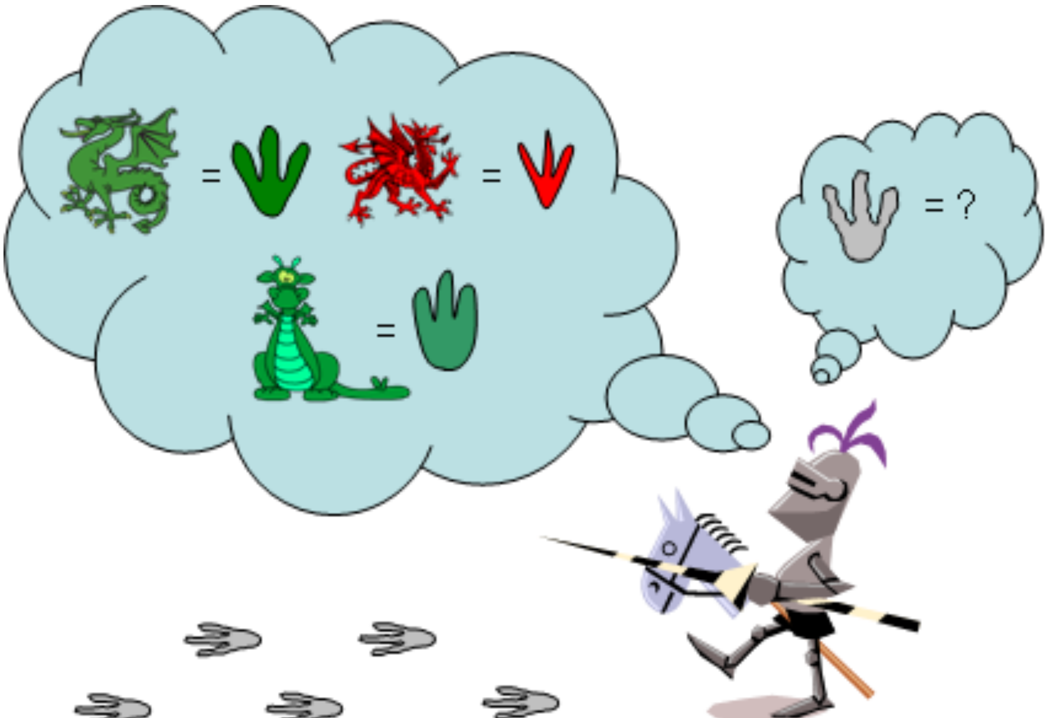
MCEN 4228/5228 Section 009:
Inverse Methods

Spring 2021



(image credit: K. J. Daun)

What is an inverse problem? Consider the summary from Albert Tarantola (Nature Physics, 2006): *Using a physical theory for predicting the results of observations corresponds to solving the 'forward modelling problem'. The reciprocal situation, using the result of measurements to infer the values of the parameters representing a system, corresponds to the 'inverse modelling problem'.*

This course will address fundamental aspects of inverse problems that arise in an array of engineering and geophysical applications, such as tomography, atmospheric remote sensing, air quality, seismology, image reconstruction, and signal processing. Specific topics and methods include:

- ill-posed nature of inverse problems, and why they are a challenging, yet common, occurrence
- linear regression (least squares estimation, analysis of residuals, model selection and inference)
- collinearity and rank-deficiency, singular value decomposition
- regularization, ridge regression, truncated singular value decomposition, Tikhonov methods
- choosing regularization parameters, L-curve, generalized cross-validation
- iterative methods: conjugate gradient, Levenberg-Marquardt, Gauss-Newton
- Bayes theorem and statistical inversions
- Markov chain Monte Carlo, Metropolis-Hastings algorithm
- data assimilation: variational (adjoint), Kalman filtering, ensemble techniques

Course details

Instructor: **Daven K. Henze, Professor**
Lectures: TTh, 3:355 pm – 5:10 pm, conducted remotely.
Primary Text: *Parameter Estimation and Inverse Problems*, by Aster, Brochers and Thurber.
Additional reading from texts by: C. Rodgers, A. Tarantola, and P. C. Hansen.

Comfort with basic linear algebra and experience with tools such as MATLAB or equivalent programming environment strongly recommended.