

Towards Model Fusion in Geophysics: How to Estimate Accuracy of Different Models

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One of the main objectives of geophysics is to determine the density at different depths and at different geographical locations. There exist several methods for estimating the density: e.g., we can use seismic data, or we can use gravity measurement. Each of the techniques for estimating the density has its own advantages and limitations: e.g., seismic measurements often lead to a more accurate value of density than gravity measurements, but seismic measurements mostly provide information about the areas above the Moho surface. It is desirable to combine ("fuse") the models obtained from different types of measurements into a single model that would combine the advantages of all of these models.

Similar situations are frequent in practice: we are interested in the value of a quantity, and we have reached the limit of the accuracy that can be achieved by using a single available measuring instrument. In this case, to further increase the estimation accuracy, we perform several measurements of the desired quantity x -- by using the same measuring instrument or different measuring instruments -- and combine the results of these measurement into a single more accurate estimate.

The need for fusion appears when we have already extracted as much accuracy from each type of measurements as possible. This means, in particular, that we have found and eliminated the systematic errors (thus, the resulting measurement error has 0 mean), and that we have found and eliminated the major sources of the random error. Since all big error components are eliminated, what is left is the large number of small error components. According to the Central Limit Theorem, the distribution of the sum of a large number of independent small random variables is approximately normal. Thus, it is natural to assume that each measurement error is normally distributed with 0 mean and some variance. According to the Maximum Likelihood Principle, we select the value x for which the above corresponding probability is the largest possible. This fused value depends on the accuracies of different models. Thus, to adequately fuse the models, we need to know the accuracies of different models.

We show that the traditional methods cannot be directly used to estimate these accuracies. For example, we cannot use calibration to find these accuracies, since for that, we need to have a "standard" estimating method which is several times more accurate than the one that we currently use. In geophysics, however, seismic (and other) methods are state-of-the-art, no method leads to more accurate determination of the densities.

In this talk, we propose a new method for estimating the accuracies of different models, a method based on estimating the variance of the differences between values from different models.