Expert Knowledge Makes Predictions More Accurate: Theoretical Explanation of an Empirical Observation

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Empirical observation that needs explaining. It is known that the use of expert knowledge makes predictions more accurate. A typical improvement – as cited in [1] on the example of meteorological temperature forecasts – is that the accuracy consistently improves by 10%. How can we explain this?

Towards an explanation. Use of expert knowledge means, in effect, that we combine an estimate produced by a computer model with an expert estimate. Let $\sigma_m$ and $\sigma_e$ denote the standard deviations, correspondingly, of the model and of the expert estimate.

In effect, the only information that we have about comparing the two accuracies is that expert estimates are usually less accurate than model results: $\sigma_m < \sigma_e$. So, if we fix $\sigma_e$, then the only information that we have about the value $\sigma_m$ is that it is somewhere between 0 and $\sigma_e$.

We have no reason to assume that some values from the interval $[0, \sigma_e]$ are more probable than others. Thus, it makes sense to assume that all these values are equally probable, i.e., that we have a uniform distribution on this interval. For this uniform distribution, the average value of $\sigma_m$ is equal to 0.5 $\cdot$ $\sigma_e$. Thus, we have $\sigma_e = 2 \cdot \sigma_m$.

In general, if we combine two estimates $x_m$ and $x_e$ with accuracies $\sigma_m$ and $\sigma_e$, then the combined estimate $x_c$ – obtained by minimizing the sum $\sigma^2_m + \sigma^2_e$ is $x_c = x_m \cdot \sigma^2_m + x_e \cdot \sigma^2_e$, with accuracy $\sigma^2_c = \frac{1}{\sigma^2_m + \sigma^2_e}$. For $\sigma_e = 2\sigma_m$, we have $\sigma^2_c = 0.25 \cdot \sigma^2_m$, thus $\sigma^2_c = \sigma^2_m \cdot \frac{1}{1 + 0.25} = \sigma^2_m \cdot \frac{1}{1.25} = 0.8 \cdot \sigma^2_m$, thus $\sigma_c \approx 0.9 \cdot \sigma_m$.

So we indeed get a 10% increase in the resulting prediction.