Why Swarms of Agents Are Better than Clouds?

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Formulation of the problem. Expert estimates are often very crude and approximate. It is known, however, that if we ask several independent experts to estimate a quantity, and then average the resulting estimates, we often get a reasonably accurate estimate. This is the main idea behind crowd intelligence.

It was recently discovered that if we first divide the experts into small groups (“swarms”), let each group combine their estimates into a single value, and only average the group results, we get a much more accurate estimate of the quantity of interest; see, e.g., [1]. But why is this more complicated swarm intelligence lead to better results than the crowd intelligence?

Our explanation. Let \( x_1, \ldots, x_n \) be estimates of different experts, and let \( \rho(x) \) denote the probability density function that describes the probabilities of different values of the expert’s approximation error. Then, ideally, we should select an estimate \( a \) with the largest possible likelihood

\[
L = \prod_{i=1}^{n} \rho(x_i - a).
\]

It is known that when \( \rho(x) \) is a normal distribution, maximum likelihood estimate is indeed the arithmetic average

\[
a = \frac{1}{n} \sum_{i=1}^{n} x_i.
\]

However, for other distributions, the maximum likelihood estimate is different from the arithmetic average – which explains why the crowd intelligence results are not perfect.

When we allow agents from each swarm \( s \) to come to an agreement between themselves, it is reasonable to assume that within each swarm, the agents will come up with a maximum likelihood (ML) estimate \( a(s) \) for which the value

\[
\prod_{i \in s} \rho(x_i - a(s))
\]

is the largest. It is known that when the number of combined estimates is reasonably large, the ML estimates \( a(s) \) are approximately normally distributed. Thus, to combine values corresponding to different swarms, we can use the method which is optimal for normal distributions – i.e., taking the arithmetic average.

So, the estimate provided by swarm intelligence is asymptotically equal to the maximum likelihood one and is, thus, (asymptotically) optimal.