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 $L \stackrel{\text{def}}{=} \prod_{i=1}^{n} \rho(x_i - a)$.

It is known that when $\rho(x)$ is a normal distribution, maximum likelihood estimate is indeed the arithmetic average $a = \frac{1}{n} \cdot \sum_{i=1}^{n} x_i$. 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.

[1] L. Rosenberg, D. Baltaxe, and N. Pescetelli, "Crowds vs. smarms, a comparison of intelligence", *Proceedings of the IEEE Swarm/Human Blended Intelligence Workshop SHBI'2016*, Cleveland, Ohio, October 21–23, 2016.