03 An information theoretic approach to originality and bias in science

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The originality of a scientific idea or research question is a generally accepted necessity to perform a brilliant research. Yet, too often, funding agencies and reviewers in high-profile journals seem to disregard or not even understand this key component of research. Perhaps, they have of a lack of this quality or have other motives? For example, many scientists have been turned down multiple times by National Science Foundation with the following argument: ***High-risk research*!!!** High-risk means the results cannot be predicted, which indicate a clear-cut, original, open problem. The refusal of so-called high-risk projects indicates that the preferred type of funded projects have largely predictable outcomes that make them "low-risk", no surprise.

One of the main conclusions of our T3 project is that NSF should actually pre-filter and refuse all the science projects that are not high-risk. Then it should select the winners solely from the set considered as high-risk, based on validity and importance.

To get to this conclusion; first of all, we must understand what is scientific research and how to measure the originality of a scientific question. Scientific research is the creation of new objective information about the target of the study. As Chaitin and Renyi pointed out, deterministic logic operations cannot increase information content thus the information entropy of results deterministically calculated from axioms cannot be more than that of the axioms themselves. This problem is similar to the problem of free will, where Chaitin and others used computational complexity based approach similarly to the generation of true random numbers.

Therefore, we introduced a new measure of originality, which is the information entropy of the scientific question. The higher the uncertainty, that is, the "higher the risk", of the expected output of the research, the higher is its information entropy and originality. In this scheme, the scientific research process form a communication channel, where the transmitter is the object of research and the recipient is the reader of the published paper.

However, this simple approach of ours works only in simple idealistic cases. When bias – either natural or instrumental – or errors and error corrections are present, the entropy formula needs corrections. Our final formula for problems with 1-bit responses (0 or 1) is shown below. It gives a pessimistic approach to the potential information content, that is, the originality, of the research question.

$$S=(0.5+x)\log_2\left(\frac{1}{0.5+x}\right)+(0.5-x)\log_2\left(\frac{1}{0.5-x}\right) \qquad \text{where} \qquad x=|\Delta p_1|+\sum_i|b_i|+\sum_j|\varepsilon_j|+\sum_k|\varepsilon_{ck}|$$

where S is the information entropy, x is the generalized bias shift which is the sum of: the shift Δp_1 of the probability of answer 1 due to natural bias; the absolute value of shifts due to other biases b_i (absolute values to avoid compensation and show worst case scenario); the absolute values of shifts ε_j due to errors (absolute value to avoid compensation and show worst case scenario); and the absolute values of shifts ε_{ck} due to error corrections (absolute value to avoid compensation and show worst case scenario).

Important open question: Evolution dynamics of bias, errors and error corrections due to society-pressures: Political and financial pressures in hiring, funding and publication processes can act as a positive feedback to increase bias. A systematic positive feedback can potentially evolve into singularities such as large-scale breakdown in power grid systems (blackouts) [9].

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