A Note on Complexity and Creativity

by

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The last decade has seen an increasing level of debate about engineering: How does one characterise it, how should it be taught, what does it contribute to society, do we have too many or too few engineers, and so on. In all of this, one often gets the impression that engineering is viewed as a mechanical activity, as a trade or a craft, and that one has lost sight of the essential element of engineering and the one which distinguishes an engineer from a technician, namely, creativity. The hallmark of the engineer is the ability to generate solutions to "new" problems, or to generate "new" solutions to problems for which one or more solutions already exist. This raises a number of questions, e.g. what is a "new" problem, what is a "different" solution, and what is a "better" solution. One approach to this complex of questions is through the following line of thought (which has its roots in Shannon's theory of information).

Consider a problem to which all possible solutions form a finite set, s_i, $i=1,...,N$. Assume that nothing further is known about these solutions, so that *a priori* one would not have any reason to prefer one solution over another. Or, in other words, the probability of selecting one solution is equal to that of selecting any other, and $P_i = 1/N$, $i=1,...,N$. Clearly, in some way the value of N must relate to the **complexity** of the problem. If N is very small, limited for example through very detailed standards, one does not have much choice, and the few variants available can all be checked to find the best one. (The question of measuring "best" will be dealt with shortly.) However, in most real cases, the value of N is so large that it is out of the question to pursue each possible solution to the point where the best one is evident. One needs to have a "feel" for where to look, and the larger N is, the more complex is the problem and the more creative one needs to be to find the best solution.

It would now not be unreasonable to take the entropy, Q, defined by

$$Q = -\sum P_i \ln(P_i) ,$$

as a measure of complexity, and in the present case it equals $\ln(N)$. But taking Q also as a measure of creativity is not appropriate, as the following considerations show.

The assumption of a uniform probability distribution is unrealistic; no engineer approaches a new problem with a blank mind. He is either aware of existing solutions, or he is familiar with solutions to similar problems, or his previous experience and training would make him prefer a particular subset of solutions, or certain subsets of solutions are in at the time, and so on. Thus, if one gave the problem to (infinitely) many engineers to pick a solution, one would obtain a non-uniform *a priori* probability distribution, as illustrated in Fig.1. Because of this existing knowledge about the problem, it is less complex, and this is indeed reflected in the lower value of the entropy, Q. However, to say that producing a solution to this problem is necessarily less creative than in the case of the uniform distribution is not correct. It is exactly in those cases where everyone believes that the solution has to be of a certain type that coming up with a totally different but better solution is particularly creative. Rather than using the entropy as a measure, creativity should be measured by something like $1/P_j$ or $-\ln(P_j)$, if s_j turns out to be the best solution.

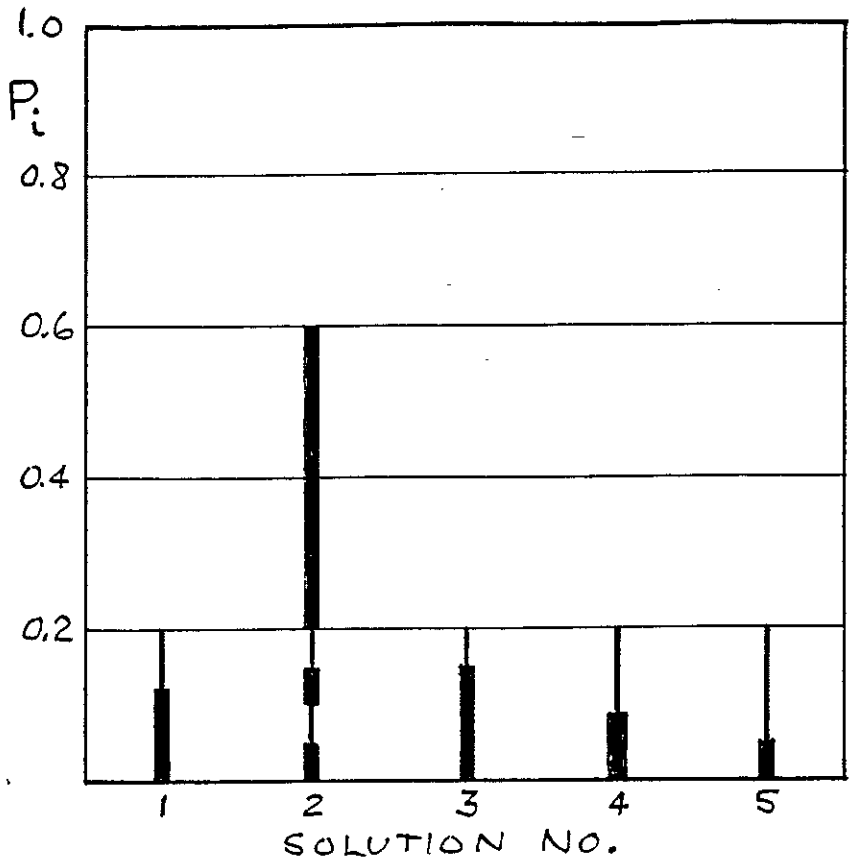

Fig.1 An example of a problem with five possible solutions. Case a (thin bars): Uniform probability distribution, $P_i=0.2$, and $Q=ln(5)=1.6$. Case b (bold bars): Non-uniform distribution, $Q=0.9$, but solution no.4 would be highly creative.

There remains to say something about the use of the word "best". Generally, the all-encompassing measure of the solution to an engineering (or any other) problem is its cost-effectiveness; it is a matter of correctly identifying and quantifying all costs (including social cost, environmental cost, the value of human life, etc.) and the values of all elements making up the service offered by the solution. In practice, this is such a complex task (and one that cannot be carried out by engineers alone) that one is satisfied with defining a set of **acceptable** solutions by comparison with one or more existing solutions or solutions to similar problems. A new solution is acceptable if it is at least as cost-effective as the existing ones, and the "best" solution is determined solely by comparison within this set. This may not be a particularly satisfying situation to some people, but it illustrates that creativeness is largely divorced from the process of setting values; it occurs equally within quite diverse sets of value judgements.

In summary, it is argued that although there is a connection between complexity and creativeness, they are different in nature. Solving a complex problem is not necessarily creative; conversely, finding a new and better solution to what was until then considered an almost trivial problem may be very creative. Finally, creativity is largely value-independent.