Toward a Quantitative Theory of Design

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Abstract. I present a proposal for a new quantitative test for design, in contrast to previously proposed standards such as "order" and "irreducible complexity."

If I say, "The universe looks designed," have I made a scientific statement? In recent years, many people have debated this question. Even among Christians who affirm that the universe is designed, some argue that we can never measure or quantify that property of design. Some would argue that by speaking of design we enter the arena of religion and leave the world of science.

Why should this statement necessarily be off-limits to science? Certainly it cannot be just because it is a qualitative rather than a quantitative statement. Science does not necessarily require equations and graphs; qualitative descriptions often are good science, and sometimes using equations actually makes a description less scientific. For example, a botanist working in a new field who lists and describes various plants without using equations can be very scientific; an English professor who runs a book through a computer which counts the frequency of the letters may make substantially worse descriptions of books than a person who makes qualitative comparisons of styles. Many things have properties which we cannot quantify; like pornography, we "know it when we see it" but find it hard to make precise definitions. In many ways, design is like that. In Paley's famous example, if we find a

watch, we expect that a watchmaker exists. But exactly what property of the watch makes us expect that?

Christians have long been in the position of saying "I know it when I see it" in regard to design. I consider this a valid observation, just as saying that something is beautful is valid without recourse to mathematical equations. This kind of description does have the weakness, however, that others may simply say that they don't see it.

One can therefore see the appeal of trying to formulate a quantitative standard of design. So far, we have not had a successful quantitative theory. We are, in effect, at the same point in history in regard to design as scientists in the Middle Ages trying to formulate chemistry. There is nothing intrinsically unquantitative about chemistry, and these days chemistry is highly quantitative, but at that time alchemists were reduced to simply describing the elements qualitatively because they had no better theory. Their qualitative descriptions were, in fact, good science and laid the basis for later more quantitative theories. In the same way, the qualitative discussion of design is not inherently unscientific, but it begs for greater exactitude.

We would like a standard by which we can say that one thing has *more* observable design than another thing. We also would like a standard by which we can make predictions, in other words, by which we can take some thing which is not known *a priori* to be designed and assess its level of design.

1 What We Mean by Design

When we say a system is "designed," we mean that its *function* is connected to a *purpose*. By "purpose," we mean an estimation of future events with an intent to control those events.

In speaking of "purpose," we enter the realm of "teleology." As Barrow and Tipler [1] have reviewed in their admirable survey, teleology was once considered a valid field in Western thought, but in the past century teleology has fallen into disrepute. Many philosophers have argued that we can observe only the *function* of a thing, not the purpose of a thing.

Yet purpose is not always unobservable. We have one obvious example in which purposes are made known to us: the actions of other people. People tell us that they are doing things for a purpose, and we see that their goals are often achieved. Clearly, people design things.

To argue for design from non-human sources, we want to begin by iden-

tifying the attributes of things which humans have designed. By induction, we look at the attributes of things which we have been told are designed, and try to establish the universal properties of these things, such that in our experience all designed things have these properties and no undesigned things do. If then we see these same properties in things from non-human sources, we can then argue inductively that they also arise from design.

The form of the argument is the same as that by which we reason that hydrogen atoms exist in other parts of the universe. We start by establishing the universal identifying properties of things which we know contain hydrogen, e.g. optical line spectra. When we then observe the same line spectra coming from other stars, we reason that these effects arise from the same cause.

The argument that some things outside human control are designed is therefore an inductive argument based on our experience with human design. The argument goes as follows:

- All the things which appear to be designed come either (1) from human intent, which we know to be purposeful, or (2) from automatic processes in existing systems which themselves appear to be designed, for which we do not have direct observation of their origin. (The appearance of offspring is not new design, but simply copying of existing design into a new embodiment, e.g., through the transmission of DNA.)

- Since the only known examples of appearance of new design come from human purpose, we reason that the design which exists in automatic processes of existing systems outside of ourselves comes from a similar cause. In other words, we conclude that something in the universe is similar to us in the aspect of having intent and purpose.

This argument makes sense if we agree that certain things which humans did not create appear designed. Again, this begs the question of what makes something appear to be designed. In the case of things not created by humans, we do not have any way of observing purpose; we can only observe function. Can observation of function alone imply design?

2 Proposed Standards for Appearance of Design

Several quantitative approaches of the appearance of design have been proposed, with various weaknesses. An old theory is that "order" indicates design, and that by quantifying the order of something, we can quantify its level of design. Order is easily quantified; for instance, we can easily measure periodicity by means of a correlation function. The problem is that many things have a high degree of perceived order even though they are actually in the maximally *disordered* state (the highest entropy state) allowed by the environment. For example, a crystal has a high degree of observable and quantifiable order– the atoms are all aligned in rows. Yet a typical crystal can not become more disordered without raising its energy. The order comes from the strong attraction of the atoms, which forces them into the closest packing they can find.

Why do we associate order with design? Because in our general experience, perfect periodic order is uncommon in nature except when produced by humans. People set things in rows and columns, but most of nature is much more random to the eye. We value crystals for this reason, because they are rare. Their order, however, comes from the close packing which arises from the strong bonds between the atoms.

Periodicity is not the only measure of order. More generally, one can speak of *entropy* as a measure of order. The quantity of entropy is found by counting all the possible equivalent states of a system. The more equivalent states, the more entropy a system has. This notion assumes the idea of macroscopic "course graining." At the microscopic level, every different state of a set of atoms in a gas has a slightly different characteristic, and if we knew the exact position and momentum of each atom, different states would not be equivalent. When we take a large sample, however, i.e. a "coarse grained image," many of these states become equivalent.

The Second Law of Thermodynamics states that entropy in nature must always stay the same or increase. Another proposed quantification of design is therefore that design involves violation of the Second Law. This does not mean that a designed system violates the Second Law on an ongoing basis. A refrigerator does not violate the Second Law in its normal operation. The spontaneous appearance of a refrigerator from random pieces of metal and plastic *would* violate the Second Law, however, and therefore a proposed

standard of design is that designed systems must violate the Second Law to appear, in the absence of a designer. The problem with this proposal is that no one was around to observe the appearance of the systems under debate, namely life, and therefore we cannot prove that the Second Law was violated. Some unknown force, like the strong attraction between atoms in a crystal, could theoretically have arranged the system.

Another possible measure of design is "probability." We tend to assume that extremely improbable occurences only happen if there is a intelligent agent involved. For example, if I walk into a room and find 100 dice all lined up showing "ones," I instantly conclude that a person has arranged them that way. It is physically possible that they have simply fallen that way from a random throw, but that possibility is extremely improbable, so much so that I don't even waste time considering the possibility. I *know* that someone has arranged the dice.

There are two problems in using probability as a measure of design. First, in strict statistics, we cannot assign a probability without an enumeration of all the possible states. Enumerating all the possible states available in the process leading to life is extremely difficult. If we allow possible other universes with different physical laws, the calculation seems impossible.

Based on our experience in other fields, however, it may not necessarily be so difficult. For example, in statistical mechanics, probabilities are calculated over the set of all possible states of atoms in a gas. No one could ever enumerate all the possible configurations of the atoms. Nevertheless, a few simple assumptions about the range of possibilities allow one to calculate and predict gas behavior extremely accurately. In this case, however, we are confident we know all the rules of the game, so to speak, while in the case of life, we are not sure we know all the rules.

The second problem with the probability argument is that even if something is seen to be improbable, that does not necessarily prove the existence of design. Accidents do happen. Even if something is so improbable that it is unlikely to occur even once in the lifetime of the universe, that fact alone does not strictly prove it is designed. If a meteor hit the tip of the Empire State Building, would the improbability alone prove that it was a sign from God? What is perhaps a tighter argument is to say that if something appears designed, *and* is extremely improbable, then it is fair to conclude it is actually designed. But this brings us back to the question of what makes something appear designed.

Another proposed measure of design is "complexity." Intelligent design

often leads to complex things, such as the internal parts of a computer. Not everything which is complex is necessarily designed, however. It may be complicated to determine all the positions of the fibers in a wad of cotton, but this does not mean the cotton ball is a highly designed system.

Recently, Dembski and Behe [2] have proposed the notion of "irreducible complexity" as a standard for design. In this proposal, the observable function of a system requires a minumum level of complexity. This is extremely useful in arguing that a thing could not have evolved by incremental development, if several parts together are needed for a thing to have any useful function at all. This concept does not immediately lend itself to quantitative analysis, however, other than counting the total number of necessary parts. Even that measure is made difficult because there can be debate about what count as "parts." Nevertheless, this proposal has some similarity to my proposal here, as I discuss below.

3 The Proposal

A first step toward a quantitative definition of design can be made by noting that a thing is more designed when more of it has a purpose. Since we do not directly observe purpose, this may seem unhelpful. But the converse helps: things with less design have more parts with no purpose. This allows us to talk in terms of function. Things with no purpose make little difference in the function of a system. In other words, in a well-designed system, every little thing has a designed function, while in a poorly designed system, some things have no particular function.

This leads to a further implication: in a poorly designed system, it is likely that some things can be changed without affecting the overall behavior, because those things have no function. In a well-designed system, the opposite is true. This leads to the proposal,

> **In a well-designed system, small changes in the internal structure will lead to large changes in the overall function.**

This allows a discussion in terms of mathematics. Function of a system can be defined in terms of quantitative observables such as lifting capacity, number of offspring, amount of energy collected, etc. If a functional observable y depends on some internal parameter x according to the rule $y = ax^p$,

we call this a power-law dependence, and the higher p is, the stronger the dependence. An exponential dependence $y = ce^{ax}$ is even stronger than a power-law dependence. Logarithmic depencence $y = a \log x + c$ is much weaker than power-law dependence.

One can see immediately that this standard works for many systems we know are designed. For example, if you open your computer and remove a small part, it will likely have a large effect on the function of the computer; if you open the hood of you car and remove a small part or two, it will likely have a drastic effect on the function of the car. This definition also works well for things we know are not designed. If I remove a few parts from a garbage heap, it remains a garbage heap; if I remove a few fibers from a cotton ball, it still has the same basic properties.

For this definition to be truly useful, we would like to be able to say that there are no exceptions. In other words, we would like to say that *all* designed systems have this kind of sensitivity to internal changes, and no *undesigned* systems have this sensitivity. Can we think of any exceptions?

One possible exception might be an modern art painting. Such a painting may have random blotches, so that we conclude that the exact position of the blotches would make little difference on the overall effect of the painting, yet we know the painting is designed. If you believe this is the case with a particular modern art painting, try going into the museum and making a few small changes in it with magic marker. You will find that the museum guards and the owner definely do believe that small changes make a big difference! The artist would say that every spot was there for a purpose, and the overall effect of the painting could be ruined by small changes. Even "interactive" art, which allows the audience to make changes within a limited range of possibilities, has its own internal machinery which must not be changed, which determines the range of possibilities.

A possible exception of the converse nature might be an avalanche. In this case, a system which is clearly *not* designed shows extreme sensitivity to small changes. A small shift of snow at the top of a hill can make a big difference in the behavior of the rest of the snow. In this case, however, not only do internal changes make a big difference, various fluctuations in the environment, such as wind or rain, can also lead to the breakdown. This is the opposite of what we expect for a well-designed system. A well-designed system should be robust and durable, and not break down or radically change its function when the environment changes. This means we must add a second attribute to the proposed quantitative definition of design, which can

be called the condition of robustness:

> **In a well-designed system, large changes in the external environment will lead to small changes in the overall function.**

In the case of an avalanche, the effects of environmentally-induced changes are the same as those of internal changes. In a quantitative theory, this would lead to two terms which cancel out.

These two definitions taken together require a distinction between "internal" and "external" parameters. This distinction, of course, may be the subject of debate. No theory can avoid the intrinsic vagueness of words. In general, however, it should not be so hard to make the distinction. We may admire a well-designed car which has a sensitive fuel injection system inside; if it also has a rugged frame and durable exterior, we admire it even more. In another example, loaded dice have both aspects of design. If the dice have heavy weights on one side, the function of the dice will be robust to external changes– the dice will frequently come up with the same number. If the weights are too heavy, however, then another person will instantly know they are loaded. The function of the dice is therefore very sensitive to small changes in the internal parameter of the load weight– if it is too heavy, it will be easily detected, and if it is too light, the dice will not have a robust function.

This proposal incorporates and extends the Behe/Dembski proposal of "irreducible complexity." It is clear that a system with several necessary parts will be highly sensitive to internal changes, e.g removal or alteration of one of the parts. A designed system need not have many parts, however. One author showed that a mousetrap can be made of a single "part," a wire bent in a complicated pattern [3]. Would this type of mousetrap be undesigned? While it has only one "part," a glance at this "single-part mousetrap" shows that its function is still ultrasensitive to small changes; slight bends in the wire will prevent the delicate balance necessary to trigger the spring on the mouse at just the right time.

4 Defining Undesign in a Designed Universe

In the above definition of appearance of design, we have tried to define an "if and only if" condition– all systems which are designed have these properties,

and no systems which are undesigned do. Our standard is confirmed by testing it against systems which are known to be designed and undesigned. A difficulty arises, however, in defining exactly what we mean by "undesigned." If we simply say that everything not designed by humans is defined as "undesigned," then we define all animal and plant life as undesigned, and trivially eliminate the question of the design of life by definition. On the other hand, if we allow that some things not created by humans have the properties of our standard of design, how do we know that our standard is not flawed, and that some system which we say looks designed is not, in fact, undesigned?

To argue for the validity of our standard, we do not need to divide the entire universe *a priori* into two classes, either designed or undesigned things. To argue inductively, we only need to have two classes with a large number of elements, one which contains things we know are designed and another which contains things we know are undesigned. If there are no exceptions to our standard, then we have a good inductive argument, even if we cannot prove that no exception will ever come along.

As discussed above, it is easy to find things which belong in the class of designed things, because the designers (humans) tell us that the things are designed. Finding undesigned things is trickier, however. If a person is not involved, how do we know that, for example, a rock pile is to be included in the class of undesigned things while a weed is not?

We can not say we know something is undesigned simply because no human designed it. We can say something is undesigned if a human is involved, controls the entire set of parameters of interest, and tells us the thing has no design. As humans, we do not control the whole world, but we control some subsets of it. Within those subsets, we expend more or less energy in designing things. A typist controls the entire content of a sheet of paper, and can either type randomly (without purpose or design) or carefully (according to a plan.) A randomly typed page could easily have a few letters changed and still look like a randomly typed page; i.e. have the same function, conveying the same small amount of information. Clearly, humans create things which have little design, such as messy rooms, junkyards, and random babbling.

Christians often say that the entire universe is designed by God, however. If we say that the entire universe is designed by God, how can we say that some parts of it, those controlled by humans, are undesigned?

We must be careful in our theology in saying that some things lie in a sphere controlled by humans, and things have no design within that sphere. This is not the same as saying that God does not have control over those

things. The Bible teaches that God has control over all things ("even the hairs on your head are numbered,") but often the means of that control are hidden from us. Underlying all that we do, there may be a hidden design of God, but at our level, we can say that we do indeed control things. Working at this level, and not that deeper level, it is proper to say that we have created things with little or no design.

Sometimes, indeed, we penetrate the veil and see some of God's design at a deeper level. We can admire the delicate fine tuning of the laws of interactions between subatomic particles, which we are made out of. If slight changes were made in these laws, their function would drastically change (e.g. life would be impossible, as pointed out by numerous authors [1, 4].) The design at this lower level does not prevent us from saying that undesign exists at a higher level, unless we subscribe to the reductionist view that subatomic particle interactions are all that matter.

5 The Question of Poor Design

A standard objection to the argument for design is the "Panda's Thumb" argument [5]– if we look at some living systems, they appear to have instances of poor design. Does this imply that God cannot have designed it?

A quantitative standard of design helps in understanding this issue. Suppose I look at a Mercedes-Benz, and decide that the hubcaps are not aerodynamic enough. Should I conclude that the Mercedes-Benz is not a designed system? Or should I simply say that it is designed but does not have the highest possible level of design?

In the case of the Mercedes-Benz, perhaps I have missed some other function of the hubcaps. For example, perhaps they are designed for good looks instead of aerodynamics. In the same way, some authors have made much of the poor design of certain living systems without taking into account their other possible functions in a larger system. For example, peacock tails may make peacocks less efficient, but they have the function of pleasing people. Shade trees convert sunlight less efficiently than algae, but shade trees provide shade for humans, and algae doesn't.

It is possible for a system to have undetected design. If we do not observe the function for which something is designed, then we will not see its functional dependence on anything. A young child looking at a piece of scientific equipment designed to create nanosecond digital pulses may see nothing but

a box with blinking lights and not see any function at all. We can therefore talk about "detected design." If we see no design, we cannot prove that it is undesigned, we can only say that we see no evidence of design. With a quantitative measure of design, we may also say that we see only a certain degree of design.

As Augustine of Hippo argued, no thing but God can be perfect in every way. Therefore every created thing has "imperfections" to some degree. We therefore can speak of a heirarchy of design, from inanimate objects to "lower" life forms to "higher" ones, with increasing quantitative measure of design. This is warranted, for example, by the narrative of Genesis 1, which sets mankind over animals, animals over plants, and plants over the rest. Jesus also said, "Are you not much more valuable than they?"

Finding something further down in degree of design does not imply that no thing has design. In the same way, finding a simple little ditty written by Mozart does not mean he was a poor composer. People make various things for various uses, and there is no logical resaon why God could not do the same.

We must also distinguish between poor design and systems with good design but which have purposes that we do not like. A shark is a well designed killing machine. This raises the question of the problem of evil, which is a separate question. A well-designed, destructive system does not imply the lack of existence of design. It may imply a well-designed instrument of wrath.

6 Conclusion

The argument for design is esentially an inductive argument based on comparison of things to other things which we know are designed by humans. Goodness of design by humans implies that the designed system is extremely sensitive to internal changes and insensitive to external (environmental) changes. Such things seem intrinsic to the nature of design, because in a well-designed system, every little thing has a designed function, while in a poorly designed system, some things have no particular function, and well-designed systems are designed to last.

If our experience is that such systems fall only into two categories, either (1) known to be designed (by humans) or (2) already existing (whether in original or transmitted form), in other words, if it is our experience that all

new design, as quantified here, comes from designers, then we are justified inductively in positing that the systems in the category (2) arise from a source with attributes similar to the known designers of things in category (1).

By defining a quantitative standard of detected design, we can compare degrees of design without needing to categorize all things as simply either designed or undesigned. Some things may evidence little design, while others show it to a high degree. Different people may have different standards of what level of design is defined as "obviously" designed versus possibly coincidental, but a quantitative standard allows the debate to revolve around scientifically determined quantities rather than personal impressions.

References

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[3] http://udel.edu/ mcdonald/mousetrap.html

[4] P.C.W. Davies, *The Accidental Universe*, (Cambridge University Press, Cambridge, 1982).

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