Run the Gambit of Complexity

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Robert J. Marks:

Greetings. I'm your pronounced host Robert J. Marks, on this podcast of Mind Matters news. Today on Mind Matters news on the podcast, we're going to talk about fine tuning. Scientists know the universe is finely tuned. For example, take the pronounced atheist Sir Fred Hoyle. Hoyle was a great astronomer, maybe known best for his coining of the term, big bang to describe the beginning of the universe. Hoyle did not at first believe the universe had a beginning and coined the term in a mocking way. Mocking the theory of the beginning of the universe. He didn't like it. So he tried to make fun of it. But nevertheless, Hoyle's term is mocking term stuck and today we refer to the beginning of the universe, as physicists talk about it, as the big bang. Hoyle was also convinced despite his beliefs that the science of the universe dictated that it had to be fine tuned.

Robert J. Marks:

In fact, most scientists knew there's little controversy that the universe in terms of Biology, Chemistry, and the cosmos is fine tuned. Hoyle said the following about fine tuning. He said, "A common sense interpretation of the facts suggest that a super intellect has monkeyed with Physics." I love that word monkey with Physics. A super intellect as monkey with Physics, as well as with Chemistry and Biology." This monkeying with Physics, Chemistry and Biology is the topic today on Mind Matters news. We have two guests who have published extensively in the literature about fine tuning. Dr. Ola Hossjer is a Mathematics professor, or actually Mathematical Statistics professor at Stockholm University in Sweden, and he joins us from Sweden. Ola, welcome.

Ola Hössjer:

Thanks a lot, Bob, for inviting me to your podcast. Thanks a lot.

Robert J. Marks:

We're going to have fun. And our second guest is Dr. Daniel Diaz. He's a research assistant professor of biostatistics at the University of Miami. Daniel, welcome to you too.

Daniel Díaz:

Thank you Bob. It's a pleasure to be here.

Robert J. Marks:

I tell you, what's incredible about this podcast is currently Ola is in Sweden and Daniel is in Columbia. He makes his living at the University of Miami, but his home country is in Columbia and he goes home there occasionally. So we're having this podcast across three different continents. That blows my mind. I'm an electrical engineer, and every time I hear something like that, I say all these electrical engineers, what incredible things that they can do. I have to warn the listeners that both of these guys are wickedly smart. So you better listen closely. So let's start in with the chat, with the dialogue. Fred Hoyle was already defined tuning and he says, the universe looks monkeyed with to allow life.

Robert J. Marks:

Now he's not the only one. Hoyles, one among many physicists who see fine tuning in the cosmos. The famous physicist Freeman Dyson said, "The more I examine the universe and study the details of its architecture, the more evidence I find that the universe in some sense must have known we are coming." Now, the interesting thing about the fine tuning universe is there are different ways to measure the fine tuning of the universe, to put numbers to it that makes sense to us. And the three of us Ola, Daniel, and I agreed on a list of different ways that fine tuning can be measured. And we want to go through these and discuss each one in turn. The first one is something called active information. Now, Daniel has published quite a bit in terms of active information. Daniel, could you give us a definition of active information and explain why it can be used as a measure of fine tuning?

Daniel Díaz:

Okay. Yes Bob. So let me start with how active information was born as a concept in the scientific literature, and maybe to do that, it is better to talk first about the No Free Lunch theorems. These are actually very famous results in evolutionary algorithm, assigning computer science and machine learning. And the No Free Lunch theorems say that in a big space, you can think of it as if you were shooting to some small target in a big wall. If you start looking at that target at random, then you're not going to do better than end up in a blind search. That is you can have your target in different parts, maybe of the big wall. And when you're looking for it with any algorithm on average, you're not going to do better than a uniform search or a blind search. So active information was introduced in order to measure the amount of information that the algorithm is infusing in order to get to a target, the probability better than just that given by a blind search.

Robert J. Marks:

Yeah. The No Free Lunch theorem basically says as I understand that, you have no beforehand knowledge of any domain expertise of finding the target. So you have nothing that guides you, and if you have nothing that guides you, I would say the No Free Lunch theorem says that, one technique can be used to find the target as well as any other technique. Right?

Daniel Díaz:

Yep.

Robert J. Marks:

Okay. So that's a fair way to say it. One of the examples I think about is Formula 409... Ola, do you have Formula 409 in Sweden?

Ola Hössjer:

No, I haven't heard of it, actually. That sounds interesting.

Robert J. Marks:

It's interesting. It's a bathroom cleaner in a spray bottle. And the reason they call it Formula 409, it's very, very popular in the United States. And how about Columbia, do they have it down there?

Daniel Díaz:

Nope. I haven't heard about it.

Robert J. Marks:

Okay. The reason it's popular, it works really, really well. But it's called Formula 409 because it took 409 efforts to create Formula 409. 409 experiments before they got the final solution perfected, at least to the point where they thought it was commercially viable.

Robert J. Marks:

So the thing is, is that these trials were done by somebody with a background in Chemistry. And so you had this domain expertise that went in. Now, imagine that you went in and you had no knowledge about what was happening. You didn't know anything about Chemistry, you didn't know about anything. Vinegar might work as well as water, as sulfuric acid in doing these things. If somebody came out with no domain expertise, no background in Chemistry, we would be calling that formula 5,623,000 or something like that because the domain expertise simplifies things. But the No Free Lunch theorem as I understand it, pre-assumes that there's no a priori information. And that's a very important distinction. So, okay, Daniel. Okay. So that's good. How did I do?

Daniel Díaz:

Great. You did great. So let me compliment that because your question actually, was the relation of active information to fine tuning?

Robert J. Marks:

Yes.

Daniel Díaz:

And I want to compliment that point. You think that just as in this example of the big wall, let's call it. This big wall is going to be called formally a space. And the small target is just similar to what is happening in cosmological fine tuning. Cosmological fine tuning says that actually the laws of nature and the constants in the standard models of Physics, mostly in various small intervals, such that life can exist. And those intervals actually need to have more probability too. So the point here is that there is an easy analogy in mind that comes from the small target in the big wall to the small interval among all the set of possible numbers that the constant can take. So there is this relation between fine tuning and search problems. They look for targets in computer science. And with that analogy in mind, we can use some tools of search problems, like active information in order to measure also fine tuning.

Robert J. Marks:

And you get a number there. What's the number that you get out of active information? You get actually a numerical measure, right?

Daniel Díaz:

Yes. We have some numerical measures, but those numbers are going to change in different settings and different strategies for different values that you're also considering.

Robert J. Marks:

Okay. I think that the units for active information is bits. Is that right?

Daniel Díaz:

So you're meaning the units in which it is measured? Yeah, it is measured usually in bits, just like we do usually for computation, and two, we do the same in general for measuring active information in any setting. So the units are not important. It's like measuring length in terms of kilometers or miles. You can make easy conversions from one to the other. And you can, for instance, change from bits to something that is called knots, which is a different way of measuring information. But in the end, the important thing is that from the beginning you are clear on what is the measuring that you're using and keep it constant along the whole process.

Robert J. Marks:

Okay. One of the things that you mentioned, Daniel is this idea of intervals, and I know that Ola, and you and I have done work on not just talking about the interval of fine tuning, but a probability measure of fine tuning and the difference between them and why one is the better. Ola, could you talk about?

Ola Hössjer:

Yes. And that's a very good question because we have some process that generates outcomes and it could be the generation of generating the universe by some mechanism, where it could be also in Biology, generating a protein by some evolution or algorithm or something. And as you said, we have a target that could consist of a certain region or a certain interval within this overall space of possible outcomes. And as Daniel said, when we talk about the origin of the universe and look at a particular constant of nature, it's only a very small life permitting interval for that constant of nature that corresponds to universe that it meets life.

Ola Hössjer:

So, in that case, we could say that these small life permitting interval, as Daniel said, is the target of this process that generated our universe. And then, so we have a small interval and then we would say, what is the probability that this process of generating this constant of nature, what is the probability that... If we think of this process as random in some way, what is the probability that this constant of nature falls within the life permitting interval?

Ola Hössjer:

And then intuitively we think that a smaller life permitting interval would correspond to small probability of ending up there. Whereas the large life permitting interval would correspond to a large probability of ending up there.

Robert J. Marks:

But you've shown that this isn't true, right?

Ola Hössjer:

Not necessarily. Because it depends on the various possibilities of this random outcome of generating the universe. And that's called the statistical distribution of that constant of nature that comes out from how the universe, and in particular, this constant of nature how it was generated. So in principle, it could be the case that the distribution is completely within this small life permitting interval. And then the probability would be one of ending up with a life permitting universe. At least when we talk about this particular constant of nature. And in the same way, it could be the case that we have a very large life permitting interval, but this distribution is completely outside of it. And then still the probability is zero, but these are exceptions. So in our paper, we have a general way of choosing this distributional, the value of the constant of nature, which is outside of the universe.

Ola Hössjer:

So how it was constructed, we have very little knowledge about it. So we use maximum ignorance or maximum entropy. So that gave us a clue, which distribution to choose for this constant of nature. And then it's typically the case that a small interval gives us more probability and the large interval gives a large probability. And actually, we have some freedom of choice of choosing these distributions. So we actually take the... We are quite conservative. So we take the largest possible probability of ending up in this life permitting interval. And if it's still a small, then we can say with more confidence that yes, this universe is fine tuned with respect to this constant of nature.

Robert J. Marks:

So a question is you use the term maximum entropy. I think most people are familiar with the idea of maximum entropy associated with thermal dynamics. And I think there's a relationship here. But as a statistician, you used the term maximum entropy in a different context in a more of a mathematical context, is that right? Could you elaborate on that a little bit?

Ola Hössjer:

Yes. That is correct. And this is something called Bayesian statistics. So we have a certain parameter, the value of this constant of nature, and we use a certain prior distribution for that constant of nature. And then there is something we observe, the life permitting interval or physicists have determined it. That's the likelihood part. And then the question is in Bayesian statistics, how do we choose this prior information? And you could choose this in different ways. It could be chosen on subjective grounds, different people chose it differently.

Robert J. Marks:

Now with this prior it'd be something like the domain expertise that I talked about?

Ola Hössjer:

Yes, it could be. Yes. Then if you have prior knowledge, then you can use that. If you have previous data, you could use that in order to choose the prior distribution. But if you don't have any prior knowledge or prior data whatsoever, then you can let the prior be chosen in such a way that it corresponds to lack of knowledge. And that is maximizing epistemic uncertainty. So it's not like in thermo dynamics. When entropy means another thing, the degree of disorder. Here, it means the degree of lack of knowledge about the value of, in this case, the constant of nature. So we want to maximize our degree of uncertainty about the value of these constant of nature before we have observed anything. And that means maximizing entropy. And that's a bit more tricky when the domain is unbounded. For a bounded domain, is simply taking a uniform distribution. But we have a way to circumvent that.

Robert J. Marks:

Yeah, that's one of the relationships between the mathematical idea of maximum entropy and the thermodynamic. Usually we think of thermodynamics as if you're in a room then maximum entropy corresponds to all of the velocities of the particles, the distribution being the same, and every point in the room. And we can't have the situation where all the molecules accumulate in the upper right-hand corner of the room. They have to be spread uniformly. And that is directly to the idea of maximum entropy that you're talking about in mathematical sense. But also the way that I relate to this is that maximum entropy is applicable elsewhere in unbounded domains.

Robert J. Marks:

One of which is the distribution of pressure on earth from the surface as you go to outer space. Now, it isn't bounded in a room, but as you go from the surface to outer space, you still have a maximum [inaudible 00:17:06] distribution, but that turns out to be something called an exponential distribution. And that is maximum entropy with those boundary conditions. So those are the things that you're talking about in terms of maximum entropy in different domains, bounded and unbounded. Does that fair?

Ola Hössjer:

Yeah. So, we talk about maximum entropy in terms of maximizing our degree of ignorance, our epistemic uncertainty about the value of this constant. So even though when we talk about pressure and things like that, then we talk about a physical system in a slightly different way. It's still amazing that you get a distribution that maximizes entropy and in this case, yes, as you say, we have an unbounded domain, but the exponential distribution... If we look at all the distributions on the positive realign or the distribution that puts all its probability mass on positive numbers, then the exponential distribution maximizes entropy subject to a constraint, the side constraint on the expected value or the distribution, the first movement. So yeah, it's amazing that we can actually have maximum entropy distributions in nature in this way, even for unbounded domains. So yeah, that's amazing.

Robert J. Marks:

Yeah. It seems to be ubiquitous. Doesn't it? You mentioned Bayes'. And Daniel, I'd like to ask you about this. One of the thing about Bayes' is that it's criticized by its a posteriori or after the fact probability. Let me illustrate. If you were to apply Bayesian analysis or after the fact analysis to the probability that the three of us would be here. One in Sweden, one in Columbia, one in Texas, and we've been doing a podcast. I don't know if it makes a lot of sense to talk about the probability we would be here doing this. So what am I missing here?

Daniel Díaz:

Yeah. So before answering that question, Bob, let me just make another comment on small intervals, small probability on fine tuning.

Robert J. Marks:

Yes, please.

Daniel Díaz:

Because fine tuning is usually taught in terms of the small life permitting interval for the given constant of nature. But I think that what we have shown it is more important, it is more probability for the small interval than the length of the interval itself. So that being said, the good definition for fine tuning basically of an event is just that that event has a very small probability. That is a better definition of fine tuning than just having a small length interval. Maybe it is more appropriate to speak about the small probability of the interval, because in that sense, it does not matter if the interval, as Ola was saying, has a big length or a small length. What is important is the probability that is associated to it. And that's going to be a better definition of fine tuning, a much more accurate definition of fine tuning.

Robert J. Marks:

That makes a lot of sense to me. I've seen some fine tuning videos and they say, okay, this constant, whatever it is, maybe the speed of light, that if the universe has fine tuned to allow for the existence of life, let's say this is an inch. And we look at all the other possibilities, then that spatial interval extends from the surface of the earth, the surface of Jupiter or something like that. And the probability, not the probability, but the interval for life permitting is a small one. That's really not important as to what you're saying is that, it isn't that the interval is small. The question is what is the probability that you exist within that interval?

Daniel Díaz:

Yes, that's right. And there's something very interesting about it. I think Ola also mentioned a little bit about this too. And it is the fact that actually... This could lead to a reconfiguration of the fine tuning problem in which sometimes even very, very large intervals. Intervals of a very large length, even infinity could actually have a small probability. And that happens sometimes in probability. You can have some intervals even of infinite length that half is more probability, but also...

Robert J. Marks:

Wait, say that again, you can have intervals of infinite length, which have small probabilities. That was an important statement. I just wanted to pause there and point out and let that sink in a little bit. Go ahead.

Daniel Díaz:

So let me choose give... This is a technical example, but imagine that your space is the whole real length and you know then the distribution you were thinking of has a first finite moment, that's going to be the mean, and then it has source of a second moment that is finite too, which is saying that it has a variance. Then you know that the maximum entropy distribution for that space is going to be a normal distribution with that mean and that variance that you were thinking of.

Daniel Díaz:

In that case, you can take for instance, the interval from minus infinity, I don't know, to my news, 10 trillions. And that's going to be an interval of infinite length, but the probability is going to be very, very slow. It is going to be more close to zero than to any other thing, basically to put it informally. The probability is still going to be positive, but it's going to be so, so small that it is negligible in most cases. So that's a good definition. Then fine tuning it's the better definition to think of this more probability of the event that you're considering than the volume or the length of the event itself.

Robert J. Marks:

Okay. So I think the takeaway here is that intervals are okay, and okay way to measure fine tuning, but probabilities are much better?

Daniel Díaz:

Yeah. It's a much more accurate.

Robert J. Marks:

It's better to talk about the probability.

Daniel Díaz:

Yeah. That's true. And now regarding your second question or the question about the importance of Bayes' theory, or as it is called in the statistics in contrast to frequentist theory. This has been a long, long debate. It's very long debate in the history of statistics between these two positions. Between frequentist and Bayesianist as you could think of. These are two different approaches to statistics. And the interesting thing is that as far as I'm concerned, I can see many cases in which one of the approaches is better than the other, and the opposite is also through in many cases in which the other approach is better than the previous one. So it depends on the problem that you are working on, that you're going to have some....Problems for each of the approaches you were considering.

Robert J. Marks:

Okay. And in fact, both of them have applications. As an engineer I'm always interested in reduction to practice. And one of the things that Bayesian statistics is used for is something like spam filtering, where you gather a lot of emails and you figure out what is the probability that if a Nigerian prince is mentioned in the spam. We all remember the spam about the Nigerian prince trying to get you to give money to this Nigerian prince. And it was a spam and a lot of people fell for it. But you can look at data that appeared in the past, and the probability that the Nigerian prince given spam, and you can figure that out. You can look at all of the labeled emails and look at all of the ones that have been labeled spam and figure out how many that had Nigerian prince in them were actually spam.

Robert J. Marks:

And then Bayes flip side around and your spam filter figures out the probability it was spam given that it mentioned the Nigerian prince. And so therefore it's much more complicated than... Not more complicated, but well, the spam filter is much more complicated than this. But that's a simple illustration. And this works, and this is the reason we use Bayesians statistics. Now, if you look at an email that has Nigerian prince in it, it's either spam or it isn't. But your Bayesian statistics can say, what is the probability that this email already given or already sent, already received? What is the probability that it is spam? So it does make sense to me. And as an engineer, I always say that reduction to practice is the proof of the validity of a theory. So I think that the criticisms of Bayesian statistics that I mentioned was totally inaccurate. It's not a good argument.

Daniel Díaz:

Yes, you're right. So it all depends on the context that you are talking of. So as you were mentioning for spam filtering, Bayesian approach is very useful. It is also useful in some areas of medicine. I work in biostatistics, so I know that in many, many analysis of treatments, Bayesian results are very useful and more useful in some cases than the frequentist approach. But as I say, there are other approaches, there are other problems in which the frequentist approach works better. The important thing for our conversation is that actually the right way, I think, to approach our problem was using Bayesian theory and Bayes' theorem in order to determine what was the distribution of maximum entropy to use. So for fine tuning in order to avoid certain problems that were there in the past, the right approach was to consider that prior distribution was given in terms of the maximum entropy. And that is also done with the help of the Bayes' theorem on Bayesian theory.

Ola Hössjer:

Yes. I totally agree with that because we use Bayesian statistics and put a prior distribution on the possible values or a certain constant or nature. Because the Bayesian statistic approach, not the frequentist approach, we are in fact, able to talk about the probability of this interval, because we use a Bayesian approach. With a frequentist approach that would not have been possible. We could only talk about how consistent each possible constant of nature is with data and so on.

Robert J. Marks:

Excellent. So the frequentist approach talks about probabilities events, which haven't happened yet, whereas Bayesian talks about the probability of events that have already occurred by turning that around. I think that that's an accurate depiction. Is that fair?

Ola Hössjer:

Yes. Because in Bayesian statistics, you have probabilities of the past, that is your prior, what you believe about a certain parameter, for instance the constant of nature. And then what is going to happen, that is a data that you might not have collected yet. Then you also have a distribution or that also in Bayesian statistics, whereas in frequentist statistic you only impose a probability distribution on data for the future, so to speak, not from the past. From the past, you regard each possible value of this parameter, is possible value of these constant or nature as a fixed constant. You don't put the distribution on it.

Robert J. Marks:

Excellent. Well, I want to bring us back on track just to remind what we're doing. We're talking about fine tuning and the ways that fine tuning could be measured. We've gone through the method of active information, measuring of active information, measuring small intervals, and also probability of fine tuning existing. The next one I want to ask Daniel about is specified complexity as a measure of the fine tunedness. Is that the right word? How well a process is fine tuned? Daniel, what is specified complexity and how does it measure fine tuning?

Daniel Díaz:

Okay. So let me talk about a specified complexity in the context of fine tuning of our main topic here. So we can think of the life permitting interval as an interval that is a satisfying a very special or that is fulfilling a very special function. And it is that outside it, life as we know it could have not existed in our universe. So in that sense, that is more interval is fulfilling a very important function. It is satisfying a very important function in that sense, just to put it in very simple terms. We could say that, that life permitting interval is a specified. Now in a specified complexity, there are basically two components, the specification and the complexity. So the specification is given by the function the interval is fulfilling. As I said again, if the constant is inside the interval, it is going to allow for a universe to have life.

Daniel Díaz:

But if the constant is outside the interval, then no life could exist in the universe at least as we noted. We are thinking of carbon based life here. And that is as much as we can say, in very simple terms, or we can talk in very simple terms of their specification. On the other side, complexity is more simple to understand. It is simple. You can think of complexity as very small probability. So in very simple terms, you can think of complexity, something that is improbable. So complexity is inversely proportional to probability. The more probable an event is the less complex it is. And also the less probable an event is, the more complex it is. So when we are thinking in terms of fine tuning, then the life permitting interval is specified. So what we need to measure now is its complexity. We need to know if it's probability is more. And then that is how a specified complexity makes its way in the context of fine tuning.

Robert J. Marks:

Okay. Excellent. The last topic that we want to talk about that measures fine tuning is so-called irreducible complexity. And how does that measure fine tuning? Ola, could you talk about that?

Ola Hössjer:

Yes. And this is a nice follow-up of Daniel's nice explanation of specified complexity. Because irreducible complexity is a special case, I would say of specified complexity. As Daniel said, specified complexity, then something is complex. It has a small probability of occurring by chance. And there is an independent specification. For instance, the universe admits life or in Biology, molecular machine that works and so on. And irreducible complexity is a special case when this complexity is like a machine that has many parts to it. And in order for this machine to be specified, in order for it to work, all the parts have to work.

Ola Hössjer:

So if you remove one single part of all these many parts, the machine ceases to function, and that's typically makes this machine more complex because as Daniel was saying, complexity has an inverse relation to probability. The more parts that are all needed, we put to this machine, the less likely it is for this machine to have evolved by chance. So the summary is that irreducible complexity is a special case. So specified complexity when the structure consists of many parts that are all needed.

Robert J. Marks:

Excellent. Well, we've been going over the methods that fine tuning can be measured. It's heuristically obvious, but it's a lot better if we can put numbers to them. And let me just summarize, we're going through active information, small intervals, the probability measure of the fine tuning. We've gone through specified complexity. And then Ola has just talked about irreducible complexity. So we've run the gambit. I think that we've gotten all of the methods with which me and our guests are familiar with. And so that's going to conclude our podcast. We've been chatting about measuring fine tuning with Dr. Ola Hossjer from Stockholm University and Dr. Daniel Diaz from the University of Miami. We've been talking about different ways to measure fine tuning. Next time, we'll talk more specifically about monkeying as Hoyle said. Monkeying with the universe in Biology with some fine tuning that allows life. Until then be of good cheer.

Announcer:

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