# The Simulation Argument and Incompleteness of Information

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**Abstract:** Nick Bostrom, in his paper titled "Are you living in a computer simulation?" [*Philosophical Quarterly*. **2003**, 53, 243-255], presented an argument as to why the possibility of an advanced human civilization that can generate human-like observers greatly bolsters the view that we might be living in a simulation. Bostrom argues why the fraction of simulated observers among all types of observers with human-like experiences would be close to one, provided one accepts some assumptions, and then the bland principle of indifference dictates as to why one must thus, assuming himself to be a random observer, put the highest credence in the option which is the most common. Bostrom's case rests on the idea that we lack evidence to shift our credence the other way, against the probabilistic conclusions, significantly, however, I argue that we are justified in doing so and a priori. Using Bayesian analysis, I show that the conclusion of the argument need not possess similar credence as the argument suggests, even granting all its assumptions.

**Keywords:** Simulation Argument; Epistemic Probability; Bayes' Theorem; Skepticism

## 1. Introduction

The idea that we might be living in a simulation, and are being controlled by a superior civilization of aliens or future humans, at first, seems to be something out of the pop culture, wherein the wild imagination assumes every possibility existent and logically possible. However, even in academia, the idea of the world being not real in a sense often it is assumed to be has been defended by a few people, with philosophical rigor.

The credit for origination of modern day simulation arguments may be, at least to some extent, given to Tipler who defended the idea of immortality of humanity in a unique way. Tipler proposed that in future, it is possible that the consciousness of already existing humans could be and probably would be revived by future humans with their sophisticated technology and the conscious life would permeate the whole

Universe for eternity [1]. This principle referred to as the “ultimate anthropic principle” is used by Tipler to present his Omega Point Theory which incorporates certain aspects of Judeo-Christian Theology.

Leslie, on the other hand, argued in favour of impending death of humanity as it exists in the Doomsday Argument which is based on the idea that it is more likely that a person who lives currently is more likely to be part of a reference class that is overall smaller in number than the one which is larger in number [2]. This argument is based on the anthropic reasoning that an observer should assume himself to be a random observer out of the set of all observers in a reference class [3].

The anthropic reasoning of the doomsday argument and a belief in the idea that an intelligent life has the capability to develop a technology that can simulate a large number of conscious or seemingly conscious observers can be attributed to be, to some extent, behind the modern simulation arguments. The simulation argument by Bostrom is one the prominent ones, in which Bostrom argues that given that (i) conscious experience can be generated by a computer, (ii) it is not unlikely that humans will be able to have requisite technology to simulate human minds and/or universes in future, and (iii) it is not unlikely that humans will be interested in running those simulations, one ought to believe that he is in a simulation [4].

The conclusions of the simulation argument have quite significant effects on the ontological, epistemic, and ethical considerations. Granting that there is a significant probability that our Universe is a simulation, the theories that argue for an information based reality seem more plausible. That will fundamentally change current understanding of the Universe as the expression of Universe as a simulation would incorporate key informational theory aspects regarding the creation and interaction of material objects. The skepticism regarding the exact nature of the world also would change how we view events occurring in the nature, and instead of events being completely or classically dependent on deterministic aspects of the Universe, there might exist a probabilistic curve on which the reasonable outcomes are just more probable but not entirely determined. The existence of most miracles would be merely a deviation from the norm and the random deviations from the ideal result might be more than just fluctuating conditions affecting the measurement. Similarly, in the ethical/moral realm, the theistic outlook may grace a challenge as it would become more likely that the creator(s) of our Universe might not be a being that could be classified as *"summum bonum"* but just an advanced civilization that might have moral capacities as ours. In fact, all deontological ethical systems would suffer from the problem as the rules for ethical action may already be designated by the creators of the simulation.

The challenges that the simulation argument poses to our current understanding of Universe cannot be easily overstated. Thus, a careful examination of the argument is required to understand the reasons for its deviation from what may be called intuitive belief of humans about their world, granted that the assumptions that Bostrom makes for the conclusion of us being in a simulation are reasonable.

In this paper, I will try to show why even after assuming those premises, and granted a few other reasonable assumptions, one still has sufficient grounds to reject the idea of being in a simulation. The aim of the paper is not to find a flaw in Bostrom's argument as he lays it but to show that how a better way to understand the implications of it renders the conclusions untenable and thus the Bostrom's argument might not possess that level of existential dread as one might think it does.

## 2. Definitions and Assumptions

Firstly, let us define few terms. Let '$S_P$' be a set of all possible worlds, '$S_A$' be a set of all worlds existing in actuality and 'R' be the real world. The term "world" here represents a universe that is collection of all civilizations at the same and continuous level of existence. Different simulations by different civilizations of a real world or simulated world (if one accepts that simulated civilizations can also simulate further civilizations) would be different worlds. It is to be noted here that Bostrom defends the possibility of simulations inside simulations and such a possibility has not been rejected in the analysis [5].

To critique Bostrom's arguments, two assumptions are required to be made. One of the assumptions that this critique of the Bostrom's argument depends upon is that our world can be the real world, where a real world simply means a world that is not simulated. The assumption seems justified in the context of Bostrom's argument. For if indeed our world cannot be real, and thus has to be simulated, there is no need for a simulation argument. Whatever fact establishes the non-reality of our world definitively, overrides probabilistic argument of Bostrom, even if by a small margin. Secondly, Bostrom himself, bases his empirical evidence of possibility of a real world civilization performing simulation of human-like observers on the properties of our own world. If our world cannot be real, it would not be possible for us to determine the capabilities of the real world from our world, for the capabilities of the simulated world may appear greatly exaggerated than the properties of the real world (like in virtual games where the characters can perform amazing feats). While, in such case, the real world could still be capable of simulating our world, it would be impossible to know, from mere these facts, as whether that real world could simulate millions or even thousands of worlds like ours.

The other assumption is that all human like observers in a simulated world are simulated and all human like observers present in real world and not in simulated world are not simulated. This assumption is implicit in the definition of the world as defined in the paper because a real world would not be at the same level of existence as a simulated world. Thus a real world is separated from the simulated world and they are not intertwined as they have no common observers in the same way. It is to be also noted that Bostrom and Kulczycki present a problem with Bostrom's original argument and means to rectify it [6]. As the problem in the argument arises because of differences in averages of numbers of observers in pre-post human phase of the civilizations that end up running ancestors-simulations and civilizations that do not, assuming that no such difference exists in the two sets of civilizations allows us to analyze the core of the argument. In fact, instead of focusing on the civilizations in a given universe, the focus on the "worlds" is far more appropriate, considering differences in civilizations that may affect validity of Bostrom's argument are assumed to be insignificant. It is to be noted though that this assumption is not necessary for the critique to be valid, in general, but it helps to simplify the situation so as to make the critique understandable.

## 3. Analysis and Modification of the Argument

Let us look at the equation derived by Bostrom [3] -

$$f_{sim} = \frac{f_p f_n \overline{N}_1}{f_p f_n \overline{N}_1 + 1}$$

Where,

$f_{sim}$ is the actual fraction of all observers with human type experiences that live in simulations

$f_p$ is the fraction of all human level technological civilizations that survive to reach a posthuman stage

$f_n$ is the fraction of posthuman civilizations that are interested in running ancestor − simulations

$\overline{N}_1$ is the average number of ancestor − simulations run by a posthuman civilization

Bostrom, then, argues that because $\overline{N}_1$ is extremely large, one of the following must be true –

i. $f_p \approx 0$

ii. $f_n \approx 0$

iii. $f_{sim} \approx 1$

$f_p f_n \overline{N}_1$ in Bostrom's argument could be assumed to represent total number of simulated worlds, as separately run simulations would have no continuous level of existence. Consequently, $f_{sim}$ can be assumed to be the probability that a given world is simulated, and thus, not real. Let us denote $f_p f_n \overline{N}_1$ by n. So,

$$f_{sim} = \frac{n}{n+1}$$

And,

$$f_{real} = 1 - f_{sim} = 1 - \frac{n}{n+1} = \frac{1}{n+1}$$

Real world here means a world that is not simulated. The conditional aspect of Bostrom's argument, that gives the third premise as a conclusion could be stated as the condition that the expected value of 'n' is not equal to or close to zero. This condition is the core of the critique of Bostrom's argument. In his argument, Bostrom calculates the value of a given world being simulated in terms of two variables whose value is contingent on factors that are unknown. If the value of these two variables, Bostrom argues, is not close to zero, then the third option of our world being simulated becomes very likely. Instead of either completely accepting or rejecting the first two conditions, the probability of us being in a simulation is calculated based on the condition that that the two conditions proposed by Bostrom for the third option to be correct have a strong likelihood of being met. That is to say, we include the lack of certainty in the value of the two variables $f_p$ and $f_n$ before we accept or reject any conditions.

That is important because by complete acceptance or rejection of conditions, one may get a different answer than one would have got if the probabilistic nature of the variables was considered. This is illustrated via an example, as follows –

Assume that two persons, X and Y are performing a reaction in a chemistry laboratory, for which they need exactly 3 ml of distilled water. The distilled water can be obtained from a tap which is connected to a tank which is almost empty. Only 60 drops of water are likely to be obtained and each drop of water would contribute exactly 0.05 ml of water if caught by the test tube. X can catch the falling drops of distilled water inside the test tube with an accuracy of 99 out of every 100, while Y who is a little clumsier can catch them with an accuracy of 98 out of every 100. Only one person can attempt to catch the drops at a time and once one of the person starts catching the drops, he cannot be switched with the other person. Assuming that X is 3 times more likely than Y to be chosen to perform this task, what is the probability that they will be able to complete the task?

As every drop of water has to be caught, if X is chosen, the probability that X and Y will be able to complete the task would be around 0.5471. If Y is chosen, the probability value would be 0.2975. Now, because X is more likely to be chosen than Y for the task, if we reject the idea that Y would be chosen, then the it is more likely than not that the task would be completed.

However, if we consider the uncertainty in choice of X or Y, the expected probability of X and Y completing the task reduces to 0.4847 making it less likely that they would be able to complete the task than not.

In this sense, it is to be understood what $f_{sim}$ denotes. The value of $f_{sim}$ has not been derived by taking a ratio of all simulated worlds to all worlds that exist or measuring that ratio over a sample that is assumed to be representative of the population of worlds.

The ratio is merely a theoretical estimation of the value obtained when the total number of simulated observers in all different cases that may be possible is divided by total number of observers in those cases. In fact, for a given case, the value of the ratio may differ significantly from the estimated value of ratio. It is not different from the case of rolling a dice 'n' number of times. While the expected probability of any particular number, let's say 1 being on the top face of a six sided fair dice in 'n' number of rolls would be 'n/6', in actual rolls, it is possible the number may not even show up once on the top face of the dice. In fact, the value of the probability theoretically determined can be only reasonably expected to be equal to the value obtained by observation, if 'n' tends to infinity.

Just like the contingent factors like the force of the throw, wind speed, etc., and uncertainty in their values during the rolls of the dice can cause a deviation in the observed frequency of a particular face of the dice being on top from the expected frequency of such that is derived from the theoretical estimation, similarly, the uncertainty in values of $f_p$ and $f_n$ can create an uncertainty in the value of $f_{sim}$ and a deviation from the value of $f_{sim}$ calculated assuming a particular value of $f_p$ and $f_n$ and in that case, the most reasonable way of calculating the expected value of $f_{sim}$ would be by consideration of different cases that may be probable along with the probability of their occurrence.

This is an important fact to bear in mind as it relates to the three options Bostrom presents as consequences of his argument. As the objective of the paper is to present a case against the third option, i.e., $f_{sim} \approx 1$, $f_p$ and $f_n$ are not assumed to be close to 0, which means that it is not assumed the almost no human level technological civilizations are assumed to reach a post-human stage or that out of those civilizations that reach the post-human stage, almost none is interested in running ancestor-simulations, thus satisfying the conditions for his third premise to be the only reasonable conclusion of his argument. This is not granting the presence of knowledge that values of $f_p$ and $f_n$ are close to 1, but that they could be, for there is no way to know as a fact that from the information present currently. This analysis is captured in the assumption of expected value of n not being equal to or close to zero.

### 4. Missed Relevant Information

Bostrom while presenting the conclusions of his argument agrees that the it is possible that some information or evidence might change the probability of us being in a simulation, for then the value of the ratio that is calculated would be contingent on that piece of information, however, he argues that the speculations regarding such evidence are tenuous [7].

There is however, one piece of evidence, the belief in which is not tenuous if one accepts the basic premise of Bostrom's argument. That is, that at least one real world exists. That world would have to necessarily exist for simulations, as thought by Bostrom, to occur. Unless one holds to a series of simulations *ad infinitum*, there must be at least one real world where all sets of simulation series must converge. Bostrom himself, includes the existence of that world in his calculation of fraction of all observers with human-type experiences that live in simulation by including a non-zero number denoting number of observers with human-type experiences that do not live in simulation, and hence in real world.

One may argue at this point that the presence of real world is included in the fraction calculated by Bostrom and is thus, not an information that has not already been taken into account. While it is true that the existence of such world is presumed in the calculation, the mathematical quantity itself, does not establish the proper necessity of existence of such real world. The mathematical calculation is independent of the nature of the world being discussed and treats each separate term only as some quantity of an object, wherein the nature of that object may be completely different to that of other objects. In the calculation of the fraction, some information is lost, which is pertinent to distinguish whether the fraction is a result of frequentist or theoretical approach or treatment on a Universal set. To understand the distinction, one may imagine a standard deck of fifty-two cards. There would be only one Ace of Spades in that deck of cards, and thus the probability of picking that card, if the deck is randomly shuffled, is 1/52. Now, if one draws a random sample of thirteen cards from the deck, and then shuffles that sample, the probability of Ace of Spades existing in that sample of thirteen cards is still 1/52.

Yet, the probability of the Ace of Spades existing in the set of cards from which the pick is made, is different in both the cases. While in the first case, the probability of Ace of Spades existing in the set (of 52 cards) is 1, in the second case, the probability of Ace of Spades existing in the set (of 13 cards) is 1/4.

The fraction 1/52 does not capture all the information present in the initial problem that might be necessary for the argument to be a good argument. Similarly, in Bostrom's argument, the calculated fraction is just representative of the ratio of frequencies. In order to include the information, one has to use Bayes' theorem to calculate the impact of the new information on the fraction and thus, probability of us not being in a simulation. In most cases, the use of Bayes' theorem in these situations would be unnecessary but in this case, it is relevant as we will see after we perform the analysis.

## 5. Bayesian Analysis of the Argument

Now, applying Bayes' theorem ('R' as discussed signifies "the real world") -

$$\mathrm{P}\left(\frac{\text{We live in R}}{\text{R exists}}\right)$$

$$= \frac{\mathrm{P}\left(\frac{\text{R exists}}{\text{We live in R}}\right) \times \mathrm{P}(\text{We live in R})}{\mathrm{P}\left(\frac{\text{R exists}}{\text{We live in R}}\right) \times \mathrm{P}(\text{We live in R}) + \mathrm{P}\left(\frac{\text{R exists}}{\text{We live in a simulated world}}\right) \times \mathrm{P}(\text{We live in a simulated world})}$$

Let us examine each term of the equation separately.

1. $\mathrm{P}(\text{R exists}|\text{We live in R}) \times \mathrm{P}(\text{We live in R})$

If we know that we live in a real world, we would implicitly know that at least one real world exists, which will be our world. In line with our earlier assumption of possibility of this world being real, it is not impossible that our world is the real world.

Hence,

$$\mathrm{P}\left(\frac{\text{R exists}}{\text{We live in R}}\right) = 1$$

And,

$$\mathrm{P}(\text{We live in a real world}) = f_{\text{real}} = \frac{1}{n+1}$$

So,

$$\mathrm{P}\left(\frac{\text{R}}{\text{We live in R}}\right) \times \mathrm{P}(\text{We live in R}) = \frac{1}{n+1}$$

2. $\mathrm{P}(\text{R exists}|\text{We live in a simulated world}) \times \mathrm{P}(\text{We live in a simulated world})$

The probability that we live in a simulated world would be, as discussed, $n/(n+1)$. Now, one is just left to ponder the probability that real world exists given that we live in a simulated world. One may reply that in line with the reasoning outlined earlier, the probability of a real word existing in such scenarios would always be 1. That is based on the reasoning that without the presence of a real world, the simulated worlds would not exist. However, just from the knowledge that the world we may be living in has a property 'X', is it possible to know that there is a world also which has the property 'not X'? Is it possible from the knowledge of, for example, all crows one has ever seen being black in color that there exists a crow which is white in color or not black? The knowledge of there being at least one real world, because "simulation" implies a "simulator" is not present in the fraction derived by Bostrom but present in the term. In fact, the more the number of simulated worlds we encounter or theorize to be, the lesser will be our belief in the actual existence of a non-simulated world, if do not consider the necessity of the real world for the simulated worlds to exist.

Now, one may look at the case in which the knowledge of the fact that the existence of simulated world guarantees the existence of the real world. In that case, we find that we get the same results as Bostrom, which is not surprising considering the way in which the Bayes' theorem is applied is not inaccurate and unfair representation of Bostrom's argument. For the first case, however, assume that the inclusion of impact of that necessity of real world in the equation is rejected. In such a case, just like it is impossible to know what is the probability of a white crow existing if the relevant knowledge one has regarding such is merely the observation that all crows one has ever seen have been black, the derived probability of the real world existing from the information that one lives in a non-real world is undefined and would be based on other information one might possess.

One might argue that such a probability could be calculated from the ratio itself, given the number of worlds that exist, the probability of at least one real world existing could be found out. However, we do not know the number of worlds that actually exist and because we have assumed that the we know that a real world exists, deriving the probability of such from the another information would be reasoning in circles, i.e., the one variable of the equation would not be independent of the other variable.

To understand this, consider again a standard deck of 52 cards. Out of this standard deck of 52 cards, we select 13 cards randomly. Let that selection be termed as 'S' The probability that any one of these 13 cards is an Ace of Spades is exactly 1/52. However, let's say we know that the Ace of Spades exists in that selection of 13 cards. Now, the probability that any one of these 13 cards is an Ace of Spades is exactly 1/13. Let of Ace of Spades be defined as 'AoS'.

Applying Bayes' theorem however, we get interesting results.

$$\mathrm{P}\left(\frac{\text{AoS is drawn}}{\text{AoS exists in S}}\right)$$

$$= \frac{\mathrm{P}\left(\frac{\text{AoS exists in S}}{\text{AoS is drawn}}\right) \times \mathrm{P}(\text{AoS is drawn})}{\mathrm{P}\left(\frac{\text{AoS exists in S}}{\text{AoS is drawn}}\right) \times \mathrm{P}(\text{AoS is drawn}) + \mathrm{P}\left(\frac{\text{AoS exists in S}}{\text{AoS is not drawn}}\right) \times \mathrm{P}(\text{AoS is not drawn})}$$

As before, let's examine each term separately.

1. $\mathrm{P(AoS\ exists\ in\ S|AoS\ is\ drawn)} \times \mathrm{P(AoS\ is\ drawn)}$

The probability that Ace of Spades exists in S given that it is drawn from S, is obviously 1. The probability that Ace of Spades is drawn, however that is not contingent on knowledge that it exists in S, is 1/52 and not 1/13, because a random selection does not result in change in original probabilities

2. $\mathrm{P(AoS\ exists\ in\ S|AoS\ is\ not\ drawn)} \times \mathrm{P(AoS\ is\ not\ drawn)}$

The default probability that Ace of Spades is not drawn is 51/52. However, what will be the probability that Ace of Spades exists in S, given that Ace of Spades is not drawn? It will be 12/51, because the Ace of Spades can still occupy any one of the 12 positions out of the total 51 positions that may contain it.

Putting the values in the equation, we get 1/13, which is as expected.

However, an interesting thing is to be noted. Could the value of 12/51 ever be known from either the value of 51/52 or the value of 12/13 provided we don't know both the values? The answer is clearly no, as the value of 12/51 needs both the values as it is the ratio of respective denominators when one is subtracted from them; the one obviously denoting the loss of one card from the reference class that is drawn.

Now, imagine that instead of the deck of 52 cards existing in actuality, they existed virtually and only 13 randomly selected cards were printed in actuality. The rest of the 39 cards of the standard deck were scheduled to be printed later on or never printed in reality. And the same experiment was performed. The results would remain the same.

Now, imagine that the deck of cards represented $S_P$, the selection of 13 cards represented $S_A$, and the card that is drawn out (Ace of Spades, in this case) of the selection represented our world, i.e., R.

In that scenario, unless we know the count of $S_A$, we can never know the probability of our Universe being real, contingent on the belief that a real world exists within the set of actual worlds.

In short, it means that the ratio estimated by Bostrom's equation covers all possibilities, not all of which are actualized. However, the existence of the real world is an actualized event.

The set of actual worlds may include, for example, only one world in which case, it is definite that that world would be the real world and that world would obviously be our world, for this world is, as we know, existent. That value would be vastly different from what the equation by Bostrom estimates. To calculate the expected value nevertheless, one would have to consider all possible cases with their respective probabilities (and not just one case, favoring either Bostrom's view or being against it) and that would require a probabilistic function. Unless such a function that is reasonable is available, the criteria that is required for a justified estimation of probability of our world being simulated is not met.

## 6. A Passable Case as an Example

However, if one still intends to calculate the probability of our world being a simulation, the following may be one approach towards it. As long as we have seen only our world, we can believe that most likely, the set of actual worlds consists of only our world. That would be because the reality of our world is a matter of experience for us and the option of there being only one world in actuality could be assumed to be at least as reasonable as the option of there being any other number of worlds in actuality.

Then the expected probability of a given world being simulated, given that we know that at least one real world exists would be as follows -

$$P\left(\frac{f_{real}}{R\text{ exists}}\right) = \sum_{i=1}^{\infty} P_i \frac{1}{i}$$

Where $P_i$ is the probability of there being a total of 'i' worlds.

For i = 1, $P_i \geq 0.5$,

$$P\left(\frac{f_{real}}{R\text{ exists}}\right) \geq 0.5 + \sum_{i=2}^{\infty} P_i \frac{1}{i}$$

As $P_i \frac{1}{i}$ would be positive for all values of 'i', hence –

$$P\left(\frac{f_{real}}{R\ exists}\right) \geq 0.5$$

This solution may also satisfy the condition of expected value of n not being equal to or close to zero, for the expected value of 'n' can be written as follows –

$$E(n) = -1 + \sum_{i=1}^{\infty} P_i\, i$$

The value of one is subtracted from the right hand side of the equation because 'n' denotes all worlds except the real world.

. For i = 1, $P_i \geq 0.5$,

$$E(n) = -0.5 + \sum_{i=2}^{\infty} P_i i$$

It is possible to choose $P_i$ such that $E(n) \geq 0$. One example is choosing $P_i$ such that $P_{100} \geq 0.25$.

However, there is one more condition left to satisfy, which could be represented as the following -

$$f_{sim} = \frac{n}{n+1}$$

It is to be noted that because n would be equal to E(n) under the new approach, the above criterion is fulfilled by fulfillment of the criteria before it. However, because n and E(n) have to be finite (it is assumed that simulation of infinite number of worlds is not possible), $P_i i$ must be a convergent series, which is also possible. One of the convergent series that can be used for example, is the following –

$$\sum_{i=1}^{\infty} \frac{1}{i^2}$$

The following can be the value of $P_i$ that satisfies all conditions –

$$P_i = \left\{ \begin{array}{c} 0.5 \ \text{ if } i = 1 \\ 0.25 \ \text{ if } i = 100 \\ \frac{0.25\ k}{i^3\ (1 - 1.000001\ k)} \quad \text{otherwise} \end{array} \right\}$$

Where ‘k’ is a constant with a positive value (the reciprocal of Apéry's constant).

In such a case, the value of E(n) could be calculated as follows –

$$E(n) = -1 + 0.5 + 25 + \sum_{i=2}^{99} P_i i \ + \sum_{i=101}^{\infty} P_i i$$

On simplifying, we get the following –

$$E(n) = 24.5 + \sum_{i=2}^{99} \frac{0.25\ k}{i^2\ \ (1 - 1.000001\ k)} + \sum_{i=101}^{\infty} \frac{0.25\ k}{i^2\ \ (1 - 1.000001\ k)}$$

Now, we know that -

$$\sum_{i=1}^{\infty} \frac{1}{i^2} = \frac{\pi^2}{6}$$

Therefore –

$$E(n) = 24.5 + \frac{0.25\ k}{(1 - 1.000001\ k)} \left( \frac{\pi^2}{6} - 1 - 0.0001 \right)$$

As -

$$\frac{\pi^2}{6} > 1.0001$$

And,

$$k > 0$$

And,

$$(1 - 1.000001\ k) > 0$$

Therefore, $E(n) > 0$.

As $P_i$ is the probability of there being ‘i’ number of worlds in actuality, the following condition must also hold –

$$\sum_{i=1}^{\infty} P_i = 1$$

Now -

$$\sum_{i=1}^{\infty} P_i = P_1 + \sum_{i=2}^{99} P_i + P_{100} + \sum_{i=101}^{\infty} P_i$$

Putting the value of $P_i$, we get -

$$\sum_{i=1}^{\infty} P_i = 0.5 + \sum_{i=2}^{99} P_i + 0.25 + \sum_{i=101}^{\infty} P_i$$

The above equation can be written as –

$$\sum_{i=1}^{\infty} P_i = 0.75 - \frac{0.25\ k}{1^3\ (1 - 1.000001\ k)} - \frac{0.25\ k}{100^3\ (1 - 1.000001\ k)} + \sum_{i=1}^{\infty} P_i$$

Now, because -

$$\sum_{i=1}^{m} \frac{1}{i^3} \leq \sum_{i=1}^{m} \frac{1}{i^2} \quad \text{for all m from 1 to } \infty$$

As the latter series is convergent, the former series will also be convergent.

Because -

$$\sum_{i=1}^{\infty} \frac{1}{i^3} = \frac{1}{k}$$

Therefore –

$$\sum_{i=1}^{\infty} P_i = 0.75 - 0.25 \frac{k}{(1 - 1.000001\,k)} - 0.00000025 \frac{k}{(1 - 1.000001\,k)} + 0.25 \frac{k}{(1 - 1.000001\,k)} \sum_{i=1}^{\infty} \frac{1}{i^3}$$

$$\sum_{i=1}^{\infty} P_i = 0.75 + 0.25 \frac{k}{(1 - 1.000001\,k)} \left(\frac{1}{k} - 1.000001\right)$$

Hence -

$$\sum_{i=1}^{\infty} P_i = 1$$

Thus, all conditions are satisfied. It is to be noted that the value of k is assumed to be equal to the reciprocal of Apéry's constant, which is an irrational number whose value is approximately 1.20205. The value of E(n), thus can be calculated as follows –

$$E(n) \approx 24.5 + 0.25 \times 1.20205 \times (1.644837 - 1 - 0.0001)$$

Calculating the value of the right hand side of the above equation, we get –

$$E(n) \approx 24.69375$$

Which is not close to zero.

## 7. Unconditional Knowledge of Existence of Real World

The reason why Bostrom’s argument fails here is because the while we are sure that there is one real world that exists in the set of actual worlds, we don’t know how many worlds exist in actuality. And a theoretical estimation of such, in presence of limited knowledge that we currently have, will always include the possible cases that will never be actualized.

However, one of the cases remains which is based on the fact we can know from the fact of us living in a simulated world that a real world exists. In such a case,

$$P\left(\frac{\text{Real world exists}}{\text{We live in a simulated world}}\right) = 1$$

This could be written as –

$$\frac{C(S_A)}{C(S_P)}=1$$

Where C is a function that counts all the unique elements in the given sets.

Which means –

$$C(S_A) = C(S_P)$$

As $S_A$ is a subset of $S_P$ by definition (all actual worlds are possible), and none of the sets contain any repeated elements, it means that both the sets are identical.

But that is clearly not the case. It is always possible to imagine a world, knowing all actual worlds, that differs from the actual worlds in some respect, unless there is a world that exists in actuality for every possibility. That would be quite significant metaphysical assumption. However, that suggests that it would be impossible that the simulating civilizations do not simulate a world that could possibly exist. Simulation would appear more as a necessity than a choice because if it is a choice then one could always simulate fewer civilizations.

Or it could be that the real world is completely a necessary entity, along with its all components, all states and all configurations. In this case, talking about simulation hypothetical seems largely redundant.

However, in both the cases, Bostrom's simulation argument would still work. However, that metaphysical assumption would be hard to accept.

## 8. Conclusion

It is to be noted that nothing in this article suggests that Bostrom's argument is wrong. However, it is argued in the paper that using a different approach that is better for evaluating the probability of us being in a simulation, we are at best left with agnosticism about the issue. Bostrom himself states that he believes that humans are probably not being simulated [5]. The intuitive belief is defended in the paper by showing that Bostrom's argument suffers from a problem of trying to establish likelihood of a proposition before incorporating all uncertainty in the variables leading to the conclusions of the proposition, which means we are left with only the binary choice of accepting or rejecting the uncertainty in those variables. Bostrom's simulation argument might work if the value of the number of actual worlds was derived from having an actual count of all the worlds and not a theoretical guess, which results in conflation of possibility with actuality. In such a case, the actuality may appear to take values that seem probabilistically rare, though the reason for that is simply the fact that in case of limited trials, the observed value of probability can differ significantly from the theoretical value of probability.

Incorporating all the information, the two different probabilistic values must converge, at least epistemically, and thus, there is a reason to reject the specific conclusion of the simulation argument.

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