The Movie Graph Argument Revisited

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Abstract

In this paper, we reexamine the Movie Graph Argument, which demonstrates a basic incompatibility between computationalism and materialism. We discover that the incompatibility is only manifest in singular classical-like universes. If we accept that we live in a Multiverse, then the incompatibility goes away, but in that case another line of argument shows that with computationalism, the fundamental, or primitive materiality has no causal influence on what is observed, which must must be derivable from basic arithmetic properties.

1 Introduction

Computationalism is the idea that our minds are computational processes, and nothing but. In particular, an appropriate program running on a computer will instantiate consciousness just as well as brains made of neurons. Bruno Marchal, who developed the Movie Graph Argument[3] is fond of introducing this concept via a parable:

You have just discovered you have terminal brain cancer, and the doctor treating you proposes replacing your brain by an electronic computer running an artificial intelligence program initialised by the synaptic weights read out from your old brain prior to its destruction.

Would you say “yes” to the doctor? Do you think you will survive the transplant? If not, then what if the doctor proposes replacing your brain with a detailed emulation, including chemical and electrical properties, of all of the atoms making up your brain? If not, then what if the proposal were a detailed quantum mechanical simulation of the elementary particles making up your atoms.

If you say yes at any point, you are affirming computationalism.

However, computationalism implies a number of surprising consequences. Because it is easy to copy a computer program, it should be possible to be cloned into a doppelgänger, whose memories are identical to one’s own up to
the point of being cloned. The computer program can be transferred over the
internet, allowing teleportation.

Moreover, it is possible to reimplement the exact same program in different
ways, for example by coding the program using different programming lan-
guages. The detailed use of a machine’s registers, and instructions executed
will differ dramatically in each case, yet the conscious experience should be
identical if the program is implemented correctly. Furthermore, if the original
program is run again with the exact same input, the same conscious experience
will be generated, and the exact same sequence of register states will be acti-
vated. A recording of this sequence of register states when played back will be
physically indistinguishable from the running of the original computation. The
Movie Graph Argument seeks to parlay this into an absurdity, whereby if the
physical activity were all that was important for consciousness, we would need
to attribute consciousness or not to a physical system, only if the system were
observed. One is left to conclude that computational and physical supervenience
are fundamentally incompatible concepts.

Before introducing the Movie Graph Argument, I’d like to introduce a num-
ber of prerequisite topics, the Universal Dovetailer Argument, the concept of
supervenience, and Tim Maudlin’s Olympia argument.

2 Universal Dovetailer Argument

The universal dovetailer is a computer program invented by Marchal[4] that
effectively executes all possible computer programs, on all possible inputs, albeit
with exponential slowdown. It works by executing the first step of the first
program, then the first step of the second program, the second step of the first,
second of the second, first of the third, and so on, zig-zagging between executing
the next step and starting a new program.

Clearly, if computationalism is valid, then all possible experiences are in-
stantiated by the dovetailer. Each experience will occur with a certain measure
within the dovetailer, a measure moreover that is independent of the specific uni-
versal machine, or the specific universal dovetailer used (see appendix). What
we experience will be drawn randomly from those experiences, hence typically
one with high measure in the dovetailer.

One of the consequences of the universal dovetailer argument is that you
cannot tell which computer program is you. For every program that instantiates
your current conscious state, there are an infinite number of other possible
programs that generate the same history of conscious states to that point in
time, but differ after that time, corresponding to different possible futures. This
leads to an irreducible indeterminism — even an omniscient god cannot know
what you will experience next. The question is ill-posed — which of the possible
future “yous” is the real one?

This indeterminism, which Marchal calls first person indeterminacy (FPI)[2]
is related strongly to how quantum indeterminism appears within the determin-
istic Many Worlds Interpretation of quantum mechanics.
This indeterminism also implies we are made up of all computations having the same initial history that computes our current conscious state. This will feature in the definition of the computational supervenience thesis in §7.

However, the Church-Turing thesis implies that it doesn’t matter what physical computer the dovetailer is run on. It could equally be a contraption of gears and cogs, like Babbage’s analytic engine, or pebbles on a lattice with an infinitely patient child moving them according to the rules of the Game of Life, as an electronic computer we know today. Our experienced physical world must therefore be independent of any such such primitive physical substrate. The supposition that the computations instantiating our minds run on a particular piece of hardware serves no explanatory purpose whatsoever. All physical experiences are grounded in the properties of the Universal Dovetailer running on a Universal Machine, which is a purely mathematical notion. We might describe this consequence of the Church-Turing thesis as a Turing curtain, that prevents us from ever accessing ontological reality.

The Universal Dovetailer Argument[2] steps 1–7 presents this radical conclusion that the phenomenally observed physical world cannot be ontologically primitive if computationalism is true, in a series of steps that build gradually upon the reader’s intuition.

The wrinkle is to suppose that the ontological universe doesn’t have sufficient resources to run a universal dovetailer, in which case it really does matter how powerful the hardware is running our reality. Whilst a universal dovetailer can be coded and run on the physical computers we have today, in practice only a short initial portion of the UD can be run. What if the universe goes into a heat death before any conscious program is started? In such a case, properties of the ontological world leak through the the Turing curtain — ontological physics is reflected in phenomenal physics. It should be pointed out that if this were true, then there must be a largest number that is computed during the universe’s history, a philosophy of mathematics going by the name of ultrafinitism[8] or strict finitism[7].

To distinguish between these cases, Marchal calls a universe capable of running a universal dovetailer fully a robust universe. Whilst such a universe is necessarily infinite, we can, for the purposes of this argument, consider robust universes to be ones that can run enough of the universal dovetailer for programs instantiating all possible human experiences of consciousnesses within a human life time be executed. This is still an immense universe, but not necessarily an infinite one.

Since all our possible experiences will be instantiated, and observed, our phenomenal physics depends only on the properties of the universal machine, not on any underlying physical substrate. The only phenomenal impact will be a subtle departure from the universal dovetailer measure.

A non-robust universe is incapable of generating consciousness by running the universal dovetailer. Conscious entities can only appear by a correct program being instantiated at a primitive physical level, whilst other experiences and entities are not so instantiated. The primitive physical world then potentially has a causative effect on phenomenal physics, for example by allowing
some experiences to be experienced, and not others.

The Movie Graph Argument (MGA) was developed to show that even in non-robust universes, primitive physics plays no explanatory role. But before presenting the MGA, we must first introduce the notion of supervenience, and also discuss a rather similar argument by Tim Maudlin, pointing at the inconsistency of computationalism with materialism.

3 Supervenience

Supervenience is an attempt to capture the dependence of some phenomenon on its substrate[6]. Loosely speaking, a phenomenon supervenes on a substrate if a change in the supervening phenomenon necessarily entails a change in the substrate. For example, consider the phenomenon of speech. The different situations where the spoken words “hello” and “hi” are uttered, will necessarily involve different motions of the air molecules, so we can say that speech supervenes on molecular motion.

In the case of consciousness, it is widely believed that consciousness supervenes on our brains, as it is observed that different conscious experiences are accompanied by different brain states.

Now consider the scenario of a class of school children, one of whom is named Alice, and another Bob. Does Alice’s consciousness supervene on the class? Well, yes, as we observe that any change in Alice’s consciousness must correspond to a physical change in the classroom, concentrated in Alice’s brain. But we can ask a slight different question — does consciousness supervene on the class. In this case, we’d have to answer no, because both Alice’s conscious states and Bob’s, not to mention the teacher’s and other students are all present in the class. A difference in conscious state does not correspond to a physical difference, but merely to an indexical change: which consciousness we’re referring to. We can express the same conundrum using the speech case, exploiting the so-called “cocktail party” effect. Alice says “hello”, and Bob says “hi” simultaneously — but which word we hear depends on who we’re actively listening to at the time. The words no longer supervene on the air molecules, but on the state of the listener.

To see how this applies to the universal dovetailer, recall that the universal dovetailer instantiates all possible experiences. A different experience does not entail a difference in the universal dovetailer. So counterintuitively, consciousness cannot supervene on the universal dovetailer itself, even though according to computationalism, it will supervene on some of the non-dovetailing computations being executed by the dovetailer.
4 Computational Supervenience and Counterfactual Equivalence

The basic idea of the computational supervenience thesis is that a conscious state supervenes on a computation. Of course there are many running programs that perform the same computation. The most trivial example of these being programs that perform the same steps up to some time $t$, but then diverge after that time, which is the source of the first person indeterminism. But it is also true that two distinct programs can pass through the same sequence of machine states, without being computationally equivalent.

The simplest example of such a difference might be if program A executes the “or” instruction on registers $x$ and $y$, and B executes the “and” instruction. If it so happens that both $x$ and $y$ both contain the same value (both true or both false), then the resultant machine state is identical with each program. Yet the two programs are quite different, as if the two registers had different values, the resulting machine state would be quite different. We call this “if it had been different” a counterfactual. In this case, programs A and B are not counterfactually equivalent.

Computational supervenience entails that two counterfactually equivalent programs instantiate the same conscious experience, but is mute on whether two counterfactually inequivalent programs that happen to pass through the same sequence of machine states instantiate the same conscious experiences. On the other hand, physical supervenience, required by materialism, asserts that two machines passing through the same states must instantiate the same conscious experience.

The heart of the Movie Graph Argument, and also of Tim Maudlin’s is to set up an absurdity, where a very simple computation that seems unlikely to be instantiating consciousness, nevertheless only differs physically from a conscious computation by mostly physically inactive components.

5 Maudlin’s Olympia Argument

Tim Maudlin presented an interesting argument that computationalism is incompatible with materialism, which he defines as a form of physical supervenience — that consciousness supervenes on physical activity. To summarise his argument, he transforms the physical process performing a conscious computation into one replaying a recording of the process. In a nod to Hoffman’s tale *Der Sandmann*, Maudlin calls the former machine Klara and the latter Olympia. The machinery passes through the exact same sequence of states in both cases, but clearly in the second case the computation is utterly trivial — reading the machine state from a recording. The unstated assumption is that Olympia is too simple to be conscious.

It might be objected that Olympia is not counterfactually correct. Klara performs the calculation, and so would produce a different result if some of the intermediate results differed. Olympia, on the other hand, knows ahead of time
what the states of the registers are. If the registers were different, it would still produce the same sequence of states as specified in the recording.

To counter this objection, Maudlin introduces a baroque construction of attaching a copy of Klara to each and every state of the sequence. Each Klara has been advanced to the point in calculation corresponding to the step to which it is attached. If the intermediate result differs (not that it will) from that of the recording at some step, the attached Klara will take over the computation from that point, thus preserving counterfactual correctness. Yet, these Klaras are physically inert, as these counterfactual states never occur. Maudlin’s point is that if counterfactual correctness is relevant, then a simple switch connecting the physically inert Klaras to Olympia suffices to switch consciousness on and off.

An interesting objection to Maudlin’s construction was pointed out by Colin Klein[1], in which he notes that Olympia is a special case of a more powerful machine called an oracle machine, where the oracle consists of the output of a Turing computation, and so shouldn’t really be considered the sort of computation that consciousness might supervene on.

6 Multiverse objection to Maudlin’s argument

If the Many Worlds Interpretation of quantum mechanics is literally true, then we must also consider that the counterfactuals will occur in alternate universes. In Maudlin’s setup, the program either has fixed inputs, corresponding to a specific history, or has no inputs, perhaps corresponding to a dreaming state. If the situation is one of fixed inputs, then it is easy to see that the quantum multiverse must also contain versions of the same program with differing inputs. If it is the no input situation, then counterfactual states must also occur in any physical implementation due to the possibility of error or noise in the implementation.

So if counterfactual situations are physically realised somewhere in the multiverse, then one can no longer claim that the attached Klaras in Maudlin’s thought experiment are physically inert.

Nevertheless, this objection is not a valid objection to the use of the Maudlin’s argument, nor the MGA for step 8 of the UDA to obtain the incompatibility of computationalism and materialism for non-robust universes. The reason is that a multiverse is a physical quantum computer, and at least all possible human experiences are experienced somewhere in the Multiverse, if not all possible conscious experiences. Thus the Multiverse, even if finite in size, should be considered a robust universe.

A slightly different corollary that sidesteps the issue of whether the Multiverse is real is to conclude that conscious states can only occur if the conscious computation is accepting inputs from a physical environment that is non-computational. The physical environment observed by conscious being instantiated by the universal dovetailer is non-computational, precisely because of the presence of randomness induced by first person indeterminacy. Non input
computations of the sort Maudlin uses in his argument, sometimes described as “dreaming states”, cannot be conscious.

It should be pointed out that when an animal dreams, the brain is processing stochastic data generated within the brain, such as synaptic noise amplified by chaotic dynamic system effects. So to describe a dream as the running of a non-input program is an unjustifiable assumption, and consequently the necessity of a stochastic environment can be compatible with the conscious experience of dreams.

7 The Movie Graph Argument

Marchal originally presented his argument in French as l’argument du graphe filmé[3], literally the filmed graph argument, which got rendered into English as the Movie Graph Argument. The idea is that the conscious computation is implemented as a graph (or network) of stateful objects (eg abstract neurons) embedded in a glass plate, exchanging photons for messages. This allows a movie camera to record a movie of the operation of the artificial brain. Then by parts, he severs some of the network links between neurons, but by projecting the movie back onto the network, is able to excite those neurons as though they were still connected. The result, like Maudlin’s argument, is a physically identical process (at the state level) that is however, computationally not identical. The resulting system consists of two parts, the original glass plate, which is now basically inert, and the projector of the movie. Since the glass plate now has no causal effect, it can be exised from the system, leaving the movie. But then the light illuminating the film has no causal role, and can be switched off. Finally, one is left with a film moving through the pellicule. But motion is relative, so this is equivalent to the film being stationary, and the observer being in motion. So no physical supervenience entails that the entity is conscious if and only if an observer is in relative motion to the film — an absurdity indeed.

Where this argument appears to break down is where the film comes from in the first place. In the thought experiment, the original physical process supporting the conscious moment is filmed or otherwise recorded. In replaying the recording, the conscious moment is not changed in any way. The physical environment observed by the conscious moment remains unchanged too. If the conscious moment differed, then the recording, if any, would differ, however absence of a recording does not diminish the conscious experience. Thus there is a partial supervenience of the consciousness on the recording. To subvert this line of thinking, Marchal talks of physical supervenience at a time and place. Even though the replaying of the recording is physically identical to the earlier computation (aside from some additional machinery that merely extends the physical system), it’s presence at a time and place does not attach that conscious experience to that time and place. The conscious experience supervenes only on the original computational process.
8 Conclusion

Physical supervenience is simply not compatible with computational supervenience in a non-robust universe. In order for physical supervenience to be compatible with computational supervenience, we need to inhabit a Multiverse, which as noted above is a robust case.

The anthropic principle is the notion that our physical environment is compatible with our physical existence within that environment. This is a form of physical supervenience, and observed evidence consistently points to the anthropic principle as being true.

If we wish to assert we don’t live in a Multiverse, then we need to abandon the computational supervenience thesis. But that would entail that a copy of a conscious program need not be conscious, contradicting the so called “Yes, doctor” axiom of computationalism. So we would also need to abandon computationalism.

However, if we embrace computationalism in a robust Multiversal reality, then we are led to the conclusion that the exact form and structure of any primitively executing computer can have no explanatory or causative role on empirical physics. Thus we are led to the reversal, physics is entirely determined by the properties of universal computation, which in turn is completely determined by any sufficiently rich system, such as integer arithmetic.

References

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A Measure over the universal dovetailer

Fix a universal machine $U$, and let $P$ be the set of all programs of $U$.

First we need to define the equivalence class of programs that perform an identical computation for their first $k$ steps.

**Definition 1** $\alpha_{jk} \subset P$ is a partitioning on $P$, i.e. $\bigcup_j \alpha_{jk} = P$ where $p \in \alpha_{jk}$ iff $\forall x \in \alpha_{jk}$, the first $k$ steps of $p$ are counterfactually equivalent to those of $x$.

Since it is a partitioning, we are interested in the probability measure $\mu(\alpha_{jk})$ of a program $p \in \alpha_{jk}$ eventually being executed by a universal dovetailer, which would correspond, under COMP, to a measure over observer moments, when suitably restricted to conscious programs.

**Definition 2**

Let $u_p(\alpha_{jk}) = \begin{cases} 1 & \text{iff } p \text{ eventually emulates a program } x \in \alpha_{jk}. \\ 0 & \text{otherwise} \end{cases}$ (1)

**Remark 1** For most programs $p$, $u_p(\alpha_{jk}) = \delta_{px}$, $\exists \pi \in \alpha_{jk}$, but for dovetailers and other interpreters, the distribution differs from the Kronecker delta. In particular, for a universal dovetailer $p$, $u_p(\alpha_{jk}) = 1, \forall j$.

For a given universal dovetailer running on a given reference prefix-free universal machine, the probability measure is given by summing over programs $p \in P$:

$$
\mu(\alpha_{ik}) = \sum_{p \in P} 2^{-\ell(p)} u_p(\alpha_{jk}) \\
= \sum_j \sum_{p \in \alpha_{jk}} 2^{-\ell(p)} u_p(\alpha_{ik}) u_p(\alpha_{ik}).
$$ (2)

with the second form coming from the partitioning $\bigcup_j \alpha_{jk} = P$.

For this measure to be universal for all universal dovetailers and all reference machines, it suffices to show that this measure can be written recursively, in terms of itself and coefficients that only depend on the chosen partition of programs ($\{\alpha_{ik}\}$). This demonstrates that the measure takes into account contributions from all nested universal dovetailers, as well as any other program that ends up executing a counterfactually equivalent program $x \in \alpha_{ik}$, such as programs of other reference universal machines composed of a compiler plus a program $p \in \alpha_{ik}$.

Such a decomposition is given by

$$
\mu(\alpha_{ik}) = \sum_j \mu(\alpha_{jk}) \sum_{p \in \alpha_{jk}} 2^{-\ell(p)} u_p(\alpha_{ik}) / \sum_{p \in P} 2^{-\ell(p)} u_p(\alpha_{jk}),
$$ (3)
which can be seen by substituting equation (2).

From a computationalist point of view, a measure over observer moments will be a measure over the sets \( \alpha_{ik} \) of equivalent programs that support particular observer moments. Such a measure is not likely to be normalisable over all observer moments, however, since each \( \alpha_{ik} \) decomposes into subsets \( \alpha_{jk+1} \subset \alpha_{ik} \), so \( \sum_{m \geq k} \sum_{j: \alpha_{jm} \subset \alpha_{ik}} \mu(\alpha_{jm}) \) will be infinite in general. In spite of not being normalisable, the relative measure between an observer moment and its successor \( \mu(\alpha_{jk+1})/\mu(\alpha_{ik}) \) is well defined.