

The First Nobel Prize for Insidious Software Degradation (Transcript with figures)

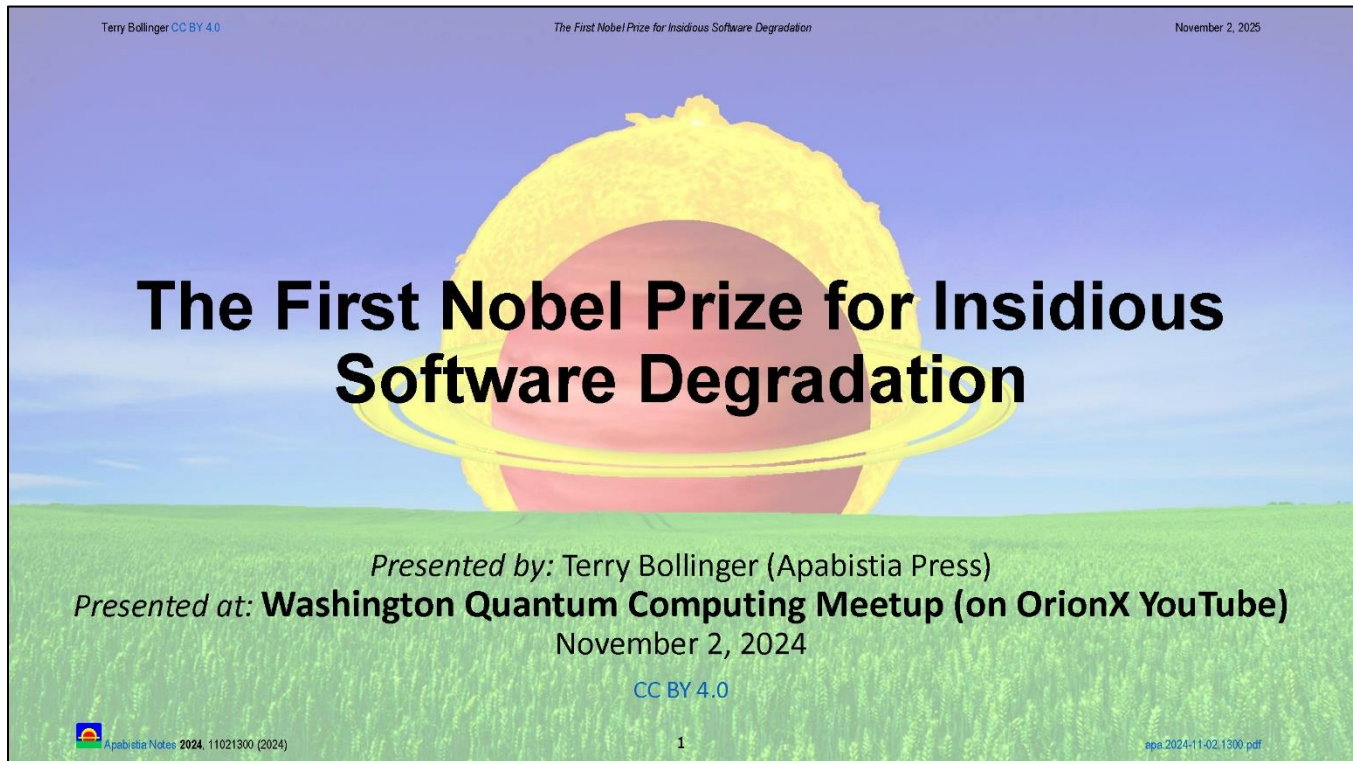
Terry Bollinger

Presented at: Washington Quantum Computing Meetup (on OrionX YouTube)
2024-11-02.13:00 EST Sat

This is the edited YouTube transcript. You can view the full video at https://youtu.be/qq6_cJqVX5E

[0:00] YC: Welcome back to another meetup. Today on Saturday November 2nd at 1 pm, today we have Terry Bollinger just talking about a quick chat on the Nobel Prize, the history of the first cargo cult Nobel Prize, and how it deceived generations of researchers and put software at risk, and what are the next steps.

Quick background: Terry... He did his Bachelor of Science and his Masters is in computer science at the Missouri University of Science and Technology, worked with the government for many years to approve using open source software in federal systems. Yeah, his work for us federal agencies has included hard science technology assessments in physics, chemistry, biology, biochemistry, and information sciences. He has helped guide and get funding for artificial intelligence research... and, yeah, many years at the MITRE corporation and without further ado: Terry Bollinger.



[1:17] TB: Good afternoon everybody, and I'm going to try to make the presentation at the slotted to *up to three hours*, but frankly I think short presentations tend to carry the message better, so I'm *not* going to try to make a long presentation. If I finish within an hour I'll be quite happy with that. If there's conversations or questions we can go on as long as as needed, but I will try in the direction of brevity as opposed to just trying to stretch it out.

So this particular presentation started when I was *very shocked* to see that the Nobel Prize in physics had been awarded to a topic that's *not* normally considered to be physics and I think many people in Information Technology thought that was *really* cool, but I have a very mixed background, where I have a lot of IT background, but also a lot of physics background, and I found that *very* unusual.

I was just... I was... The physics Nobel committee usually is *quite strict* about what they decide is going to be a physics topic and there have been topics (super string theory being an example) that have gone on for *decades* that they just refused to touch it because it didn't meet the criteria for *precise* physics, *testable* physics, [and] number of other criteria that they would apply. So I was quite *shocked*. I was a little bit surprised also that Yann LeCun... I remember thinking that Yann LeCun could easily have been a candidate for that also and Yann LeCun is someone I know personally, so it was an interesting combination of who that prize was awarded to.

So that was my first reaction when I saw that and then I started digging into it a lot more closely about *why* exactly did they give this, what was the *announcement*, what did they *say* they were giving it for, and that became a *far* more interesting story (*much* more interesting story), because one of the two candidates ([John] Hopfield) is *very much* a physicist. It's just that the particular paper they *awarded* the prize for was *not* a classic physics paper. But he had done papers *years* before, just *beautiful* work in quantum mechanics, biological molecules... great stuff, great stuff, and very much in the the physics domain.

You could... One of my comments on that is he could... Certainly Hopfield *could* have won a Nobel prize for the physics that he had done. He didn't *get* one, but it's a very competitive area, but if you look at some of those *papers*, it's just *marvelous* stuff, where he has insights that brings out the complexity in molecular physics in ways that people have not really perceived. So, you know, that... The flip side of this Nobel Prize awarding is even if you don't (as I do not) agree with the specific reason why it was allocated, you certainly have some very good work, and *hidden* of course.

It was one of the three recipients of the Turing award. *Absolutely* deserved it! *Amazing* work that Hinton has done! I mean *so* many... so much of the foundational work was done by Hinton and he's part of that trio of which he's the only one that I never met or interacted with from that Trio, but deserving people, but *still* an odd combination.

Now, given that background, what surprised me *most* was that to be *blunt* about it, the physics for which this was supposedly granted as a Nobel Prize was in fact *non-existent* physics. So, that's *not good*, and with the *current timing* of what's going on with the world right now, it's *especially* not good, because however you look at it, the Nobel Prize committee is part of society. They understand what's going on. They've watched this *enormous* expansion of the LLMs, of the new definition of what "AI" [is], which changes every ten years.

As folks who've been in this field know, but the current incarnation of "AI" is these large language models and the gigantic, *gigantic* server farms, and certainly that had some kind of influence on the *giving* of this Nobel Prize. Either it was considered this is a proven success, because all these things were out there, or it was just something that somebody, you know, they got it... whatever it was, they got enthused about this particular topic, and by giving the Nobel Prize they also give of the imprimatur of success for that same undertaking.

Well, if you're one of the people who've been tracking this closely, *there* are a *lot* of *scary* things going on with the *massive* deployment of the LLMs, and that's where you start getting into an interesting interaction between these two.

Have you experienced anything like this?

Me: “Are schools open today, October 14, 2024?”

AI: “No, there were no classes on October 3, 2023.”

Why does this happen so often, and to so many people?

- Large Language Model (LLM) AIs follow a “what word sounds best next” path... and that’s *all*. They are entirely mindless.
- LLMs achieve this goal by storing lots of human data in very clever, high-cost, but also lossy (noise-adding) data format.

Question: *Why did the Swedish Academy of Sciences award its 2024 Physics Prize for massive, global over-deployment of a mindless, error-prone data compression algorithm?*

[6:20] So let’s pop into the *first* one.

Simple question, and I would be astonished if your answer was not yes... This is something that happened to me in real life, just a few weeks ago. I asked my phone, said “Are the schools open today?”. October 4th... I think I gave the date (October 14, 2024) and the “AI” ... Now, I used to get perfectly reliable answers to that kind of question for *years*. I’ve gotten good answers to that kind of question, and yet *this time* my answer was “No, there were no classes on October 3rd, 2023.”. So... Anyone who has used an AI and use it for a topic *with which they are familiar*... and maybe there’s some exceptions... I have not seen a *single* case in which one suddenly said “Oh, the answers were so much better than what I could have given!”.

Have you ever... Have any of *you* ever encountered that? I’m guessing probably *not*. What you instead get is always the same thing: [it] says “Well, if you were an *amateur* or if you were *learning* or if you were *tolerant* of the errors, yeah this might be a good *mediocre* answer.”. Terence Tao gave an answer that somebody was asking Terence Tao about: “What did you think about the math?” and that was *exactly* the kind of answer he gave. Well, yeah, it’s *not* leading edge... and the thing you *never ever* see is someone saying “Oh, that system was so much smarter than I was.” *if* it’s an area that they know.

Now, if it’s an area that they *don’t* know, it *looks* impressive. You go like “Wow, yeah, this has got *lots* of good stuff in here.” ... *So* much information, because it has access to literally everything ever *written* about it. So you get this huge deluge of information and it’s very impressive, but if you poke at the edges and say “Yeah, but is it actually better on any point?” you I get same answer. You say: No. It’s not. In fact, actually it’s *terrible*. It can’t even get the *year* right and it [(search engines and such)] *used* to get the year right. Now it doesn’t get the year right, so *why is that?* What’s going on with that? *Why* does this happen so much?

Now, I like to start out with kind of the conclusion, and the simple answer is right in the name of the model: it is a *large language model*. What does that mean? It means that for *every word you say* there’s a probability that another word will follow next.

I remember writing a piece of software that did this on a Xenix Unix machine back in... oh gosh, I don't know, in the 80s, and I remember thinking how cool it was that I could get it to respond with a little bit of word mimicry. So it would follow that path, but I remember thinking it made it feel *smart*.

Martin Gardner discussed this in Scientific American. He was fascinated by this idea, that if you simply track what word is most likely to occur next and *generate*, that it *sounds* impressive. Martin Gardner totally gave up on it when he had a larger system and found out all it does was chunking pieces of information in *larger and larger* pieces. Suddenly the intelligent part evaporated.

That was back in the 70s, 80s? I think maybe *late 70s*? So, it's not like these systems haven't been around. It's not like this concept hasn't been around. It's been around for *decades*, but what's changed is we have hardware (gigantic hardware) that can do it *so much better* than any anything else, but the *bottom line* is it's *still just tracking probabilities*, nothing more, and there's a problem with that, because probabilities are averages of what has *happened*. They're not predictive. They're not saying "I understand this.". These systems literally are entirely mindless. They... There's nothing *back there* to say "Well, I *should* say *this*.". There's not even a goal in a sense, other than saying like "If I say this, I'll get...". Let me put it this way: "If I say this, I'll get away with it." is the *blunt* way of putting it, and they *do*. They say "Well, if I say October 3rd, 2023, I think I can get away with that."

Of course it's not even thinking *that much*, but... and of course it *doesn't* get away with it, not if you understand exactly what's going on, but because it's *trying* to do it that way I see a *degeneration*, not an *enhancement*, a degeneration of the answers I get, because the previous software would have looked for a database, found the exact answer. There would have been everything specific about it. So, instead you get this this situation of just *strange strange* answers, and yet they're being pushed at *vast* levels, and I live in Ashburn. I can *tell* you why it's being pushed at vast levels: When you invest *trillions of dollars* in gigantic server farms, all because you think it's going to give better results than anyone ever got before, *you* are going to be really into *marketing* that, and I remember even even two years ago when it first started I said "This is going to be a *ride*. This is going to be something.", because I don't have to go somewhere to see the server farms. I already saw that, but if somebody has invested *that much money*, this is going to be a *big* push for putting your stuff out there, and that can get into an interesting situation.

So, what do these LLMs *actually* do? The way I would describe it, and I think it's not that hard to see that there's a transition there, is that they're *really* just clever ways of *formatting and compressing* a lot of data, but people don't *express* it that way, but that's the whole thing this talk is about, because [if there's any theme to get out of this], if you drop out right now and didn't hear anything else, *that's* the theme I'm *really* trying to get over. It's [that] all of these systems wind up putting data into stored bits, and yes there's some *incredibly complicated algorithms* to go into it, they take an enormous amount of energy to do it, but if you think of these is being an active dynamic system in the sense of the human brain right now... I have all sorts of state information and a kind of complex interplay of goals... That's *not* there, *none* of that's there. This is *bits* and the whole thing boils down to bits, and I'll be getting into *great detail* on that, because that's where it *really* gets fascinating, and there's some intri—... and also some interesting potential... I think some very interesting research potential to help improve some of these issues.

So the question is... is specifically on this award: Why did the Swedish Academy of Sciences, in 2024, decide to award a prize that no matter *how* they phrased it in the announcement... And they were very careful in how they phrased it; [they emphasized] uses in physics, and that's absolutely true... *Great* use of these systems in physics for *tracking* data, *recording* data, but those are *limited niche uses* in which you have full control of the data going in... That's where they're really powerful... So... But they awarded at a time where what's going on globally is *over-deployment* of what is bluntly a *mindless* and *definitely* error prone *data compression algorithm*.

You put in a hundred different versions of somebody's answers, it comes out with an average, says "Here's some of the deviations from the average.", and that's how I'll answer, because I only follow *words*, as if it could think... It can't even think *that* much.



So you get this question: Why did you do that? Because these systems are *not* ready for prime time no matter how much they've been deployed yet.

If you want to put them into a particularly scary use, which is really where the title of this talk comes from, it's when you start doing all of your *software* with these systems, *because* they are *fantastically* good at telling you how *most* people did a search loop the last time. What they're *terrible* at is saying "... and how do I adapt that search loop to the particular circumstance of what I'm doing right now?" and it says "Well, I think if you just do this, you know, probability says if I guess *this* that'll probably be good enough.", and if... When you do software that way you get into an interesting situation very quickly. In some ways it's *worse than a blatant error* because probabilistic programming simply means you make a very *convincing* bit of software that then, because a machine did it, you'll never be able to go back and *track* and say what was the actual logic behind it, because there *was none*, because they're just doing it.

So you get this *scarily attractive* thing of saying "Oh, reuse is good." I'm a huge reuse advocate. This is the best thing about these systems is reusability. You go back and say like "Oh, if I could just reuse that software instead of reinventing it.". That's the positive side. The *trouble* is in the details. The devil's in the details on this one *for sure*. It is that, *yeah...* but then are you *adapting* that with *actual comprehension of what you're doing*, or are you just *mindlessly* saying follow the probabilities, follow the probabilities, and if you follow probabilities in software you *are* going to introduce some *extremely interesting errors* that are going to be very hard to track down.

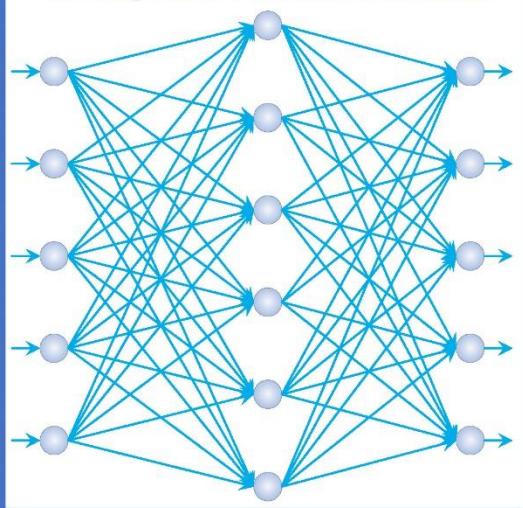
I would make the assertion that what we're doing *right now* to our software (with heavy use of software in some industries) that is being generated by these LLMs, is that we're creating a problem that's going to take *decades* to *unravel*, and it's going to have *short-term* benefits. It's going to say like "Oh, gosh, I could *fire my whole programming staff* and look at the software I did.", and in individual examples people say I can just take a picture of my screen and I get the software to do that. It's true, *but* if you have to distribute that software to a million people you have a *catastrophe*, because the errors that didn't bother you for one person for a few times then get amplified. So we have to be *very very* careful about where you're using these things. There's a end-user modification in how these things are deployed for software that that needs to be there.

You know, it's just like your... Your printers... Small printers in the end work out well. Small uses of this "AI", for people who are not familiar with the software... That can work out well, but when you get back to the *infrastructure* side, to the *internet itself*, you got to start being *very very* careful, and in general... You keep going back to it: these things *always* add some errors.


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Hopfield's Hope: Mistaking Data Formatting for Emergence

Data Organization in Neural Nets & LLMs

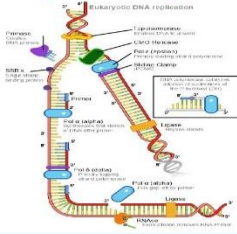


High-Dimensional Holographic Data



The Microscope. Walter Spering, 1984. Screen capture from "How Are Holograms Possible?," 3Blue1Brown, Oct 5, 2024. <https://youtu.be/EmKQsSDIaa47I=0m48s>

≠ Hopfield's "Improbable Emergences"



Eukaryotic DNA Replication Wikimedia LadyofHats. Public domain. https://commons.wikimedia.org/wiki/File:Eukaryotic_DNA_replication.svg

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[17:12] Now, this is my, you know, *one picture summary* of where I think this thing *totally* went south, and that is an interesting combination of Hopfield's work. Hopfield... If you look on the lower right side of this slide... He did work on what I would call an *improbable emergence*, the idea that something could pop up that *just* is statistically impossible, and when you talk about *enzymes* in biology you're talking about *improbable* emergences.

The two cases that are listed in the Noel Prize were that he showed how a bunch of molecules just *randomly* running into each other *slap, whack, whack...* and some of them look like they're the wrong kind of molecules. He showed how those molecules *nonetheless* could mediate an almost perfect transfer of an energy electron from one molecule to another molecule, which as you can guess is extremely important if you want to do things like I'm doing right now. That's the basis of how we *how we move around*, but the mechanisms for doing it are completely (to this day) incomprehensible to us. We don't understand... I won't say... Maybe that's overstated. Maybe people have done some good work since then, but *I* sure haven't *seen* it, in which they say *how exactly did that work?*

How did you get a bunch of random things in thermal chaos, at all sorts of... you know, take one look at one of these videos of all the things going on in a cell and you get some idea of what I mean. How does all this *random motion* turn into what we think of as a precise mechanical transfer. The other paper that Hopfield did (same year '74) was on verification of DNA reading — making sure the information is being transferred. Same idea. [In] one case you had *power* being transferred. In this case you have *information* being transferred, and there are some mysterious things about how that happens that, again... We don't know that, and Hopfield was very good at pointing [that] out and [said] "This is *strange* stuff. This is *really* odd stuff. *How* does that *smart* capability pop out of these chaotic molecules."

So you get this thing that... all of a sudden the improbable is what *happens*, and of course this is the fundamental basis of life. We... None of us could be here, we couldn't be having this conversation, we couldn't have these computers, if down at the molecular level these kinds of *ridiculously* absurd coincidences [weren't happening] all the time, because they're *not* coincidences. They're designed, but not in the way that we make big machines. Okay.

So that was Hopfield's background, and when *he* uses the word emergence he tends to use it in *that fashion*. So, fast forward eight years. He's starting to work on the *mechanical analog* for neural nets and anybody who thinks that neural nets (artificial neural nets) are a good mimic of *actual neurons* ... I could give you a list, just from the last... from the meeting I've been in recently... I could give you a list of references, you know, you know... This is... I don't know... *quite long* on why that is an *incredibly naive* assumption.

The mechanical models that we have from neurons *to this day* remain rather *superficial* to say the least. So they're interesting devices, and they do that... So Hopfield jumped into it and he *kind of*, though, took them pretty seriously. He was saying like "Yeah, these are...". The knowledge was not as good at that time also, so he took them pretty seriously, saying "Yeah, this is a good model of how neurons work.", and *went with that biology assumption*. So, when he talks about these networks doing interesting things, *that's* kind of [what] he's going for.

He's saying like "Yeah, just like I saw back in '74, these emergences... *I'm* kind of thinking that these neural nets, or these mechanical models of neural nets, also have some kind of emergence.". I think a lot of people would agree that neural networks (the actual biological kinds) certainly have some kind of improbable emergence or we wouldn't be *creating and thinking things*. So, it's got a good point.

Now the question is are the models he was using really that, and the assertion is (which I would strongly stand by at this point... in fact, the more I get into it the more interesting it gets) is *no!* What he *actually* did was he invented a *holographic algorithm* that uses bits in a computer instead of emulsions on a *film*, and I would put it that bluntly, that just as you see this picture of these holograms (which for some reason kind of faded in the last couple decades, maybe because we got too many them on our credit cards these days, you know, you get a little hologram on a credit card these days)... but holograms are *really* impressive bits of data organization.

They have some *amazing* capabilities and there's no fundamental reason why if you have a big slew of bits... and they may or may not be organized as as real numbers, it doesn't really matter... Well it does matter in terms of the details, but the bottom line is it's a bunch of bits. So [if] I go to these server farms not too far from me there's an *enormous* number of *bits*, and the question is well what if you interpret those bits as an *emulsion*, as a medium through which I send information and I make use of holographic principles, what could I do? Now, Hopfield does not seem to have been familiar with holograms. I wish he had been. I wish he had been, because I think what he did is actually came up with a *superb algorithm* for creating digital holograms

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Hopfield's Clever Pseudo-Orthogonality Algorithm

The information storage algorithm
 Suppose we wish to store the set of states V^s , $s = 1 \dots n$. We use the storage prescription

$$T_{ij} = \sum_s (2V_i^s - 1)(2V_j^s - 1) \quad [2]$$

but with $T_{ii} = 0$. From this definition

$$\sum_j T_{ij} V_j^{s'} = \sum_s (2V_i^s - 1) \left[\sum_j (2V_j^{s'} - 1) \right] \equiv H_j^{s'}. \quad [3]$$

The mean value of the bracketed term in Eq. 3 is 0 unless $s = s'$, for which the mean is $N/2$. This **pseudoorthogonality** yields

$$\sum_j T_{ij} V_j^{s'} \equiv \langle H_j^{s'} \rangle \cong (2V_i^{s'} - 1)N/2 \quad [4]$$

and is positive if $V_i^{s'} = 1$ and negative if $V_i^{s'} = -1$. Except for the noise coming from the $s \neq s'$ terms, the stored state would always be stable under our processing algorithm.

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J. J. Hopfield, *Neural networks and physical systems with emergent collective computational abilities*, Proceedings of the National Academy of Sciences **79** (8), 2554–2558 (1982).

[23:11] In fact, *this* is his algorithm, and you notice... I'll just point through the terminology, which I've highlighted blue, but pseudo-orthogonality is a result of the algorithm that he describes here, and I want to go over this algorithm a lot more than I have so far, but from the *looks* of this design, if someone had presented me a problem and said "How do I go about pretending that my database is a photographic emulsion and then holographically [store] information on it?". I, from what I can tell, this gets *darn close* to what you would have to do, at least as a first step for doing just that.

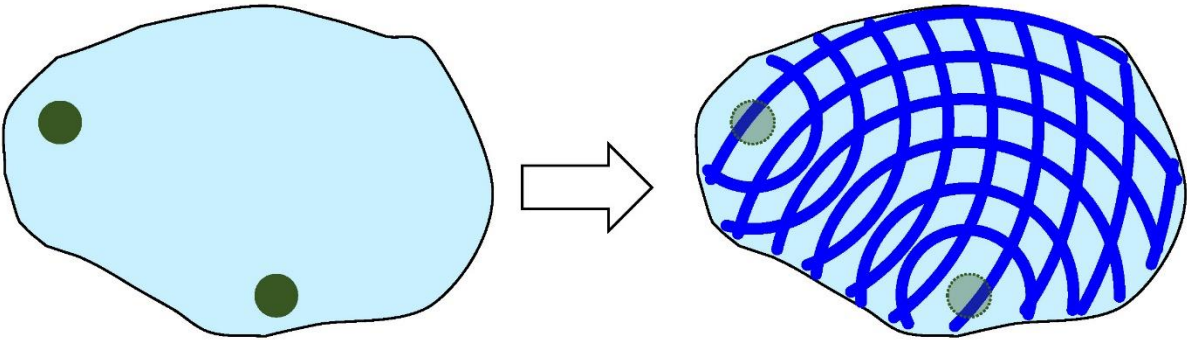
He's doing the proper thing of coming in from different angles and integrating and relating these things to each other. He's using the back propagation in ways that had not been done before, but I think without *realizing* it he created an extremely clever *holographic emulation algorithm*, but he didn't interpret it that way, and I think this algorithm that he came up with should have gotten a *Turing* award, you know. I... This is... It's good stuff, and it has some nice potential with that.

So, you know, in a nutshell, there's an interesting *reinterpretation* of good work, but it was then interpreted in a quite different way, because again, Hopfield was coming from that biological magical emergence viewpoint, so he was looking for more *emergence*. He was looking for, say [(for example)], "Wow, there's something [popping] out of this that could not have happened otherwise, that would be *improbable*.", and you can just tell that this whole paper has that focus, [that is to say:] "So where is the... Where is the improbability coming out? Where's the unlikely emergence coming from?"

*[25:05] ... and I'm going to *do*... Actually, I'll get back to that point.

I'm going to do a little bit of a tangent here, because I just said he's doing... It's not a tangent. It's actually the main theme of what I'm talking about... He has... I've asserted that he has done essentially a hologram. So what's a simple way of understanding a hologram? Now what I would assert to you is that they're *easier* to understand than you might think.

A Quick Holography Intro: The Pond Analogy



- Wave-particle duality is one of the deepest principles in nature
- The waves “encode” the two points almost as well as the stones
- Wave overlap (superposition) is *not* a problem in the wave view

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[\[25:31\]](#) ... and the analogy I give... If you have you have two people and you have a pond... They both toss rocks in the pond. [It] doesn't matter if they toss them in at the same time, slightly different time... The point is they both make waves and the waves go out and the waves cross over and without getting into too much detail about it there's just a *deeply* fundamental aspect of nature... (This goes *way* into the physics)... that you *have* to have this *duality*, that things can go... They talk about the location-momentum duality? That's one of these. Energy-time is another, but also just much more mundane things.

Anything has a wave representation. Anything has a particle representation, and throwing those rocks into the pond create these waves that *overlap* in our space, so it looks like a mess, but actually those waves wind up encoding the particle *almost* perfectly, saying here's it was, here's where it fell in, and you can kind of you can kind of *see* it. You've seen a pond wave. You've probably witnessed... You see a wave coming across a pond and you say “Oh, something must have fallen in over *here* that created that wave.”

So, you see it, and you go like “Well, could I make use of that?” and it turns out *yes!* Yes, you can make *all sorts of use out of that*, because [there's] this duality between the wave representation and the particle. Those waves capture an *enormous* amount of information about what happened to that particle. They can overlap in very *strange* ways that seem odd to us... or do they? Because, have you ever tuned around through some radio stations? You tune to one station, tune to another station... Did you ever think that *all* of those electromagnetic waves are just *one giant mess of electromagnetics* going through your area, because they *are*.

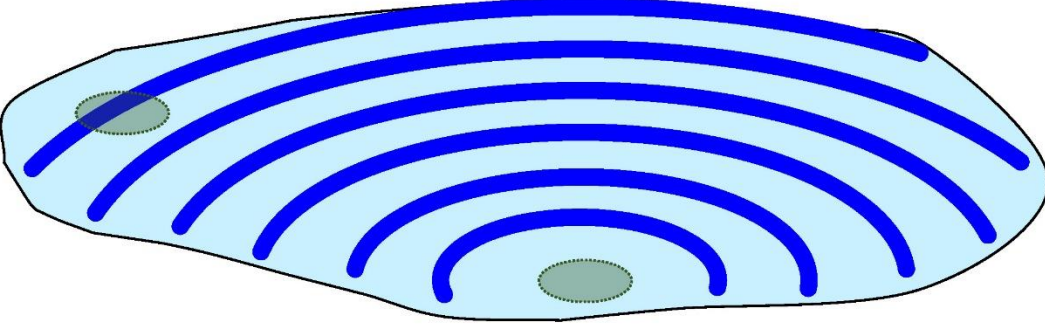
I mean all the waves are interacting with each other, they're messed up, they're... One interacts with another. Just like this picture here with the pond, they're all a *mess* and *yet* all you have to do is put your radio onto that one frequency and say this is my criteria, this is my dimension, this is my axis, and all of a sudden, *boop* ... out comes all the information that you thought you had lost, and this again is this very deep physics principle of this duality between waves and particles.

You don't *lose* things even though they wind up overlapping on the other side. When you hear about superposition, if... You hear this on Quantum issues... Of course in quantum *computing* superposition is a *huge* issue. This is *another* aspect of that. You can't have superposition without a wave of interpretation, which is

something I think they kind of miss when they talk about qubits and stuff. You want to realize that it's *not* just the qubits. This *wave* feature is a part of it. You can't discard one without the other.

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Holography Encoding is Naturally Hebbian



- Reinforced access: The wave stands out as you get closer
- Close splashes build stronger waves (compression, nearness)
- The wide-spread wave is more tolerant of flaws in the surface

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[28:25] One of the features of these that I think is intriguing, especially from this perspective, is there's a naturally Hebbian approach where you *reinforce* things. You talk about this in neurons, but it also happens in *nature*. So waves that reinforce from the same angle in a *holographic* structure *also* tend to reinforce. So, I'm sure there's some cute phrase someone can come up with you know: "Waves that splash together..." like, I have... I have no idea. I'm sure there's some equivalent phrase you do that with, but these waves naturally *encode* ideas like content-based access, because like in the pond example, if you get near a pond and you watch some wave structures, the waves tend to *pop out*.

You've seen the rows of corn, like where you go... You get to a certain angle all of a sudden, "ching!", some kind of *pattern* pops out. [That's] very much the same sort of thing, because that is a wave occurrence also. You have a regular periodic appearance and certain angles bring *access* to that particular perspective, so all of these things have just *really* neat properties. So you're getting *compression*, because if the data is all very similar, if you drop several stones in a row in a certain sequence, the wave patterns recognize that and so "Oh, you're just doing the same thing.". That's just... You know... I don't need to put a *lot* of information in that. That's just the same thing over and over again.

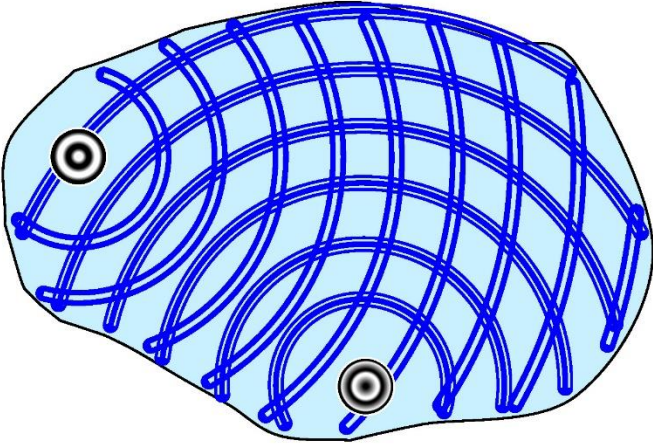
So you go there and you code that in and you get this *marvelous* compression. So things that are very similar in how they do it wind up in the wave representation *also* to be very similar. You get criteria of nearness, because if you're just a *little* off you *still* get part of the information. You can actually kind of *steer* yourself right back into it. So you have this nice *nearest* type approach.

Fault tolerance is absolutely inherent because you don't have to have all of your information stored in *one* spot. You don't have just *one* little spot on the... Can I do this? Yes, I can. So if you have you have a flaw right here, a flaw right there, or a flaw over here; you have another rock sticking up or you have a tree stomp or something. It *doesn't* destroy the pattern. It will do some damage. There's always going to be some loss, but because your

location is in all these places at once it tends to be very fault tolerant. So this is a nice thing about holographic storage.

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Extending Dimensionality Via Additional Coding



- If you make waves more complex, each splash can code more
- Well-coded (e.g., Walsh) waves are nicely pseudo-orthogonal

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[30:50] Now, here's where it actually gets *more* interesting. The pond is just *two* dimensions. That's *boring*. You know, two dimensions... that's not much. You know, you can put points on there, so you have a bunch of points there, but there's another question you have to ask, it's "Well this wave idea seems to be pretty tolerant. What if I start getting cute? What if I do a little cutesy thing where I start making the stones... **and** they vibrate and they vibrate with a very specific pattern? Not that different from what I was talking about with radio waves.

So you could have, for instance, *two* wave patterns superimposed on the same stone and just like with a radio you can tune into one frequency or tune into the other, for the same wave pattern. Why not do that and figure out [that] "Oh, I'm tuned into *this* pattern and you're tuned into *that* pattern.". They're both coming out of the same radio transmitter, but you don't *care*. [It] says "No, I can still tell them *apart*.". You have a different pattern coming *this* way. The ones here have *one* structure. The other ones have *that*. Then you could overlap these coming from the same things, and again... We do this all the time.

This is how we get radios. This is how we get radio reception, but it becomes powerful *here* because it means that you can have not entirely arbitrary, but fairly arbitrary patterns that just generate unique dimensions of information. So this two-dimensional structure suddenly explodes. You go like "Oh, well I have a *lot* more than two dimensions. I have like... I start with *four*. I could have eight.". Now you say "Is there a limit to it?". Yes, of course there's a limit, because sooner or later you're going to get too much information stuffed onto these little wavelets, and it's all going to start blurring together.

When you're talking about the radio domain and you're talking about your Wi-Fi, you call that *bandwidth*. You have a finite bandwidth *and* for the same reason. You're saying that, "Yes, I can code this scheme and I can make a *lot* of information out of it, but there are limits." Still, this is a *powerful* technique, because it means that all of us running around with our cell phones can all be using the same radio towers all the time and using this.

This is one of several different methods. One of the two major methods, called code division multiplexing, is just this. [It's] putting arbitrary patterns that have been *carefully* selected... One of the earliest versions... Walsh code... The Walsh paper was back in 1923, so this has been around for a while. So you get the patterns... You get... Certain patterns allow you to do this better, because they come out nicely pseudo-orthogonal. Remember that name, from back on Hopfield? Pseudo-orthogonal. Interesting!

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Two Important Corrections

The Royal Swedish Academy of Sciences has decided to award
the Nobel Prize in Physics 2024 jointly to

John J. Hopfield and Geoffrey E. Hinton

compressed holographic data storage
“for foundational discoveries and inventions that enable ^v *machine learning*
with *artificial neural networks*”
[^]
pseudo-orthogonality of high-dimensional data

Scientific Background to the Nobel Prize in Physics 2024 for Foundational Discoveries and Inventions that Enable Machine Learning with Artificial Neural Networks, The Royal Swedish Academy of Sciences, Oct. 8, 2024.

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[33:32] So, let me suggest a rephrasing of the Academy Award announcement. “The Royal Society has decided to —... to award the 2024 physics prize to John J. Hopfield and Geoffrey E. Hinton for... fundamental discoveries and inventions that enable...” Machine learning? What’s machine learning? Machine learning? Really? Is it really learning? You’re just stuffing... How about we say *instead* compressed holographic data storage? You know why? Because that’s a *less confusing* way of describing what’s actually happening.

You go back to Hopfield’s nicely holographic algorithm... You’re saying like “Eh, okay, so we need more data storage to do this.” His ratio, I think, is about 1.15, so you have to have some extra data, but then you... because he goes through this in some detail. So you have to have *that*. So have the redundancy, but then you actually wind up having this *nice property* of fault tolerance and of some of these other features in your data storage and it also compresses the data and it also allows things that... You know, to look at it from different angles. And, foundational inventions that enable holographic storage with... *artificial neural networks*?

Are these *really* neural networks? Nah... not really. I mean, they’re *similar*. They certainly can be modeling *some* aspects of what [neural networks] are. But they are really more digital interaction networks. How about if we call that “pseudo-orthogonality of high-dimensional data that is *created* by these networks.”

And I think that, again, is a *better* description of what’s going on. You’re getting compressed holographic storage, with this beautiful little algorithm Hopfield came up with, which *imitates* some of the characteristics of how holographic wave data is encoded.

Birth of the LLM Spontaneous Emergence Myth

The myth: “*The bridge between simple circuits and the complex computational properties of higher nervous systems **may** be the **spontaneous emergence** of new computational capabilities from the collective behavior of large numbers of simple processing elements.*” — Hopfield 1982

The reality: Hopfield devised a clever compression technique for storing unique data facts as “almost-orthogonal” vectors in a high dimensional, Hilbert-like holographic space. However, the data remains data. Hopfield’s real innovation was auto-generation of Walsh-like pseudo-orthogonality codes help isolate the vectors.

[35:37] Here’s where the problem comes in. ... Hopfield was *very* focused [on emergence]. And, I think, reasonably so, since he had seen and documented and *beautifully* covered spontaneous emergence — this unlikely emergence — in *quantum biomolecular systems* that have been optimized by [billions of years of evolution]. Your cells wouldn’t *work* if they weren’t optimized for this. So, these are actually complex little machines here. They are *highly* optimized, but [even given that,] they still come out with this *improbable* behavior from random chaotic interactions of molecules of some property you *want*.

So *he* started postulating... This is the quote that I think captured it best in his paper: “The bridge between simple circuits and complex computational properties *may* be ‘spontaneous emergence’ of new computational capabilities from collective behavior of large numbers simple processes.”

If any of you who might be familiar with the history of biology, then when you see that part — what I outlined in blue — that should be a little *bell* going off, because until, oh a hundred years ago (even certainly in the 1800s), there was this concept called spontaneous emergence of life, of spontaneous... I think the last representatives were the silver eels in England. They... Nobody... They actually *have* no sexual organs. They came out of nowhere. Nobody could figure out where they come from, so there was a persistent belief that they just emerged spontaneously from the mud, and I think the silver eels were, because they were so *incredibly* hard to figure out what was going on with them. They have five different life forms, [and] that’s why they were so hard to figure out. The silver eel [form] was one of the last [proposed examples of spontaneous emergence] to die. So people just thought that, you know, life can just pop up... just, *plink!*, like that.

Spontaneous emergence: You have to be *very* careful with it, because it has a *strong* connotation of that idea of a kind of magical capability [in which] randomness just sometimes decides, you know, “*Whee!* I’m going to do something!”

What [Hopfield] *really* did — and I think you can document this in *remarkable* detail — was figure out a way to generate these almost-orthogonal vectors in a high dimensional space, which is what you need for a Hilbert space.

Every angle that you look at a hologram [at], you need to have essentially a different unique *axis*. Now you have them *blending over* into each other, but you *have* to have this high dimensionality, and that's what he *really* devised, and the trouble is that the data remains data. Data doesn't *emerge*. Data doesn't suddenly say "Oh, I've decided to become more data." and do that. Even if you have a lot of computational processing around it, the data itself can't do that.

The data is just *dumb*. It's... That's kind of the *nature* of what... We *want* data to be dumb. We don't want it going around morphing itself. So *his* innovation I think was this auto-generation of these Walsh-like pseudo-orthogonality codes and I... By the way, I think he may have *had* some what'd you call a limited form of emergence in *that*, because this thing, with the back propagation... *He* was able to get it to kind of organize *itself* into the axes. They were competing with each other. Fairly straightforward kind of thing like, well, you know... "Dan, what's the frequency? George, what's the frequency?", and they kind of negotiate with each other and figure out which one... "Well I'm going to have *this* unique frequency. Dan's going to have *that* frequency." So they all eventually resolve the question of "What's the frequency **Dan**?" and yes that's a reference to it (for old-timers).

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What is Emergence?

Folks call two very different phenomena "emergence."

- **Simplifying emergence** discards & reduces complexity
 - **Temperature** is the classic example: Enormous numbers of extremely complicated molecular motions "average out" to the vastly simpler (but useful) concept of temperature.
- **Implausible emergence** beats impossible odds
 - **Cellular metabolism** is a vast collection of implausible *quantum-level* emergences (e.g., electron transfers) from thermally chaotic mixes of molecules (Hopfield 1974).

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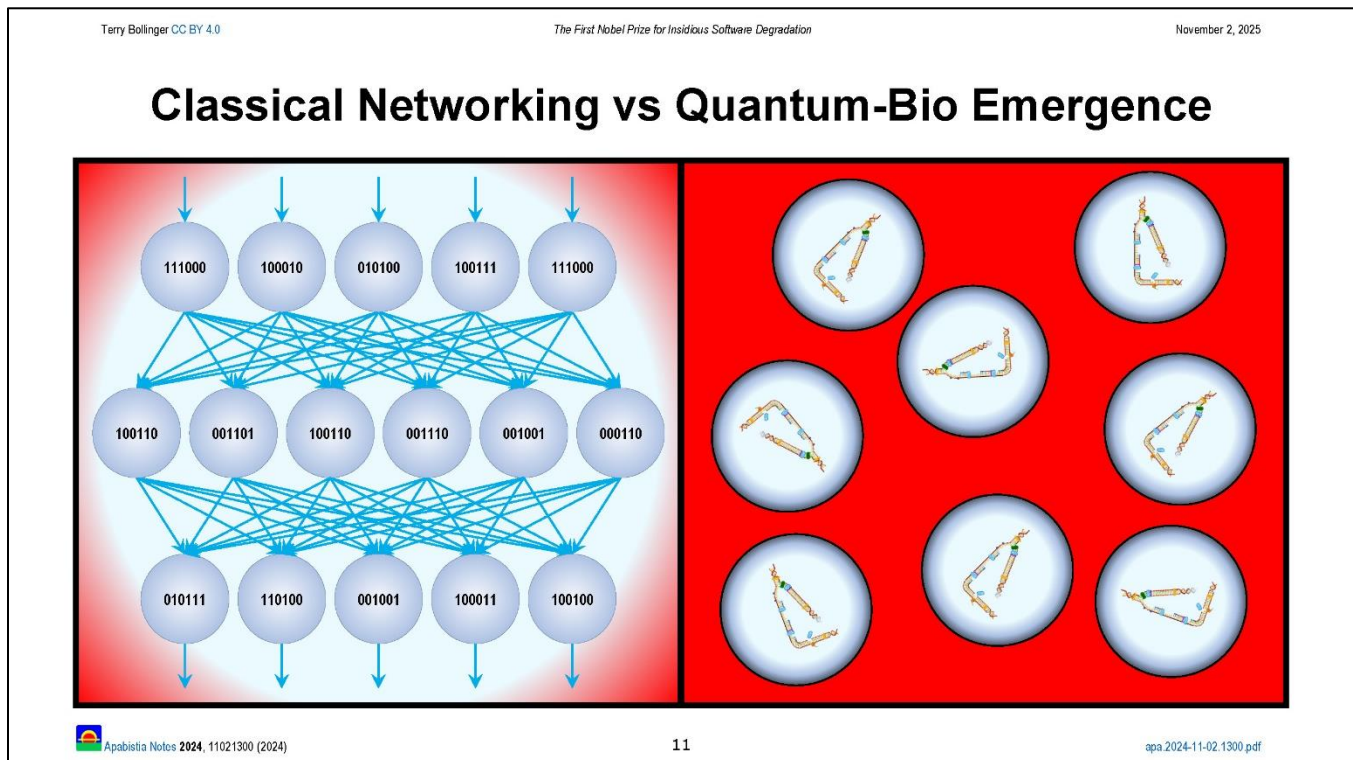
[\[39:35\]](#) So, **what is emergence?**

... and this is where it gets important to make some distinctions. This is a word has two (at *least* two) *very very* different meanings. Simplifying emergence reduces and discards complexity. It still leads to *very* interesting effects. Those effects may in fact be *powerfully* useful in all sorts of situations. Temperature is just the obvious example.

What is temperature? It's an *enormous*, number of very complicated molecular motions that just average out into a *single* quantity that is *far* too simplified if you get down to the details. I mean if you start working with individual molecules you can't use temperature anymore. That's just... That's *nonsense* at that point, but for *larger* sets? *Very very useful*. Does it always work? No. Sometimes there are concepts where the idea of temperature doesn't even make *sense*. You can't really define it, which (by the way) I think you can make some

interesting arguments about relativistic space-time, but sometimes you have to be careful *there* too. It's not always easy to define exactly what you *mean* in relativistic situations.

Implausible emergence is where you beat the odds, and I think that's a *very* important distinction to make. Temperature does not beat the odds. Temperature just wipes everything out. Implausible emergence is what Hopfield looked at with biological systems, where they're somehow able to *do* these things, figure it out, and come out with a really powerful outcome. That's good. You've *got* to make a distinction between these two, because if you start talking about emergence and you're talking about *one* of these, and you're actually talking about the *other* one, you're going to get in some trouble.



[41:19] Now, on the specific issue of Hopfield networks versus... and by the way that's not a very good Hopfield net. I should have... Yeah, if I did it over again I'd draw that as a Hopfield... Now it's just... That's a layered approach there, but the same general idea though. You've got networks where you've got *very, very* classical connections, where you're transmitting *very, very* stubborn little bits who engineers work for their entire lifetime to make sure that bit doesn't change when it gets transferred and stored, and then you've got on the other side... you've got these quantum issues.

There's no *networking* going on there, at least not any network *we* can figure out. They're local little *beasts* that (at a *very* small level) figure out how to do things in extraordinary ways, and we have *some* inkling of how it happens, but if you've ever seen either quantum physicists or conventional... anybody with a computer trying to model quantum mechanics, you will find out very quickly that if you get over about *two* atoms it starts getting difficult, maybe *three*.

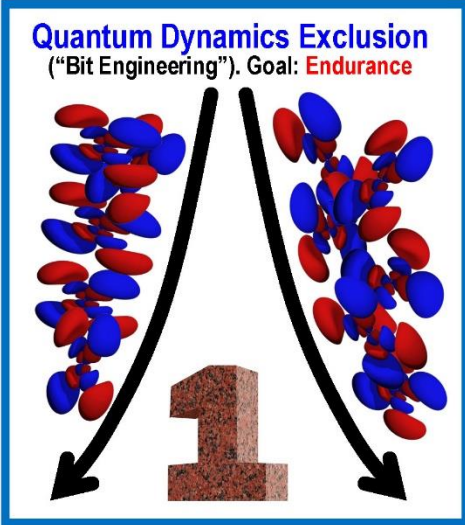
Now look at these DNA molecules, these mechanisms that handle DNA. There, see... These are *tens of thousands of atoms*. We don't know how that works. We can *pretend* we do, but we don't understand how that works. We can't map out what's going on at the physics that applies at that level, so we use a modified mechanical model where we *kind of* say it's *sort of* like a machine. Yeah, except when you get into the details of the *actual* final interaction. There we always get in trouble.

These are *very* different architectures. I mean over here you've got these hyper-classical hyper-connected things going on *here* and over here you've got these very quantum, very microscopic things going on here, showing true emergence on that. So, you want to be *careful*, you want to be careful about saying that these are in any way similar systems

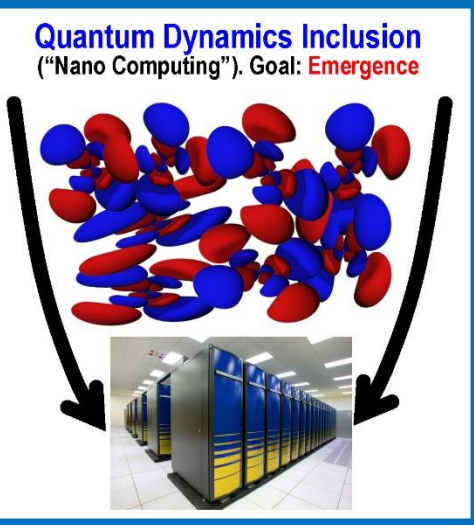
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A Quantum Emergence Surprise: Bits *Hate* Quantum

Quantum Dynamics Exclusion
(“Bit Engineering”). Goal: **Endurance**



Quantum Dynamics Inclusion
(“Nano Computing”). Goal: **Emergence**



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[43:32] This is almost an aside, but I always like to put this out. I think we have a very *unfortunate* focus on what we mean by bits, especially when we're talking about quantum computation. If... How do I put this bluntly? If you take quantum mechanics, strangle it to within a nanometer of death, and then allow just a *little* bit of a tweak room, so it's not *totally* extinguished yet, that's a qubit, because qubit are modeled under one of the most classical concepts in the universe which is a stubbornly persistent value of one or zero that lasts forever through space and time, and you have to do an *enormous* amount of work to make that happen.

If any of you out there have ever worked or touched the semiconductor industry or some of the circuit designs on *how* you make a bit reliable, you realize that the idea of storing a stable bit function of zero or one is *not* trivial. It takes machinery. It takes concepts. Even the classic example from quantum computing of electron spin... People forget that the electron spin has no meaning until you put a *gigantic magnet* around it, and that's your *real* bit You know, the fact that it has a spin doesn't mean *anything* until you make it into a bit and that means you have to add machinery.

So what will you do with bits, which we focus on as our *center* for doing quantum computation, which is... There's a *remarkable* paradox there. First thing we do is *strip* out any trace of quantum interference. Make sure that nothing quantum gets into that bit. Just make it solid as granite. You want that thing locked solid.

When you look at Hopfield's 1974 stuff, whatever is going on there... By the way, those things are not blue and red blood cells. They are orbitals. So, you know, pardon the... I looked at that myself. It looks more like blood cells and weird colors than anything else, but the idea is quantum orbitals. We have a general idea of what they are, but when we get into the details of their interactions? They are doing something it takes us an *enormous* array of computers just to figure out a small bit of that, but instead of tossing that out, like we do when we create bits, the quantum emergence at a *cellular* level (where we get these *very* improbable outcomes) is somehow working

with all that chaos, because these are chaotic systems and you've got quantum chaos suddenly leading to a really *interesting* result, and we don't usually think of quantum computing that way, but I would say we *should*.

[Yuri Ivanovich] Manin did, back [in] 1980. He immediately discarded it, because he was so enthused about computers, which is unfortunate, but he *certainly* pointed out the idea, that there's *incredible* amounts of computation going on in just the simplest things, and life *in particular* seems to do a better job of making use of that with its emergence. So endurance versus emergence: not the same things, not the same things at all.

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Hopfield's "Spontaneous Emergence"

When Hopfield said "[spontaneous emergence](#)" in 1982, what kind of emergence did he mean?

- His 1974 work firmly identified *implausible emergences*
- His 1982 "new computational capabilities" remarks suggests he believed he had found a new implausible emergence

[The reality:](#)

- By his own equations, the total complexity of the *data* stored in his clever networks is always lossy to varying degrees
- His "new" capabilities arise from his clever classical encoding


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[46:45] Hopfield said "spontaneous emergence," so I'm going to *pick on him again* for that use of that terminology. If you, especially, put it into the context of the Nobel Prize announcement — which does a nice job of doing that — [Hopfield] was talking about these implausible emergences, *which are new physics*. If somebody can figure that out, *that* is worth a *dozen* of Nobel Prizes, because we still don't *get it*, and we have such an *incredible* [loss of] computational time to get good models for that.

So I mean, *yeah*, if you could... What *he* did was confine the problem and point out that it *existed*, that this stuff *existed*, and that was *beautiful* work that he did, but he puts a *lot* of biological terminology mixed in with his computational designs in his 1982 paper, and it really looks (as far as I can tell... somebody could go out and ask him) that he thought he had found a new implausible emergence. That this was something that should not happen, but does anyway.

So, if you look at *that* though, in combination with his *own* equations, his *own* analysis of complexity (because he *did* look at this as an information problem), he was perfectly *aware* that these were lossy networks. They weren't perfect. You know, he had figures where he shows how [if] you push it too far you get this much of a loss. So he was aware of that, and that *too* is a deep aspect of this quantum duality I talked about earlier, this... It's not just quantum. It's in life in general. If your wave is limited in size, you're trimming off some of the accuracy of the bits, [it's] as simple as that.

So if you have an *infinite* pond, you have an *infinitely* precise bit, but most ponds aren't infinitely big, so you lose something, and this is one of the dangers of holographic encoding, and Hopfield was aware of this. I mean he...

like I say... he puts in charts and he did some tests and had some good *results* showing what was going on with that. The trouble is (and this is where I think things went wrong) ... is he didn't quite recognize (he doesn't seem to have quite recognized) that the capabilities were coming from his encoding strategy, that he came up with this brilliantly clever encoding strategy, but he was not a hologram—... he was not a holographic guy. He didn't think of that way. He *describes* the properties of holograms *beautifully*, like you can take us half of the hologram and still have most of the data. So he *describes* the properties, but it doesn't make that cross-link

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A Confusion of Causes

Hopfield in 1982: “Additional *emergent collective properties* include some capacity for generalization, familiarity recognition, categorization, error correction, and time sequence retention.”

More accurately: “Additional *holographically distributed data properties* ~~emergent collective properties~~ include some capacity for generalization, familiarity recognition, categorization, error correction, and time sequence retention.”

- Generalization = Near-axis access and matching to data items
- Familiarity = Access to existing data axes when new data is similar
- Categorization = Slotting of new data base on similarity to existing axes
- Error Correction = Close-match-access + resilience to localized flaws
- Time sequence recall = Similarity-based axis linkages (dot products)

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[49:17] Hopfield in 1982... [one of those lines he said]... “Additional emergent collective properties include” some of these: blah, blah, blah, blah, blah... and again I would do this little *correction* here (or suggested correction, but I would suggest it very strongly).

Emergent collective is... Emergence especially is a *really* loaded term in this context. If you instead say holographically *distributed* data properties, suddenly it pops into a lot of clarity about where some of these things are coming from. Generalization is from that [near axis access] of the encoded dimensions in your hologram. Familiarity is because you already have these existing data accesses, so it gives you a classifier. You can say “Oh, this new wave coming in? It’s just an example of that. We’ve *seen* that wave before. We know about that wave.”

That’s the wave that (in an LLM) is the *cat wave*. That’s the *cat* axis. That’s how you identify it’s a *cat*, and I’m suggesting that there’s an *actual* wave structure in the bits as you go down in [that]. I think one of the areas where there could be some *very* interesting research is saying “Well, what’s the wave structure?”. Instead of thinking of it in terms of abstract numbers, think of it in terms of bit structures... Categorization: Slotted new data goes right in there. Error correction: This is one more than anything else where Hopfield seemed to think that *that* was emergent, because he’d seen that in like both of those cases I mentioned earlier. He had seen *error correction*, that... you know, the ability to tolerate *noise* in the transfer of the electron.

He’s seen the ability to *correct* errors in the translation of DNA in the other paper he did that same year.

So error correction to him was an important emergent property and I think that's where he kind of flipped over and said "Oh, this must... This too must be an emergent property", but *again* the difficulty is that if you don't recognize this is holographic data format encoding, then you will come out with a more exotic explanation for it then you *should*, because he's *really* just saying that *individual* devices don't matter, which he actually does say *exactly* that: Individual devices don't matter. It's tolerant to that. Yes, because it's holographic. You've distributed each of the data items over a larger sequence.


He also brings up something called time sequence recall... *This* one I want to look at more closely, because I think he's... Judging by his references (more than what he says), I think he's linking a little bit too much into the *real* neuron behaviors in which we have loop behaviors and all sorts of interesting attraction points and I think he was [glomming on] maybe a little bit too much, because I don't *really* see his structure supporting that very well, but it... He may have just been talking about the the correlation between the axes, but I would like to look a little more closely that one, but either way at the bottom line it comes out and says "If you describe this as *how* he created a beautiful new way to do a data structure with properties that made it fairly easy to compute... *fairly* easy to compute (it was still difficult for that time), I think you just get a lot clearer idea of where these behaviors are coming from."

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2023: LLM Superposition Needs a Holographic Perspective

“Superposition is really annoying, really important, and terribly understood. Superposition is the phenomenon, studied most notably in Toy Models of Superposition [1], where models represent more features than they have neurons/dimensions. We consider understanding how to reverse-engineer circuits in superposition to be one of the major open problems in mechanistic interpretability.”

N. Nanda, S. Rajamanoharan, J. Kramár, and R. Shah,
“Why superposition?” in *Fact Finding: Attempting to Reverse-Engineer Factual Recall on the Neuron Level*,
AI Alignment Forum, Dec. 22 (2023).

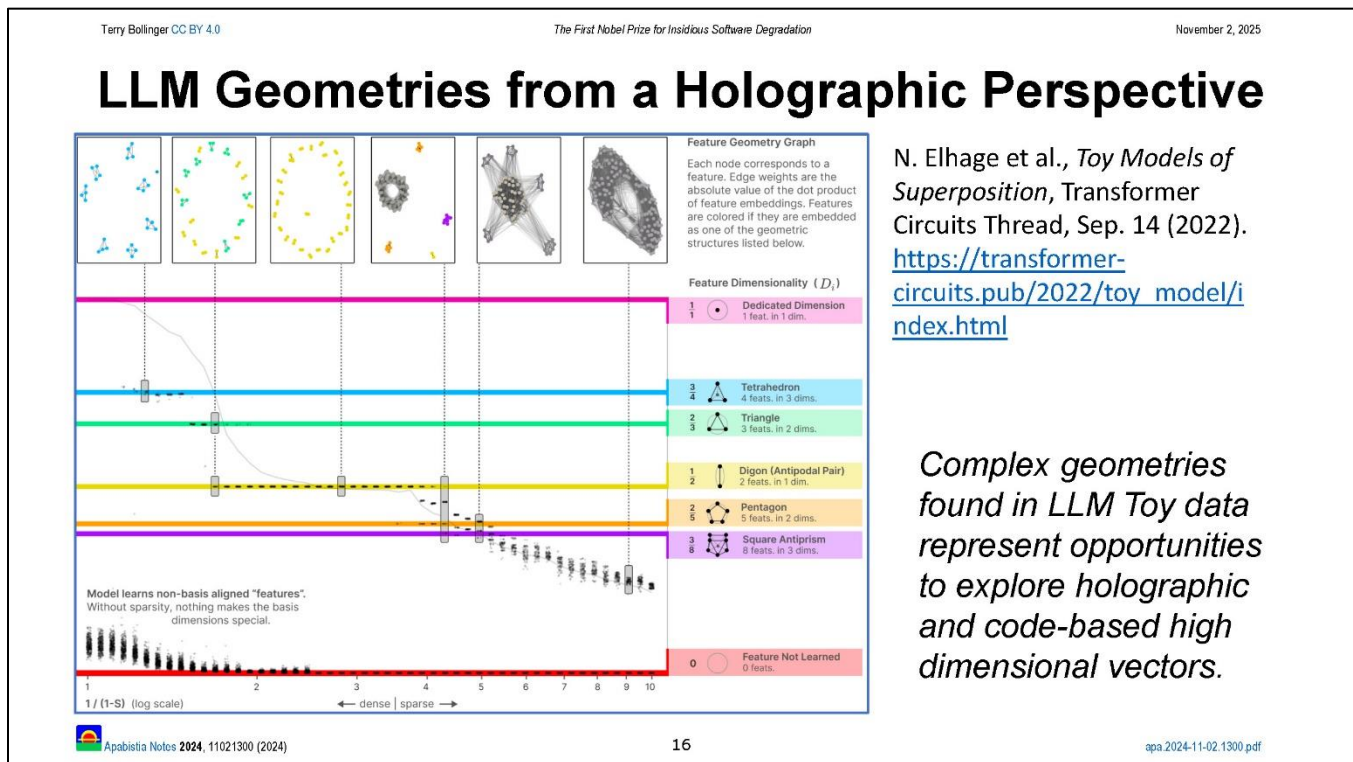
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[\[52:29\]](#) Now, 2023... Let's jump to the present.

If you look at... There's lots of *great* work online looking at these systems, saying "Where is the data? Where is it at? What's going on? What's the *physical meaning* of some of these systems?". This one in particular, you find this online... I did *not* give a link there, but it's in the paper, so if you look at the paper version of this... But why superposition? In fact finding that... When he says fact finding he's saying like "Where are the facts?"

Where do we find the facts in the LLM, because it's *not* easy. They're not just *sitting there* at one spot and *of course they're not*, because they're holographic is what I would say is [the counter on that], and you *see* this coming out... When the superposition topic comes up it just frustrates people and I would suggest that "*Yeah!* It is superposition.", but look at it more from the physics viewpoint (from a wave-particle duality viewpoint) and I think that might start making a lot more sense.

You're having coding spread out throughout your memory, and you're simply *tuning in* to the different directions of what the information is. I think that could give much more *clarity* to some of these issues that are still driving people a little bit *buggy* with this.



N. Elhage et al., *Toy Models of Superposition*, Transformer Circuits Thread, Sep. 14 (2022).
https://transformer-circuits.pub/2022/toy_model/index.html

Complex geometries found in LLM Toy data represent opportunities to explore holographic and code-based high dimensional vectors.

[53:57] Here's an example. This is from the same group. They've got *marvelous* work. I *highly* recommend (and that one I *did* give a reference to) ... on the different *structures* that emerge inside of LLMs and *this* one just particularly fascinated me, because you have these *features* where there... If you took... This happens in atoms, by the way... If you took a bunch of electrical charges and [said] "How do I spread them out in a sphere so they don't run into each other, so they interfere with each other [*in the least*]?", you wind up with these different structures.

My *suspicion* is that some of this has to do with this the self-encoding concept, that the idea that Hopfield came up with a structure that self-encodes *different* unique signatures for the different accesses. [It] doesn't put them in explicitly. So it winds up being encoded, but I'm... Pretty good chance that when you're getting *this* level of geometric *structure* emerging *spontaneously* that you are actually getting into the coding aspect of how these vectors come into existence.

The Dangers of Cult Thinking in Science

- In most situations, Hopfield's unrealistic 1982 hope for improbable, quantum-like emergence in a "dead data" system with clever formatting would be no big deal
- However, as Feynman once noted, Cargo Cult science is always a danger. That is when beliefs bases on what superficial resemblances, such as error correction versus molecular quantum order emergence from chaos, dominate
- In this case, the Hopfield Hope cult of improbably emergence from dead data has already enabled massive, often subtle damage to domains that depend on facts, including software.
- The Nobel Physics Committee did *no one* a favor on this pick

[\[55:06\]](#) Now, blunt part...

This usually would have been just, you know... We all like to be optimistic. Every one of us likes to think we found something *new* and something *really cool* and I think that's what happened with Hopfield [*maybe*] too. [It's that] he said "Oh, this especially the like... fault tolerance ability on that *sure* seems like one of those *cool* emergences that I saw in the other thing." The *blunt* way of going after that though is what Feynman, with his typical Feynman pointedness, called *cargo cult science*. Cargo cult science is very simply that you look at the *superficial resemblance* and from that you *think* that you are actually understanding what's going on.

The specific example that Feynman gives is [that] people would make a little... On some of the islands where cargo planes had come in, they would make little wooden headsets with bamboo antennas in the belief that that was the way you invoke... to get a train... a plane to land, to get this back this *marvelous* thing that had been happening for a while during World War II where all sorts of new items are coming to these very remote locations.

We *do* that and this is what Feynman worried about. He *warned* us about this. He said this is *cargo cult science* and it's a *lot* easier to do than we *think* it is. It is *very* easy to get our hopes... to get carried away with us and we see a superficial resemblance, and if we see it in something like oh, say, a global network of digital circuits, the next thing you know we might be thinking that "Well, yeah, that's just chaos and it's disorganized, but *maybe* an intelligence will emerge out of it spontaneously anyway." and unfortunately *that* was the critical point that Hopfield encouraged.

I would assume he's not the *only* one, but he certainly made a sufficiently powerful argument for it that the Nobel committee noticed it and the Nobel committee accepted it as a real emergence, and that is *very* unfortunate, because what *really* was going on here is something I think *much much* simpler. It is still *extremely* interesting. It deserves a Turing award.

I don't think it deserves a... *That paper* I don't think deserved a Nobel Prize. I could argue that his *other* papers maybe *did*, but the fact that they focused on that one as the center point gives people an unfortunate impression

that just like the mud produced the silver eels in England the dead data of our global web just might spontaneously produce an intelligence, and this is *not* true.

It's just... The two are *far* too similar. I mean the eel and this intelligence [idea], and how many people have you met that are terrified that the internet is suddenly going to become spontaneously intelligent. I was one of them. I think I had that view for, *gosh*, for years and that's one of the reasons why this is so fascinating as I got into it and said like... I was believing in a bunch of *hooey*. This is... It's *not* that there isn't a danger that somebody's going to create an artificial intelligence someday that might be smarter than people. My guess is [it's] more likely it would just be incredibly unstable and just destroy itself almost instantly and then we'll slowly get it more stable, but I'm *not afraid of this anymore*.

I'm afraid of this doing *stupid* things with the internet. In fact, I'm *so* not afraid of this I'm go like this is just a cargo cult. This is... There's no *reality* to it. There's no spontaneous emergence here. Some entity is not going to *pop up* and suddenly take over the internet, but *people* might. So this is why I say the Noel physics committee... I... To me this was an egregious error and the reason is they essentially awarded a prize for non-existent physics and in a time in which people are going berserk on just that physics, but again we're all human. [The] Nobel committee has seen all this... you know, these server farms and all this thing. I think they were a little too optimistic *too* and they were forgiving, just like everybody else [who says] "Oh, if we *train* it just a little bit more maybe it will suddenly do what we want."

Five Recommendations for Future LLM Research

1. **Drop Hopfield's "Spontaneous Emergence" Myth** for LLMs; transition to holographic interpretations with telecom crossovers
2. **Explore Optical Holographic Language Models** as a more efficient replacement for digital matrix multiplication
3. **Restart Molecules-as-Computers Research** as first proposed and self-abandoned by Yuri Manin in 1980
4. **Develop and Apply Improbable Emergence** to counteract persistent data holographic data degradation in ANNs and LLMs
5. **Develop Energy-&Info Aware Formalisms** for modeling quantum dynamics; abandon naïve Hilbert space dynamics

[59:52] A little more positive side, [here are] Five recommendations for the future of LLM research — because, goodness, we've certainly put in *a lot of money* on LLM research already and all those server farms. We're in the *trillion-dollar* range here, and they do useful things, but they *don't* suddenly become spontaneously intelligent.

So, first suggestion: Get rid of the myth. Second suggestion... This to me is the most *intriguing* one, because I think there's some *mileage* on this:

If all these things are is giant holograms with the bits representing photographic emulsion bits, *why* not use actual holography, which is so... What? I don't know... many, many, *many* orders of magnitude more efficient. Optical

holography is *unbelievably* energy efficient. Bit-based Nvidia board-based matrix multiplication version[s] of the transforms that you need to do to accomplish holographic transformation is probably the most *inefficient* way that you can *possibly* go at that problem. So if this is actually holography I'm saying that we... Somebody ought to be paying close attention to the optical equivalent. We have optical holographic memory. There's technology that already exists. Some have been around for decades actually. It's never really *caught on*.

Third idea is [to] take those molecules more seriously. If it's so difficult to do the molecules... to compute the molecules, *why* aren't we doing more about trying to understand *how* we could compute with them. Our cells do it all the time. Maybe we could do something also. Along those lines we need to understand this idea of improbable emergence, *specifically* to counteract what we... [the] situation we've got ourselves into with these artificial neural nets and LLMs. We can't keep up with what we're doing. We've created an *enormous* overload of sloppy information and trying to correct it with humans and *that* does not work.

A final point is I would argue that we *need* to be more careful with some of our mathematics. We have beautiful mathematics for the subset cases, but often when we get... when we touch on these areas about information spread, energy spread, energy limits, the universe pays *very, very, very* close attention to all those issues in *its* formalisms, and they *are* formalisms. You know, the universe does things in very precise ways. The models we use for those *aren't* always that precise and probably we should be a little more careful on that. I particularly pick on Hilbert space, because it's got some interesting issues.

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1. Drop Hopfield's "Spontaneous Emergence" Myth

Thinking that chaos and chance are your friends in LLM design and training annihilates all chances of building reliable systems

- Linear interpolation between known cases the *opposite* of cognition, as is "guessing" at entropic language limits
- Actual cognition jumps into an incremental framework at such points: Looking at the problem from new angles, often literally

Never accept that emergence *must* happen with "enough" training

- This thinking *always* turns into a scale explosion of complexity
- It is the software-support version of an endless Ponzi scheme

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[\[1:02:53\]](#) So, again, drop this spontaneous emergence mess. Let's get *rid* of that. It *doesn't* help if you're in the *middle* of this doing, you know, post-doc research or PhD research on how these LLMs work. *Drop this*. It's not going to help you. It's not going to help you understand what's going on, because it's just... it's relying on randomness as having magic properties and randomness does not have magical properties. It has very *interesting* properties and they *relate* to—... I mean stochastic amplification. You can certainly *use* randomness, but *don't* rely on it to just *do* things for you.

One of the points I put out... This is Doctor [Zojus] in Toronto. He talks about... In fact, he's proposed something called a visual Turing test, because if you look at how the eyes work with the brain in order to understand a problem of recognition or identification or finding *they* have things going on there that are *jumpy*, that are constantly exploring, scouting, you know, collecting information. *This* seems to be a better indication of how *actual* biological cognition works and I've encouraged [John] to please write a paper on this. [There's] a visual Turing test, because the current Turing test (which I've not only used but elaborated on at different points), it's just been *gamed* to death. It's not doing its job anymore.

The power of the hardware has made it obsolete, and again, emergence does not *happen* if you just keep adding training. This is a *disastrous* way to *think* of this problem, because it just... you just... It never *ends*! All you're actually doing is increasing the scale of the [fringy] information where the thing goes *probabilistic* on you and drifts off into *nonsense*, and then that gets incorporated into the system and you just... You know, this is... The analogy (I've used this before, but I mean it very seriously): It is the intellectual content version of a *Ponzi scheme*. You're always putting off the *payment* in the future thinking that *suddenly* it's all going to work, and *it won't!* It's just going to make the problem *worse*. So, we need *corrections* to this and we need better ways for correcting.

2. Explore Optical Holographic Language Models

Replacing electronic (Hopfield *et al.*) pseudo-orthogonal holography with optical holography has interesting research potential

- The possibility of enormous energy cost reductions exists
- Such literally light-speed systems may also prove faster

Existing LLM research could inspire and guide the transition

- Borrow existing optical storage methods as starting points
- Reinterpret the total capacity of and LLM as an optical medium
- Look for ways to translate LLM structures into coded waveforms



[1:05:24] Optical holographic models? *Enormous* energy reductions is probably an *understatement*. I mean... Fourier transforms are *so* cheap with... You can use a *single photon* to do... *One photon* can do fantastic Fourier transforms on *enormous* objects, including gravitational lenses ten million times around... That always amazes me. How does this single photon do that? We don't get that very well, but we've *seen* it, so this is observation *fact*. This is not some hypothesis. That... A single photon can be *curved* by a lens ten million light years across.

Well, if one photon can do *that*, that's a pretty good energy efficiency for the scale of what you're talking about. Possibilities like that *definitely* exist on that and of course they are as literally as light speed as you can imagine. You've got optical storage medium[s] out there, so there's not... it's not a blank. You don't have to start completely from scratch. I think LLM people, if... You know, using their expertise and like some of those *marvelous* figures I just showed a little bit ago... use their understanding of the *structure* of the existing LLMs' transformation process and how the transformers work I think they could give some *really* good insights on *how*



this could be made into an *optical* conversion. So, I think it could be a really interesting interaction there, and translate those structures into coded waveforms.

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3. Restart Molecules-as-Computers Research

First proposed and quickly self-abandoned by Yuri Manin in 1980

- Flip the usual perspective upside down: If modeling even small molecule requires supercomputers and quantum computers ...
- ... then what can one small molecule compute for us?
- This is closer to Feynman's 1982 view of quantum computing

Not an easy task! Molecules would be come tiny, hard-to-control, multi-function devices that no one know how to set or read

- Chemistry, especially that of enzymes, could be a starting point
- Bose condensates have some potential as "giant" single atoms

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[1:07:00] Molecular research, computers research... Yuri Manin, again, he mentions this idea and he was... It was in 1980 and physics was just *fascinated* by information in that time period. They were just absolutely *entranced* by it. So, they didn't see all of the electrical engineers working so hard to make the bits small and make the bits really stable. They didn't see any of that all. All of a sudden everybody was seeing these *powerful* new computers coming out and I think it gave a biased viewpoint about the the *naturalness* and the *simplicity* of bits, because they're *not!* They're not simple! They're not easy!

You have to work hard to make them. They're hyper-classical. By that I mean they're so self-observed and pinned down that you can't *change* it. That's the idea! You want it to be *persistent*. So bits... and if you think about that, if bits are machines that you have to work at *that* hard to make, then you want to be careful about assuming that they are the fundamental fabric of the universe, because you just made... You know, you've just made *engines* into the fundamental fabric. Don't do that. Get something simpler.

So Feynman had a *better* idea of the quantum computing. He actually was close to the idea that said we need to *borrow* this stuff. We need to—... Yeah, he never introduced the idea of a qubit. He never went to the binary thing. As soon as you get to the binary thing you've gone hyper-classical and then you're just backing off just *ever so slightly* so you can make it quantum. No wonder we have to cool the machines down so cold, because it's *hard* to make a machine quantum. They're big and they're classical, so molecules don't do it that way. We don't know *how* [we're going to do it]... Enzymes... Bose condensates... Now those have been used *recently* for *powerful* sensors that can detect gravitational differences over a small distance. So Bose condensates might have some interesting potential for that.

4. Develop and Apply Improbable Emergence

Dynamic emergence is *needed* to counteract persistent and inherent data holographic data degradation in ANNs and LLMs


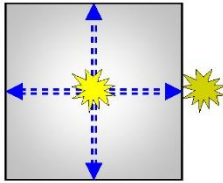
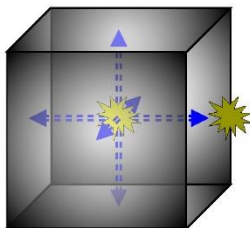
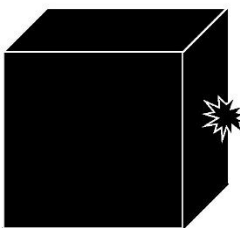
- Scales needed for LLMs are beyond human capacities
- Current methods try (and fail) to use human correction

This is a hugely difficult problem!

- The biomolecules of life *may* give powerful example...
- ... but they may be more akin to predesigned machines
- Likely important: What role does quantum play in improbably emergence? What do biomolecules do that machines cannot?

[1:09:05] How we're going to do this... We don't... I think just facing the fact that we *don't* understand what improbable emergence is... I think there's a *very* good chance that until we understand features of quantum mechanics at the molecular level better than we do now, because right now we just... we don't *do* well. It just becomes... It turns into a combinatorial explosion and we just wind up not making good progress. So, if we can understand that better, there's *got* to be some interesting physics.

Sidenote: Hilbert Spaces Don't Model Dynamics Well

 <p>$n = 1$ constant (color force)</p>	 <p>$n = 2$ $1/r$ (pond waves)</p>
 <p>$n = 3$ $1/r^2$ (electric force)</p>	 <p>$n = \infty$ null (Hilbert space)</p>

[1:09:41] Side note: In preparation for the last slide, which I'll just suddenly... wrap it up: The Hilbert spaces don't model dynamics well. This is a beef I have (I mentioned it earlier) that we *have* to be careful with mathematics that is *overly* simplified. Yeah... Now, you think about that. This is almost like... *This* can be a culty thing too. If you have an *extremely* simple equation, do you say "You know, that equation probably is oversimplified and I *probably* should look for a more complex context.". Too often the reflex is *the other way around*. [It] says "The math is so simple that, you know, I think that's the perfection. That's where the universe is. The universe starts with—...". This is a whole school called S-matrix [(i.e. scattering matrix)] from back in the 70s, but, you know, I think the math is the actual heart... core of it.

The trouble with that is you *can't* do that experimentally. So if you're building real advices it *never* works out that way. There's always some complexities to it. In the specific context of what we're talking about here for LLMs, the Hilbert space model is a *great* model for state space, because these things get *enormous* numbers of dimensions and that's what a Hilbert space is. It's just saying a space with a very large number of axes orthogonal or pseudo-orthogonal to each other, and my point with *this* slide is an *oddly* simple one, which you've heard how explosives are not *allowed* to go through tunnels? Trucks with explosives are not allowed to go through tunnels? Why? Because when you're in a one-dimensional world, [when] an explosion goes off the full strength of the explosion propagates down the distance *indefinitely*, and that means *everybody* is dead, not just the person in that, the *entire* tunnel all dies.

So this is an example of dynamics based on dimensionality, which is something that gets *oddly* skipped over. I don't really understand why. The color force actually is an example of this. Color force... if you stretch it it's like a bungee cord. It just keeps adding energy at a fixed rate until it breaks or something else happens.

Pond waves... They dissipate as one over $1/r$. So *this* time, if you have an explosion in there, you've got a chance of surviving over here because, you know, at least the energy has dissipated, and the farther away you are the better off you are.

Three-dimensional space... Electric force, gravity... We have a $1/r^2$ situation, where things fall off pretty quickly, and you have to take that into account if you want to get an accurate accounting of the dynamics. So let's say we build an LLM with an *enormous* number of axes and so much so that we can say it approximates infinity.

If you *look* at this and *assume* that everything's fine for the interaction between the axes, you're going to be in for a surprise, because the dissipation rate for an infinitely dimensional space is, well, essentially it's null. You just... The dynamics don't travel. So if you try to send a signal out there, everybody's in darkness and saying like "I can't send... Every signal I send just dissipates, you know, *everywhere*".

Now, even though the spaces that we use in LLMs are *abstract* spaces, they still have *real* energy relationships and limits, and I've heard people talk about how the *actual* operation of these [space-time]—... I don't remember. Someone made an interesting comment just along those lines. It's more like a *lightning strike*, you know. Something... You suddenly subset the Hilbert space. You go to a much *narrower* pathway [to what you want] and that just makes sense from a physics information viewpoint, because these things don't... You *have* to be careful about modeling dynamics with overly simplified static-only models, and however respected Hilbert spaces are for that, they're *not* ones that you want to just casually think you can use for dynamics, which is a problem that faces some of these.

5. Develop Energy-&Info Aware Formalisms

Math models such as Hilbert spaces map out *static* state spaces

- Real-world dynamics do not seem to work that way
- “Bursts” of local activity instead penetrate these dark infinities

Most math models include “fairy dust” (details not seen in physics)

- Example: A Bloch sphere with infinite number density at the top
- Example: Coordinate systems whose definition outdistance the speed of light (Einstein 1911 and “clouds of clocks”)

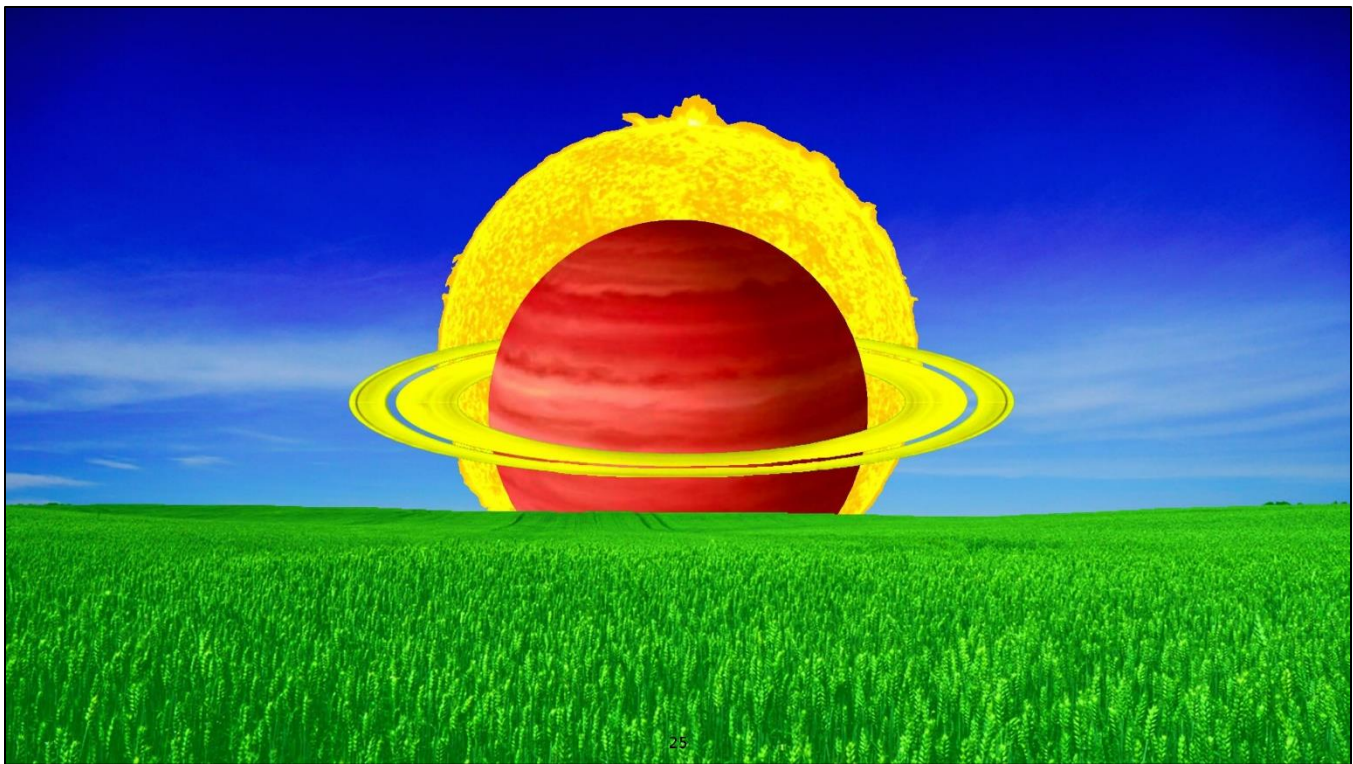
Can math formalisms include energy, information, and lightspeed limits more naturally and at all experimental scales?

[1:13:48] So, and that was my final point. It was just energy-aware formalisms, energy and info aware formalisms. I think we need a little more *sophistication* in some of how we *deal* with these. There was a talk I *was* going to give about fairy dust [laughs], and that one actually is nicely *blunt* too in a whole different way, and everybody here probably (this is quantum computing)... You’ve probably seen a Bloch sphere. Have you *ever noticed* that the bottom of the Bloch sphere has like *digits*... really... the numbers really close, you know, quite close to each other. So like zero and one (real close). If you go to the *top* of the Bloch sphere, they’re *infinitely* dense. The numbers are infinitely dense at the top, and we think, we said “Well, yeah, but it doesn’t matter. It still lets me, you know, track the binary nature.

That is true, but you want to be careful about infinite assumptions about information. Why? [It] goes back to the same thing I said earlier: Bits are *machines*, so if you want to model the *actual* universe, as a opposed to some abstraction that is not *really* the universe because it would be infinitely expensive energetically, then a Bloch sphere is *not* a good model for a qubit, because it represents an *unreachable* situation when you have infinite saturation at one end or the other.

Quaternions... I love quaternions. Quaternions are a much better way, probably closer to how the universe does it. So, you know, we want to keep our models close to how the universe actually *does* things. Almost like a *duh*, but *why not?* Because, you know, that’s one of the reasons why quaternions have taken off in so many simulation areas, because they seem to be closer to how the actual systems do it, and that makes an interesting thing.

Another example of that... This one is actually... I... This is something [where] I took off time from doing this, but this is... Einstein actually *redefined* space in terms of clocks back in 1911, then he went over to general relativity and abandoned that, and in doing so he actually *limited* the definition of space, so that you don’t just set up a set of coordinates. He actually put *time limits* on the definition of an inertial frame, which is just *absolutely fascinating* and something which I wish he had worked more on, but again he off to something called *general* relativity, so he never followed up at his own models with that, but I would make the assertion that especially when we’re doing these stressful limits on information, we need some better formalisms and this would be an interesting thing to do, and I *believe* that is it. Yes.



Questions and Answers from after the presentation:

YC = Young Chun (Team OrionX)

TB = Terry Bollinger

CP = Caetano Peng

#1 = 1st unknown speaker

#2 = 2nd unknown speaker

#3 = 3rd unknown speaker

JG = John Gostoms...

HM = Helen Ma (Team OrionX)

#4 = 4th unknown speaker

...

[1:16:41] TB: So, I think it's time for questions, if there are questions.

[1:16:49] YC: Yeah, okay. Just checking... Did anyone *have* any questions? Did anyone just want to put their hands up, just ask directly? Just putting it out there. Okay, guess not. Yeah, there's some questions in the *chat* Terry. Yeah, so Caetano Peng asked "Why are we trying to assume that 'AI' is omnipotent, free from any possible error?"

[1:17:33] TB: I think that's a good point, that there's an *assumption* that if you can produce a system that shows emergence of intelligent-like behavior, that with sufficient hardware behind it, it will suddenly start correcting *itself* at a rate that a human can never could, because we have much slower neurons. So I think when people come out with that idea that somehow an "AI" is going to be perfect they're reflecting that idea. They're saying that

“Yeah... because of the amount of circuitry and the speed they can do things [that...]”, and of course the whole point of my talk *here* is that I think that the whole precept is wrong, that all we’re really looking at is chaotic bit systems. If we *want* to make an artificial intelligence, it’s going to be hard work, *really* hard work, and I know some *fantastic* researchers who are working on just that kind of stuff and the *depth* of what we *don’t* know, what we *don’t* know about *real* intelligence in *real* systems in *real* biology is just *astounding*.

We’ve got this idea that because somebody invented these neural net analogs back in the 40s... (there’s... all the way back in the 40s)... that we *understand* them and we *don’t*. So I think there’s interesting potential, but they’re not going to be perfect, and this... to me this is actually a relief. I was one of the people who at different times said “Oh man, what if one of these things takes off? Are we going to get this this Arnold Schwarzenegger scenario?”, and I have stopped worrying about that. I’m going like, yeah... I’m much more worried about how people *use* computers and *someday* I think we’ll get to more intelligent ones, but I think it’s going to be a long haul.

[1:19:18] YC: Great. Another question in the chat: “For the wave-particle duality can you explain what you mean by ‘the wave encodes the two particles’ including the stones?”

[1:19:41] TB: Okay. Now, it doesn’t include (encode) the *stones*, but if you have a *pulse*, where you have a... like you took your finger and you go *snap*. You hit a *water surface* and you’re considering that the entity itself. The duality

is that you have a location on the surface, you have some... just like we think of it, you know, as a location on a map... So you have that map, but when you *tap* it like that, if you have the ability to convert that into a wave, you get this spreading wave, which you’ve all seen, and the remarkable thing about that wave is it *fully encodes* that original location, but it encodes in a very *weird* way. You know, it has these concentric circles that just keep focusing back, but if you follow the focus you can see, you say “Oh yeah! It’s *pointing* back to where the particle was.”, and there are many places in reality... like I say, this is really *deep* principle. There are many places where you can just keep *doing* that.

You go back and forth between these representations. When people talk about particle-wave uncertainty, that is *exactly* what they’re talking about. They’re talking about how the *wave* of the particle (that which becomes an actual wave that you can represent)... If you can get it to *snap back* and turn back into that *particle*... and the *details* of how that happens... That’s one of the problems, is nobody has ever worked out the full details of that yet. There’s some strange relationship on how this flips back and forth, but big concentric circles... They *point back* to where the original particle was.

Now if you want to get *farther* into it. It’s actually even *more* interesting than that. There is a two-way duality, where every time you have a wave you can represent it as that particle, but also the particles can be represented in a wave space, and this is where you get into... There’s a concept in quantum mechanics called *momentum space*, and you can *remap* the entire world into momentum space, and it looks *really, really* weird when you do it, but it’s also a powerful technique on what you’re doing, and I say... as best I can... [It’s] probably not that good of an answer, but the duality goes with the fact that waves have a *shape* that always allows you to retrack, reverse what it is, and come back to the point-like representation.

[1:22:20] YC: Great. Somebody also asked “Is this information bandwidth limitation not something that happens with quantum computing?”

[1:22:29] TB: This information bandwidth limitation *absolutely* is something that happens with quantum computing, and one of the *dangers* in some of the mathematical models that are *sloppy* on that is that you may not notice this, and this is not a minor problem in physics, because I don’t want to get into it too much, because I... many people are very *vested* in this idea of *infinite* precision of the models in quantum mechanics, but when you talk about *many worlds* models, where they say there’s an *infinite* number of universes, that is *exactly* what



they're saying. They're saying that the energy, as defined by quantum mechanics does *not* behave like the energy that we've seen in *every example of physics ever done*, which is a problem [{laughs}].

There's a physicist that... I've written to him multiple times on that and said "You *do* realize that when you say energy, you're *not* saying 'energy'?", and he *kind of* acknowledged it at one point, but he's very invested in it, and it's *not* that complicated a point. Nothing we see in the physical universe has infinite bandwidth. Material objects (like atoms) have *enormously* higher bandwidth, because they got a lot of mass, but it's always *finite*, and when you get mathematical theories, such as the many-worlds theory... I can tell you the exact line where Everett it did it, in which he just went "Weeee! I don't care." or **I don't... but** worse I don't think he *understood* it. I don't think he got the fact that he was doing something that required *breaking the speed of light*, that required *infinite* energy, that required *infinite* time. *All* of those things apply to the *key* sense in which he said "Oh! There's an infinite number of universes every time something changes.", and I don't think Everett just... I just... He didn't *get it*.

He was looking at it from a *very* pure math viewpoint and I don't think he had much *physics* background, so he just *looked* at the equation said "Weeee! I'll just do it like that.", but in every version of quantum mechanics that we can *actually* access *in a lab* to get a useful result there is *always* a bandwidth constraint. There is always a speed of light constraint, that when you go from one state to another state it *doesn't* infinitely change the entire universe, *including entanglement*.

There's a... One physicist, Peres (Asher Peres)... one of the most *interesting* comments he made is he was talking about **[the allocs]** and well... A and B, whichever one you want to do. You know, someone changes something here on an entangle particle pair. He made the *very* good statement that you *don't change anything over at B*. Nothing changes! It doesn't *change* anything. The problem does not emerge until the information travels at light speed and reaches that point, *then* you have a problem **[of]** interpretation, but often people act as if entanglement is a phenomena that actually goes faster in the speed of light.

Asher Peres caught that better than anyone else I saw. First time I read that from him I said "I don't understand what this man is saying, but I *really* like his point, and I see that it's correct (experimentally correct).", but we don't understand entanglement well, because there's an aspect to it of the interpretation *must* travel at speed of light and until you actually get past that nothing happens. So, we're not modeling that well. That's a piece of **[poor math]**.

[1:26:15] YC: Great. So, in your "What is emergence?" slide, Terry, somebody asked "What is the frequency?"

[1:26:24] TB: [{laughs}]... What... The emergence... Is he kidding or not, because I did make a reference (a joking reference) to... There was a famous episode where a reporter (an anchor man named Dan Rather, [who] a lot of people don't even know anymore)... He was **[accosted on]** the street and people kept asking him "What's the frequency Dan?". So I don't know if that's a reference to that... What... Read the question to me again.

[1:26:55] YC: It was George, who was just asking "What's the frequency?". Yeah.

[1:27:02] TB: I will answer that in a different tangential fashion, which is this: Somehow in Hopfield's algorithm, and this something... I *really* want to look more closely at his algorithm. I believe he has spontaneously emerging frequencies. I think they're negotiating with each other and that was the reference where I brought in that thing about "What's the frequency Dan?", where the two axes are looking at each other and saying "Well, what's your frequency?". "What's your code?" really would be more accurate than frequency, but "What is your code?", "What is *your* code?"... says "Okay. We're going to put ourselves onto a sphere and push each other out as far away from each other as we can, and that's going to produce an interesting geometry in which you have a good degree of quasi-orthogonality.", which is exactly what they're *seeing* in some of these toy problems with LLMs, which I find fascinating, because they... In fact, some of these points are going out to different **[layers]**.

It's as if they're trying to generate their own frequency (their own code) to *define* that and that might be where that's emerging from, but that's something I want to look at more closely and see if that is what it is. The point I wanted to get at though is this: If a large chunk of the back track... of the back propagation on many of our LLMs is *actually* for the purpose of creating codes that then separate the dimensions.

We could short-circuit that and say "You don't have to generate your own code. I'll give you a Walsh code. Here take it!", and it would say "Oh, yeah, thank you. You just saved me about a *gazillion* watts of processing time (of energy cost), because that back propagation process is *expensive*." So, I think there's a potential shortcut here, where instead of the different pieces asking "What's the frequency?" they... *We* say to them "*Here's* your frequency. *Here's* your code. I will define it for you, using more formal processes, and *you* don't *have* to go through that mess, because that's a slow negotiation, especially if you have a lot of dimensions in that."

So there's another one of the areas where even with the purely digital systems I think there's a potential for considerable energy savings if we look at them as holographic and say that "How am I coding my dimensions with that?" So, no more, "What's the frequency?" We just go, "*Here's* the frequency," and see what happens. And *my* guess is that we could do some *nice* shortcuts with that.

[1:29:37] YC: Right. Another question from John: "So, the Nobel Prize was actually given for the logic circuit, or the logical algorithm?"

[1:29:50] TB: The Nobel Prize was phrased carefully — and actually I think they did a good job of phrasing it. The justification for the Nobel Prize (the best justification), which is in the announcement, is that these artificial neural nets have proven extraordinarily useful to physics, because they can process information at speeds and in quantities that humans cannot do. So particle colliders... Oh gosh... Weather modeling... Take your choice. Any place where these things are *controlled* and not trying to tend to be *humans*, they're incredibly useful, and this is the... I *supported* the research on this. I mean this is one of the things where, you know, at different times people tried to pull the funding *out* from people like Yann LeCun, because it's "Ah, that's old fuddy-duddy stuff. You want to go with the other stuff.", and I'm one of the people who supported [it and] said "No, this is good work.", but you want to... and... I *completely* lost the train of where I was going with that! Okay, good work on that. Okay, so...

[1:31:00] YC: Right. Yeah, just a final question from Lewis. Lewis asks: "Isn't IBM using biology for computing?"

[1:31:11] TB: I think they've had some research that has *looked* at aspects of that. I don't know about IBM. I think there's some other groups that have used biological aspects of computing. I think the most famous one right now is the slime molds that are able to calculate a pathway (that might be the one you're referring to) to calculate a network (an efficient network) faster than most of our computer systems. So, yeah. Yeah, there are some good examples of where living organisms (simple ones) can do some quite *remarkable* computations.

[1:31:55] YC: Okay. I think there's just one more question. Yeah, somebody asked: "Regarding emergence could you comment on Philip Anderson's "More is Different"."

[1:32:11] TB: I'm not familiar... I don't *think* I'm familiar with Philip Anderson's "More is Different". Is this a paper, [is this] a comment? My apologies. I just don't know the... I don't know the context.

[1:32:25] YC: I do not know either.

[1:32:30] The questioner is welcome to explain if they want.

[1:32:37] YC: Okay. It's fine.



[1:32:44] TB: By the way, what was the previous question again? Because I was talking about Yann LeCun and some of the history of that, and I know I got off track and I don't know if I ever got to the final answer. The previous question was...?

[1:33:00] Are you asking about the Nobel Peace Prize question or...?

[1:33:03] TB: The question right before this one was about the... Nobel Prize was... Oh, it was awarded... Yeah, that's where I got off [track]... It was awarded for all of the the very real uses of these of artificial neural nets for high speeds, high capacities, high densities. Humans can't possibly take them and I think that's appropriate in that sense, that that's the thing you focus on for the Nobel Prize. That's good. They *did* specifically call out *that* paper that I was grousing about as the one where they introduced this emergence theme.

So I... That's the part that I wish they had not done, because I think that exacerbates an existing problem with emergence [that's not there]. So, yeah, that was the part I lost when I got got off into reminiscing about some of the issues with Yann LeCun. Anything else?

[1:33:58] YC: Great. Yeah, so that is all the questions that we had in the chat. Did anybody else in the Zoom have like a question that they wanted to flag? Anything that they want to bring up, before we wrap it up here?

[1:34:15] #1: Can I make just comment and question [some time]? You know, when I read the title of your talk, [specifically] the word *degradation* [in it] I start[ed] thinking "Oh this degradation may be something which *erodes* with time or [causes more] damage with time — [that] kind of thing." So, I thought that you're going to talk about *changes*. Things will change with time. So your talk mostly appeared to me

me that it would be challenging that Nobel Prize, in terms of it's... to some extent [it] appears to be a bit *pedantic*. You know, you're replacing the spontaneous emergence, see, with the *holographics* data kind of thing. So I want... If you set apart this question... It's pedantic issue of emergence, because emergence could have different interpretation[s]. For me I was thinking *emergence* is something spontaneous. Emergence [is] something which *occurs* due to mutations.

If you look at biological systems and evolution of a biological system as being through hereditary [lineages] and mutations... So I was thinking that whether the... In the computation side also you could have these mutations in software as time progresses and we *don't know* the *outcome* of those mutations. Those mutation could either be [in the] hardware or mutations in the software. So I wonder what you think about this issue?—

[1:36:10] TB: That's a great question and I was... I could have retitled the talk like "Holographic Interpretation of...". The reason I phrased it the way I did it is *that* was a serious concern. The expansion of... The Nobel laureate... The Nobel Prize going for *this* has increased the likelihood that people will just put some of these LLM coding systems willy-nilly into their systems and produce degradation that's going to be *extremely* hard to get out.

So there was a very... There's a very *real* intent in that system... I think it's just unfortunate that even though they have all those good things that they brought out, which was some really good things, they also put the imprimatur of, you know, "This is a good thing. This is a real thing." on something that's *not real*. That's not what's going on. I would strongly assert that that's not what's going on.

The question you mentioned about the evolutionary part... This is... This seems to be a related type of issue. I would argue that the *entire world* is a giant digital hologram type thing and that most of the properties that comes from it are like that. We *try* to do the software evolution thing... and this is, again, a topic I've tracked. I've had enthusiasm for it. I've had disappointments in it. *Mostly* it's disappointment. It *never* seems to work out the way we think it would. Instead it always winds up... One of the most common ones is you *stress* a system, you try to put your different boundaries on it, to put it under stress. You try to make it evolve and it *does*, but what you wind up doing is you just *reprogram* the environment in a *very very* costly [and] painful way.



So it never comes up with anything new. It just finds a way to *mimic* what you had, and *that's* very similar to that. Biology... This is where I think... There's something *fascinating* about how biology *does* this. It seems to have an ability to adapt better than we can, at least experimentally. We've not had good luck with this. We almost always try to do it by digital exhaustion of the space, and the one case where I think that *really* worked out well was AlphaGo. That is the *only* case I've ever seen of a system that actually gave me a shiver when I read it.

I said "Oh my gosh. This system just totally *blew the pants off* what humans can do." That's the *only* one I've ever seen that [for]. Now Alpha... The AlphaFold is a *marvelous* system, but *that* doesn't give me that kind of feeling, because there is an *enormous* amount of training and I think [that] the "Alpha" was just a marketing choice on that. But AlphaGo had a constrained exploration space and *they* could do digital digital evolution by exhaustion and go into that space, but the trouble is that seems to be a very niche area and it *never* works well with the physical world, because the physical world *never* is that fully contained.

We always have the uncertainty on the edge on where it goes and we don't seem to know how to *deal* with that and *biology* when it does this... Again, and keep in mind, all this evolution that's going on in biology *is* at that very same level where I just said that Hopfield had some marvelous insights about "How is it doing this? How in the heck is it able to take all these random motions and come up with a working molecule?"

So if I had to put a wild guess out (and it would be nothing more than that) it is that biology is using some of those same... in, you know, *very* unlikely emergence techniques... in how it deals with mutations, and we don't know how to do that. So when we get a mutation it almost always lands into the damaging category. Life, it's still damaging, but life seems to be a little bit smarter and I think it goes all the way back to that literal quantum molecular *whatever it's doing* ability to say "Well, I don't like this, but yeah. Okay. Here's a path." and life seems to be able to do a better job of finding that path than any algorithm *we've* come up with.

I say digital evolution is a fascinating topic. I used to *really* enjoy it and then I just got... after decades I just got disappointed with it, because it... like I say, it always wound up being an *very expensive* way to program, as opposed to *genuinely* finding a better path.

[1:40:49] #1: Thank you very much.

TB: Thank you.

Anyone else?

[1:40:57] #2: Yeah. So I had a question about... also about emergence. I think it's understood that you can abandon the concept of intelligence just *emerging* out of an LLM based on a critical size, or if forever *gets* to a critical size. So my question for you is "Are...? What other types of technologies beyond LLMs have interested you in finding a better route to human-like intelligence, whether it's some sort of knowledge encryption type of thing, or cause and effect modeling, etc?" —

[1:41:59] TB: Yeah. Good question. The... And by the way on that part about LLMs not doing that. Three Stanford professors didn't... It's in the references in the paper. I didn't include them in the slides... But they did an excellent study where... I think it was *Google*? One of the LLM groups... I think it was a Google work... where they had documented some cases where it *looked* like they might be getting some few-shot emergences, which is kind of code for saying that... Yeah, it's figuring out something that it didn't have enough data to really figure out yet, and the Stanford professors, even for those very sparse examples, kind of just *really* skewered that and said "No. This was a metrics issue."

You... If could use different metrics and come to the *exact opposite conclusion* to those cases. So, experimentally, *not* having emergence is just... It's hard to deny that it's just... The actual data, apart from the



theoretical side, is not supporting that. Technologies that *might* lead to an emergence... I *think* there has to be some quantum and quantum computational aspect to it and this... and I've gone different directions on this, and I think the biology, where it *mimics* quantum mechanics, *might* be a more conventional way in which [in which you could do that].

Really interesting presentation and I hope I'm not... Have they published that yet? I'm not sure. I think I'm okay on saying this one, but one thing for neural nets that I think could improve the likelihood of a smarter behavior is the use of complex-valued neural net as supposed to real-valued neural nets. I've seen some interesting discussion about that. The reason I think it's okay for me to say that is I've been advocating that for I think going on ten years now and just saw a case where some people actually *did it*, and all of a sudden blurry images that just sort of faded away suddenly got *sharp* and started doing a good prediction of what the future was.

So the reason for complex-valued is because everything in real neurons is *phased* and the irony is even back in I think '43, when they did the first papers on some of these ideas, they knew that. There was inhibitory and executory phases, but I think... I can't remember his name... [Falthwin]?... But the fellow who first came up with it... He was just... He didn't *want* that. He didn't want that *complexity*. He wanted something simpler.

So, I found it deeply ironic that they had *not* gone to that. If you pay attention to phase and how incredibly important phase is in *actual* neural networks, to me that just says... You know, complex numbers are a better form for doing that, because it's really just placing one number with two numbers, but conceptually it just keeps track of that phase, but more importantly the computations just *snap* into a whole different domain, and this whole idea of action potential (minimization of action) suddenly becomes an *inherent* part of that, and *that* is one of the things I *would* say, that if you want more *powerful* systems, *stop* using just simple real number statistics and averaging. Start getting into where you do things called minimization of action.

Now if you're not familiar with it, this is the... Action is the quantity that binds those two representation together. So you have the wave representation, you have the point representation... Action is the units that plank constants are written in, but it also applies to the classical world. So, but seeing these results and seeing some actual *examples* where they *showed* that effect, that (you know) a prediction of where an object might move in the future instead of just becoming a diffuse blob, suddenly it *sharpens up* and you get a probability that's it's going to go in this [fashion].

I think that is some good immediate term directions. It's just getting a little more clever on how closely we map actual neurons when we try to build these devices, and the simple [and] cheapest... That's the one simplest [and] cheapest one[s] and again I *hope* I'm not presuming on... I say this on the basis of... Again, I've been advocating this for ten years, so it's certainly not a new idea. I've said it in many meetings that folks ought to look at this complex value, but I think there's some interesting potential there.

Long range quantum, as defined by the... What was the name of that recent...? There's a recent paper on how the same amino acids that are used structurally are capable of a long range suppression and enhancement quantum effect *in thermal systems*. So, it's I don't know *how* many decades I have complained about Roger Penrose's idea that you're having quantum effects and I *have* actually sent him emails and once or twice got a reply [and I said] "Why do you keep focusing on these *giant* molecules? They don't... They're not quantum!", and it... The whole starting of that turned out... got a lot more interesting when some real studies found out there's these suppression effects. There were... The phenomenon is related to what makes lasers work, where you get... Photons can have [incomprehensible muffled audio].

So, I've over done that one, but yes I think some of the quantum aspects and there's some interesting stuff that has been going on on long-term thermal range [incomprehensible muffled audio] things [incomprehensible muffled audio] that nobody knows [about].—

[1:47:56] #3: Thanks, some really interesting concepts in that response. Thank you.



TB: Thank you.

[1:48:03] YC: Okay. Yeah, just for the interest of time, we're just gonna have just one question in the chat. Mary asked "Have biologists offered a critique of LLMs and neural nets?"

[1:48:21] Bio-neurologists are... a mix of heavily using these models, elaborating on these models... I think the the most common attitude is to make good use of these as tools and find better improvements for them, and I'm talking about from a *relatively* small subset. I... Biologists in general... I would not know, but for ones who are interested in neurological research and how in the *heck* our brains do some of the *astounding* things they do, which is just becoming *more* and *more* apparent, not less apparent, as the sensors get better... They're just... They want to use these as tools. They're good starting points, but everybody wants to make them better, and to feed in some of this remarkable data that's coming in from modern sensors.

I'll give you one quick example of modern sensors: something called a two-photon sensor allows you to actually poke at a single neuron and find out what that neuron is **[doing]**. Did you know that there are *lasers* that can now adapt to your retina and see every single cell and activate them individually and I've talked to people who have seen a color that cannot be *mapped* onto any existing color chart, because the color does not exist in nature. Now the color itself is a blue-green color that is not... You know, it's not a totally different color from *that*, but there's an intensity to it and there's some parameters to it that are not possible with normal human vision.

So in that sense these folks can actually see a different color. That's the level of *tech* we're getting these days. I mean we're getting... Just some of the things that it's possible to measure now was inconceivable not that many years ago. People who have... can query the entire six levels of the neuron simultaneously with various optical and mechanical techniques... New sensors... I saw... There's a *lot* going on and it's looking at the LLM stuff, not... They're not worried about the language model stuff. They're worried about the *real* use of it and saying "How can I use this to make better models?", so I think it's a good synergy going on right now.

[1:50:52] YC: Okay, awesome. Yes, so we *are* at the 3:00 [pm] mark, so I think we are just going to wrap it up here. I did notice a hand that was up before, but it's not up anymore, so I guess we're good on that... unless you [(meaning an audience member)] just wanted to hop in really quick or okay... Okay, cool. Yeah, no, Terry. Just want to say thank you for the chat. It was actually a really interesting topic and I think it was like pretty helpful for people, you know, with like little experience to like a high knowledge in the space, so I thought it was an interesting discussion and a presentation overall. Thank you so much.

[1:51:36] TB: Thank you. Much appreciated—

[1:51:37] YC: Yeah, and in terms of everybody else, thank you for joining today to another meet up on a Saturday on Halloween weekend, but I just wanted to give everyone a heads up that the next one will be November 16th at 1:00 Eastern Standard Time. Remember to push your clocks back an hour today, because daylight saving time is officially over starting tomorrow. So 1:00 Eastern Time, November 16th, the topic will be a series challenge to quantum mechanics part three, a theory led by Doctor **[Powell Gora]**.

Yeah, that's it on my end. Terry, was there anything you wanted to say on your end. I just appreciate the chance to talk, thoroughly enjoyed it, and thank [you all for the] great questions. [I] appreciate the questions.

[1:52:28] JG: Thank you very much. Yeah. [{claps}]

YC: Great. Helen, was there anything on your side as well?

[1:52:33] HM: Yeah, if you have more discussions please go ahead to discuss. I see Jordan just raised his hand.



YC: Oh okay, I guess Helen will stick around for the last minute. Terry, I guess are you free to stick around as well.

TB: Yes.

YC: Okay. All right. So I guess, yeah, if anyone had any other questions.

[\[1:52:53\]](#) #4: Thank you. Terry, I want to say thanks, and what I wanted to just add to this was (you know) with the inherent risks of a probabilistic nature of a stochastic system there's also increased risk with data integrity. So the whole area of this new attack surface of poisoning the training data, prompt injections, also increases risks with the system on top of the (you know) how *you* proposed of having this type of system... The risks multiply, so to say, and I just want to say thank you too. I really enjoyed the presentation

[\[1:53:28\]](#) TB: Well, thank you, and I would agree with your point *emphatically*. The *insidious*... I use the word *insidious*, because that's the *slow* burning one. I think the corruption and the intentional corruption and subversion is an *enormously* higher risk right now, because that is *hard to handle* in these systems, so good point. Thank you.

[\[1:53:59\]](#) HM: Does anyone have more questions for Terry?

Seems like there's no more questions. I think we're... Looks like we're good.

[\[1:54:18\]](#) HM: Yes. So, if you have more questions we can reach out back to Terry. Thank you for coming. Goodbye.

TB: Thank you everybody.