CRAIG: [00:07](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=7.3) Hi, this is Craig Smith with a new podcast about artificial intelligence. This week I speak with Pedro Domingos, a well-known machine learning researcher and professor at the University of Washington in Seattle. Pedro rose to public prominence in 2015 with the publication of his book, The Master Algorithm, which proposes that there should be a single algorithm that can learn any knowledge in any domain, much as the elusive master theory in physics is meant to unify relativity and quantum mechanics.

CRAIG: [00:42](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=42.1) Much of Pedro's work since then has been on generalization across domains. The conversation included a discussion about the future of democracy and authoritarianism in an AI-driven world before looping back to the search for a master algorithm. But we began by speaking about machine learning and the realm of geopolitics. Unlike many of the researchers I've spoken to, Pedro believes strongly that the great powers are engaged in an AI arms race with America's Defense Advanced Research Projects Agency, or Darpa, pitted against China's military and industrial dynamo. I hope you find his views as compelling as I did.

PEDRO: [01:30](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=90.29) I think whether we like it or not, that race is here. There are some analogies to the Cold War. That was a race for technological superiority between America and the Soviet Union and America won. This new race is going to be very different. It's not at all clear who is going to win. But I think the race is here and at this point I think the Chinese got into that race mode before Americans did because hey, they were the up and coming ones. And there were people sounding the warning like Eric Schmidt and whatnot, but I think at this point like people at the policy level understand that this is a race and if we lose the race, we're in trouble.

CRAIG: [02:01](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=121.74) Well actually that's a good point. I don't quite understand why people see it as a race because significant things are published and with the Internet and things like arxiv, things are visible immediately everywhere in the world. So unless China has like a Manhattan project to get to artificial general intelligence that no one knows about, we pretty much know what's happening in China. China pretty much knows what's happening here. And if they make advancements, they're reproducible here and ... you think that's naive, you're laughing.

PEDRO: [02:36](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=156.29) I'm thinking, wouldn't it be nice if that was the case? I think two things. One is, things are much less open and reproducible than you might imagine. All of these companies, they have the things that they make public and then they have the things that they do not make public.

CRAIG: [02:50](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=170.74) Well that's right. So that's competition between corporate interests and that's very different ...

PEDRO: [02:54](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=174.46) Yeah, but, but, but one thing feeds the other. And then also the reproducibility is very, very low. If you publish a NeurIPS paper and then I try to reproduce it, chances I won't be able to. I should be able to, but I probably, you know, can't. And in some ways it serves the purposes of these companies for things to only be reproducible up to a point. This is like quantum mechanics. Quantum mechanics was an international effort. And in fact, most of the prominent scientists were German. If you had handicapped the race, you know, in 1939 who will get an atomic bomb first? It was going to be Germany. And this is why Einstein was alarmed. So it's one thing to be advanced in the fundamental science and there it is international, but then the application, that can be secret. And in fact it was secret. And you know, like, the Germans had their project, the Japanese had their project.

PEDRO: [03:41](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=221.44) And the thing is that, like, there's the economic race and then there's the military race. The military race is a military race. And it's interesting like for example, how many machine learning algorithms were invented by government scientists in the sixties or fifties or seventies and they were later discovered and published in the literature and it has only been now, 50 years later, that we realize that they actually were already being used to detect tanks and whatever, but nobody was saying anything about it. So some of those secret things can actually remain secret for a long time.

PEDRO: [04:10](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=250.12) Darpa is the biggest funder of AI, you know, in the world ever, at least up to this point because the potential military impact of AI is completely obvious. I'm sending up human flesh against your squadrons of machines. If you have an army of robots and I don't, I'm hosed.

PEDRO: [04:24](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=264.79) So that race is there. And now what we're actually seeing, unfortunately, at least from humanity and scientific point of views is that, like, we're seeing this increasing cleavage because the US doesn't want its secrets to go to China and they're trying to see how they can stop that. We could talk about how much that can be done on how much should be done, but that race is materialized. But the other thing to realize is that the economic race is also between countries but primarily between companies, but the two are very closely tied together because progress in one builds on progress in the other. Darpa at one point really started to foster this notion of dual use technology because it's actually good for everyone. Now you can buy components in the market, so they're much cheaper, you know, like electronic components. So they actually deliberately foster that. In fact, AI is the ultimate dual use technology.

PEDRO: [05:07](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=307.75) There is really no difference between military and civilian AI. In the same way that you can take a factory worker, you put a rifle in his hands and he's now a soldier, I can take a house bot, put a rifle in its hands and it's now a soldier. I mean, the technology is the same like the video understanding, the face recognition, the robotics -- the technology is all the same and therefore we're going to see this very interesting thing where, and in fact I think China in some ways is playing this game much better than the US so far, is that the government and the companies mutually help each other. The companies also have less choice. It's not like they have the option. But when you compare that with, like, you know, Google employees saying Google must not work on any defense related projects, right, there's a very big difference between what's happening on the two sides.

CRAIG: [05:50](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=350.921) Yeah. So you do think that in China, for example, there are secret programs, government programs, at least at the application level.

PEDRO: [05:58](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=358.96) I think there are secret government programs across all of computer science and technology, just as there are in the US ...

CRAIG: [06:04](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=364.57) At the application level, but not necessarily at the basic research level.

PEDRO: [06:09](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=369.08) The thing is that at the basic research level, closed programs don't make that much progress. This is the beauty of research -- is that having an open system, it's how you make a lot of progress. And then at the application level where you have a very specific goal in mind, but again, part of why Darpa has been very smart and like the way research has been funded is that they understand that they fund basic research with applications in mind, but their whole mission is like here's an application that the military cares about, but the basic research that would underpin it is missing. So now we're going to fund that. And then what they often do is they come up with a civilian application that is an isomorph of the military application and then we work on the civilian application. But they know how to transfer that to whatever the real problem is. And we have some inklings of what the real problem is, but sometimes we don't.

PEDRO: [06:54](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=414.53) So there's a very interesting boundary between the basic and the applied and in fact, negotiating that boundary well is key to success. And the US actually, historically, at least, they're just better than anybody. Because the basic research was mostly not done by government labs. It was farmed out to universities, they had to compete, but then there was like the whole VC system to make it transfer to practice. So that worked very well compared to the Soviet Union. Compared with how China is today, I don't know. Right. They have a pretty savage form capitalism going on right now. More savage than in America.

CRAIG: [07:26](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=446.32) Yeah. Yeah. I spent a lot of my career in China and when China sets his mind to doing something, it gets done quickly.

PEDRO: [07:34](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=454.65) You know, one chilling thought is that maybe democracy is better than authoritarianism, but authoritarianism will win because China's bigger.

CRAIG: [07:41](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=461.15) Yeah. And AI will help it win.

PEDRO: [07:43](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=463.69) Well, yeah. That's the thing about AI that I think we were not very attuned to 10 years ago, but now we are is that AI can be a great tool for the masses. Maybe the greatest ever, because now you can have your own personal doctor, lawyer everything. It's an amazing equalizer and it makes for better democracy, etc., etc. But at the same time, AI is the ultimate tool of the dictator. AI has no conscience. It can keep tabs on everybody the whole time and never get tired. Never doubt. And the uses that China has been making of AI are quite frightening.

CRAIG: [08:15](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=495.39) Yeah. What's amazing to me, the Chinese, partly because the culture is an imperial Confucian culture, people relinquish a lot of personal responsibility to authority, but there's very little concern among my friends in China below that veneer of urban intelligentsia that are in touch with the West. But you know, you get down to people who are not interfacing with the West or listening to western concerns and there's tremendous support for the social credit system. There's tremendous support for Xi's unfettered appointment -- his lifetime presidency. And there's very little concern about data privacy because they already assume that the government has ... I mean everyone's grown up with a dossier at the local police station.

PEDRO: [09:00](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=540.91) They've never lived in a free country. Not for the last, whatever, 10,000 years. It was never really a free country. So the culture isn't there? And I think the West has been very complacent about saying, like, 'Oh, our system is just better.' I think the reality is a little bit more subtle. And having said that, I think that maybe one measure that people should consider more is the following. We used to think like, oh, you know, like as the middle class rises, they will demand more freedoms and the government will have to give them to them. And the same thing will happen in China that happened in South Korea and Taiwan. And so we should just, you know, aid and abet them. And that hasn't happened. But here's something that has happened, which is if instead of just measuring things about how democratic their political process is, you measure things by how responsive is the government to the population.

PEDRO: [09:46](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=586.47) The Chinese government is vastly more responsive now than it was 50 years ago. It has no choice. In North Korea, the government is still not because the people have no power. But the truth is that as the middle class grows and you know, like, the amount of power in China that now belongs to the Communist Party, despite Xi's increased authority, is still shrinking. Think of Singapore and in fact, Singapore has been in many ways the model for China's opening and whatnot. Singapore is not a democracy or least like a full democracy, but at the same time that regime is quite responsive to what the people are thinking. So maybe the news is not so bad in that sense. I think one possibly not too bad option is that China could wind up being a country that is authoritarian in name only.

PEDRO: [10:30](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=630.57) You could still be an old fogy in the Communist Party and think that Marx still rules the roost, while that's not what the reality is. It'll be very interesting to see how all this plays out and I actually think it will probably wind up being different from the things that we know so far. And I also think that like we in the West, we are now at the point where we should learn from some of the things that people do in China and not just technologically. And I think there's a lot of room to perfect democracy. In fact, I think one of the uses of AI and machine learning can and should be, and there are people working on these things, to make for better democracy. Where instead of you communicating your few bits per year to your representatives, which is like something out of the 19th century, you communicate at the same bandwidth that you communicate with Amazon or Google or so on. So I think we shouldn't take this as, like, we just need to defend democracy as it is. We need to make democracy evolve faster than China is evolving authoritarianism.

CRAIG: [11:21](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=681.75) Yeah. One thing I've talked to a number of people about is the likelihood that the west and the east can see eye to eye on conventions to control misuses of AI. I'm not talking about slaughter bots or something like that, but just in terms of bias and fairness or the degree to which you apply machine learning to surveillance of the public. Do you have any opinion on that? My sense is that China will go as far as a can before agreeing to any conventions and those conventions will be very general and very low level.

PEDRO: [11:59](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=719.8) I think it's unlikely that China and the West will agree on these conventions governing AI. The first reason for that is what we were talking about, is that the cultures are very different and you know, China's whole frame of mind I think is that, you know, the West can't tell us what to do anymore. We are the big boy now. They're going to have to adapt to our way of seeing things. So this whole thing like, yeah, privacy, human rights, you know, like they're getting a little tired of, you know, lip syncing to this and feeling like they don't need to anymore. I actually think that the U.S. and Europe are also very different in this. I think China is on one end, Europe is on the other end, and the U.S. Is actually in the middle.

PEDRO: [12:35](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=755.5) I was in Berlin for this AI conference organized by the Aspen Institute six months ago with a lot of German ministers and so on. And I don't even remember what the title of the conference was, but like, even the title was pessimistic. Like, like I know how is AI going to disrupt us? And it's like they just have this view of technology as the enemy and their whole attitude is to control that bad force.

PEDRO: [12:55](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=775.631) The U.S. does not have that attitude. The U.S. is, number one, more technophilic and number two, much more a free for all. Americans are as suspicious of the government as Europeans are of companies. But compared to China, the U.S. Is like a very big privacy, blah blah blah, so. And now what we're going to see is what, how these things play out. And I think clearly Europe is falling behind, which is a shame because in terms of research Europe has always been and is a leader in research and it's not a mystery why they're falling behind.

PEDRO: [13:24](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=804.61) What is surprising is how quickly China managed to rise. Now we can't even agree on such conventions within the U.S., let alone between the U.S. and China. So I think there's a good debate to be had about this, but you know, in some sense there's a lot of confusion. I think. AI has now become, risen above the radar. Most fields of research and technology, like, fly safely below the radar, right? AI is now well above the radar and I think it's distinguished by being extraordinarily target rich. Climate science used to be a backwater. It has one hot button issue, which is global warming. That has been enough to mess up everything. They see AI through the filter of their preoccupations. It's fairness, it's privacy, it's jobs, it's warfare. And so there are a lot of people converging on AI with strong opinions coming from their political backgrounds. And I mean we've seen this in other fields, right? And then like they don't see AI as is it is, they see AI as they see the world.

PEDRO: [14:18](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=858.881) What's your work right now?

PEDRO: [14:20](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=860.801) So there are these different paradigms within machine learning, the connectionists, as they may be better known or these days, deep learning, are one. But there are several. And I've actually worked in most of them, which is unusual. A lot of my work has been on unifying these paradigms because I believe, and a lot of people do, that one of them will not get us to solving the machine learning problem. We need some kind of grand unified theory of machine learning, like, you know, they have in physics and other fields. So a lot of my work has been on unifying, for example, symbolic learning and visual learning - these days, symbolic and neural learning. There's been a lot of progress at the scientific level. We actually now for the most part, know how to unify all the paradigms, which I think is remarkable because superficially, they look completely different. But if you go a little bit deeper. I think we're almost there. Now, whether that's all we need, I don't think it is, but it's a step forward

CRAIG: [15:11](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=911.43) But unifying so that you could have one system that draws on all the paradigms to solve one problem

PEDRO: [15:18](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=918.97) Or one master algorithm, which is why my book is called The Master Algorithm. Before I wrote the book, I actually talked with a bunch of the top machine learning researchers and 'do you think there is a master algorithm?' And, you know, two of the ones that were most strongly in favor of that idea where Rich Sutton and Geoff Hinton. Of course they believe in different master algorithms. For Rich Sutton, it's reinforcement learning. And for Geoff Hinton it's whatever learning the brain uses. But that's the hope. And a master algorithm for machine learning will do something much more complex than, you know, say the Standard Model in physics, so, by a different order of magnitude. But still, I think it's very important to have on, and I think we're getting there.

CRAIG: [15:54](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=954.85) A master algorithm is another way of saying human level intelligence.

PEDRO: [16:00](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=960.28) So what does Master Algorithm mean, right? It's, in the same way that a master key opens every lock, a master algorithm is an algorithm that solves every problem. Now, this may sound crazy, right? But this is actually exactly what machine learning is all about. Traditional computer science, traditional programming, can do all of these things. You can have an ATM, you can have, you know, fly a plane, you can make Pixar movies, but you have to write a separate program to do every one of these. And there's millions of algorithms at this point. The thing that's amazing about machine learning is that the same one algorithm can do all of these things, if you give it the appropriate data. So for example, you know the connectionist master algorithm is back propagation. That one algorithm can learn to play chess and Go to human-champion level. It can learn to recognize images, it can learn to translate speech simultaneously, it can learn all of these things that people are doing.

CRAIG: [16:50](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1010.74) Although it's one component, it's not the algorithm that does these things,

PEDRO: [16:55](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1015.28) Right. I mean the learning algorithm always has to be learning about something on some substrate. So just giving you back prop is not the whole answer. You need to say like, well what is the architecture of the network on which back prop is running and so on and so forth. But it's the key component. It's the 20% of the work that gets you 80% of the way, but then there's still a lot of engineering to be done.

CRAIG: [17:14](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1034.82) The issue with getting AI agents or systems to cross domains or to go from a narrow problem to another narrow problem is being able to generalize and transfer learning. From what I can see, there really isn't that much generalization going on. Is that correct?

PEDRO: [17:34](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1054.7) The beauty of machine learning is that it does generalize, right? It's inductive reasoning instead of deductive reasoning. So in the 80s, in the previous AI summer, it was all based on what I called expert systems and knowledge based systems and the idea was that like if you wanted a system to do medical diagnosis, you have to interview doctors and write down the rules by which they diagnose things. People realized this was never ending. Because it was very brittle. As soon as I went to a little bit outside those rules, the system collapsed. Whereas a human doctor would figure things out. Now, machine learning is vastly more powerful than that and that's why it's now at the basis of AI and of all these successes. Because you do generalize from the examples you see. Like, in my PhD thesis I was working with this repository of databases half of what your medical diagnoses.

PEDRO: [18:18](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1098.75) We have algorithms that learn in 30 seconds to diagnose most things better than the doctors. So they generalize amazingly well. Having said that, when you compare that with the human ability to generalize, everything we have is pathetic today. So now actually to get back to your previous question, if we have this master algorithm, would we be at human level? No. Because there's more than one master algorithm, right, there's not necessarily only one. There is a master algorithm, you know, running in your brain right now. If you believe in reductionism and what scientists do. If you write down in code what, you know, those neurons are doing and how they're connected, well then that's your master algorithm, right? It by definition learns everything you learn. But we are very, very far from figuring that out.

PEDRO: [18:57](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1137.901) Now, some people are more optimistic than others. Like, you know, Geoff Hinton is more optimistic than most people and there's even some, you know, Gung Ho connectionist thesis of like, yeah, you know, we'll get there with back prop and a few more bells and whistles. But I think the more prevalent view and probably the correct one is that we are very far. Like in any field of knowledge, you start out by importing to this problem the things that you know from other areas. And this is what people did in machine learning. In fact, these five paradigms, every decade a different one is on the ascendant. But the interesting thing is that they were all born at the same time when the field was born and they haven't changed. Right. It's learning inspired by the brain, learning inspired by evolution, learning inspired by psychology and analogical reasoning, learning inspired by learning inspired by the scientific method [and learning inspired by statistics]. None of that has changed. My feeling - I can't prove it - is that the really important, fundamental machine learning ideas haven't been discovered yet. And the irony is that, like, we the experts in some ways are the worst people to discover them because we're already thinking along the tracks of our paradigm. So, you know, part of my hope in writing the book was that some high school kid would read it and think of thoughts that we have never had, because I think we really need that.

CRAIG: [20:07](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1207.86) There's been a lot of focus in advancement on auto ML. I mean, that takes care of a lot of the basic tasks. Is there any promise that that could advance more basic research?

PEDRO: [20:20](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1220.67) Well, I think auto ML is part of the solution and it's the logical next step. So then the industrial revolution automated manual work, but now you have all these dumb machines, right? And then if you think about what computers do, right, is that they automate a lot of mental work. Once we had, like, the machines and industrial revolution, it used to be that labor or muscle power was the bottleneck to what we could do in the world. You only have so much power right? But then the bottleneck became mental work. Now the beauty of computers, right, and programming is that it automates the mental work. So now that's no longer the bottleneck, but now the programmers are the bottleneck, right? There just aren't enough good ones or enough. And now what machine learning does is it automates the creation of programs. But now guess who becomes the bottleneck? It's the machine learning researchers who are now very expensive.

PEDRO: [21:03](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1263.371) You know, you can think of machine learning as being the automation of automation. And auto ML is the automation of the automation of automation. If you're Google and you employ these thousands of very expensive machine learning researchers and yet they are wasting most of their time tweaking the hyper parameters and the architecture, auto ML is definitely the way to go. We'll see how far it gets. But you know, definitely I think it's part of the solution. Having said that, doing this kind of like automatic model combination and selection aren't really a unification of the paradigms. It's more like a shallow way to know how to pick and choose one or another. So I think it's definitely a useful thing in practice. I don't think that'll get us there. There are some people these days that are like, 'oh, the problem is mostly solved. We just need bigger datasets and more computing power.' And this to me is just like eerily reminiscent of the 80s when it was like, yeah, we just need more rules and more computing power. I spent the first part of my career working on scaling up learning algorithms so they could learn from our data and we were more successful than we imagined we ever could be.

PEDRO: [22:04](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1324.12) But even if he gives them infinite data, the algorithms are too dumb. So having GPUs and vast masses of data is wonderful. Definitely. It's kind of like the easiest way to make progress, but I think it's an illusion to think that we don't need any big new ideas.

PEDRO: [22:17](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1337.68) Of all the rivalries between these schools, there's none sharper than the rivalry between the symbolists and the connectionists. I really think that you need ideas from both. And in fact from other paradigms as well. I think the notion that you're going to solve the whole problem with just connectionism or symbolism is like - think of your brain, right? Your brain definitely has a connectionist level but it also definitely has a symbolic processing level. This problem is hard enough that we should go at it from every direction that we can. We should let a thousand flowers bloom and at the end of the day I think what we already see is combinations of these things.

PEDRO: [22:48](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1368.97) So for example, if you look at things like AlphaZero, people were like, oh great success for deep learning. But actually it has all these components that are different types. Some of them are symbolic components like you know Monte Carlo tree search, you know, so like you already see these combinations and I think maybe at the end of the day what will happen is that every camp will be able to look at the results and squint and say, like, 'see we won. It's a symbolic system.' Or, like, 'you see, no, no, it's a connectionist ...' In some ways. I think people are just talking about very different levels of things, right? It's like the neurons are there and the symbols are there, but there's many levels between these things that we don't understand yet.

CRAIG: [23:21](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1401.99) I was talking to Yoshua Bengio and he was talking about neuroscience and machine learning and he's had a few papers on what he calls equilibrium propagation, where instead of back propagation, it's kind of a bi-directional propagation as a model for how neurons might work. Is that revolutionary enough to move things forward or when you say that there's need for something completely new, it is well beyond that?

PEDRO: [23:48](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1428.89) I think that the stuff that Yoshua is doing is interesting, but it's very speculative at this point. It's very unproven. As is, for example, Geoff is working on this idea of capsule networks, which I think, you know, to me it makes a lot of sense. And again, people like Geoff and Yoshua have tried a lot of different things. Back prop is not a realistic model of how the cortex learns. You know, back prop seems to be a potential reasonable model of how your cerebellum works, which is the part that does motor control, which is a much more primitive part of your brain. And there you actually have a structure and the type of connections and backwards propagation that maybe could be more like back prop. The real success of deep models is conv nets, which is visual. But the irony of all this is that it's the architecture of the neocortex with a learning algorithm of the cerebellum, which makes no sense, right?

PEDRO: [24:36](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1476.95) I think people, you know, are going to look back at this 10 years from now or 20 and go like what a strange Frankensteinian things that was. And I think people, as much as they are happy with the successes, they are a little frustrated. For example, Yann Lecun, he says something that I think could be the model of deep learning, which is, we should be inspired by nature, but not too much. We know that algorithms are not what the cortex does and yet the cortex is where the real action is. Then somehow we need to find a way to understanding how that works.

CRAIG: [25:04](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1504.58) Talking to Rich [Sutton] about this, he believes very strongly that reinforcement learning is the direction because that's how people learn, or one of the main ways that humans learn. Is that your view as well? I mean it seems that supervised learning has been pretty well explored and that if you want generalization, you want to create an agent that you send into an environment and it learns without everything being labeled, you would want rewards to motivate learning systems.

PEDRO: [25:34](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1534.34) I think reinforcement learning is part of the solution, but it's very far from the whole solution. I think that reinforcement learning is part of how we learn and it's a very important part and it's very attractive to people who really want to solve the AI problem because intelligence at the end of the day is a sequential decision making problem. Like it's not a supervised learning problem. We have to make a sequence of decisions and we don't see the results until later and reinforcement learning is the theoretical framework that we have today to model that. Having said that, I think it's very easy to conflate two different things. One is the sequential decision making problem of making decisions over time. In some sense that is, you know, the overarching problem in intelligence. I think most people would agree. But reinforcement learning is one approach to that problem.

PEDRO: [26:15](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1575.68) It's the one that has all the oxygen because people haven't come up with too many other good ones, but my feeling is, just a feeling, is that the reason why reinforcement learning has had such a hard time making progress is that in some ways there are important things that it doesn't capture. And I think one of the important things is that inside every reinforcement learner is a supervised learning problem. And then aligned with that supervised learning problem is an unsupervised problem. If you look at human beings, little children, like infants, babies, most of their learning is not supervised, it's not reinforcement learning. It is just unsupervised learning. They explore the world, they, you know, they touch things, right? And this is how most of your learning happens. And then you do some supervised learning from your parents and teachers and various signals that you can get -- that's a smaller but important part but it has to build on the unsupervised learning. And then finally know like Yann likes to say, reinforcement learning is the cherry in the cake.

PEDRO: [27:04](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1624.17) Well at the end of the day you're going to maximize rewards because that's how you feed yourself and reproduce and so on. But it has to build on these other kinds of learning. So if you try to solve the whole problem as just reinforcement learning, you're not going to get very far. I think reinforcement learning is important, but it has to build on all this other stuff. And people have been saying over the decades, like, yeah, supervised learning is played out, let's go on to less boring things. And then what always happens is that the amazing new things don't quite pan out. Probably because they are too hard. And then supervised learning makes yet another leap of progress. And this is exactly what has happened in the last, you know, half dozen years. Then truly I think supervised learning, as much as it's by far the most mature area in machine learning, it's still very far from solved, very, very far from solved. So we'll see.

CRAIG: [27:52](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1672.29) Far from solved because you can't explain how and why it works or far from solved because it's still so fragile.

PEDRO: [28:00](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1680.24) Because it's very fragile. I mean at the end of the day I think we will only be able to explain so much. We don't know how to explain how our brains work, right? Because if we did the problem would be solved. You cannot just ignore it, try to say something about it, but truly we don't know what's going on in there. And I think it'll be the same thing with this. The whole point of machine learning in some sense to learn things that are beyond our capability. That's, you know, the real sign that we haven't solved the problem yet is, like, how brittle all of these things are. I have something that seems to be great at recognizing cats and dogs and whatever, but then I tweak a pixel and then it thinks that the dog is an airplane.

PEDRO: [28:31](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1711.67) Right. This is a real example. I'll give you a related example. One of my colleagues at UW did these experiments where they learn to distinguish dogs from wolves. Ten percent of ImageNet is dogs. So it becomes very good at learning about dogs. And then they were precisely trying to make it more understandable. So they had this method to see what was happening inside the network and it was very accurate at telling dogs from wolves. Like 90 something percent. And then they went to see like, well how did the network figure out how to discriminate between dogs and wolves. You know what it was? It was detecting long horizontal white patches in the image. You know, why? Snow. Because the wolves were in the snow background. So here we are thinking that this network knows how to tell dogs from wolves and all it has learned to do is detect snow in the background.

CRAIG: [29:13](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1753.82) That's right. So where is their progress right now?

PEDRO: [29:17](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1757.76) I mean there is progress across the board, within the different fields of machine learning and also within different fields of AI. Machine learning is just one field of AI. And a lot of people in AI are very annoyed that, you know, deep learning is sucking up all the oxygen and we hear various complaints about that. I think when there's a lot of progress to be made in one area, people should jump on it. Part of why there's a lot of progress being made today is that it is now so clear that AI is economically important that all of these very powerful companies are pouring resources into it. The amount of machine learning research that happens in one year today is more than used to happen in a decade. So by that standard, we are making progress 10 times faster.

PEDRO: [29:55](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1795.06) How much of it winds up being useful or not is a different question. But there's a lot of progress being made because number one, the manpower is being put there. Number two, and this is also very important, machine learning feeds on data and, you know, as the data grows exponentially our machine learning algorithms get better. We get it almost for free. Then also, I remember like giving this talk like 10 years ago, you know where my argument was, 'AI is 50 years old, but no one has yet really worked on AI because we do not have the computing power to work on AI. So we work on these small sub problems like understanding one image at a time.' People spent a decade or two, you know, dealing with one image and then you know, dealing with a thousand was the huge, you know, improvement and then a million is another improvement.

PEDRO: [30:34](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1834.15) Now, and you can debate exactly where the crossing point is, but roughly speaking, we actually now for the first time have at our disposal computing power that is comparable to the computing power of the brain. Because up until not that long ago, people had a great excuse, which is like, well the hardware isn't there. We're going up against like the world's greatest super computer, which is the one in your skull with like piddling things. But now they're not that piddling anymore. So now we're actually at the point that we can really, you know, seriously do AI and so I think because of that there will be a lot of progress.

PEDRO: [31:06](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1866.161) Unfortunately what all those years of low computing power created was like all these siloed sub fields that are each doing their thing. And now in some ways that's an overhang and the hallmark of intelligence is integration. The thing that's amazing about your brain is that all these things are working very well together and that's what we do not know how to do in computer science or any --science and engineering are all about divide and conquer. And I think now despite those kind of like, in some sense, bad habits from the past, we are starting to break down those barriers. So I think there's going to be a lot of progress in the next decade or decades.

CRAIG: [31:39](https://www.temi.com/editor/t/rZVJzEfi93VsnP2RnW7JR-yfJWlUhI-DAVpSZZH9JKVKRJZYbNr1iX-95rUZzYkZYBLUsvLvtu02j3Fl8RObHP3NcWs?loadFrom=DocumentDeeplink&ts=1899.66) That’s it for this week’s podcast. I want to thank Pedro for his time. For those of you who want to go into greater depth about the things we talked about today, you can find a transcript of this show in the program notes along with a link to our Eye on AI newsletters. Let us know whether you find the podcast interesting or useful and whether you have any suggestions about how we can improve.

 The singularity may not be near, but AI is about to change your world, so pay attention.