CRAIG: 00:00 Hi, I'm Craig Smith and this is high on AI.

CRAIG: 00:11 We begin 2020 by looking back at some of the highlights from 2019 including conversations with Turing award winners, Yoshua, Bengio and Yann Lecun, as well as with the father of reinforcement learning, Rich Sutton. For me, the most interesting trends in AI fall into three broad categories: applying machine learning to the climate crisis; competition between the U S and China for dominance in AI; and the future of machine learning through various kinds of unsupervised learning. I'd like to begin by listening to Google Distinguished Scientist John Platt explaining the stakes of the climate crisis and the order in which things need to be done for us to survive as a species.

MUSIC: 00:58 INTERLUDE

JOHN PLATT: 01:03 You want zero carbon energy source, Ideally that is cheaper than old fossil fuel plants - and that's very difficult. Things like fusion might eventually become that, but it might take a number of decades before fusion becomes cheap enough and ubiquitous enough if we can get to all work now. So a lot of these hoped for technology breakthroughs might kick in after 2040 or 2050, it might be a number of decades just to develop the technology to bring it to production and to make enough plants to actually make a difference. So we should still do that. That's a great thing to do to bring prosperity to the world that we really want sort of ubiquitous, very inexpensive. zero carbon energy. I think that's where we'll end up at the end of this century. But we have a much more pressing issue now. Right now. Start decreasing carbon just from the present fossil fuel infrastructure.

JOHN PLATT: 01:57 If you just let it continue through the lifespan of the infrastructure, we're still, we're committed to another 660 roughly gigatons or billion tons of CO2. That's essentially enough to blow us past 1.5 Celsius and almost to 2 Celsius. And if you count things that are currently under construction or planned, then we will, if - we essentially have to stop building fossil fuel infrastructure now, like today, to get to 2 Celsius. This is assuming that we don't take any carbon dioxide out of the air in the second half of the century, which many people are hoping that we'll do. But if we don't, if we can't do that, if that's not economically effective, we have to stop now in order to even hit 2 Celsius. So it's really very, very urgent. We have no more time to waffle or think about it. 2 Celsius, because of the [Paris Agreement](https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement), is the general sort of threshold for what's considered dangerous climate change.

JOHN PLATT: 02:56 And if you go and look at the [IPCC reports](https://www.ipcc.ch/reports/), various things happen. You know, for example, a very concrete thing is they're expecting 99% of all coral reefs to die at 2 Celsius. At 2.5 Celsius, you start to get sort of food yield impact because essentially things just get too hot or too dry or too wet. Many of the ecosystems, this happens for early, much like the coral reefs start to, you know, get very strongly affected even at two Celsius. The trouble is this, like I said, I think if we have a sharp right turn, no we'll hit two Celsius. Unless we can figure out how to get CO2 out of the atmosphere in the second half.

JOHN PLATT: 03:33 If we could solve this zero carbon thing, it's a good thing to increase energy because I would love to see the entire world get a developed economy and as economies develop, the pattern in past has been that they consume more energy cause their, their GDPs grow very quickly.

JOHN PLATT: 03:50 So I would like to be in a world where in 2100 at the UN projects that there's 11.2 billion people that all of them use as much energy as people the United States do. Except for carbon, that would be a wonderful world. Everyone will be prosperous. It'll be, it'll be a wonderful world. I would love. That's part of the reason why I work on future and I want to reach that world, but we can reach that world with fossil fuel. We just can't, even though people worry about running out of fossil fuel, there's more than enough fossil fuel in the ground to completely bake the climate. That is not the limiting factor if it weren't for climate changes. CO2, fossil fuels are wonderful. They're portable, they're inexpensive. Coal has a lot of pollution, but things like natural gas - it's just, it's the, it's the greenhouse gases that are the problem.

JOHN PLATT: 04:35 I think we will avoid the utterly catastrophic climate change in both like three Celsius. And so we have to really keep everything below three. I mean, three is not a good thing. So now I think it's going to be a knife fight for every 10th of a degree Celsius between two and three. So I'm optimistic that we can avoid, you know, existential risk at like four Celsius that I think there's enough that we can do to keep it below three. So now let's try to make the world be as good of a place as we can by sort of fighting for every 10th of a degree below three. So that's why I'm sort of, I don't know if that's an optimism or if it's just sort of a determination.

MUSIC: 05:19 INTERLUDE

CRAIG: 05:23 John is part of an organization called climate change, a AI that is applying machine learning to the climate crisis. I spoke to David Rolnick and Priya Donti, two of the people driving that organization, their website ClimateChange.AI has a collaboration platform through which scientists and engineers can communicate as well as a link to a paper written by the group that serves as an overview of the ways in which machine learning can be brought to bear on the climate problem.

PRIYA DONTI: 05:55 Our organization is CCAI, climate change AI, and we are the group that wrote this paper on tackling climate change with machine learning and we care about applications of machine learning to accelerate solutions across climate change mitigation and adaptation. But we are one movement here and there've been other movements who have been working on parts of this problem as well, so [Climate Informatics](http://climateinformatics.org/) is one of these, the [Computational Sustainability Network](http://www.compsust.net/) and a number of others that have been thinking about how we can essentially get the machine learning community and the computer science community engaged in climate change, environment and other issues of societal good.

DAVID ROLNICK: 06:32 I felt that it would be useful to have a founding document for this movement and something that went into great detail as these difficult topics deserved. It was a survey and a set of recommendations for what can be done moving forward, so not just a review of what has been done, but also some recommendations for what we see happening in the future.

DAVID ROLNICK: 06:54 For a long time there's been a lot of pent up desire to help in this issue, as in other issues among the machine learning community. I hope we can help to channel some of those skills and that eagerness. Our goal is to be a nexus for communication, collaboration and resources for work in climate change and AI with the understanding that the important work in this space is being done by individuals across many institutions, universities, companies, startups, public organizations. We hope to facilitate that work and also to facilitate communication and collaboration between those different stakeholders and different people who are meaningfully contributing to this area and can meaningfully contribute.

PRIYA DONTI: 07:44 There are a couple of cross cutting themes certainly that come up in the paper. So one of these is materials discovery, so discovering new materials that will allow us to do things like capture energy from the sun and turn it into liquid fuels that can then be used in transportation or various other things, or creating alternatives to cement where cement is a very carbon intensive material, to creating more efficient carbon dioxide [sorbents](https://en.wikipedia.org/wiki/Sorbent), which are basically like sponges for carbon dioxide when you try to suck it out of the air. And so discovering new sorbents would allow us to do carbon capture more efficiently. So there are a variety of ways that we outline where machine learning can help with the materials discovery process and also in characterizing existing materials.

DAVID ROLNICK: 08:29 Another recurring theme that represents in some sense low hanging fruit for machine learning practitioners is remote sensing, detecting things and labeling things from satellite or aerial imagery. So there are many different applications of remote sensing. They're relevant to climate change from marking the locations of solar panels and wind turbines, which we don't actually know the locations of in many cases, to detecting methane emissions using hyperspectral imagery, to pinpointing where deforestation is happening so that laws can be enforced. Certainly machine learning is not going to be the magic bullet that solves everything. However, it is an accelerator of those technologies which are impactful. So to the extent that many technological paths forward exist, machine learning can potentially work to supplement them.

MUSIC: 09:33 INTERLUDE

CRAIG: 09:37 I encourage you to check out Climate Change AI at climatechange.ai and get involved. Meanwhile, governments continue to talk but do little to avert the looming climate disaster. Instead, they're focused on much less existential threats such as warfare. Vladimir Putin has famously said that whoever dominates in AI will rule the world. The world's major powers are responding as such. The main competition to date is between the United States and China. China's best known AI commentator, Kaifu Lee, gave his assessment of the competition on the podcast

MUSIC: 10:18 INTERLUDE

KAIFU LEE: 10:23 If you have extremely strong competency, you will become the leader in the world. So, China has a number of unique advantages, the greatest of which is the huge amount of data and then the great engineers, companies, entrepreneurs who are using it to find holes in its sometimes backwards traditional economy and when the economy's backwards you can have a late mover advantage.

KAIFU LEE: 10:54 Also, I think the government has taken a very techno utilitarian approach, which is really to let technologies to be tried before going to regulation and not working out the kinks before getting the technology to launch. And these factors will propel China forward. While the US does have a much deeper research bench, China is rapidly catching up and developing a young cadre of very smart AI engineers who arguably matter more than having a small number of AI superstars. Because we're now in the age of implementation, we have a very different set of competencies that makes China way ahead and some areas and still way behind in others. But the ones that really matter for the foreseeable future are the elements in which China is strong.

MUSIC: 11:49 INTERLUDE

CRAIG: 11:53 Eric Schmidt and Robert O. Work, former chairman of Google and Deputy Secretary of Defense, respectively, also talked about that competition. Eric and Bob are co-chairs of the National Security Commission on a AI. They talked about the challenge of threading the needle; competing with China while remaining engaged with China.

BOB WORK: 12:14 A lot of people say China has an advantage because it has so much more data, but by aggregating all of the democratic nations and working together, you know, we feel that we can offset any problem in that regard. We've actually made good headway on our allies. We've met so far with the United Kingdom, the European union, Japan, Canada, and the Australians and we have solicited their views and we've made the case that working together we can solve any data disparities and we intend to talk with other countries also.

ERIC SCHMIDT: 12:53 AI in the United States needs to be done with American values and American values are broadly liberal in the sense that they're not authoritarian, they're democratic, they encourage discussion, they're not, we don't favor censorship. There are many, many aspects of those values which I think are easily included by my comment. And we also pointed out in the report that the Chinese are functioning in an alternative system and that it's, it's just a different system. It's not our system. And that there is a question of diffusion of those models and you'd see this in their surveillance techniques.

ERIC SCHMIDT: 13:32 The other thing our report talks about, using China as an example, is that we are not taking a position of decoupling versus entanglement. We're trying to thread the needle, as Bob likes to say, through those choices. So I would encourage you not to think of this as black and white, right? You know, us versus them. There's probably competition and cooperation in many of these areas. One of the things that the report does say is that it would be very expensive to totally disconnect from China. And when I say expensive, I don't mean in money. I mean in terms of strategy, the commission states quite clearly that we heard from the research community of America that Chinese nationals, for example, are important for our research enterprise in our universities.

ERIC SCHMIDT: 14:21 We also point out in the report that there are ways in which you can build systems that are trusted of untrusted components. And so my point here is that it's not, you know, ban or be married, right? There's a middle path, which is probably the most powerful from a United States perspective. Our job is to make sure that the United States wins.

BOB WORK: 14:48 Look, we have to act to protect our interest in light of state directed espionage, the concerted efforts to extract AI acknowledged from private and public institutions and the centrality of AI to China's strategic ambition. But as Eric said, there are benefits from cooperation, especially in the AI field. So it's really trying to understand the direct and indirect costs of the choice between disentanglement and entanglement.

BOB WORK: 15:20 The United States has never faced a strategic competitor with a gross domestic product greater than 40% of its own The Soviet Union just barely got there in the Cold War, even if you added Japan and Germany together in World War II, it was right around 40%. China has surpassed the United States in purchasing power parity already. And if trends continue, and you know, this is no guarantee, there is a possibility they could surpass the United States in absolute terms of GDP in the late twenties. So we've never faced a strategic competitor with an economy greater than 40% of our GDP. We may be faced with a competitor that has an economy that's bigger than us.

Then China, beyond AI wants to become the world's innovation leader. It wants to surpass the United States as the world's innovation leader, not only in AI but in a wide variety of different things. So they're inextricably linked, Craig. I mean, if they meet their economic goals, they will be able to put more money in the technology innovation side. And this becomes a tremendous competitor for the United States. And that's why the commission spend so much time saying, look, this is a competition that we could lose.

BOB WORK: 16:47 In the inter war period, everyone knew that mechanization was happening. Everyone knew and had radios and everyone knew about the advances in aviation. It was diffuse, it was all over the place. It was the competitor that put them together in an operational concept they called Blitzkrieg that gave them an enormous advantage. So what the Department of Defense worries about is, could the Chinese in developing an operational concept take machine learning in decision support systems, 5G in their communications, could they put them together in a way which would give them a battlefield advantage?

BOB WORK: 17:26 That is something that is very difficult to judge. You have to actually know what they're doing. So it's not so much the technology I worry about. They're going to be fast followers. We want the US to keep winning. We want to be the leader. We don't want to be a fast follower. We want to be able to keep all of the competitors in a tail chase with us.

ERIC SCHMIDT: 17:47 China has a national plan for 2030. It has a national budget for 2030. It has identified four national champions in different areas. They are working very, very hard to generate national capabilities in this and a number of other strategic areas. What is the US answer? And we highlight that without proposing an answer because it's not time yet.

MUSIC: 18:08 INTERLUDE

CRAIG: 18:11 Pedro Domingos, a well-known researcher and author of the bestseller, The Master Algorithm, had a darker view of the competition.

PEDRO DOMINGOS: 18:19 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, you know, America won. This new race is going to be very different. It's not at all clear who's going to win, but I think the race is here and at this point I think the Chinese got into their race long before the Americans did because they were the up-and-coming ones. 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 already being used to detect tanks and whatever. But nobody was saying anything about it, right?

PEDRO DOMINGOS: 19:05 So some of those secret things can actually remain secret for a long time. DARPA is the biggest funder of AI, you know, in the world ever, at least up to this point because of the potential military impact of AI is completely obvious. 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 we can stop that. We could talk about how much that can be done and how much should be done, but that race is materialized. But the other thing to realize is that the economic crisis is also between countries, but primarily between companies.

PEDRO DOMINGOS: 19:33 AI is the ultimate dual use technology. There is really no difference between military and civilian AI. 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.

PEDRO DOMINGOS: 19:49 China in some ways is playing this game much better than the US so far, in that the government and the companies mutually helping each other. You know, one chilling thought is that maybe the Marcus, he is better than authoritarianism, but I'll try to move with whim because China is bigger.

PEDRO DOMINGOS: 20:02 And 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, et cetera, et cetera. But at the same time, AI is the ultimate tool of the dictator. That's right. AI has no conscience. It can keep tabs on everybody the whole time and never get tired and never doubt.

PEDRO DOMINGOS: 20:29 The uses that China has been making of AI are quite frightening.

MUSIC: 20:33 INTERLUDE

CRAIG: 20:37 Meanwhile, the research marches on. I spoke to Yoshua and Samy Bengio about the advance beyond supervised learning with new forms of unsupervised learning,

YOSHUA BENGIO: 20:49 Deep learning, the phrase deep learning and the ideas there, really came about with unsupervised learning methods. So unsupervised-led learning methods were the first ones that allowed us to train deep networks. And then around 2010, 2011 there, you know, there was a switch where we realized that we could, in fact thanks to some work we did in in my group, we could, we didn't need these unsupervised learning techniques. We could train directly supervised models that are very deep and then the industrial applications started coming very quickly with computer vision, speech recognition, machine translation and things like that. But it is not going to be enough for human level AI, like humans don't need that much supervision.

SAMY BENGIO: 21:33 I think also it's not just supervising and unsupervised. There's multiple things in the middle. There's a self-supervised, there's reinforcement learning, for sure. There are many ways to get supervision cheap from the data you already have. So it became a much more complex space. But what links all of that is more about how you represent the data in a better way so that it can actually solve some tasks, either the one you have at hand or later. So representation learning is actually becoming more central.

MUSIC: 22:04 INTERLUDE.

CRAIG: 22:09 Yann Lecun, who shared a Turing award with Yoshua and Geoffrey Hinton, talked about his bet on self-supervised learning.

YANN LECUN: 22:18 There is a limit to what you can apply deep learning to today due to the fact that you need a lot of labeled data to train them. And so it's only economically feasible when you can collect that data and you can actually label it properly. And that's only true for a relatively small number of applications. So that's one mode of training, right, supervised learning. It works great for, you know, categorizing objects and images for translating from one language to another, if you have lots of parallel texts. You know, it works great for speech recognition, if you have collected enough data. So I have a form of it called self-supervised learning, which is a very natural idea. Imagine that you give the machine a piece of input. Let's imagine it's a video clip for example. You mask a piece of the video clip and you ask the machine, pretend you don't know this and, you know, try to predict what is next from what you are seeing.

YANN LECUN: 23:11 So predict the future of this video clip. What's going to happen in that video from what you can see from the past? Or here's an image, I'm going to block a piece of it. Like can you reconstruct that piece? In the context of texts, you give it a window of, I don't know, 1,000 words on a, on a text, and you take out 20% of the words and you ask the system, can you predict what words are missing? And so when the machine trains itself to do this kind of filling in the blanks, it has to develop some representation of the data so it can do this job. Yeah. So to be able to predict what's going to happen in the video, you kind of have to understand, you know, that there are objects that move independently of backgrounds and there are objects that are animate and others that are inanimate. The inanimate objects have predictable trajectories, the other ones don't. And so the idea is that you would train a system in this self-supervised manner with tons and tons of data. There's no limit to how many YouTube videos you can make the machine watch. It will distill some representation of the world out of this. And then what you would do is when, whenever a particular task comes in, like learning to drive a car or recognizing particular objects, you use that representation as input to a classifier, and you train that classifier supervised.

YANN LECUN: 24:27 Could we build machines at some point that will be as intelligent as humans in all the tasks that humans are intelligent in? And the answer is, of course, there's no question. It's a, it's a matter of time. And it's very important to make progress in that direction because we'd like to have machines that have some level of common sense, because we'd like to be able to build, you know, virtual assistants that help people in their daily lives, can answer any questions you have, you know, can manage your interaction with the digital world and with each other.

YANN LECUN: 25:01 There is something that, you know, animals, some learning process that animals have access to, to acquire all the knowledge they have about the world that we don't have, you know, machines. So one hypothesis is - so, my money is on things like self-supervised learning for machines to learn by observation, or learn without requiring so many labelled samples, perhaps accumulate enough background knowledge by observation that some sort of common sense will emerge. And we'll have, you know, not just intelligent virtual assistants, we'll have dexterous robots, you know, you know, the household robots that everyone has been dreaming of. Right. There's no question that can be answered. It's a matter of how much, you know, how long is it going to take and how is it going to be done?

MUSIC: 25:42 INTERLUDE.

CRAIG: 25:44 Rich Sutton talked about the form of unsupervised learning that he pioneered: reinforcement learning.

RICH SUTTON: 25:52 I was looking for something that was real learning that was like reinforcement learning because reinforcement thing is an obvious idea if you study psychology, because there are two basic kinds of learning, Pavlovian conditioning and instrumental or operative conditioning. Pavlovian conditioning is like ring the bell and then you give the dog steak and after a while, just from ringing the bell, he salivates showing that he anticipates the steaks arrival. So it's a kind of prediction learning. And then there's also control learning and control learning is called instrumental conditioning or operative conditioning, at least those two names, where you're changing your behavior to cause something to happen. In Pavlovian conditioning, your salivation doesn't influence what happens. Whereas the canonical operative conditioning is, you know, the rat presses a bar and then gets a food pellet. The act of pressing the bar is instrumental in getting the reward.

RICH SUTTON: 26:40 So that's really the idea of reinforcement learning. It's modeled after this obvious thing that animals and people do all the time. It was all about making the claim and substantiating the claim that this kind of learning is different from the regular kind of learning, supervised learning. In supervised learning, it tells you what you should have said. In supervised learning, the feedback instructs you as to what you should have done. In reinforcement, the feedback is a reward and it just evaluates what you did. What you did is a seven and you have to figure out if seven is good or bad, something that you could have done better. So evaluation versus instruction is the fundamental difference.

MUSIC: 27:16 INTERLUDE

CRAIG: 27:19 And finally, Sergey Levine, one of the world's most prominent researchers at the intersection between machine learning and robotics, talked about taking unsupervised learning into the real world with the robots he works with at the Berkeley Artificial Intelligence Lab.

SERGEY LEVINE: 27:39 Our hope in the long run is that work. Like this can be a stepping stone towards a future where you have many networked robots that are just out there in the world and when they're not busy doing something more productive, they'll just play with their environment and learn. They'll essentially say, okay, if I'm not currently tasked with a job, if my human owner doesn't want me to do anything in particular, I'll just use my free time to practice. I'll play around with objects in my environment, understand more about how the world works and use it to sort of build up my body of knowledge so that when I'm later on placed in some new setting, hopefully I've learned enough from many past situations I've been in to do something reasonable in this new setting. And that will be the transfer. And the transfer, as an all learning systems, comes from seeing sufficient breadth of experience.

SERGEY LEVINE: 28:15 So if you have enough breadth, you have seen enough variety, then you're ready for anything. So that's the dream. The reality right now is that this is kind of an early step in that direction. So right now the robot learns about one particular environment, so right now it spends a few hours playing with a door, moving it this way and that and it can open that one door. One of the things we want to do next is actually scale this up. Maybe we have multiple, or in the lab downstairs we have six different robots. Perhaps we're going to have all of them playing with different kinds of doors and maybe then we'll see that when we give it a new door, it will actually generalize to that new door because it's seen enough variety.But the system right now is not there yet.

SERGEY LEVINE: 28:45 Variety is key to generalization and to transfer, but I also think that in robotics in the long run, that shouldn’t be a problem because robots exists in the real world, the same real world that we exist in and that real world forces that diversity on you. You can't escape it.

SERGEY LEVINE: 28:57 Our working assumption is that if we build sufficiently general algorithms, then all we really have to do, once that's done, is to put them on robots that are out there in the real world doing real things and the variety of experience will come to the robots because they're in the real world just like we are. So the robot essentially imagines something that might happen and then tries to figure out how to make that happen. And, of course, it's imagining things that could happen requires some understanding of what are realistic situation in the world and what are not realistic situations.

SERGEY LEVINE: 29:21 So I can set a goal for myself. I can say I'd like to make this cup levitate. That’s going to be a very difficult goal for me to reach because in this universe that's just not a realistic situation. But if I set myself a goal, I want this cup to be five centimeters to the left. That's something I can do and I can learn how to do it and I can practice and that will teach me something about the physics of this cup.

MUSIC: 27:16 [STOLEN GIN](https://www.facebook.com/stolengin/) - [SECOND TO THE SUN](https://www.youtube.com/watch?v=eflzJOM7_sg)

CRAIG: 29:43 I hope you have enjoyed the podcast and I look forward to bringing some terrific episodes to you this year. For those who want to go into greater depth about the things on the podcast today, you can find a transcript of this show in the program notes along with a link to our newsletters. Let us know whether you find the podcast interesting or useful and whether you have any suggestions about how we can improve. I'd like to give a shout out to our sponsors. Infinite Red, an application development and design firm that offers a free introductory course on machine learning called AI Demystified. You can find it at learn.infinite.red. Check it out.

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