Field of artificial intelligence has been moving extremely quickly in the last few years. Do you know how AI will affect your life in the future? I have some ideas. I’m Jeff DEAN. I’m a Google senior fellow at Google. That means a coupe of things. First means I’m kind of old. Second, it means that I get to spend my time working on problems that I think are the most important for the company. I’m working on artificial intelligence. I lead the Google brain team--our artificial intelligence research team based in mountain view California. Our team does long term research on how to make machines intelligent. And we didn’t work with product teams at Google in order to make machines products that are intelligent. We want to use intelligence to argument the abilities of people, to enable us to accomplish more, to eliminate tedious, repetitive tasks, and allow us to spend more time on our creative endeavors. AI is going to be more impactful than the invention of the personal computer and the spread of mobile phones in your pocket. So the idea of artificial intelligence is not new. It’s been around since the very earliest day of computing. It’s a grand project to build machines that are intelligent. And there are many ways of pursuing this, captivated by the scientists ever since. The most promising approach though is the area of machine learning. Rather than trying to embody machines with everything they need to know up front. Rather we want to enable them to learn, to learn how to learn. So that they can learn from their observations of the world, and to make inferences based on those observations. The field of deep learning is a particular kind of machine learning that I’ll be talking about. And it’s been shown in the last 4 or 5 years to be remarkably effective for a wide variety of problems. Although it’s actually much older.

Before we start, how do we learn? We learn from examples of things and from repeated practice. Repeated practice and examples are really key to machine learning as well. So through machine learning, we’re going to expose a system to examples of behavior we want to have. And those examples are going to teach it to learn from those examples how to do sth. So in this very simple diagram I have a model where we’re gonna try to teach computer to tell whether a photograph contains a cat or a dog. And we’re going to have example where we know the right answer (we have some that we say, that’s a cat.. that’s a dog...) and we’re gonna essentially show the computer an example and say “what do you think?” and it will say “well, i think that’s a dog.’ and there you go. If you get the right answer you’re done. Just like doing your homework problems. If you get it right you don’t have to do more. But if you get it wrong, we’re gonna make little adjustments to what we believe about the world and what we believe about this example to make it more likely that the next we see that example or one like it we’ll get the right answer not the wrong one. Deep learning in particular has a particular way of doing this. It is very important, so it builds these layers of abstraction automatically as part of a learning process. with the lowest level things or things like, you know, does this part of image contains a little splash of brown, and then as you go up through the layers, the kinds of things that burns get more complicated things. Things like is there here at the part of the picture or sth looks like a couple of eyes, maybe some whiskers. And those features emerge automatically as part of the learning process, which is really critical aspect of learning. You don’t have to tell it how to tell a cat from a dog. It just learns that there’s these things called whiskers. And they seem to appear on lots of photos. And they seem to appear more often than ones about cats. And that’s really helpful. And those features develop automatically in learning process. To know that can learn much more than just how do you tell the cat from the dog. They can learn to distinguish thousands of different categories of objects, you know tens of thousands of this is a ostrich, or a fire truck or fire boat, things like that. They can learn from an audio stream, to give you a transcript of words that were said in that audio steam; how cold is it outside; they can take in an English sentence “hello, how are you?” and spit out the corresponding French sentence “.........” sorry for my French. They can take in the pixels of an image and give you more than just a category about it. They can actually write a sentence, a caption if you will, about that picture-- ”a blue and yellow train traveling down the train tracks.” That shows a pretty high level of understanding of what’s going on in that scene. One of the great things about deep learning is that all of those things that I showed you can be expressed using a relatively simple set of algorithms and can be expressed in a common software framework. So we can build software framework that enables us to express all these different learning problems and then use it over and over for our research and for our product.

So the system we build is called TensorFlow. And we use it internally for everything that we do in this area. And last year we decided we would open-source it, because we wanted people that have the ability to take the software downloaded for free and use it for their learning problems. It’s been really great to see different things that people have used it for. So here’s one example. There was a Japanese cucumber farmer, and it turns out when you harvest your cucumbers you have to sort them into all kinds of different categories for sale. Small ones, medium ones, large ones, prickly ones, and NOT prickly ones, straight ones, curved ones... it’s pretty complicated. It’s pretty time consuming at harvest time. So the farmer was able to take a camera and use a computer vision model that was trained with TensorFlow, actually uh have the vision model determine what category of cucumber is looking at and then rigged it up to some conveyer belts and some little switches that would push the cucumber into the right box. And so this eliminated many days of labor that the farmer and his wife have to do at harvest time. That’s just one tiny example of something you can do now that would be harder before.

So as I said Neural Nets are not new. They’ve actually been around since that 1980s and 1990s and they showed really promising results on kind of small toil problems then, but they really couldn’t show great results on realistic large problems at that time. And the reason is we just lack enough computational power. The process of making these adjustments to the model, and every example and processing every example many times in order to build this model of the world, is very computational intensive. And so we just need faster computers. Fortunately, we have faster computers now. Computers have been dramatically improving in performance every year for the last 30 or 40 years. And we’ve reached this point where Neural nets are actually practical on real problems. So the computer you have in your phone is now a hundred to a thousand times as powerful as the computer you have on your desktop 20 or 30 years ago. And that makes all the difference.

So we now have enough computer computation and just to take an example, the field of computer vision. Every year there is a contest where teams compete to see who can give the right categories out of a thousand different categories, when given am image. And in 2011 before people were using Neural nets, the winning team got an error rate of 26%. Which doesn’t sound too good when you think that humans are 5% on this test. But fast forward just 5 years, and we are now at 3% errors using deep learning, and a much more computational power. We’re actually better than humans on this task. That’s really powerful and transformative thing. Think about this, computers can now see, and they didn’t used to. If you think back to the time in evolutionary biology when the computer when animals of all dies, that was likely a time of great change, and incredible and amazing things start to happen. And computers are now at that point in computer. For example, this is really really useful if you’re trying to build a robot. If you can’t see, it’s really hard to do stuff. So here we have an example of robots using deep learning to teach themselves hand-eye coordination. So essentially, there’s a video camera for each robot get to look over its shoulder and the model is going to take the pixel inputs from the camera and go directly to 6 torque motor commands for the different joints of the robot. And essentially, they just gonna through trial and error practice picking things up. So you see they’re just trying things and they can tell if they succeeded or failed by whether their gripper closed all the way or whether they were actually successful in picking things up. And they are learning like what kinds of grips work well for different shape objects based on the vision of their development and they’re pretty good at it. We bought a bunch of variety packs of toys and tools on amazon.

Another area where I think machine learning has incredible opportunities is in the area of health care. I’ll give you just one example. So diabetic retinopathy is the fast growing cause of blindness in the world. There’s 400 million people at risk who should really get screened basically every year. But often people don’t get the screening they should. So we wanted to tackle this with computer vision. You get an image like this, traditionally we use ophthalmologist scans to try to assess how serious the signs are if there are any. So we got a large collection of these eye images that we had human ophthalmology to label them. So if you have 2 human ophthalmology scores these, they agree with the rating 60% of the time. Finding more worrisome though is if you ask the same ophthalmology to screen the same image a few hours later, they only agree with the themselves 65% of the time. It’s really just a hard problem. Right? It’s sort of an interpretation of like how dark those spots should not be a 2 or 3 in this rating scale and so on. So in work published earlier this week by our group in the journal of the American medical association, we now have a machine learning model that performs on par perhaps even slightly better than ophthalmologist at this task. This is really important because it can make ophthalmologist much more efficient. They can actually dedicate their time to the people who deserve the attention and not spend as much time on screening most people most of whom don’t have any signs of this.

It also can be more creative by having tools that understand the art we’re trying to create. That will be very helpful. I’ll show you another example. Leon Gatys ... and his colleagues from the university of Tübingen and the Max Planck institute in Germany last year published this amazing paper. Where they have an algorithm that can take 2 things---an image, photograph and painting. And what the algorithm does is it renders that photograph in the style of that painter. So here you see that same picture rendered in 3 different styles automatically by those 3 different artists. That’s pretty amazing. And I think there’s going to be a real opportunity for creating tools for human artists that allow them to really interact with systems like this and more rapidly get the ideas in their head out into really new and creative kinds of art.

Remember how they advance from 1980s to now was caused by much more computational power. So the same thing is going to be true in the future. We want more computational power so that we can train larger models so we can learn more. So deep learning is actually transforming how we designed and built computers as well. There’s two interesting properties that neural nets and learning algorithms were using have. The first is that reduced precision is OK. It’s fine when you’re multiplying numbers for now let’s say about 1.2 times, about 0.6. sounds like 0.7. That’s good enough. We don’t have to spend every last detail of our computational budget preserving all the digits of precision, the traditional CPUs and computers are designed to built. And that’s really helpful if you youself you need to multiply a bunch of things and you were able to be very approximate like that you could do many more operations. Same thing is happening in your labs. The other thing is all the learning systems I showed you in all the algorithms rely on just a handful of specific operations. They don’t need the full generality that the general purpose computers have. They want to be able to do things like matrix multiplies, vector operations, things from linear algebra, and that’s about it. So that allows us to build specialized computers that can do these things extremely well and not much else. So here is a system that we built in Google about in the last 3 years called the tensor processing unit. It’s essentially a custom designed chip that it accelerates neural-net computations only. But because these kinds of deep learning algorithms are so applicable to many problems. This is great because we now have sth that can speed up those kinds of computations by an order of magnitude compared to traditional CPUs. That’s really powerful and allows us to use more powerful models in our products and get sort of better systems there.

Let me take you on a tour of some queries from the future. One of the things that we have observed is that as systems get more intelligent users expect more from what they can do. So “which of these are images showing symptoms of diabetic retinopathy?” Well I’ve already showed you we can actually do that today. “Describe this video in Spanish”, we can’t quite do that. We can describe still images pretty well but not quite moving videos, but that will come. “Find me documents related to reinforcement learning for robotics and summarize them in German. ” that’s pretty complicated, but imagine how productive will be able to be if we are able to have tools that can do that. “Please fetch me a cup of tea from the kitchen. ” Having robots operating in messy environment like your kitchen is actually pretty complicated, but the very baby steps of things like the hand-eye coordination work I showed you are steps along that path.

In closing, AI is going to be help us to be healthier, happier, more productive and more creative. Are you excited to see what the future if AI helps? I really am.