

Stanford  
Artificial  
Intelligence  
Lab

FEBRUARY 2019



## Maneesh Agrawala

Professor, Computer Science;  
Director, the Brown Institute for  
Media Innovation

**Computer graphics, human-  
computer interaction,  
visualization**

*To improve the effectiveness of media  
of all kinds*

## Gill Bejerano

Associate Professor, Computer  
Science, Developmental  
Biology, Pediatrics  
(School of Medicine)

**Computational genomics**

*To discover the relationship between  
the genotype and phenotype*

## Jeanette Bohg

Assistant Professor, Computer  
Science

**Robotics, machine learning,  
computer vision**

*To understand the fundamental  
principles of complex, sensorimotor  
behavior and how it can be generated  
on robots*

## Emma Brunskill

Assistant Professor, Computer  
Science

**Machine learning/deep  
learning**

*To advance the frontiers of  
reinforcement learning*

## Ron Dror

Associate Professor, Computer  
Science

**Computational biology**

*To determine spatial structure and  
dynamics at the molecular and  
cellular levels*

## John Duchi

Assistant Professor, Electrical  
Engineering, Statistics

**Machine learning,  
optimization and statistics**

*To understand the limits and  
application of statistics and AI*

## Stefano Ermon

Assistant Professor, Computer  
Science

**Machine learning, statistics,  
sustainability**

*To solve impactful problems in  
sustainability*

## Ron Fedkiw

Professor, Computer Science

**Computer graphics, computer  
vision, fluid dynamics, solid  
mechanics, biomechanics**

*To design computational algorithms*

## Michael Genesereth

Associate Professor, Computer  
Science

**Computational logic**

*To solve problems in business, law,  
and game playing*

## Noah Goodman

Associate Professor, Psychology,  
Linguistics (courtesy), Computer  
Science (courtesy)

**Computational psychology,  
machine learning, linguistics**

*To understand cognition, language  
and social behavior*

## Leo Guibas

Professor, Computer Science

**Computer vision, computer  
graphics, geometry**

*To accurately describe the real  
physical 3D world*

## Thomas Icard

Assistant Professor of  
Philosophy and (by courtesy) of  
Computer Science

**Machine learning/deep  
learning, big data, knowledge  
bases, logic**

*To understand how reasoning works,  
and how we might like it to work*

## Dan Jurafsky

Professor, Linguistics,  
Computer Science

**Computational linguistics**

*To solve problems and provide  
insights in behavioral and  
social sciences*

## Oussama Khatib

Professor, Computer Science

**Robotics**

*To enable a new generation of robots  
that cooperate with humans and other  
robots in complex and unpredictable  
environments*

## Mykel Kochenderfer

Assistant Professor, Aeronautics  
and Astronautics, Computer  
Science (courtesy)

**Machine learning, decision  
theory**

*To develop safe and efficient  
systems for air traffic, drones, and  
autonomous vehicles*

## Daphne Koller

Adjunct Professor, Computer  
Science; CEO, insitro

**Machine learning**

*To solve real-world problems  
involving complexity and uncertainty*

## Anshul Kundaje

Assistant Professor, Genetics  
(School of Medicine), Computer  
Science

**Computational biology,  
machine learning**

*To analyze all kinds of genomic  
and genetic data to understand gene  
regulation*

## James Landay

Professor, Computer Science

**Human-computer interaction,  
NLP, autonomous vehicles**

*To design user-centered AI systems  
that augment and support people  
rather than replace them*

**Jure Leskovec**

Associate Professor,  
Computer Science

**Data mining, machine learning**

*To study the workings of large social  
and information networks*

**Fei-Fei Li**

Professor, Computer Science,  
Psychology (courtesy)

**Computer vision, machine learning, computational cognitive neuroscience**

*To help computers see better to help  
and work with humans*

**Percy Liang**

Assistant Professor, Computer  
Science, Statistics (courtesy)

**Machine learning, natural language processing**

*To build systems that allow humans  
and computers to communicate*

**Tengyu Ma**

Assistant Professor, Computer  
Science, Statistics

**Machine learning/algorithms**

*To understand and develop machine  
learning algorithms*

**Chris Manning**

Professor, Computer Science,  
Linguistics; Director, Stanford  
Artificial Intelligence Lab

**Natural language processing, machine learning**

*To develop computers that can process,  
understand and generate human  
language*

**Andrew Ng**

Adjunct Professor,  
Computer Science

**Machine learning**

*To solve problems in autonomous  
driving, robots, image analysis and  
language*

**Juan Carlos Nieves**

Senior Research Scientist,  
Computer Science

**Computer vision, machine learning**

*To allow computers to understand  
objects, scenes, activities and events in  
images and videos*

**Vijay Pande**

Adjunct Professor,  
Bioengineering

**Statistical mechanics, Bayesian statistics, biophysics, biochemistry**

*To push the limits of simulation  
and statistics to answer questions in  
biophysics and biochemistry*

**Marco Pavone**

Assistant Professor, Aeronautics  
and Astronautics

**Robotics; decision theory; autonomous vehicles**

*To push the limits of robot autonomy  
via principled decision-making and  
learning algorithms*

**Christopher Ré**

Associate Professor, Computer  
Science

**Database, machine learning, theory**

*To create the future of data systems  
for unstructured and structured data*

**Dorsa Sadigh**

Assistant Professor, Computer  
Science, Electrical Engineering

**Machine learning/ deep learning, robotics, autonomous vehicles**

*To design algorithms for robots that  
safely interact with people*

**Ken Salisbury**

Professor (Research), Computer  
Science

**Robotics**

*To develop useful robots for surgery,  
imaging, haptics and personal  
assistance*

**Silvio Savarese**

Associate Professor, Computer  
Science

**Computer vision, robotics, geometry, machine learning**

*To push the limits of computer vision  
for object, scene and human behavior  
understanding and applications in  
social robots and autonomous vehicles*

**Sebastian Thrun**

Adjunct Professor, Computer  
Science; CEO, Udacity

**Robotics, machine learning**

*To improve robotics, autonomous  
vehicles, smart homes, healthcare and  
drones*

**Dan Yamins**

Assistant Professor, Psychology,  
Computer Science (courtesy)

**Computational neuroscience**

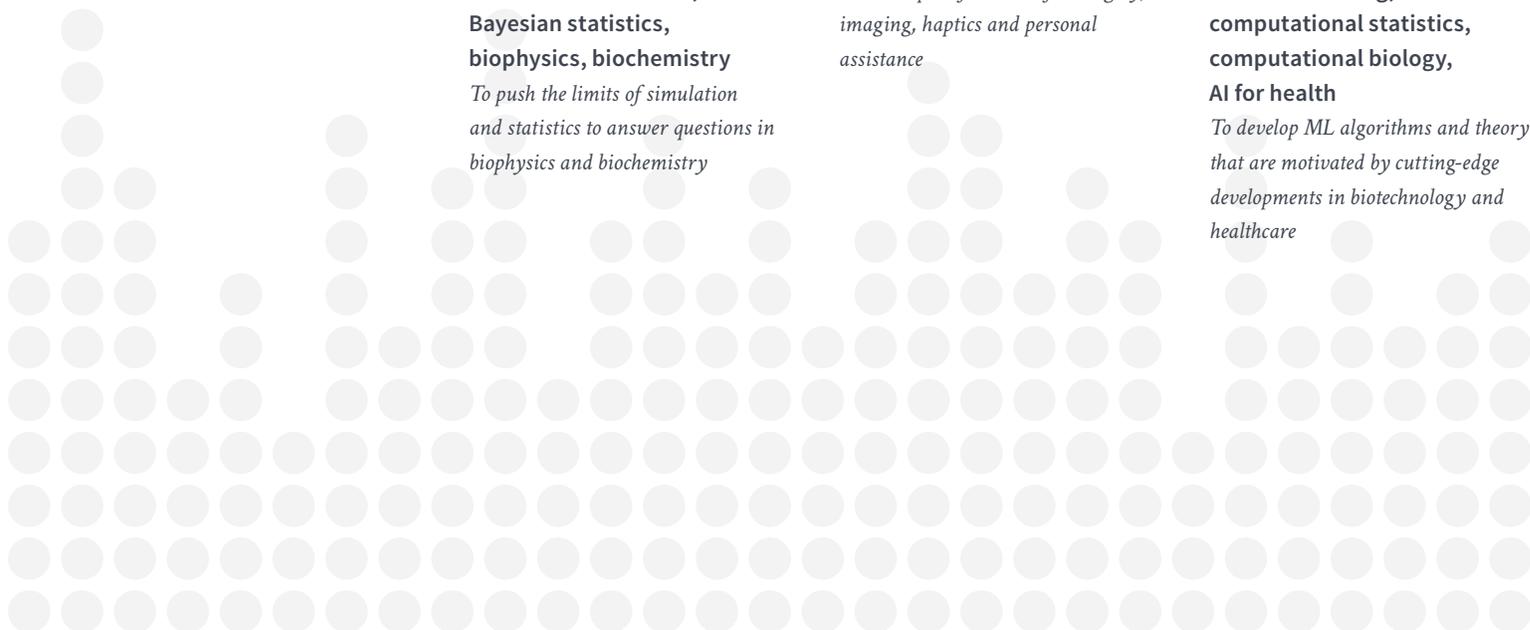
*To reverse engineer the human brain  
and build more effective AI systems*

**James Zou**

Assistant Professor of  
Biomedical Data Science and (by  
courtesy) of Computer Science  
and of Electrical Engineering

**Machine learning, computational statistics, computational biology, AI for health**

*To develop ML algorithms and theory  
that are motivated by cutting-edge  
developments in biotechnology and  
healthcare*



# Introduction

Dear Friends,

Welcome to the Stanford Artificial Intelligence Lab

The Stanford Artificial Intelligence Lab (SAIL) was founded by Prof. John McCarthy, one of the founding fathers of the field of AI. While the discipline of AI has transformed in many fundamental ways since its inception in the 1950s, SAIL remains a proud leading intellectual hub for scientists and engineers, an education mecca for students, and a center of excellence for cutting edge research work. With this brochure, we hope to share with you some of the latest research and activities at SAIL.

Reflecting on the history of AI, the past fifty years are mostly what I call the “AI in vitro” times, during which most AI research was conducted in academic laboratories. This is the time when AI researchers laid the foundations for our fields, including the questions we are pursuing, the methodologies, the measurements and metrics, and the potential applications. AI grew from a small set

of ideas to important areas such as robotics, natural language processing, computer vision, computational genomics and medicine, among others.

An important development in the field of AI was the emergence of machine learning in the 1980s. The recent convergence of modern computing hardware, big data and powerful machine learning algorithms has led to some breathtaking breakthroughs in many applications of AI, from speech recognition, to image recognition, to self-driving cars. We have now entered the time of “AI in vivo,” where AI technologies are changing people’s everyday lives as products of chatbots, photo organizers, assistive driving technology, and much more.

My colleagues at SAIL have been at the forefront of this AI revolution, just like they were the pioneers in establishing the AI field half a century ago. They continue to push the boundaries of fundamental research and innovative applications in many different areas of AI, from teaching computers to translate between languages, to developing a swimming robot that can explore shipwrecks deep under water following haptic instructions from an archaeologist at the surface, to enabling computers to read satellite images that can help governments to monitor the state of regional economy, to creating a smart visual robot that can navigate among crowds in socially courteous ways that have been unique to humans, or to developing algorithms to sort

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ARTIFICIAL INTELLIGENCE

through millions of gene sequences to discover the genetic makeup of fatal diseases. And the list goes on.

Equally important to the mission of technology innovation, we believe in the education of the next generation of technologists. As part of the Stanford Computer Science Department, SAIL faculty and researchers have been teaching students across the Stanford campus and from outside. It is well known that Computer Science has become the largest undergraduate major at Stanford since 2015. Less known is the fact that except for the introductory classes, all the most popular CS classes are now in AI: AI Principles and Techniques, Machine Learning, Natural Language Processing and Computer Vision. In the various research groups of SAIL, undergraduates, including women and under-represented minority students, are often working alongside researchers on the most cutting-edge research projects. In this brochure, we highlight two unique programs at SAIL that are beloved by the students. One is AI Salon, the regular SAIL-wide discussion. The other is Stanford AI4ALL, which was the first in a now growing number of summer camps for high schoolers. Stanford AI4ALL targets high school girls focusing on humanistic AI.

This is a historic time for AI researchers, technologists, educators and students. There has never been so much excitement and hope for the potential promises of AI. But equally important, there has never been so much need to create benevolent AI technologies and to educate humanistic AI technologists for our world. To address this need, SAIL is strongly involved in creating a new university-wide Human-centered Artificial Intelligence Initiative and we will have much more to tell you about that in the coming year.

We have come a long way, but the journey ahead of us is still long. None of today's intelligent machines come close to the breadth and depth of human intelligence. So all of us at SAIL are striving to build better algorithms and machines that will help humans to live better, safer, more productive and healthier lives.

Sincerely yours,

Christopher Manning  
Director, Stanford Artificial Intelligence Lab  
Thomas M. Siebel Professor in Machine Learning



The SAIL research lab and community  
are blossoming.

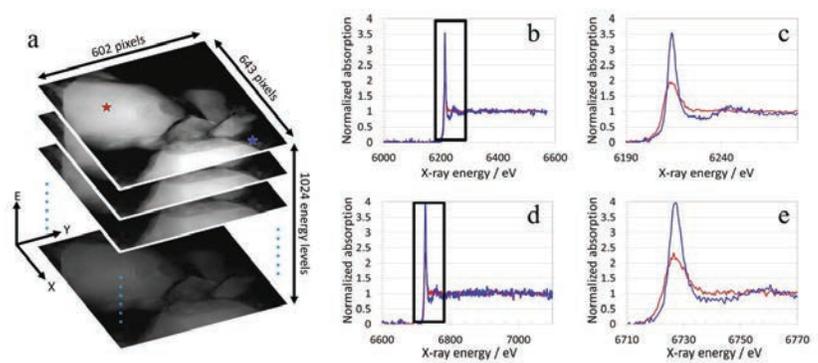




Machine learning replaces the complexity of writing algorithms that cover every eventuality with the complexity of processing lots of data. Processing the data can be a simpler task. With sufficient computing resources, the machines can learn much faster than programmers can teach them.

Machine learning can be applied to tasks that seem far afield. For example, Stanford professor Stefano Ermon looks for societal problems that can be addressed with machine learning techniques. Identifying poverty levels in underdeveloped countries is a difficult but important task for governments and poverty fighting organizations. Ground level surveys are expensive and difficult. Financial data are scarce.

Ermon obtained high resolution satellite images of villages in Africa where asset levels had been documented by surveys. He used those to train a machine learning system. The system was able to spot features like roads, plowed fields and metal roofs as signs of relative wealth. After validating the program's conclusions, Ermon published his results and made the program available to governments and NGOs, where it is starting to be used. Because satellite images cover every corner of the world and are



frequently updated, agencies can even study areas like Somalia where warfare makes human surveys too dangerous.

He has used similar techniques to look at growth in farm fields. Other applications involve energy and the environment.

He hopes to use machine learning to figure out ways to maximize battery life in electric cars. Other researchers are trying to crowd-source sufficient data to get new insights. One target: understanding bird migration and species distribution by getting amateur bird watchers to report their observations. Ermon thinks machine learning could also provide guidelines on how to manage fisheries to benefit fishermen while preserving the population stock.



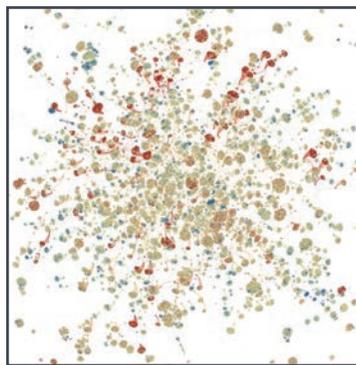
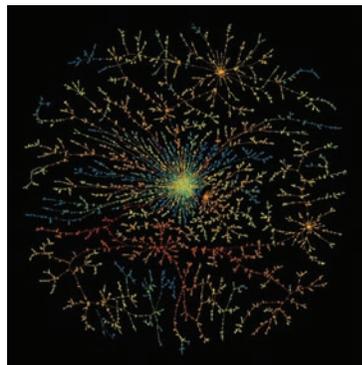
## Machine Learning / Deep Learning

Still, many humans are likely to be skeptical of relying on machines that have essentially trained themselves. When neural networks learn things on their own, they sometimes err. In 2015, an automated labeling feature of Google Photos mistakenly identified some black people as “gorillas.” Google says it has tweaked the feature, but it’s impossible to predict other unexpected results.

In some cases, people will undoubtedly insist on a full understanding of the machine-learning process. As AI guides robots, cars

and planes, if an accident occurs, and engineers can’t reconstruct the decision-making process, liability lawyers will have a field day.

Machine learning will be a core component of solving the next generation of AI problems. Robotics, natural language conversations and understanding videos are all tasks that require machine learning, probably augmented by other techniques that are still under development. ■



Prof. Kochenderfer's students use partially observable Markov decision processes (POMDPs) to represent problems that involve decision making under uncertainty. Techniques developed by his students are being used to derive optimal control strategies for automatically finding GPS jammers that could interfere with air traffic control.



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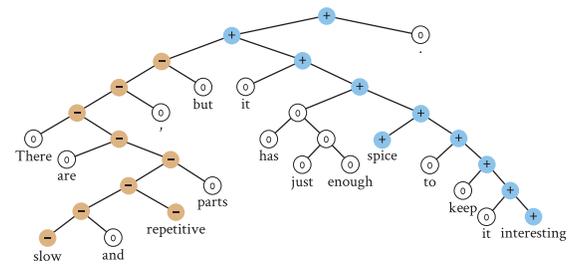


# Natural Language Processing

**A**rtificial intelligence has made dramatic progress in understanding speech. Computers commonly make transcripts and provide phrase-by-phrase translations. But understanding human language is a thornier problem.

Natural language processing is one of the liveliest areas of AI research, in part because it addresses so deeply the issue of what makes humans human. Computers can listen to speech and learn the meanings of individual words and phrases. Processing speech is susceptible to using neural networks that train themselves to recognize the streams of bits that represent spoken words. But really understanding full sentences in context or having a dialogue is still a daunting task. AI methods pioneered at Stanford have made it possible to extract the grammatical structure of a sentence with high accuracy.

Nevertheless, computers are getting better at natural language. AI has made huge progress in improving language translation using deep learning techniques and neural networks. By looking at hundreds of thousands or even millions of documents in English that have been translated to Chinese, a neural network can learn how to translate a full sentence. Stanford NLP Group founder Chris Manning and his students have helped advance this new Neural Machine Translation paradigm.



Sentiment tree. Jason Chuang and Richard Socher

By using large databases of newspaper articles, neural networks can learn to generate summaries or headlines for articles. That can make it easier for humans to scan search results and find what they need.

Researchers are also applying AI techniques to understand the social meanings behind written and spoken language, people's opinions, attitudes, and emotions. For instance, Stanford professor Dan Jurafsky works on sentiment analysis, to understand how groups of people feel about a subject discussed on social media like Reddit or Twitter. One challenge is that words have sharply different connotations in

**SAIL faculty working in natural language processing include:**

Noah Goodman, Dan Jurafsky, James Landay, Percy Liang, Chris Manning, James Zou



## Natural Language Processing

Analyzing natural language can give new insights in the field of computational social science. The language people use about everyday culture like food can tell social scientists a lot. Examining one million Yelp reviews of restaurants, Jurafsky found that disappointed diners write in the past tense and use words similar to those used by people who have been traumatized. Looking at online menus from restaurants, he found that words used in meal descriptions are a strong indicator of price. For example, “fresh” is used in downscale menus; in expensive restaurants it’s assumed the food is fresh.

One goal of natural language processing is using insights to improve the evaluation and training of humans. Stanford professor Jure Leskovec has applied natural language processing to online chats at a crisis hotline, to learn what successful counselors do to aid troubled callers.

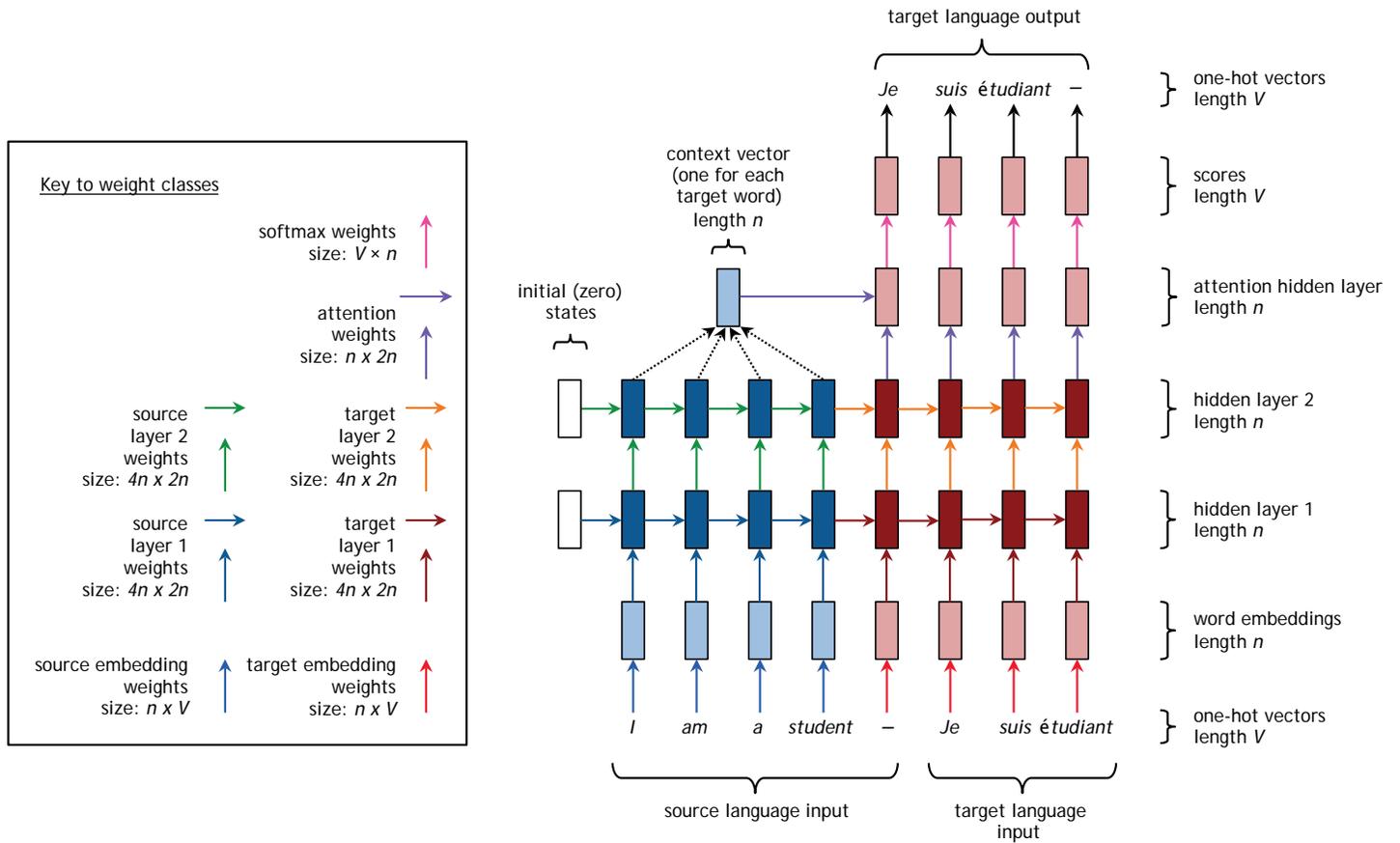
Another goal of natural language researchers is to make it possible for machines to answer questions and carry on conversations with humans. While computers have long been able to fool some people into thinking they are conversing, actually working reliably with people remains an elusive goal.

Stanford AI researcher Percy Liang says “language is very context dependent. It’s about the connection between language and the world.” For example, if someone says “the election” the listener understands what election and probably what opinion the speaker has. A computer probably doesn’t. “So much of their inability to understand is that they don’t have the world context,” Liang says.

Industry is increasingly unveiling chatbots that answer questions in specific domains from obtaining visas to picking a dress. But carrying on conversations with machines on unspecified subjects often causes frustration for humans. Liang notes that the goal is to create a personal assistant that can respond to under-specified requests like “find me a flight,” by incorporating understanding of the user’s past preferences for non-stop flights, and avoiding the “red-eye” flight as well as showing the lowest price.

Liang says having a general conversation is “much more difficult. We’re not there yet.” But, “we’re making good progress” toward solving the conversation problems for specific domains like travel. ■





Analyzing natural language can give new insights  
in the field of computational social science.



# Computer Vision

Computer vision has become one of the most fruitful areas of AI research and development in the past decade. And its growing maturity is opening up new pathways to intelligence in fields like robotics, machine learning and intelligent vehicles.

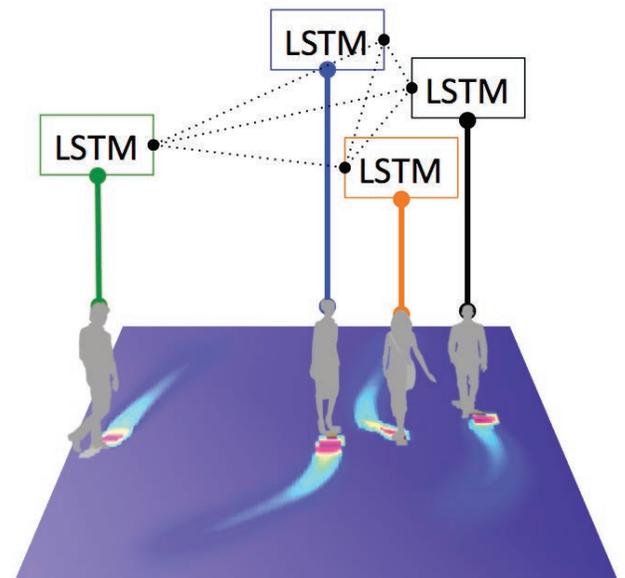
Humans are producing and storing an exploding amount of visual information from visual sensors like mobile phones or surveillance cameras that take beautifully detailed photos and videos with sound. But computers continue to struggle to make sense of it all. Recording the series of numbers that represent pixels in a digital photograph doesn't enable a computer to understand their meaning.

Humans look with their eyes, but they see with their brains. Computer vision lets computers see by processing the information in individual pixels and putting it together in the computer to create concepts. Researchers need to teach computers to see.

Computer vision took a great leap forward in 2009 when researchers led by Fei-Fei Li, the head of Stanford's Vision Lab, organized ImageNet, a database of 14 million photographs of tens of thousands of types of objects that were labeled by nearly 50,000 online human workers through the Amazon Mechanical Turk

platform. By training neural networks using ImageNet, researchers developed the ability to identify objects almost as well as humans can.

Neural networks have remade the science of computer vision. Just as children learn to identify objects by seeing hundreds of millions of images of the real world, neural networks are trained by examining labeled images from the



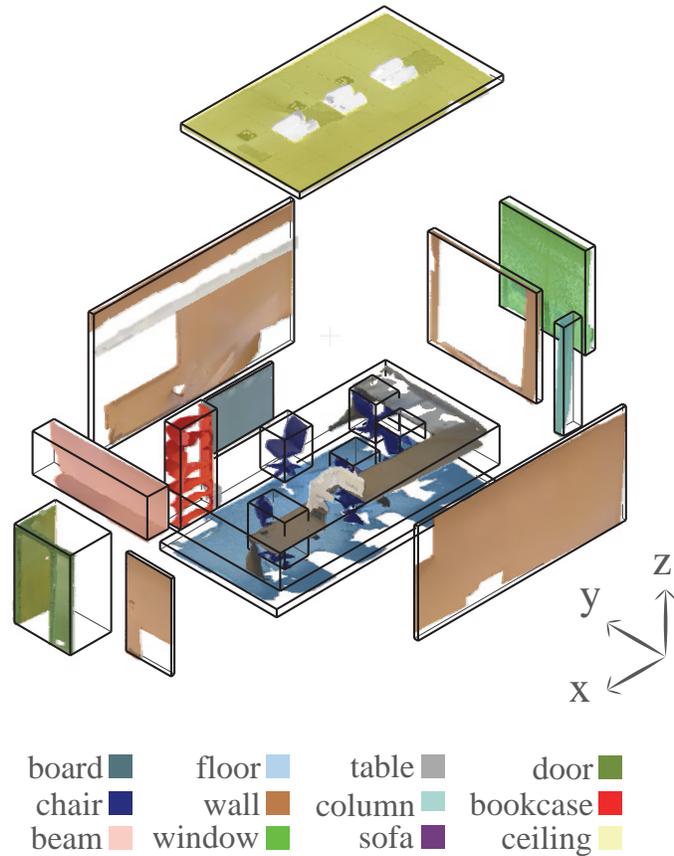
**SAIL faculty working in computer vision, haptics, and sensing include:**

Maneesh Agrawala, Jeannette Bohg, Ron Fedkiw, Leonidas Guibas, Oussama Khatib, Fei-Fei Li, Juan Carlos Nieves, Ken Salisbury, Silvio Savarese, Sebastian Thrun, Dan Yamins, James Zou.

Internet. The neural networks used to develop machine vision have 24 million nodes and almost 15 billion connections.

The next step in evolving computer vision was to identify multiple objects in an image. That often involves interpreting partial images such as the top of a head. Stanford researchers have developed vision systems that are better than humans at some tasks such as instantly identifying thousands of cars by make, model and year. Using car images from Google StreetView, the researchers have correlated car prices with certain city neighborhoods. That turns out to predict not only wealth, but also crime patterns and voting preferences.

The next step is teaching computers to describe the relationships in a picture, such as “a cat lying on a bed next to a laptop,” and make sentences and even stories about them. High-level visual recognition and reconstruction problems such as understanding a scene or recognizing human behavior in the complex 3D world requires more sophisticated algorithms. Even a 4-year-old child knows that a boy blowing out candles on a cake is celebrating his



## Computer Vision

birthday. Helping computers reach that level of understanding is something that Stanford researchers are starting to achieve today.

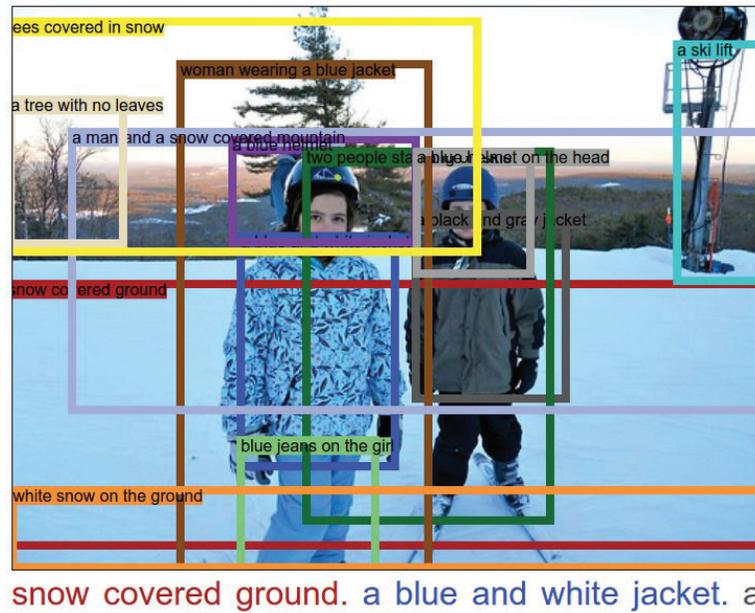
Silvio Savarese, a SAIL professor and the head of Stanford's Computational Vision and Geometry Lab, says that one goal is to help robots have real relationships with humans. To interact with people, "You need to infer intention and have a good understanding of how to put together all the components into a coherent interpretation," he says.

In his lab, researchers are using neural networks to interpret videos of scenes, so that a robot will learn to act appropriately. That requires more understanding than merely avoiding collisions. For instance, looking at a video of a cocktail party, the algorithm learns what distance people maintain while having a conversation. It has to learn that when getting drinks, people form a queue at the bar, and when crossing a room, they avoid passing between two people who are talking.

SAIL researchers are also trying to use machine vision to provide expertise that humans can't. One project involves construction-project monitoring. A vision system learns a building by scanning a detailed 3-D model of the completed building. Then it goes through the building week-by-week while it is under construction and compares progress to the project-management plan. By identifying delays and incomplete areas early, the technology can help avoid delays and costly overruns.

When machines can see, they will be able to improve security by being tireless watchers, continuously observe medical operations as a separate set of eyes, and improve the ability of cars to interpret and react to changing conditions. Seeing a pedestrian on a street corner and predicting whether he will cross or wait will help make independent vehicles safer. Computer vision is a crucial aspect of AI that is helping machines and people coexist in an intelligent way. ■





Humans look with their eyes,  
but they see with their brains.



# Robotics

**R**obotics goes beyond the goal of traditional AI—replicating human intelligence—by attempting to build machines that physically act like humans. It extends well beyond computer science, into the fields of mechanical engineering, electrical engineering, bioengineering and even cognitive science and psychology of learning.

Robotics developed on factory floors with programmable arms in safety cages doing tightly constrained activities. But around the beginning of the 21st century, sensors and actuators improved to the point that scientists could start to develop robots that perform tasks in a human environment.

Stanford's Robotics Center at SAIL specializes in developing robots that can work in conjunction with humans. Robots can be dangerous. For safety, they must be able to sense humans near them both visually and by touch to avoid hurting them inadvertently. They need to be able to perceive their environment and adapt to their tasks so they can pick up iron bars or porcelain vases with the same grippers.

Roboticists have long instructed robots how to move by creating computer programs that describe the movement of each joint. But that isn't how people move. Oussama Khatib, who heads SAIL's robotics center, says, "Humans don't move precisely. They move to make contact and then modify their position." Stanford's robotics researchers have worked

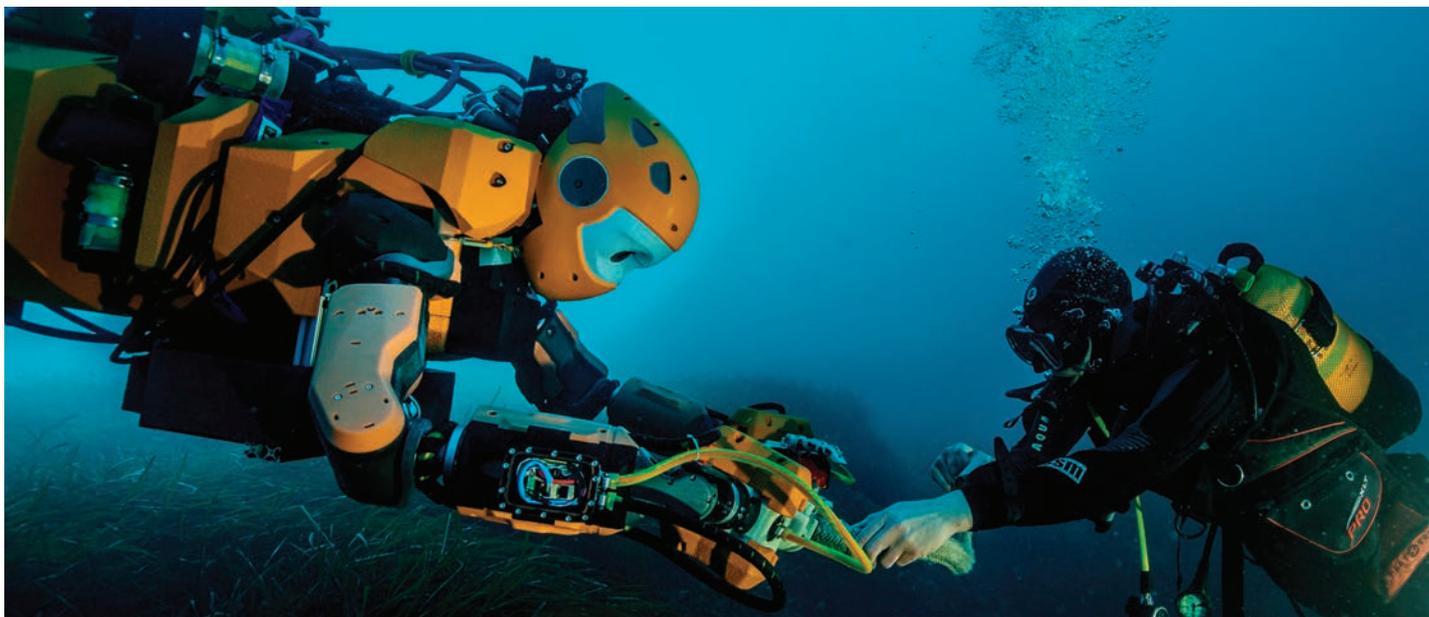
with biomechanics researchers to model the human musculoskeletal system in order to make robots move the way humans do.

Rather than program the motion of every limb, robotics researchers today try to mimic biological systems. Sensors on robots respond to stimuli. They provide the information that controls or modifies the next movement.



**SAIL faculty working in robotics include:**

Jeannette Bohg, Oussama Khatib, Mykel Kochenderfer, Andrew Ng, Marco Pavone, Dorsa Sadigh, Ken Salisbury, Silvio Savarese, Sebastian Thrun, James Zou.



With those capabilities provided to robots, researchers can use different techniques for instructing robots to move. Based on computer models of human motion that they had developed through careful analysis, “we could understand the human strategy behind the motions,” Khatib says. Then they encoded the strategies into the robot. As a result, they are able to encode complex motions into a robot without writing extremely complex code.

One of the most exciting examples of work by the robotics center is Ocean One—a humanoid diver. Khatib says it is actually more like a mermaid with two arms, but no legs. Several propellers around its torso give Ocean One

a range of motion. The robot was designed to assist archaeologists who want to explore shipwrecks hundreds of feet beneath the surface. Human divers can’t go that deep and are limited to shorter times. Submersible vessels can’t maneuver the way divers can. The robot provides a solution.

Humans have the innate ability to “read” one another. When people walk in a crowded public space such as a sidewalk, an airport terminal, or a shopping mall, they obey a large number of (unwritten) common sense rules and comply with social conventions. For instance, as they consider where to move next, they respect personal space and yield right-of-way.



## Robotics

The ability to model these “rules” and use them to understand and predict human motion in complex real world environments is extremely valuable for the next generation of social robots. Researchers in the Stanford Vision and Learning (SVL) Lab have developed a self-navigating mobile manipulator robot, “Jackrabbot”, that is capable of learning and interacting with people in pedestrian spaces.

In addition to social navigation, researchers in the Intelligent and Interactive Autonomous Systems (ILIAD) group at Stanford study the design of robotics algorithms that safely and reliably interact with people in a diverse set of collaborative settings.

Researchers at ILIAD look into building computational and predictive models of human behavior, and leveraging such learned models in better interaction, collaboration, and coordination with robots. They formalize the interactions between humans and robots in domestic environments as well as in human-robot teaming. Going beyond interaction, Stanford roboticists are interested in social implications of automation on humans. Specifically, how autonomous systems can influence societal objectives, e.g., the role and influences of autonomous vehicles in mixed-autonomy roads, or emergent behaviors in human-robot teams.

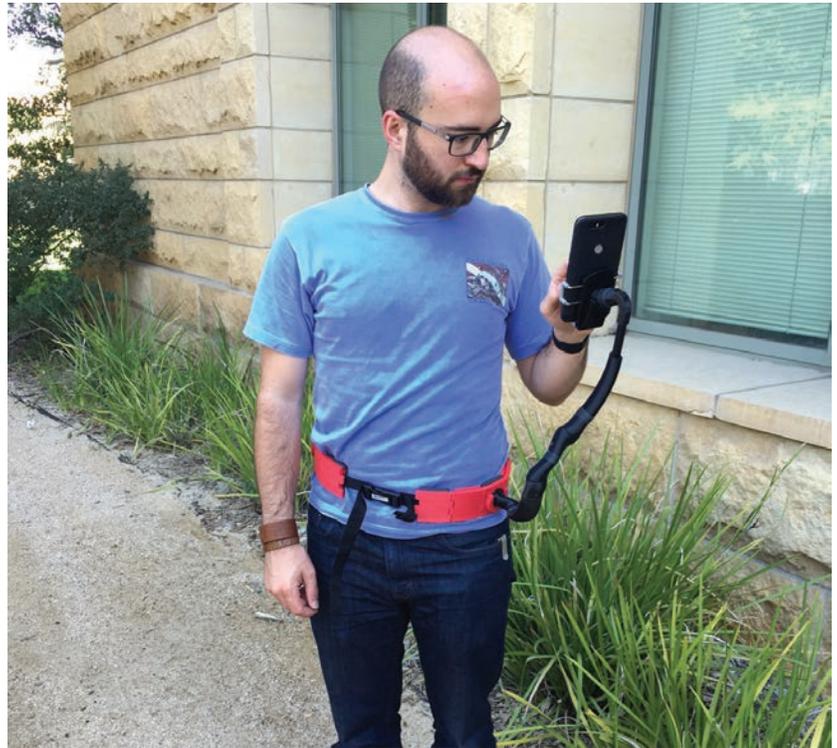
Another fundamental challenge in robotics is generalizability. Researchers at the Interactive Perception and Robot Learning (IPRL) lab at Stanford are studying the underlying principles of robust sensorimotor coordination for problems such as autonomous robotic manipulation. Robotics researchers at Stanford develop algorithms and systems that unify reinforcement learning, control theoretic modeling, and visual scene understanding to teach robots to perceive and to interact with the physical world.

Stanford researchers have used the improved haptic controls to explore the way the brain instructs muscles and limbs to move. Moving



a hand, for example, requires signaling 50 different muscles. To study how that occurs, researchers need to analyze brain activity in conjunction with physical activity. They placed a subject wearing haptic controllers on his hands in an MRI machine. The subject can respond to virtual reality while the scanner records the related brain activity.

Increasingly, robotics researchers are focused on teaching robots to respond to their experiences and learn from them. When the robot is told to carry an object across a room, the researchers want it to observe its environment and adapt to changes like people walking around. Algorithmic programming and learning techniques need to combine to produce robots that function with the skills they will need in the future. ■



Increasingly, robotics researchers are focused on teaching robots to learn from their experiences.



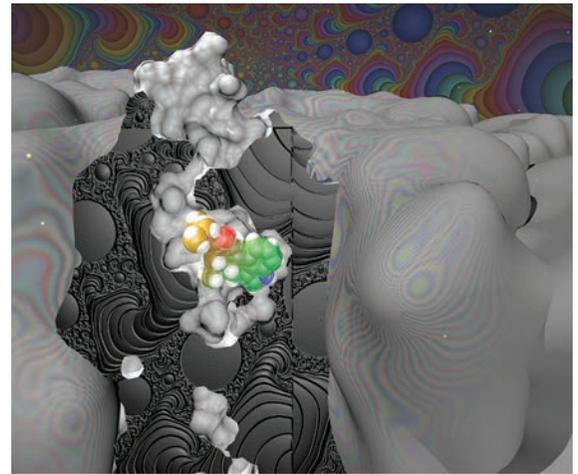
# Genomics and Healthcare

**G**enomics is where medicine meets computer science. Mapping the human genome is something only machines can do. And once a genome has been mapped, AI techniques are being used to decode it.

Traditionally, doctors have tried to understand diseases by looking at phenotypes, and figuring out what caused the phenotypes. Many physical ailments are rooted in the gene sequence that defines every human.

Looking at diseases through the lens of genomics opens up countless new avenues to understand genotypes and phenotypes. Instead of looking at outcomes, genomicists look for the gene sequences that cause them. Stanford researchers have found that variances from normal in gene sequences are correlated with diseases from hypertension to narcolepsy.

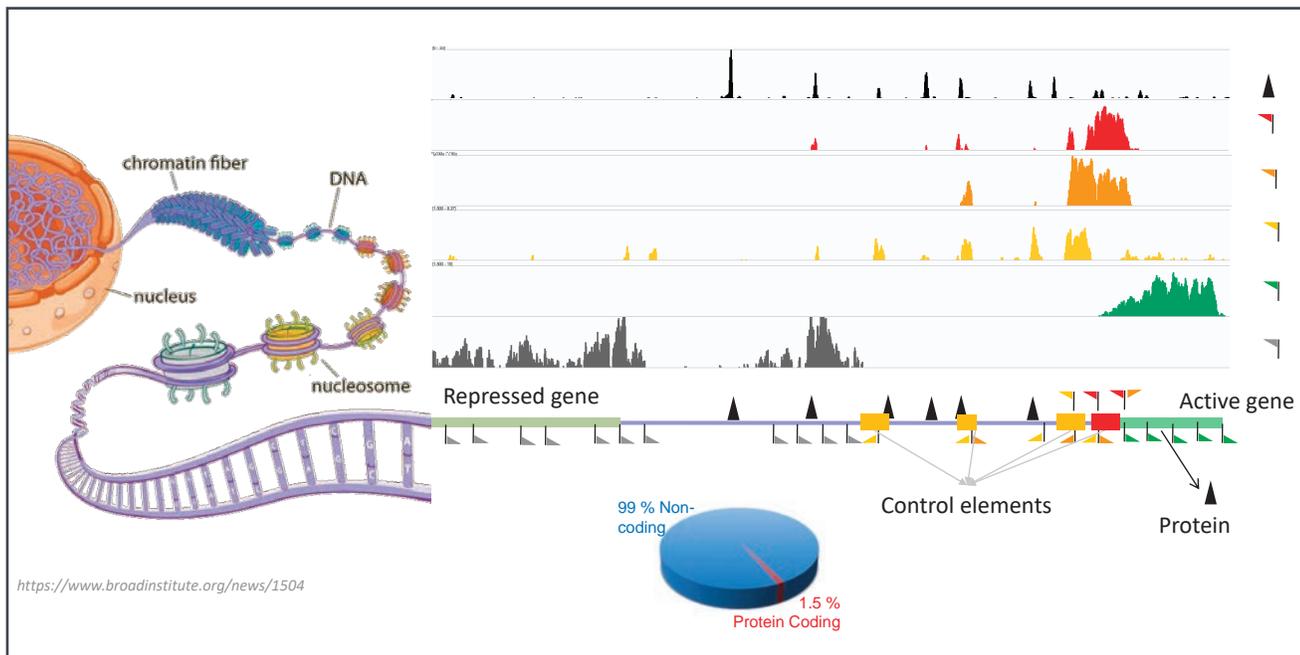
The cutting edge of genomics today involves machine learning: teaching machines to sort through millions of gene sequences. Then they try to identify the sequences that correlate with particular phenotypes—the observable characteristics linked to the genes. One fruitful avenue pioneered at Stanford is examining just the regulatory regions of a person's gene sequence. For example, mutations in a region associated with regulating cardiac output appear in the gene of a person with a family history of sudden cardiac failure.



Starting with the genomic code reverses the way people traditionally view the human body and its diseases. Physicians and clinical researchers usually start by trying to understand body parts such as organs and systems. Then they try to understand phenotypes related to disease of those parts. But it turns out that variations in the genome may damage multiple body parts in different ways. Understanding the full impact may help doctors devise individualized medical treatments or predict side effects.

**SAIL faculty working in genomics, medicine, and healthcare include:**

Gill Bejerano, Ron Dror, Daphne Koller, Anshul Kundaje, Fei-Fei Li, Vijay Pande, Ken Salisbury, Dan Yamins, James Zou.



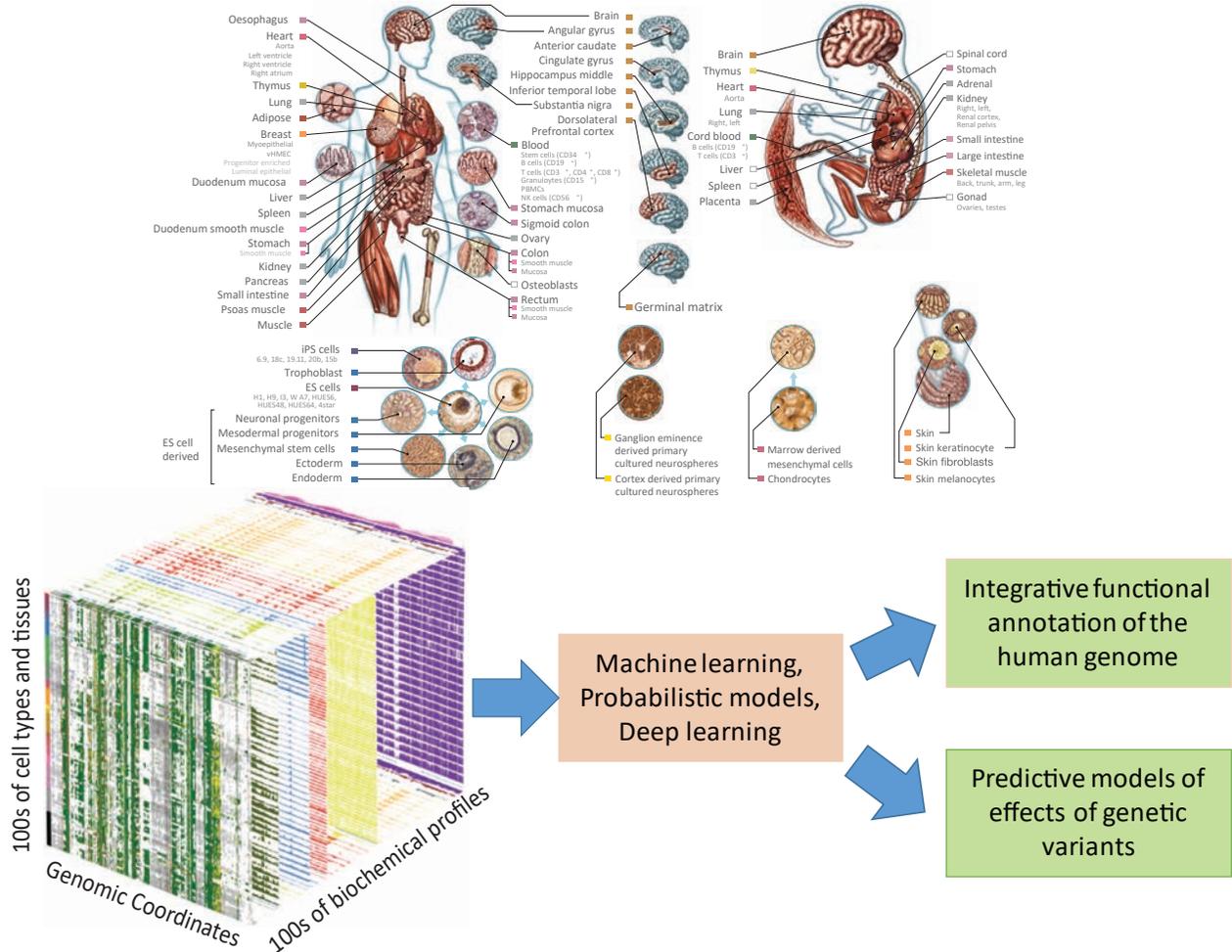
#### Biochemical markers of cell-type specific functional elements

Biologists once thought that decoding the human genome would provide a clear path to understanding many human characteristics. They hoped that identifying anomalies in a gene sequence would explain a specific disease. They hoped that would suggest pathways for cures.

But the genome is more complex than expected. Figuring out which gene sequences matter is a huge challenge. Moreover, they seem to interact in many ways, some of which have unnoticed significance.



# Genomics



Gill Bejerano, a Stanford researcher, says the biology is complicated. In a typical patient’s three billion nucleotide genome there might be four million mutations, and 300 of them might look suspicious—far too many to test experimentally.

Now, he says, researchers in his lab and elsewhere are focusing on using machine learning neural network techniques to find correlations among genotypes and phenotypes—the genes and their outcomes. “We are trying to take patient groups with a single disease and ask if they have anything in their genome in common.” Using machine



learning techniques, he has been able to demonstrate ways to eliminate all but a few of the 300 suspicious mutations.

This research avenue has become much more fruitful with the development of CRISPR-Cas9 gene editing technology. CRISPR allows researchers to go to a specific point on a genome and cut it or block its enzymatic activity in order to see how the loss of that part of the code affects the cell. When a gene has been identified as the likely cause of a disease, it can be tested. If the gene sequence exists in a mouse or in a blood cell, the gene can be replaced using CRISPR, and researchers can see whether changing it had the expected effect.

Even without finding a cure, identifying rogue genes in a patient can help provide genetic counseling. When a child has a genetic disease, parents want to know whether future siblings might be affected as well. That requires

mapping the parents' genes. If one or both have the same gene sequence, it makes it more likely future children will inherit it. But if neither has the gene, the anomaly is probably just random and is unlikely to appear in other children.

One of the most fascinating areas of genomic research involves comparing genetic variation among species. Many genes are common even among vastly different species like humans and rats. Understanding the differences can give valuable insight into species variation.

Bejerano's lab has studied dolphin genomes, and found that they lack a gene that is present in many mammal species and is associated with virus fighting capabilities. He suspects that mutation may help explain the periodic die-offs of pods of dolphins. He hopes further genomic research can determine what in the gene allows dolphins "to echo-locate and what allows them to live in the ocean." ■

Every single genome sequenced is a  
treasure chest of secrets ... this is  
an amazing time to be a genomicist.



# Autonomous Vehicles

**D**riverless cars, planes and boats are going to profoundly change people's lives and our environment over the next decades. Making them work in a world of unpredictability and ambiguous information remains a challenge. Researchers at SAIL are exploring ways to help vehicles operate safely in an environment that is constantly changing due to unpredictable human behaviors.

Autonomous cars are already on the roads in some places, but there are significant restrictions on their performance.

AV researchers say it will be a number of years before cars and trucks can be set loose on city streets where pedestrians, bicyclists, arm-waving traffic cops and double-parked delivery trucks constantly alter the driving environment.

Stanford researchers from fields including robotics, computer vision, human-computer interaction, machine-learning and decision-making are working on ways to make cars interact safely with humans—no easy task for a 3,500 pound robot on wheels that can travel 100 miles per hour.

Teaching cars to observe and predict human actions is vital. There is bound to be a lengthy transition period before all 260 million U.S. cars and trucks are replaced by fully autonomous vehicles. Even then, cars will share spaces with bicyclists and pedestrians. Moreover, for a number of years, new cars will have increased autonomy while still requiring humans to take over in some situations such

as navigating unmarked parking lots, following police directions that override traffic signals or merging multiple traffic streams.

Some Stanford researchers are working on issues related to the car's interaction with its own driver. They study drivers in an immersive AV simulator and see how they react to various



This is a Mercedes-Benz E-Class outfitted with lidar and radar sensors. This vehicle is being used to collect data for the development of deep stochastic sensor models, which will allow the efficient simulation of autonomous vehicles in realistic environments. This work is being conducted by Tim Wheeler in Prof. Kochenderfer's lab in collaboration with the Technical University Darmstadt in Germany. The vehicle is owned by TU Darmstadt.

#### SAIL faculty working in autonomous vehicles and intelligent machines include:

Maneesh Agrawala, John Duchi, Stefano Ermon, Leonidas Guibas, Oussama Khatib, Mykel Kochenderfer, James Landay, Fei-Fei Li, Juan Carlos Niebles, Marco Pavone, Christopher Ré, Dorsa Sadigh, Ken Salisbury, Silvio Savarese, Sebastian Thrun, James Zou.

situations. They are developing vision systems that observe the driver's attentiveness. One issue with part-time automation is that drivers tend to nod off while the car is handling things. When the car isn't sure what to do, it has to make sure the transfer of control to the driver is fail-safe.

Human drivers easily understand many things happening in the outside environment but teaching them to a car requires more than just identifying objects. Senior Research Scientist Juan Carlos Niebles, a computer vision expert who is Associate Director of Research at the Stanford-Toyota Center for AI Research, says: "We have very good cameras today. The bottleneck is the software that correctly interprets the world and what the pixels are showing."

For example, a child wobbling along in a bike lane requires more caution than a spandex-clad bike messenger. A ball rolling onto the street may be followed by a child. A driver in the next lane who is texting or putting on makeup is a bigger risk than someone with both hands on the wheel. Drivers and pedestrians will need to accept the fact that a vision system in every passing car is watching and analyzing them, (although they may not be storing the video).



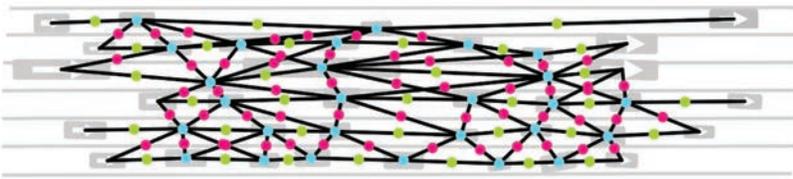
The Prius V is used as part of the Toyota SAIL project to create driver-centric datasets to support machine learning around driver emotion, physiology, and elicited responses during naturalistic driving.



As part of the Toyota SAIL project, students of Mark Cutkosky and Chris Gerdes test applications of a skin stretch haptic steering wheel on experimental testbed X1 for navigation cues, collision avoidance warnings, and autonomous previews.



## Autonomous Vehicles



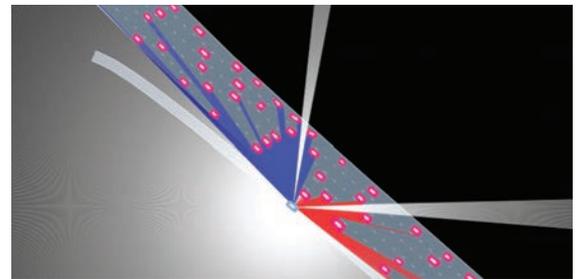
Prof. Kochenderfer's students are developing new methods for randomly generating realistic driving scenes and trajectories.

Decision-making is one of the key issues for AVs, because there are far more possible situations than programmers can ever model in advance. Good human drivers are told to follow the rules of the road. But good driverless cars may be better off with innovative software that follows the probabilities of the road.

Past work on decision-making by Mykel Kochenderfer, an AI professor at Stanford, has led to a rethinking of the way airplanes' collision avoidance software is designed. He has proved that in domains where uncertainty is unavoidable, probabilistic models are safer than rules-based models.

A similar approach may be needed for the vastly more complicated problem of making cars that can safely navigate roadways.

In some cases, the car must decide to swerve slightly to one side in order to give itself a better view of an intersection. Writing an expert system that gives yes-no answers to every question would be impossible given the variety of situations that develop. But Kochenderfer acknowledges that consumers and regulators are generally more comfortable with rules-based systems that humans can understand than they are with turning over control to a computer, whose decision-making process is obscure. ■



Creating the intelligence for fully autonomous vehicles is one of the great opportunities of AI.



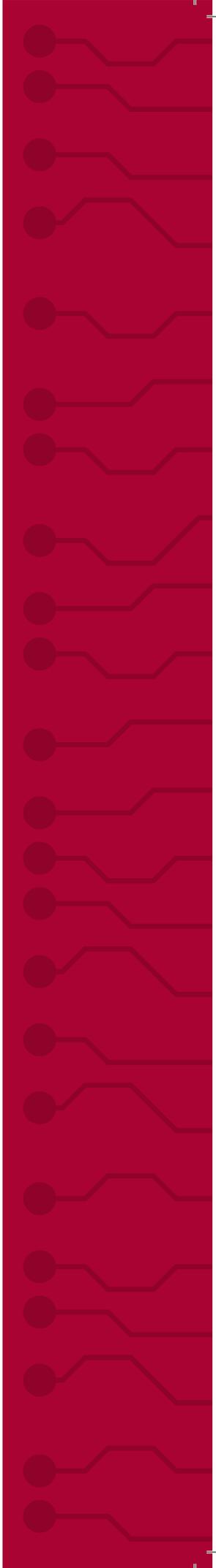
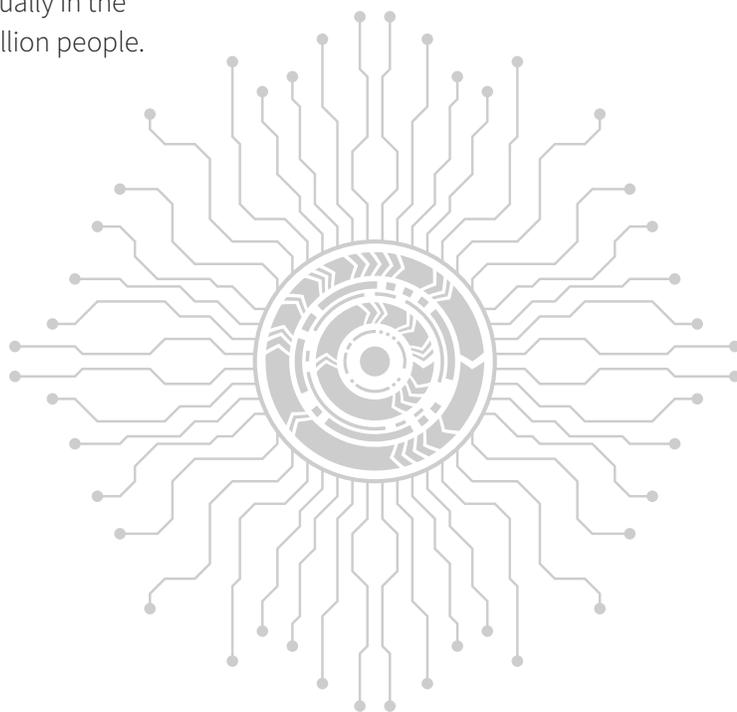
# Centers

## **SAIL-TOYOTA CENTER FOR AI RESEARCH**

Recognizing the leadership position of Stanford's AI research community, SAIL and Toyota came together in 2015 to create a multi-year research center focusing on human-centric AI research in autonomous vehicles and robotics. Today, the SAIL-Toyota Center hosts more than a dozen research projects led by twenty principal investigators and their students and postdoctoral scholars. Research topics span from theoretical estimation of uncertainties, to large-scale database querying of anomalies, to visual-motor deep reinforcement learning, to in-car human behavior studies. The world will have to take incremental steps toward fully autonomous vehicles. But the benefits of getting there will be immense. Fully autonomous vehicles will liberate elderly and disabled people who can't drive. And AVs can be programmed to use the streets much more efficiently, reducing congestion. Most important, roads will be much safer. Driver error is the main cause of the six million accidents that occur annually in the U.S. and permanently injure two million people.

## **SAIL-JD AI RESEARCH INITIATIVE**

The SAIL-JD AI Research Initiative supports research on developing and applying artificial intelligence to supply chain management, intelligent customer service, automation in warehouses and delivery as well as other areas of innovation and automation in e-commerce. Cutting edge research funded by this Initiative includes: Text mining to predict future behavior using temporal graphs and deep embedding methods, virtual shopping experiences, emotional language generation, AI-powered autonomy for smart warehousing, and human activity and intention understanding for smart spaces and smart robots. ■



# AI Salon

A special piece of SAIL's culture is the AI Salon, which is a biweekly event modeled after the 18th century French enlightenment salons. At each salon, we invite two Stanford graduate students, faculty, or guests to share contrasting thoughts on a topic of relevance to artificial intelligence. The goal is to foster discussion that takes a wider view than typical day-to-day research; for instance, past topics have included "AI and the Legal System," "Software Engineering for Machine Learning," "Trust in AI Techniques/Algorithms," and "Diversity in AI." While the Salon culture is driven by graduate students and faculty, we also regularly have invited guests ranging from visiting professors to CEOs, journalists, and judges.

Salon attendees are treated to wine and cheese. In exchange, we enforce a rule of absolutely no electronics, both to remind us of the enlightenment era, and so that everyone is fully present during the discussion. We take this seriously—time is even kept with an hourglass rather than a clock. Everyone is invited to participate in the discussion; while two hosts introduce a topic at the beginning, the majority of discussion comes from the audience at large.

Salon topics typically lead popular awareness. For instance, in April and October 2015 we held Salons discussing how filtered newsfeeds shape society; this later became a major topic of discussion during the 2016 U.S. election season. In April of 2015, Elon Musk participated in a discussion of the future of AI, prompting lively debates with students on both the promises and perils that advanced AI technology will bring to the society. In January 2016, Tino Cuellar, Stanford





affiliate faculty and one of the Supreme Court justices of the State of California, came to talk to SAIL members about AI and its challenges to our legal system. Several SAIL emeritus faculty have participated in our Salons, including Ed Feigenbaum and Nils Nilsson. They had dialogues with current students at SAIL on both the history and the prospects of AI.

By bringing together the many bright minds at Stanford, as well as expert guests, we hope to give Stanford graduate students and faculty the resources to become leaders in the public dialogue around artificial intelligence. Given AI's growing impact on society, engaging with this dialogue is more important than ever. ■

Given AI's growing impact on society, engaging with this public dialogue is more important than ever.

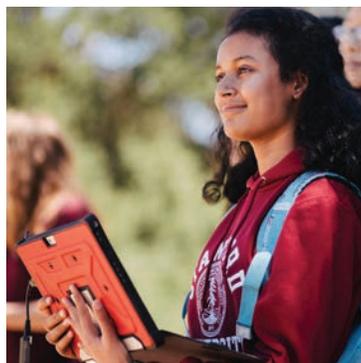
# Stanford AI4ALL

**A**s the field of AI continues to make a bigger impact in the world, researchers and educators at SAIL believe that to develop the most inclusive, humanistic, and benevolent technologies, it is imperative that the field of AI includes students, researchers, and technologists from all walks of life. With this mission in mind, SAILORS (short for the “Stanford Artificial Intelligence Laboratory’s Outreach Summer Program”) was created in 2015 to expose high school students in underrepresented populations to the field of artificial intelligence. This program has since been renamed to Stanford AI4ALL, signaling a partnership between SAIL and education non-profit AI4ALL. This annual summer program is built upon the hypothesis that to increase diversity representation in the field of AI, CS, and STEM at large, it is critical to introduce the technology along with its humanistic mission statements. And in turn, the long-term vision for AI and STEM is for the fields to train a more diverse generation of technologists who have humanistic goals in mind when designing next generation technologies.

The original SAILORS and the present Stanford AI4ALL is aimed at rising 10th-grade young women. Originally two-weeks, this three-week full-time program continues to provide both broad exposure to AI topics through faculty lectures and industry field trips, as well as an in-depth experience with a research area through hands-on projects. Every part of the Stanford AI4ALL curriculum is designed to combine rigorous technical exposure with important humanistic applications. For example, in prior years, the robotics team worked on self-driving cars to help aging seniors. The natural language processing team worked on document analysis using Twitter data for disaster relief. The computer vision team worked on clinician hand hygiene behavior analysis using depth-image videos from hospitals. And the computational genomics team worked on leukemia classification.

The students also had a chance to visit local companies, as well as the Computer History Museum, personally curated by SAIL emeritus professor, Turing Award winner Professor Edward Feigenbaum.

Stanford AI4ALL/SAILORS was co-founded and co-directed by Prof. Fei-Fei Li, her former PhD student Professor Olga Russakovsky (Assistant Professor at Princeton University), and Dr. Rick Sommer (Executive Director of Stanford Pre-Collegiate Studies). Now renamed, this program continues to be based in the Stanford Artificial Intelligence Laboratory, but with an updated curriculum developed by AI4ALL, an education nonprofit organization dedicated to training the next generation of AI researchers. AI4ALL was also founded by Dr. Fei-Fei Li and Dr. Russakovsky. Juan Carlos Niebles, Senior Research Scientist at SAIL, was named as the Director for Stanford AI4ALL 2018.



More than 40 members of the Stanford CS department helped make the program possible each year, including Professors Gill Bejerano, Stefano Ermon, Noah Goodman, Oussama Khatib, Mykel Kochenderfer, Anshul Kundaje, Percy Liang, Chris Manning, Ken Salisbury, and Silvio Savarese, as well as undergraduates, graduate students and postdoctoral fellows.

Renowned computer scientists Dr. Ruzena Bajcsy (Robotics Professor at UC–Berkeley) and Dr. Maria Klawe (President of Harvey Mudd College) delivered the keynote speeches in respective years. In 2015, two undergraduate students of Computer Science, Marie Eve Vachovsky and Grace Wu, performed a rigorous study of Stanford AI4ALL as a summer undergraduate research project through the CURIS program. Their finding was published in a research paper at SIGCSE2016, a premier

conference in computer science education. Wired Magazine had a feature story on Stanford AI4ALL in their August issue in 2015. In 2015 and 2016, Stanford AI4ALL was free for commuter participants thanks to the generous support of Dropbox, Google, Bloomberg, Oculus, Intel, Airbnb, Baidu, Pinterest, and many other companies and individuals. Since then, the program has evolved into a residential program that requires tuition, however, Stanford AI4ALL does offer financial aid in order to best serve a global, diverse audience.

Efforts for Stanford AI4ALL 2018 are well underway now. This will be the second year that the program is residential, having expanded to 32 students. AI4ALL is now partnering with several other universities, creating similar programs aimed at increasing diversity and access to computer science research. ■

AI will change the world.  
Who will change AI?

## Faculty Focus

The Stanford Artificial Intelligence Laboratory (SAIL) has been a center of excellence for Artificial Intelligence research, teaching, theory, and practice since its founding in 1962.

MANEESH AGRAWALA



**MANEESH AGRAWALA**  
 Maneesh Agrawala works on computer graphics, human computer interaction and visualization. His focus is on investigating how cognitive design principles can be used to improve the effectiveness of audio/visual media. The goals of this work are to discover the design principles and then instantiate them in both interactive and automated design tools.

GILL BEJERANO



**GILL BEJERANO**  
 The Bejerano Lab studies genome function in human and related species. We are deeply interested in the following broad questions: Mapping genome sequence (variation) to phenotype (differences) and extracting specific genetic insights from deep sequencing measurements. We take a particular interest in gene cis regulation. We use our joint affiliation to apply a combination of computational and experimental approaches. We collect large scale experimental data; write computational analysis tools; run them massively to discover the most exciting testable hypotheses; which we proceed to experimentally validate. We work in small teams, in house or with close collaborators of experimentalists and computational tool users who interact directly with our computational tool builders.

JEANNETTE BOHG

**JEANNETTE BOHG**

Jeannette Bohg is an assistant professor in the Department of Computer Science at Stanford University. She leads the Interactive Perception and Robot Learning Lab that

seeks to understand the underlying principles of robust sensorimotor coordination by implementing them on robots. The lab is specifically interested in developing methods that are goal-directed, real-time and multi-modal such that they can provide meaningful feedback during action execution and learning. The research is at the intersection of robotics, computer vision and machine learning applied to the problem of autonomous manipulation and grasping. Topics include real-time visual tracking, learning to grasp, vision-based control and robotic system building as well as interactive perception.

RON DROR

**RON DROR**

We are a highly multidisciplinary lab whose work spans fields ranging from high-performance computing, computer vision, and machine learning to biochemistry, cell biology, and drug discovery.

We study the spatial organization and dynamics of biomolecules and cells in order to develop better medicines and quantitatively explain the workings of living systems.

EMMA BRUNSKILL

**EMMA BRUNSKILL**

Emma Brunskill is an assistant professor in the Department of Computer Science at Stanford University in the Statistical Machine Learning Group and Stanford Artificial Intelligence

Laboratory. Her work focuses on reinforcement learning in high stakes scenarios—how can an agent learn from experience to make good decisions when experience is costly or risky, such as in educational software, healthcare decision making, robotics or people-facing applications. Key areas of focus in her group include the theoretical foundations of efficient reinforcement learning, "What if" reasoning for sequential decision making, and human-in-the-loop systems. She is the recipient of multiple early faculty career awards (NSF, ONR, Microsoft) and her group has received several best paper nominations and awards.

JOHN DUCHI

**JOHN DUCHI**

I am an assistant professor of Statistics and Electrical Engineering at Stanford University. I completed my PhD in computer science at Berkeley in 2014. My research interests

are a bit eclectic, and they span computation, statistics, optimization, and machine learning; if you like any of these, we can probably find something interesting to chat about. At Berkeley, I worked in the Statistical Artificial Intelligence Lab (SAIL) under the joint supervision of Michael Jordan and Martin Wainwright. I obtained my master's degree (MA) in statistics in Fall 2012. I was also an undergrad and a masters student at Stanford University, where I worked with Daphne Koller in her research group, DAGS. I also spend some time at Google Research, where I had (and continue to have) the great fortune to work with Yoram Singer.

# Faculty Focus

continued

STEFANO ERMON



STEFANO ERMON

We research innovative computational approaches to help address the societal and environmental challenges of the 21st century. We combine research on the foundations of artificial

intelligence and machine learning with applications in science and engineering. Our work enables computers to act intelligently and adaptively in increasingly complex and uncertain real world environments.

RON FEDKIW



RON FEDKIW

Fedkiw's group generally works on designing numerical algorithms for the simulation of physics based systems spanning a range from classical applied mathematics and engineering all the way to

Hollywood special effects for feature films. He has two Academy Awards: one for his work on water simulation for *Pirates of the Caribbean*, *Harry Potter*, etc. as well as a second award for destruction simulation in *Transformers*, *The Hulk*, *Avengers*, etc. More recently, he has been focused on a variety of special effects simulation problems that require real world computer vision and related data in order to augment the simulations themselves to a new level of fidelity. Current efforts include the flying of drones to capture, reconstruct, and subsequently simulate very large scale detailed trees, novel cloth simulation technologies that allow for the capture, interpretation, and further use of detailed wrinkling processes, and a hybrid approach to 3D face and body simulation and data capture methods incorporating biomechanical systems as priors. His most recent work on face simulations that target and improve real world data capture has just been used on King Kong's face in the new *Skull Island* movie that releases Spring 2017.

MICHAEL GENESERETH



MICHAEL GENESERETH

The focus of work in the Logic Group is Computational Logic. (Computational Logic is that branch of Computer Science concerned with the representation and processing of

information in the form of logical statements.) Current research topics include logical languages, automated deduction, automated reformulation, paraconsistent reasoning, and dynamic logic. While the group's work is primarily theoretical, a considerable amount of effort is devoted to applications of research results. Application areas of special interest at this time include Logical Spreadsheets, Data Integration, Logic Programming, Enterprise Management, Computational Law, and General Game Playing.

NOAH GOODMAN



NOAH GOODMAN

The Computation and Cognition Lab at Stanford studies the computational basis of natural and artificial intelligence, merging behavioral experiments with formal methods from statistics and

programming languages. Our research topics include language understanding, social reasoning, and concept learning. We also create technologies to ease the use of complex techniques for cognitive modeling and artificial intelligence applications, such as probabilistic programming languages.

## LEONIDAS GUIBAS



## LEONIDAS GUIBAS

The Geometric Computation Group, headed by Professor Leonidas Guibas, addresses a variety of algorithmic problems in modeling physical objects and phenomena, and studies computation, communication,

and sensing as applied to the physical world. Current foci of interest include the analysis of shape or image collections, geometric modeling with point cloud data, the development and annotation of the ShapeNet 3D model repository, machine learning for geometric objects, the analysis of mobility data, and modeling the shape and motion biological structures. More theoretical work is aimed at investigating fundamental computational issues and limits in geometric computing and modeling, including the handling of uncertainty, the analysis of networks of maps and correspondences, and the geometric properties of deep networks. The group is also interested in automated interactive teaching tools.

## THOMAS ICARD



## THOMAS ICARD

Thomas works in formal philosophy on topics at the intersection of philosophy, artificial intelligence, and cognitive science, including causal reasoning, natural language

semantics, and action theory and decision making. The main technical focus is on formalisms combining rich logical structure with probabilistic and statistical reasoning. An ongoing philosophical interest, connected with central issues in philosophy of AI, is how descriptive questions (“What is in fact the case?”) relate to normative questions (e.g., “What ought we do?”).

## DAN JURAFSKY



## DAN JURAFSKY

Dan Jurafsky is Professor and Chair of Linguistics and Professor of Computer Science at Stanford University. He is the recipient of a 2002 MacArthur Fellowship, is the co-author with Jim Martin

of the widely-used textbook “Speech and Language Processing,” and co-created with Chris Manning one of the first massively open online courses, Stanford’s course in Natural Language Processing. His new trade book “The Language of Food: A Linguist Reads the Menu” came out on September 15, 2014, and was a finalist for the 2015 James Beard Award. Dan received a BA in Linguistics in 1983 and a PhD in Computer Science in 1992 from the University of California at Berkeley, was a postdoc 1992-1995 at the International Computer Science Institute, and was on the faculty of the University of Colorado, Boulder until moving to Stanford in 2003. His research ranges widely across computational linguistics; special interests include natural language understanding, machine translation, spoken language and conversation and the relationship between human and machine processing.

# Faculty Focus

continued

OUSSAMA KHATIB



**OUSSAMA KHATIB**  
Oussama has made fundamental contributions to robotics, control, and human motion analysis. His work includes the development of potential fields for control, the operational space control framework, whole body multi-contact control with prioritized null spaces, elastic planning, articulated body dynamic simulation, haptic rendering, and biomechanics based analysis of human motion.

MYKEL KOCHENDERFER



**MYKEL KOCHENDERFER**  
The Stanford Intelligent Systems Laboratory (SISL) researches advanced algorithms and analytical methods for the design of robust decision making systems. Of particular interest are systems for air traffic control, automated vehicles, and other applications where decisions must be made in uncertain, dynamic environments while maintaining safety and efficiency. Research at SISL focuses on efficient computational methods for deriving optimal decision strategies from high-dimensional, probabilistic problem representations.

DAPHNE KOLLER



**DAPHNE KOLLER**  
My main research focus is on the use of machine learning to analyze and extract valuable insight from large biomedical data sets, and on the development of novel machine learning methods to address the unique challenges of these data. The techniques used include traditional and Bayesian classification and regression, deep learning, and probabilistic graphical models. My work involves data at the cellular scale (including multiple types of omics data and microscopy), physiological scale (including diverse phenotypes as well as imaging), and population cohorts over time. A particular focus is on understanding the mechanisms underlying aging and age-related diseases, with the goal of identifying interventions that can help people live longer, healthier lives.

ANSHUL KUNDAJE



**ANSHUL KUNDAJE**  
The Kundaje lab is an interdisciplinary computational biology lab in the departments of Genetics and Computer Science at Stanford University. Our research focuses on deciphering the molecular and genetic basis of disease by integrative analysis of diverse types of large-scale genomic data. The Kundaje lab develops statistical and machine learning methods to map functional elements in the human genome across diverse cell types and tissues, model the three-dimensional genome architecture, reverse engineer mechanisms of gene regulation and interpret the molecular impact of natural and disease-associated genetic variation. We have led the integrative analysis efforts for two of the largest functional genomics consortia—The Encyclopedia of DNA Elements (ENCODE) and The Roadmap Epigenomics Project resulting in the most comprehensive functional annotation of the human genome to date. We specialize in developing interpretable machine learning methods based on deep neural networks to integrate diverse types of large-scale genomic data and infer the genomic and molecular basis of health and disease.

JAMES LANDAY

**JAMES LANDAY**

James Landay was named the Anand Rajaraman and Venky Harinarayan Professor in the School of Engineering in 2016. He specializes in human-computer interaction – the study,

design, and implementation of the interaction between people and computers—and how it can be used to improve and inform people’s health, sustainability, education and more.

JURE LESKOVEC

**JURE LESKOVEC**

Jure Leskovec studies massive complex networks, which allows him to model large complex interconnected systems at all scales, from interactions of proteins in a cell to interactions between humans in a society.

He and his research group work on machine learning and data mining approaches to study complex networks, their evolution, and the diffusion of information and influence over them. Computation over massive data is at the heart of his research and has applications in computer science, social sciences, economics, marketing, and healthcare.

FEI-FEI LI

**FEI-FEI LI**

Dr. Fei-Fei Li is an Associate Professor in the Computer Science Department at Stanford, and the co-Director of the Human-centered Artificial Intelligence Initiative and the Stanford Vision Lab.

Dr. Fei-Fei Li’s main research areas are in machine learning, deep learning, computer vision and cognitive and computational neuroscience. She has published more than 150 scientific articles in top-tier journals and conferences, including Nature, PNAS, Journal of Neuroscience, CVPR, ICCV, NIPS, ECCV, IJCV, IEEE-PAMI, etc. Dr. Fei-Fei Li obtained her B.A. degree in physics from Princeton in 1999 with High Honors, and her PhD degree in electrical engineering from California Institute of Technology (Caltech) in 2005. Dr. Li is the inventor of ImageNet and the ImageNet Challenge, a critical large-scale dataset and benchmarking effort that has contributed to the latest developments in deep learning and AI. In addition to her technical contributions, she is a national leading voice for advocating diversity in STEM and AI. For her work in AI, Dr. Li is a speaker at the TED2015 main conference, a recipient of the IAPR J.K. Aggarwal Prize, the 2016 nVidia Pioneer in AI Award, 2014 IBM Faculty Fellow Award, 2011 Alfred Sloan Faculty Award, 2012 Yahoo Labs FREP award, 2009 NSF CAREER award, and the 2006 Microsoft Research New Faculty Fellowship.

# Faculty Focus

continued

PERCY LIANG



PERCY LIANG

Percy Liang's research focus spans understanding theoretical foundations of machine learning to building practical natural language understanding systems.

An overarching goal is to build virtual assistants that can perform complex tasks based on natural language instructions. A few technical themes include: program induction: inferring how to perform a task given what to do; interactive learning: how to learn with humans in the loop; and reliable learning: how to design machine learning systems that are robust and understandable when deployed in the real world.

TENGYU MA



TENGYU MA

Tengyu Ma's research focuses on algorithm design and machine learning. The overarching goal is to achieve the fundamental understanding of machine learning and other areas of

artificial intelligence, which can lead to practical implications. His work results in novel efficient algorithms with theoretical guarantees as well as wide applications. In particular, he has worked on non-convex optimization, representation learning, deep learning, distributed optimization, and high-dimensional statistics.

CHRIS MANNING



CHRIS MANNING

Christopher Manning is a professor of computer science and linguistics at Stanford University. His PhD is from Stanford in 1995, and he held faculty positions at Carnegie Mellon University

and the University of Sydney before returning to Stanford. His research goal is computers that can intelligently process, understand, and generate human language material. Manning concentrates on machine learning approaches to computational linguistic problems, including syntactic parsing, computational semantics and pragmatics, textual inference, machine translation, and deep learning for NLP. He is an ACM Fellow, a AAAI Fellow, and an ACL Fellow, and has co-authored leading textbooks on statistical natural language processing and information retrieval.

ANDREW NG



ANDREW NG

Dr. Andrew Ng is a globally recognized leader in AI (Artificial Intelligence). He was until recently Chief Scientist at Baidu, where he led the company's ~1300 person AI Group and was responsible for driving

the company's global AI strategy and infrastructure. He led Baidu Research in Beijing and Silicon Valley as well as technical teams in the areas of speech, big data and image search. Dr. Ng is an Adjunct Professor at Stanford University's Computer Science Department. In 2011 he led the development of Stanford's Massive Open Online Course (MOOC) platform and taught an online machine learning class that was offered to over 100,000 students. This led to the co-founding of Coursera, the world's leading MOOC (Massive Open Online Courses) platform, where he continues to serve as chairman. Previously, Dr. Ng was the founding lead of the Google Brain deep learning project. Dr. Ng has authored or co-authored over 100 research papers in machine learning, robotics and related fields. He holds degrees from Carnegie Mellon University, MIT and the University of California, Berkeley.

## JUAN CARLOS NIEBLES



## JUAN CARLOS NIEBLES

Juan Carlos Niebles received a B.S. degree in Electronics Engineering from Universidad del Norte (Colombia) in 2002, an M.Sc. degree in Electrical and Computer Engineering from University of Illinois

at Urbana-Champaign in 2007, and a Ph.D. degree in Electrical Engineering from Princeton University in 2011. He is a Senior Research Scientist at the Stanford AI Lab and Associate Director of Research at the Stanford-Toyota Center for AI Research since 2015. He is also an Assistant Professor of Electrical and Electronic Engineering in Universidad del Norte (Colombia) since 2011. His research interests are in computer vision and machine learning, with a focus on visual recognition and understanding of human actions and activities, objects, scenes and events. His computer vision research has been sponsored by a Google Faculty Research award (2015), the Microsoft Research Faculty Fellowship (2012), a Google Research award (2011) and the Colombian science agency, COLCIENCIAS.

## VIJAY PANDE



## VIJAY PANDE

Vijay Pande's research centers on novel cloud computing simulation techniques to address problems in chemical biology. In particular, he has pioneered distributed computing methodology to

break fundamental barriers in the simulation of protein and nucleic acid kinetics and thermodynamics. As director of the Folding@home project, Prof. Pande has, for the first time, directly simulated protein folding dynamics, making quantitative comparisons with experimental results, often considered a "holy grail" of computational biology. His current research also includes novel computational methods for drug design, especially in the area of protein misfolding and associated diseases such as Alzheimer's and Huntington's Disease.

## MARCO PAVONE



## MARCO PAVONE

Marco Pavone is an Assistant Professor of Aeronautics and Astronautics at Stanford University, where he is the Director of the Autonomous Systems Laboratory and Co-Director of the

Center for Automotive Research at Stanford. He received a Ph.D. degree in Aeronautics and Astronautics from the Massachusetts Institute of Technology in 2010. His research combines tools from control theory, optimization, and machine learning, and is aimed at devising computationally-efficient and provably-correct planning, decision-making, and learning algorithms for autonomous robotic systems, with an emphasis on self-driving cars, autonomous aerospace vehicles, and future mobility and logistics systems. He is a recipient of several awards, including a Presidential Early Career Award for Scientists and Engineers, an ONR YIP Award, an NSF CAREER Award, and a NASA Early Career Faculty Award. He was identified by the American Society for Engineering Education (ASEE) as one of America's 20 most highly promising investigators under the age of 40.

# Faculty Focus

continued

CHRISTOPHER RÉ



**CHRISTOPHER RÉ**  
Christopher Ré is an associate professor in the Department of Computer Science at Stanford University in the InfoLab who is affiliated with the Statistical Machine Learning Group, Pervasive Parallelism

Lab, and Stanford AI Lab. His work's goal is to enable users and developers to build applications that more deeply understand and exploit data. His contributions span database theory, database systems, and machine learning, and his work has won best paper at a premier venue in each area, respectively, at PODS 2012, SIGMOD 2014, and ICML 2016. In addition, work from his group has been incorporated into major scientific and humanitarian efforts, including the IceCube neutrino detector, PaleoDeepDive and MEMEX in the fight against human trafficking, and into commercial products from major web and enterprise companies.

DORSA SADIGH



**DORSA SADIGH**  
Dorsa Sadigh is an assistant professor in Computer Science and Electrical Engineering at Stanford University. Her research interests lie in the intersection of robotics, control theory, formal methods,

and human-robot interaction. Specifically, she works on developing efficient algorithms for autonomous systems that safely and reliably interact with people. Dorsa has received her doctoral degree in Electrical Engineering and Computer Sciences (EECS) at UC Berkeley in 2017, and has received her bachelor's degree in EECS at UC Berkeley in 2012. She is awarded the NSF and NDSEG graduate research fellowships as well as the Leon O. Chua departmental award, the Arthur M. Hopkin departmental award, and the Google Anita Borg Scholarship.

KEN SALISBURY



**KEN SALISBURY**  
Professor Salisbury received his PhD from Stanford in Mechanical Engineering in 1982. At MIT from 1982-1999, he served as Principal Research Scientist in Mechanical Engineering and as a member of

the Artificial Intelligence Laboratory. Some of the projects with which he has been associated include the Salisbury (Stanford-JPL) Robot Hand, the JPL Force Reflecting Hand Controller, the MIT-WAM arm, and the Black Falcon Surgical Robot. His work with haptic interface technology led to the founding of SensAble Technologies Inc., producers of the PHANTOM haptic interface and 3D FreeForm software. In 1997 he joined the staff of Intuitive Surgical, in Mountain View CA, where as a Fellow and Scientific Advisor his efforts focused on the development of telerobotic systems for the operating room. In the fall of 1999 he joined the faculty at Stanford in the Departments of Computer Science and Surgery where his research focuses on medical robotics and surgical simulation, and the design for robots for interaction with and near humans. The most recent spinout from his lab resulted in the founding of the personal robotics program at [www.willowgarage.com](http://www.willowgarage.com).

## SILVIO SAVARESE



## SILVIO SAVARESE

Savarese's research addresses the theoretical foundations and practical applications of computational vision. His group's interest lies in discovering and proposing the fundamental principles,

algorithms and implementations for solving high level visual recognition and reconstruction problems such as object and scene understanding as well as human behavior recognition in the complex 3D world. Savarese earned his Ph.D. in Electrical Engineering from the California Institute of Technology in 2005 and was a Beckman Institute Fellow at the University of Illinois at Urbana-Champaign from 2005-2008. He joined Stanford in 2013 after being Assistant and then Associate Professor (with tenure) of Electrical and Computer Engineering at the University of Michigan, Ann Arbor, from 2008 to 2013. He is recipient of several awards including the Best Student Paper Award at CVPR 2016, the James R. Croes Medal in 2013, a TRW Automotive Endowed Research Award in 2012, an NSF Career Award in 2011 and Google Research Award in 2010. In 2002 he was awarded the Walker von Brimer Award for outstanding research initiative.

## SEBASTIAN THRUN



## SEBASTIAN THRUN

We are a team of expert computer scientists with the singular aim of significantly helping society through artificial intelligence technologies, and are constantly on the lookout for high-impact projects.

We have worked on robotics, self-driving cars, automated homes, healthcare, drones, and a number of other applications. We currently focus on three areas: AI for healthcare, AI for people-prediction, and smart-homes.

## DAN YAMINS



## DAN YAMINS

Daniel Yamins is a computational neuroscientist at Stanford University, where he's an assistant professor of Psychology and Computer Science (by courtesy), a faculty scholar at the Stanford

Neurosciences Institute, and an affiliate of the Stanford Artificial Intelligence Laboratory. His research group focuses on reverse engineering the algorithms of the human brain, both to learn both about how our minds work and build more effective artificial intelligence systems. He is especially interested in how brain circuits for sensory information processing arise via the optimization of high-performing cortical algorithms for key behavioral tasks. Most recently, he has used performance-optimized deep neural networks to build neurophysiologically accurate models of higher visual and auditory cortex. He received his AB and PhD degrees from Harvard University, was a postdoctoral research at MIT, and has been a visiting researcher at Princeton University and Los Alamos National Laboratory. He is a recipient of the James S. McDonnell Foundation award in Understanding Human Cognition.

## JAMES ZAO



## JAMES ZOU

Dr. ZOU works on a wide range of problems in machine learning (from proving mathematical properties to building large-scale algorithms) and am especially interested in applications in genomics and computational

health. I received a Ph.D. from Harvard in 2014 and was a member of Microsoft Research New England. Before this, he completed Part III in math at the University of Cambridge and was a Simons fellow at UC Berkeley. He joined Stanford in Fall 2016 and is excited to be an inaugural Chan-Zuckerberg Investigator. Dr. ZOU lead the Stanford Laboratory for Machine Learning, Genomics and Health. Recent projects include: adaptive data analysis, contrastive learning, ML for genome editing, human cell atlas (aka Google map of the human body), analyzing EHR and genetics of millions of people, and AI for cardiology. Our Ph.D. students come from CS, EE, Statistics, and Chemistry, and we collaborate closely with the Medical School and the Chan-Zuckerberg Biohub. We are also deeply interested in the broader social impact of ML, and actively work on improving the fairness, robustness, and transparency of ML.

## About the Stanford Artificial Intelligence Lab

Artificial Intelligence comprises the complete loop from sensing to perception, learning, communications, and action. Stanford's Artificial Intelligence Lab is devoted to the design of intelligent machines that serve, extend, expand, and improve human endeavor, making life more productive, safer, and healthier. These intelligent machines will learn everything about anything using multi-sensory information and the entire cyber world of information and knowledge.

The faculty members of the Stanford AI Lab are changing the world. Their research includes deep learning and machine learning; robotics; natural language processing; vision, haptics, and sensing; big data and knowledge base; and genomics, medicine, and healthcare. The approach is personalized, adaptive, anticipatory, communicative, and context aware.



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