The MIT Quest for Intelligence

The MIT Quest for Intelligence is a campus-wide initiative launched in 2018 to advance our understanding of natural intelligence by integrating scientific inquiry with engineering to address real-world applications that are beyond current artificial machine capabilities.

In January 2020, MIT Quest joined the MIT Stephen A. Schwarzman College of Computing as one of its research arms. This organizational shift coincided with a restructuring of leadership with Jim DiCarlo, Aude Oliva, and Nick Roy assuming co-director leadership roles, and Antonio Torralba stepping down as director of the Quest to assume a new role as head of faculty of the artificial intelligence (AI) and decision making subunit within the Department of Electrical Engineering and Computer Science (EECS). The MIT Quest vision, goals, and strategic planning around supporting research missions were subsequently refocused during this transition.

COVID-19 has had a significant impact on MIT Quest's research and activities. Several events were canceled, and an MIT Quest research mission request for proposals was delayed when campus shut down in March 2020. However, MIT Quest leveraged the expertise of its AI engineers and its unique ability to bring together researchers from across campus to develop a predictive modeling system: the MIT COVID-19 Response System (MCRS). MCRS uses anonymized COVID-19 test results and campus mobility data, in part, to help MIT predict and minimize campus risk. This spring, our affiliated MIT-IBM Watson AI Lab also issued a call for AI-related research proposals to address COVID-19 and its social and economic consequences. The lab has funded 10 MIT-led projects to date.

By bringing together researchers from across the Institute, MIT Quest aims to go beyond business as usual. Our research portfolio has grown to more than 100 projects, and we have sponsored 143 student appointments through MIT's Undergraduate Research Opportunities Program (UROP). Research topics range from fundamental problems in the science and engineering of intelligence to applications with shorter term, more immediate benefits. MIT Quest remains committed to its holistic vision for shaping the future of the science and engineering of intelligence and develops tools for real-world impact, and we look forward to expanding on this work with the MIT Schwarzman College of Computing (SCC).

Goals, Objectives, and Priorities

MIT Quest believes that we must treat the study of natural intelligence and efforts to build intelligent systems as interlocking aspects of the same grand challenge. New scientific theories of natural intelligence must be developed, and computational models of those theories must be implemented and compared with, and tested in, real-world situations. MIT Quest's approach does not merely require a crossing of boundaries, but a true integration across disciplines.

MIT Quest will execute on this vision by providing seed funding to incubate so-called missions, composed of interdisciplinary research teams focused on specific domains of natural or artificial intelligence. The missions are defined by the following guiding principles:

- A mission is focused on a problem domain where naturally intelligent systems outperform current AI systems.
- A mission has identified real-world problems that would benefit from achieving that performance in AI systems, and the stakeholders who care about solving the problem.
- A mission has a process for building AI systems that test theories of that outperformance by iterative comparison to natural intelligence and iterative validation on those real-world problems.

MIT Quest's Values

- Fundamental research: We are committed to progressing our understanding of natural intelligence. We choose problems that require advances from both science and engineering.
- High-impact applications: We are committed to solving real-world problems for MIT and the world at large. We validate our work on problems that people care about.
- Social responsibility: We recognize that our work will affect society in ways that are hard to predict. We are thoughtful about those effects; we are transparent and accountable.

Who is Served?

- The MIT community: MIT is served in two ways: first, we serve MIT by advancing our understanding of intelligence and developing new models, algorithms, and techniques. Second, we serve MIT by building a set of engineered systems designed to address technical, on-campus issues encountered by faculty, students, and researchers.
- Our country and the world: By developing a new science of natural intelligence and new systems that implement that science, we will ensure that the United States maintains its preeminent position as the leader of intelligent and learning systems. At the same time, we take seriously our responsibility to educate the world and create substantial economic growth for all.
- Humanity: Advances in our understanding of natural intelligence and its implementation in artificial systems will expose new ways to ameliorate brain disorders, better ways to educate people, and will further revolutionize how people live and work the world over. For example, communication, transportation, and manufacturing systems are already being transformed by progress in AI. New forms of intelligent systems that are on par with human intelligence in terms of capability, generalization, and efficient energetics are essential for continuing to create such transformations in all areas of human life.

Industry Research Collaborations

MIT Quest has built a three-tier industry engagement program (Discovery, Exploratory, Visionary) offering companies a variety of ways to advance their strategic goals. We also host three research affiliates, the MIT-IBM Watson AI Lab, the Center for Deployable Machine Learning, and the MIT-Liberty Mutual Insurance Collaboration.

With these combined sources of income, MIT Quest in FY2020 had a total spent fund volume of $2.3 million. Total research volume spent for the MIT-IBM Watson AI Lab was $6.4 million; of that, $5.2 million came from secondary sponsored research.

- We have eight members at the Discovery level ($275,000/year, three year commitment), which provides exposure to a broad range of faculty and AI projects via participation in MIT events, opportunities to access MIT talent, and previews of Quest research and tools in emerging fields of AI and machine learning.
- We have one member at the Exploratory level ($1 million/year, three year commitment), which multiplies the impact of Discovery membership with targeted research, providing the opportunity to develop a set of research projects with MIT Quest researchers and engineers.
- We have one member at the Visionary level ($5 million/year, five year commitment), which provides broad access to faculty, students, and state-of-the-art research via joint projects, early access to research results, platforms and tools, and options for corporate researchers to join MIT as a scientist in residence. Liberty Mutual signed on as a Visionary member in April 2019.

MIT-IBM Watson AI Lab: A Founding Quest Affiliate

The MIT-IBM Watson AI Lab aims to advance AI science and discovery, hardware, software, and algorithms related to deep learning and reasoning; amplify AI's impact in industries such as health care and cybersecurity; and explore the economic and ethical implications of AI on society. Co-led by Aude Oliva, co-director of MIT Quest, and David Cox, of IBM Research, and co-chaired by Anantha Chandrakasan, dean of the School of Engineering, and Dario Gil, vice president of AI at IBM Research, the lab represents an investment of $240 million in AI research and education over 10 years. In FY2020, the lab raised an extra $30 million by signing new IBM corporate members to the lab.

In three years, the lab has solicited more than 330 research proposals and awarded a total of 93 grants to 23 departments, labs, and centers across campus. The lab launched 50 new projects in AY2020, including 10 related to COVID-19. More than 100 principal investigators from MIT, and 45 researchers from IBM, are actively engaged on single and multiyear projects. MIT and IBM researchers have co-authored more than 100 peer-reviewed papers since the lab's founding.

Center for Deployable Machine Learning

From self-driving cars to real-time language translation, technology once dismissed as science fiction is close to becoming reality. Or is it? The truth is, most AI systems aren't ready for prime time. They're prone to failure beyond the narrow settings in which

they were designed, vulnerable to malicious interference, and may carry unexpectedly high societal costs when scaled. To build next generation AI systems that are robust, trustworthy, and socially responsible, we need a radically different approach. The new MIT Center for Deployable Machine Learning offers the breadth and depth of knowledge to help AI achieve its potential in science, industry, and society. Led by Aleksander Madry, a professor in EECS, the center brings together faculty experts in interpretability, security, computer vision, and applied machine learning.

The MIT-Liberty Mutual Insurance Collaboration: Visionary-Level Member

The MIT-Liberty Mutual Liberty Collaboration represents a $25 million, five year commitment to advance artificial intelligence research in computer vision, natural language processing, machine learning fairness, data privacy and security, and risk-aware decision making, among other topics. In its first year, Liberty Mutual solicited 23 research proposals and awarded seven grants totaling $2 million to researchers in the School of Engineering, School of Science, MIT Sloan School of Management, and MIT Schwarzman College of Computing. Funded projects include: developing natural language processing systems to analyze policy language and legal outcomes; developing tools to optimize internal job opportunities for employee retention; and analyzing data sharing between manufacturers and suppliers to improve business relationships and opportunities. Aude Oliva serves as the PI of this collaboration.

Resource Development

We are committed to working closely with SCC to provide philanthropic partnership opportunities to help advance our mutual vision. Current philanthropic support for MIT Quest includes a $5 million gift from Eric Schmidt to fund a range of AI education projects; a $10 million gift from David Siegel to fund research missions, including "Scaling AI the Human Way"; a $3 million gift from SenseTime founder Tang Xiao'ou to fund Diversity, Equity, and Inclusion graduate fellowships, research missions, and the Quest COVID-19 mission; and a new $750,000 gift from Neil Webber to support Quest engineering activities.

MIT Quest Response to the COVID-19 Pandemic

Not long after MIT closed its campus in March 2020, senior administrators tasked the MIT Quest's engineering team with building a model, MCRS, to help them model the spread of COVID-19 on campus and plan for a safe reopening. A collaboration of MIT Quest, MIT Lincoln Laboratory, and researchers across the Institute, MCRS required redirecting Quest engineers to build infrastructure for ingesting a variety of data and fusing them into a daily picture of how COVID-19 might be spread on campus.

Analyzed data include plans from PIs, health attestations, and building-access card reader data. The data are carefully managed and anonymized to protect individual privacy, with close oversight by MIT's Legal, Ethical, and Equity Committee and the Information Technology Governance Committee.

In addition to the campus models, MIT Quest spent $1 million in SenseTime funds to fund five research groups, as well as MIT Quest software engineers, to build models of COVID-19 prevalence at the zip code level, COVID-19 transmission across Boston public transit, and aerobic COVID-19 transmission across MIT buildings. The team also performed a sensitivity

analysis of existing models. Data will be integrated into a dashboard developed by MIT Lincoln Laboratory to help MIT senior administrators understand how the combined movements of people on campus might affect the viral reproduction rate on campus.

Selected Research

We highlight some of our current MIT Quest and MIT-IBM Watson AI Lab-funded projects below. In addition, MIT Quest broadly supported AI research on campus by transferring $1.3 million in cloud-computing services to MIT's Research Computing Committee, and Information Systems and Technology Office for use by students and researchers in AY2020. Google provided $1 million in cloud credits; and Microsoft Azure provided $300,000.

MIT Quest

A More Efficient Nuclear Reactor

MIT Quest is working with Koroush Shirvan, associate professor in the Department of Nuclear Science and Engineering, to train a reinforcement learning agent to find the best way to lay out fuel rods in a reactor core. To simulate the process, the researchers turned the problem into a game, borrowing a machine learning technique for producing agents with superhuman abilities at the games chess and Go.

Making More Livers Available to Patients Who Need Them

To approve a liver for transplant, pathologists study a slice of tissue and estimate whether its fat content qualifies as low enough. But there are often too few qualified doctors to review tissue samples on the tight timeline needed. Viable livers are inevitably discarded. In this project, researchers are training a deep learning model to pick out globules of fat on a slide to estimate the liver's overall fat content. Eventually, the model will learn to isolate fat globules in unlabeled images on its own, outputting an estimate with the fat globules circled.

Pinpointing New Dendritic Spines to Understand How Memories Form

Improved imaging techniques have allowed neuroscientists to see up close the tiny nubs on brain cell dendrites that grow and change shape as memories form. By tracking the evolution of dendritic spines in cells linked to a single memory trace, before and after a learning episode, researchers can estimate where memories may be physically stored. But hand-labeling these before-and-after images is tedious and time-consuming. In this project, MIT Quest is working with Picower Professor Susumu Tonegawa's lab to train an AI model to automatically identify new spines, and potentially new memory traces.

MIT-IBM Watson AI Lab

Providing Global Access to a Coronavirus Vaccine

A vaccine against SARS-CoV-2 would be a crucial turning point in the fight against the COVID-19 pandemic. Yet, its potential impact will be determined by the ability to rapidly and equitably distribute billions of doses globally. In this project led by Professor of Biology Anthony Sinskey and Stacy Springs, researchers will build data-driven statistical models to evaluate trade-offs in scaling the manufacture and supply of vaccine

candidates. The goal is to give decision makers the evidence needed to cost-effectively achieve global access.

A Return to Normalcy via Mass Testing and Other Measures

In less than a year, the COVID-19 pandemic has devastated towns and cities worldwide. Researchers are now trying to understand how policies can limit new infections and deaths and protect the most vulnerable. In this project led by Dimitris Bertsimas—Boeing Leaders for Global Operations Professor of Management, professor of Operations Research, and associate dean for Business Analytics, MIT Sloan School of Management—researchers will study the effects of targeted lockdowns to reduce new infections, hospital admissions, and deaths. In a second phase, they will develop machine learning models to predict how vulnerable a given patient is to COVID-19, and if personalized treatments can help. They will also develop a fast, inexpensive COVID-19 test that can pave the way for mass testing.

Treating COVID-19 with Repurposed Drugs

As the COVID-19 pandemic's global death toll mounts, researchers are racing to find a cure among already approved drugs. Machine learning can expedite screening by letting researchers quickly predict if promising candidates can hit their target. In this project led by Rafael Gomez-Bombarelli—Cheah Assistant Professor in Material Science and Engineering—researchers will represent molecules in three-dimensions to see if added spatial information can help to identify the most effective drugs. They will use federal supercomputers to further speed up the screening process.

Designing Proteins to Block the New Coronavirus

Proteins are the basic building blocks of life, and with AI, researchers can explore and manipulate their structures to address long-standing problems. As an example, take perishable food: the MIT-IBM Watson AI Lab recently used AI to discover that a silk protein made by honeybees could double as a coating for quick-to-rot foods to extend their shelf life. In this project led by Markus Buehler—Jerry McAfee (1940) Professor in Engineering and professor of Civil and Environmental Engineering (CEE)—and Benedetto Marelli—associate professor of CEE—researchers will enlist the protein-folding method from their honeybee silk discovery to try and defeat the new coronavirus. Their goal is to design proteins that block the virus from binding to human cells, and to synthesize and test their unique protein creations in the lab.

Reverse Engineering a Child's Common-Sense Reasoning

To improve how deep learning models perform in real-world settings, researchers are trying to reverse engineer a child's ability to perceive the world in three dimensions, manipulate physical objects, and infer the mental states of other people. In this project led by Vikash Mansinghka—principal research scientist of Brain and Cognitive Sciences—and Josh Tenenbaum—professor of Cognitive Science and Computation, researchers are using their recently developed probabilistic programming language, Gen, to remove errors from the output of deep learning algorithms using symbolic generative models. Their goal is an AI architecture that can be used in robotics, including on computer vision and cognitive tasks.

Training and Testing AI Systems in a 3D World Like Our Own

Modern AI systems are trained on large, labeled datasets to see and hear in a process that bears little resemblance to real-world learning. To create more realistic scenarios, and drive further advances in AI, MIT and IBM researchers have created a virtual environment, ThreeDWorld, with cutting-edge video game technology. Through a range of tasks in this simulated world, they will try to train AI systems to perceive physical structures and events so that they can develop a more humanlike perceptual intelligence.

Finding Efficient "Lottery Tickets" for Deep Learning

Under the Lottery Ticket Hypothesis proposed by MIT researchers, deep neural network models contain much smaller subnetworks that can be isolated and trained to full accuracy. If the right subnetwork is found early in training, models can sort images and perform other tasks with 90% fewer connections. Here, researchers will extend the idea to other settings, and explore ways to further cut the computational expense of model training.

Community Outreach and Activities

Events

The COVID-19 pandemic forced us to cancel several events in spring 2020, including a workshop on our early-phase research mission, Scaling AI the Human Way. But we did host two major workshops in summer 2019 and several smaller events:

The Algonauts Project: Explaining the Human Visual Brain (July 2019)

This two-day challenge and workshop brought together biological and artificial intelligence researchers to exchange ideas for collaborating to advance both fields. The challenge portion of the event focused on building computer vision models that simulate how the brain sees and recognizes objects. The event drew about 200 students and researchers, and resulted in a published paper about the workshop in the journal *Nature Machine Intelligence*.

Workshop on Collective Intelligence (September 2019)

Financial markets operate on the principle of collective intelligence to set prices for stocks. So does internet search to deliver answers to questions thousands have asked before. Computers can make groups even smarter, but how should humans and machines interact? This workshop explored the ways that people and machines, working separately and together, can leverage their strengths, resolve conflicts, and create value for society. The workshop featured MIT experts who are exploring various aspects of collective intelligence.

Other notable events include the following:

- We co-sponsored the MIT-IBM Watson AI Lab's second-annual AI Research Week at MIT, featuring speakers, panels, workshops and networking opportunities. (September 2019)
- With the MIT-IBM Watson AI Lab, we co-hosted a Green AI Hackathon to introduce students to Satori, MIT's new supercomputer, and inspire new energy saving hacks for training deep learning models. (February 2020)

- We organized an informal research mixer on embodied intelligence, with posters and spotlight talks focused on understanding the nature of intelligent behavior by studying human intelligence and designing intelligent agents. (October 2020)
- We hosted the National Security Commission on AI for a presentation on the implications of AI on national security and research. (February 2020)
- We co-sponsored several lectures that brought familiar names in computing to MIT, including University of Washington's Batya Friedman and Facebook's Edith Beigné.

Education

MIT Quest trains and mentors undergraduates interested in neuroscience, psychology, and software engineering through UROP. We sponsored 43 fall and 46 spring UROP projects. We sponsored 15 Super UROP projects and 31 projects over the winter Independent Activities Period (IAP).

MIT Quest helped pilot several educational programs. As part of Massachusetts STEM week in October 2019, Cynthia Breazeal and her lab, with i2 Learning, piloted the first AI and ethics curriculum for middle school. With the Girl Scouts of eastern Massachusetts, Breazeal's lab piloted a new children and data privacy curriculum. Exercises included a debate on the new data privacy bill at the Edward Kennedy Institute.

MIT Quest and the MIT IBM-Watson AI Lab helped sponsor events, conferences, and student activities for the benefit of the AI community at MIT and beyond. They include the following:

- AI Latin America Summit at MIT (August 2019); student organizers profiled in MIT News
- IEEE MIT Undergraduate Research Technology Conference (August 2019)
- HackMIT Computer Hackathon (November 2019)
- IAP Course 6.S191 Introduction to Deep Learning (January 2020); organizers Ava Soleimany and Alexander Amini were profiled in MIT News
- International Conference on Computer Vision (ICCV) Multi-Moments in Time Challenge (November 2019)
- MIT Machine Learning Retreat (February 2020)
- The undergraduate Artificial Intelligence Club at MIT (formerly Machine Intelligence Community) (AY2020)
- MIT Quest provided the engineering support for MIT students to build a virtual replica of MIT's campus in the videogame Minecraft during the early days of the COVID-19 lockdown (March 2020)
- Funded Workshop on Learning from Instructional Videos at the Conference on Computer Vision and Pattern Recognition (June 2020)

Research conferences, talks, and student activities supported by MIT Quest are as follows:

- Shared Visual Representations in Human and Machine Intelligence Workshop at NeurIPS 2019 (December 2019)
- Funded two undergraduate internships to improve the state of Massachusetts' unemployment benefit system (via MIT Priscilla King Gray Center for Public Service) (June 2020)
- Machine Learning across MIT MLTea graduate student seminar series (AY2020)
- Helped organize, with IBM, the AI Club@MIT's second annual research blitz featuring lightning talks by MIT researchers (October 2019)
- Presented MIT Quest's research at the European College of Sport Science Congress (Prague, July 2019), VistaPrint Emerging Tech Conference (Waltham, MA, September 2019), Industrial Liaison Program MIT Startup Showcase (Santa Clara, CA, October 2019), MIT Sports Summit (Cambridge, MA, November 2019), and Google Sports Analytics Meetup (Cambridge, MA, March 2020)

Communications

We produced 26 research and education stories for MIT News in the last year featuring MIT Quest or MIT-IBM Watson AI Lab work, and were featured in seven staff-written articles. The MIT-IBM Watson AI Lab was cited or featured in the mass media 38 times; highlights include a discussion in the New York Times about neuro-symbolic AI by the lab's IBM director, David Cox; coverage in *The Verge* of a new object-recognition dataset led by Boris Katz; and a piece in *Wired* on methods devised by Song Han, associate professor in EECS, to speed video recognition. A variety of research projects led by MIT Quest were featured this spring in *MIT Spectrum*.

With original content and other AI-related press coverage, we continued to add followers to our Twitter and Facebook accounts, now at 1,960 and 527 respectively. We continue to build out our website to feature news, staff, newsletter and annual report content, selected research projects, and messaging for prospective corporate and philanthropic donors. Our engineering team also built out a website to streamline project management and data sharing. The MIT-IBM Watson AI Lab's Twitter feed, launched and managed by MIT Quest, has grown to 2,333 followers.

We are now producing a quarterly newsletter for MIT-IBM Watson AI Lab and a biannual newsletter for MIT Quest. MIT Quest did not put out a 2020 annual report due to the pandemic.

This year we helped redesign and launch a new MIT-IBM Watson AI Lab website to raise the lab's visibility. We wrote and uploaded profiles for more than 90 MIT researchers, and continue to help write and pitch stories about lab-funded research, which are posted on the site. Based on the success of the redesign, we are now building a new and improved Quest website in Drupal which will allow us to highlight Quest-funded research in a more flexible and engaging way.

Administration and Governance

Under our new leadership structure, MIT Quest now has three co-directors:

James DiCarlo

The scientific lead is responsible for advancing the understanding of natural intelligence in different, domain-specific challenges identified by the application lead, and coordinating the development of models of natural intelligence implemented by the engineering team.

Aude Oliva

The application lead is responsible for developing domain-specific problems that can be engaged and advanced by models of natural and artificial intelligence that are implemented and adapted by the engineering team.

Nick Roy

The engineering lead is responsible for leading a team of software engineers who can implement and test computational models of natural intelligence proposed by the scientific team, to address domain-specific problems developed by the application team.

New hires in FY2020 are: Gilbert Cordova, administrative officer, August 2019; Allison Provaire, project and events administrator, September 2019; and Rose Rizzo, financial administrator, January 2020; and Erik Vogan, managing director of corporate engagement for MIT Quest and head of operations for MIT Quest engineering team, March 2020.

Research scientist hires in FY2020 are: Kyle Keane, who brings substantial experience on applying AI to physical systems and materials science, September 2019; and Ruijie He and Dhaval Adjodah, who bring their expertise in building platforms for data analytics and modelling time-series data to aid the COVID-19 MCRS project, summer 2020.

Milo Phillips-Brown was hired as MIT Quest's first distinguished postdoctoral scholar in ethics and technology. Supervised by David Kaiser, SCC associate dean of Social and Ethical Responsibilities of Computing, the job is meant to assess the challenges and opportunities of AI, to offer insights for better design, policy, and outcomes.

James DiCarlo
Co-Director, Scientific Lead, MIT Quest for Intelligence
Head, Department of Brain and Cognitive Sciences
Peter de Florez Professor of Neuroscience

Aude Oliva
Co-Director, Application Lead, MIT Quest for Intelligence
MIT Director of the MIT-IBM Watson AI Lab
Senior Research Scientist, Computer Science and Artificial Intelligence Laboratory

Nick Roy
Co-Director, Engineering Lead, MIT Quest for Intelligence
Head, Computing Sector, Department of Aeronautics and Astronautics
Professor of Aeronautics and Astronautics