

B8104 – Technology Breakthroughs – Fall A term 2023

Professor Shih-Fu Chang, Dean School of Engineering and Applied Sciences

520 Mudd

sc250@columbia.edu

Professor Costis Maglaras, Dean Columbia Business School

352 Kravis Hall

c.maglaras@gsb.columbia.edu

Time: Mondays 2:20pm – 5:35pm (except first class on Fri Sept 8th)

Office Hours: by appointment

Course Description:

Technological breakthroughs have relentlessly driven change and disruption, affected every aspect of our lives, transformed traditional industries and created new ones for digital goods and services, and ushered a time of opportunity and change across the business spectrum and society.

In this course we will review six such areas – deep learning and neural networks; large language models and generative AI; imaging and vision; AI and robotics; dexterous robotics; blockchain. In each area, we will get an overview of the state of the art, gain understanding of the problems being addressed, what are important open questions to be addressed in the future; we will review successful applications, and try to glean insight as to areas where successful implementation is still more elusive; and finally, discuss the investment and entrepreneurial landscape in each such area.

Each 3-hr session will be organized as follows (distribution of time is flexible):

* 90 min overview lecture… what are the key questions / issues / challenges / opportunities; what is the state of the art; where has it been applied successfully and impactfully and (perhaps) why; what are the key problems for the next 5/10 years; risks (if applicable); where will we see change/disruption/applications
* 45-60 min panel discussion between the faculty and investors or entrepreneurs (practitioners) and about what is happening now; what do we feel about the future; …
* 30-45 min Q&A

For each session there will be a) some accessible pre-read; b) a short homework assignment based on the pre-read (often multiple choice); c) a set post-session readings for students to learn more about the area; d) a set of post-session questions (mostly multiple-choice or simple answer) on Canvas and a related Canvas discussion to help on debriefing the material; and e) 2-3 ideas for a course project that could be analysis of a technology; analysis of an innovative firm or firms; etc.

**COURSE ADMINISTRATION**

*Teaching and Course Team:*

Shih-Fu Cheng and Costis Maglaras serve as course leaders and will lead the introduction and participate in the discussions in the various sessions. Each session will be led by faculty experts from Business and SEAS: Daniel Guetta (DRO, Business) and Garud Iyengar (IEOR, SEAS) on deep learning and neural networks; Kathy McKeown and Vishal Misra (CS, SEAS) on generative AI and LLM; Shree Nayer and Carl Vondrick (CS, SEAS) on imagine and vision; Hod Lipson (Mech Eng, SEAS) on AI and Robotics; Matei Ciocarlie (Mech Eng, SEAS) on dexterous robotics; Ciamac Moallemi (DRO, Business) and Tim Roughgarden (CS, SEAS) on blockchain.

The teaching assistant(s) TBD.

*Course Materials:* There is no textbook required. The class readings and class slides will be posted on the class website on Canvas.

*Grading:* The course grade will be determined based on participation in-class (25%), Canvas discussions and session pre- and de-debrief questions (25%) and a course project (50%) on a topic to be agreed upon with SC and CM that can explore some of the suggestions of the course faculty leaders for each session, or be on related topics.

*Course project deliverables will be papers (of ~2500 words; 6-10 pg) may be done in groups of up to three people. Project ideas will be provided for each session below. You should seek approval for your chosen topic from one of us by Oct 3.*

***Final papers are due by 9:00AM on Monday, October 30. Students are encouraged to provide updates of project progress to SC or CM before the final deadline.***

*Connection to the Core Curriculum:* Topics in Business Analytics, Strategy Formulation are related to thinking about the technologies and their adoption in industry.

Session plan:

Class 1 – Fri Sept 8

Deep learning and Neural Networks

Professor [Daniel Guetta](https://danguetta.github.io/) (CBS, DRO) and Professor [Garud Iyengar](https://www.ieor.columbia.edu/faculty/garud-iyengar) (SEAS, IEOR)

Every part of our lives is becoming increasingly data-driven; from deciding whether we're likely to click on an ad, to determining whether we'll be able to repay a loan, to deciding whether a smudge on an X-ray is a malignant tumor. This revolution has been enabled by massive strides in data science - a computer's ability to understand massive amounts of data as a human would. Supreme among data science techniques are deep neural networks - algorithms that attempt to mimic the workings of the human brain, and work astonishingly well in many situations, sometimes even beating humans. In this lecture, we will introduce neural networks, discuss their history and recent rise to prominence, and discuss various challenges (both technical and societal) associated with their *use.*

**Class 2 – Mon Sept 11**

**Imagine and Vision**

**Professor** [**Shree Nayer**](http://www.cs.columbia.edu/~nayar/) **(SEAS, CS) and Professor** [**Carl Vondrick**](http://www.cs.columbia.edu/~vondrick/) **(SEAS, CS)**

This session will discuss technologies that enable machines to capture visual information (imaging) and analyze visual data (vision). Over the next several years, advances in computational imaging and computer vision will transform communication, transportation, shopping, health, and the media throughout our society. The session will introduce the basic technologies that have been developed, breakthroughs that are on the horizon, and the impact imaging and vision have had on the way we live our lives. We will identify grand challenges for the future, solutions to which can dramatically impact the way visual information is used by both humans and machines.

Class 3 – Mon Sept 18

Generative AI and Large Language Models

Professor [Vishal Misra](https://www.engineering.columbia.edu/faculty/vishal-misra) (SEAS, CS) and [Kathy McKeown](http://www.cs.columbia.edu/~kathy/) (SEAS, CS)

**Class 4 – Mon Sept 25**

**Robotics and AI**

**Professor** [**Hod Lipson**](https://www.me.columbia.edu/faculty/hod-lipson) **(SEAS, ME)**

From drones to driverless cars, Robots -- the physical embodiment of artificial intelligence – are making their way into every aspect of our lives. We’ll cover the basic driving technologies behind the ascent of robotics, including AI, digital manufacturing and battery power. We’ll explore how different types of robots can help address some of the world’s greatest challenges and opportunities, from disrupted supply chains to elder care. We’ll end by taking a long view into the future of robotics, looking at robots that do what you’d least expect machines to be doing: Self-replicate, self-reflect, ask questions and be creative.

Class 5 – Mon Oct 2

Blockchain

Professor [Ciamac Moallemi](https://moallemi.com/ciamac/) (Business, DRO) and [Tim Roughgarden](http://timroughgarden.org/) (SEAS, CS)

In this session, we will explore the technology, economics, and applications of blockchain.  These systems, with Bitcoin and Ethereum the biggest and most well-known examples, maintain a consistent view of the world in a "decentralized" manner, beyond the control of any single entity.  General-purpose platforms such as Ethereum can also execute "smart contracts" --- effectively multi-agent computer programs --- that in turn can reliably implement potentially very complex and high value mechanisms for interaction between participants. Amazingly, this can be done without the need for trust amongst participants or any underlying legal recourse.  
  
In addition to the underpinnings of the core technology, we will survey applications in the area of "decentralized finance," including platforms for core financial functions such as trading and lending, but in the absence of trusted intermediaries. We will also discuss decentralized governance protocols, which offer mechanisms by which groups can coordinate control of economic assets, as an alternative or complement to traditional legal structures such as corporations, partnerships, and non-profits.

Class 6 – Mon Oct 9

Dexterous Robotics and Embodied AI

Professor [Matei Ciocarlie](https://www.engineering.columbia.edu/faculty/matei-ciocarlie) (SEAS, ME)

Our society has already been fundamentally shaped by robots: for more than half a century, industrial robots have been performing billions of cycles of highly repetitive tasks on assembly lines the world over, building affordable cars, phones, and everything in between. But the field is changing: the emergence of artificial intelligence is letting robots step away from the highly structured assembly line, and into the unstructured, complex, messy real world. What new applications await there, and how far are robots from being deployed for each? In this section, we will look at recent breakthroughs in artificial intelligence applicable to agents with physical embodiments (robots), such as deep reinforcement learning, motor learning and control, new sensor technologies for touch and proprioception, etc. Then, we will look at how these breakthroughs are enabling robotic locomotion, perception, and manipulation to be deployed in new domains, such as manufacturing, logistics, healthcare, or even consumer products in the home. We will pay particular attention to dexterous manipulation, an example of a very difficult motor control problem with potential for deployment across a wide spectrum of fields.