Columbia Business School

B8104 – Technology Breakthroughs – Fall A term 2022

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Time: Mondays 2:00pm – 5:15pm; first session on Fri Sept 9 2:00 – 5:15pm
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; AI and robotics; imaging and vision; photonics; blockchain; smart / digital cities. 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):

- 75 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 set post-session readings for students to learn more about the area; c) a set of brief (mostly multiple-choice or simple answer) questions on Canvas and a related Canvas discussion to help on debriefing the material; and d) 2-3 ideas for a course project that could be analysis of a technology; analysis of an innovative firm or firms; a new application of the technology with potential business models, 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; Hod Lipson (Mech Eng, SEAS) on AI and Robotics; Shree Nayer and Carl Vondrick (CS, SEAS) on imagine and vision; Michal Lipson (EE, SEAS) on photonics; Ciamac Moallemi (DRO, Business) and Tim Roughgarden (CS, SEAS) on blockchain; Andrew Smyth (Civil Eng, SEAS) on digital cities.

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 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. Groups consisting of both CBS MBA and SEAS MS students are welcomed but not required. Project ideas will be provided for each session below. You should seek approval for your chosen topic from one of us by Oct 10.

Final papers are due by 9:00AM on Monday, October 31. 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 9

Deep learning and Neural Networks
Professor Daniel Guetta (CBS, DRO) and Professor 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 12

Computational Imagining and Vision
Professor Shree Nayer (SEAS, CS) and Professor Carl 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 19

Robotics and AI
Professor Hod Lipson (SEAS)

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 4 – Mon Sept 26

Photonics
Professor Michal Lipson (SEAS, EE)

In the past decade the photonic community witnessed a complete transformation of optics. We are now able to define and control the flow of light using thousands of monolithically integrated optical components – all on a silicon chip. The main drive for silicon photonics is the ability to transmit and manipulate ultra-high bandwidth with low power dissipation. Today there are hundreds of products being developed and commercialized towards this goal.

The field of silicon photonics is rapidly evolving and is now enabling completely new applications, ranging from Lidar to novel computing systems. This is partly due to the development of novel chip-scale technologies, novel devices and novel materials compatible with silicon photonics. Many of these technologies and devices can manipulate light across the whole VIS, IR and the Mid IR spectrum. I will discuss these emerging applications, as well as the advancement brought by these novel devices and materials. I will also describe the challenges of the field and some of the recent innovations that can potentially address these challenges.

Class 5 – Mon Oct 3

Blockchain
Professor Ciamac Moallemi (Business, DRO) and Tim Roughgarden (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 10

Digital Cities
Professor Andrew Smyth (SEAS, Civil Eng)

As more of the world's population than ever lives in cities, and cities hold enormous creative and sustainability potential, it is essential we overcome urban challenges associated with increased growth and congestion and make cities work better for all. The potential of making

cities more livable by adding a digital layer to complement our physical layer has been progressing in fits and starts around the world in various ways through public and private ventures. These smart cities initiatives have addressed numerous sectors including mobility, public safety, city services, environment, energy, connectivity, governance and more. While new technological breakthroughs in advanced wireless networks and edge computing, coupled with AI and computer vision can enable a second generation of more exciting real-time high-precision driven applications, challenges to smart cities advances are appearing on the horizon - among them, data privacy concerns, security robustness in an increasingly cyber-physical world, and scope creep and bleed over from other technological disruptions, in particular, e-commerce. In democratic societies there is an opportunity to develop new applications through the convergence of technologies in a manner that will be accepted by cities and their residents.