Economics of Artificial Intelligence

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1 Course Description

In this course, we provide students with basic understandings of the operation of the modern economy shaped by the so-called second machine age (Brynjolfsson and McAfee, 2014), the third digital revolution (Gershenfeld, Gershenfeld and Cutcher-Gershenfeld, 2017), or the fourth industrial revolution (Schwab, 2017). Basically, this economy is technologically underpinned by Web 2.0, mobile devices, smartphones, internet of everything, ubiquitous computing, clouds, big data, machine learning, blockchains, software agents, and robots. This series of technologies has transformed the economy from the earlier information-rich environment to an interaction-intensive environment or a computationally intensive economy or, simply, an intelligent economy, which has been manifested by the new faces, such as what is known as platform economy, gig economy, sharing economy, blockchain economy, and cryptocurrency economy. The changes and impacts are overwhelming. It has fundamentally changed the operation of labor markets and financial markets, the supply chains (the flow from production to consumption), and the way that ordinary people make their choices and decisions. As all past industrial revolutions, many jobs are anticipated to go extinction, except that this time, not just labor-intensive jobs will disappear, many brian-intensive jobs will disappear too; furthermore, the space left for middlemen will be substantially reduced, leading to what is known as disintermediation.

While the appearance of such an economy has already been seen in many fictionary novels and movies, these imaginations, no matter how mindblowing they are, are not substitutes for a solid knowledge of this bewildering economy. Neither can it be simplified just into science or engineering. To have a full harness of the economy, one needs to have a grasp of the history which brings us here, and what our ancestors in their time said about our time. Humanities, therefore, definitely plays a role. Just a reading of those scientifically-induced monsters created by novelists already propelled us to appreciate the discussions of the future possible wars between humans and machines. Philosophy or philosophy of machines also provides us the general framework or abstractions to reflect upon this economy, but it is economics that serves as the ladder which allows us to come to the ground.

This course provides a brief review of AI in economics in the following senses. First, from a historical viewpoint, the course provides a review of AI in the history of economic analysis. There are great economists who are pioneers in AI but are often ignored by economics students, such as Oskar Lange (1904-1965), Fredrich Hayek (1899-1992), John von Neumann (1903-1957), and Herbert Simon (1916-2001). Second, computer science, a young emerging field in the 1960s, is constantly shaped by economics. The so-called distributed AI or behavioral AI, as an alternative for the classical AI, is under the direct influence of economics. This connection between AI and economics is often left unnoticed by both economists and computer scientists. This course will then fill some of these gaps. For example, while introducing the algorithms, be they artificial neural networks, evolutionary computation, or swarm intelligence, we focus on the economic principle underlying the algorithms.

Having that said, in this course, we aim to cover computational intelligence in light of the recent progress in agent-based computational economics. Specifically, computational intelligence is used as a tool to construct the agent-based economic models, for example, to construct autonomous agents, and is also used as a tool to study social phenomena emerging from the built agent-based models.

2 Course Objectives

First, this course is interdisciplinary and takes a pluralistic approach to economics. Since the French student movement, known as the 'post-autistic economics' movement, happening in June 2000, economics education has been long criticizedas its narrowness and irrelevancy (Fullbrook, 2003). Econ students generally do not have proper knowledge of the sister disciplines in social sciences, specifically, moral philosophy, psychology, sociology, anthropology, political economy, history, and ideologies. The immediate consequence is that econ students have been long 'brainwashed' by the neoclassical economics without even being aware of the cultural hegemony in economics, sometimes known as economic imperialism (Michie, Oughton, and Wilkinson, 2002; Grimm, Phringer, and Kapeller, 2018). We hope that students after taking this course will break the curse of single-minded neoclassical training, and can develop their own thinking required for the dialogues with peoples from different backgrounds and owning different perceptions of the world.

Second, a large part of this course is to help students get familiar with various heuristics, which facilitate decision making under great uncertainty. Decision making under risk has already been well studied in microeconomics and econometrics; however, decision making under uncertainty is not. As pointed out by Frank Knight, Mayland Keynes, and many Post Keynesians, such as Paul Davidson, and even behavioral economists, such as Herbert Simon, Richard Tayler, Reinhard Selten, Gerd Gigerenzer, the probabilistic paradigm to decision making is very limited when the real environment is generally non-ergodic, which can fail the assumptions of many formal statistical or econometric analysis. People, nonetheless, make decisions all the time, relying on their intuitions (gut feeling) and experiences and developing rules of thumbs on that ground. This set of heuristics probably are far important than the von-Neumann-Morgenstern expected utility maximization paradigm and the behavioral rules derived from there (Gigerenzer,

2007).

Third, for Econ students, they will find that AI is not something so distant from their niche, while this misperception has been long held due to the narrowness of economics mentioned earlier. In fact, after taking this class, students will be able to appreciate more their economics training, since almost all AI tools introduced in this class can be endowed with an interpretation from economics, be they psychologically-inspired, biologically-inspired, neuroscientifically-inspired or mathematically-inspired. Even more evidently, many AI tools are the application or the substantiation of market dynamics subject to severe competition, such as self-organizing maps (Week 10), genetic algorithms (Week 13), genetic programming (Week 14), ants swarm intelligence (Week 15). However, quite ironically, Econ students may not even learn this dynamic competition in their Econ classes, since the great loyalty to analytical trackability normally prevents them from seeing anything exceedingly dynamic and complex. Economist Deirdre McCloskey already said lots of this for decades, and there is no need here to repeat what she said. Some other tools involve auction behavior, such as reinforcement learning (Weeks 3 and 4), decision trees (Week 12), or pricing in the supply chain (artificial neural networks, Week 5), and so on. Indeed, here, we are talking about the economics of artificial intelligence.

Fourth, one of the key question ahead of us in this era is what can happen for the wellbeing of the human when we are 'fully connected' to the extent that our ancestors have never experienced before. We cannot blame them for not leaving the advice to us, and we have to take the baton to walk out our own path. Yet, the search for the answer cannot just be left for engineers or mathematicians alone, social scientists must get involved; otherwise, the next-generation AI is no longer just solutions for us, but problems too (Kissinger, 2018). This is the age that social scientists need to be passionate again, like those great men in the Age of Enlightenment. This course, then, helps social scientists with this vision to know a little tech to facilitate their sophisticated thinking on what may happen when we are 'fully connected'.

3 Class Schedule

General Specication:

1. The student is expected to spend 12 hours per week on this course, which means 9-hour preparation and review work plus 3-hour class attendance.

2. While the readings will be given at the end of each lecture notes (ppt), the students do not feel obliged to read all of them. Nevertheless, we do expect students to read the lecture notes in advance to facilitate in-class discussions (for that purpose, the lecture notes will be made available before the class too). The power point is well organized, but due to the time constraint, we can only highlight some of them. The rest is for you to read through. Anything unclear is welcome to bring into the in-class discussions.

3. There will be a total of 14 lectures given in the class, since May 20 (week 14) is the anniversary day of the university and June 3 (week 16) is a national holiday,The schedule below is only suggestive; sometimes, some subjects will take more time than we plan, and in this case rescheduling becomes inevitable, but our goal is

to cover all the subjects listed below. Therefore, due to time constraint, for the subjects which we are only able to skim through, we do expect students to pick up by themselves.

Weekly Progress

1. Week One (Lecture 1, Feb 18, 2022)
   Lecture 1 (Opening Lecture) A Panoramic View of AI in Economic Theory and Digital Economy (The opening lecture will give you a panoramicview of this class. It basically addresses AI in the modernity of the digital economy.)
   (a) The Web 2.0 Economy
   (b) Leon Walras (1834-1910) and the Tatonnement Process
   (c) Non-Tatonnement Process and the Multi-Agent System
   (d) Big Data: What Makes Data Big
   (e) Internet of Everything
2. Week Two (Lecture 2, Feb 25, 2022)
   Lecture 2: A Panoramic View of AI in Philosophy
   (a) John von Neumann and his "Theory of Self-Reproducing Automata"
   (b) Automata and Natural Computationalism
   (c) Natural Automata and Artificial Automata
   (d) Crowds: Bacterial Computing and Social Computing
   (e) Nature of the Sharing and the Gig Economy
3. Week Three (Lecture 3, March 4, 2022)
   Lecture 3. Psychology and Microeconomic AI: Reinforcement Learning
   (a) Minimal Rationality in a form of Discrete Choice
   (b) The Paradox of Choicesand Nudges
   (c) Learning in 'Groundhog Days'
   (d) Multi-armed Bandit Problems
   (e) Parameter-Free Reinforcement Learning
   (f) Psychologically-constrained Reinforcement Learning
4. Week Four (Lecture 4, March 11, 2022):
   Lecture 4. Game-Theoretic AI: Generalized Reinforcement Learning
   (a) Cognitive Capacity, Cognitive Hierarchy, and Learning
   (b) Belief Learning: Cournot Play and Fictitious Play
   (c) Experience-Weighted Attraction (EWA) Learning
   (d) Role of Counterfactual Thinking and Imagination in Learning
   (e) Sophisticated EWA and Level k reasoning: Simulating what other simulating

5. Week Five (Lecture 5, March 18, 2022)
Lecture 5. Neuroscientific AI: Artificial Neural Networks (I)

   (a) History and Origins
   (b) McCulloch and Pitts (1943)
   (c) Rosenblatt's Perceptrons
   (d) Rumelhart's Backpropagation Algorithms
   (e) Biological Neural Networks
   (f) Multi-Layer Perceptrons (Feedforwarded Neural Networks)

6. Week Six (Lecture 6, March 25, 2022):
Lecture 6. Artificial Neural Networks (II)

   (a) Training Feedforwarded Neural Networks with the Backpropagation Algorithm
   (b) Auto-Association Neural Networks and Non-linear Principal Analysis
   (c) Recurrent Neural Networks and Non-linear Time Series

7. Week Seven (Lecture 7, April 1, 2022)
Lecture 7. Support Vector Machines (I)

   (a) Statistical Learning Theory
   (b) Support Vector Classifiers (SVCs)
   (c) Optimal Hyperplane
   (d) Support Vectors

8. Week Eight (Lecture 8, April 8, 2022)
Lecture 8. Support Vector Machines (II)

   (a) Kernel Functions
   (b) Feature Expansion
   (c) Non-linear Support Vector Machines
   (d) Support Vector Regression

9. Week Nine (Lecture 9, April 15, 2022)
Lecture 9. Competition-Oriented AI: K-Means Clustering and Self-Organizing Maps

   (a) Supervised Learning vs. Unsupervised Learning Week
   (b) K-Means Clustering
   (c) Connectionism vs. Symbolism
   (d) Donald Hebb (1904-1985) and Friedrich Hayek (1899-1992)
   (e) Kohonen's Competitive Learning
   (f) U Matrices and Sammon Mapping

(g) Applications: Chartistand Financial Patterns

10. Week Ten(Lecture 10, April 22, 2022)
Lecture 10. Case-Based Reasoning and Nearest Neighbors

(a) Lazy Learning: Instance-Based or Case-Based Learning
(b) Regression Approach
(c) Dynamic System Approach
(d) Takens Theorem
(e) Embedding Dimension, Fractal Dimension, and Correlation Dimension
(f) Lyapunov Exponents
(g) False Neighbor Methods
(h) Applications: Foreign Exchange Market Prediction

11. Week Eleven (Lecture 11, April 29, 2022)
Lecture 11. Decision Trees

(a) Statistical Mechanism and Information Theory
(b) Top-Down Greedy Algorithm
(c) Entropy: A Measure of Information
(d) Information Gain
(e) The Minimum Description Length Principle
(f) Quinlan's C5 and Cubist
(g) Applications: Real Estate Market Prediction
(h) A Perspective from Behavioral Economics

12. Week Twelve (Lecture 12, May 6, 2022)
Lecture 12. Biologically-Inspired AI: Genetic Algorithms

(a) Innovation and Chance Discovery
(b) Evolutionary Cycles
(c) Chromosome as the Representation
(d) Selection Schemes
(e) Crossover and Mutation
(f) Schema Theorem
(g) Variants of Simple GAs

13. Week Thirteen (Lecture 13, May 13, 2022)
Lecture 13. Biologically and Linguistically-Inspired AI: Genetic Programming

(a) LIST Programming
(b) Parse Tree Representation of Computer Programs
(c) Symbolic Regression

(d) Content-Free Grammar and theBackus?Naur Form

(e) Strategy Inference

(f) Applications: Experimental Games

(g) Applications: Market Fraction Hypothesis and Diansours Hypothesis in Financial Markets

14. Week Fourteen (May 20, 2022)
NCCU Anniversary Day. No class.

15. Week Fifteen (Lecture 14, May 27, 2022)
Lecture 14.Linguistic AI: Fuzzy Logic

(a) Vagueness, Ambiguity, and Uncertainty

(b) Granularity

(c) Membership Function

(d) Fuzzy Set Operators

(e) Fuzzy Inference System

16. Week Sixteen (Lectured on June 3, 2020)
National Holiday (Dragon Boat Festival). No Class.

17. Week Seventeen (June 12, 2020)
Final Exam. The Exam will be distributed online at 18:00 and the student can take or download the exam anywhere he/she likes. There is no need to come to the classroom.

4 Teaching Approach

The course will be taught in English unless there are no international students registering for the class. The course will proceed in lectures. All lectures are prepared in power points, and the students will be able to get these power points before or after the classes. Students are encouraged to use skype to interact with the instructor between classes.

5 Teaching Assistant Tasks

Teaching assistant shall help the instructor to supervise and assist students' term project progress. Assistant shall assist the instructor in classroom preparation, such as the projector, internet connection, etc. Assistant shall help instructor to grade the term project and help answer various administration problem associated with the class, such as classroom change (if needed), information announcement, lecture notes upload, etc.

6 Course Requirements and Grading Standards

The evaluation of the student performance will be based on a term project (60%) and a final exam (40%).

1. Term Project (60%):
   We accept different forms of the term project, from the application domains to the theoretical domains.

   For the former, the student needs to choose a dataset that interests himself/herself and to apply at least one AI tool to exam it. For example, the student may choose the financial time series, say S&P 500, and apply nearest neighbors (week eleven) to build a forecasting model. This will suffice to define a term project that satisfies the minimum criterion. However, the student may try more than one tool and more than one dataset, and even be restricted to only one tool or one dataset but consider different experimentations, instead of just a one-shot design. The point of this kind of term project is to see whether the student is able to put the tools taught in the class into practice so as to have a hands-on experience on them; hence, it is not required to write a paper on it (i.e., the usual section on motivation and literature review is an option). The bottom line is that the student needs to be clear on introducing the data, the employed computational software, the experimental designs, and the presentation of the results. These have to be written in a well-organized manner. Leaving just a bunch of numbers, statistics, or figures, without sufficient information to accompany them, will be turned down outright.

   For the latter, we accept literature review, book review, philosophical or methodological polemics, agent-based modeling, etc. The student is also welcome to do this term project combined with his/her research paper or even thesis. In the latter case, submitting the whole research paper will also do the job.

   The term project is due on Sep 1, 2020, and the late submission will not be accepted. The student needs to give a sketch on what he/she plans to do in his/her final exam. Indeed, in the final exam, there will be a question asking for this, and the student simply just fill in the answer without submitting a separate report. The student is very welcome to discuss what they plan to do with the instructor using the office hours or skype.

2. Final Exam (40%):
   The final exam will be held in the final week (week seventeen). It will be an open-book exam, and the student will be given two weeks to do it. So, for example, if the exam is on June 10, 18:00 sharp, then the student only needs to submit his/her answer before June 24, 18:00. Again late submission will not be accepted.

7 Textbooks and References

There will be no textbooks for this class. The lecture notes (power points) will be the main reference for students to begin with and, by self-learning morale, they can decide how extensive or intensive they want to pursue further along with the readings provided in

the class. The lecture notes are available in the Google drive. To be able to get access to the lecture notes, students need to send me their google email account so that I can invite them to the indicated drive. Your request with your gmail account can be sent to my gmail: chen.shuheng@gmail.com Notice that we have already uploaded the lecture notes for you to study in advance, but do notice that these notes will be constantly revised, albeit mostly to a marginal degree. So, make sure that you have the most updated lecture notes; in particular, when the entire class is over.

8 Course Related Links

We have an online discussion group, *Economics of AI*, using skype. If you want to join this group, please send me you skype account so that I can invite you in.

9 Office Hours

The office hours are (a) Wednesday 7:30-9:30 pm (b) Friday 3:00-5:00 pm (c) by appointment. The office is #271646, 16F, General Building, South Tower.

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