2023 Piedmont Project

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Abstract

The 2030 Agenda for Sustainable Development by United Nations presents a collection of 17 Sustainable Development Goals (SDGs) designed to serve as a *"shared blueprint for peace and prosperity for people and the planet, now and into the future"*. The specific global challenges identified by the United Nations in the context of these SDGs uphold the fact that it is the need of the hour for experts from different disciplines to work towards addressing these global challenges.

My areas of research expertise include Big Data, Artificial Intelligence, Machine Learning, Pattern Recognition, Deep Learning, and Natural Language Processing. I have co-authored several journal articles and conference papers in these areas with a specific focus on SDG #3: Good Health and Well-Being. Since joining the Department of Computer Science at Emory University, I have developed two new courses - CS 211: Introduction to Artificial Intelligence and CS 323: Machine Learning Applications. In addition to working in these areas, in the last few years, I have followed recent research in the areas of Machine Learning and Deep Learning, which focused on one or more SDGs.

I attended the 2023 Piedmont Project workshop on May 10, 2023, and May 11, 2023, to learn more about Sustainability, SDGs, and recent works in these areas. This document presents my proposal for a new course *CS 285: Topics in Computer Science: Deep Learning for Sustainable Development*, developed specifically for the 2023 Piedmont Project. The goal of this undergraduate-level course on Deep Learning for Sustainable Development is primarily two-fold. First, this course will cover different concepts of Deep Learning, such as Hyperparameters and Validation Sets, Gradient-Based Learning, Back-Propagation and Differentiation Algorithms, Sparse Representations, Neural Network Optimization, Convolutional Neural Networks, Recurrent and Recursive Nets, Linear Factor Models, Structured Probabilistic Models, and Deep Generative Models. Second, this course will expose students to concepts of Sustainable Development and Sustainable Development Goals and how concepts of Deep Learning can be applied to address challenges in Sustainable Development. The course will also include coverage of different emerging challenges in the area of Sustainable Development, such as Urban Sustainability, Sustainable Economic Development, Sustainable Agriculture, Sustainable Futures for the Arctic North, and Climate Change.

CS 285: Topics in Computer Science: Deep Learning for Sustainable Development

Fall 2023

Date and Time of Lecture Meetings: To be decided

Instructor

Name: Nirmalya Thakur, Ph.D.
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Course Description

From accurate product recommendations on e-commerce websites to self-driving cars and to the selection of inspection-worthy soil and rock samples on Mars, it is increasingly commonplace to discover machines using data to make critically intelligent decisions using concepts of Deep Learning. Deep Learning has the potential to play a crucial role in addressing a wide range of sustainability problems faced by the present and future generations. The goal of this undergraduate-level course on Deep Learning for Sustainable Development is primarily two-fold. First, this course will cover different concepts of Deep Learning, such as Hyperparameters and Validation Sets, Gradient-Based Learning, Back-Propagation and Differentiation Algorithms, Sparse Representations, Neural Network Optimization, Convolutional Neural Networks, Recurrent and Recursive Nets, Linear Factor Models, Structured Probabilistic Models, and Deep Generative Models. Second, this course will expose students to concepts of Sustainable Development and Sustainable Development Goals and how concepts of Deep Learning can be applied to address challenges in Sustainable Development. The course will also include coverage of different emerging challenges in the area of Sustainable Development, such as Urban Sustainability, Sustainable Economic Development, Sustainable Agriculture, Sustainable Futures for the Arctic North, and Climate Change.

Learning Objectives

By the end of this course, students will be able to:

- Develop an understanding of basic concepts of Deep Learning, Sustainable Development, and Sustainable Development Goals (SDGs).
- Implement Neural Networks, Convolutional Neural Networks, and Gradient-Based Learning using Python.
- Develop an understanding of applications of Neural Networks, Convolutional Neural Networks, and Gradient-Based Learning for Sustainable Development.
- Implement Recurrent and Recursive Nets using Python.
- Develop an understanding of applications of Neural Networks, Convolutional Neural Networks, and Gradient-Based Learning for Sustainable Development.
- Implement Structured Probabilistic Models and Deep Generative Models using Python.
- Develop an understanding of applications of Structured Probabilistic Models and Deep Generative Models for Sustainable Development.
- Develop an understanding of different emerging challenges in the area of Sustainable Development, such as Urban Sustainability, Sustainable Economic Development, Sustainable Agriculture, Sustainable Futures for the Arctic North, and Climate Change, and how concepts of Deep Learning can be applied to address these challenges.

Prerequisites

CS 110 or CS 170 or CS_OX 170 and CS 211

Required Textbooks

- Deep Learning by Ian Goodfellow, Yoshua Bengio, and Aaron Courville, MIT Press, ISBN: 978-0262035613

- Exploring Sustainable Development: Geographical Perspectives by Martin Purvis and Alan Grainger, Routledge Publishers, ISBN: 978-1853834721

Course Website
https://canvas.emory.edu/

Important Dates
August 23: First day of Fall 2023 classes
September 4: Labor Day
September 6: Add/Drop/Swap Ends for Fall 2023 Courses
September 26: Extended Drop Deadline for Fall 2023 Courses
October 9–10: Fall Break (No Classes)
October 11: Deadline for Letter Grade/Satisfactory-Unsatisfactory Changes [Fall Semester 2023]
October 11: Partial Withdrawal Deadline (Without Penalty) [Fall Semester 2023]
November 22–24: Thanksgiving Recess (No Classes)
December 5: Last Day of Class [Fall 2023 Semester]
December 6: Reading Day
December 7–13: Exams [Fall 2023 Semester]

Course Components
- Lectures – The lectures will be used to introduce terminologies, ideas, and problem-solving techniques. The slides used in the lectures will be posted in the Modules section of this course on Canvas.
- Exams – There will be one Midterm Exam and one Final Exam. The Midterm Exam and the Final Exam will account for 40% of the Final Grade.
- Assignments: There will be 12 assignments in this course. The assignments will account for 60% of the Final Grade.

Grading Scheme
- Assignments: 60%
- Midterm Exam: 20%
- Final Exam: 20%

Final Grade Determination
The standard scale for grades is as follows. Note that the instructor reserves the right to grade on a curve if considered necessary based on the class performance.

Name:	Range:	
A	100 %	to 93.0%
A-	< 93.0 %	to 90.0%
B+	< 90.0 %	to 87.0%
B	< 87.0 %	to 83.0%
B-	< 83.0 %	to 80.0%
C+	< 80.0 %	to 77.0%
C	< 77.0 %	to 73.0%
C-	< 73.0 %	to 70.0%
D+	< 70.0 %	to 67.0%
D	< 67.0 %	to 60.0%
F	< 60.0 %	to 0%

Accessibility Policy
The Department of Computer Science at Emory University supports equal access for all students. Any students needing accommodations due to a disability should speak with someone in the Office of Accessibility Services,

and arrangements will be made. For more information, contact accessibility@emory.edu

Honor Code
All students must adhere to the provisions of the Honor Code. See the following:
https://college.emory.edu/oue/documents/honor-code-2022/honor-code.pdf

Using an artificial intelligence program (such as ChatGPT) to generate any content for any assignment in this course (including, but not limited to, examinations, papers, homework, and creative work) constitutes plagiarism and is a violation of the Honor Code. The use of an artificial intelligence program in this course without permission from the instructor may also constitute seeking unauthorized assistance or violate other provisions of the Honor Code. Any suspicion of academic misconduct will be reported to the Honor Council. Appropriate citation of all external sources is required. This also includes the acknowledgment of any collaboration or assistance. The academic integrity violations most frequent in this course are cheating and excessive collaboration.

Cheating
Cheating occurs when you take "shortcuts" to get a higher grade, or you help someone else take such "shortcuts". Some examples of cheating include (but are not limited to):

- Copying other students' work (either in class or outside of class).
- Copying computer code or an answer from the Internet (even if you modify it).
- Asking someone else to do your homework.
- Executing code that is supposed to be manually traced in quizzes and exams.
- Notice that also giving your work to someone else is cheating. In a cheating incident, both the provider and the recipient are equally accountable for their misbehavior.

Excessive Collaboration
Excessive Collaboration happens when you request or provide an amount of help that undermines the learning effectiveness of the activity you are supposed to perform. The boundaries of excessive collaboration may be subtle to identify. If you are uncertain about whether a certain behavior is acceptable or not, ask your instructor for guidance as soon as possible.

Communication
Please check your Emory Email ID, Canvas Announcements, and Canvas Messages at least once a day. All emails to the instructor and/or the TA must come from your Emory Email ID and must include a [CS285] tag in the subject line.

Policy on COVID-19
We will follow Emory's guidelines on COVID-19 - https://www.emory.edu/forward/resources/policies-guidelines-protocols/index.html as and when applicable.

Late work policy
Each assignment will have a due date. The late policy is a 25% penalty for each day late. I may grant individual time extensions on due dates if you ask in advance.

Tentative Schedule

Week	Topics	Readings
1	Basic Concepts of Deep Learning and Sustainable Development • Concept of Learning Algorithms • Capacity, Overfitting, and Underfitting • Hyperparameters and Validation Sets	• Deep Learning by Ian Goodfellow, Yoshua Bengio, and Aaron Courville, MIT Press, ISBN: 978-0262035613, page numbers: 99 to 153 • Exploring Sustainable Development: Geographical Perspectives by Martin Purvis and Alan Grainger, Routledge Publishers, ISBN: 978-1853834721, page numbers: 1 to 30

	• Estimators, Bias, and Variance • Maximum Likelihood Estimation • Building a Machine Learning Algorithm • What is Sustainable Development? • The Challenge of Sustainable Development • Sustainable Development as an Ambiguous Compromise • From Economic Growth to Sustainable Development • Economic Theories of Sustainable Development • Geographical Perspectives on Sustainable Development	
2	Deep Feedforward Networks and Sustainable Development Goals (SDGs) • Gradient-Based Learning • Hidden Units • Architecture Design in Deep Learning • Back-Propagation and Other Differentiation Algorithms • History of Sustainability • SDGs overview, goals, and targets • Applications of Deep Learning for SDGs • Assignment 1	• Deep Learning by Ian Goodfellow, Yoshua Bengio, and Aaron Courville, MIT Press, ISBN: 978-0262035613, page numbers: 168 to 224 • Exploring Sustainable Development: Geographical Perspectives by Martin Purvis and Alan Grainger, Routledge Publishers, ISBN: 978-1853834721, page numbers: 33 to 48
3	Regularization for Deep Learning and Spatial Interactions in Sustainable Development • Regularization and Under-Constrained Problems • Multi-Task Learning • Sparse Representations • Bagging and Other Ensemble Methods • Adversarial Training • Tangent Distance, Tangent Prop, and Manifold Tangent Classifier • Structuring Global Space for Sustainable Development • Interaction between Different Spatial Levels • Recent works in Regularization toward addressing SDGs • Assignment 2	• Deep Learning by Ian Goodfellow, Yoshua Bengio, and Aaron Courville, MIT Press, ISBN: 978-0262035613, page numbers: 244 to 270 • Exploring Sustainable Development: Geographical Perspectives by Martin Purvis and Alan Grainger, Routledge Publishers, ISBN: 978-1853834721, page numbers: 50 to 83

4	Optimization for Training Deep Learning Models and Forecasting Urban Futures using Deep Learning • How Learning Differs from Pure Optimization? • Challenges in Neural Network Optimization • Parameter Initialization Strategies • Algorithms with Adaptive Learning Rates • Approximate Second-Order Methods • Optimization Strategies and Meta-Algorithms • The Complexity of Urban Sustainability • A Systems Perspective: Urban Modelling and Sustainability Assessment • Models of Sustainable and Urban Development • Recent works in Neural Networks for Urban Sustainability • Assignment 3	• Deep Learning by Ian Goodfellow, Yoshua Bengio, and Aaron Courville, MIT Press, ISBN: 978-0262035613, page numbers: 274 to 317 • Exploring Sustainable Development: Geographical Perspectives by Martin Purvis and Alan Grainger, Routledge Publishers, ISBN: 978-1853834721, page numbers: 99 to 116
5	Convolutional Neural Networks and Applications of Neural Networks for Development of Sustainable Cities • The Convolution Operation • Convolution and Pooling as an Infinitely Strong Prior • Variants of the Basic Convolution Function • Structured Outputs • Efficient Convolution Algorithms • The Neuroscientific Basis for Convolutional Networks • The Quantifiable City Program: Sustainable Urban Development • Problems and Prospects for Urban Sustainability Modelling • Applications of Neural Networks for the Development of Sustainable Cities • Assignment 4	• Deep Learning by Ian Goodfellow, Yoshua Bengio, and Aaron Courville, MIT Press, ISBN: 978-0262035613, page numbers: 330 to 371 • Exploring Sustainable Development: Geographical Perspectives by Martin Purvis and Alan Grainger, Routledge Publishers, ISBN: 978-1853834721, page numbers: 119 to 127
6	Recurrent and Recursive Nets (RNNs) and their Applications for Making Smart Cities more Sustainable • Unfolding Computational	• Deep Learning by Ian Goodfellow, Yoshua Bengio, and Aaron Courville, MIT Press, ISBN: 978-0262035613, page numbers: 373 to 416

	Graphs • Recurrent Neural Networks • Bidirectional RNNs • Encoder-Decoder Sequence-to-Sequence Architectures • Deep Recurrent Networks • Recursive Neural Networks • The Challenge of Long-Term Dependencies • Echo State Networks • Leaky Units and Other Strategies for Multiple Time Scales • The Long Short-Term Memory and Other Gated RNNs • Optimization for Long-Term Dependencies • Planning for Urban Sustainability • Urban Challenges in the Developing World • People as Planners: Participation in the Search for Sustainable Urban Development • Recent works in RNNs for Urban Sustainability • Assignment 5	• Exploring Sustainable Development: Geographical Perspectives by Martin Purvis and Alan Grainger, Routledge Publishers, ISBN: 978-1853834721, page numbers: 128 to 152
7	Linear Factor Models and Sustainable Economic Development • Probabilistic PCA and Factor Analysis • Independent Component Analysis (ICA) • Slow Feature Analysis • Sparse Coding • Manifold Interpretation of PCA • Foundations of Sustainable Economic Development • Sustainable Economic Development as Eco-efficiency • Are Win–Win Arguments Sustainable? • Applications of Linear Factor Models for Sustainable Economic Development • Assignment 6	• Deep Learning by Ian Goodfellow, Yoshua Bengio, and Aaron Courville, MIT Press, ISBN: 978-0262035613, page numbers: 473 to 499 • Exploring Sustainable Development: Geographical Perspectives by Martin Purvis and Alan Grainger, Routledge Publishers, ISBN: 978-1853834721, page numbers: 156 to 177
8	• Midterm Exam Review • Midterm Exam	
9	Deep Learning for Sustainable Agriculture	Exploring Sustainable Development: Geographical Perspectives by Martin Purvis and Alan Grainger,

	• Modern Agriculture • Sustainable Farming: Different Places, Different Solutions • Greater Resource Efficiency • Redistributing Resources • Recent Works in Deep Learning for Sustainable Agriculture • Assignment 7	Routledge Publishers, ISBN: 978-1853834721, page numbers: 179 to 204
10	Sustaining the Flow: Japanese Waterways and New Paradigms of Sustainable Development • 21st-Century Japan: Poised for Sustainable Development? • Past Imperfect • River Management: The Context • Technocentric River Planning and the Ministry of Construction • Reassessing the Role of Rivers • Problems Behind the Projects: Environmental Quality and Participation • Recent works in Deep Learning for addressing the Problems Behind the Projects • Assignment 8	Exploring Sustainable Development: Geographical Perspectives by Martin Purvis and Alan Grainger, Routledge Publishers, ISBN: 978-1853834721, page numbers: 207 to 227
11	Structured Probabilistic Models for Deep Learning • Graphs to Describe Model Structure • Sampling from Graphical Models • Advantages of Structured Modeling • Learning about Dependencies • Inference and Approximate Inference • The Deep Learning Approach to Structured Probabilistic Models • Assignment 9	Deep Learning by Ian Goodfellow, Yoshua Bengio, and Aaron Courville, MIT Press, ISBN: 978-0262035613, page numbers: 558 to 585
12	Sustainable Futures for the Arctic North • Varieties of Development • Unsustainable Development: Past Practice and Conflict over Renewable and Non-renewable Resources • Moves Towards More Sustainable Development: The North American Experience • Lessons for the Russian Arctic • Recent Works in Probabilistic	Exploring Sustainable Development: Geographical Perspectives by Martin Purvis and Alan Grainger, Routledge Publishers, ISBN: 978-1853834721, page numbers: 230 to 248

	Modeling to Promote Sustainable Development in the Arctic North • Assignment 10	
13	Deep Generative Models • Boltzmann Machines • Restricted Boltzmann Machines • Deep Belief Networks • Deep Boltzmann Machines • Convolutional Boltzmann Machines • Boltzmann Machines for Structured or Sequential Outputs • Back-Propagation through Random Operations • Directed Generative Nets • Drawing Samples from Autoencoders • Generative Stochastic Networks • Other Generation Schemes • Evaluating Generative Models • Assignment 11	Deep Learning by Ian Goodfellow, Yoshua Bengio, and Aaron Courville, MIT Press, ISBN: 978-0262035613, page numbers: 654 to 720
14	Applications of Deep Generative Models for Climate Change • Climate Change: A Threat to Sustainable Development? • Adaptation to Current and Future Climate Regimes • Scales of Change: Theory and Practice • Discourses in Conflict at the United Nations Conference on Environment and Development • Climate Change: The Predominance of an Isolated Globalist Discourse Mitigating Climate Change with Deep Learning • Assignment 12	Exploring Sustainable Development: Geographical Perspectives by Martin Purvis and Alan Grainger, Routledge Publishers, ISBN: 978-1853834721, page numbers: 250 to 276
15	• Final Exam Review • Final Exam	

Disclaimer

The plans in this Syllabus are subject to change, but I will announce any such changes in a timely manner.