MSDS 458 Section 56

Artificial Intelligence and Deep Learning
Spring 2019
Course Syllabus

Instructor

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Office Hours: By appointment

Response Time: Response to emails within 24-48 hours

Biography

I am the faculty director of the Data Science program at Northwestern University. I have designed the initial versions of many courses for the program, including Practical Machine Learning, Foundations of Data Engineering, Marketing Analytics, Advanced Modeling Techniques, Data Visualization, Web and Network Data Science, and the capstone course. I have published six data science textbooks with Pearson/FT Press (the series entitled "Modeling Techniques in Predictive Analytics"). I also own a publishing and consulting firm, Research Publishers LLC, located in Manhattan Beach, California. I consult and provide training services in machine learning, natural language processing, data and knowledge engineering, sports analytics, retail site selection, product positioning, segmentation, and pricing in competitive markets. I also provide full-stack software development services, specializing in machine learning, natural language processing, and conversational agents. Before joining the faculty at Northwestern, I spent fifteen years in business IT in the computer and transportation industries. I also directed the A. C. Nielsen Center for Marketing Research and taught market research and business strategy at the University of Wisconsin-Madison. I hold a Ph.D. in psychology (psychometrics) and a master's degree in statistics from the University of Minnesota and an MBA and master's degree in economics from the University of Oregon.

Teaching Assistant

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Biography

I have worked the industries of management consulting, manufacturing, and transportation. I recently switched jobs. Currently, I am the Director of Analytics and Business Operations at a technology start up focused on online program management for higher education. My company provides a full suite of services such as marketing, lead generation, learning and design, and student success. I lead the analytics team to provide insights on operations, business strategy, and marketing. I am a recent graduate of the MSPA program (Summer 2018). I also have a bachelor's degree in accountancy from the University of Illinois Urbana Champaign.

Syllabus over Canvas Course Site

This syllabus in its Adobe Acrobat Portable Document Format (pdf) form is the defining document for this section of MSDS 458. This syllabus defines course objectives, requirements, due dates, and grading standards. If there is ever a discrepancy between this syllabus and the Canvas course site, rely on this syllabus as the final word.

Course Description

An introduction to the field of artificial intelligence, this course illustrates probability-rule-based generative models as well as discriminative models that learn from training data. The course reviews applications of artificial intelligence and deep learning in vision and language processing. Students learn best practices for building supervised learning models and, in particular, deep neural networks for classification and regression. Students also learn about feature engineering, autoencoders, and strategies of unsupervised and semi-supervised learning, as well as reinforcement learning. This is a project-based course with extensive programming assignments.

Course Learning Objectives

By the end of this course, you should be able to:

- Identify key phases in the history of artificial intelligence (AI), including recent developments in deep learning.
- Distinguish among supervised, unsupervised, semi-supervised, and reinforcement learning problems.
- Describe the structure and operation of neural networks, including deep learning networks.
- Employ neural networks and deep learning to address classification and regression problems (supervised learning with backpropagation).
- Employ probability-rule-based, generative models for deep learning.
- Describe the relevance of AI and deep learning methods to a wide range of applications, including vision and natural language processing.

Prerequisites

MSDS 420-DL Database Systems and Data Preparation or CIS 417 Database Systems Design and Implementation and (2) MSDS 422-DL Practical Machine Learning or CIS 435 Practical Data Science Using Machine Learning.

Required and Optional Readings and Resources

Required Textbooks

- Chollet, F. 2018. *Deep Learning with Python*. Shelter Island, N.Y.: Manning. [ISBN-13: 978-1617294433] Source code available at: https://github.com/fchollet/deep-learning-with-python-notebooks.git

- Maren, A. J. (draft, expected publication 2019), *Statistical Mechanics, Neural Networks, and Artificial Intelligence.* Draft chapters available in Canvas course content for this course, and also at: http://www.aliannajmaren.com/book.

Reference Textbooks (Available Online)

- Goodfellow, I. Bengio, Y. and Courville, A. 2016. *Deep Learning.* Cambridge Mass.: MIT Press. [ISBN-13: 978-0262035613] This is a highly regarded textbook. It is also very mathematical and abstract. Other texts may be more suitable as introductions. Available online at: https://www.deeplearningbook.org
- Nilsson, N. J. 2010. *The Quest for Artificial Intelligence: A History of Ideas and Achievements.* New York: Cambridge University Press. [ISBN-13: 978-0-521-12293-1] Available online at: http://ai.stanford.edu/~nilsson/QAI/qai.pdf

Note: Additional Required Readings will be identified within specific Canvas Modules, and will typically be classic and recent influential papers in artificial intelligence, neural networks, and deep learning. In all cases, web links to accessible sources will be provided. Some of these readings will be referred to in graded discussion forums.

Course Reserves

Selected readings are available through the Course Reserves. For assistance with Course Reserves, use electronic mail: e-reserve@northwestern.edu. To ask a librarian for assistance, visit Northwestern's Ask A Librarian page.

Optional Readings and Resources

- Géron, A., 2017. *Hands-On Machine Learning with Scikit-Learn and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems.* Sebastopol Calif.: O'Reilly. [ISBN-13: 978-1491962299] Used as one of the required textbooks in MSDS 422, a prerequisite for this course. Source code available at https://github.com/ageron/handson-ml
- Maren, A. J., Pap, R. M., and Harston, C. T., 1990. *Handbook of Neural Computing Applications.* New York: Academic Press. Accessible via Google Books. ***Note:*** These chapters are being supplanted by new chapter drafts in Maren's *Statistical Mechanics, Neural Networks, and Artificial Intelligence* book.
- Russell, S. J. and Norvig, P. 2015. *Artificial Intelligence: A Modern Approach* (third ed.). Upper Saddle River, N.J.: Pearson. Encyclopedic reference on the field.
- Deep Learning Reading List: http://deeplearning.net/reading-list/
- Deep learning articles as summarized / linked to on my own website (and I'm transferring this list to the Canvas course site as I write); see: http://www.aliannajmaren.com/readings-deep-learning/ - I will be posting commentary on these various articles giving you an upfront sense of what the value may be to you, so you can pick-and-choose accordingly.
- https://github.com/songrotek/Deep-Learning-Papers-Reading-Roadmap - a very good place to start, begins with the text that we'll be using; this is a curated list.
- Deng, L. and Yu, D., *Deep Learning: Methods and Applications*: (a 197-page monograph): http://research.microsoft.com/pubs/209355/DeepLearning-NowPublishingVol7-SIG-039.pdf
- Reading list for the Carnegie Mellon University course on Deep Learning, taught by Bhiksha Raj: http://deeplearning.cs.cmu.edu/ (Includes a number of classic neural network papers.)
- MS PPT ™ slidedecks and videos, posted on the Canvas course site.
- Because AI and deep learning are fast-moving fields, new readings (required and optional) may be introduced throughout the term.

Assignments and Grading Scale

Grading: Grading and feedback turnaround will be one week from the due date. You will be notified if turnaround will be longer than one week. The discussion forums and written assignments will be graded based on specific grading guidelines.
Language(s): The course employs Python with TensorFlow and Keras.
Assignments: There are no quizzes or exams. Rubrics are provided for assignments.

Class Participation	Graded discussion threads (10 points per week)	100 Points
Assignment 1	First Research/Programming Assignment (Week 3)	100 Points
Assignment 2	Second Research/Programming Assignment (Week 5)	100 Points
Assignment Proposal	Proposal for Fourth Research /Programming Assignment (Week 6)	0 Points
Assignment 3	Third Research/Programming Assignment (Week 7)	100 Points
Assignment 4	Fourth Research/Programming Assignment: Deep Learning (Complete one of many options) (Week 10)	100 Points
	Total	500 Points

Grade	Percentage	Total Points (out of 500)
A	93%–100%	465– 500 points
A-	90%–92%	450 – 464 points
B+	87%–89%	435 – 449 points
B	83%–86%	415 – 434 points
B-	80%–82%	400 – 414 points
C+	77%–79%	385 – 399 points
C	73%–76%	365 – 384 points
C-	70%–72%	350 – 364 points
F	0%–69%	0 – 349 points

Course Procedures

Assignment Due Dates

Each Monday introduces a new week, and its corresponding weekly Module. All discussions and assignments are due Sunday evening at 11:55 p.m. Central time.

Participation and Attendance

This course follows the asynchronous distance learning approach of Northwestern University School of Profession Studies. The course does not meet at a particular time each week. Learning objectives and assessments are supported through classroom elements that can be accessed at any time. To measure class participation (or attendance), your participation in threaded discussion boards is required, graded, and paramount to your success in this course.

Real-time, synchronous meetings (Sync Sessions) are scheduled for Thursday evenings on selected weeks. Sync Sessions are conducted with Webex. While your attendance is highly encouraged, it is not required. You will not be graded on your attendance or participation. All Sync Sessions are recorded.

Refer to the weekly schedule at the end of this syllabus for details about weekly learning objectives, required and optional readings, assignments, and Sync Sessions.

Late Assignment Turn-Ins

Students should provide written notification of late assignment work 24 hours prior to the deadline. A grace day is allowed for those who provide late work notification. Late papers may be subject to point reductions.

Discussion Forums

The purpose of the discussion boards is to allow students to freely exchange ideas. It is imperative to remain respectful of all viewpoints and positions and, when necessary, agree to respectfully disagree. While active and frequent participation is encouraged, cluttering a discussion board with inappropriate, irrelevant, or insignificant material will not earn additional points and may result in receiving less than full credit. Frequency matters, but contributing content that adds value is paramount. Please remember to cite all sources—when relevant—in order to avoid plagiarism. Please post your viewpoints first and then discuss others' viewpoints.

The quality of your posts and how others view and respond to them are the most valued. A single statement mostly implying "I agree" or "I do not agree" is not counted as a post. Explain, clarify, politely ask for details, provide details, persuade, and enrich communications for a great discussion experience. Please note, there is a requirement to respond to at least two fellow class members posts. Also, remember to cite all sources—when relevant—in order to avoid plagiarism.

Online Communication Etiquette

Beyond interacting with your instructor and peers in discussions, you will be expected to communicate by Canvas message, email, and sync session. Your instructor may also make themselves available by phone or text. In all contexts, keep your communication professional and respect the instructor's posted availability. To learn more about professional communication, please review the Communicating Effectively with Faculty guide.

Just as you expect a response when you send a message to your instructor, please respond promptly when your instructor contacts you. Your instructor will expect a response within two business days. This will require that you log into the course site regularly and set up your notifications to inform you when the instructor posts an announcement, provides feedback on work, or sends you a Canvas message. For guidance on setting your notifications, please review How do I set my Canvas notification settings as a student? It is also recommended that you check your u.northwestern e-mail account regularly, or forward your u.northwestern e-mail to an account you check frequently.

In this class, in all interactions, it is important that we each remain respectful of the viewpoints and positions of others. When necessary (as some conversations may become spirited), we may have to "agree to disagree."
Discussion board posting should be used exclusively for topic-related postings; posting inappropriate, irrelevant, or insignificant material will actually earn you a negative score.

Frequency is not unimportant, but content of the message is paramount. A rubric for evaluating discussion posts will be provided within the first week of class. When you use material from an external source, please follow full professional (academic) citation styles, so that you (and others) can reference this material later. (Keep in mind that citing sources is a means of avoiding plagiarism.) For more information, read the 10 Rules of Netiquette.

Study Teams (optional)

Student study teams may be utilized in this course as a means to foster a collaborative learning environment. Blue Jeans is available as a conferencing tool. Preliminary groups have been set up under the People/Study Teams tab of Canvas. Each student is encouraged to join a study team. It may make sense to join a team based on time zone (Eastern, Central, or Mountain/Pacific) and preferred personal computer operating system (Mac OSX or Windows). It is recommended that teams consist of no more than four students.

Student Support Services

AccessibleNU

This course is designed to be welcoming to, accessible to, and usable by everyone, including students who are English-language learners, have a variety of learning styles, have disabilities, or are new to online learning. Be sure to let me know immediately if you encounter a required element or resource in the course that is not accessible to you. Also, let me know of changes I can make to the course so that it is more welcoming to, accessible to, or usable by students who take this course in the future.

Northwestern University and AccessibleNU are committed to providing a supportive and challenging environment for all undergraduate, graduate, professional school, and professional studies students with disabilities who attend the University. Additionally, the University and AccessibleNU work to provide students with disabilities and other conditions requiring accommodation a learning and community environment that affords them full participation, equal access, and reasonable accommodation. The majority of accommodations, services, and auxiliary aids provided to eligible students are coordinated by AccessibleNU, which is part of the Dean of Students Office.

SPS Student Services

The Department of Student Services supports the academic and professional growth of SPS students. The Student Services team guides students through academic planning, policies, and administrative procedures, and promotes a supportive environment to foster student success. Students are encouraged to actively make use of the resources and staff available to assist them: Academic and Career Advisers, Counseling and Health Services, Student Affairs, Legal Services, Financial Aid and Student Accounts, among other services.

For a comprehensive overview of course and program processes and policies and helpful student resources, please refer to your SPS Student Handbook.

Academic Support Services

Northwestern University Library

As one of the leading private research libraries in the United States, Northwestern University Library serves the educational and information needs of its students and faculty as well as scholars around the world. Visit the Library About page for more information or contact Distance Learning Librarian Tracy Coyne at 312-503-6617 or tracy-coyne@northwestern.edu.

Program-Specific Library Guides

- Information Systems
- Data Science

Additional Library Resources

- Connectivity: Campus Wireless and Off-Campus Access to Electronic Resources
- Reserve a Library Study Room
- Sign up for an in-person or online Research Consultation Appointment
- Getting Available Items: Delivery to Long-Distance Patrons
- Social Science Data Resources
- Resources for Data Analysis

The Writing Place

The Writing Place is Northwestern's center for peer writing consultations. Consultations are free and available to anyone in the Northwestern community: undergraduates, graduate students, faculty, or staff. To book an appointment, go to The Writing Place website.

The Math Place

The Math Place is a free tutorial service provided to students currently enrolled in Northwestern University's School of Professional Studies courses or in other Northwestern University courses. Students of all levels can benefit from the individual tutoring provided from this service, whether they are taking undergraduate or graduate level courses. To book an appointment, go to The Math Place website.

Academic Integrity at Northwestern

Students are required to comply with University regulations regarding academic integrity. If you are in doubt about what constitutes academic dishonesty, speak with your instructor or graduate coordinator before the assignment is due and/or examine the University Web site. Academic dishonesty includes, but is not limited to, cheating on an exam, obtaining an unfair advantage, and plagiarism (e.g., using material from readings without citing or copying another student's paper). Failure to maintain academic integrity will result in a grade sanction, possibly as severe as failing and being required to retake the course, and could lead to a suspension or expulsion from the program. Further penalties may apply. For more information, visit The Office of the Provost's Academic Integrity page.

Some assignments in SPS courses may be required to be submitted through Turnitin, a plagiarism detection and education tool. You can find an explanation of the tool here.

Course Technology

This course will involve a number of different types of interactions. These interactions will take place primarily through the Canvas system. Please take the time to navigate through the course and become familiar with the course syllabus, structure, and content and review the list of resources below.

Canvas

The Canvas Student Center includes information on communicating in Canvas, navigating a Canvas course, grades, additional help, and more. The Canvas at Northwestern website provides information of getting to know Canvas at Northwestern and getting Canvas support. The Canvas Student Guide provides tutorials on all the features of Canvas. For additional Canvas help and support, you can always click the Help icon in the lower left corner to begin a live chat with Canvas support or contact the Canvas Support Hotline.

The Canvas Accessibility Statement and Canvas Privacy Policy are also available.

Python, TensorFlow, and Keras

This course will use the programming language Python and the TensorFlow and Keras packages. Python can be downloaded at Anaconda. Download and install the Python 3.6 version of Anaconda. Additional documentation on downloading and installing Anaconda can be found at Anaconda Documentation. After installation, you should be able to access the Anaconda Navigator. To work with a Python-aware editor and an iPython shell, Spyder is recommended. This graphical user interface can be launched via the Anaconda Navigator. This course will also be using Jupyter notebooks to build and store Python files for various assignments. Jupyter can also be launched via the Anaconda Navigator.

Webex and BlueJeans

We will use Webex for optional synchronous meetings. You can review the Privacy Policy here and the Accessibility statement here.

Please note that any scheduled synchronous meetings are optional. While your attendance is highly encouraged, it is not required and you will not be graded on your attendance or participation. These synchronous sessions will be recorded, so you will be able to review the session afterwards.

BlueJeans video conferencing is available for student use in optional study teams.

Panopto

Videos in this course may be hosted in Panopto. If you have not used Panopto in the past, you may be prompted to login to Panopto for the first time and authorize Panopto to access your Canvas account. You can learn more about using Panopto and login to Panopto directly by visiting the Panopto guide on the Northwestern IT Resource Hub. Depending on the assignment requirements of this course, you may be asked to create videos using Panopto in addition to viewing content that your instructor has provided through Panopto.

The Panopto Privacy Policy and the Accessibility Features on Panopto are also available.

Minimum Required Technical Skills

Students in an online program should be able to do the following:

- Communicate via email and Canvas discussion forums.
- Use web browsers and navigate the World Wide Web.
- Use the learning management system Canvas.
- Use integrated Canvas tools (e.g., WebEx, Bluejeans, Panopto, Course Reserves).
- Use applications to create documents and presentations (e.g., Microsoft Word, PowerPoint).
- Use applications to share files (e.g., Box, Google Drive).
- Use software for predictive analytics (e.g., Python, TensorFlow, Keras).

Systems Requirements for Distance Learning

Students and faculty enrolled in SPS online master's degree programs should have access to a computer with Minimum System Requirements.

Technical Help and Support

The SPS Help Desk is available for Faculty, Students and Staff to support their daily IT needs. For additional technical support, contact the Northwestern IT Support Center.

Course Calendar

1) The pages that follow show the plan for topics and assignments week-by-week.
2) In the syllabus and Canvas course site, “week,” “session,” and “module” are synonymous.
3) Changes to the syllabus will be posted to the Canvas course site with an Announcement.

Winter 2019 Weekly Calendar with Assignments

- Week 1. April 1–7. AI: Past, Present, and Future
- Week 2. April 8–14. The Multilayer Perceptron (MLP) in Action
- Week 3. April 15–21. Simple Neural Networks: Architectures and Design Principles, ***First Research/Programming Assignment***
- Week 4. April 22–28. Deep Neural Networks: Architectures and Design Principles
- Week 5. April 29–May 5. Spatial (Image) Data Processing—Convolutional Neural Networks (CNNs), ***Second Research/Programming Assignment***
- Week 6. May 6–12. Temporal Data Processing—Recurrent Neural Networks (RNNs), ***Proposal for Fourth Research/Programming Assignment***
- Week 7. May 13–19. Generative versus Discriminative Methods in Deep Learning, ***Third Research/Programming Assignment***
- Week 8. May 20–26. The Restricted Boltzmann Machine and Deep Learning
- Week 9. May 27–June 2. Reinforcement Learning
- Week 10. June 3–9. Review and ***Fourth Research/Programming Assignment***

Week 1

AI: Past, Present, and Future

Learning Objectives

After completing Module 1, the student should be able to:

Theory:

- ***Define, characterize*** and/or ***explain,*** and ***give examples*** for the ***Week 1 key terms and concepts***,
- ***Differentiate and give examples*** of different representation levels:
  - Signal / statistical,
  - syntactic / semiotic, and
  - symbolic, and
- ***Explain*** how the symbol level is used in AI knowledge representation.

Practicum:

- ***Ontology Development: Design*** and ***develop*** a small-scale ontology (symbol-level knowledge representation), using ontology references and instances of Google's Knowledge Graph as guides ***(10 pts)***,
- ***Work in advance on the Week 2 neural network:*** Begin studying the neural network code that we will use in Week 2: Neural Networks - the Multilayer Perceptron in action, and specifically ***correlate*** specific lines in Python code for a MLP network (with no learning for Week 1) with the neural network design, and specifically identify the role of:
  - Output-to-hidden weight updates, and
  - Hidden-to-input weight updates.

Readings and Resources

Required Readings:

- Chollet, F. 2018. *Deep Learning with Python*. Shelter Island, N.Y.: Manning. [ISBN-13: 978-1617294433] Chapter 1 What is deep learning? (pages 3–24). Source code at: https://github.com/fchollet/deep-learning-with-python-notebooks.git
- Goodfellow, I. Bengio, Y. and Courville, A. 2016. *Deep Learning.* Cambridge Mass.: MIT Press. [ISBN-13: 978-0262035613] Chapter 1. Introduction (pages 1–28). Available online at: https://www.deeplearningbook.org
- Nilsson, N. J. 2010. *The Quest for Artificial Intelligence: A History of Ideas and Achievements.* New York: Cambridge University Press. [ISBN-13: 978-0-521-12293-1] Passim. Available online at: http://ai.stanford.edu/~nilsson/QAI/qai.pdf

The purpose of the next three readings is to gain ***context and awareness*** for how we have evolved our thinking about AI and knowledge representation over the past (approximately) forty years. Read to get a sense of things; do not feel compelled to read in depth, and certainly skip any equations or algorithmic references that you do not immediately understand.

- Chen, X.L., Li, L.-J., Li, F.F., and Gupta, A. (2018). Iterative Visual Reasoning Beyond Convolutions, arXiv:1803.11189v1 (***Note:*** Read for context and overview; in-depth understanding is not required.)
- Newell, A. (1980, Aug 19). The knowledge level*. Presidential Address, American Association for Artificial Intelligence. AAAI80,* Stanford University*.* Later published in *Artificial Intelligence and AI Magazine (1981, July). (**Note:** Use the link provided on the Canvas Course site for Module 1 to access this document. Read the introduction and then skim the rest; this is for context and not for deep reading.)*
- Bengio, Y., Courville, A., and Vincent, P. Representation Learning: A Review and New Perspectives. *arXiv: 1206.5538 [cs.LG]. (**Note:** Use the link provided on the Canvas Course site for Module 1 to access this document. Read the introduction and then very lightly skim the rest; this is for context and not for deep reading.)*

Optional Readings / Resources:

- Found in the Canvas website for this Module

Discussions / Assignments

- ***Discussion D.1: Who's Who in AI:*** (Discussion Board) ***Build*** an ontology, using resources at your disposal, centered on a single researcher in AI. (End Week 1; ***10 points***)
- ***Discussion – Student Introductions:*** (Discussion Board) Introduce yourself, interact with at least three colleagues. (End Week 1; ***no points***)

Sync Session

Thursday, April 4, beginning at 7 p.m. Central time
Sync Session attendance is optional. Each Sync Session is recorded.

Week 2

The Multilayer Perceptron (MLP) in Action

Learning Objectives

After completing Module 2, the student should be able to:

THEORY:

- ***Define and give examples*** for the Week 2 key terms and concepts,

- ***Describe structure and operation*** of a MultiLayer Perceptron (MLP), at both:
    - The microstructure level - the internal structure of a neural "node" or computational unit, and
    - The mesostructure level - the actual architecture and configuration of the network,
- ***Write and describe functionality*** for the equations for different kind of transfer functions, characterizing different microstructure (node-level) functional options, obtain the derivative of each, and identify which transfer function(s) you would choose to use for different network layers, and why you would make these choices:
    - Sigmoid transfer function,
    - Logistic transfer function, and
    - ReLU and approximate ReLU transfer function,
- ***Derive*** the learning equations for a MLP trained with back-propagation, for both:
    - Output-to-hidden layer weight connections and their learning rule updates, and
    - Hidden-to-input layer weight connections and their learning rule updates (OVERVIEW ONLY; will be continued in Module 3).

PRACTICUM:

- Work through a full Python code for a simple neural network (with a fixed number of nodes) trained with backpropagation, ***being able to trace***:
    - How the flow of control passes from one procedure and/or function to another,
    - How the training data is stored within the code (which incorporates both the input data and the desired results), and
    - How both feedforward and feedback processes are carried out in the code,
- ***Correlate*** specific lines in Python code for a MLP network, trained with backpropagation, with specific equations in the backpropagation derivation, for both:
    - Output-to-hidden weight updates, and
    - Hidden-to-input weight updates (OVERVIEW ONLY; will be continued),
- ***Concisely describe*** the nature and particular significance of the X-OR problem, as a challenge that a trained neural network can solve,

- ***Evaluate the backpropagation learning rule in action*** – Working with a simple neural network, ***train*** it using the backprogagation learning algorithm to ***solve*** the X-OR problem,
- ***Assess and evaluate*** the influence of different parameters in the neural network code on training and performance:
    - "Eta" - the learning rate,
    - "Alpha" - the steepness of the transfer function, and
    - "Epsilon" - the criteria for accepting that the network has been sufficiently trained, and
- ***Describe*** the connection weight values as an overall "pattern" (positive or negative values, large or small), and also how the hidden node activations respond to the input patterns once the network is trained.

SITUATION AWARENESS:

- ***(Optional:) Identify***, by ***selecting and describing*** a single article on AI, deep learning, and/or neural networks, the key shifts in AI going from symbolic to connectionist representations, and now (more recently) including symbolic once again.

Readings and Resources

Required Readings:

- Chollet, F. 2018. *Deep Learning with Python*. Shelter Island, N.Y.: Manning. [ISBN-13: 978-1617294433] Chapter 2 Before we begin: the mathematical building blocks of neural networks (pages 25–55). Source code at: https://github.com/fchollet/deep-learning-with-python-notebooks.git

- Maren, A.J. (Draft manuscript). *Statistical Mechanics, Neural Networks, and Artificial Intelligence.* Chapter 4: Neural Network Microstructures and Transfer Functions, and Chapter 5: Backpropagation. (Note: Both chapters available as PDF files in the Canvas course content page "*Dr. A.J.'s Book: Statistical Mechanics, Neural Networks, and Artificial Intelligence*," in the *Welcome* Module.)
- Python code for a backpropagation neural network to solve the X-OR problem; code is provided via a link in the Week 2 module.

Optional Readings / Resources:

- Found in the Canvas website for this Module

Discussions / Assignments

- ***Discussion D.2: X-OR NN*** (End Week 2; ***10 points***)

Week 3

Simple Neural Networks: Architectures and Design Principles

Learning Objectives

After completing Module 3, the student should be able to:

THEORY:

- ***Define and give examples for Week 3 key terms and concepts,***

- ***Complete the derivation*** for the learning equations for a MLP trained with back-propagation, for both:
    - Output-to-hidden layer weight connections and their learning rule updates (review), and
    - Hidden-to-input layer weight connections and their learning rule updates (detailed derivation),
- ***Effectively implement*** the “rules of thumb” for selecting appropriate numbers of hidden nodes for a simple neural network, and
- ***Describe and demonstrate*** how credit assignment works in a neural network.

PRACTICUM:

- Work through a full Python code for a simple neural network (with a variable number of nodes) trained with backpropagation, being able to ***trace***:
    - How the training data is stored within the code (which incorporates both the input data and the desired results), and
    - How both feedforward and feedback processes are carried out in the code,
- (Continued:) ***Correlate*** specific lines in Python code for a MLP network, trained with backpropagation, with specific equations in the backpropagation derivation,
- ***Design and develop*** a simple MLP architecture, appropriately ***selecting***:
    - Numbers of hidden nodes for given input / output vector lengths and data set complexity, and
    - Transfer functions for the hidden and output nodes, and
- Further ***describe*** the influence of different parameters in the neural network code on training and performance, ***for more complex classifications***, specifically:
    - "Eta" - the learning rate,
    - "Alpha" - the steepness of the transfer function, and
    - "Epsilon" - the criteria for accepting that the network has been sufficiently trained, and
- ***Develop*** design-and-test methodologies to assess:
    - How hidden node performance correlates with total numbers of hidden nodes for various network configurations, and
    - How hidden node activations correspond with a given input and output training pair.

SITUATION AWARENESS:

- ***(Optional:) Identify and describe*** how neural networks perform in classification problems, selecting a recent article addressing this topic.

Readings and Resources

Required Readings:

- Chollet, F. 2018. *Deep Learning with Python*. Shelter Island, N.Y.: Manning. [ISBN-13: 978-1617294433] Chapter 3 Getting started with neural networks (pages 56–92). Source code at: https://github.com/fchollet/deep-learning-with-python-notebooks.git
- Additional readings, found in the Canvas website for this Module, provide you with:
    - Backpropagation code, expanded to work with variable numbers of input, hidden, and output nodes
    - Discussions and examples for working with this code, and
    - A *Week 3 Practicum*; guidance for working with this code.

Optional Readings / Resources:

- Found in the Canvas website for this Module

Discussions / Assignments

- ***A.1 First Research/Programming Assignment***. (End Week 3; ***100 points***)
- ***Discussion D.3: Classifier NNs*** – identify an article in the recent literature in which neural networks (simple or deep) are used for a classification task. (End Week 3; ***10 points***)

Sync Session

Thursday, April 18, beginning at 7 p.m. Central time
Sync Session attendance is optional. Each Sync Session is recorded.

Week 4

Deep Neural Networks: Architectures and Design Principles

Learning Objectives

After completing Module 4, the student should be able to:

THEORY:

- ***Identify*** and ***describe*** bottlenecks with simple neural networks (MLPs),
- ***Design*** a classification strategy so that a network can be trained to recognize classes of inputs (and not just specific inputs) via studying how hidden nodes learned to recognize specific features in similar inputs (from Week 3).

PRACTICUM:

- ***Assess*** the hidden node outputs from the previous (Week 3) exercise to determine what features the nodes were responding to; correlate the features with similar characteristics of letters in that data set.
- Based on the hidden node responses and similar features, ***identify*** a set of "big shape classes" that replace the previous classification of a given letter per class to a smaller number of classes that have common "big shapes."
- ***Train*** the neural network to classify inputs into the desired "big shape" class:
    - ***Modify*** the training data by expanding it to include noise and variants
    - ***Describe*** hidden node performance for each class detection, trying to identify input data features to which the hidden nodes are responding,
    - ***Assess*** the classes in terms of classification / misclassification rates, refine classes, re-examine hidden nodes.
- ***Identify and describe*** the functional steps of the code-portion that saves the (trained) connection weights to a file.

SITUATION AWARENESS:

- ***Identify and describe*** how neural networks perform in deep learning, selecting a classic or highly regarded article addressing this topic.

Readings and Resources

Required Readings:

- Chollet, F. 2018. *Deep Learning with Python*. Shelter Island, N.Y.: Manning. [ISBN-13: 978-1617294433] Chapter 4 Fundamentals of machine learning (pages 93–116). Source code at: https://github.com/fchollet/deep-learning-with-python-notebooks.git
- As with Week 3, there are also links to code, tutorials / commentaries, and a Practicum discussing the code.

Optional Readings / Resources:

- Found in the Canvas website for this Module

Discussions / Assignments (110 points)

- ***Discussion D.4: Deep learning*** – describe recent experimental results OR identify an article in the literature identifying how deep learning works. (End Week 4; ***10 points***)

Sync Session

Thursday, April 25, beginning at 7 p.m. Central time
Sync Session attendance is optional. Each Sync Session is recorded.

Week 5

Spatial (Image) Data Processing—Convolutional Neural Networks (CNNs)

Learning Objectives

After completing Module 5, the student should be able to:

THEORY:

- ***Identify*** the kinds of tasks for which Convolutional Neural Networks (CNNs) are used,
- ***Define and give examples*** of the key CNN terms and concepts,
- ***Describe*** how CNNs operate:
    - How masking filters produce feature-specific inputs,
    - How different CNN architectures achieve specific goals, and
    - How the various hyperparameters work in a CNN architecture, and
- ***Describe and give examples*** of how CNNs learn to recognize specific kinds of patterns.

PRACTICUM:

- Working with a base program provided by the instructor, conduct CNN tasks and ***appraise and evaluate*** the results, and
- ***Modify*** the program to investigate how performance can be improved via:
    - Different architectures and hyperparameter selection, and
    - Different kinds and numbers of masking fields, and
- ***Appraise and evaluate*** how various training patterns can be grouped into classes, even though they may have differences in pattern location, orientation, etc.,
- (Optional:) ***Modif***y the basic CNN network by incorporating a Grey-Box subnet into the same network as a CNN; investigate and ***appraise and evaluate*** the results.

SITUATION AWARENESS:

- ***Identify and describe*** how convolutional neural networks address image problems, selecting a recent article addressing this topic.

Readings and Resources

Required Readings:

- Chollet, F. 2018. *Deep Learning with Python*. Shelter Island, N.Y.: Manning. [ISBN-13: 978-1617294433] Chapter 5 Deep learning for computer vision (pages 119–177). Source code at: https://github.com/fchollet/deep-learning-with-python-notebooks.git
- Alex Krizhevsky, Ilya Sustkever, and Geoffrey Hinton (2012). ImageNet Classification with Deep Convolutional Neural Networks, *Advances in Neural Information Processing Systems 25 (NIPS 2012)*. (***Note:*** this is the "breakthrough" paper; read for context and overall understanding, but not necessarily in depth.)
- The Canvas Readings and Resources page for this week provides links to two excellent introductory tutorials as well as a blogpost that identifies key papers in the evolution of deep networks for computer vision. (***Note:*** Read for context and historical perspective; it is not necessary to read each cited paper in depth.)
- As with previous weeks, there are also links to code, tutorials / commentaries, and a Practicum discussing the code.

Optional Readings / Resources:

- Found in the Canvas website for this Module

Discussions / Assignments

- ***A.2 First Research/Programming Assignment***. (End Week 5; ***100 points***)
- ***Discussion D.5: Convolutional NNs*** – Describe experimental results from this week's Practicum OR identify an article in the recent literature identifying how either or both (1) CNNs are used for an interesting application, and/or (2) assessments of different CNN architectures. (The recent series of deep CNNs over the past decade, leading to progressively better results for the ImageNet LSVRC competitions, would be a good choice, and there are other – more recent – options also.) (End Week 5; ***10 points***)

Week 6

Temporal Data Processing—Recurrent Neural Networks (RNNs)

Learning Objectives

After completing Module 6, the student should be able to:

THEORY:

- ***Identify*** the kinds of tasks for which Recurrent Neural Networks (RNNs) and other temporal-data-processing networks are used,
- ***Define and give examples*** of the key terms and concepts introduced in this study of neural networks for temporal data processing,
- ***Describe*** how classic temporal-processing neural networks operate:
    - Backpropagation through time,
    - Time-delay neural networks (TDNNs),
    - Recurrent neural networks (RNNs),
    - Long short-term memory networks (LSTM networks), and
    - Other temporal data processing networks, and
- ***Identify and describe*** different RNN and LSTM architectures, and
- ***Appraise and evaluate*** how RNNs and LSTMs train and operate.

PRACTICUM:

- Working with a base program provided by the instructor, conduct studies using a RNN and/or LSTM network, and ***appraise and evaluate*** the results.

SITUATION AWARENESS:

- ***Temporal data processing applications: Identify*** an application in which temporal data processing neural networks has made crucial advances; ***appraise and evaluate*** reported results.

Readings and Resources

Required Readings:

- Chollet, F. 2018. *Deep Learning with Python*. Shelter Island, N.Y.: Manning. [ISBN-13: 978-1617294433] Chapter 6 Deep learning for text and sequences (pages 178–232). Source code at: https://github.com/fchollet/deep-learning-with-python-notebooks.git
- The Canvas Readings and Resources page for this week provides links to three excellent introductory tutorials. (***Note:*** Read until you understand how RNNs and LSTM NNs work; one or another of these tutorials may prove to offer the best insights for you.)

Optional Readings / Resources:

- Found in the Canvas website for this Module

Discussions / Assignments

- ***Proposal for A.4 Fourth Research/Programming Assignment*** (End Week 6; ***no points***, this is for feedback only)

- ***Discussion D6: Temporal and Sequence Data Processing*** – Identify an article in the recent literature addressing temporal data processing, preferably using a RNN or LSTM, or a more recent and innovative approach. Assess and evaluate. (End Week 6; ***10 points***)

Sync Session

Thursday, May 9, beginning at 7 p.m. Central time
Sync Session attendance is optional. Each Sync Session is recorded.

Week 7

Generative versus Discriminative Methods in Deep Learning

Learning Objectives

After completing Module 7, the student should be able to:

THEORY:

- ***Identify*** situations in which supervised learning (as studied in the previous three weeks) is not the ideal approach,
- ***Discriminate*** between the roles of generative vs. discriminative learning methods (and identify how these correlate with unsupervised vs. supervised learning),
- ***Describe*** how semi-supervised methods compare with generative / unsupervised and also discriminative / supervised,
- Correctly ***formulate*** and knowledgeably ***describe*** the Bayesian probability postulates associated with generative vs. discriminative methods,
- ***Identify*** how the key equations supporting generative learning methods operate,
- ***Identify*** how generative neural networks correlate with Boltzmann machine learning (typically expressed now as Contrastive Divergence) and other energy-based models,

PRACTICUM:

- ***Perform initial steps to develop, build, conduct experiments, analyze results, interpret the findings, assess and refine*** your selected project for EITHER space (using convolutional NNs) OR time (using RNNs or LSTM NNs).

SITUATION AWARENESS:

- ***Differentiate*** the nature and role of discriminative vs. generative learning.

Readings and Resources

Required Readings:

- Chollet, F. 2018. *Deep Learning with Python*. Shelter Island, N.Y.: Manning. [ISBN-13: 978-1617294433] Chapter 7 Advanced deep-learning best practices (pages 233–268). Source code at: https://github.com/fchollet/deep-learning-with-python-notebooks.git
- Salakhutdinov, R. and Hinton, G. (2012, August). An Efficient Learning Procedure for Deep Boltzmann Machines, *Neural Computation* **24** (8), 1967-2006. (Note: This is the classic breakthrough paper, however, it is written using the language of statistical mechanics (a branch of physics), and is further particular to G. Hinton's specific vocabulary. Thus, read for general context, but not depth.) The link for this paper is found in the first linked-page on the **Week 7 Required Readings** content page; ***Week 7: Required Readings (1) - Deep Learning: Where It All Began***. It is about halfway down the page, after a historical introduction.
- The Canvas Readings and Resources page for this week provides links to introductory tutorials. (***Note:*** Read until you understand how RNNs and LSTM NNs work; one or another of these tutorials may prove to offer the best insights for you.) There is also a link to code; this is not precisely a generative-learning code; it's an emulation exercise.

Optional Readings / Resources:

- Found in the Canvas website for this Module

Discussions / Assignments

- ***Discussion D.7 Generative vs. Discriminative Methods. Differentiate*** between generative vs. discriminative learning methods. Alternatively, identify an article in the recent literature identifying either (1) how generative methods are used (in distinction to our previous studies focused on discriminative methods), and/or (2) an interesting application using a generative network as at least one component, which may potentially be a Generative Adversarial Network (GAN) or an autoencoder, and/or (3) a semi-supervised neural approach (preferably in contrast with either or both a generative and/or supervised training method). Alternatively (4), address how deep architectures may be partially trained first using a generative approach, with the weights refined using a discriminative training method. (End Week 7; ***10 points***)

- ***A.3 Third Research/Programming Assignment*** *(End Week 7,* ***100 points****)*

Sync Session

Thursday, May 18, beginning at 7 p.m. Central time
Sync Session attendance is optional. Each Sync Session is recorded.

Week 8

The Restricted Boltzmann Machine and Deep Learning

Learning Objectives

After completing Module 8, the student should be able to:

THEORY:

- ***Identify*** and characterize bottlenecks with simple neural networks (MLPs),
- ***Describe*** fundamental strategies for creating effective deep neural networks,
- ***Identify and describe*** architecture and design principles for deep neural networks,
- ***Identify and describe*** useful training strategies for deep neural networks,
- ***Evaluate and select*** appropriate transfer functions for different hidden layers as well as the output layer,
- ***Design*** a neural network architecture that enables generative learning, and

- ***Identify*** how generative learning plays a role in two key applications:
    - Generative Adversarial Networks (GANs), and
    - Autoencoders.

PRACTICUM - Final Work on A.3 – Deep Learning for Time & Space:

- ***(Primary): Final steps to develop, build, conduct experiments, analyze results, interpret the findings, assess and refine*** your selected project for EITHER space (using convolutional NNs) OR time (using RNNs or LSTM NNs).

SITUATION AWARENESS:

- ***Identify*** how deep neural networks learn and operate; ***distinguish*** from simple (single hidden layer) NNs.

Readings and Resources

Required Readings / Resources:

- Chollet, F. 2018. *Deep Learning with Python*. Shelter Island, N.Y.: Manning. [ISBN-13: 978-1617294433] Chapter 8 Generative deep learning (pages 269–313). Source code at: https://github.com/fchollet/deep-learning-with-python-notebooks.git
- Blogpost, “The Restricted Boltzmann Machine;” the link for this post is found in the **Week 8 Required Readings** content page.
- Walia, A.S. (2017, May 18). Generative Models and GANs (Links to an external site.)Links to an external site., *Towards Data Science* (blog). (Again, the link for this post is found in the **Week 8 Required Readings** content page.)

Optional Readings / Resources:

- Found in the Canvas website for this Module

Discussions / Assignments

- ***Discussion D.8: The Leading Edge in AI***. Identify an article in the recent literature identifying how either or both (1) deep learning networks are used for an interesting application, and/or (2) assessments of different deep learning architectures. (End Week 8; ***10 points***)

Week 9

Reinforcement Learning

Learning Objectives

After completing Module 9, the student should be able to:

THEORY:

- ***Identify*** the kinds of tasks for which reinforcement learning is used,
- ***Define and give examples*** of the key terms and concepts introduced in this study of reinforcement learning,
- ***Describe*** how reinforcement learning operates:
    - Describe and give an example of a Markov decision process,
    - Describe how Q-learning works, and
- ***Differentiate*** between (model-free) reinforcement learning and various model-based learning methods (e.g., supervised learning, together with unsupervised learning, and semi-supervised learning).

PRACTICUM:

- ***Coding & Analytics: Continue to develop, build, conduct experiments, analyze results, interpret the findings, assess and refine*** the project that you have devised as your Final Project. ***Summarize*** your findings.

Readings and Resources

Required Readings:

Chollet, F. 2018. *Deep Learning with Python*. Shelter Island, N.Y.: Manning. [ISBN-13: 978-1617294433] Chapter 9 Conclusions (pages 314–339). Source code at: https://github.com/fchollet/deep-learning-with-python-notebooks.git

Sutton, R. and Barto, A. G. 2018. *Reinforcement Learning: An Introduction* (second ed.). Cambridge, Mass.: MIT Press. [ISBN-13 9780262039246] Chapter 1: Introduction (pages 1–22). Online: https://drive.google.com/file/d/1opPSz5AZ_kVa1uWOdOiveNiBFiEOHjkG/view

The following are introductory or “warm-up” readings. These are blogposts; links are available on the Canvas course Week 9 Readings and Resources page, or you can use the link provided as hypertext:

- Reinforcement learning is on the advance wave of neural network methods for AI. (Links to an external site.).
- Here's a good overview of the overview paper (Links to an external site.).
- THIS blog from Google's DeepMind (Links to an external site.). (Note: This blog gives a great visualization of how AlphaGo's performance has improved in subsequent versions.)

This is an important paper:

- D. Silver et al. (2017, Oct. 19). Mastering the game of Go without human knowledge (Links to an external site.)Links to an external site., Nature 550, 354–359. doi:10.1038/nature24270 (Note: As usual, read for context and perspective, not depth.) Use THIS LINK to access the PDF: ***https://deepmind.com/documents/119/agz_unformatted_nature.pdf***
- Sutton, R. S. and Barto, A. G. 2018. *Reinforcement Learning: An Introduction* (second ed.). Cambridge, Mass.: MIT Press. [ISBN-13 9780262039246] This is a highly regarded textbook that covers the primary reinforcement learning methods. Chapter 1: Introduction (pages 1–22). Online: https://drive.google.com/file/d/1opPSz5AZ_kVa1uWOdOiveNiBFiEOHjkG/view

Optional Readings / Resources:

- Found in the Canvas website for this Module

Discussions / Assignments

- ***Discussion D.9 AI in Movies:*** Describe how the Week 9 “Movie of the Week” portrays artificial intelligence, and how people have been responding to this portrayal. Identify issues that come up with the evolving role of AI in society. Summarize and synthesize your observations over the set of cultural resources (movies, books, and online articles / discussions) that you’ve examined over these weeks. (End Week 9; ***10 points***)

Sync Session

Thursday, May 30, beginning at 7 p.m. Central time
Sync Session attendance is optional. Each Sync Session is recorded.

Week 10

Review and Final Assignment

Learning Objectives

There will be no new material introduced during this week.

Readings and Resources

Required Readings / Resources:

- No new required readings this week.

Optional Readings / Resources:

- Any optional materials will be found in the Canvas website for this Module

Discussions / Assignments

- ***Discussion D.10 Final Project Discussion -*** the “Lessons Learned” by posting a brief discussion to the Week 10 Discussion Board. (***10 points***)
- ***A.4 Fourth Research/Programming Assignment: Deep*** Learning (Pick one of many options) (End of Week ***100 points***)