

CSCI E-82a

Probabilistic Programming and AI

Introduction

Steve Elston



HARVARD
Extension School

Why Probabilistic AI?

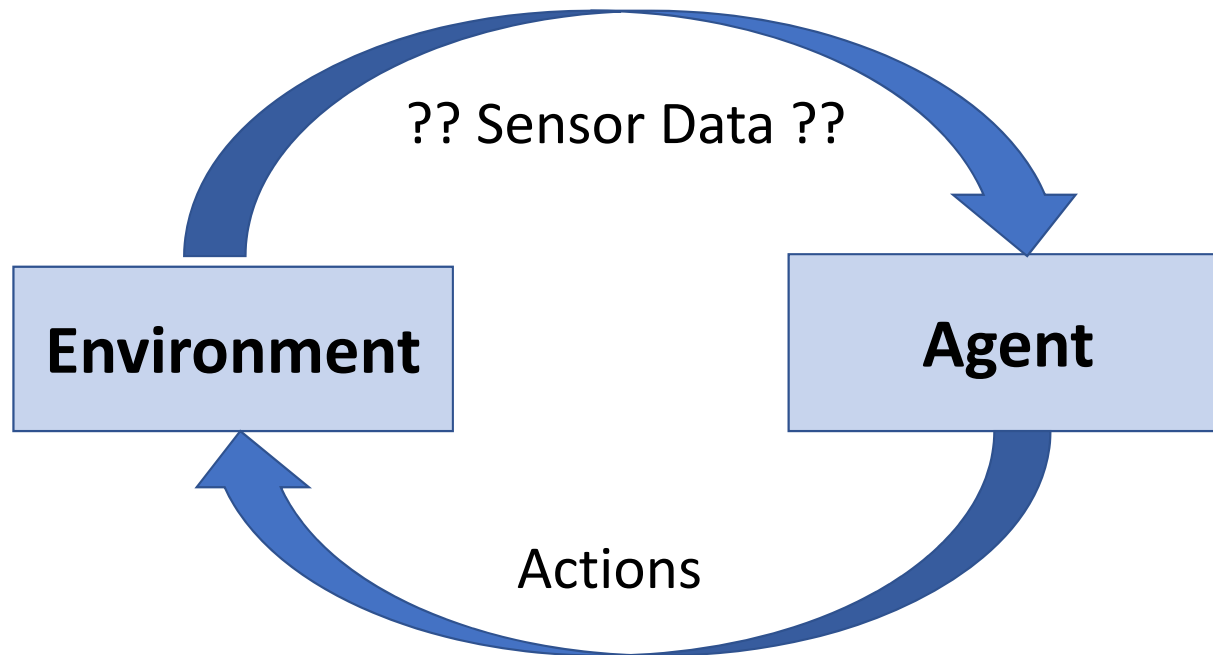
The common theme of this course is making **optimal decisions** in **complex and uncertain environments**

- Intelligent agents must interact with a complex world
- Complex environments lead to uncertainty
- Agents require algorithms that deal with uncertainty
- Probabilistic models, such as **Bayesian models** and **Markov decision processes (MDP)**, allow us to address these problems

Why Probabilistic AI?

Intelligent agent interacts with uncertain environment

- Information from the environment is incomplete and prone to errors
- Agent must take optimal actions given uncertain information



The Intelligent Agent

Fundamental functions of a probabilistic intelligent agent

- **Representation:** A good representation is often the key to good machine intelligence. A good representation is a mapping of the model and the environment. Good representation is key to effective AI!
- Representations are often **approximate** given **high complexity** of real world

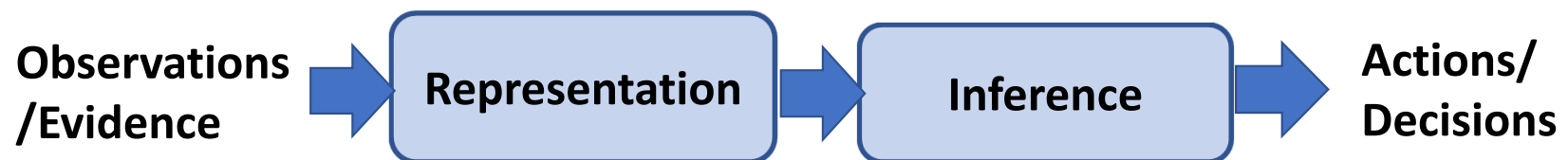


Representation

The Intelligent Agent

Fundamental functions of a probabilistic intelligent agent

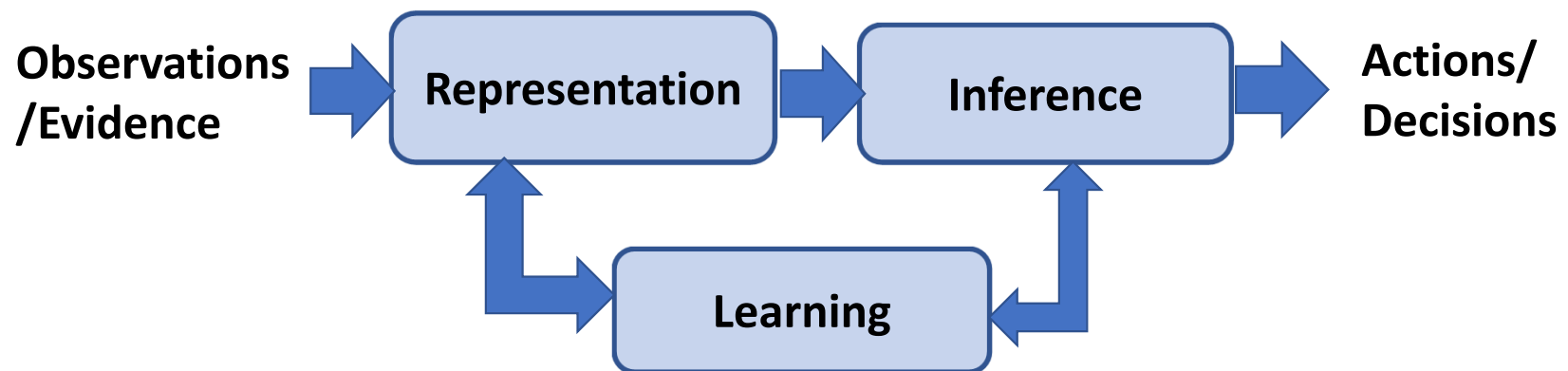
- **Inference or Reasoning:** The process of computing actions or decisions from **queries** of the model given the **evidence**. In the simplest form a query returns a mathematical result, such as the **marginal probability distribution** or the **maximum a posteriori** value.
- Reasoning computes a specific action which is applied to the environment.



The Intelligent Agent

Fundamental functions of a probabilistic intelligent agent

- **Learning:** The agent performs **learning** using data or **evidence** to update the model. The evidence is observed by **sensors** which provide information to the model on the **state of the environment**



Uncertainty in the Environment

Agent must navigate to destination

- Plans optimal route
- How much does the traffic volume change?
- Does the plan account for road repair?
- Does an accident block a route?
- In other words, which decisions are required to minimize travel time?
- Poor response to unexpected information is known as **brittleness** in a model

Uncertainty in the Environment

Integrate sensors for collision avoidance in self-driving car

- Sensors have different range and accuracy
- How are sensors affected by fog, rain or darkness?
- How accurate is traffic sign recognition?
- What is the response of each sensor to snow and ice covered roads?
- In other words, what is the posterior probability that a change in speed or direction is required?

Uncertainty in the Environment

Unobservable information adds to uncertainty

- The intentions of other drivers
- The cards held by other players in a game of poker
- The spot price of wheat in the future
- Net result is **incomplete information**

Probabilistic Reasoning Recognized as Fundamental Method

Check out videos: https://amturing.acm.org/award_winners/pearl_2658896.cfm

The screenshot displays the ACM Turing Award website. At the top, there's a header with the ACM logo and the text "A.M. TURING AWARD". Below this, a navigation bar includes "A.M. TURING CENTENARY CELEBRATION WEBCAST", a search bar, and a grid of laureate portraits. A secondary navigation bar lists "ALPHABETICAL LISTING", "YEAR OF THE AWARD", and "RESEARCH SUBJECT". The main content area features a large portrait of Judea Pearl on the left. To his right, his name "JUDEA PEARL" is displayed with a "DL" icon, followed by "United States – 2011". Below this, a "CITATION" section reads: "For fundamental contributions to artificial intelligence through the development of a calculus for probabilistic and causal reasoning." At the bottom, five icons represent different resources: "SHORT ANNOTATED BIBLIOGRAPHY", "ACM TURING AWARD LECTURE VIDEO", "RESEARCH SUBJECTS", "ADDITIONAL MATERIALS", and "VIDEO INTERVIEW". A "Photo-Essay" link is also visible at the bottom left.

acm
MORE ACM AWARDS

A.M. TURING AWARD

A.M. TURING CENTENARY CELEBRATION WEBCAST

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ALPHABETICAL LISTING YEAR OF THE AWARD RESEARCH SUBJECT

JUDEA PEARL DL

United States – 2011

CITATION

For fundamental contributions to artificial intelligence through the development of a calculus for probabilistic and causal reasoning.

Photo-Essay

SHORT ANNOTATED BIBLIOGRAPHY ACM TURING AWARD LECTURE VIDEO RESEARCH SUBJECTS ADDITIONAL MATERIALS VIDEO INTERVIEW

About Your Instructor

- Principle Consultant at Quantia Analytics
- Instructor, Harvard Extension School, University of Washington
- MS and PhD in Geophysics from Princeton University
- Work in machine learning starting in 1980s
- Co-founded analytics businesses
- Worked in a number of areas:
 - Capital markets risk
 - Image analysis
 - Fraud detection
 - Forecasting
 - Failure prediction

About Your Teaching Fellow

- Sarah Asano – asano.sar@gmail.com
- Electro-Optical Engineer, Lockheed Martin, Sunnyvale, California
- MS Robotics, Carnegie Mellon University
- BS Mechanical Engineering, California Institute of Technology
- Experience in:
 - App development
 - Game development
 - Internet of things
 - Embedded systems
 - Robots

About This Course

Focus on two different classes of probabilistic algorithms

- Graphical models
 - Computationally efficient method to compute posterior probabilities distributions
 - Sequential decision models
 - Explainable models
- Reinforcement learning algorithms
 - Agent learns by experience
 - Model free
 - Learn policy for complex and stochastic environment
- Models related through Markov Decision Processes (MDP)

About This Course

Grading is based on hands on work and class participation

- Homework assignments – 70%
 - Assignment most weeks
 - Focus on hands-on coding
 - **Read directions carefully and answer all questions;** don't miss points!
- On campus weekend – 30%
 - 9am – 5 pm Dec 7-8. **You must attend the entire session** for course credit!
 - Meet at one Brattle Square, Cambridge
 - Team challenges
 - Book rooms, etc. early

About This Course

Course participation

- Your participation important to get maximum value from this course!
 - Students who attend lection and sections tend to do better.
- On-line lecture – Wednesdays 5:50 – 7:50 pm US Eastern Time
 - Lecture focused on theory
 - Lectures will be recorded
 - Please remind your instructor to record!!
- Section – TBD
 - Section focused on code, questions and homework
 - Perhaps, some background supplement for theory

About This Course

Text Books

- Readings are from two text books
- Both available at the Coop: <https://tinyurl.com/300-F19-CSCI-E-82A-1>
- Or free pdf downloads
 - Bayesian Reasoning and Machine Learning, Barber, 2012, Cambridge University Press:
<http://web4.cs.ucl.ac.uk/staff/D.Barber/textbook/091117.pdf>
 - Reinforcement Learning, an introduction, Second edition, Sutton and Barto, 2018, MIT Press:
<https://mitpress.ublish.com/book/reinforcement-learning-an-introduction-2>

About This Course

Other reference sources I draw material from:

- *Artificial Intelligence, A Modern Approach*, Stuart Russell and Peter Norvig, Prentice Hall, Third edition, 2010
- *Probabilistic Graphical Models, Principles and Techniques*, Daphne Koller and Nir Freedman, MIT Press, 2009
- *Decision Theory Under Uncertainty: Theory and Applications*, Kochenderfer, et. al., MIT Press, 2015.
- *Machine Learning: A Probabilistic Perspective*, Murphy, MIT Press, 2012.
- *Deep Learning*, Ian Goodfellow, Yushua Bengio, and Arron Courville, MIT Press, 2016

About This Course

Getting help with this course – essential component of class participation

1. Plan to attend the section
 - Bring your questions for class discussion
2. Use Piazza – <https://piazza.com/class#fall2019/cscie82a>
 - Ask questions
 - Answer questions
3. Email Steve – stephen.elston@quantia.com
 - Please only ask **questions of a private nature**; e.g. grading questions
 - Please direct general questions on course material and homework to the aforementioned venues – if you have a question, others likely will too!
4. Grading questions: email Sarah – asano.sar@gmail.com

Course Materials

- Obtain course materials from course Github repository
 - https://github.com/StephenElston/CSCI_E_82A_Probabilistic_Programming
 - Jupyter notebooks with review of theory and code
 - Slides
 - Course material will be updated regularly – **plan on doing a pull regularly**
- Homework assignments will be at:
https://github.com/StephenElston/CSCI_E_82A_Probabilistic_Programming/Homework
- Submit completed homework and receive grades in Canvas

First Assignments

- Lesson 0– Self-paced
 - Review of probability concepts – In Github repository
 - Not graded
 - **Decide if this class is for you!**
- Homework 1 – Directed graphical models
 - Due September 18 at 24:00 (midnight) US Eastern Time

AI Is Still A Work In Progress!!

Views of 21st century AI

