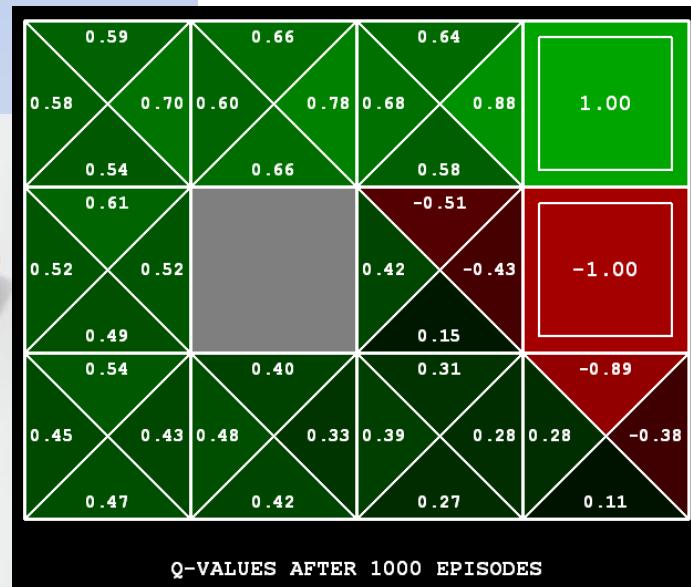
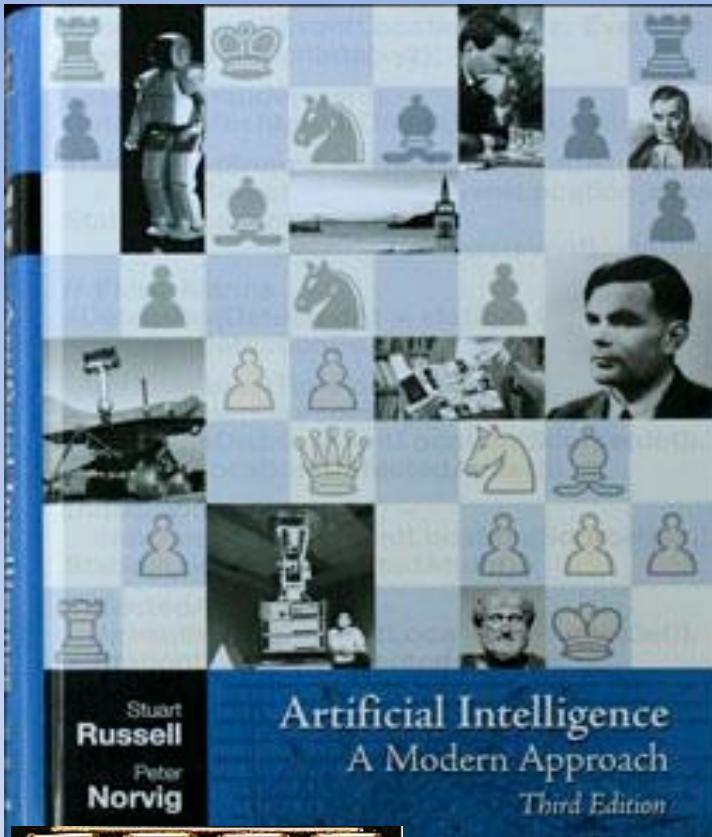


# Artificial Intelligence



# Grading

Period	Presentations/Examinations/Assignments	Points
Various	In-Class Participation/Presentations	125
	Search	125
	Probabilistic Reasoning	125
	Quizzes	125
	Midterm	200
	Final	300

# Assignments (Programming)

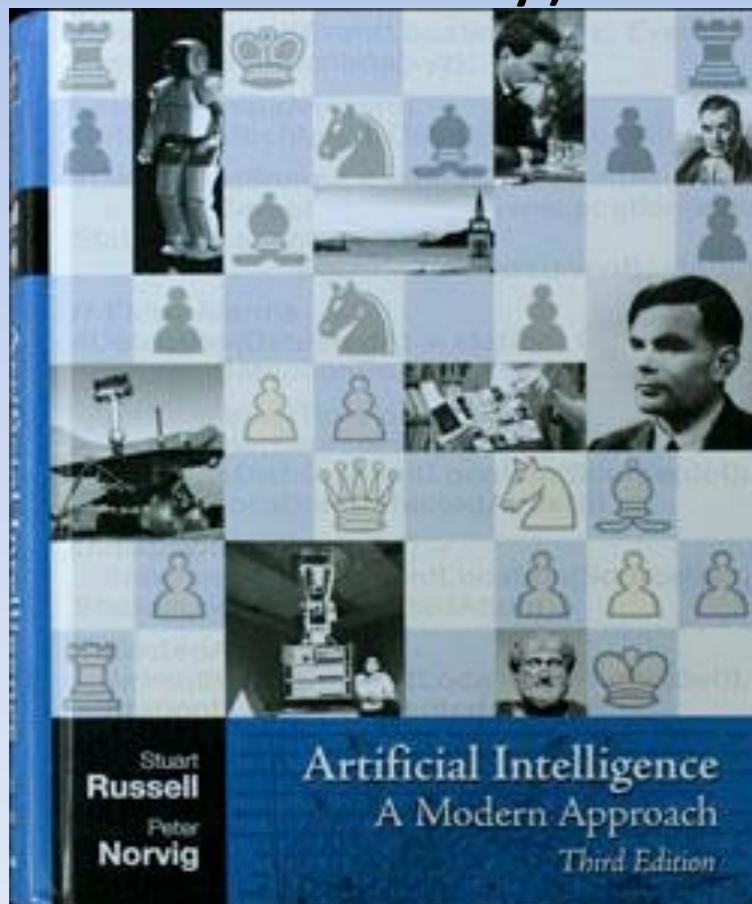
- Assignment 1: Search
- Assignment 2: Probabilistic Reasoning

# Tests

- Midterm (20%)
- Final (30%)

# Textbook

- The 22nd most cited computer science publication on Citeseer (and 4th most cited publication of this century).



# Dr. Stuart Russell

Professor of Computer Science and Michael H. Smith and Lotfi A. Zadeh Chair in Engineering,  
Computer Science Division  
University of California  
Berkeley, CA 94720

Adjunct Professor of Neurological Surgery, University of California, San Francisco

**Tel.** (510) 642-4964

**Fax** (510) 642-5775

**Email** russell@cs.berkeley.edu

**Home page** <http://www.cs.berkeley.edu/~russell>

## Education

B.A. (Hons.) 1st Class, Physics, Wadham College, University of Oxford, 1979--82.

Ph.D., Computer Science, Stanford University, 1982--86.

## Employment history

2012--present, Professeur Invité, Université Pierre et Marie Curie, Paris

2012--present, Professeur, Fondation de l'École Normale Supérieure, Paris

2008--present, Adjunct Professor, Department of Neurological Surgery, University of California, San Francisco

2008--2010, Chair, Department of Electrical Engineering and Computer Sciences, University of California, Berkeley

2006--2010, Chair, Computer Science Division, University of California, Berkeley

1996--present, Professor, Computer Science Division, University of California, Berkeley

1991--96, Associate Professor, Computer Science Division, University of California, Berkeley

1986--91, Assistant Professor, Computer Science Division, University of California, Berkeley

1986, Summer employee, MCC, Austin, Texas, Machine learning research in the Large Scale KB Project (CYC)

1985--86, Research Assistant, Computer Science Dept., Stanford University

1983, Teaching Assistant, Computer Science Dept., Stanford University

1981, Programmer, graphics research project, IBM Los Angeles Scientific Center

1978--80 (1 year total), Programmer, IBM Systems Engineering Centre, Warwick, UK



# Dr. Peter Norvig

## Professional Employment (Full-Time)

2001-now	<a href="#">Google</a>	Director of Research (2006-now); formerly Director of Search Quality (2002-2006) and Machine Learning (2001).
1998-2001	<a href="#">NASA Ames Research Center</a>	Division Chief, Computational Sciences
1996-1998	<a href="#">Jungle Corp.</a>	Chief Scientist
1994-1996	<a href="#">Harlequin, Inc.</a>	Chief Designer
1991-1994	<a href="#">Sun Microsystems Labs</a>	Senior Scientist
1986-1991	<a href="#">University of California, Berkeley</a>	Research Faculty Member
1985-1986	<a href="#">University of Southern California</a>	Assistant Professor
1978-1980	<a href="#">Higher Order Software, Inc.</a>	Member of Technical Staff
1977-1977	<a href="#">Woods Hole Oceanographic Institute</a>	Summer Programming Intern

I also have served as an advisory board member for various companies, including: [Root-1](#), [Fetch](#), [CleverSet](#), [Ask Jeeves](#), [Thinking Software](#), [PersonalGenie.com](#).

## Education

1980-1985	Ph.D. Computer Science	<a href="#">University of California, Berkeley</a>
1974-1978	B.S. Applied Mathematics	<a href="#">Brown University</a>

## Personal Information

Citizen: U.S.  
Raised: RI, MA, CA.  
Status: Married with 2 children.  
Erdos #: 3 (Erdos to Peter Cameron to Stuart Russell to me)



# Additional Materials

- AAAI
- KDD

## ■ LINKS

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### Registration Information

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### Program

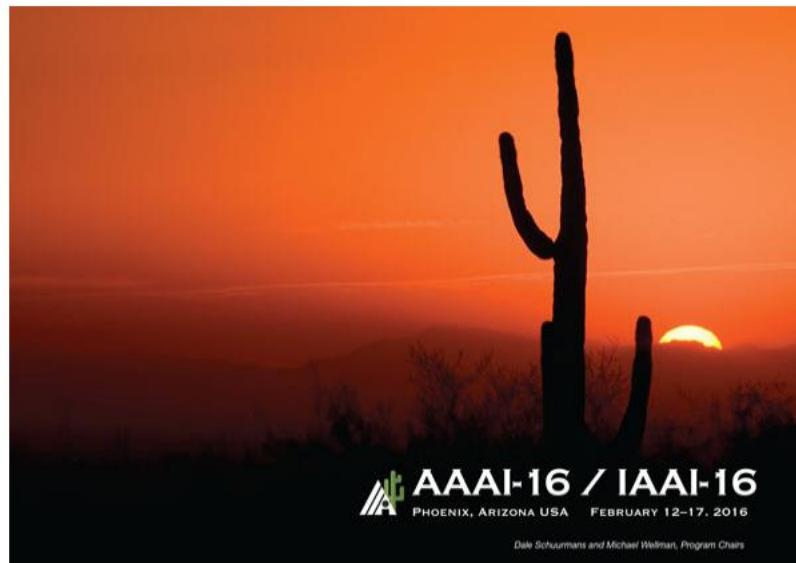
[Program Overview](#)  
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[Program \(PDF\)](#)  
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[IAAI Schedule](#)  
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### Conference Organization

[Conference Committee](#)

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[DC Call for Applications](#)  
[Student Volunteer Program](#)



## ■ PLEASE JOIN US FOR THE THIRTIETH AAAI CONFERENCE (AAAI-16)!

**February 12–17, 2016, Phoenix, Arizona USA**

### *[NEW! Registration Information!](#)*

The Thirtieth AAAI Conference on Artificial Intelligence (AAAI-16) will be held February 12–17 at the Phoenix Convention Center, Phoenix, Arizona, USA. Please note the alternate day pattern for AAAI-16. The workshop, tutorial, and doctoral consortium programs will be held Friday and Saturday, February 12 and 13, followed by the technical program, Sunday through Wednesday (at noon), February 14–17.

<http://www.aaai.org/Library/AAAI/aaai16contents.php>

## Technical Papers: Applications

Inferring Multi-Dimensional Ideal Points for US Supreme Court Justices / 4

*Mohammad Raihanul Islam, K. S. M. Tozammel Hossain, Siddharth Krishnan, Naren Ramakrishnan*

Little Is Much: Bridging Cross-Platform Behaviors through Overlapped Crowds / 13

*Meng Jiang, Peng Cui, Nicholas Jing Yuan, Xing Xie, Shiqiang Yang*

Scientific Ranking over Heterogeneous Academic Hypernetwork / 20

*Ronghua Liang, Xiaorui Jiang*

MUST-CNN: A Multilayer Shift-and-Stitch Deep Convolutional Architecture for Sequence-Based Protein Structure Prediction /

27

*Zeming Lin, Jack Lanchantin, Yanjun Qi*

Hospital Stockpiling Problems with Inventory Sharing / 35

*Eric Lofgren, Anil Vullkanti*

Predicting ICU Mortality Risk by Grouping Temporal Trends from a Multivariate Panel of Physiologic Measurements / 42

*Yuan Luo, Yu Xin, Rohit Joshi, Leo Cel, Peter Szolovits*

Learning to Generate Posters of Scientific Papers / 51

*Yuting Qiang, Yanwei Fu, Yanwen Guo, Zhi-Hua Zhou, Leonid Sigal*

Face Behind Makeup / 58

*Shuyang Wang, Yun Fu*

Social Role-Aware Emotion Contagion in Image Social Networks / 65

*Yang Yang, Jia Jia, Boya Wu, Jie Tang*

Survival Prediction by an Integrated Learning Criterion on Intermittently Varying Healthcare Data / 72

*Jianfei Zhang, Lifei Chen, Alain Vanasse, Josiane Courteau, Shengrui Wang*

On the Minimum Differentially Resolving Set Problem for Diffusion Source Inference in Networks / 79

*Chuan Zhou, Wei-Xue Lu, Peng Zhang, Jia Wu, Yue Hu, Li Guo*

**Program**

- [Program Overview](#)
  - [AAAI Guidebook Schedule](#)
  - [Accepted Papers](#)
  - [Program \(PDF\)](#)
  - [AAAI Program Schedule \*New!\*](#)
  - [IAAI Program Schedule](#)
  - [Invited Speakers](#)
- 

**Conference Organization**

- [Conference Committee](#)
- 

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- 

**Robotics Programs****Other Programs**

- [\*\*NEW!\*\* AI in Practice](#)
  - [Exhibit Program](#)
  - [Tutorial Forum](#)
  - [Workshop Program](#)
- 

**■ PLEASE JOIN US FOR THE THIRTY-FIRST AAAI CONFERENCE (AAAI-17)!****Register! 4 – 9 February – San Francisco, California USA**

- [AAAI Guidebook Schedule](#)
- 

Selected lectures and programs from this conference have been posted at [VideoLectures.Net](#).

The Thirty-First AAAI Conference on Artificial Intelligence (AAAI-17) will be held February 4–9 at the Hilton San Francisco, San Francisco, California, USA. The workshop, tutorial, and doctoral consortium programs will be held Saturday and Sunday, February 4 and 5, followed by the technical program, Monday through Thursday, February 6–9.

The chairs of AAAI-17 are Satinder Singh (University of Michigan) and Shaul Markovitch (Technion-Israel Institute of Technology).

The purpose of the AAAI conference is to promote research in artificial intelligence (AI) and scientific exchange among AI researchers, practitioners, scientists, and engineers in affiliated disciplines. AAAI-17 will have a diverse technical track, student abstracts, poster sessions, invited speakers, tutorials, workshops, and exhibit and competition programs, all selected according to the highest reviewing standards. AAAI-17 welcomes submissions on mainstream AI topics as well as novel crosscutting work in related areas.

<https://aaai.org/Library/AAAI/aaai17contents.php>

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## ■ OTHER LINKS

## ■ THIRTY-FIRST AAAI CONFERENCE ON ARTIFICIAL INTELLIGENCE

*Sponsored by the Association for the Advancement of Artificial Intelligence*

**Satinder Singh and Shaul Markovitch, Program Cochairs.**

February 4 –9, 2017, San Francisco, California USA. Published by The AAAI Press, Palo Alto, California. [This proceedings](#) is also available in book format.

**Please Note:** Abstracts are linked to individual titles, and will appear in a separate browser window. Full-text versions of the papers are linked to the abstract text. PDF file sizes may be large!

### Contents

#### Applications

[SnapNETS: Automatic Segmentation of Network Sequences with Node Labels / 3](#)  
*Sorour E. Amiri, Liangzhe Chen, B. Aditya Prakash*

[Taming the Matthew Effect in Online Markets with Social Influence / 10](#)  
*Franco Berbeglia, Pascal Van Hentenryck*

[A Leukocyte Detection Technique in Blood Smear Images Using Plant Growth Simulation Algorithm / 17](#)  
*Deblina Bhattacharjee, Anand Paul*

[Partitioned Sampling of Public Opinions Based on Their Social Dynamics / 24](#)  
*Weiran Huang, Liang Li, Wei Chen*

[Novel Geometric Approach for Global Alignment of PPI Networks / 31](#)  
*Yangwei Liu, Hu Ding, Danyang Chen, Jinhui Xu*



# KDD2016

22nd ACM SIGKDD Conference on Knowledge Discovery and Data Mining  
August 13 - 17, 2016 | San Francisco, California

<http://www.kdd.org/kdd2016/program/accepted-papers>

KDD2016

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# Accepted Papers

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## PROGRAM

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Plenary Panel

Applied Data Science

Invited Talks

Applied Data Science

Invited Panels

Hands-On Tutorials

## Accepted Papers

Tutorials

Workshops

VC Office Hours

Session Feedback

## RESEARCH TRACK PAPERS - ORAL

### Title & Authors

#### **NetCycle: Collective Evolution Inference in Heterogeneous Information Networks**

Author(s): Yizhou Zhang\*, Fudan University; Xiong Yun, ; Xiangnan Kong, Worcester Polytechnic Institute; Yangyong Zhu, Fudan University

#### **Lexis: An Optimization Framework for Discovering the Hierarchical Structure of Sequential Data**

Author(s): Payam Siyari\*, Georgia Institute of Technology; Bistra Dilkina, Georgia Tech; Constantine Dovrolis, Georgia Institute of Technology

#### **Skinny-dip: Clustering in a Sea of Noise**

Author(s): Samuel Maurus\*, Helmholtz Zentrum München; Claudia Plant

#### **Goal-Directed Inductive Matrix Completion**

Author(s): Si Si\*, Ut austin; Kai-Yang Chiang, UT Austin; Cho-Jui Hsieh, UT Austin; Nikhil Rao, Technicolor Research; Inderjit Dhillon, UTexas

#### **Sampling of Attributed Networks From Hierarchical Generative Models**

Author(s): Pablo Robles Granda\*, Purdue University; Sebastian Moreno, ; Jennifer Neville, Purdue

#### **Joint Community and Structural Hole Spanner Detection via Harmonic Modularity**

Author(s): Lifang He\*, ; CHUN-TA LU, UIC; Jiaqi Ma, Tsinghua University; Jianping Cao, NUDT; Linlin Shen, ; Philip S. Yu, UI Chicago



# KDD2017

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## Research Track

### BEST PAPER AWARD

#### Winner

##### [Accelerating Innovation Through Analogy Mining](#)

Tom Hope (Hebrew University of Jerusalem);Joel Chan (Carnegie Mellon University);Aniket Kittur (Carnegie Mellon University);Dafna Shahaf (Hebrew University of Jerusalem)

#### Runner Up

##### [Toeplitz Inverse Covariance-Based Clustering of Multivariate Time Series Data](#)

David Hallac (Stanford University);Sagar Vare (Stanford University);Stephen Boyd (Stanford University);Jure Leskovec (Stanford University)

#### Best Reviewers

- Karthik Raman, Google
- Kevin Small, Amazon
- Zoran Obradovic, Temple University
- Pauli Miettinen, Max Planck Institute

- Monday
- Wednesday

#### Important Dates

- Camera Ready Deadline  
June 9, 2017
- Startup Grant Deadline  
June 16, 2017
- Student Grants Deadline  
June 17, 2017
- Promotional Video Deadline  
June 18, 2017
- Tutorials  
August 13, 2017
- Workshops  
August 14, 2017
- Main Conference  
August 15 - 17, 2017

#### Program

- Keynote Speakers
- Applied Data Science Invited Panels
- Applied Data Science Invited Talks
- Plenary Panel

# Personal Computer Science Focus

## CSCI 164. Artificial Intelligence Programming

Prerequisite: CSCI 117. Introduction to problem-solving methods from artificial intelligence. Production systems. Knowledge-based systems. Machine learning. Topics chosen from fuzzy logic, neural network models, genetic algorithms. Verification, validation, testing.

Units: 3

## CSCI 166. Principles of Artificial Intelligence

Prerequisite: CSCI 164. Analysis of knowledge-based and neural models, including self-organization, sequential learning models, neurally inspired models of reasoning and perception. Integration of different paradigms.

Units: 3

## CSCI 174. Design and Analysis of Algorithms

Prerequisites: CSCI 115, CSCI 119. Models of computation and measures of complexity, algorithms for sorting and searching, set representation and manipulation, branch and bound, integer and polynomial arithmetic, pattern-matching algorithms, parsing algorithm, graph algorithm, NP-complete problems.

Units: 3

## CSCI 126. Database Systems

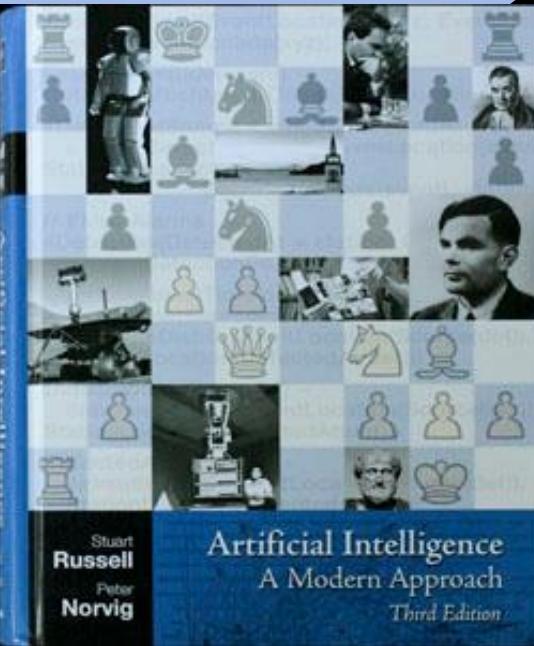
Prerequisites: CSCI 124. Database concepts; hierarchical and relational network models; object-oriented data models. Data normalization, data description languages, data manipulation languages, and query design.

Units: 3

Course Typically Offered: Spring

# Personal Computer Science Focus

- Search
  - AI, Algorithms, RDMS
- Data
  - Machine Learning, Algorithms, RDMS
- Puzzles
  - AI, Algorithms
- Books...



## CSCI 174. Design and Analysis of Algorithms

Prerequisites: CSCI 115, CSCI 119. Models of computation, measures of complexity, algorithms for sorting, representation and manipulation, branch-and-bound, polynomial arithmetic, pattern-matching algorithms, graph algorithm, NP-complete problems

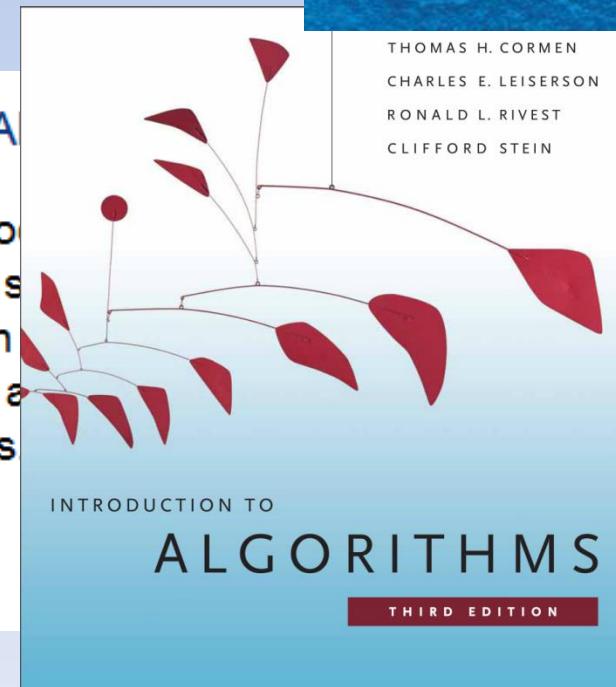
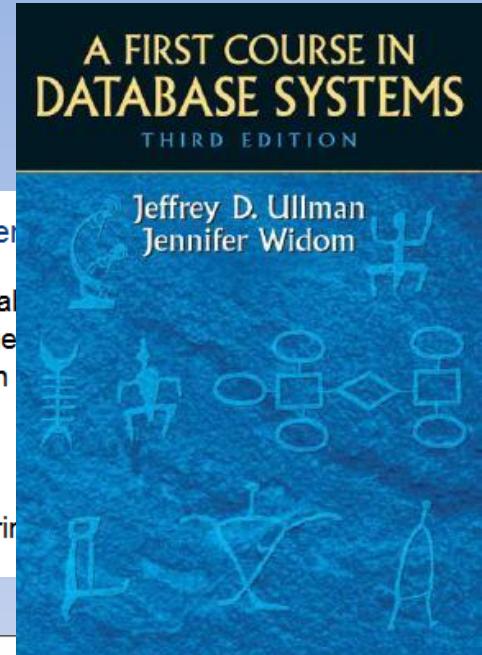
Units: 3

## CSCI 126. Database Systems

Prerequisites: CSCI 124. Data structures, relational algebra, relational network models; object-oriented modeling, normalization, data description languages, and query design.

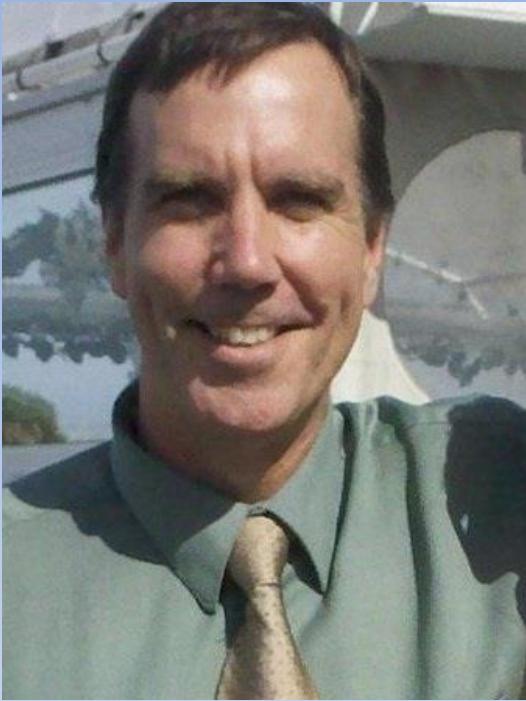
Units: 3

Course Typically Offered: Spring



# Personal Computer Science Focus

- Search
  - AI, Algorithms, RDMS
- Data
  - Machine Learning, Algorithms, RDMS
- Puzzles
  - AI, Algorithms
- Books... Authors....



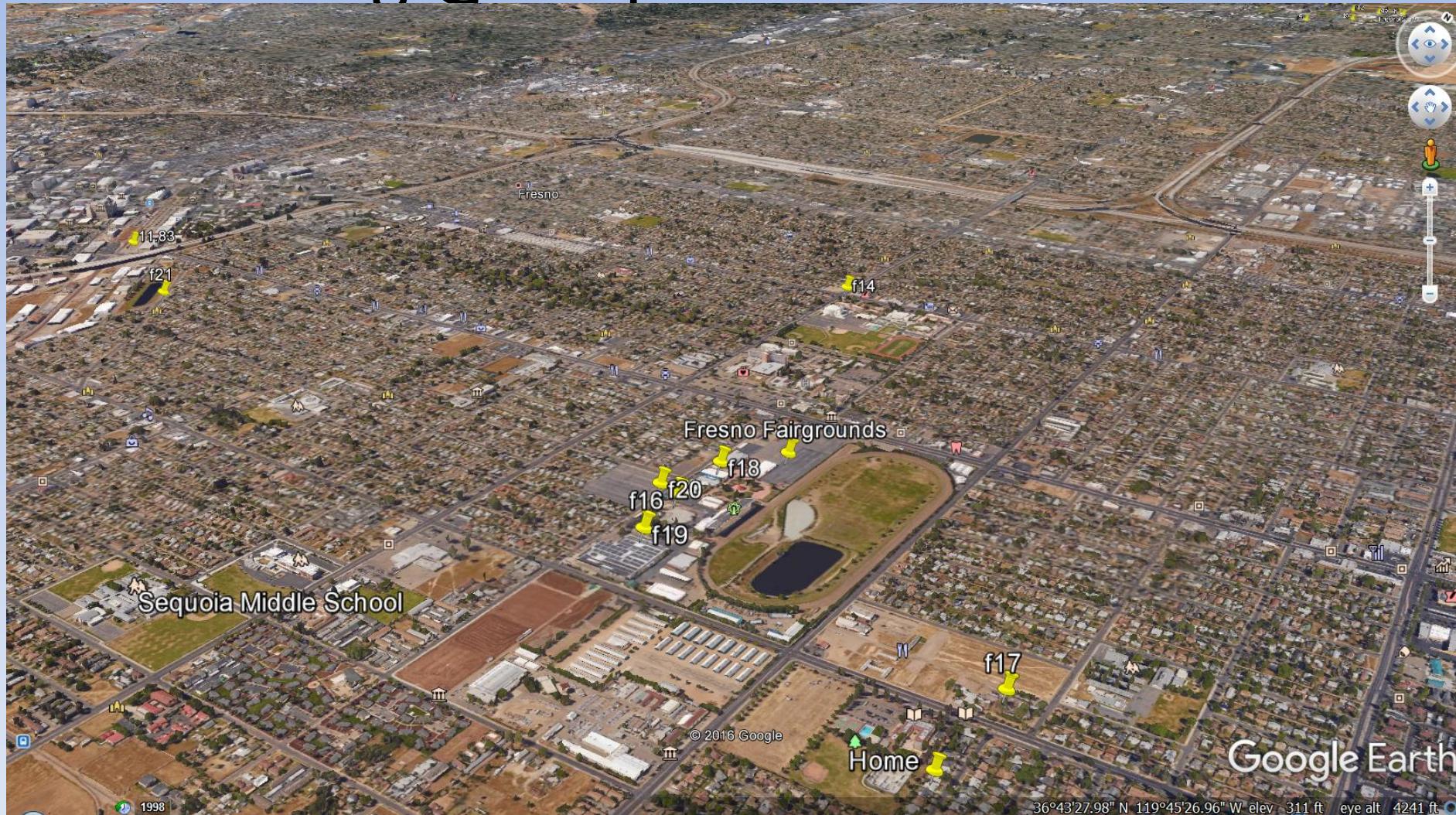
David Ruby

# Class Instructor

- Office
  - Science II – 273
- Email:
  - druby@csufresno.edu

- First-Generation College Student
- How PhD?

# Father Floyd Fresno Career Custodian Ending @ Sequoia Middle School



Google Earth

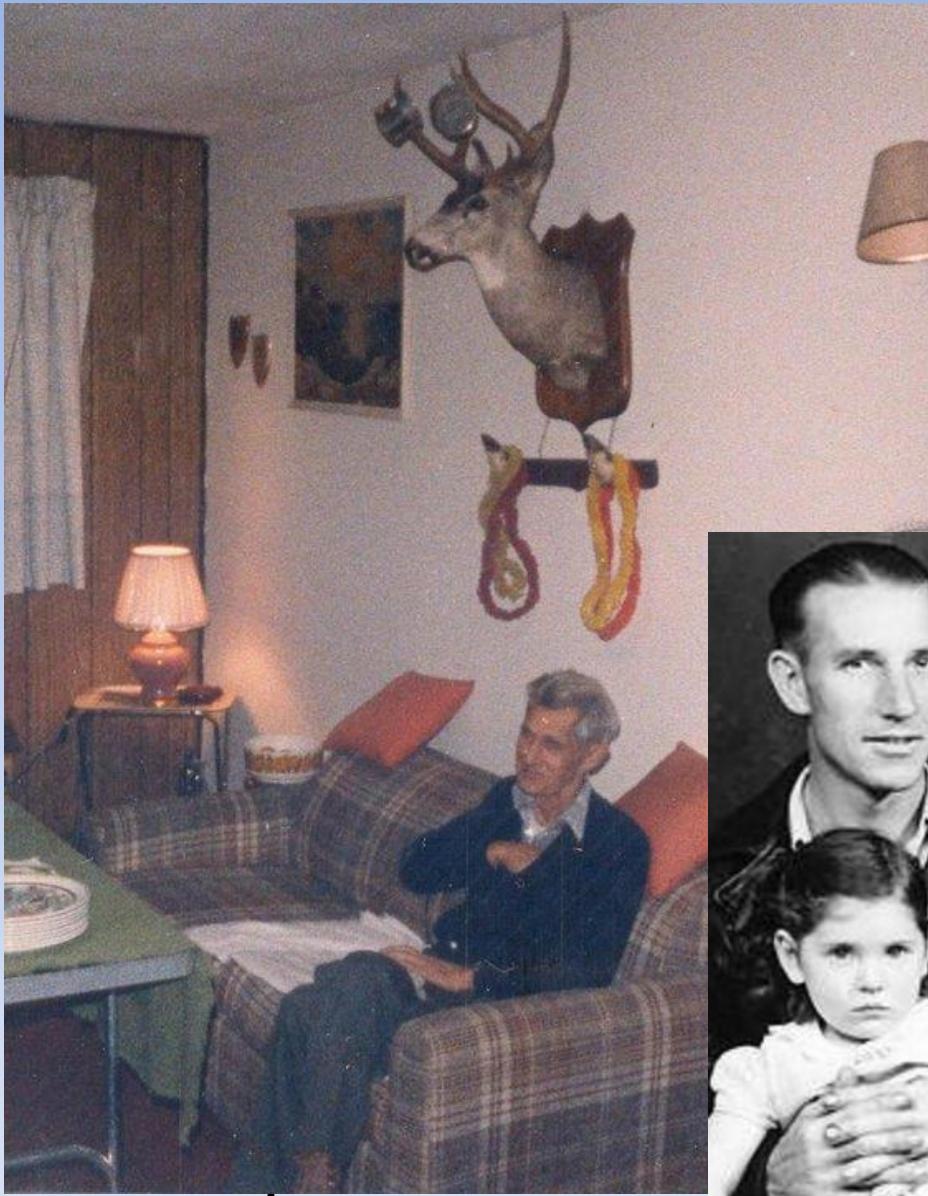
36°43'27.98" N 119°45'26.96" W elev 311 ft eye alt 4241 ft



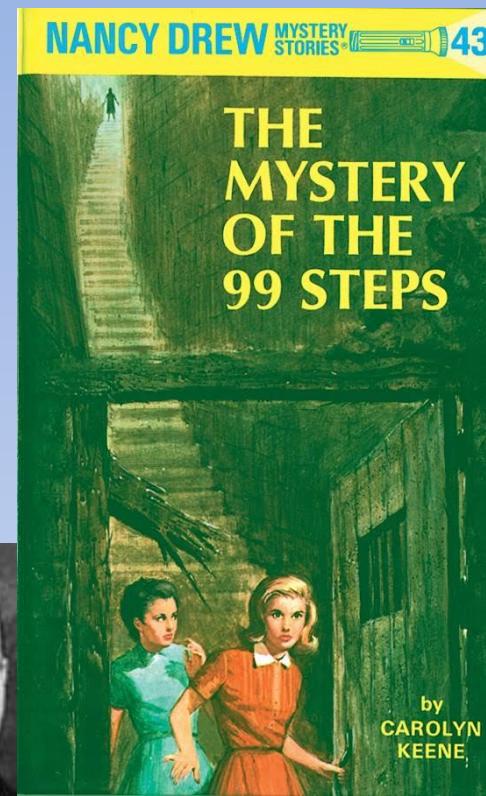
# Compute Science Focus: Jobs/Degrees

- Students want...
  - Jobs!
  - Advanced Degrees!!
- How???

# Interest In Puzzles



- Family  
Memories



# Memories.. eXciting Puzzles !

- Home Hedges Maze Crawwwwwl !
- Also – First time w/ Sliding Tile Puzzle



Start State

1	2	3
4		6
7	5	8



1	2	3
4	5	6
7		8



1	2	3
4	5	6
7	8	

Goal State

# Thesis: Tile-Sliding Puzzle



# Artificial Intelligence

Branch: master ▾ [ics1293](#) / [Papers](#) / [Ruby.AAAI91-082.pdf](#) [Find file](#) [Copy path](#)

 **everestso** paper 017b894 4 days ago

1 contributor

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## SteppingStone: An Empirical and Analytical Evaluation\*

David Ruby and Dennis Kibler  
Department of Information & Computer Science  
University of California, Irvine  
Irvine, CA 92717 U.S.A.  
[druby@ics.uci.edu](mailto:druby@ics.uci.edu)

### Abstract

Decomposing a difficult problem into simpler subproblems is a classic problem solving technique. Unfortunately, the most difficult subproblems can be as difficult, if not more difficult, than the original problem. This is not an obstacle to problem solving if the difficult subproblems recur in other problems. If the difficult subproblems recur often, then its solution need only be learned once and reused. SteppingStone is a learning problem solver that decomposes a problem into simple and difficult-but-recurring subproblems. It solves the

SteppingStone operates on problems defined with a state space representation consisting of a set of goals, a set of operators, and an initial state. The goal orderer takes as input a set of goals. It orders these goals so that the constrained search method will likely solve them. It does this by ordering them so as to reduce the likelihood of subgoal interactions using a domain independent heuristic we call *openness* [Ruby and Kibler, 1989]. It produces an ordered set of subgoals as output.

The constrained search component takes as input an

# My Idea...

# Memories are constructed.. Not stored complete!

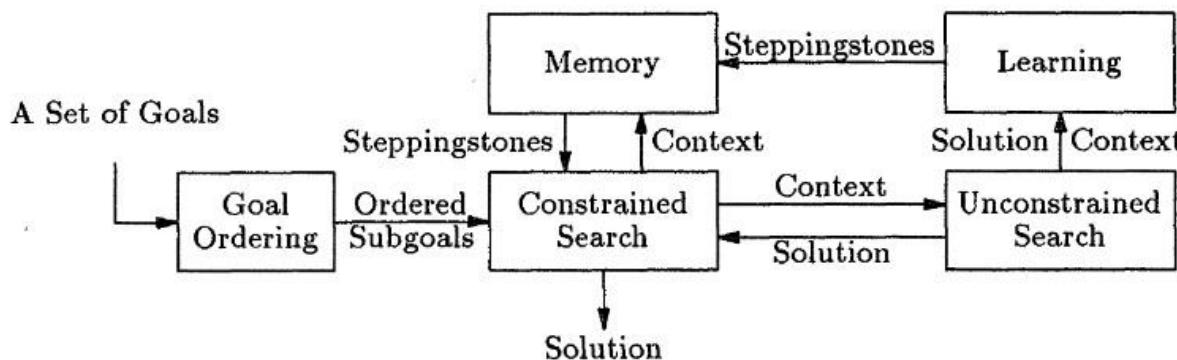


Figure 1: Overview of SteppingStone

the original impasse state.

When memory fails to return any useful steppingstones the constrained search component calls the unconstrained search component. The unconstrained search component takes as input a context, just as the memory component did. Unconstrained search relaxes the protection on the solved subgoals in its search for a solution. If it resolves the impasse, it returns the sequence of moves found to the constrained search component. The unconstrained search component also sends its impasse solution, along with the context, to the learner.

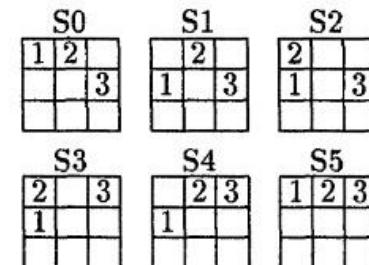
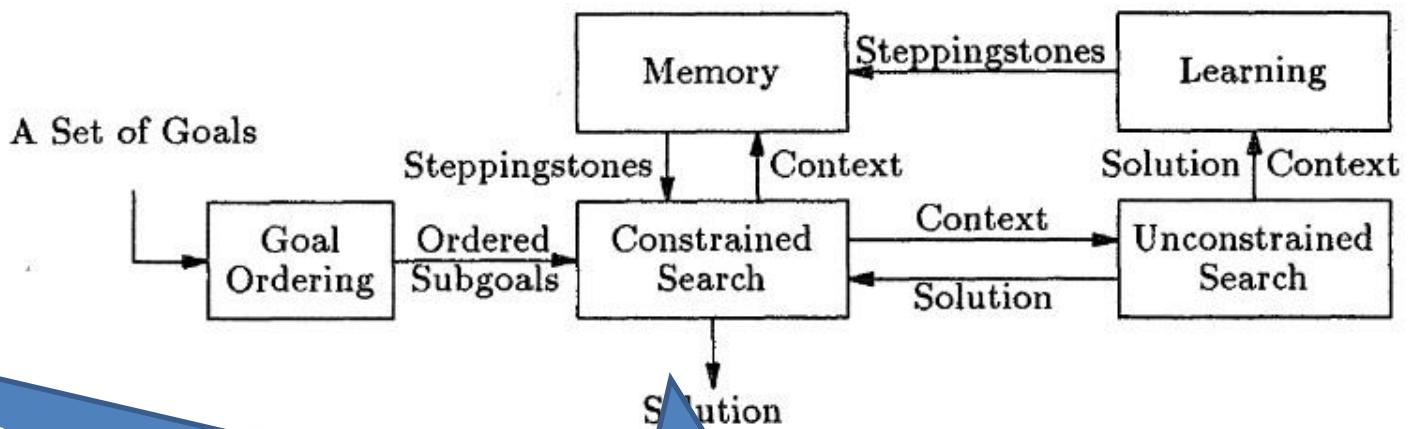


Figure 2: Steppingstones from Memory

# Thesis: Tile Sliding Domain



1: Overview of SteppingStone

When stones the constrained search component takes as input a context from the memory component did. Unconstrained search removes the protection on the solved subgoals in its search for a solution. If it resolves the impasse, it returns the sequence of moves found to the constrained search component. The unconstrained search component also sends its impasse solution, along with the context, to the learner.

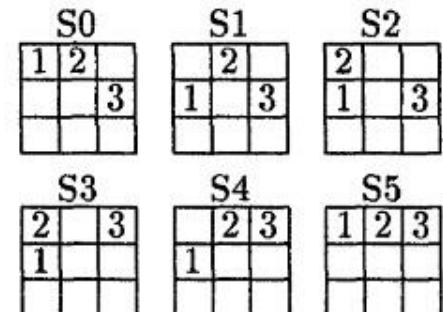
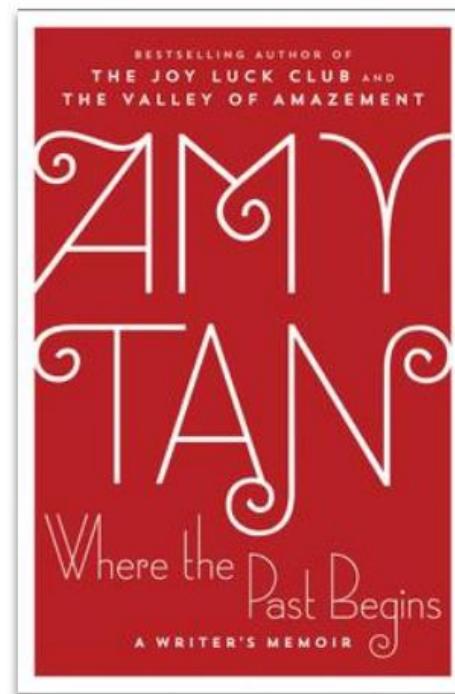
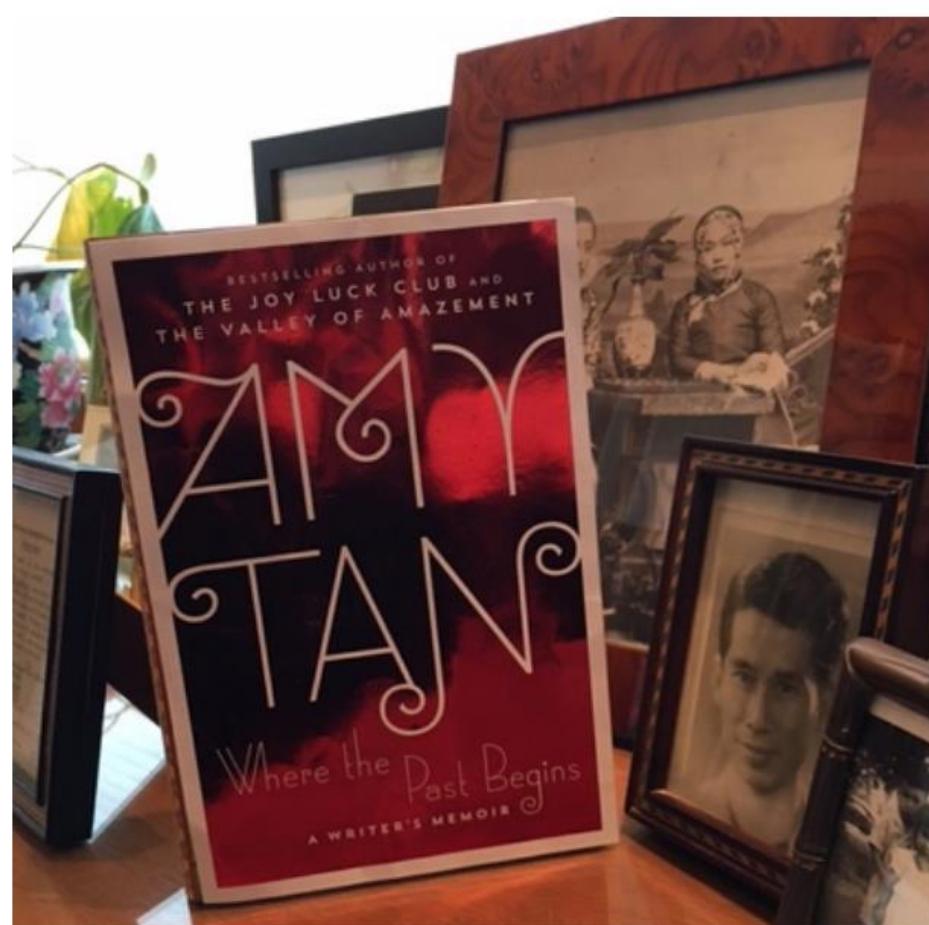


Figure 2: Steppingstones from Memory

# Emotional Memory: Retrieving/Writing Stories



*coming*  
*Oct 17, 2017*  
[Pre-order](#)

# Malleable Memory (Gaps)

## Learning & Memory w/ Elizabeth Loftus



# CORRUPTED MEMORY

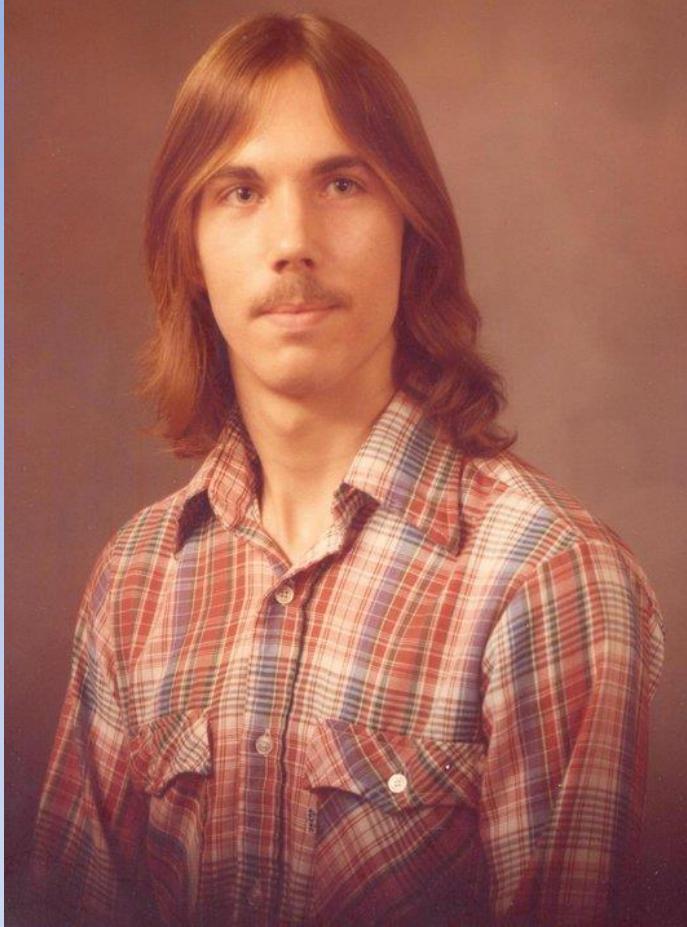
*Elizabeth Loftus has spent decades exposing flaws in eyewitness testimony. Her ideas are gaining fresh traction in the US legal system.*

BY MOHEB COSTANDI



Elizabeth Loftus is a cognitive psychologist at the University of California Irvine.

# eXciting Mazes Memories!



- ME:
  - Do you remember the FUN maze?
- NEIGHBOR:
  - Do YOU remember this other HORRIBLE thing??
- ME:
  - Hmm .. I guess not.
- Language influencing memory ??

# Memories & Learning

JOURNAL OF VERBAL LEARNING AND VERBAL BEHAVIOR 13, 585-589 (1974)

## **Reconstruction of Automobile Destruction: An Example of the Interaction Between Language and Memory'**

ELIZABETH F. LOFTUS AND JOHN C. PALMER

*University of Washington*

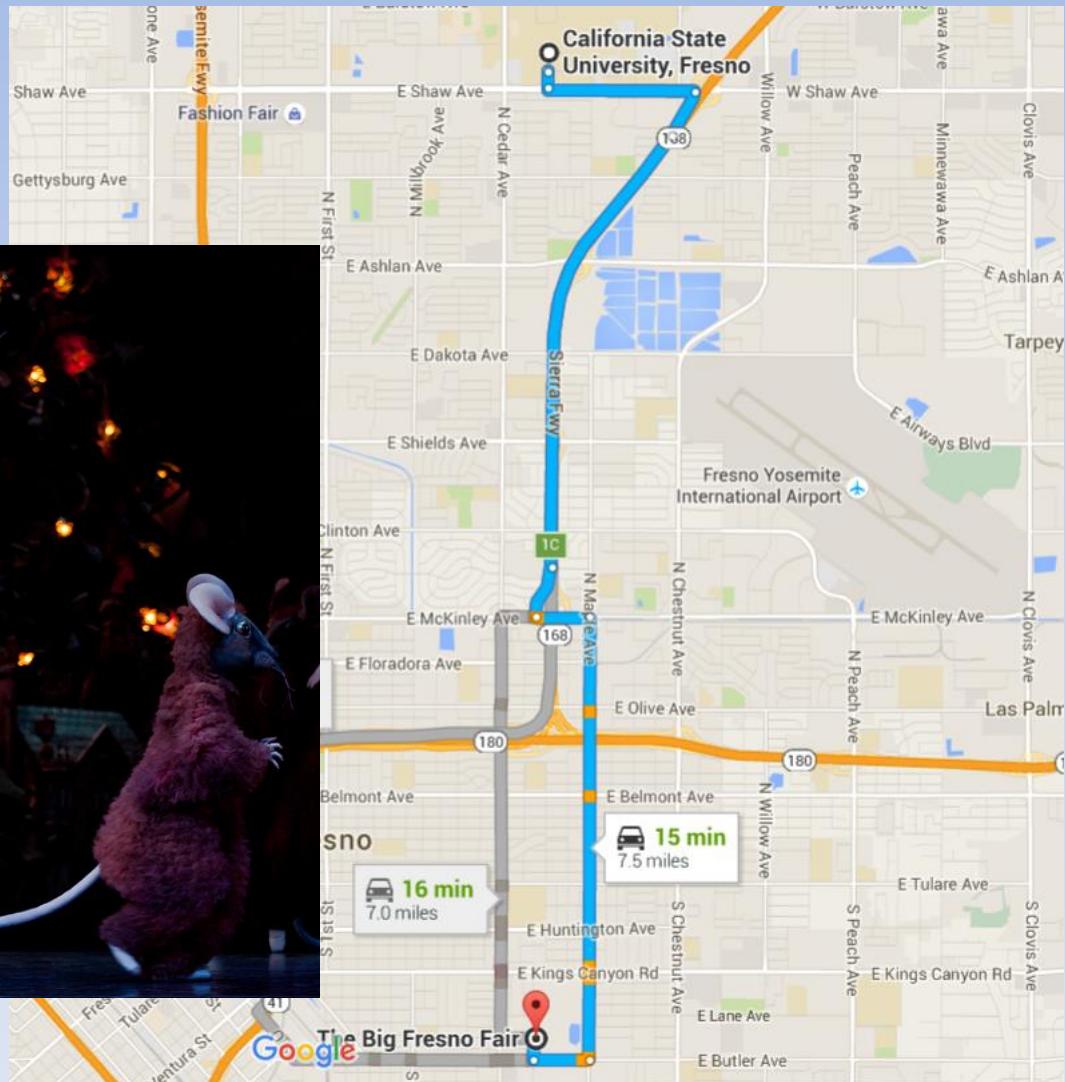
Two experiments are reported in which subjects viewed films of automobile accidents and then answered questions about events occurring in the films. The question, "About how fast were the cars going when they smashed into each other?" elicited higher estimates of speed than questions which used the verbs *collided*, *bumped*, *contacted*, or *hit* in place of *smashed*. On a retest one week later, those subjects who received the verb *smashed* were more likely to say "yes" to the question, "Did you see any broken glass?", even though broken glass was not present in the film. These results are consistent with the view that the questions asked subsequent to an event can cause a reconstruction in one's memory of that event.

# Computer Science / Memories

- Puzzles
- Abstractions
- Memories

# Current Interest: Abstraction

- Hello, World!



# Abstraction: Computational Thinking

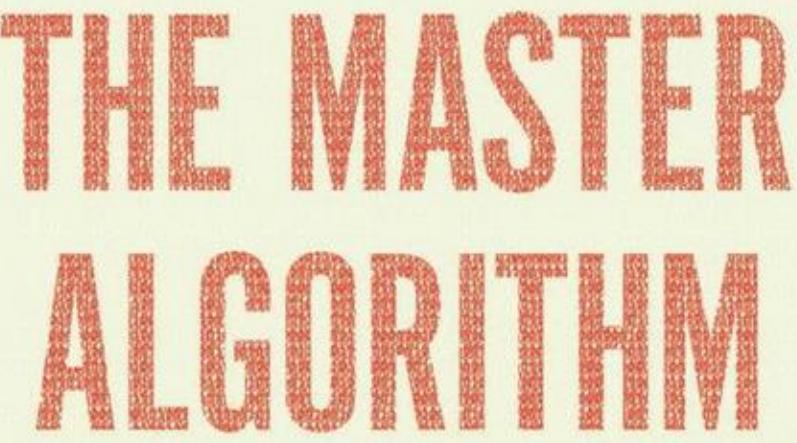
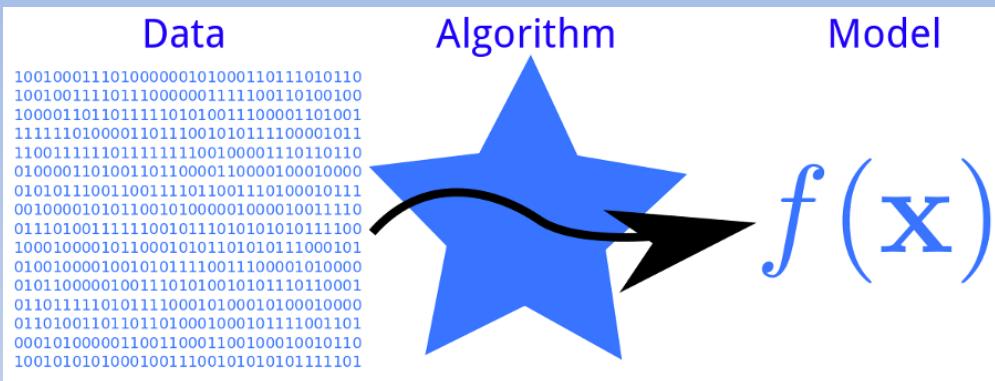
- Abstraction
- Automation
- Algorithms/Analysis

# Intelligence (Problem Solving) Requires..

## ..Learning from Experiences

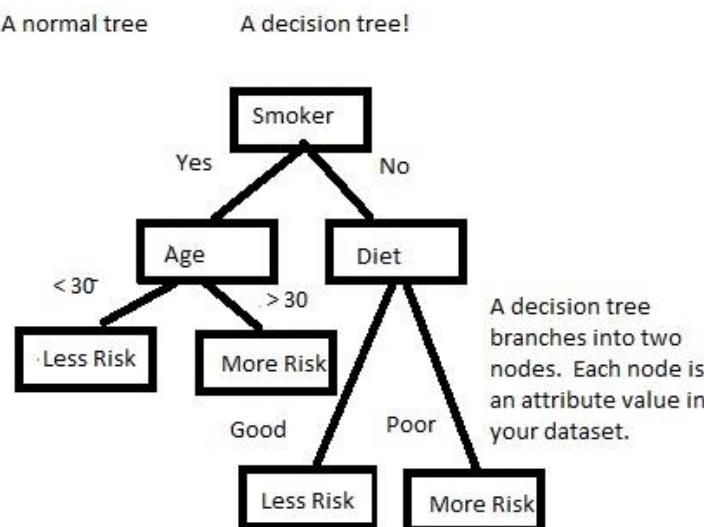
- Intelligence requires learning from experiences.

# Machine Learning - AI

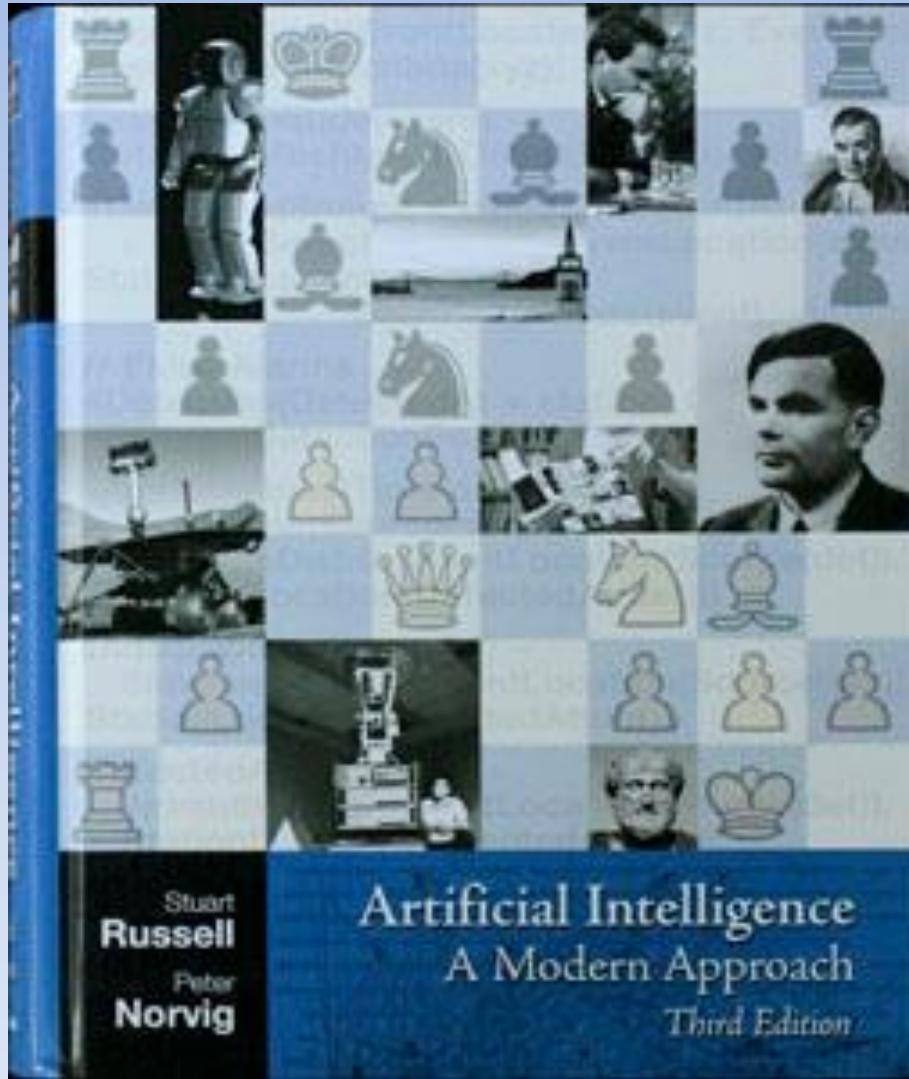


HOW THE QUEST FOR  
THE ULTIMATE  
LEARNING MACHINE WILL  
REMAKE OUR WORLD

PEDRO DOMINGOS



# Tentative Course Schedule



- Chapters 1-7
- Chapters 13-15
- Chapters 17, 18, 20, 21

# Chapter 1

# What is AI?

- What is Intelligence?



# **Chapter 1**

# **What is AI?**

- Introduce Science of Artificial Intelligence
- History of AI

# Chapter 2: Intelligent Agents

- Agents operate in world
- Is Agent Intelligent?

# Chapter 2:

## Problem Characteristics

- Examine problems
  - Problems people solve
  - Problems not currently solved by computers
- Develop characteristics for describing problems.

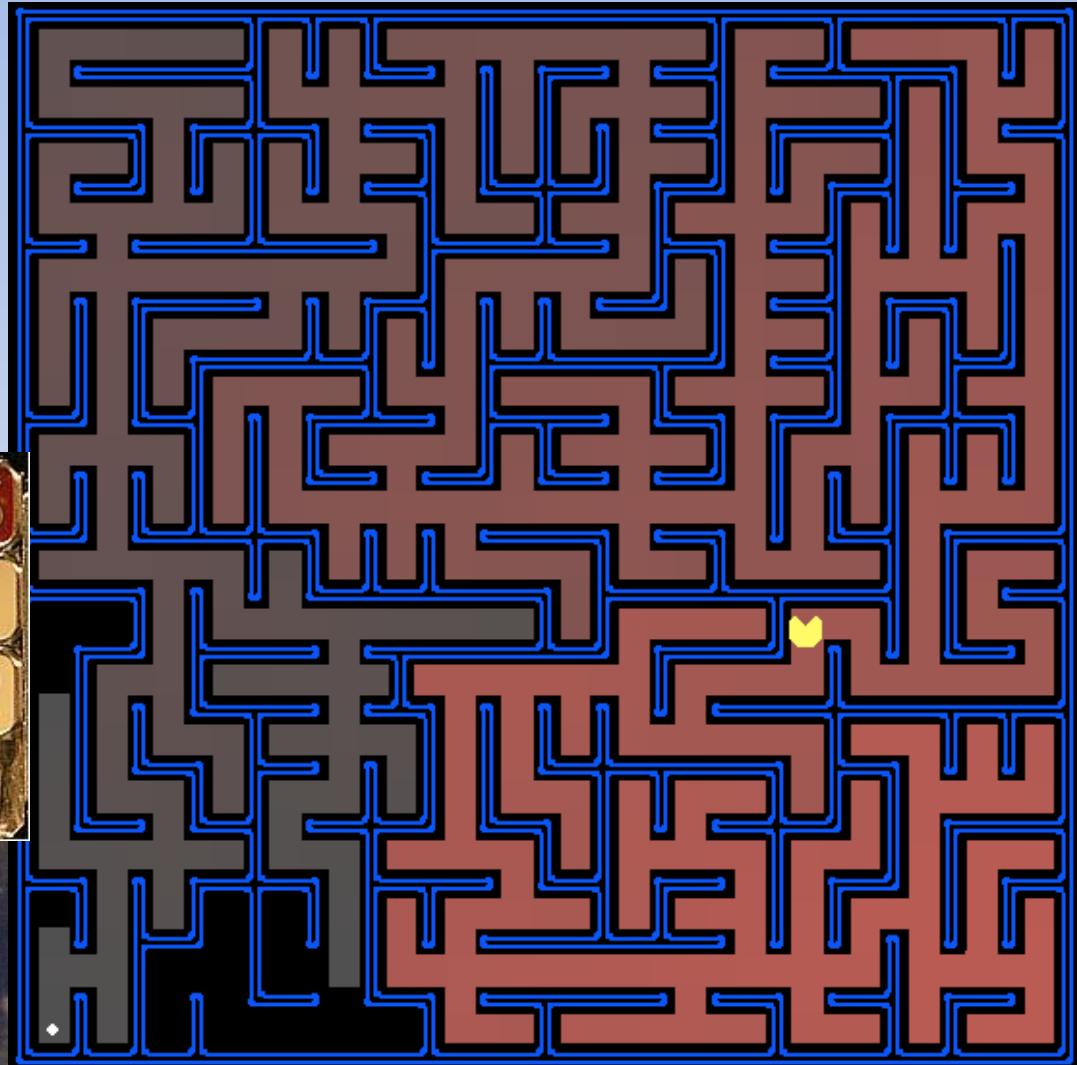
# Chapter 3:

## State-Space Search

- Uniformed Search
- Heuristics
- Informed Search
  - A\*

# State-Space Search

- Uniformed Search
- Heuristics
- Informed Search



# Chapter 4: Beyond Classical Search

- Additional Search Methods
  - Beam Search
  - Genetic Algorithms
- Incomplete Knowledge
  - And/Or Trees

# Chapter 5 Adversarial Search

- Multiplayer Games
- Minimax
- Alpha Beta Cutoff



# Chapter 6: CSP

- Constraint Satisfaction Problems
- AC-3 Algorithm
- Cutsets
- Etc...
- Assignment 4: CSP



# Chapter 7: Logical Agents

- Propositional Logic

246

Chapter 7. Logical Agents

$P$	$Q$	$\neg P$	$P \wedge Q$	$P \vee Q$	$P \Rightarrow Q$	$P \Leftrightarrow Q$
<i>false</i>	<i>false</i>	<i>true</i>	<i>false</i>	<i>false</i>	<i>true</i>	<i>true</i>
<i>false</i>	<i>true</i>	<i>true</i>	<i>false</i>	<i>true</i>	<i>true</i>	<i>false</i>
<i>true</i>	<i>false</i>	<i>false</i>	<i>false</i>	<i>true</i>	<i>false</i>	<i>false</i>
<i>true</i>	<i>true</i>	<i>false</i>	<i>true</i>	<i>true</i>	<i>true</i>	<i>true</i>

Figure 7.8 Truth tables for the five logical connectives. To use the table to compute, for

249  $P \wedge Q$  is false, first look on the left for the row  
 $\neg P$ ). Then look in that row under the  $P \vee Q$  column

Section 7.5. Propositional Theorem Proving

$$\begin{aligned}(\alpha \wedge \beta) &\equiv (\beta \wedge \alpha) \text{ commutativity of } \wedge \\(\alpha \vee \beta) &\equiv (\beta \vee \alpha) \text{ commutativity of } \vee \\((\alpha \wedge \beta) \wedge \gamma) &\equiv (\alpha \wedge (\beta \wedge \gamma)) \text{ associativity of } \wedge \\((\alpha \vee \beta) \vee \gamma) &\equiv (\alpha \vee (\beta \vee \gamma)) \text{ associativity of } \vee \\\neg(\neg\alpha) &\equiv \alpha \text{ double-negation elimination} \\(\alpha \Rightarrow \beta) &\equiv (\neg\beta \Rightarrow \neg\alpha) \text{ contraposition} \\(\alpha \Rightarrow \beta) &\equiv (\neg\alpha \vee \beta) \text{ implication elimination} \\(\alpha \Leftrightarrow \beta) &\equiv ((\alpha \Rightarrow \beta) \wedge (\beta \Rightarrow \alpha)) \text{ biconditional elimination} \\\neg(\alpha \wedge \beta) &\equiv (\neg\alpha \vee \neg\beta) \text{ De Morgan} \\\neg(\alpha \vee \beta) &\equiv (\neg\alpha \wedge \neg\beta) \text{ De Morgan} \\(\alpha \wedge (\beta \vee \gamma)) &\equiv ((\alpha \wedge \beta) \vee (\alpha \wedge \gamma)) \text{ distributivity of } \wedge \text{ over } \vee \\(\alpha \vee (\beta \wedge \gamma)) &\equiv ((\alpha \vee \beta) \wedge (\alpha \vee \gamma)) \text{ distributivity of } \vee \text{ over } \wedge\end{aligned}$$

Figure 7.11 Standard logical equivalences. The symbols  $\alpha$ ,  $\beta$ , and  $\gamma$  stand for arbitrary sentences of propositional logic.

# Chapter 7: Logical Agents w/ Wumpus World

- Wumpus World

238

Chapter 7. Logical Agents

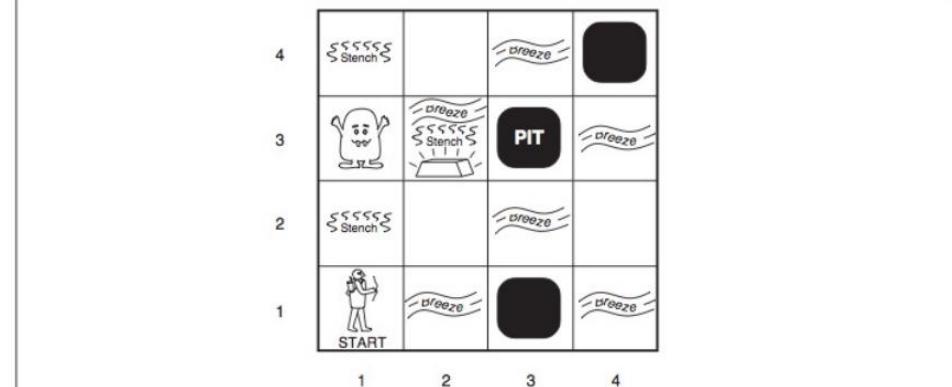


Figure 7.2 A typical wumpus world. The agent is in the bottom left corner, facing right.

$P_{x,y}$  is true if there is a pit in  $[x, y]$ .

$W_{x,y}$  is true if there is a wumpus in  $[x, y]$ , dead or alive.

$B_{x,y}$  is true if the agent perceives a breeze in  $[x, y]$ .

$S_{x,y}$  is true if the agent perceives a stench in  $[x, y]$ .

# PROBLEMS!!!

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Chapter 7. Logical Agents

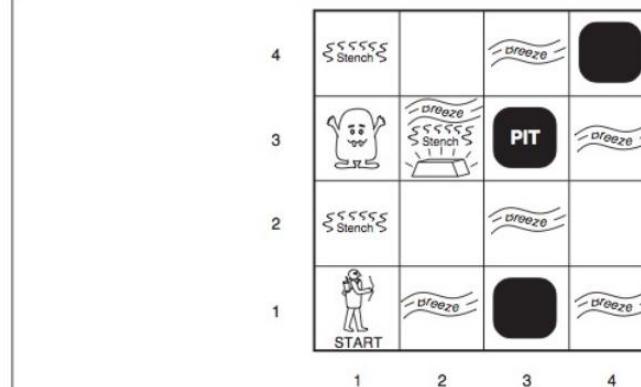


Figure 7.2 A typical wumpus world. The agent is in the bottom left corner, facing right.

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$B_{x,y}$  is true if the agent perceives a breeze in  $[x, y]$ .

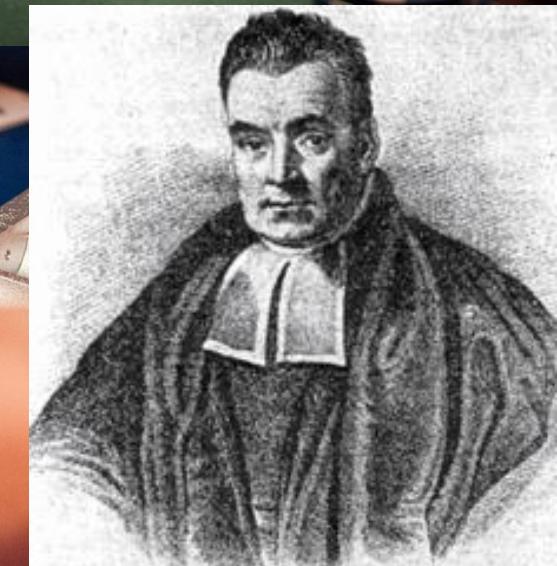
$S_{x,y}$  is true if the agent perceives a stench in  $[x, y]$ .

# Uncertainty

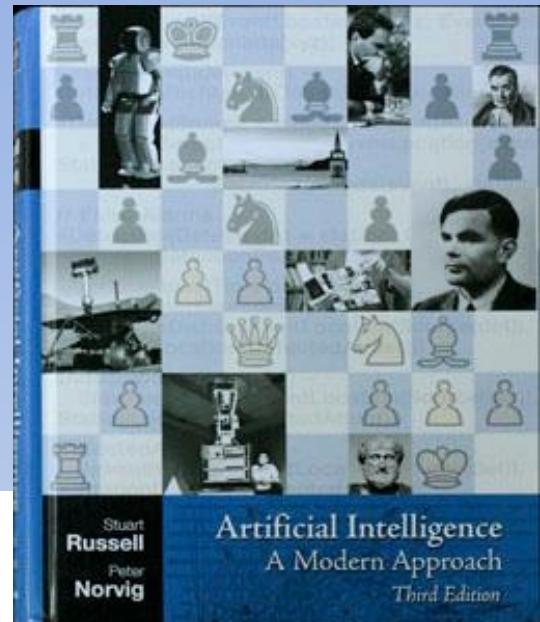
uncertainty

# Chapter 13: Dealing w/ Uncertainty

- Probability Review



# Dealing w/ Uncertainty



## IV Uncertain knowledge and reasoning

### 13 Quantifying Uncertainty

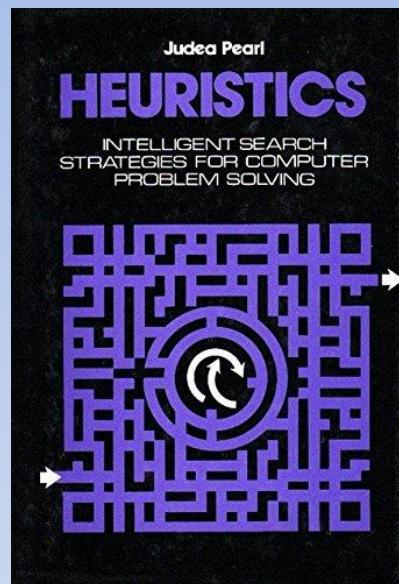
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### 14 Probabilistic Reasoning

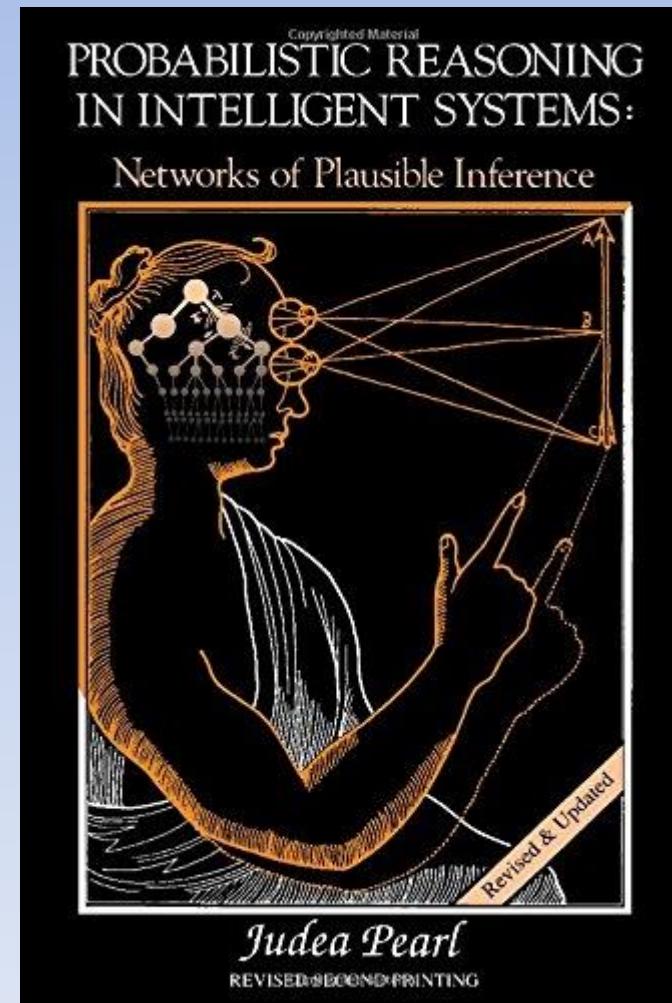
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# Judea Pearl

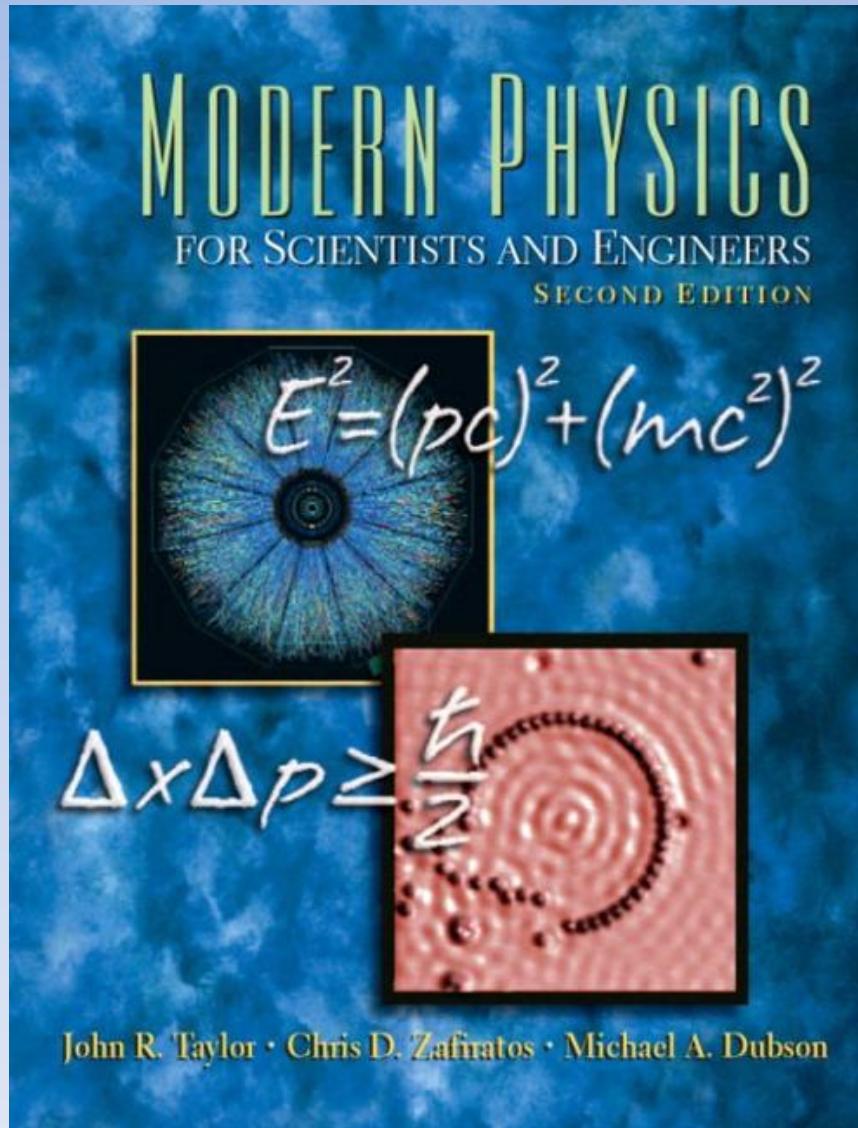
## Heuristics -> Probabilistic Reasoning



- April 1984
- September 15, 1988



# Uncertainty in Science



# Classical Mechanics



# Probability & Physics



- Albert Einstein
- Quantum mechanics is certainly imposing. But an inner voice tells me that it is not yet the real thing. The theory says a lot, but does not really bring us any closer to the secret of the "old one." **I, at any rate, am convinced that *He* does not throw dice.**
  - Letter to [Max Born](#) (4 December 1926); *The Born-Einstein Letters* (translated by Irene Born) (Walker and Company, New York, 1971)  
[ISBN 0-8027-0326-7](#).
- In a 1943 conversation with William Hermanns recorded in Hermanns' book *Einstein and the Poet*, Einstein said: "**As I have said so many times, God doesn't play dice with the world.**" ([p. 58](#)).

# Uncertainty in Science

## Schrödinger's Equation

$$i\hbar \frac{\partial}{\partial t} \psi(\mathbf{r}, t) = -\frac{\hbar^2}{2m} \nabla^2 \psi(\mathbf{r}, t) + V(\mathbf{r}, t) \psi(\mathbf{r}, t)$$

$i$  is the imaginary number,  $\sqrt{-1}$ .

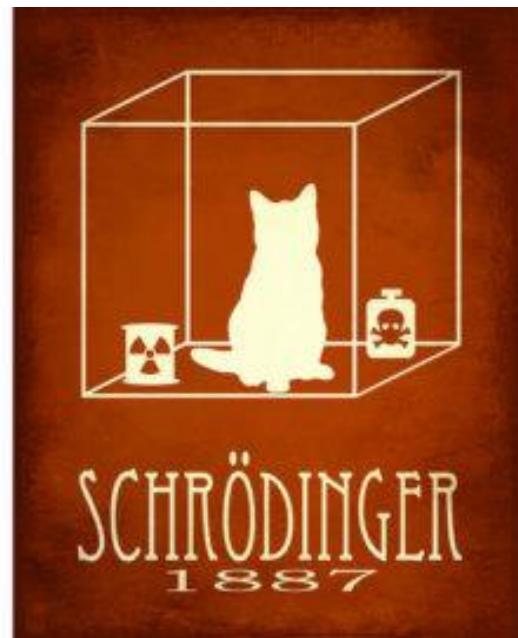
$\hbar$  is Planck's constant divided by  $2\pi$ : 1

$\psi(\mathbf{r}, t)$  is the wave function, defined over

$m$  is the mass of the particle.

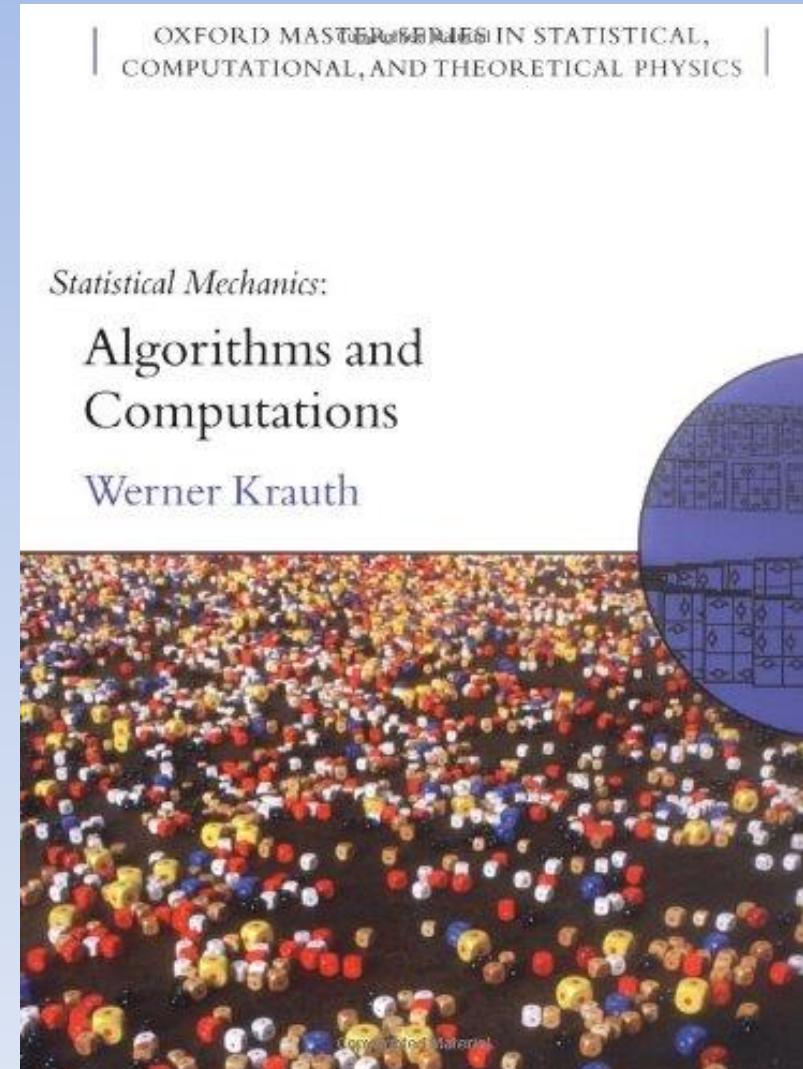
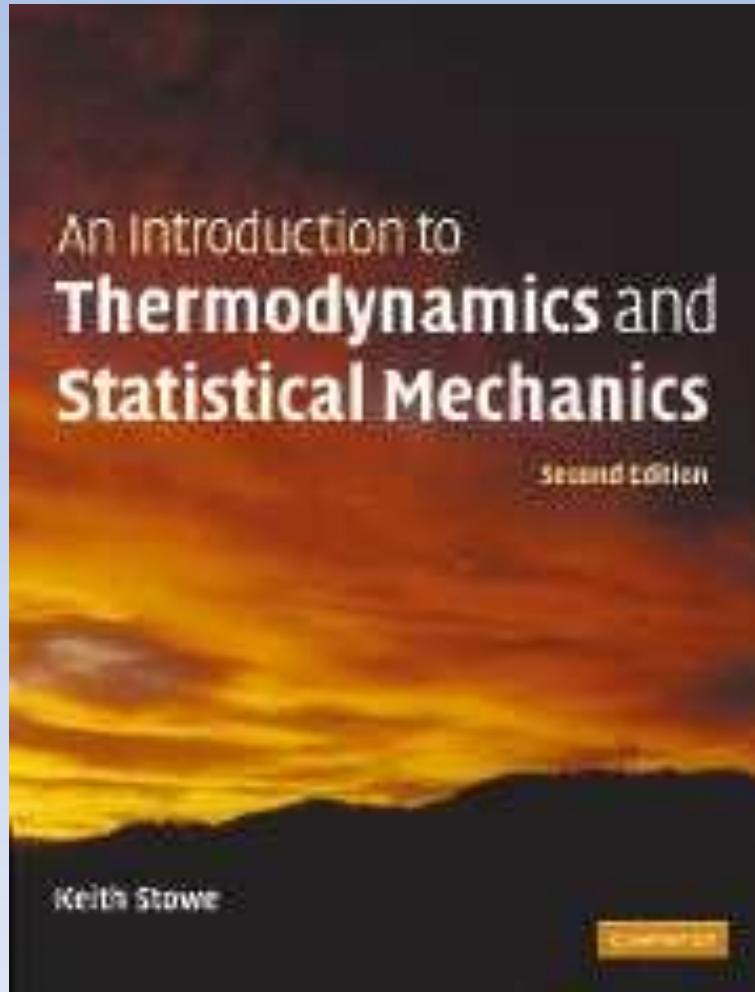
$\nabla^2$  is the Laplacian operator,  $\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$

$V(\mathbf{r}, t)$  is the potential energy influencing



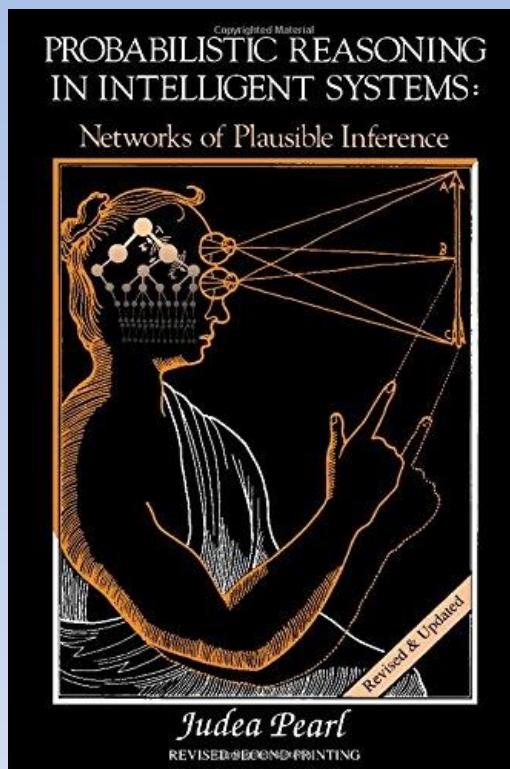
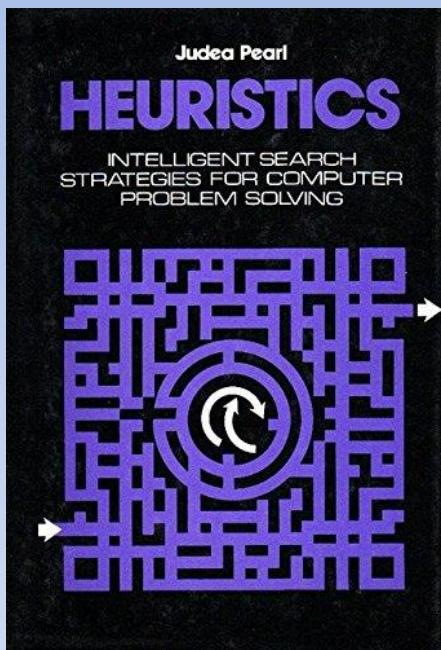
# Uncertainty in Science

## Classical Mechanics versus Statistical Mechanics

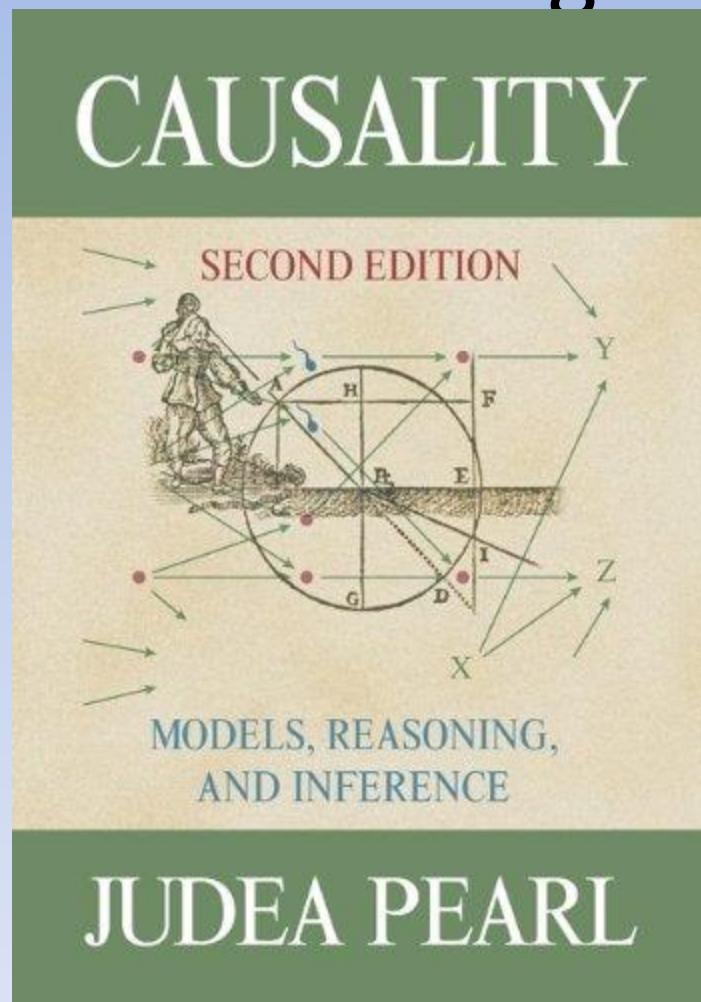


# Judea Pearl

## Heuristics -> Probabilistic Reasoning



- April 1984
- September 15, 1988
- 



September 14<sup>th</sup>, 2009

# History of Probability (AI Text)

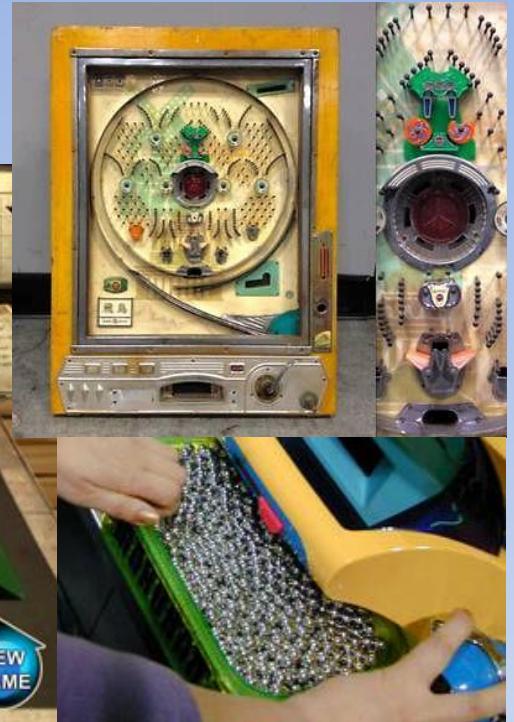
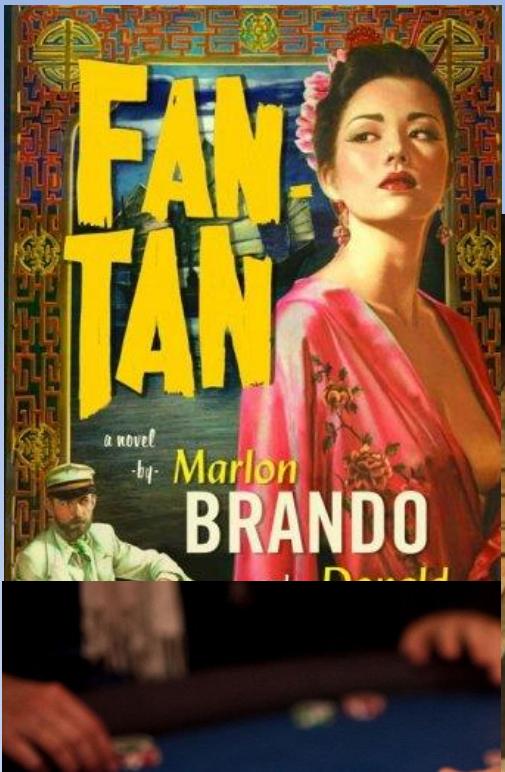
- In about 850 A.D. the Indian mathematician Mahaviracarya described how to arrange a set of bets that can't lose (what we now call a Dutch book).

## Mahāvīra (mathematician)

From Wikipedia, the free encyclopedia

Mahāvīra (or Mahaviracharya, "Mahavira the Teacher") was a 9th-century Jain mathematician from Mysore, India.<sup>[1][2][3]</sup> He was the author of *Ganitasārasaṅgraha* (or *Ganita Sara Samgraha*, c. 850), which revised the *Brāhmaś�uṭasiddhānta*.<sup>[1]</sup> He was patronised by the Rashtrakuta king Amoghavarsha.<sup>[4]</sup> He separated astrology from mathematics. It is the earliest Indian text entirely devoted to mathematics.<sup>[5]</sup> He expounded on the same subjects on which Aryabhata and Brahmagupta contended, but he expressed them more clearly. His work is a highly syncopated approach to algebra and the emphasis in much of his text is on developing the techniques necessary to solve algebraic problems.<sup>[6]</sup> He is highly respected among Indian mathematicians, because of his establishment of terminology for concepts such as equilateral, and isosceles triangle; rhombus; circle and semicircle.<sup>[7]</sup> Mahāvīra's eminence spread in all South India and his books proved inspirational to other mathematicians in Southern India.<sup>[8]</sup> It was translated into Telugu language by Pavuluri Mallana as *Saar Sangraha Ganitam*.<sup>[9]</sup>

# Uncertainty w/ Gambling Games



# Gambling Concepts

- Games of Chance
  - Poker
  - Roulette
  - Fan Tan
- Odds
  - Sports Book
  - Horse Racing

# 1565 Girolamo Cardano

- In Europe, the first significant systematic analyses were produced by Girolamo Cardano around 1565, although publication was posthumous (1663).
- Gambling Motivated



# Meaning and Probability Theory

- 20 to 1 in the 5<sup>th</sup>
  - What does 20 to 1 Mean?
  - Where does 20 come from?

# Joints & Marginals

		Intelligence		
		low	high	
Grade	A	0.07	0.18	0.25
	B	0.28	0.09	
	C	0.35	0.03	
			0.3	1.0

- $P(\text{Intelligence}=\text{high}) = ?$

# More Problems...

		Intelligence		
		low	high	
Grade	A	0.07	0.18	0.25
	B	0.28	0.09	
	C	0.35	0.03	
			0.3	1.0

- $P(\text{Intelligence}=\text{high}) = ?$

# INTRACTABILITY

# INTRAC TABILITY

# Computational Thinking!!!

## Algorithms & Data Structures

- Representation
  - Bayesian Networks
- Algorithms
  - Exact Inference
  - Approximate Inference

# PLAN

## The Bayesian Network (Chapter 14)

- Exploit Islands of Tractability in High Dimensional Space Probability Distributions
  - Worst Case is Intractable
  - Real World Frequently NOT Worst Case
  - Efficiently Exploit properties in Real World Probability Distributions to induce Tractability
- Primary Tool:

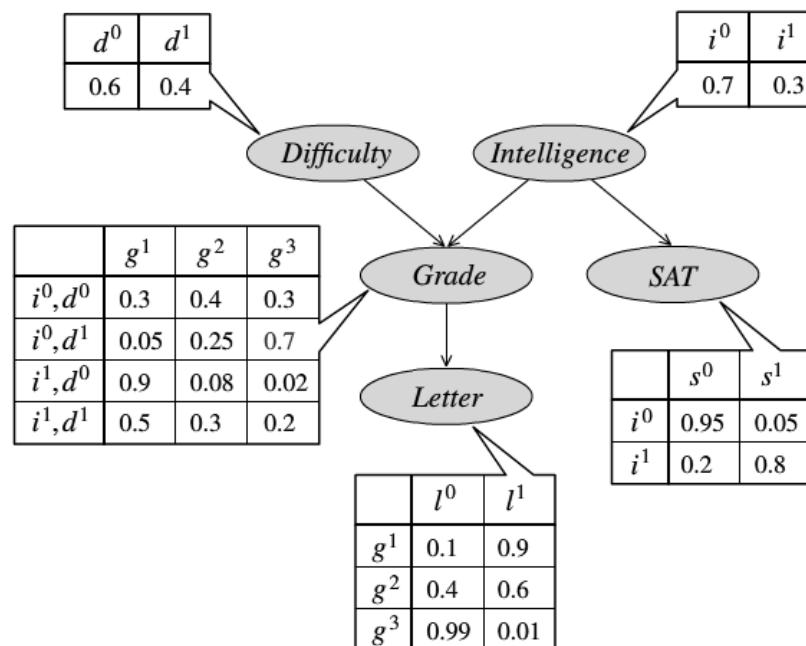
**INDEPENDENCE!**

# Bayesian Networks : (CPD's)

- Each variable is associated with a conditional probability distribution (CPD) that specifies a distribution CPD over the values of X given each possible joint assignment of values to its parents in the model.
- For a node with no parents, the CPD is conditioned on the empty set of variables.

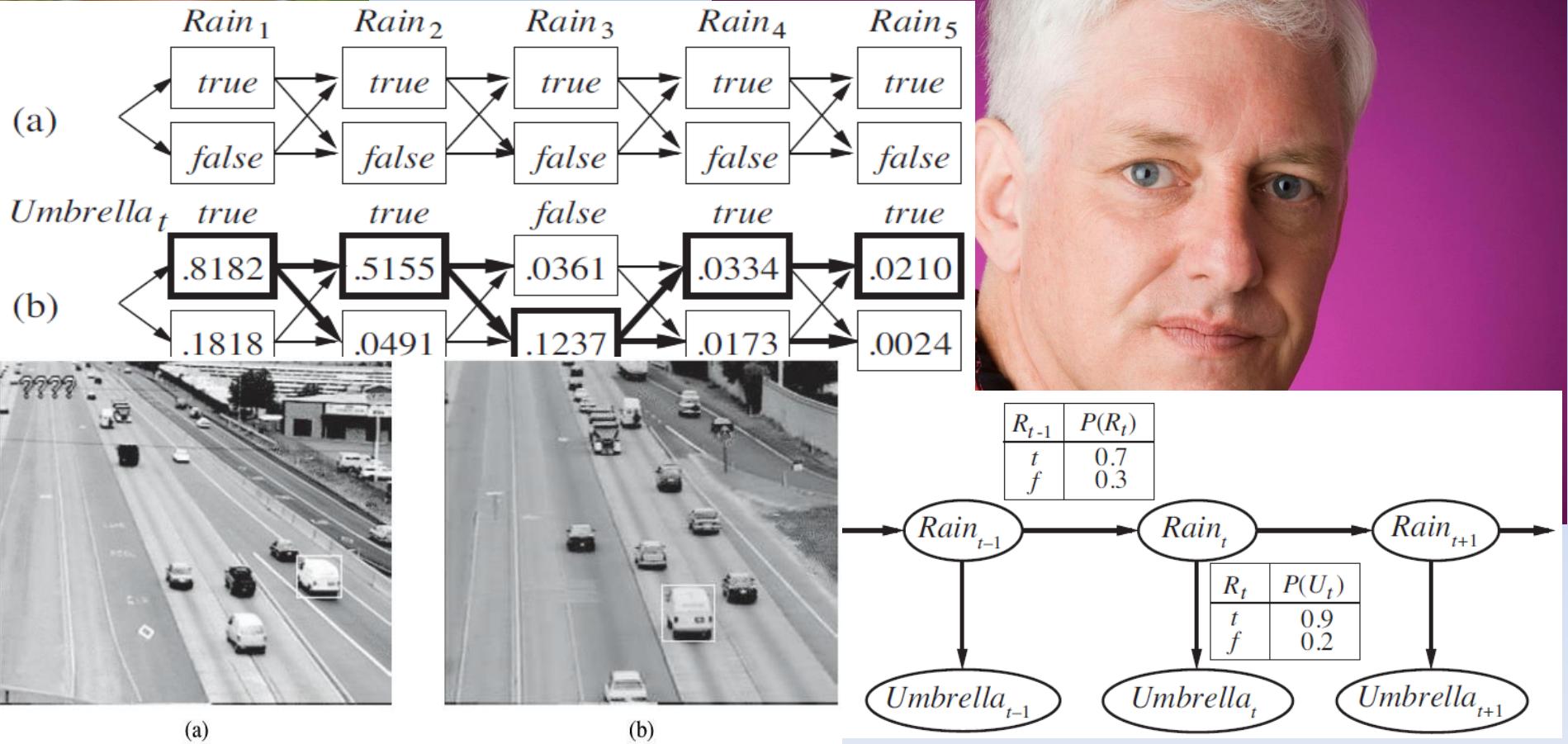
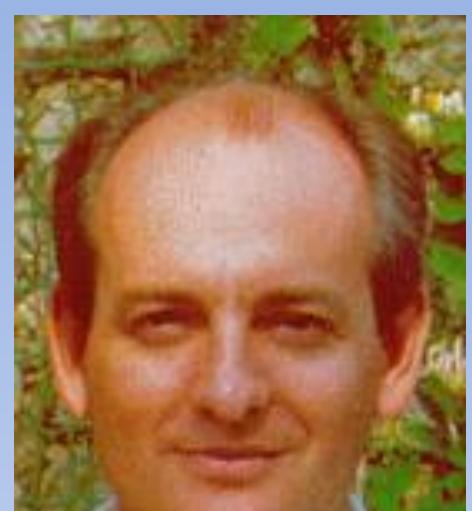
3.2. Bayesian Networks

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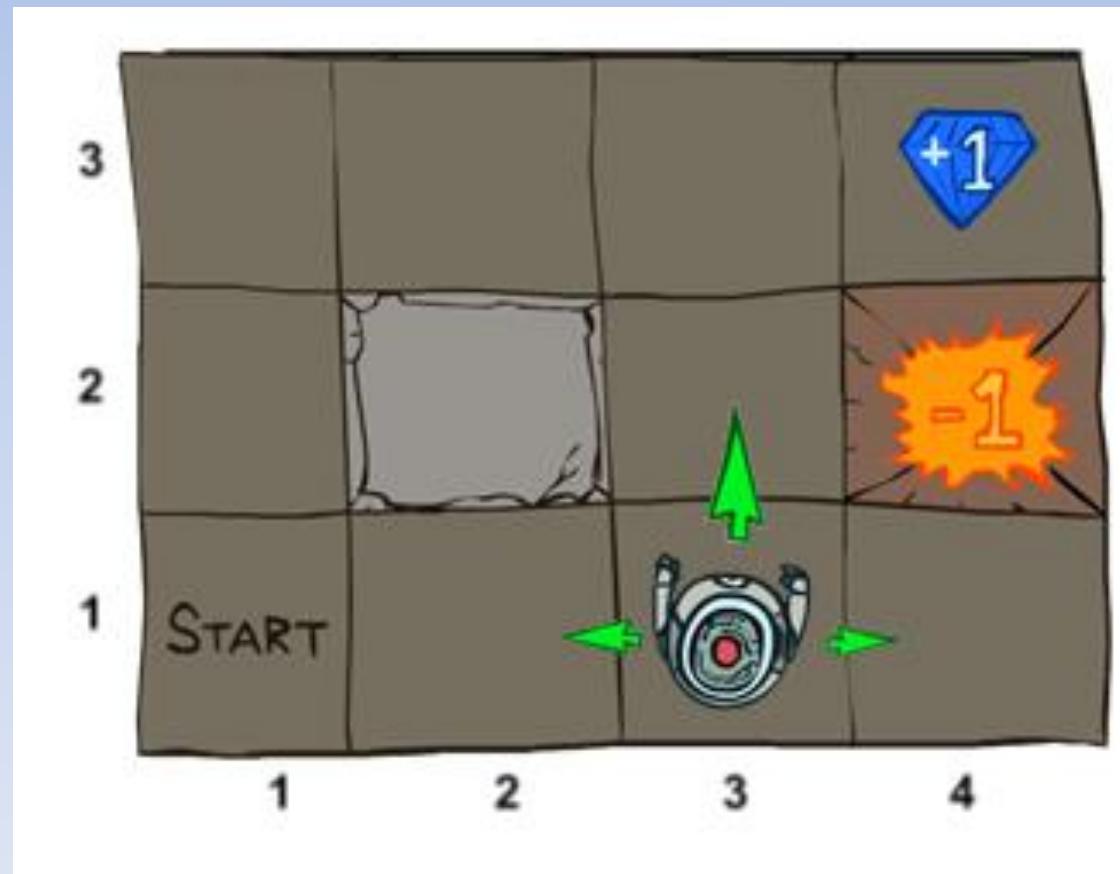
# Chapter 15:

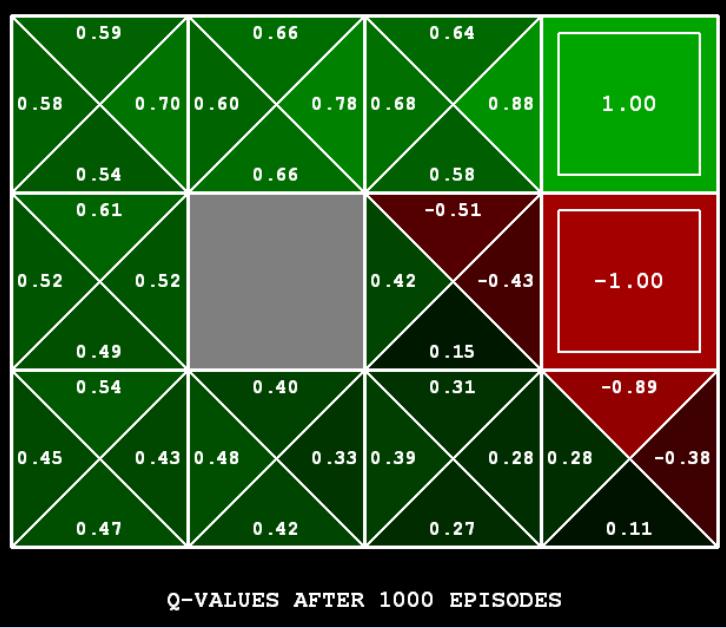
## Probabilistic Reasoning over Time



# Chapter 17: Making Complex Decisions

- Markov Decision Process





# Chapter 21:

# Reinforcement Learning

- Q-Learning
- Approximate Q-Learning

# Scientific Transitions

- Rational To Real
  - $a/b$
  - Ratio of Circle to Circumference
  - Hypotenuse of right triangle with two equal sides
- Logical To Approximation
  - Undecidable problems
  - Perfect Information
  - Uncertainty
  - Machine Learning/Neural Nets

# Chapter 18: Learning from Examples

- Decision Trees
- Linear Models
- Neural Nets

# Chapter 20 : Learning Probabilistic Models

- Naïve Bayes

# Final

- Chapters 1-7
- Chapters 13-15
- Chapters 17, 18, 20, 21