CS 188: Artificial Intelligence

Conclusion

Instructor: Anca Dragan --- University of California, Berkeley

These slides were created by Dan Klein, Pieter Abbeel, Anca Dragan for CS188 Intro to AI at UC Berkeley.

All CS188 materials are available at http://ai.berkeley.edu.
[Ratliff et al. *Maximum Margin Planning*]
[Levine et al. Continuous Inverse Optimal Control with Locally Linear Examples]
Continuous Inverse Optimal Control with Locally Optimal Examples

driving policies learned from human examples
P2 Mini-Contest Results!
Mini-Contest 2 Statistics

- 22 teams
- Great work by everyone!

Creative Names:
- paQman Learning
- boboBan
- RealHastaLaMuerte
- Pacific Gas and Electric
- High Winds
- d[g | j]

Final results: now
4. J&R (143.625) Junyi Zhu and Ruhang Ma
5. RealHastaLaMuerte (120.375) Aryan Luthra and Richard Padilla
6. Alpha (40.875) Max Fu
7. Q (21.25) Brian Wu and Kevin Hu
8. D-Phi (-17.125) Matthew Tang
9. d[g | j] (-48.375) Damini Grover and Delaney Smith
10. WoohooPac (-52) Akshara Methukupalli
3rd Place (190.125)

- Team Name: Pacific Gas and Electric
- Team Members: Nikhil Pimpalkhare
- Bot Description:
  - Offense: repeatedly moves towards a "safe" food pellet, where safe is defined as 1) adjacent to or part of a loop in the maze 2) a pellet which the offensive agent is closer to than any enemy
  - Defense: Prioritizes being close to the closest food pellet to the enemy. Also ensures that it is always closer to the power pellet than any enemy
In the final (1\textsuperscript{st} vs 2\textsuperscript{nd})

- Team Name: High Winds
- Team Members: Tingzheng Hou and Lu Jiang

Bot Description:
- Is my agent in Pacman state? If yes
  - In dead-end and close to enemies (dist<8)? If yes ‘run’
  - Too close to enemies (dist<3)? If yes ‘run’
- Is my agent in ghost state? If yes
  - Is this agent a closer agent to the invading enemy? If yes ‘catch’
- Else, 'eat' the nearest food
- Each action ('run', 'catch', 'eat') has an separate approximate q-learning parameters.
In the final (1\textsuperscript{st} vs 2\textsuperscript{nd})

- Team Name: noobmaster189
- Team Members: Andrea Bogle, Rohan Jhunjhunwala
- Bot Description:
  - We left one player permanently on defense and always on defense
  - We had one player play offensively, and try to go home if it had a certain amount of pellets
  - Define a square to be a dead end, if there is no cycle of squares that you can visit that contains it. Only enter a dead end square, if absolutely necessary.
  - Only worry about the enemy, if you move exactly next to it, otherwise you can always escape because you will never be in a dead end.
2nd place video – who is it?
Team Name: High Winds

Team Members: Tingzheng Hou and Lu Jiang

Bot Description:

- Is my agent in Pacman state? If yes
  - In dead-end and close to enemies (dist<8)? If yes ‘run’
  - Too close to enemies (dist<3)? If yes ‘run’
- Is my agent in ghost state? If yes
  - Is this agent a closer agent to the invading enemy? If yes ‘catch’
- Else, 'eat' the nearest food
- Each action ('run', 'catch', 'eat') has an separate approximate q-learning parameters.
Team Name: noobmaster189
Team Members: Andrea Bogle, Rohan Jhunjhunwala
Bot Description:

- We left one player permanently on defense and always on defense
- We had one player play offensively, and try to go home if it had a certain amount of pellets
- Define a square to be a dead end, if there is no cycle of squares that you can visit that contains it. Only enter a dead end square, if absolutely necessary.
- Only worry about the enemy, if you move exactly next to it, otherwise you can always escape because you will never be in a dead end.
1st place video
Top 3

- **1\(^{st}\) place:**
  - noobmaster189 Andrea Bogle, Rohan Jhunjhunwala

- **2\(^{nd}\) place**
  - High Winds Tingzheng Hou, Lu Jiang

- **3\(^{rd}\) place**
  - Pacific Gas and Electric Nikhil Pimpalkhare
Congratulations!
Pac-Man Beyond the Game!
Pacman: Beyond Simulation?

Students at Colorado University: http://pacman.elstonj.com
Pacman: Beyond Simulation!

[VIDEO: Roomba Pacman.mp4]
Bugman?

- AI = Animal Intelligence?
  - Wim van Eck at Leiden University
  - Pacman controlled by a human
  - Ghosts controlled by crickets
  - Vibrations drive crickets toward or away from Pacman’s location

http://pong.hku.nl/~wim/bugman.htm
Bugman
Crawler
Q-learning with Robot Crawler
Instructors

Anca Dragan

Email: anca@

GSIs

Wilson Yan

Head TA
Email: Admin cs188@, Personal wilson1.yan@
Hi everybody! I'm a fourth year CS and Applied Math major from the Bay Area. Aside from doing ML research, I enjoy reading, hiking, playing video games (Smash), and eating good food. Feel free to chat with me anytime, and I look forward to meeting you all!

Alan Rosenthal

Email: amrosenthal@
Hi! I'm a fourth year CS and math major. Outside of class, I love cooking, playing and listening to classical music, and badminton!

Albert Yu

Email: albertyu@

Andreea Bobu

Email: abobu@
Hi! I'm a third year PhD student working with Anca Dragan. My research interests lie at the intersection of machine learning, robotics, and human-robot interaction, with a focus on robot learning with uncertainty. In my free time, I play the guitar, do street photography, and do various outdoorsy activities.
Andy Yan
Email: yan.andy4@
Hi, I'm a 5th year masters student in CS. My research focuses on multi-task learning and robotics. Outside of school I love listening to all sorts of music and eating / spending time with friends. Hope you guys enjoy the semester :).

Carl Qi
Email: daguqihanwen@
Hello friends! I'm a 3rd-year undergrad student majoring in cs and math. In my free time, I like to play the guitar, go workout, and watch Dude Perfect. Looking forward to a fun semester!

Cathy Li
Email: cathy_li@
Hey! I'm a junior focusing on AI and ML, currently doing Computer Vision research under Prof. Gonzalez. In addition to CS, I'm broadly interested in cognition, psychology and linguistics. In my free time, I try to practice my really elementary Swedish.

Chandan Singh
Email: chandan_singh@
I'm a 3rd-year EECS PhD student studying interpretable machine learning advised by Prof. Bin Yu

Danny Geitheim
Email: dgeitheim@
I'm a fourth year student, originally from Marin County, CA. In my free time I enjoy playing tennis and basketball, as well as watching movies. I'm also a part of Camp Kesem here at Cal. In the past I was a TA for EE120 but now I look forward to being a TA for CS188!

Emma Jaeger
Email: emmajaeger@
Hi everyone! I'm Emma and I'm a senior from the DC area studying computer science. In my free time, I love going to concerts and working out (even though I'm naturally super uncoordinated). Feel free to email me with any questions you have about artificial intelligence, CS at Berkeley, or life in general—I'm always happy to help out however I can :)}
Gokul Swamy
Email: gokul.swamy@

Hey there! I'm a 4th Yr. M.S. student working with Profs. Dragan and Levine on making interaction between people and robots more intuitive and scalable. In my free time I like to read, listen to music, drink boba, and pet my friends' cats. I'm so excited you're here :)

Henry Zhu
Email: henryzhu@

I'm a senior(!) studying computers and mechanics who likes to play with learning robots out of the classroom. Come find me to talk about food videos, really cool classes, how to also start playing with robots, or really anything other than sports.

Jesse Zhang
Email: jessezhang@

I'm a 4th year CS student from Sacramento, CA, interested in deep reinforcement learning and machine learning generalization research. In my spare time I like playing smash, going to the gym, and recently just started BJJ!

Jinkyu Kim
Email: jinkyu.kim@

I am a fourth-year graduate student, pursuing a Ph.D. degree in Computer Science advised by Prof. John Canny. As a member of Berkeley Deep Drive and Berkeley AI Research Lab, I am currently interested in self-driving vehicles.

Lawrence Chan
Email: chanlaw@

Hello! I'm a second year PhD Student working on building algorithms that can better infer and assist with human preferences. In my free time, I enjoy reading and hiking.

Lindsay Yang
Email: lindsayyang@

Hi! I'm a fourth year CS/Cog Sci major, and a big part of my life at this point is how much I like boba, memes, and Bojack Horseman. I'm also the janitor of UPE, and you'll probably catch me karaokeing my heart out one of these days.
Mike Laielli
Email: laielli@
I'm a 3rd year PhD student working with Trevor Darrell and Bjoern Hartmann. My research focuses on the intersection of Computer Vision and Human-Computer Interaction.

Rachel Li
Email: rachel_li@
Hey everyone! I'm a 5th year masters student from Virginia. My academic interests include networking, theory, and AI! In my nonexistent free time, I like to draw, play Clash Royale, and watch Netflix.

Ryan Deng
Email: rdeng2614@
Hi! I’m a rising 4th year CS major from Irvine, California. In my free time I like to watch lots of TV and play pickup basketball. I hope you all enjoy 188 this semester!

Sherman Luo
Email: shermanluo@
Nice to meet you. I’m Sherman. AI is super cool, and first became curious about it years ago when computer-controlled characters would whoop me in games like Super Smash Bros Melee or Mario Kart. I’m working with Prof. Dragan as a fourth-year masters and imo CS188 is the greatest class of all time, but your mileage may vary : ) Catch me sometime and let’s talk about something totally random.

Shizhan Zhu
Email: shizhan_zhu@
Hello everyone! I am a third year PhD from BAIR lab. I am happy to join the CS 188 stuff team. My research interest lies in the area of computer vision and machine learning. I am looking forward to the experience communicating with everyone during the semester on CS 188!

Tony Zhao
Email: tonyzhao@
Hello friends! I’m a 4th year EECS undergrad here at Cal. Beyond research in machine learning, I like taking care of my hydroponic plants, building meme software, petting dogs, and occasionally getting lost.
Xiaocheng Mesut Yang

Email: xiaocheng.yang@

Hello everyone! I am a fourth year CS major. I TA'd CS188 in Summer 2018, Spring 2019, Summer 2019 (Head TA), and I am happy to rejoin this semester. My interest lies in the intersection of computer vision and reinforcement learning. In my free time, I travel to race radio-controlled vehicles at national and international events. Feel free to come talk to me, about anything!
Beyond 188: Keep building a great community

- Help out your peers on piazza and in person!
- Be mindful of the tone you use – be respectful and supportive, help everyone feel at home.
  - Also, please don’t interrupt your peers or instructors.
- Watch out for implicit bias – catch yourself before acting on it.
  - Someone’s gender, race, ethnicity, sexual orientation, etc. do NOT have anything to do with how awesome they will be in 188, and in the CS field in general.
Stickers Time!!
Google is trying to make artificial intelligence history — and it could happen this week
IN TWO MOVES, ALPHAGO AND LEE SEDOL REDEFINED THE FUTURE

SEUL, SOUTH KOREA — In Game Two, the Google machine made a move that no human ever would. And it was beautiful. As the world looked on, the move so perfectly demonstrated the enormity of its power and rather...
The Skills of Human Interaction Will Become Most Valuable in the Future

Geoff Colvin, a senior editor at large for Fortune Magazine, is the author of "Humans Are Underrated: What High Achievers Know that Brilliant Machines Never Will."

March 9, 2016

AlphaGo’s victory over Go champion Lee Se-dol reportedly shocked artificial intelligence experts, who thought such an event was 10 to 15 years away. But if the timing was a surprise, the outcome was not. On the contrary, it was inevitable and entirely foreseeable.

Playing complex games, even the most complex game ever invented, is precisely what computers do supremely well. Just as they beat the world champions at checkers and then chess, they were destined to beat the champion at Go. It’s a game of clear rules, and while winning required new forms of computing that rely on a computer that can learn from experience, a machine will eventually best all humans at tasks of this kind.

Yet I don’t believe, as some do, that human defeats like this one presage an era of mass unemployment in which awesomely able computers leave most of us with nothing to do. Advancing technology will profoundly change the nature of high-value human skills and that is threatening, but we aren’t doomed.
Solved!

Expert

Human

A Brick

Checkers  Chess  Go  Pacman

A Brick

A Brick

A Brick
How would you make an AI for Go?
MiniMax!
Why is it hard?

In particular, why is it harder than chess?
Exhaustive search
Reducing depth with value network
Value network
Reducing breadth with policy network
Policy network

Move probabilities

\[ \pi(a|s) \]

Position
Neural network training pipeline

Human expert positions

Supervised Learning policy network

Reinforcement Learning policy network

Self-play data

Value network

### Policy Search

- **Simplest policy search:**
  - Start with an initial linear value function or Q-function
  - Nudge each feature weight up and down and see if your policy is better than before

- **Problems:**
  - How do we tell the policy got better?
  - Need to run many sample episodes!
  - If there are a lot of features, this can be impractical

- Better methods exploit lookahead structure, sample wisely, change multiple parameters...
One more thing: Monte-Carlo rollouts
Mastering the game of Go with deep neural networks and tree search

David Silver, Aja Huang, Chris J. Maddison, Arthur Guez, Laurent Sifre, George van den Driessche, Julian Schrittwieser, Ioannis Antonoglou, Veda Panneershelvam, Marc Lanctot, Sander Dieleman, Dominik Grewe, John Nham, Nal Kalchbrenner, Ilya Sutskever, Timothy Lillicrap, Madeleine Leach, Koray Kavukcuoglu, Thore Graepel & Demis Hassabis

Editors summary
The victory in 1997 of the chess-playing computer Deep Blue in a six-game series against the then world champion Gary Kasparov was seen as a significant milestone in the development of artificial inte...

Related audio
Hear from the makers of the AI that mastered Go - and the professional player it beat.

Authors with Loop profiles

Julian Schrittwieser
Marc Lanctot
Mastering the game of Go without human knowledge


Download Citation

Computational science  Computer science  Reward

Received: 07 April 2017
Accepted: 13 September 2017
Published: 18 October 2017

Editorial Summary

AlphaGo Zero goes solo
To beat world champions at the game of Go, the computer program AlphaGo has relied largely on supervised learning from millions of human expert moves. David Silver and colleagues have now produced a system called

Associated Content

Artificial intelligence: Learning to play Go from scratch
Satinder Singh, Andy Okun & Andrew Jackson
Where to Go Next?
Congratulations, you’ve seen the basics of modern AI
  ... and done some amazing work putting it to use!

How to continue:
  - Machine learning: cs189, stat154
  - Deep nets: cs182
  - Intro to Data Science: CS194-16
  - Probability: ee126, stat134
  - Optimization: ee127
  - Cognitive modeling: cog sci 131
  - Machine learning theory: cs281a/b
  - Vision: cs280
  - Robotics: cs287
  - Algorithmic Human Robot Interaction: CS294-115
  - NLP: cs288
  ... and more; ask if you’re interested
That's It!

- Have a great winter break, and ...
Maximize Your Expected Utility