UNIVERSITY OF TORONTO
SCHOOL OF CONTINUING STUDIES

3547 Intelligent Agents & Reinforcement Learning

Module 1: Introduction to Intelligent Agents

Course Plan

Module Titles
Module 1 – **Current Focus: Introduction to Intelligent Agents**
Module 2 – Search
Module 3 – Logical Inference
Module 4 – Planning and Knowledge Representation
Module 5 – Probabilistic Reasoning
Module 6 – Intro to Reinforcement Learning and Finite Markov Decision Processes
Module 7 – Dynamic Programming and Monte Carlo Methods
Module 8 – Temporal Difference Learning
Module 9 – Function Approximation for RL
Module 10 – Deep Reinforcement Learning and Policy Gradient Methods
Module 11 – Introduction to Advanced DRL
Module 12 – Presentations (no content)

Learning Outcomes for this Module

- Prepare you to successfully navigate the course logistics and content
- Provide a framework for how the various techniques of AI theory fit together
- Enable you to recognize and describe the various types of intelligent agents
- Improve your ability to recognize opportunities to use AI techniques for business and other applications
- Introduce some of the puzzles and games that we will use AI to play

Topics for this Module

- **1.1** What is Intelligence?
- **1.2** Intelligent Agents
- **1.3** Problem Solving
- **1.4** Practical AI
- **1.5** Puzzles
- **1.6** Go
- **1.7** Resources and Wrap-up

Module 1 – Section 1

What is Intelligence?

What is Intelligence?

- Knowledge?
- Ability to infer?
- Ability to learn?
- Rational behaviour?
- Ability to judge?
- Use of language?
- Creativity?
- Self-awareness?
- Introspection?
- Other kinds of intelligence?
  - https://www.youtube.com/watch?v=lAEwYj5Nma4

Some Questions

- Are we better off building things that are *good* at what humans *aren't good* at?
- Does consciousness require a *brain*?
- If a machine pleads *not to be turned off* is it immoral to do so?

- How much are you willing to spend for computing resources for an AI?
- What is the risk if the AI is pushed into a situation it isn't trained for?
- Are you going to "weird out" your customers?

A Few (of the Many) Thinkers About AI

- René Descartes
- Richard Feynman
- Edwin Jaynes
- Douglas Hofstadter
- Marvin Minsky
- Roger Penrose
- Judea Pearl
- Geoffrey Hinton / Yoshua Bengio / Yann LeCun

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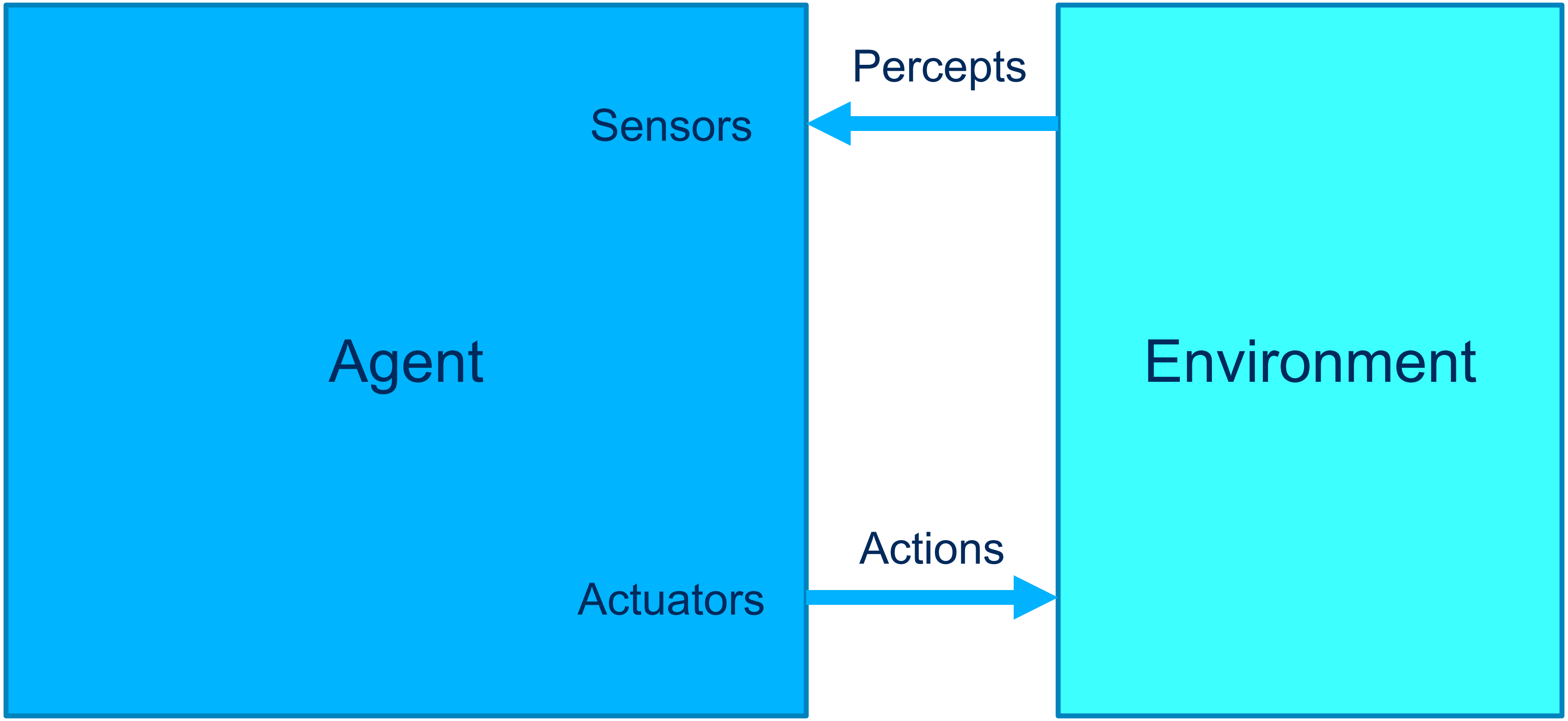
Module 1 – Section 2

Intelligent Agents

Intelligent Agents



The Task Environment ("PEAS")

- **P**erformance Measure
- **E**nvironment
  - Fully vs. partially observable
  - Single agent vs. multiagent
  - Deterministic vs. stochastic
  - Episodic vs. sequential
  - Static vs. dynamic
  - Discrete vs. continuous
  - Known vs. unknown
- **A**ctuators
- **S**ensors

Intelligent Agents

- Types
  - Simple reflex
  - Model-based reflex
  - Goal-based
  - Utility-based

- Problem-solving vs. planning vs. learning

- Exploration vs. exploitation

- Thinking vs. knowing

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Module 1 – Section 3

Problem Solving

Course Themes

- Problem Solving as…
  - Search
  - Optimization
  - Logic and Language
  - Probabilistic Reasoning
- Learning through…
  - Supervision (SCS 3253/3546)
  - Trial and error
- Making the algorithms practical

Problem Solving as Search

- Tree search
  - Depth-first
  - Breadth-first
  - A*
  - Monte Carlo
  - Minimax
- Graph search
  - Dynamic programming
- Genetic algorithms

Problem Solving as Optimization

- Constraint satisfaction solving
- Linear programming
- Non-linear programming

Problem Solving as Language

- Sapir-Whorf Hypothesis
- Formal logic
  - Propositional calculus
  - First-Order Logic
  - extensions
- Programming Languages
  - Functional e.g. LISP
  - Logic e.g. Prolog
  - Probabilistic e.g. Gen
- Category Theory: the Rosetta Stone?

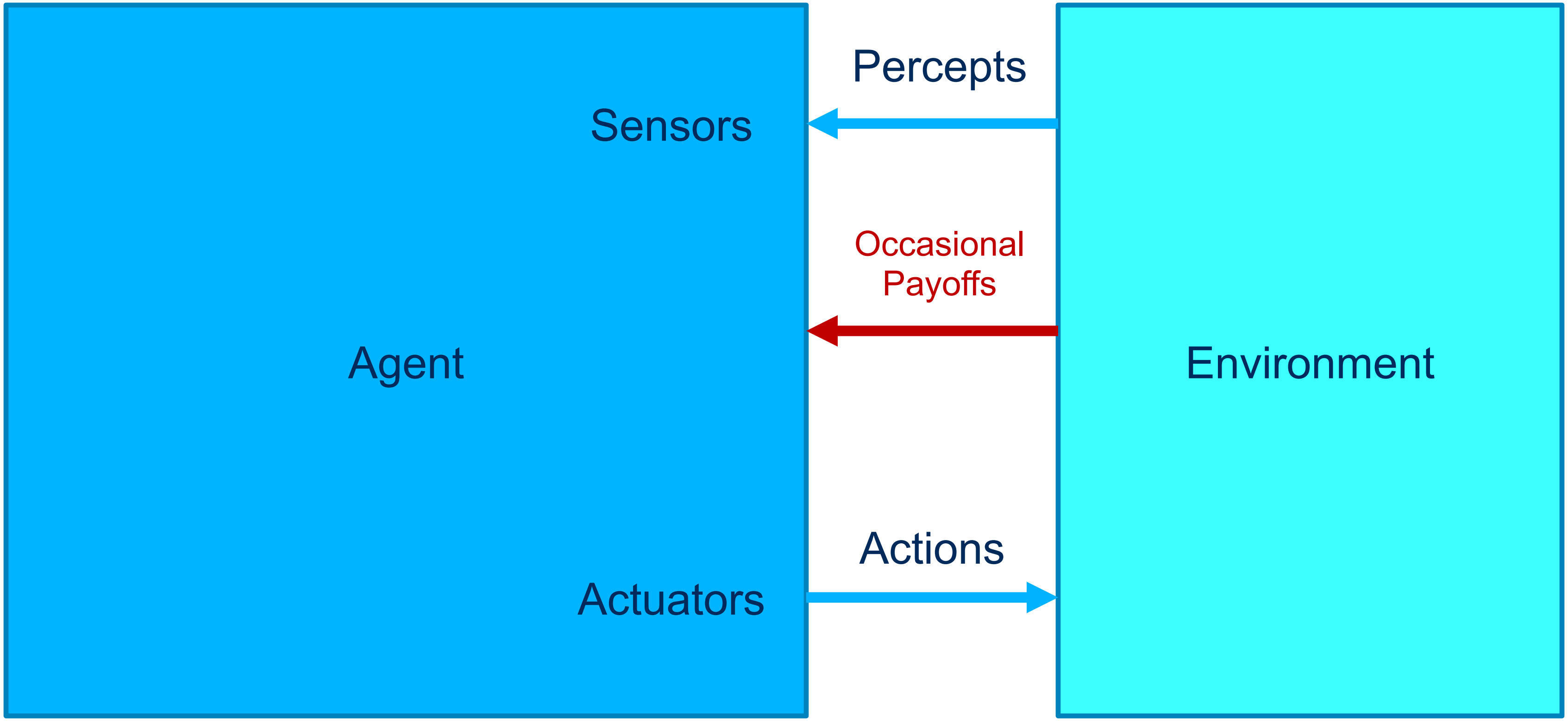
Probabilistic Reasoning

- States of the world vs. beliefs about the world
- P(Hypothesis about the world | new information) =

$$\frac{\text{P(new information | the hypothesis is true) * P(hypothesis is true)}}{\text{P(new info)}}$$

- Causality
- Probabilistic graphical models
- Probabilistic logic

Learning Through Trial and Error



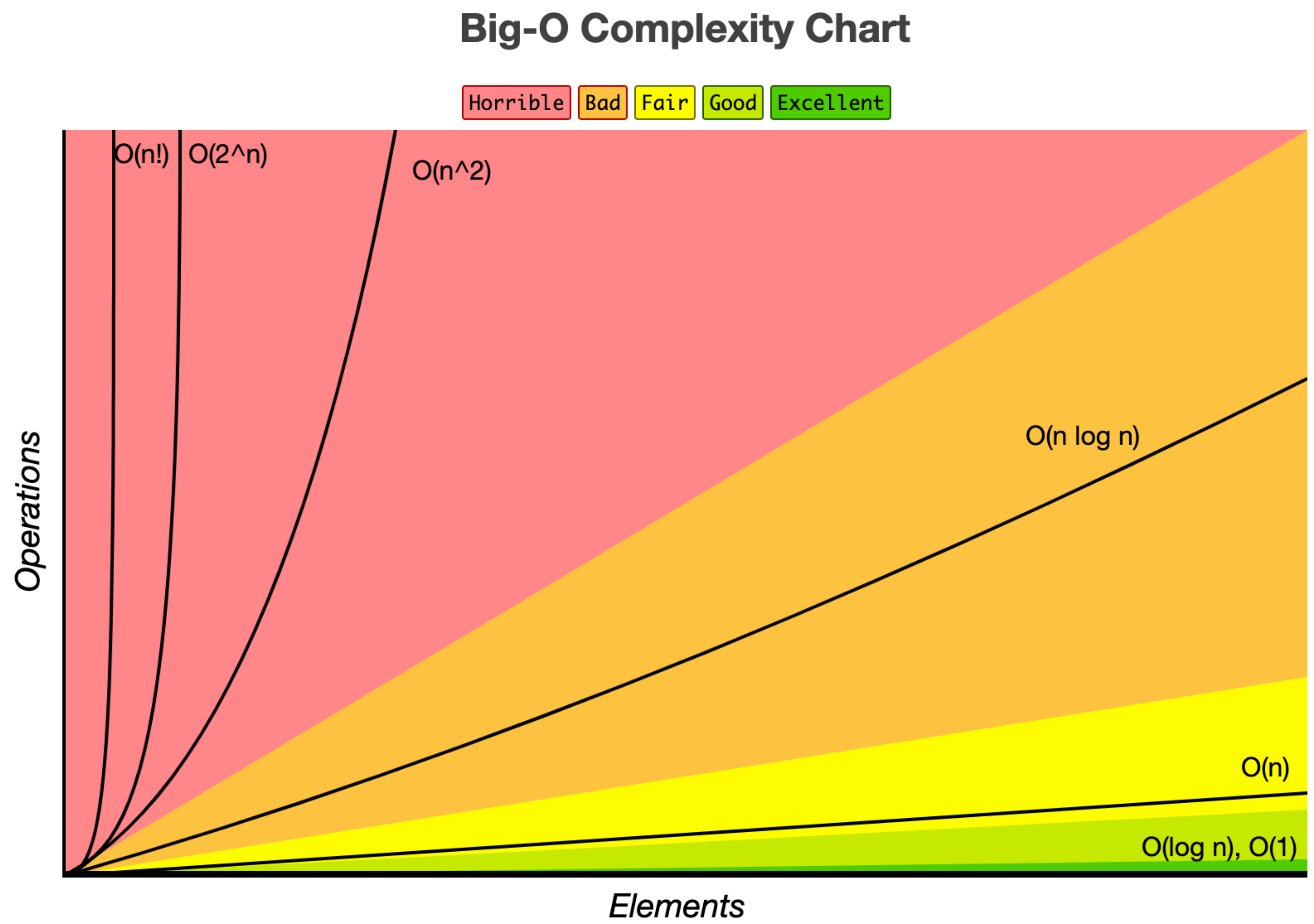
Module 1 – Section 4

Practical AI

Practical AI

- Recognizing how to adapt algorithms to real-world problems is the challenge
- Computational complexity is the demon guarding the gate
- Finding short-cuts is the secret:
  - Do you really need an *optimal* solution?

Big-O Complexity



Source: https://www.bigocheatsheet.com

Example AI Applications

- Vehicle or job scheduling
- Robotics
- Financial decision-making
- Lights-out operations
- Resource/personnel scheduling and optimization
- Entertainment
- Traffic control
- Complex systems configuration
- Recommendations
- Recognizing diseases from images

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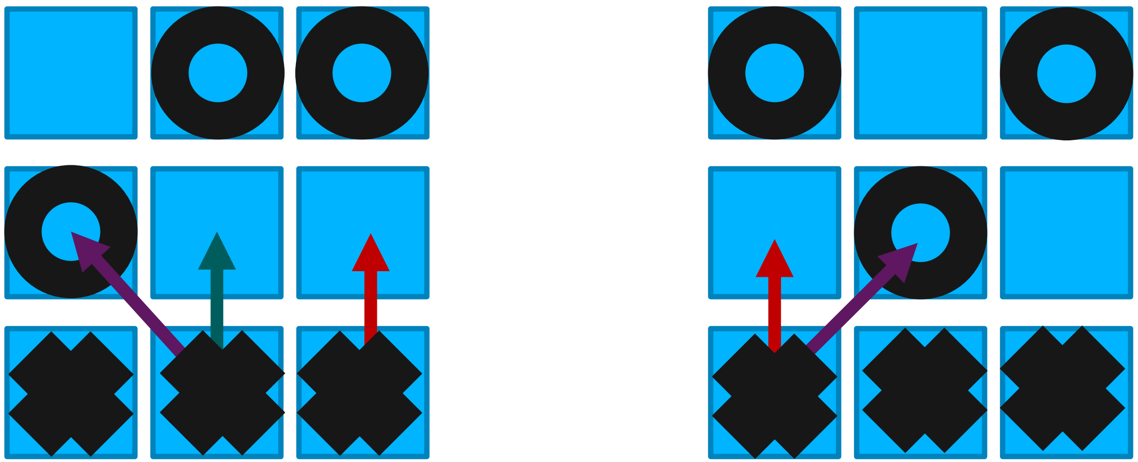
Module 1 – Section 5

Puzzles

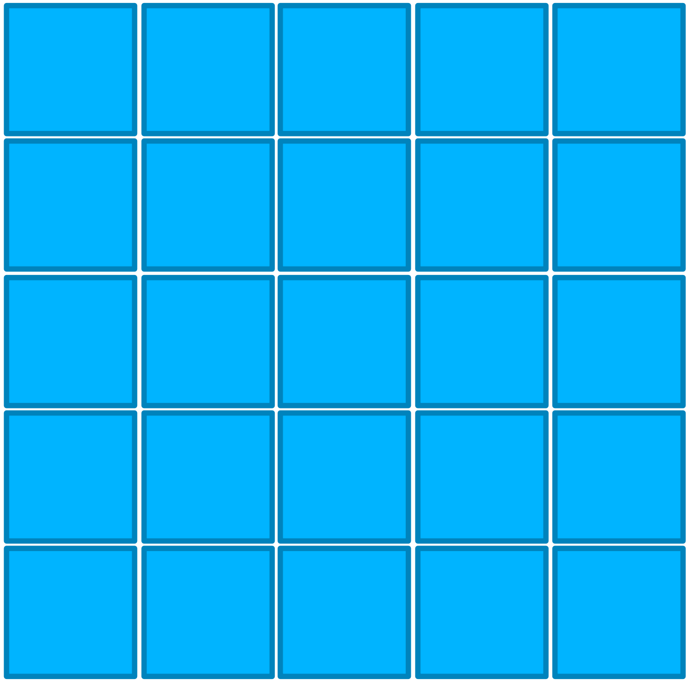
Hexapawn

Move 2



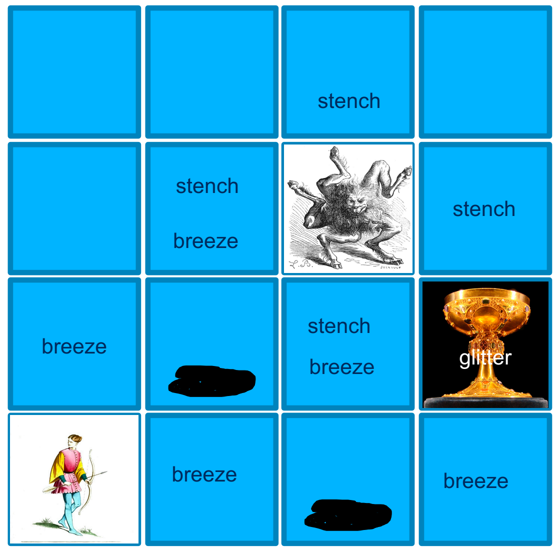
https://www.rigb.org/christmaslectures08/html/activities/sweet-computer.pdf
http://cs.williams.edu/~freund/cs136-073/GardnerHexapawn.pdf

GridWorld



WumpusWorld

WumpusWorld



Images: Public domain

Wumpus World "PEAS"

- Performance measure:
  - +1000 for climbing out of the pit with the gold
  - -1000 falling into a pit or being eaten by the Wumpus
  - -1 for each action taken
  - -10 for using up the arrow
  - Game ends when agent dies or climbs out of cave
- Environment:
  - 4 x 4 grid
  - Agent always starts in (1,1), facing right
  - Gold, pits and Wumpus
- Actuators
  - Forward, turn left, turn right
  - Grab, shoot, climb
- Sensors
  - (Stench, Breeze, Glitter, Bump, Scream)

Rubik's Cube

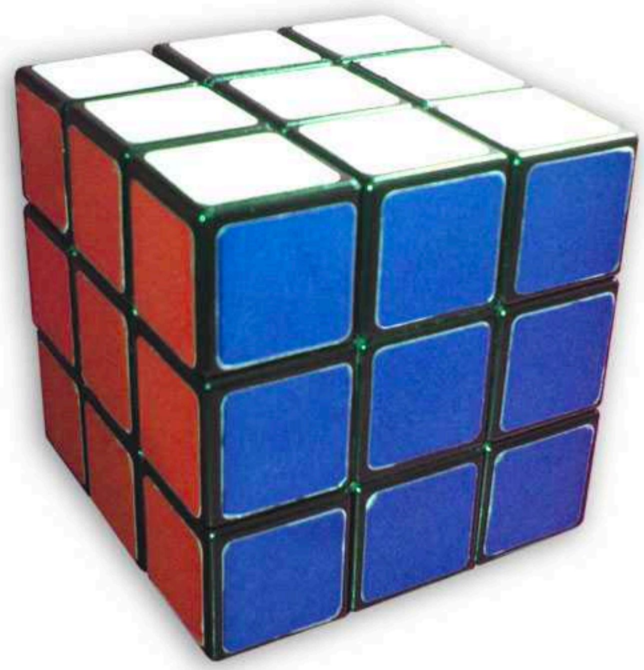


Image: Work by Mike Gonzalez (TheCoffee)

Module 1 – Section 6

Go

Deep Learning and the Game of Go

- Pumperla & Ferguson
- Build your own Go bot
- Riff on provided code
- Use repurposed code to tackle other problems

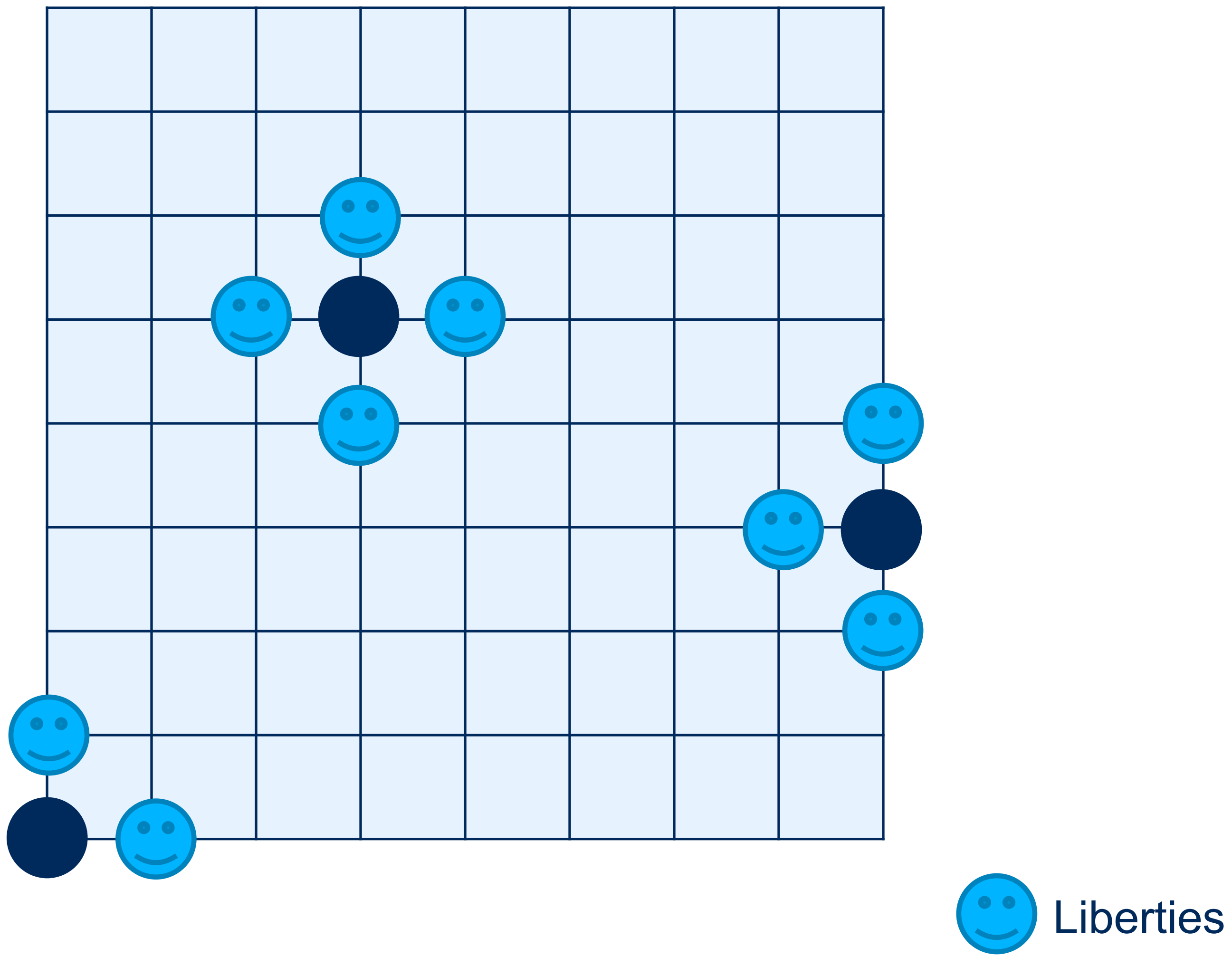
Go

By Goban1 - Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=15223468

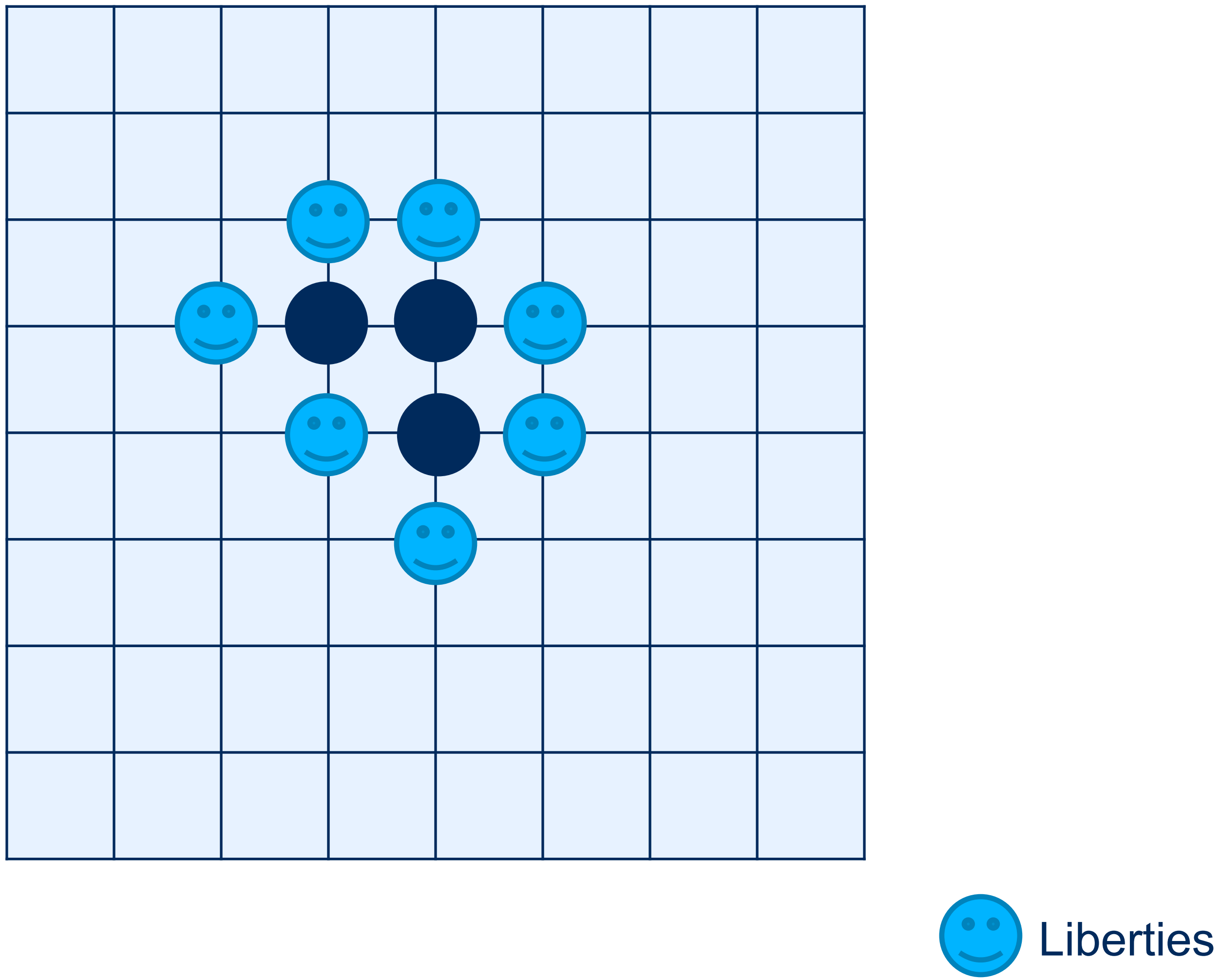
Playing Go

- Start with empty board (9x9, 13x13 or 19x19)
- Both players have an unlimited supply of stones
- Black plays first, then alternate adding stones to vacant points (line intersections, not squares)
- Stones are not moved once placed (unless captured in which case they are removed from play)
- The objective is to capture territory (and potentially your opponent's stones) by surrounding them
- At the end of the game the players count one point for each vacant point inside their own territory and one point for each stone they have captured
- The player with the higher total wins

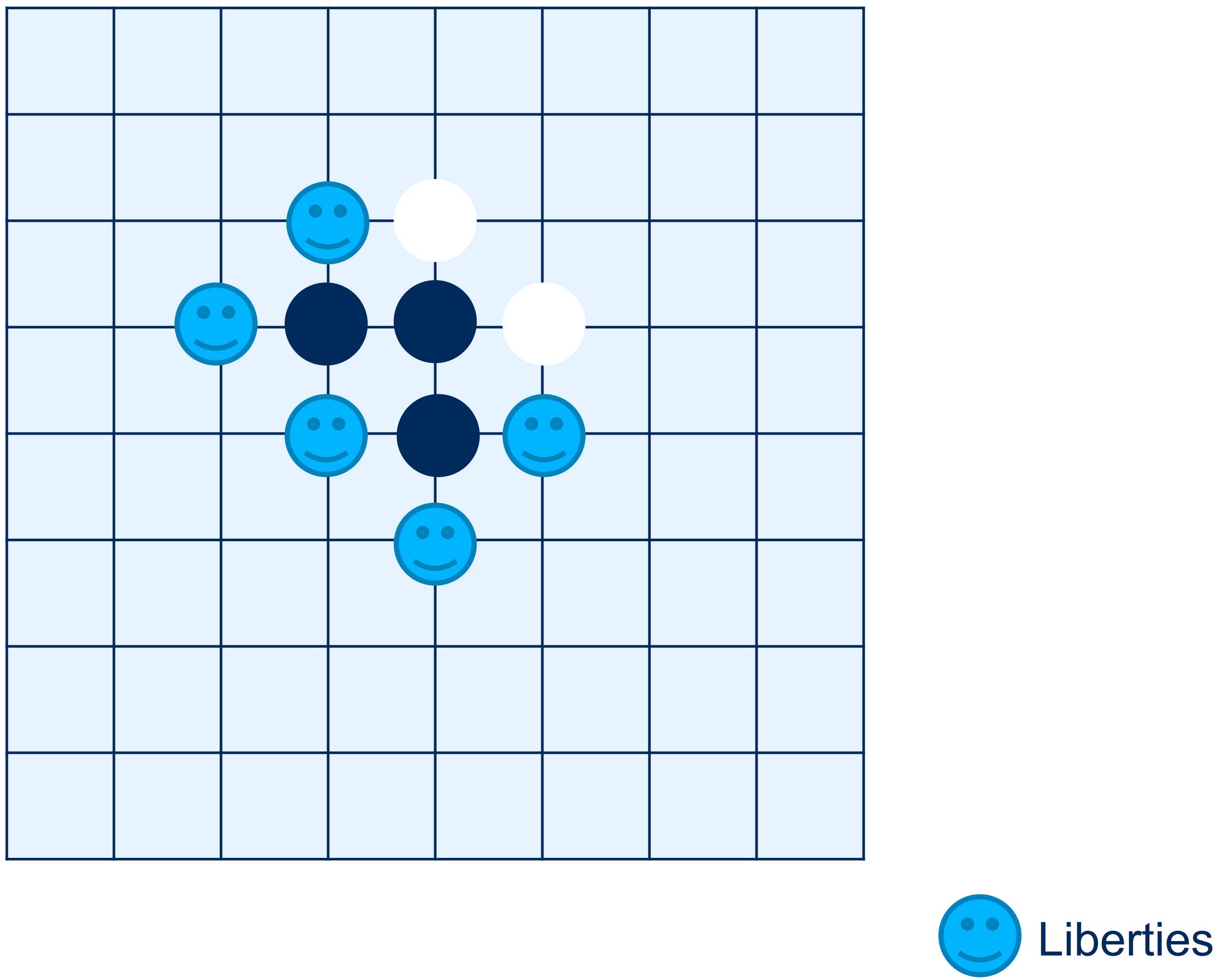
Liberties



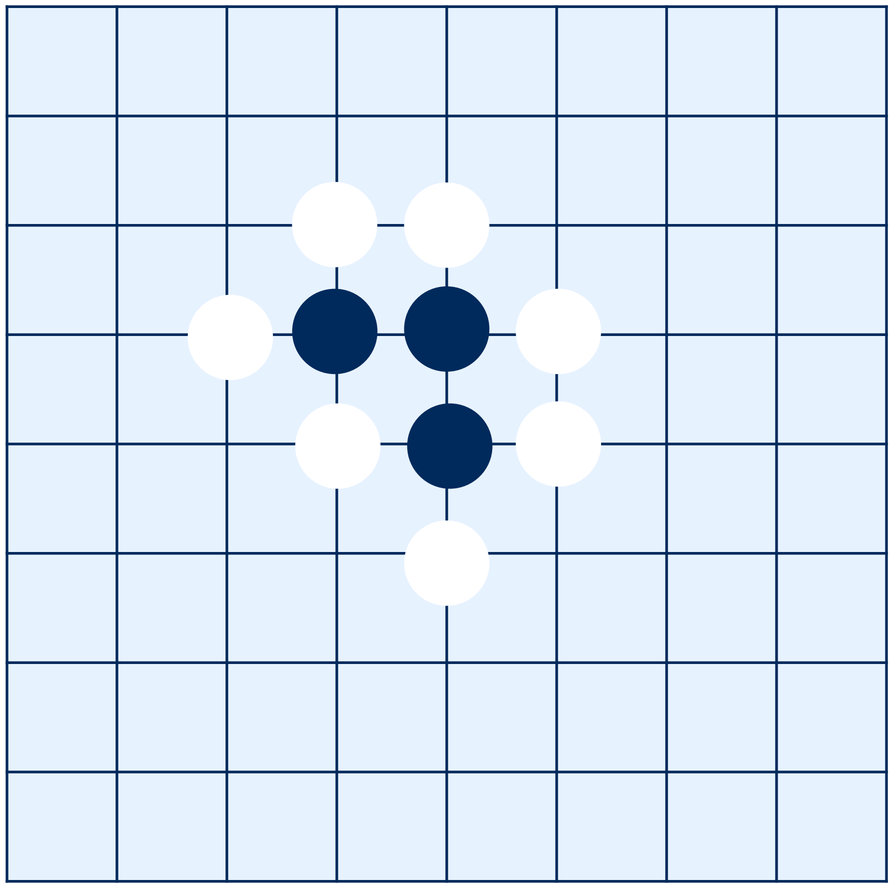
Strings and Liberties



Depriving Your Opponent of Liberties



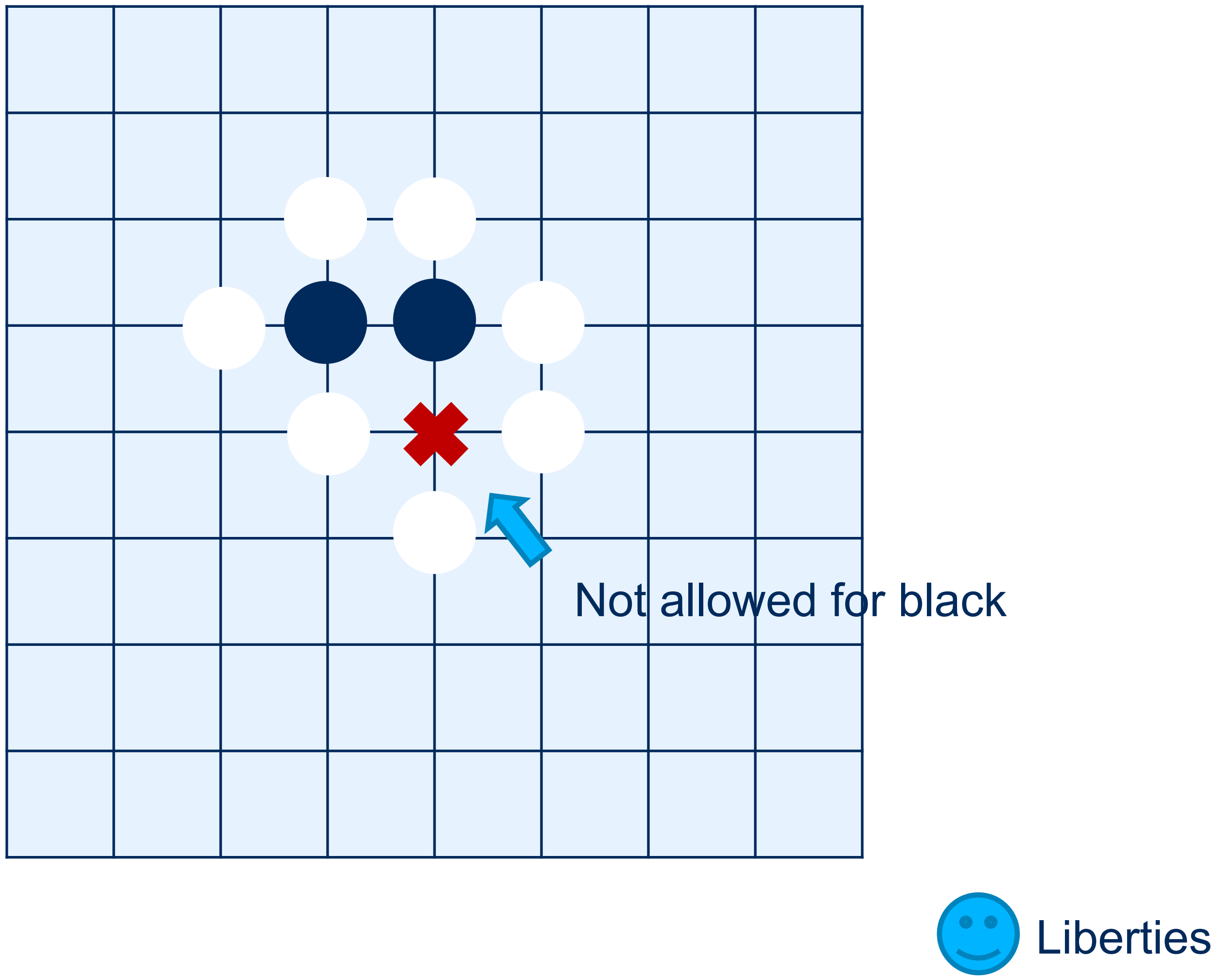
Capturing Strings



Other Rules

- A player may not place a stone where it would deprive a player's string of all liberties (i.e. self-capture) unless, as a result, one or more of the opponents stones surrounding it are captured
- "ko": A player may not place a stone that returns the board to a previous state

Self-Capture



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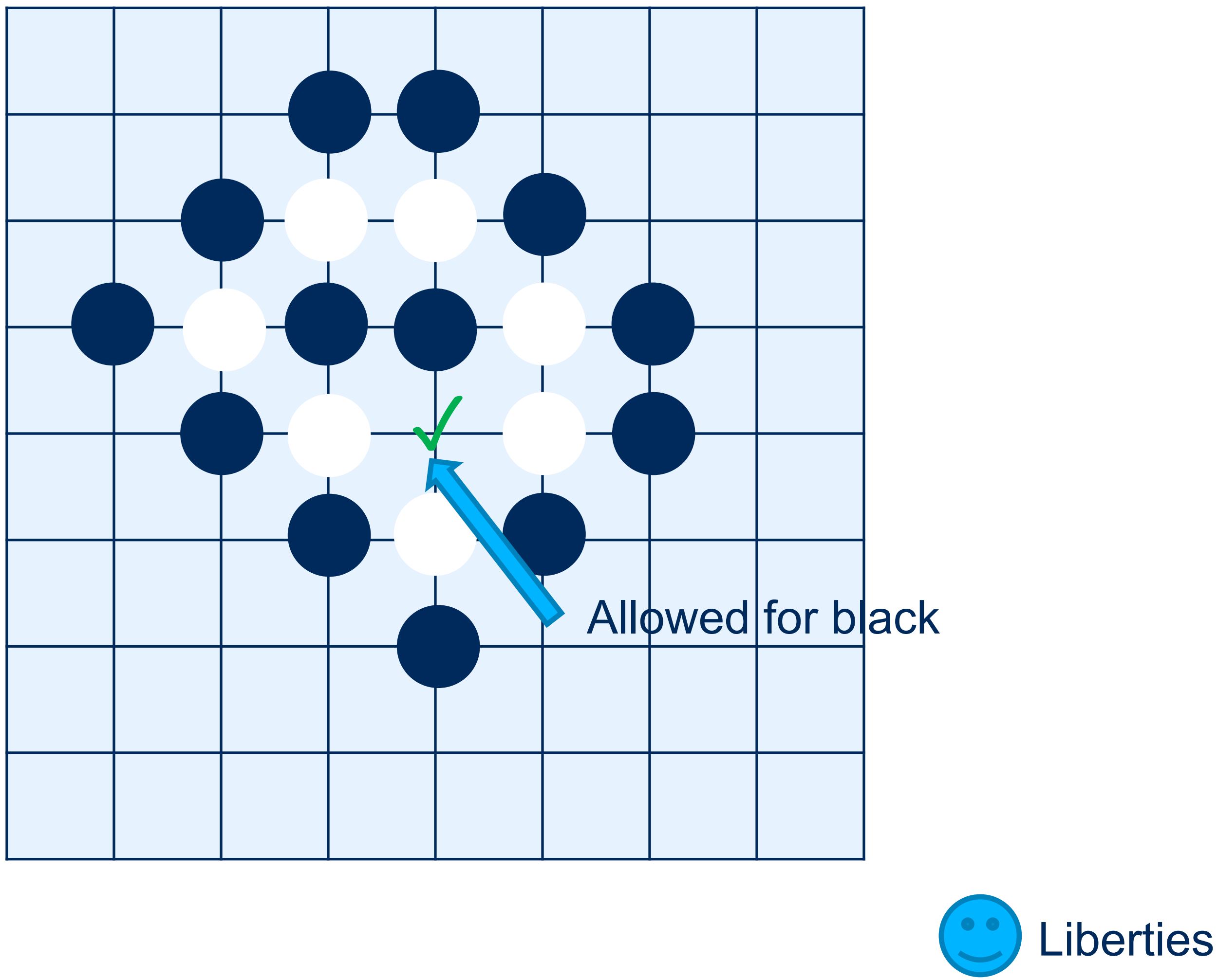
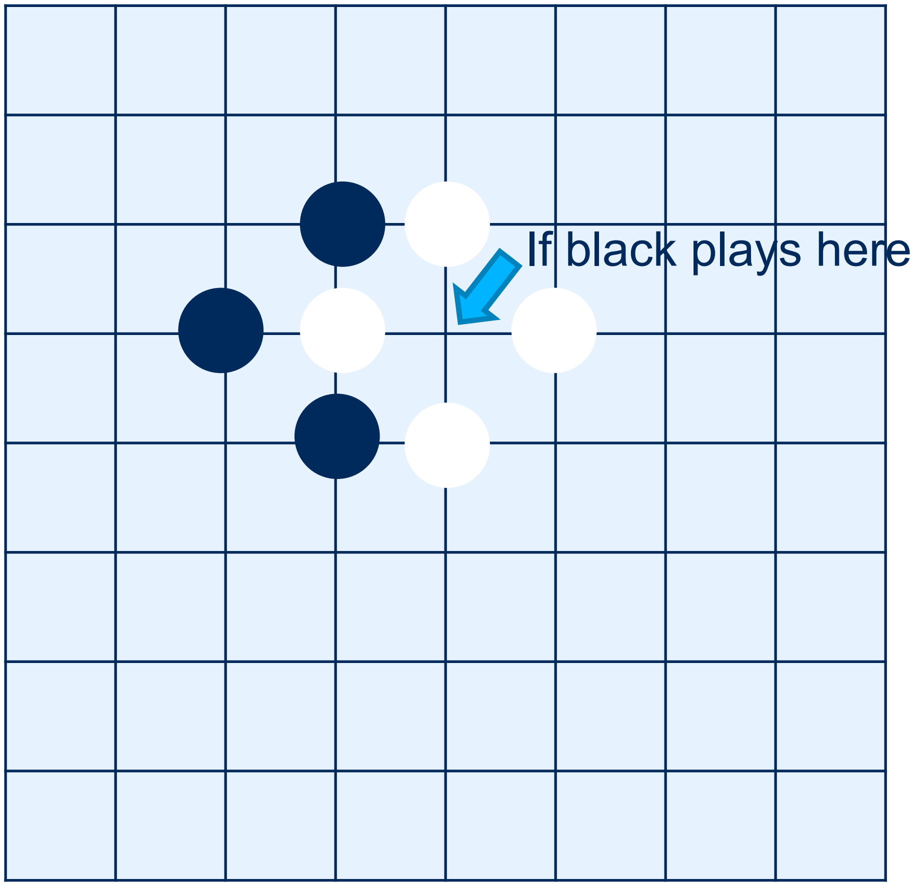
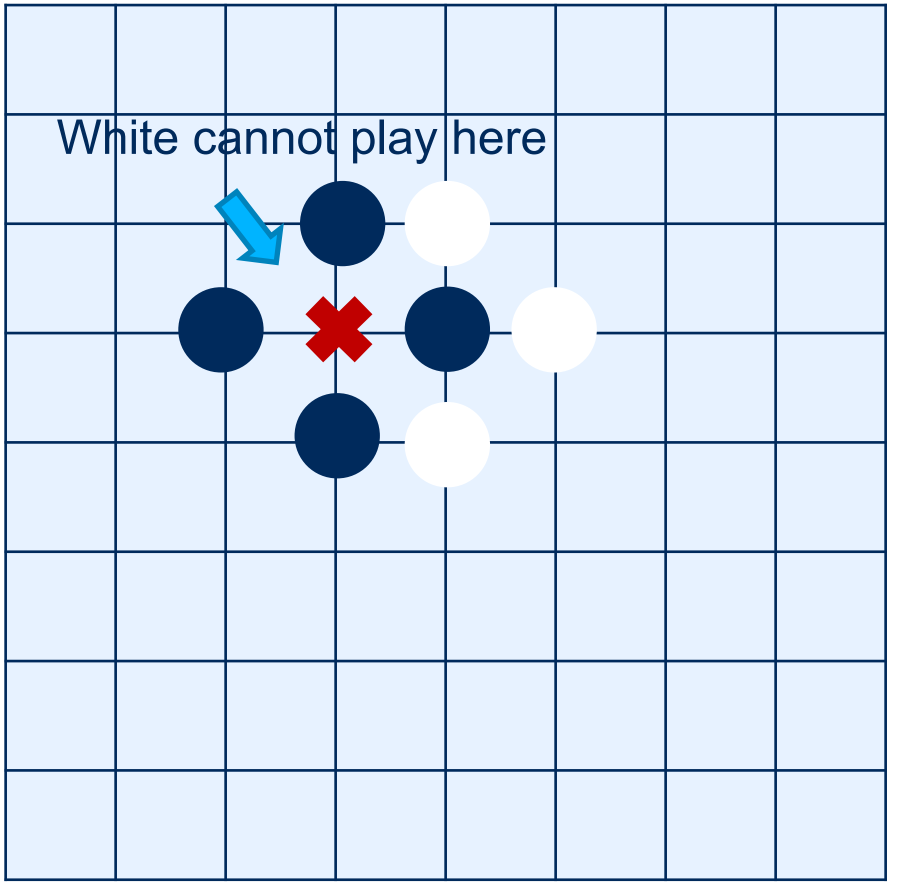
Self-Capture



ko





Module 1 – Section 7

Resources and Wrap-up

Resources

- Russell & Norvig. Artificial Intelligence: A Modern Approach, 3rd Ed. Pearson. 2010. Chap. 2.
- Poole & Mackworth. Artificial Intelligence, 2nd Ed. Cambridge University Press. 2017. Chaps. 1 & 2.
- Pumperla & Ferguson. Deep Learning and the Game of Go. Chaps. 2-3.
- https://en.wikipedia.org/wiki/Rules_of_Go
- British Go Association Rules: https://www.britgo.org/intro/intro2.html

Summary

- The AI body of knowledge is comprised of a collection of problem-solving algorithms
- These algorithms are usually optimal in some sense and come with known guarantees
- But, they are often too slow for practical purposes
- Ingenuity is required to find short-cuts to speed up the search
- Solutions to real-world problems often require a blend of these techniques

Next Week

- Searching for solutions using tree and graph search techniques
- Solving constraint satisfaction problems

Any questions?

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Thank You

Thank you for choosing the University of Toronto School of Continuing Studies