

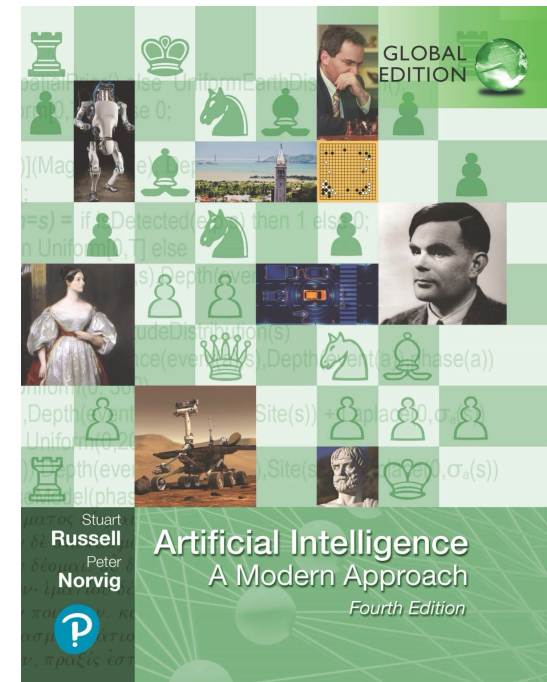
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Introduction to Intelligent Systems

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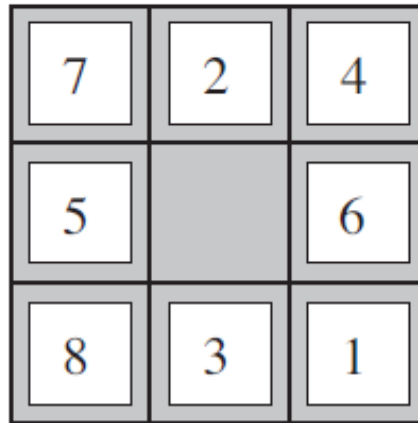
Ch. 3 – Ch. 11

TRADITIONAL AI

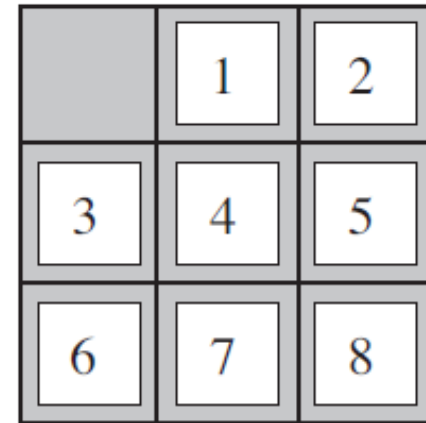


Search

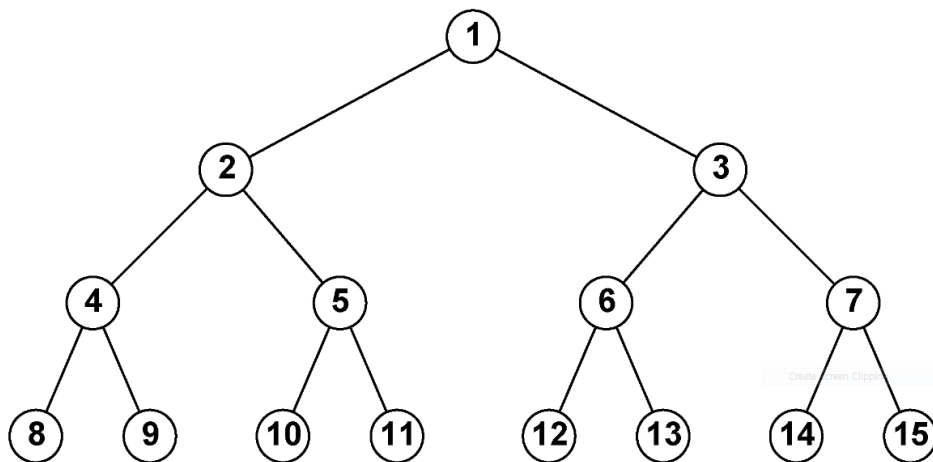
E.g., 8-Puzzle



Start State



Goal State



Search Algorithms:

- Breadth-first search
- Depth-first search
- A* search
- and many more.

Game

IBM Deep Blue vs. World Chess Champion Garry Kasparov, 1997

First match

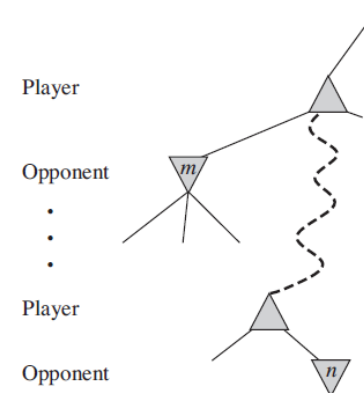
- February 10, 1996: takes place in Philadelphia, Pennsylvania
- Result: **Kasparov**–Deep Blue (4–2)
- Record set: First computer program to defeat a world champion in a *game* under tournament regulations

Second match (rematch)

- May 11, 1997: held in New York City, New York
- Result: **Deep Blue**–Kasparov (3½–2½)
- Record set: First computer program to defeat a world champion in a *match* under tournament regulations



Alpha-Beta Pruning



AlphaGo

Google DeepMind's AlphaGo vs. Lee Sedol, March 2016

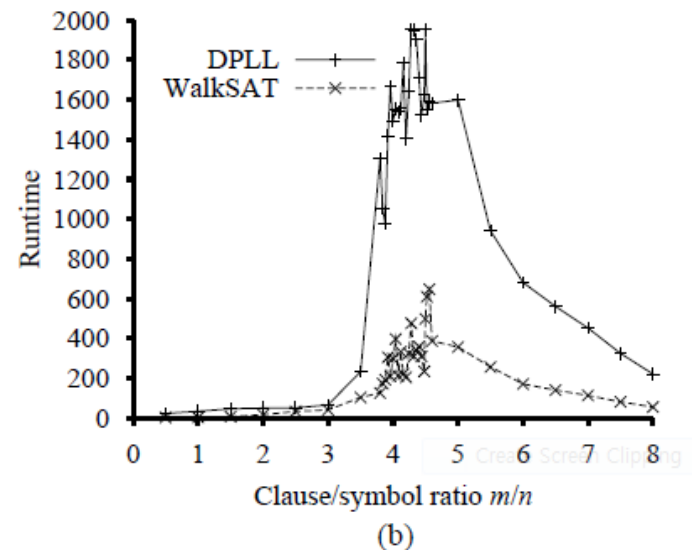
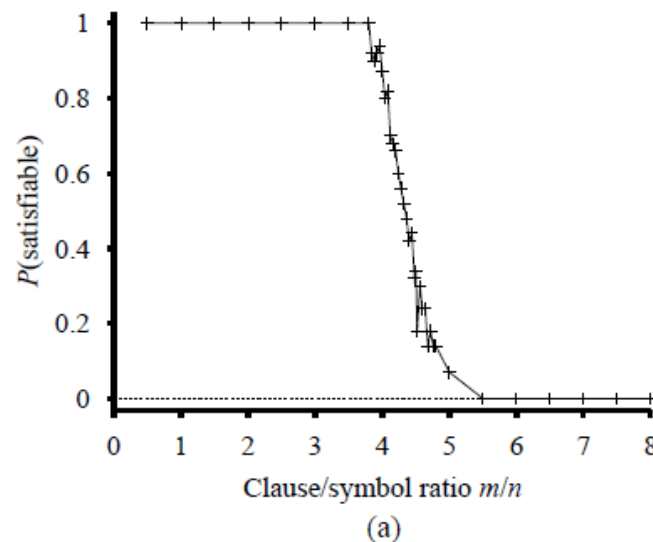
- Possible board positions of Go: 10^{170}
 - cf. Chess: 10^{47}
- Monte Carlo tree search
- Deep neural networks:
 - Value network
 - Policy network
- Reinforcement learning
- Trained from
 - 30 million human moves
 - Playing against itself
- 1,202 CPUs, 176 GPUs



Game	Date	Black	White	Result	Moves
1	9 March 2016	Lee Sedol	AlphaGo	Lee Sedol resigned	186 Game 1
2	10 March 2016	AlphaGo	Lee Sedol	Lee Sedol resigned	211 Game 2
3	12 March 2016	Lee Sedol	AlphaGo	Lee Sedol resigned	176 Game 3
4	13 March 2016	AlphaGo	Lee Sedol	AlphaGo resigned	180 Game 4
5	15 March 2016	Lee Sedol ^[note 1]	AlphaGo	Lee Sedol resigned	280 Game 5
Result: AlphaGo 4 – 1 Lee Sedol					

Propositional Logic

- **Operators:** $\neg$ (not), $\wedge$ (and), $\vee$ (or), $\Rightarrow$ (implies), $\Leftrightarrow$ (if and only if)
- Propositional theorem proving
- **SAT problem:** The problem of determining the satisfiability of sentences in propositional logic. NP-complete.
- **Conjunctive normal form (CNF):** A conjunction of clauses and each clause is a disjunction of literals. E.g., $(\neg B_1 \vee P_1 \vee P_2) \wedge (\neg P_1 \vee B_1) \wedge (\neg P_2 \vee B_1)$. 3-CNF is NP-complete.



First-Order Logic

- **Elements:** objects (constant symbols), relations (predicate symbols), functions (function symbols); E.g. $\neg \text{Brother}(\text{LeftLeg}(\text{Richard}), \text{John})$
- **Quantifiers:** $\forall$ (for all, universal quantification), $\exists$ (there exists, existential quantification)

$$\forall x \quad \text{King}(x) \Rightarrow \text{Person}(x)$$

$$\exists x \quad \text{Crown}(x) \wedge \text{OnHead}(x, \text{John})$$

$$\forall x \exists y \quad \text{Loves}(x, y)$$

$$\exists y \forall x \quad \text{Loves}(x, y)$$

- **Inference algorithms:** forward chaining (deductive database, production system), backward chaining (logic programming, e.g., Prolog), resolution-based theorem proving
- **Gödel's incompleteness theorem:** There are true statements in mathematics that cannot be proven. E.g., Turing's undecidability theorem.

Planning

$Init(On(A, Table) \wedge On(B, Table) \wedge On(C, A)$
 $\wedge Block(A) \wedge Block(B) \wedge Block(C) \wedge Clear(B) \wedge Clear(C))$
 $Goal(On(A, B) \wedge On(B, C))$
 $Action(Move(b, x, y),$
Precond: $On(b, x) \wedge Clear(b) \wedge Clear(y) \wedge Block(b) \wedge Block(y)$
 $\wedge (b \neq x) \wedge (b \neq y) \wedge (x \neq y),$
Effect: $On(b, y) \wedge Clear(x) \wedge \neg On(b, x) \wedge \neg Clear(y))$
 $Action(MoveToTable(b, x),$
Precond: $On(b, x) \wedge Clear(b) \wedge Block(b) \wedge (b \neq x),$
Effect: $On(b, Table) \wedge Clear(x) \wedge \neg On(b, x))$

