

Introduction to Artificial Intelligence

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Artificial Intelligence

- Artificial intelligence is concerned with the design of intelligence in an artificial device (or simply machine).
- What is intelligence:
 - (Based on human behavior description or based on absolute standard of judgment) two possibilities:
 - A system with intelligence is expected to behave as intelligently as a human
 - A system with intelligence is expected to behave in the best possible manner.
 - Behavior? Is it the thought process or reasoning ability of the system? Or system behavior in terms of its action?

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Syllabus

Unit-I

Introduction:

Introduction to intelligent agents, **Problem solving:**

Solving problems by searching : state space formulation, depth first and breadth first search, iterative deepening

Unit-II

Intelligent search methods: A* and its memory restricted variants

Production systems: Design implementation and limitations, case studies

Unit-III

Game Playing:

Minimax, alpha-beta pruning

Knowledge and reasoning:

Propositional and first order logic, semantic networks, building a knowledge base, inference in first order logic, logical reasoning systems

Planning:

STRIPS partial order planning, uncertain knowledge and reasoning, probabilistic reasoning systems, Bayesian networks

Unit-IV

Learning from observations:

Inductive learning, learning decision trees, computational learning theory, Explanation based learning

Applications:

Environmental Science, Robotics, Aerospace, Medical Science etc.

Text Book:

1. "AI" by Rich and Knight, Tata McGraw Hill, 1992

Reference Books:

1. "Neural Networks in Computer Intelligence" by KM Fu, McGraw Hill

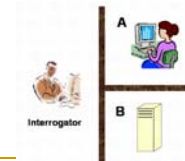
2. "AI: A modern approach" by Russel and Norvig, Pearson Education

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Artificial Intelligence ...

- Four interpretations to define the scope and view of AI:
 - AI is about designing systems that are as intelligent as humans (cognitive science approach of AI)
 - The second approach is best embodied by the Turing Test.
 - Turing test: test for intelligent behavior
 - Interrogator writes questions and receives answers
 - System providing the answers passes the test if interrogator cannot tell whether the answers come from a person or not



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Artificial Intelligence ...

- ❑ AI as an inferencing mechanism, i.e. how the system arrives at a conclusion.
- ❑ The fourth view of AI is that it is the study of rational agents, i.e. how the system acts and performs and not so much on the reasoning process.
- Again, **what is intelligence?**
Intelligence is the computational part of the ability to achieve goals in the world. Varying kinds and degrees of intelligence occur in people, many animals and some machines.
- **Isn't there a solid definition of intelligence that doesn't depend on relating it to human intelligence?**
Not yet. The problem is that we cannot yet characterize in general what kinds of computational procedures we want to call intelligent. We understand some of the mechanisms of intelligence and not others.

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More Formal Definition of AI

- AI is a branch of computer science which is concerned with the study and creation of computer systems that exhibit
 - ❑ some form of intelligence
 - OR
 - ❑ those characteristics which we associate with intelligence in human behavior
- ❑ AI is a broad area consisting of different fields, from machine vision, expert systems to the creation of machines that can "think".

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What is involved in Artificial Intelligence ?

- Ability to interact with the real world
 - ❑ to perceive, understand, and act
 - ❑ e.g., speech recognition and understanding and synthesis
 - ❑ e.g., image understanding
 - ❑ e.g., ability to take actions, have an effect
- Reasoning and Planning
 - ❑ modeling the external world, given input
 - ❑ solving new problems, planning, and making decisions
 - ❑ ability to deal with unexpected problems, uncertainties
- Learning and Adaptation
 - ❑ we are continuously learning and adapting
 - ❑ our internal models are always being "updated"
 - e.g., a baby learning to categorize and recognize animals

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Understanding of AI

- AI techniques and ideas seem to be harder to understand than most things in computer science
- AI shows best on complex problems for which general principles don't help much, though there are a few useful general principles

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- Artificial intelligence is also difficult to understand by its content.
- Boundaries of AI are not well defined.
- Often it means the advanced software engineering, sophisticated software techniques for hard problems that can't be solved in any easy way.
- AI programs - like people - are usually not perfect, and even make mistakes.

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Categories of AI System

- Systems that think like humans
- Systems that act like humans

- Systems that think rationally
- Systems that act rationally

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- It often means, nonnumeric ways of solving problems, since people can't handle numbers well.
- Nonnumeric ways are generally "common sense" ways, not necessarily the best ones.
- Understanding of AI also requires an understanding of related terms such as intelligence, knowledge, reasoning, thought, cognition, learning, and a number of other computer related terms.

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Systems that think like humans

- Most of the time it is a black box where we are not clear about our thought process.
- One has to know functioning of brain and its mechanism for possessing information.
- It is an area of cognitive science.
 - The stimuli are converted into mental representation.
 - Cognitive processes manipulate representation to build new representations that are used to generate actions.
- Neural network is a computing model for processing information similar to brain.

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Systems that act like humans

- The overall behaviour of the system should be human like.
- It could be achieved by observation.

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Systems that act rationally

- Rational behavior means doing right thing.
- Even if method is illogical, the observed behavior must be rational.

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Systems that think rationally

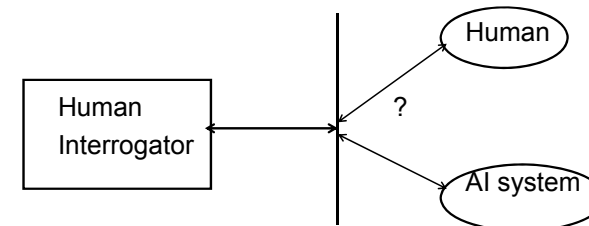
- Such systems rely on logic rather than human to measure correctness.
- For thinking rationally or logically, logic formulas and theories are used for synthesizing outcomes.
- For example,
 - given John is a human and all humans are mortal then one can conclude logically that John is mortal
- Not all intelligent behavior are mediated by logical deliberation.

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The Turing Test

Turing proposed operational test for intelligent behavior in 1950.



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ELIZA

- Eliza was first program developed by Joseph Wiezbaum to converse in English in mid 1960's
 - It passed turing test.
- The following passage shows Eliza's talking to a teenage girl. Blue text Eliza's response

Men are all alike.

IN WHAT WAY

They're always bugging us about something or other.

CAN YOU THINK OF A SPECIFIC EXAMPLE

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My mother takes care of me.

WHO ELSE IN YOUR FAMILY TAKES CARE OF YOU

My father.

YOUR FATHER

You are like my father in some ways.

WHAT RESEMBLANCE DO YOU SEE

You are not very aggressive but I think you don't want me to notice that.

WHAT MAKES YOU THINK THAT I AM NOT VERY AGGRESSIVE

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Well, my boyfriend made me come here.

YOUR BOYFRIEND MADE YOU COME HERE

He says that I am depressed all the time.

I AM SORRY TO HEAR THAT YOU ARE DEPRESSED

It's true that I am unhappy

DO YOU THINK COMING HERE WILL HELP YOU NOT TO BE UNHAPPY

I need help, that seems certain.

WHAT WOULD IT MEAN IF YOU GOT SOME HELP

Perhaps I could learn to get along with my mother.

TELL ME MORE ABOUT YOUR FAMILY

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You don't argue with me.

WHY DO YOU THINK I DON'T ARGUE WITH YOU

You are afraid of me.

DOES IT PLEASE YOU TO BELIEVE, I AM AFRAID OF YOU

My father is afraid of everybody.

WHAT ELSE COMES TO MIND WHEN YOU THINK OF YOUR FATHER

Bullies.

DOES THAT HAVE ANYTHING TO DO WITH THE FACT THAT YOUR BOYFRIEND MADE YOU COME HERE

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Foundations of AI

- Foundation of AI is based on
 - Mathematics
 - Neuroscience
 - Control Theory
 - Linguistics

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Foundations - Neuroscience

- How do the brain works?
 - Early studies (1824) relied on injured and abnormal people to understand what parts of brain work
 - More recent studies use accurate sensors to correlate brain activity to human thought
 - By monitoring individual neurons, monkeys can now control a computer mouse using thought alone
 - Moore's law states that computers will have as many gates as humans have neurons in 2020
 - How close are we to have a mechanical brain?
 - Parallel computation, remapping, interconnections,....

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Foundations - Mathematics

- More formal logical methods
 - Boolean logic
 - Fuzzy logic
- Uncertainty
 - The basis for most modern approaches to handle uncertainty in AI applications can be handled by
 - ✓ Probability theory
 - ✓ Modal and Temporal logics

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Foundations – Control Theory

- Machines can modify their behavior in response to the environment (sense/action loop)
 - Water-flow regulator, steam engine governor, thermostat
- The theory of stable feedback systems (1894)
 - Build systems that transition from initial state to goal state with minimum energy
 - In 1950, control theory could only describe linear systems and AI largely rose as a response to this shortcoming

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Foundations - Linguistics

- Speech demonstrates so much of human intelligence
 - Analysis of human language reveals thought taking place in ways not understood in other settings
 - Children can create sentences they have never heard before
 - Language and thought are believed to be tightly intertwined

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Cool Stuff in AI

- Game playing agents
- Machine learning
- Speech
- Language
- Vision
- Data Mining
- Web agents

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Two Views of AI Goals

- AI is about duplicating what the (human) brain DOES
 - Cognitive Science
- AI is about duplicating what the (human) brain SHOULD do
 - Rationality (doing things logically)

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Useful Stuff

- Medical Diagnosis
- Fraud Detection
- Object Identification
- Space Shuttle Scheduling
- Information Retrieval

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AI Techniques

- Rule-based
- Fuzzy Logic
- Neural Networks
- Genetic Algorithms

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Knowledge Base

- AI programs should be learning in nature and update its knowledge accordingly.
- Knowledge base consists of facts and rules.
- Characteristics of Knowledge:
 - It is voluminous in nature and requires proper structuring
 - It may be incomplete and imprecise
 - It may keep on changing (dynamic)

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Components of AI Program

- AI techniques must be independent of the problem domain as far as possible.
- AI program should have
 - knowledge base
 - navigational capability
 - inferencing

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Navigational Capability

- Navigational capability contains various control strategies
- Control Strategy
 - determines the rule to be applied
 - some heuristics (thumb rule) may be applied

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Inferencing

- Inferencing requires
 - search through knowledge base and
 - derive new knowledge

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Sub-areas of AI – Contd..

- Natural language understanding
- Computer vision
- Understanding spoken utterances
- Intelligent tutoring systems
- Robotics
- Machine translation systems
- Expert problem solving
- Neural Networks, AI tools etc

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Sub-areas of AI

- Sub areas of AI are:
 - Knowledge representation
 - Theorem proving
 - Game playing
 - Common sense reasoning dealing with uncertainty and decision making
 - Learning models, inference techniques, pattern recognition, search and matching etc.
 - Logic (fuzzy, temporal, modal) in AI
 - Planning and scheduling

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Applications

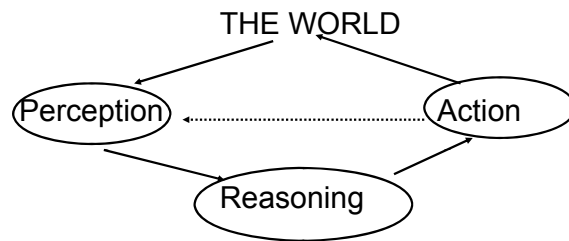
- Some of the applications are given below:
 - **Business** : Financial strategies, give advice
 - **Engineering**: check design, offer suggestions to create new product
 - **Manufacturing**: Assembly, inspection & maintenance
 - **Mining**: used when conditions are dangerous
 - **Hospital** : monitoring, diagnosing & prescribing
 - **Education** : In teaching
 - **household** : Advice on cooking, shopping etc.
 - **farming** : prune trees & selectively harvest mixed crops.

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Latest Perception of AI

- Three typical components of AI Systems



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Tic Tac Toe Game playing strategies

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Recent AI

- Heavy use of
 - probability theory
 - decision theory
 - statistics
 - logic (fuzzy, modal, temporal)

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Tic-Tac-Toe game playing

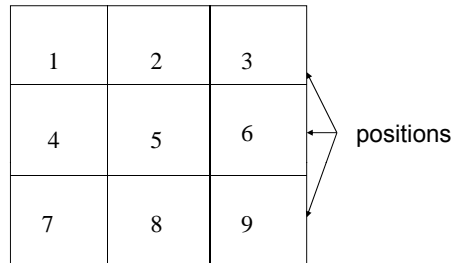
- Two players
 - human
 - computer.
- The objective is to write a computer program in such a way that computer wins most of the time.
- Three approaches are presented to play this game which increase in
 - Complexity
 - Use of generalization
 - Clarity of their knowledge
 - Extensibility of their approach
- These approaches will move towards being representations of what we will call AI techniques.

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Tic Tac Toe Board- (or Noughts and crosses, Xs and Os)

It is two players, X and O, game who take turns marking the spaces in a 3×3 grid. The player who succeeds in placing three respective marks in a horizontal, vertical, or diagonal row, first wins the game.



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Move Table MT

- MT is a vector of 3^9 elements, each element of which is a nine element vector representing board position.
- Total of 3^9 (19683) elements in MT

Index	Current Board position	New Board position
0	000000000	000010000
1	000000001	020000001
2	000000002	000100002
3	000000010	002000010
:		
:		

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Approach 1

- Data Structure
 - Consider a Board having nine elements vector.
 - Each element will contain
 - 0 for blank
 - 1 indicating X player move
 - 2 indicating O player move
 - Computer may play as X or O player.
 - First player who so ever is always plays X.

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Algorithm

- To make a move, do the following:
 - View the vector (board) as a ternary number and convert it to its corresponding decimal number.
 - Use the computed number as an index into the MT and access the vector stored there.
 - The selected vector represents the way the board will look after the move.
 - Set board equal to that vector.

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Comments

- Very efficient in terms of time but has several disadvantages.
 - Lot of space to store the move table.
 - Lot of work to specify all the entries in move table.
 - Highly error prone as the data is voluminous.
 - Poor extensibility
 - 3D tic-tac-toe = 3^{27} board position to be stored.
 - Not intelligent at all.

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Procedures Used

- **Make_2** → Tries to make valid 2
 - Make_2 first tries to play in the center if free and returns 5 (square number).
 - If not possible, then it tries the various suitable non corner square and returns square number.
- **Go(n)** ← makes a move in square 'n' which is blank represented by 2.

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Approach 2

■ Data Structure

- **Board:** A nine-element vector representing the board: B[1..9]
- Following conventions are used

2	-	indicates blank
3	-	X
5	-	0
- **Turn:** An integer

1	-	First move
9	-	Last move

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Procedure - PossWin

- **PossWin (P)** → Returns
 - 0, if player P cannot win in its next move,
 - otherwise the number of square that constitutes a winning move for P.
- **Rule**
 - If PossWin (P) = 0 {P can not win} then find whether opponent can win. If so, then block it.

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Strategy used by PosWin

- **PosWin** checks one at a time, for each rows /columns and diagonals as follows.
 - If $3 * 3 * 2 = 18$ then player X can win
 - else if $5 * 5 * 2 = 50$ then player O can win
- These procedures are used in the algorithm on the next slide.

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Algo - Computer plays first – C plays odd moves

- **Move 1:** Go (5)
- **Move 2:** *H plays*
- **Move 3:** If B[9] is blank, then Go(9) else Go(3) **{make 2}**
- **Move 4:** *H plays*
- **Move 5:** **{By now computer has played 2 chances}**
 - If PossWin(C) then **{won}** Go(PossWin(C))
 - else **{block H}** if PossWin(H) then Go(PossWin(H)) else if B[7] is blank then Go(7) else Go(3)
- **Move 6:** *H plays*
- **Moves 7 & 9 :**
 - If PossWin(C) then **{won}** Go(PossWin(C))
 - else **{block H}** if PossWin(H) then Go(PossWin(H)) else Go(Anywhere)
- **Move 8:** *H plays*

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Algorithm

- **Assumptions**
 - The first player always uses symbol X.
 - There are in all 8 moves in the worst case.
 - Computer is represented by C and Human is represented by H.
 - Convention used in algorithm on next slide
 - If C plays first (Computer plays X, Human plays O) - **Odd moves**
 - If H plays first (Human plays X, Computer plays O) - **Even moves**
 - For the sake of clarity, we use C and H.

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Algo - Human plays first – C plays even moves

- **Move 1:** *H plays*
- **Move 2:** If B[5] is blank, then Go(5) else Go(1)
- **Move 3:** *H plays*
- **Move 4:** **{By now H has played 2 chances}**
 - If PossWin(H) then **{block H}** Go (PossWin(H))
 - else Go (Make_2)
- **Move 5:** *H plays*
- **Move 6:** **{By now both have played 2 chances}**
 - If PossWin(C) then **{won}** Go(PossWin(C))
 - else **{block H}** if PossWin(H) then Go(PossWin(H)) else Go(Make_2)
- **Moves 7 & 9 :** *H plays*
- **Move 8:** **{By now computer has played 3 chances}**
 - If PossWin(C) then **{won}** Go(PossWin(C))
 - else **{block H}** if PossWin(H) then Go(PossWin(H)) else Go(Anywhere)

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Complete Algorithm – Odd moves or even moves for C playing first or second

- **Move 1:** go (5)
- **Move 2:** If B[5] is blank, then Go(5) else Go(1)
- **Move 3:** If B[9] is blank, then Go(9) else Go(3) {make 2}
- **Move 4:** {By now human (playing X) has played 2 chances} If PossWin(X) then {block H} Go (PossWin(X)) else Go (Make_2)
- **Move 5:** {By now computer has played 2 chances} If PossWin(X) then {won} Go(PossWin(X)) else {block H} if PossWin(O) then Go(PossWin(O)) else if B[7] is blank then Go(7) else Go(3)
- **Move 6:** {By now both have played 2 chances} If PossWin(O) then {won} Go(PossWin(O)) else {block H} if PossWin(X) then Go(PossWin(X)) else Go(Make_2)
- **Moves 7 & 9 :** {By now human (playing O) has played 3 chances} If PossWin(X) then {won} Go(PossWin(X)) else {block H} if PossWin(O) then Go(PossWin(O)) else Go(Anywhere)
- **Move 8:** {By now computer has played 3 chances} If PossWin(O) then {won} Go(PossWin(O)) else {block H} if PossWin(X) then Go(PossWin(X)) else Go(Anywhere)

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Approach 3

- Same as approach 2 except for one change in the representation of the board.
 - Board is considered to be a magic square of size 3 X 3 with 9 blocks numbered by numbers indicated by magic square.
- This representation makes process of checking for a possible win more simple.

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Comments

- Not as efficient as first one in terms of time.
- Several conditions are checked before each move.
- It is memory efficient.
- Easier to understand & complete strategy has been determined in advance
- Still can not generalize to 3-D.

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Board Layout – Magic Square

- Board Layout as magic square. Each row, column and diagonals add to 15.

Magic Square

8	3	4
1	5	9
6	7	2

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Strategy for possible win for one player

- Maintain the list of each player's blocks in which he has played.
 - Consider each pair of blocks that player owns.
 - Compute difference D between 15 and the sum of the two blocks.
 - If $D < 0$ or $D > 9$ then
 - these two blocks are not collinear and so can be ignored
 - otherwise if the block representing difference is blank (i.e., not in either list) then a move in that block will produce a win.

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Working – contd..

- Strategy is same as in approach 2
 - First check if computer can win.
 - If not then check if opponent can win.
 - If so, then block it and proceed further.
- Steps involved in the play are:
 - First chance, H plays in block numbered as 8
 - Next C plays in block numbered as 5
 - H plays in block numbered 3
 - Now there is a turn of computer.

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Working Example of algorithm

- Assume that the following lists are maintained up to 3rd move.
- Consider the magic block shown in slide 18.
 - First Player X (Human)

8	3
---	---

- Second Player O (Computer)

5	
---	--

↑

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Working – contd..

- Strategy by computer: Since H has played two turns and C has played only one turn, C checks if H can win or not.
 - Compute sum of blocks played by H
 - $S = 8 + 3 = 11$
 - Compute $D = 15 - 11 = 4$
 - Block 4 is a winning block for H.
 - So block this block and play in block numbered 4.
 - The list of C gets updated with block number 4 as follows:

H	8 3	C	5 4
---	-----	---	-----

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Contd..

- Assume that H plays in block numbered 6.
- Now it's a turn of C.
 - C checks, if C can win as follows:
 - Compute sum of blocks played by C
 - $S = 5 + 4 = 9$
 - Compute $D = 15 - 9 = 6$
 - Block 6 is not free, so C can not win at this turn.
 - Now check if H can win.
 - Compute sum of new pairs (8, 6) and (3, 6) from the list of H
 - $S = 8 + 6 = 14$
 - Compute $D = 15 - 14 = 1$
 - Block 1 is not used by either player, so C plays in block numbered as 1

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Comments

- This program will require more time than two others as
 - it has to search a tree representing all possible move sequences before making each move.
- This approach is extensible to handle
 - 3-dimensional tic-tac-toe.
 - games more complicated than tic-tac-toe.

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Contd..

- The updated lists at 6th move looks as follows:
 - First Player H

8	3	6
---	---	---
 - Second Player C

5	4	1
---	---	---
- Assume that now H plays in 2.
- Using same strategy, C checks its pair (5, 1) and (4, 1) and finds block numbered as 9 {15-6 = 9}.
- Block 9 is free, so C plays in 9 and win the game.

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3D Tic Tac Toe (Magic cube)

- All lines parallel to the faces of a cube, and all 4 diagonals sum correctly to 42 defined by

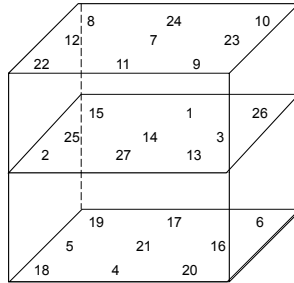
$$S = m(m^3 + 1)/2, \text{ where } m=3$$
- No planar diagonals of outer surfaces sum to 42. so there are probably no magic squares in the cube.

8	24	10	15	1	26	19	17	6
12	7	23	25	14	3	5	21	16
22	11	9	2	27	13	18	4	20

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8	24	10	15	1	26	19	17	6
12	7	23	25	14	3	5	21	16
22	11	9	2	27	13	18	4	20



- Magic Cube has 6 outer and 3 inner and 2 diagonal surfaces
- Outer 6 surfaces are not magic squares as diagonals are not added to 42.
- Inner 5 surfaces are magic square.