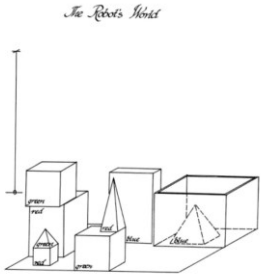
CMSC 373 Artificial Intelligence Fall 2023

Deepak Kumar

Early Integrated AI Systems

SHRDLU & SHAKEY



1

The Thinking Machine Synopsis

- Represented state-of-the-art in AI in 1961
- What makes up our thought processes?
  Studies of problem solving and game playing
- Does the nervous system work like a computer?
  No. There are some similarities but many differences.
  Dangerous to carry the analogy too far.
- Innateness versus Learning by experience
  Goose, frog, and milk experiments
- Intelligent behavior is rule-obeying behavior
  Figure out the rules and write them in programs
  Story generation example
- Brain has 10 billion neurons
- Predictions
  Can't imagine a computer being creative
  Computers will do things humans cannot do, or do them better
  Lead to a second industrial revolution
  There will be special purpose AI systems within 10-15 years
  We need to build general purpose machines with senses, reasoning with logic, learning, etc.

2

2

Early AI Methodology, 1960s…

- AGI, or general AI, is too ambitious a goal.
- Use a divide and conquer approach:

  Focus on component capabilities/aspects of intelligence

  Build theories and systems that demonstrate these capabilities

  Later, integrate them into a complete system

3

3

Identifying components of intelligent behavior

- **Perception**
  Vision, hearing, touch, smell, taste, etc. Using artificial sensors (cameras, microphones, etc.)
- **Problem Solving**
  Achieving a goal. For example, solving puzzles (Missionaries & Cannibals, Towers of Hanoi, 15-puzzle), playing games (checkers, chess, go, etc.)
- **Planning**
  Purposeful problem solving. For example, how to build a tower of blocks.
- **Reasoning**
  Representing and reasoning about knowledge about the world. For example, All red colored blocks are made of wood. Block A is colored red. Is Block A made of wood?
- **Natural Language Understanding**
  Conversing in natural language(s).
- **Machine Learning**
  Learning as carried out by humans as well as using data to make predictions.
- Etc.

4

4

SHRDLU: An Integrated AI System

- Developed by Terry Winograd at MIT (1971)
- Demonstrated language interaction and problem solving in a small (toy) blocks world (**microworld**).

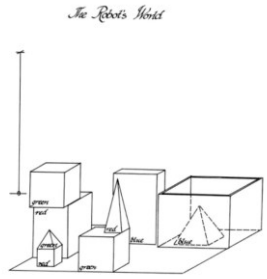
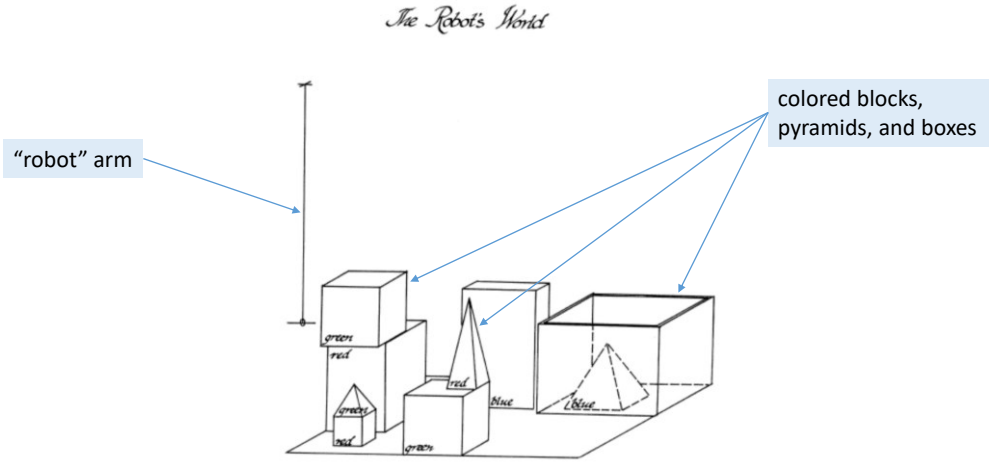


Image: From Winograd, 1971

5

5

SHRDLU (A Simulated Microworld)



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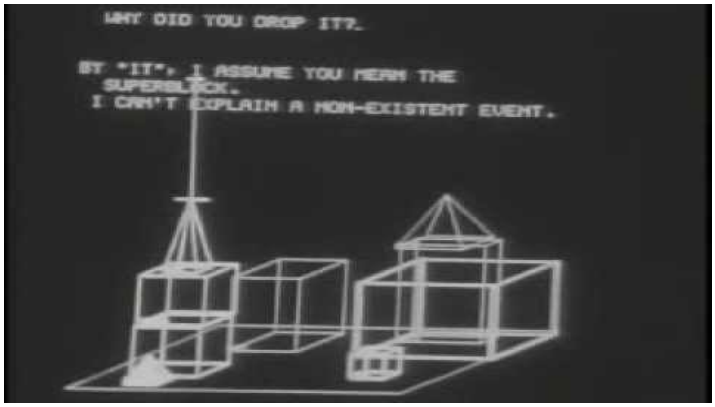
SHRDLU: Original Video



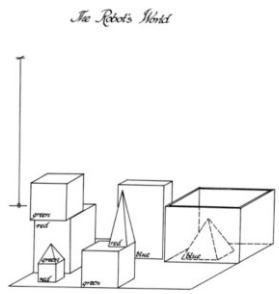
From: YouTube https://youtu.be/bo4RvYJYOzI

7

7

SHRDLU: Sample Interaction

Person: PICK UP A BIG RED BLOCK.
Computer: OK. (does it)
Person: GRASP THE PYRAMID.
Computer: I DON'T UNDERSTAND WHICH PYRAMID YOU MEAN.
Person: FIND A BLOCK WHICH IS TALLER THAN THE ONE YOU ARE HOLDING AND PUT IT INTO THE BOX.
Computer: BY "IT", I ASSUME YOU MEAN THE BLOCK WHICH IS TALLER THAN THE ONE I AM HOLDING.
Computer: OK. (does it)
Person: WHAT DOES THE BOX CONTAIN?
Computer: THE BLUE PYRAMID AND THE BLUE BLOCK.
Person: WHAT IS THE PYRAMID SUPPORTED BY?
Computer: THE BOX.
Person: HOW MANY BLOCKS ARE NOT IN THE BOX?
Computer: FOUR OF THEM.
…



From: https://hci.stanford.edu/~winograd/shrdlu/

8

8

SHRDLU: Sample Interaction

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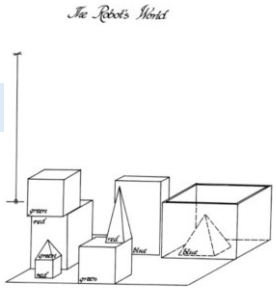
Ambiguous

Reflects, plans, and disambiguates.

Has a model of the world it can answer questions about.



From: https://hci.stanford.edu/~winograd/shrdlu/

SHRDLU Design

- **Natural Language Interaction**

  Used Systemic Grammar (syntax+semantics together)

- **Planner** – three basic actions

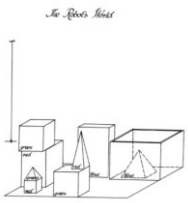
  MOVETO <location>
  GRASP <block>
  UNGRASP <block>

- **Representations:** a red block in a box

  (THGOAL (#IS ?X #BLOCK))
  (THEGOAL (#COLOR $?X #RED))
  (THGOAL (#IN $?X :BOX))

- **Procedural Semantics**

  CLEARTOP X
  1. Start
  2. Does X support an object Y? If not, go to 5.
  3. Move Y from top of X. Go to 2.
  4. Assert that X is CLEARTOP



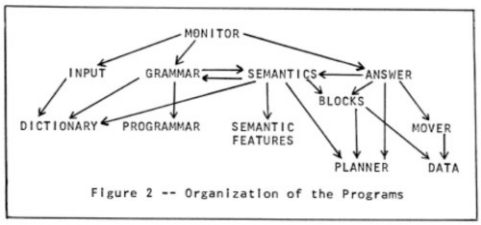


Image: From Winograd, 1971

System was written in LISP, MicroPlanner
running on DEC PDP-10
200 word vocabulary

SHRDLU Re-implemented in Java

- Download the graphical 3-D version of SHRDLU written in JAVA from: https://hci.stanford.edu/~winograd/shrdlu/
- Interact using sentences provided in the webpage. Do some of your own.

11

11

SHRDLU: Achievements (not w/o controversies)

- A **complete AI system** with several capabilities (language, question/answering, planning, acting, etc.)
- Operated in a simulated domain (*microworld*). Also **closed**.
- Limited capabilities

  Limited vocabulary (200 words)
  Only understood sentences about the blocksworld
- Argued for the development of complete systems with limited capabilities that could be expanded later.
- Considered tremendously successful and led to excessive optimism (unfounded?)

12

12

Dichotomies of AI: Procedural vs Declarative

- **Procedural knowledge**

  aka imperative knowledge
  knowing-how to do something

- **Declarative knowledge**

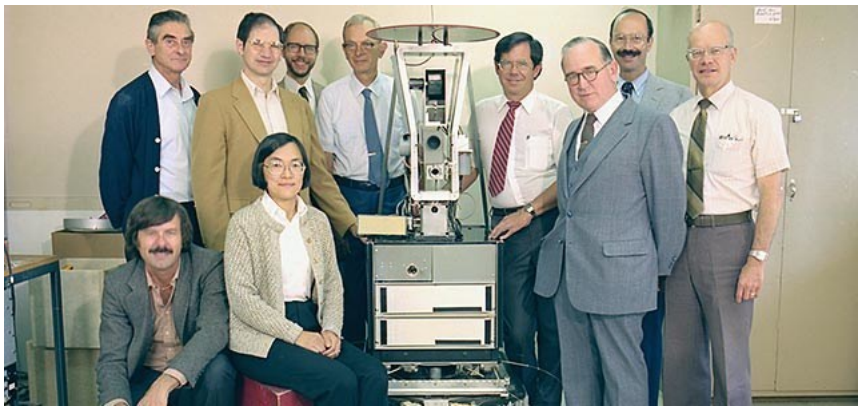
  aka descriptive knowledge
  knowledge about the facts
  knowing-that

```
CLEARTOP X
1. Start
2. Does X support an object Y? If not, go to 5.
3. Move Y from top of X. Go to 2.
4. Assert that X is CLEARTOP
5. Done
```

13

13

SHAKEY the robot (1966-1972)



14

14

SHAKEY the robot

- Developed at SRI (Stanford Research Institute)
- Integrated AI robot
- “lived” in an area with “rooms” with doorways.
- Rooms contained blocks
- Tasks were to move blocks around in different rooms
- Tasks were given using user interaction

15

Image Source: https://newatlas.com/shakey-robot-sri-fiftieth-anniversary/37668/

15

SHAKEY Demo (~5 min)

From: SRI’s YouTube Channel: https://youtu.be/7bsEN8mwUB8

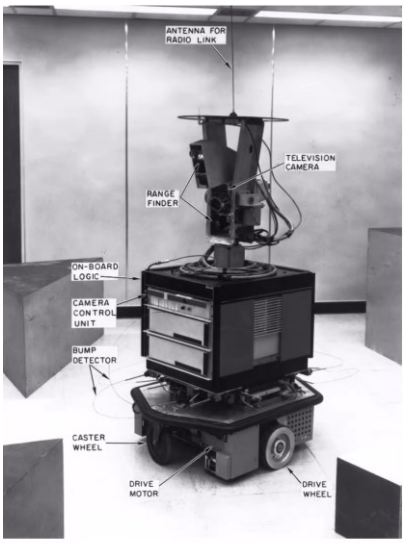
16

16

SHAKEY Capabilities

- **Sensors**
  TV camera
  Laser/sonar range finders
  Bump detectors (cat's whiskers)
  Radio Link to host computer
  Drive motors and wheels

- **Abilities**
  Constructed plans to achieve tasks
  Image analysis
  Computer vision
  Path planning



Shakey diagram photo SRI International

17

17

SHAKEY Capabilities

- **Sensors**
  TV camera
  Laser/sonar range finders
  Bump detectors (cat's whiskers)
  Radio Link to host computer
  Drive motors and wheels

Shakey solving a problem SRI International

- **Abilities**
  Constructed plans to achieve tasks (**STRIPS Planner**)
  Image analysis (**Hough Transform** for image analysis)
  Computer vision (used **Visibility Graphs**)
  Path planning (**A* search algorithm**)
  Navigation (using **dead reckoning**)

For a longer (~24 min) video, see: https://www.youtube.com/watch?v=GmU7SimFkpU

18

18

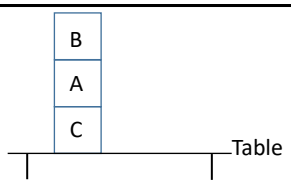
STRIPS Planner

- STRIPS (Stanford Research Institute Problem Solver)
- Explicit representation of **current state**
- Reasoned about **actions** to create **plans** to achieve **goals**
- Used a **planning algorithm** to formulate plans
  Essentially a **search algorithm**

19

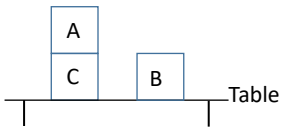
19

STRIPS Planner



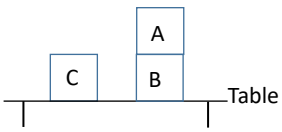
- **State** – represented as a set of facts

  {On(B, A), Clear(Table), On(A, C), On(C, Table), Clear(B)}



- **Goal**

  G1: On(B, Table)
  G2: On(B, Table) ∧ On(A, B)



- **Actions** – represented as **operators** (STRIPS Operators)

  action(<parameters>): description
  pre-conditions list
  delete list
  add list

20

20

STRIPS: Action Schema

action(<parameters>): description
pre-conditions list
delete list
add list

action(<parameters>): description
pre-conditions: <facts that need to be true>
delete: <facts that will no longer be true after action is performed>
add: <Facts that will become true after action is performed>

21

21

STRIPS: Action Schema

action(<parameters>): description
pre-conditions: <facts that need to be true>
delete: <facts that will no longer be true after action is performed>
add: <Facts that will become true after action is performed>

- Example:

move(x, y, z): move x from y to z
preconditions: [On(x, y), Clear(x), Clear(z)]
delete: [Clear(z), On(x, y)]
add: [On(x, z), Clear(y), Clear(Table)]

22

22

STRIPS Assumption

action(<parameters>): description
pre-conditions list
delete list
add list

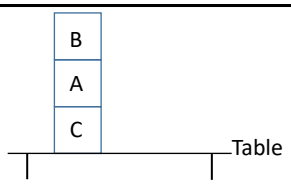
Besides what is specified about the way facts are added or removed, nothing else changes.

This was the STRIPS solution to the **Frame Problem** (the problem of having to explicitly specify everything that does not change when any action is carried out).

23

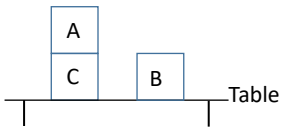
23

STRIPS: Planning as Search



- **Initial State**

  {On(B, A), Clear(Table), On(A, C), On(C, Table), Clear(B)}

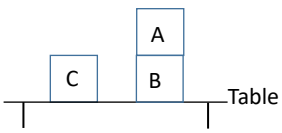


- **Goal**

  G1: On(B, Table)
  G2: On(B, Table) ∧ On(A, B)

- **Actions**

  move(x, y, z): move x from y to z
  preconditions: On(x, y) ∧ Clear(x) ∧ Clear(z)
  delete: Clear(z), On(x, y)
  add: On(x, z), Clear(y)



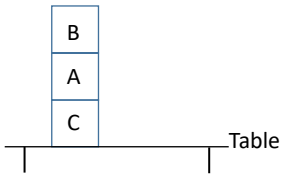
24

24

STRIPS: Example 1

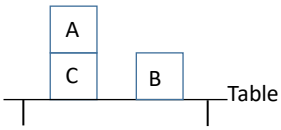
- **Initial State**

  {On(B, A), Clear(Table), On(A, C), On(C, Table), Clear(B)}



- **Goal**

  On(B, Table)



- **Plan**

  [move(B, A, Table)]

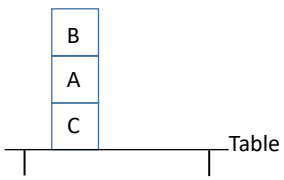
25

25

STRIPS: Example 2

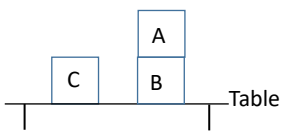
- **Initial State**

  {On(B, A), Clear(Table), On(A, C), On(C, Table), Clear(B)}



- **Goal**

  On(B, Table) ∧ On(A, B)



- **Plan**

  [move(B, A, Table), move(A, C, B)]

26

26

Try this: Class Exercise

Actions: Pickup(<Block>), Putdown(<Block>, <location>)

27

27

SHRDLU: Looking back

- Showed natural language interaction with understanding (as opposed to ELIZA) in an integrated AI system.
- Though, the dialogs were very constrained in a microworld with a limited vocabulary.
- Gave hope that the techniques used in SHRDLU might provide a route to much more general natural language understanding systems.
- Argued for the use of **procedural knowledge** in its planning/problem solving component. Many people opposed this idea.
- Highly influential and remains one of the landmark AI systems.

28

28

SHAKEY: Looking back

- Showed how one could combine perception (vision), planning, navigation and path planning in an embodied robot.
- First robot to reason about its actions
- Led to fundamental advances in visual analysis (Hough Transform, Visibility Graphs), route finding (A* algorithm), and planning of complex actions (STRIPS)
- Building robots is expensive, time-consuming, difficult, daunting, and challenging. Designers had to greatly simplify the challenges faced by the robot. E.g. Power to onboard TV cameras, specially constructed environment, very slow computers.
- "Shakey also helped open the possibilities of computer science to the public's imagination, and put SRI's Artificial Intelligence Center on the map." -: Ray Perrault, PhD, director of SRI International's Artificial Intelligence Center (2015)
- Funding for the project was from US Department of Defense.

29

29

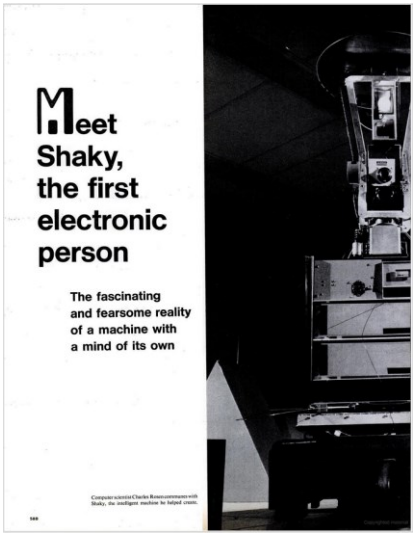
SHAKEY Funding

- ARPA (Advanced Research Projects Agency)
  US Department of Defense
  Also, National Science Foundation (NSF)
  and Office of Naval research (ONR)
- **Deceptive Project Title:** *Automaton for Reconnaissance*
  Funding was to find way for robots and AI to do military reconnaissance (a robot scout)

30

30

SHAKEY in the news (Hype!)

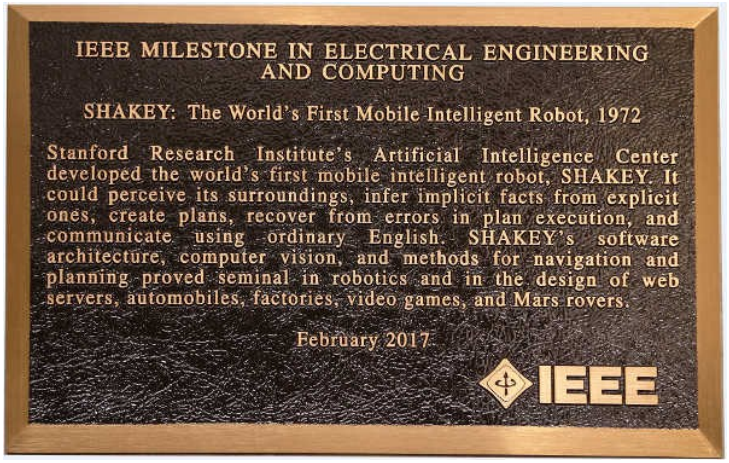


LIFE Magazine, November 1970

31

31

SHAKEY Commemorated (2017)



See: IEEE Spectrum Magazine, February 2017
Link: https://spectrum.ieee.org/sri-shakey-robot-honored-as-ieee-milestone

32

32

Implications and Current Status

Amazon.com Warehouse Robots

https://www.youtube.com/watch?v=4sEVX4mPuto

Amazon.com Warehouse Robots

References

- The Thinking Machine (video). MIT/Carousel Films, 1961. Available at: https://youtu.be/5YBIrc-6G-0
- M. Wooldridge: A Brief History of Artificial Intelligence. Flatiron Books, 2020.
- T. Winograd: Procedures as a Representation for Data in a Computer Program for Understanding Natural Language. PhD Thesis, MIT AI Technical Report 235. 1971.
- T. S. Perry. SRI's Pioneering Mobile Robot Shakey Honored as IEEE Milestone, IEEE Spectrum, February 1970. Link: https://spectrum.ieee.org/sri-shakey-robot-honored-as-ieee-milestone
- A* Search. Brilliant Worldwide Inc. Link: https://brilliant.org/wiki/a-star-search/