

CMSC 373 Artificial Intelligence

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06-ExpertSystems

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1970s

- AI unable to deliver on inflated claims
- People in AI were largely dismissive of combinatorial explosion (the Complexity Barrier)
- In, UK **The Lighthill Report** was “*fiercely dismissive of mainstream AI*”
- In the US, DARPA became frustrated with the failure of AI to deliver on its promises.



Image From: https://www.chilton-computing.org.uk/inf/literature/reports/lighthill_report/contents.htm

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1970s – AI as Alchemy

- Dreyfus was critical of inflated claims and grand predictions of AI pioneers.
- John McCarthy's response to *The Lighthill Report*

If we take [Lighthill's categorization] seriously, then most AI researchers lose intellectual contact with Lighthill immediately, because his three categories have no place for what is or should be our main scientific activity –

studying the structure of information and the structure of problem solving processes independently of applications and independently of its realization in animals or humans.

From: Review of "Artificial Intelligence: A General Survey. John McCarthy.
Available at: <https://www-formal.stanford.edu/jmc/reviews/lighthill/lighthill.html>

ALCHEMY AND ARTIFICIAL INTELLIGENCE

Hubert L. Dreyfus

December 1965

SUMMARY

Early successes in programming digital computers to exhibit simple forms of intelligent behavior, coupled with the belief that intelligent activities differ only in their degree of complexity, have led to the conviction that the information processing underlying any cognitive performance can be formulated in a program and thus simulated on a digital computer. Attempts to simulate cognitive processes on computers have, however, run into greater difficulties than anticipated.

From: <https://www.rand.org/content/dam/rand/pubs/papers/2006/P3244.pdf>

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John McCarthy's Response, *contd.*

Did We Deserve It?

Lighthill had his shot at AI and missed, but this doesn't prove that everything in AI is OK. In my opinion, present AI research suffers from some major deficiencies apart from the fact that any scientists would achieve more if they were smarter and worked harder.

...

While it is far beyond the scope of this review to try to summarize what has been accomplished in AI since Turing's 1950 paper, here is a five sentence try:

Many approaches have been explored and tentatively rejected including automaton models, random search, sequence extrapolation, and many others.

Many heuristics have been developed for reducing various kinds of tree search; some of these are quite special to particular applications, but others are general.

Much progress has been made in discovering how various kinds of information can be represented in the memory of a computer, but a fully general representation is not yet available.

The problem of perception of speech and vision has been explored, and recognition has been found feasible in many instances.

A beginning has been made in understanding the semantics of natural language.

These accomplishments notwithstanding, I think that artificial intelligence research has so far been only moderately successful; its rate of solid progress is perhaps greater than most social sciences and less than many physical sciences. This is perhaps to be expected considering the difficulty of the problem.

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1970's First AI Winter sets in...



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The Seasons of AI

- **1950s – 1966 First AI Summer: Irrational Exuberance**
Early successes in game playing, theorem proving, problem solving
- **1967 – 1977 First AI Winter**
No useful deliverables led to loss of research funding and cancellation of AI programs. In UK *The Lighthill Report* (toy AI systems do not scale due to combinatorial explosion).
- **1978 – 1987 Second AI Summer/Spring**
Rise of knowledge-based systems, success of Expert Systems. Boom times.
- **1988 – 1993 Second AI Winter**
Failure of AI Hardware companies (Symbolics, LMI, Lisp Machines) and AI Companies (Teknowledge, Inference Corp. etc.) Commercial deployments of Expert Systems were discontinued.
- **1993 – 2011 Third AI Summer (Mostly academic advances)**
Statistical approaches and extensions to logic (Bayesian Nets), Non-Monotonic Reasoning (in Logic), Fuzzy Logic, advances in Machine Learning (Decision Trees, Random Forests, Neural Nets), Cognitive Models, Logic Programming, Case-Based Reasoning, Genetic Algorithms, Agent-based approaches, etc.
- **2011 – Now Third AI Spring**
Rise of Deep Learning, Neuro-symbolic AI, ChatGPT and other chatbots, generative AI.

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1980s Knowledge is Power

- Early AI focused too much on general approaches like search and problem solving.
- These were all missing a key ingredient that is a crucial part of any intelligent activity: **Knowledge**.
- A New Agenda for AI

Capturing and using human knowledge was key to progress in AI.

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AI Approaches to *Knowledge*

- Expert Systems
- Logic
- Frames, Scripts, and Semantic Networks
- Knowledge Graphs

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The Rise of Expert Systems

- Systems that used human expert knowledge to solve specific, narrowly defined problems.
- Expert Systems showed that AI could be used for commercial interest (potential to make money).
- The idea is to try and capture human knowledge acquired by an expert over a long period of time and such systems could make that expertise more widely available.
- Led to a second boom in AI in the 1980s.

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Exemplar Expert Systems MYCIN and R1/XCON

- **MYCIN**

Designed to be a doctor's assistant about blood diseases in humans. Its expertise lies in the domain of bacterial infections. Helped physicians prescribe antibiotic treatment for patients without knowing exactly which organism may be the culprit.

- **R1/XCON**

Designed to be an expert in computer mainframe system components configuration. It advised on the configuration of I/O devices along input-output buses including selecting proper cabinets etc.

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MYCIN: Example Session

> What is the patient's name?
John Doe.

> Male or Female?
Male.

> Age?
He is 55.

> Have you obtained positive cultures indicating general type?
Yes.

> What type of infection is it?
Bacteremia.

> When did symptoms first appear?
May 5.

> Let's call the most recent culture C1. From what site was C1 taken?
From the blood.

> When?
May 9.

> Let's call the first significant organism from this culture U1. Do you know the identity of U1?
No.

> Is U1 a rod or a coccus or something else?
Rod.

> What is the gram stain of U1?
Gram-negative.

> Did U1 grow aerobically?
Yes.

> My recommendation will be based on the opinion that the identity of U1 may be

1. Pseudomonas-aeruginosa
2. Klebsiella-pneumoniae
3. E. Coli
4. Bacteriodes-fragilis
5. Enterobacter
6. Proteus-nonmirabilis

> On a scale of 0 to 4, where higher numbers indicate greater severity, how would you rate the patient's degree of sickness?
3.

> Does the patient have a clinically significant allergic reaction to any antimicrobial agent?
No.

> How much does the patient weigh?
70 kilograms.

> My first recommendation is as follows; to cover for items 1, 2, 3, 5, and 6 give gentamycin using a dose of 119 mg (1.7 mg/kg) q8h IV [or IM] for 10 days. Modify dose in renal failure. Also, to cover for item 4, give clindamycin using a dose of 595 mg (8.5 mg/kg) q6h IV [or IM] for 14 days. If diarrhea or other gastrointestinal symptoms develop, check for pseudomembranous colitis.

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Rule-Based Systems - Rules

The system has a bunch of rules of the form:

```
Rn      IF      condition1
              condition2
              ...
      THEN      assertion1/action1
              assertion2/action2
              ...
```

Example of a MYCIN rule:

```
M88    IF      ?x's type is primary bacteremia
              the suspected entry point of ?x is the gastrointestinal tract
              the site of the culture of ?x is one of the sterile sites
      THEN      there is evidence (0.6) that ?x is bacteroides
```

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Rule-Based Systems - Rules

The system has a bunch of rules of the form:

Rn	IF	condition1 condition2 ...	} Antecedent
	THEN	assertion1/action1 assertion2/action2 ...	

Example of a MYCIN rule:

M88	IF	?x's type is primary bacteremia the suspected entry point of ?x is the gastrointestinal tract the site of the culture of ?x is one of the sterile sites
	THEN	there is evidence (0.7) that ?x is bacteroides

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Rule-Based Systems - Rules

The system has a bunch of rules of the form:

Rn	IF	condition1 condition2 ...	} Antecedent
	THEN	assertion1/action1 assertion2/action2 ...	

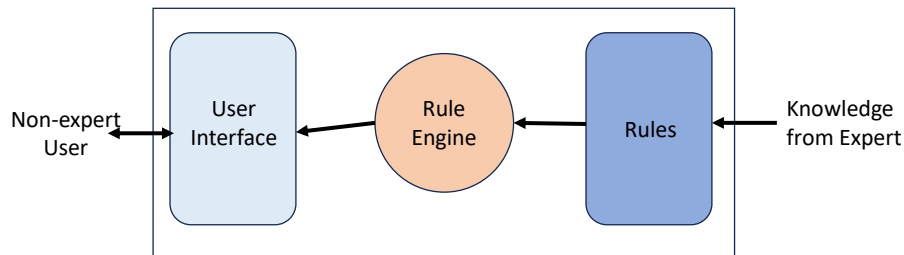
Example of a R1/XCON rule:

X2	IF	the context is doing layout and assigning a power supply an sbi module of any type has been put in a cabinet the position the sbi module occupies is known there is space available for a power supply there is an available power supply
	THEN	put the power supply in the cabinet in the available space
X3	IF	the current context is x
	THEN	deactivate the x context activate the y context

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Rule-Based Systems - Architecture



MYCIN had ~600 rules
MYCIN was a **backward chaining** system

R1/XCON had ~17,500 rules
R1/XCON was a **forward chaining** system

New job title: **knowledge engineer**

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ZOOKEEPER – A Toy Rule-Based System

Z1	IF	?x has hair	Z10	IF	?x is a carnivore
	THEN	?x is a mammal			?x has tawny color
Z2	IF	?x gives milk		THEN	?x has black stripes
	THEN	?x is a mammal			?x is a tiger
Z3	IF	?x has feathers	Z11	IF	?x is an ungulate
	THEN	?x is a bird			?x has long legs
Z4	IF	?x flies		THEN	?x has tawny color
	THEN	?x is a bird			?x has dark spots
Z5	IF	?x flies			?x is a giraffe
	THEN	?x lays eggs	Z12	IF	?x is an ungulate
		?x is a bird			?x has white color
Z6	IF	?x is a mammal		THEN	?x has black stripes
		?x has pointed teeth			?x is a zebra
		?x has claws	Z13	IF	?x is a bird
	THEN	?x has forward-pointing eyes			?x does not fly
		?x is a carnivore		THEN	?x has long legs
Z7	IF	?x is a mammal			?x is black and white
	THEN	?x has hoofs			?x is an ostrich
		?x is an ungulate	Z14	IF	?x is a bird
Z8	IF	?x is a mammal			?x does not fly
	THEN	?x chews cud		THEN	?x swims
		?x is an ungulate			?x is black and white
Z9	IF	?x is a carnivore		THEN	?x is a penguin
		?x has tawny color	Z15	IF	?x is a bird
		?x has dark spots		THEN	?x is a good flyer
	THEN	?x is a cheetah			?x is an albatross

Stretch has hair
Stretch chews cud
Stretch has long legs
Stretch has a long neck
Stretch has tawny color
Stretch has dark spots

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ZOOKEEPER – A Toy Rule-Based System

Z1	IF THEN	?x has hair ?x is a mammal	Z10	IF	?x is a carnivore ?x has tawny color ?x has black stripes ?x is a tiger
Z2	IF THEN	?x gives milk ?x is a mammal	Z11	IF	?x is an ungulate ?x has long legs ?x has long neck ?x has tawny color ?x has dark spots ?x is a giraffe
Z3	IF THEN	?x has feathers ?x is a bird		THEN	
Z4	IF THEN	?x flies ?x is a bird	Z12	IF	?x is an ungulate ?x has white color ?x has black stripes ?x is a zebra
Z5	IF THEN	?x flies ?x lays eggs ?x is a bird	Z13	IF	?x is a bird ?x does not fly ?x has long legs ?x is black and white ?x is an ostrich
Z6	IF THEN	?x is a mammal ?x has pointed teeth ?x has claws ?x has forward-pointing eyes ?x is a carnivore	Z14	IF	?x is a bird ?x does not fly ?x swims ?x is black and white ?x is a penguin
Z7	IF THEN	?x is a mammal ?x has hoofs ?x is an ungulate	Z15	IF THEN	?x is a bird ?x is a good flyer ?x is an albatross
Z8	IF THEN	?x is a mammal ?x chews cud ?x is an ungulate			
Z9	IF THEN	?x is a carnivore ?x has tawny color ?x has dark spots ?x is a cheetah			

Stretch has hair
Stretch chews cud
Stretch has long legs
Stretch has a long neck
Stretch has tawny color
Stretch has dark spots

Stretch is a mammal

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ZOOKEEPER – A Toy Rule-Based System

Z1	IF THEN	?x has hair ?x is a mammal	Z10	IF	?x is a carnivore ?x has tawny color ?x has black stripes ?x is a tiger
Z2	IF THEN	?x gives milk ?x is a mammal	Z11	IF	?x is an ungulate ?x has long legs ?x has long neck ?x has tawny color ?x has dark spots ?x is a giraffe
Z3	IF THEN	?x has feathers ?x is a bird		THEN	
Z4	IF THEN	?x flies ?x is a bird	Z12	IF	?x is an ungulate ?x has white color ?x has black stripes ?x is a zebra
Z5	IF THEN	?x flies ?x lays eggs ?x is a bird	Z13	IF	?x is a bird ?x does not fly ?x has long legs ?x is black and white ?x is an ostrich
Z6	IF THEN	?x is a mammal ?x has pointed teeth ?x has claws ?x has forward-pointing eyes ?x is a carnivore	Z14	IF	?x is a bird ?x does not fly ?x swims ?x is black and white ?x is a penguin
Z7	IF THEN	?x is a mammal ?x has hoofs ?x is an ungulate	Z15	IF THEN	?x is a bird ?x is a good flyer ?x is an albatross
Z8	IF THEN	?x is a mammal ?x chews cud ?x is an ungulate			
Z9	IF THEN	?x is a carnivore ?x has tawny color ?x has dark spots ?x is a cheetah			

Rule is triggered.
Rule is fired.
(Note: Army terminology!)

Stretch has hair
Stretch chews cud
Stretch has long legs
Stretch has a long neck
Stretch has tawny color
Stretch has dark spots

Stretch is a mammal

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ZOOKEEPER – A Toy Rule-Based System

Z1	IF THEN	?x has hair ?x is a mammal	Z10	IF THEN	?x is a carnivore ?x has tawny color ?x has black stripes ?x is a tiger	
Z2	IF THEN	?x gives milk ? is a mammal	Z11	IF	?x is an ungulate ?x has long legs ?x has long neck ?x has tawny color ?x has dark spots ?x is a giraffe	Stretch has hair
Z3	IF THEN	?x has feathers ?x is a bird		THEN		Stretch chews cud
Z4	IF THEN	?x flies ?x is a bird	Z12	IF	?x is an ungulate ?x has white color ?x has black stripes ?x is a zebra	Stretch has long legs
Z5	IF THEN	?x flies ?x lays eggs ?x is a bird	Z13	IF	?x is a bird ?x does not fly ?x has long legs ?x is black and white ?x is an ostrich	Stretch has a long neck
Z6	IF THEN	?x is a mammal ?x has pointed teeth ?x has claws ?x has forward-pointing eyes ?x is a carnivore	Z14	IF	?x is a bird ?x does not fly ?x swims ?x is black and white ?x is a penguin	Stretch has tawny color
Z7	IF THEN	?x is a mammal ?x has hoofs ?x is an ungulate	Z15	IF THEN	?x is a bird ?x is a good flyer ?x is an albatross	Stretch has dark spots
Z8	IF THEN	?x is a mammal ?x chews cud ?x is an ungulate				Stretch is a mammal
Z9	IF THEN	?x is a carnivore ?x has tawny color ?x has dark spots ?x is a cheetah				Stretch is an ungulate

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ZOOKEEPER – A Toy Rule-Based System

Z1	IF THEN	?x has hair ?x is a mammal	Z10	IF THEN	?x is a carnivore ?x has tawny color ?x has black stripes ?x is a tiger	
Z2	IF THEN	?x gives milk ? is a mammal	Z11	IF THEN	?x is an ungulate ?x has long legs ?x has long neck ?x has tawny color ?x has dark spots ?x is a giraffe	Stretch has hair
Z3	IF THEN	?x has feathers ?x is a bird				Stretch chews cud
Z4	IF THEN	?x flies ?x is a bird	Z12	IF THEN	?x is an ungulate ?x has white color ?x has black stripes ?x is a zebra	Stretch has long legs
Z5	IF THEN	?x flies ?x lays eggs ?x is a bird	Z13	IF THEN	?x is a bird ?x does not fly ?x has long legs ?x is black and white ?x is an ostrich	Stretch has a long neck
Z6	IF THEN	?x is a mammal ?x has pointed teeth ?x has claws ?x has forward-pointing eyes ?x is a carnivore	Z14	IF THEN	?x is a bird ?x does not fly ?x swims ?x is black and white ?x is a penguin	Stretch has tawny color
Z7	IF THEN	?x is a mammal ?x has hoofs ?x is an ungulate	Z15	IF THEN	?x is a bird ?x is a good flyer ?x is an albatross	Stretch has dark spots
Z8	IF THEN	?x is a mammal ?x chews cud ?x is an ungulate				Stretch is a mammal
Z9	IF THEN	?x is a carnivore ?x has tawny color ?x has dark spots ?x is a cheetah				Stretch is an ungulate

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ZOOKEEPER – A Toy Rule-Based System

Z1	IF	?x has hair	Z10	IF	?x is a carnivore
	THEN	?x is a mammal			?x has tawny color
Z2	IF	?x gives milk		THEN	?x has black stripes
	THEN	?x is a mammal			?x is a tiger
Z3	IF	?x has feathers	Z11	IF	?x is an ungulate
	THEN	?x is a bird			?x has long legs
Z4	IF	?x flies			?x has long neck
	THEN	?x is a bird		THEN	?x has tawny color
Z5	IF	?x flies			?x has dark spots
	THEN	?x lays eggs	Z12	IF	?x is an ungulate
		?x is a bird			?x has white color
Z6	IF	?x is a mammal		THEN	?x has black stripes
		?x has pointed teeth			?x is a zebra
		?x has claws	Z13	IF	?x is a bird
	THEN	?x has forward-pointing eyes			?x does not fly
		?x is a carnivore		THEN	?x has long legs
Z7	IF	?x is a mammal			?x is black and white
	THEN	?x has hoofs	Z14	IF	?x is an ostrich
		?x is an ungulate			?x is a bird
Z8	IF	?x is a mammal			?x does not fly
	THEN	?x chews cud		THEN	?x swims
		?x is an ungulate			?x is black and white
Z9	IF	?x is a carnivore	Z15	IF	?x is a bird
		?x has tawny color		THEN	?x is a good flyer
	THEN	?x has dark spots			?x is an albatross
		?x is a cheetah			

Stretch has hair
Stretch chews cud
Stretch has long legs
Stretch has a long neck
Stretch has tawny color
Stretch has dark spots
Stretch is a mammal
Stretch is an ungulate

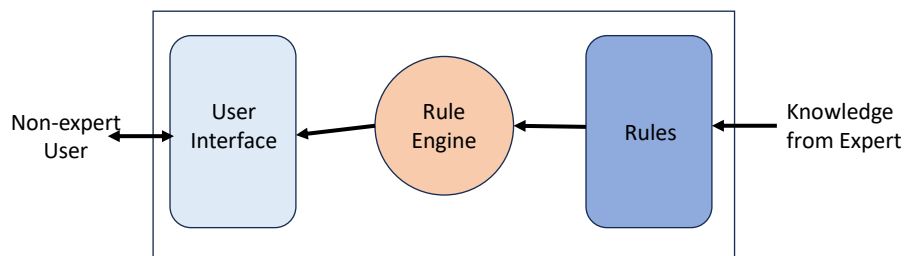
Stretch is a giraffe

This is a forward chaining system.

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Rule-Based Systems - Architecture



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ZOOKEEPER – A Toy Rule-Based System

Z1	IF THEN	?x has hair ?x is a mammal	Z10	IF THEN	?x is a carnivore ?x has tawny color ?x has black stripes ?x is a tiger	Swiftly has hair Swiftly has pointed teeth Swiftly has claws Swiftly has forward pointing eyes Swiftly has tawny color Swiftly has dark spots
Z2	IF THEN	?x gives milk ?x is a mammal	Z11	IF THEN	?x is an ungulate ?x has long legs ?x has long neck ?x has tawny color ?x has dark spots ?x is a giraffe	
Z3	IF THEN	?x has feathers ?x is a bird	Z12	IF THEN	?x is an ungulate ?x has white color ?x has black stripes ?x is a zebra	
Z4	IF THEN	?x flies ?x is a bird	Z13	IF THEN	?x is a bird ?x does not fly ?x has long legs ?x is black and white ?x is an ostrich	Is Swiftly a cheetah?
Z5	IF THEN	?x flies ?x lays eggs ?x is a bird	Z14	IF THEN	?x is a bird ?x does not fly ?x swims ?x is black and white ?x is a penguin	
Z6	IF THEN	?x is a mammal ?x has pointed teeth ?x has claws ?x has forward-pointing eyes ?x is a carnivore	Z15	IF THEN	?x is a bird ?x is a good flyer ?x is an albatross	
Z7	IF THEN	?x is a mammal ?x has hoofs ?x is an ungulate				
Z8	IF THEN	?x is a mammal ?x chews cud ?x is an ungulate				
Z9	IF THEN	?x is a carnivore ?x has tawny color ?x has dark spots ?x is a cheetah				Backward chaining example

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ZOOKEEPER – A Toy Rule-Based System

Z1	IF THEN	?x has hair ?x is a mammal	Z10	IF THEN	?x is a carnivore ?x has tawny color ?x has black stripes ?x is a tiger	Swiftly has hair Swiftly has pointed teeth Swiftly has claws Swiftly has forward pointing eyes Swiftly has tawny color Swiftly has dark spots
Z2	IF THEN	?x gives milk ?x is a mammal	Z11	IF THEN	?x is an ungulate ?x has long legs ?x has long neck ?x has tawny color ?x has dark spots ?x is a giraffe	
Z3	IF THEN	?x has feathers ?x is a bird	Z12	IF THEN	?x is an ungulate ?x has white color ?x has black stripes ?x is a zebra	
Z4	IF THEN	?x flies ?x is a bird	Z13	IF THEN	?x is a bird ?x does not fly ?x has long legs ?x is black and white ?x is an ostrich	Is Swiftly a cheetah?
Z5	IF THEN	?x flies ?x lays eggs ?x is a bird	Z14	IF THEN	?x is a bird ?x does not fly ?x swims ?x is black and white ?x is a penguin	
Z6	IF THEN	?x is a mammal ?x has pointed teeth ?x has claws ?x has forward-pointing eyes ?x is a carnivore	Z15	IF THEN	?x is a bird ?x is a good flyer ?x is an albatross	
Z7	IF THEN	?x is a mammal ?x has hoofs ?x is an ungulate				
Z8	IF THEN	?x is a mammal ?x chews cud ?x is an ungulate				
Z9	IF THEN	?x is a carnivore ?x has tawny color ?x has dark spots ?x is a cheetah				Backward chaining example

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ZOOKEEPER – A Toy Rule-Based System

21	IF	?x has hair	Z10	IF	?x is a carnivore	Swiftly has hair
	THEN	?x is a mammal			?x has tawny color	Swiftly has pointed teeth
22	IF	?x gives milk		THEN	?x has black stripes	Swiftly has claws
	THEN	?x is a mammal			?x is a tiger	Swiftly has forward pointing eyes
23	IF	?x has feathers	Z11	IF	?x is an ungulate	Swiftly has tawny color
	THEN	?x is a bird			?x has long legs	Swiftly has dark spots
24	IF	?x flies		THEN	?x has long neck	
	THEN	?x is a bird			?x has tawny color	
25	IF	?x flies	Z12	IF	?x is an ungulate	
		?x lays eggs			?x has white color	
	THEN	?x is a bird		THEN	?x has black stripes	
26	IF	?x is a mammal			?x is a zebra	
		?x has pointed teeth	Z13	IF	?x is a bird	
		?x has claws			?x does not fly	
		?x has forward-pointing eyes			?x has long legs	
	THEN	?x is a carnivore		THEN	?x is black and white	
					?x is an ostrich	
27	IF	?x is a mammal	Z14	IF	?x is a bird	
		?x has hoofs			?x does not fly	
	THEN	?x is an ungulate			?x swims	
28	IF	?x is a mammal		THEN	?x is black and white	
		?x chews cud			?x is a penguin	
	THEN	?x is an ungulate	Z15	IF	?x is a bird	
29	IF	?x is a carnivore			?x is a good flyer	
		?x has tawny color		THEN	?x is an albatross	
		?x has dark spots				
	THEN	?x is a cheetah				

Is Swiftly a cheetah?

Backward chaining example

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ZOOKEEPER – A Toy Rule-Based System

21	IF	?x has hair	Z10	IF	?x is a carnivore	Swiftly has hair
	THEN	?x is a mammal			?x has tawny color	Swiftly has pointed teeth
22	IF	?x gives milk		THEN	?x has black stripes	Swiftly has claws
	THEN	?x is a mammal			?x is a tiger	Swiftly has forward pointing eyes
23	IF	?x has feathers	Z11	IF	?x is an ungulate	Swiftly has tawny color
	THEN	?x is a bird			?x has long legs	Swiftly has dark spots
24	IF	?x flies		THEN	?x has long neck	
	THEN	?x is a bird			?x has tawny color	
25	IF	?x flies	Z12	IF	?x is an ungulate	
		?x lays eggs			?x has white color	
	THEN	?x is a bird		THEN	?x has black stripes	
26	IF	?x is a mammal			?x is a zebra	
		?x has pointed teeth	Z13	IF	?x is a bird	
		?x has claws			?x does not fly	
		?x has forward-pointing eyes			?x has long legs	
	THEN	?x is a carnivore		THEN	?x is black and white	
					?x is an ostrich	
27	IF	?x is a mammal	Z14	IF	?x is a bird	
		?x has hoofs			?x does not fly	
	THEN	?x is an ungulate			?x swims	
28	IF	?x is a mammal		THEN	?x is black and white	
		?x chews cud			?x is a penguin	
	THEN	?x is an ungulate	Z15	IF	?x is a bird	
29	IF	?x is a carnivore			?x is a good flyer	
		?x has tawny color		THEN	?x is an albatross	
		?x has dark spots				
	THEN	?x is a cheetah				

Is Swiftly a cheetah?

Backward chaining example

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ZOOKEEPER – A Toy Rule-Based System

Z1	IF	?x has hair	Z10	IF	?x is a carnivore	Swiftly has hair
	THEN	?x is a mammal			?x has tawny color	Swiftly has pointed teeth
Z2	IF	?x gives milk		THEN	?x has black stripes	Swiftly has claws
	THEN	?x is a mammal			?x is a tiger	Swiftly has forward pointing eyes
Z3	IF	?x has feathers	Z11	IF	?x is an ungulate	Swiftly has tawny color
	THEN	?x is a bird			?x has long legs	Swiftly has dark spots
Z4	IF	?x flies		THEN	?x has long neck	Swiftly is a mammal
	THEN	?x is a bird			?x has tawny color	
Z5	IF	?x flies	Z12	IF	?x is an ungulate	
	THEN	?x lays eggs			?x has white color	
		?x is a bird		THEN	?x has black stripes	
Z6	IF	?x is a mammal			?x is a zebra	
		?x has pointed teeth	Z13	IF	?x is a bird	Is Swiftly a cheetah?
		?x has claws			?x does not fly	
		?x has forward-pointing eyes			?x has long legs	
	THEN	?x is a carnivore		THEN	?x is black and white	
Z7	IF	?x is a mammal			?x is an ostrich	
	THEN	?x has hoofs	Z14	IF	?x is a bird	
		?x is an ungulate			?x does not fly	
Z8	IF	?x is a mammal		THEN	?x swims	
	THEN	?x chews cud			?x is black and white	
		?x is an ungulate		THEN	?x is a penguin	
Z9	IF	?x is a carnivore	Z15	IF	?x is a bird	Backward chaining example
		?x has tawny color		THEN	?x is a good flyer	
	THEN	?x has dark spots			?x is an albatross	
		?x is a cheetah				

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ZOOKEEPER – A Toy Rule-Based System

Z1	IF	?x has hair	Z10	IF	?x is a carnivore	Swiftly has hair
	THEN	?x is a mammal			?x has tawny color	Swiftly has pointed teeth
Z2	IF	?x gives milk		THEN	?x has black stripes	Swiftly has claws
	THEN	?x is a mammal			?x is a tiger	Swiftly has forward pointing eyes
Z3	IF	?x has feathers	Z11	IF	?x is an ungulate	Swiftly has tawny color
	THEN	?x is a bird			?x has long legs	Swiftly has dark spots
Z4	IF	?x flies		THEN	?x has tawny color	Swiftly is a mammal
	THEN	?x is a bird			?x has dark spots	Swiftly is a carnivore
Z5	IF	?x flies		THEN	?x is a giraffe	
	THEN	?x lays eggs				
		?x is a bird	Z12	IF	?x is an ungulate	
Z6	IF	?x is a mammal			?x has white color	
		?x has pointed teeth		THEN	?x has black stripes	
		?x has claws			?x is a zebra	
		?x has forward-pointing eyes	Z13	IF	?x is a bird	Is Swiftly a cheetah?
	THEN	?x is a carnivore			?x does not fly	
Z7	IF	?x is a mammal			?x has long legs	
	THEN	?x has hoofs		THEN	?x is black and white	
		?x is an ungulate			?x is an ostrich	
Z8	IF	?x is a mammal	Z14	IF	?x is a bird	
	THEN	?x chews cud			?x does not fly	
		?x is an ungulate		THEN	?x swims	
Z9	IF	?x is a carnivore			?x is black and white	
		?x has tawny color		THEN	?x is a penguin	
	THEN	?x has dark spots	Z15	IF	?x is a bird	Backward chaining example
		?x is a cheetah		THEN	?x is a good flyer	
					?x is an albatross	

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ZOOKEEPER – A Toy Rule-Based System

Z1	IF	?x has hair	Z10	IF	?x is a carnivore	Swiftly has hair
	THEN	?x is a mammal			?x has tawny color	Swiftly has pointed teeth
Z2	IF	?x gives milk		THEN	?x has black stripes	Swiftly has claws
	THEN	?x is a mammal			?x is a tiger	Swiftly has forward pointing eyes
Z3	IF	?x has feathers	Z11	IF	?x is an ungulate	Swiftly has tawny color
	THEN	?x is a bird			?x has long legs	Swiftly has dark spots
Z4	IF	?x flies		THEN	?x has long neck	Swiftly is a mammal
	THEN	?x is a bird			?x has tawny color	Swiftly is a cheetah
Z5	IF	?x flies	Z12	IF	?x is an ungulate	
	THEN	?x lays eggs			?x has white color	
		?x is a bird		THEN	?x has black stripes	
Z6	IF	?x is a mammal			?x is a zebra	
		?x has pointed teeth	Z13	IF	?x is a bird	Is Swiftly a cheetah?
		?x has claws			?x does not fly	
		?x has forward-pointing eyes			?x has long legs	
	THEN	?x is a carnivore		THEN	?x is black and white	
					?x is an ostrich	
Z7	IF	?x is a mammal			?x is a bird	
	THEN	?x has hoofs		IF	?x does not fly	
		?x is an ungulate			?x swims	
Z8	IF	?x is a mammal		THEN	?x is black and white	
	THEN	?x chews cud			?x is a penguin	
		?x is an ungulate	Z15	IF	?x is a bird	
Z9	IF	?x is a carnivore		THEN	?x is a good flyer	
		?x has tawny color			?x is an albatross	
	THEN	?x has dark spots				
		?x is a cheetah				

Backward chaining example

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ZOOKEEPER – A Toy Rule-Based System

Z1	IF	?x has hair	Z10	IF	?x is a carnivore	Swiftly has hair
	THEN	?x is a mammal			?x has tawny color	Swiftly has pointed teeth
Z2	IF	?x gives milk		THEN	?x has black stripes	Swiftly has claws
	THEN	?x is a mammal			?x is a tiger	Swiftly has forward pointing eyes
Z3	IF	?x has feathers	Z11	IF	?x is an ungulate	Swiftly has tawny color
	THEN	?x is a bird			?x has long legs	Swiftly has dark spots
Z4	IF	?x flies		THEN	?x has long neck	Swiftly is a mammal
	THEN	?x is a bird			?x has tawny color	Swiftly is a cheetah
Z5	IF	?x flies	Z12	IF	?x is an ungulate	
	THEN	?x lays eggs			?x has white color	
		?x is a bird		THEN	?x has black stripes	
Z6	IF	?x is a mammal			?x is a zebra	
		?x has pointed teeth	Z13	IF	?x is a bird	Is Swiftly a cheetah?
		?x has claws			?x does not fly	
		?x has forward-pointing eyes			?x has long legs	
	THEN	?x is a carnivore		THEN	?x is black and white	
					?x is an ostrich	
Z7	IF	?x is a mammal			?x is a bird	
	THEN	?x has hoofs		IF	?x does not fly	
		?x is an ungulate			?x swims	
Z8	IF	?x is a mammal		THEN	?x is black and white	
	THEN	?x chews cud			?x is a penguin	
		?x is an ungulate	Z15	IF	?x is a bird	
Z9	IF	?x is a carnivore		THEN	?x is a good flyer	
		?x has tawny color			?x is an albatross	
	THEN	?x has dark spots				
		?x is a cheetah				

Expert Systems can explain their reasoning:

Swiftly is a cheetah because Swiftly is a carnivore, Swiftly has tawny color, Swiftly has dark spots (Z9).

Swiftly is a carnivore because Swiftly is a mammal, Swiftly has pointed teeth, Swiftly has claws, Swiftly has forward-pointed teeth (Z6).

Swiftly is a mammal because Swiftly has hair (Z1).

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Expert Systems

- MYCIN was never actually used in practice. People raised ethical and legal issues (what if it gave a wrong diagnosis?).
- R1/XCON saved DEC \$25million/year. It processed 80,000 orders with 95-98% accuracy.
- Can be effective in domains where experts are needed to make diagnoses, judgements, predictions, decisions, etc.
- They have found uses in several industries: financial, engineering, telecommunications, healthcare, agriculture, CRM, transportation, law, etc. Most of these applications are built in-house (i.e. proprietary commercial products – no longer considered AI?)

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Some other Expert Systems

- **PXDES**
Diagnoses lung cancer in patients
- **DXplain**
Clinical Support diagnosis of various diseases
- **DENDRAL**
Helps identify structure of unknown molecules
- **CaDet**
Used to identify cancer in its early stages
- **Dipmeter Advisor**
Analysis of data gathering during oil exploration (Schlumberger Corp.).

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1980s Boom Times



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The Seasons of AI

- **1950s – 1966 First AI Summer: Irrational Exuberance**
Early successes in game playing, theorem proving, problem solving
- **1967 – 1977 First AI Winter**
No useful deliverables led to loss of research funding and cancellation of AI programs. In UK *The Lighthill Report* (toy AI systems do not scale due to combinatorial explosion).
- **1978 – 1987 Second AI Summer/Spring**
Rise of knowledge-based systems, success of Expert Systems. Boom times.
- **1988 – 1993 Second AI Winter**
Failure of AI Hardware companies (Symbolics, LMI, Lisp Machines) and AI Companies (Teknowledge, Inference Corp. etc.)
Commercial deployments of Expert Systems were discontinued.
- **1993 – 2011 Third AI Summer (Mostly academic advances)**
Statistical approaches and extensions to logic (Bayesian Nets), Non-Monotonic Reasoning (in Logic), Fuzzy Logic, advances in Machine Learning (Decision Trees, Random Forests, Neural Nets), Cognitive Models, Logic Programming, Case-Based Reasoning, Genetic Algorithms, Agent-based approaches, etc.
- **2011 – Now Third AI Spring**
Rise of Deep Learning, Neuro-symbolic AI, ChatGPT and other chatbots, generative AI.

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AI Approaches to *Knowledge*

- Expert Systems ✓
- Logic
- Frames, Scripts, and Semantic Networks
- Knowledge Graphs

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Vocabulary

AI Winter
 Knowledge in AI
 Expert Systems
 MYCIN
 R1/XCON
 Rules
 Antecedent
 Consequent
 Rule-Based Systems
 Forward Chaining
 Backward Chaining
 Explainability

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References

- M. Wooldridge: *A Brief History of Artificial Intelligence*. Flatiron Books, 2020.
- Nils Nilsson, *Artificial Intelligence: A New Synthesis*, Morgan Kaufman, 1998.
- Patrick H. Winston, *Artificial Intelligence*, Third Edition, Addison-Wesley, 1992.
- XCON, Wikipedia Entry. Available at: <https://en.wikipedia.org/wiki/Xcon>
- R1/MYCIN, Wikipedia Entry, Available at: <https://en.wikipedia.org/wiki/Mycin>

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