# CMSC 373 Artificial Intelligence Fall 2023 06-ExpertSystems

Deepak Kumar
Bryn Mawr College

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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.

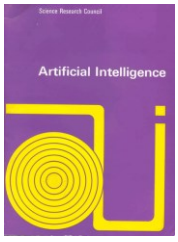


Image From: https://www.chilton-computing.org.uk/inf/literature/reports/lighthill_report/contents.htm

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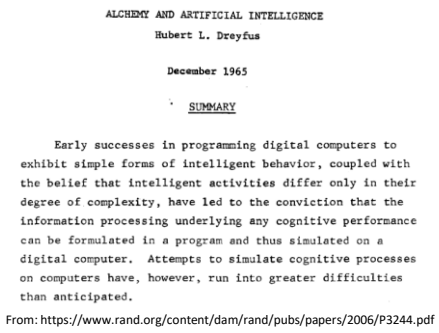
# 1970s – AI as Alchemy

- 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 Algoritms, 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 the 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.

>Lets 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, amd 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<br>condition2<br>… |
| | THEN | assertion1/action1<br>assertion2/action2<br>… |

Example of a MYCIN rule:

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

12

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# Rule-Based Systems - Rules

The system has a bunch of rules of the form:

| | | | |
|---|---|---|---|
| Rn | IF | condition1<br>condition2<br>… | Antecedent |
| | THEN | assertion1/action1<br>assertion2/action2<br>… | Consequent |

Example of a MYCIN rule:

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

13

13

# Rule-Based Systems - Rules

The system has a bunch of rules of the form:

| | | | |
|---|---|---|---|
| Rn | IF | condition1<br>condition2<br>… | Antecedent |
| | THEN | assertion1/action1<br>assertion2/action2<br>… | Consequent |

Example of a R1/XCON rule:

| | | |
|---|---|---|
| X2 | IF | the context is doing layout and assigning a power supply<br>an sbi module of any type has been put in a cabinet<br>the position the sbi module occupies is known<br>there is space available for a power supply<br>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<br>activate the y context |

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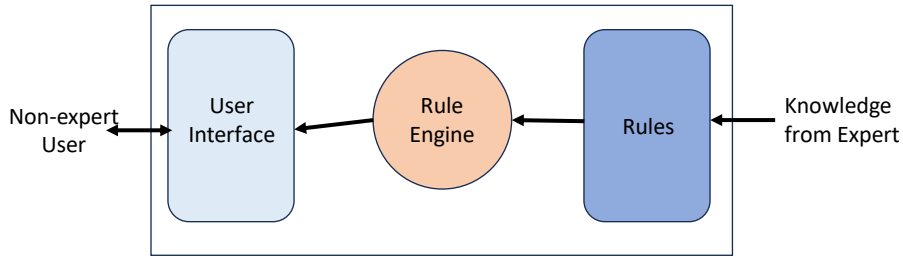
# Rule-Based Systems - Architecture




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

Stretch is a mammal



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# ZOOKEEPER – A Toy Rule-Based System

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

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| Z15 | IF | ?x is a bird<br>?x is a good flyer |
| | THEN | ?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

Stretch is a mammal



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# ZOOKEEPER – A Toy Rule-Based System

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Stretch is an ungulate



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Stretch is a mammal
Stretch is an ungulate

Stretch is a giraffe

This is a forward chaining system.

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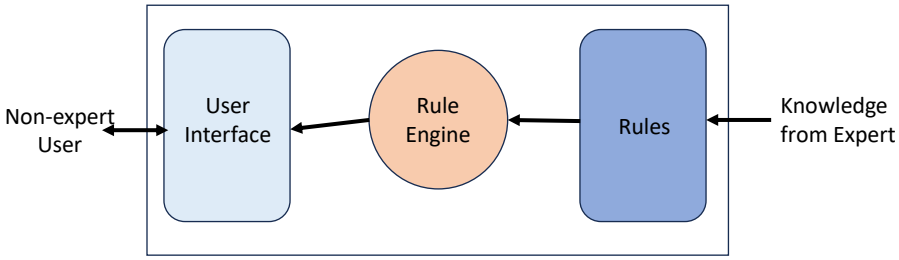
# Rule-Based Systems - Architecture

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# ZOOKEEPER – A Toy Rule-Based System

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Swifty has hair
Swifty has pointed teeth
Swifty has claws
Swifty has forward pointing eyes
Swifty has tawny color
Swifty has dark spots

Is Swifty a cheetah?

Backward chaining example





# ZOOKEEPER – A Toy Rule-Based System

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| Z6 | IF | ?x is a mammal<br>?x has pointed teeth<br>?x has claws<br>?x has forward-pointing eyes |
| | THEN | ?x is a carnivore |
| Z7 | IF | ?x is a mammal<br>?x has hoofs |
| | THEN | ?x is an ungulate |
| Z8 | IF | ?x is a mammal<br>?x chews cud |
| | THEN | ?X is an ungulate |
| Z9 | IF | ?x is a carnivore<br>?x has tawny color<br>?x has dark spots |
| | THEN | ?x is a cheetah |
| Z10 | IF | ?x is a carnivore<br>?x has tawny color<br>?x has black stripes |
| | THEN | ?x is a tiger |
| Z11 | IF | ?x is an ungulate<br>?x has long legs<br>?x has long neck<br>?x has tawny color<br>?x has dark spots |
| | THEN | ?x is a giraffe |
| Z12 | IF | ?x is an ungulate<br>?x has white color<br>?x has black stripes |
| | THEN | ?x is a zebra |
| Z13 | IF | ?x is a bird<br>?x does not fly<br>?x has long legs<br>?x is black and white |
| | THEN | ?x is an ostrich |
| Z14 | IF | ?x is a bird<br>?x does not fly<br>?x swims<br>?x is black and white |
| | THEN | ?x is a penguin |
| Z15 | IF | ?x is a bird<br>?x is a good flyer |
| | THEN | ?x is an albatross |

Swifty has hair
Swifty has pointed teeth
Swifty has claws
Swifty has forward pointing eyes
Swifty has tawny color
Swifty has dark spots

Is Swifty a cheetah?

Backward chaining example

# ZOOKEEPER – A Toy Rule-Based System

| | | |
|---|---|---|
| Z1 | IF | ?x has hair |
| | THEN | ?x is a mammal |
| Z2 | IF | ?x gives milk |
| | THEN | ? Is a mammal |
| Z3 | IF | ?x has feathers |
| | THEN | ?x is a bird |
| Z4 | IF | ?x flies |
| | THEN | ?x is a bird |
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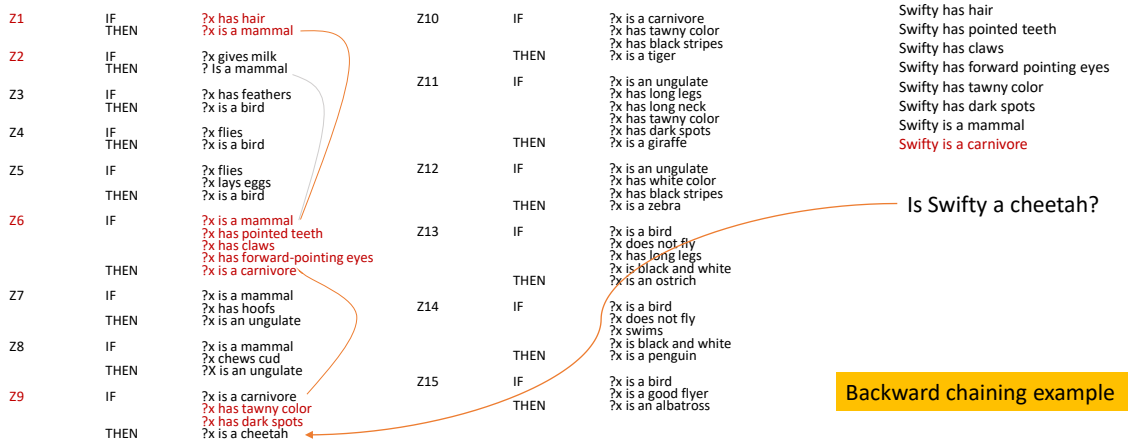

# ZOOKEEPER – A Toy Rule-Based System


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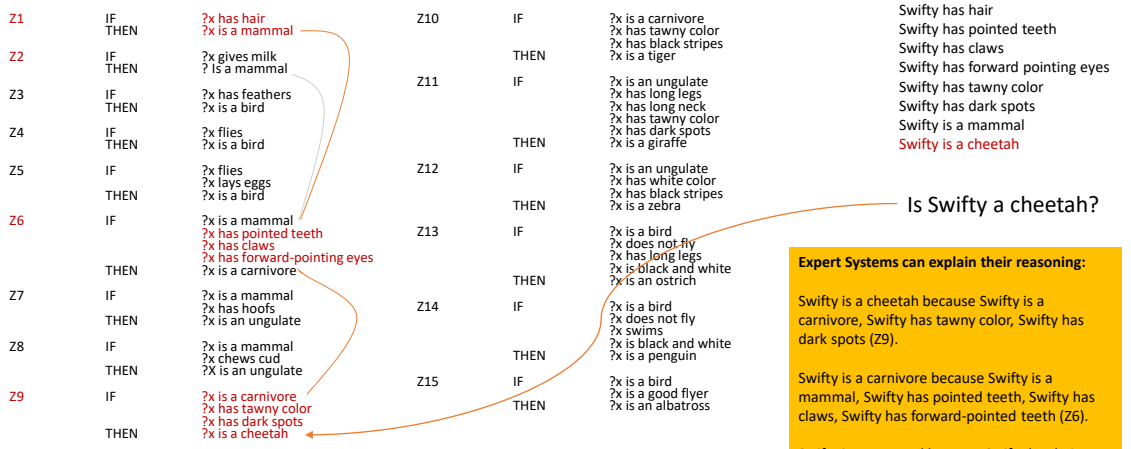
# ZOOKEEPER – A Toy Rule-Based System

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# Expert Systems

- We should note that 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





# 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 Algoritms, Agent-based approaches, etc.

- **2011 – Now Third AI Spring**

  Rise of Deep Learning, Neuro-symbolic AI, ChatGPT and other chatbots, generative AI.

# AI Approaches to *Knowledge*

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

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