Web Intelligence and Fuzzy Logic — The Concept of Web IQ (WIQ)

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In moving further into the age of machine intelligence and automated reasoning, we have reached a point where we can speak, without exaggeration, of systems which have a high machine IQ (MIQ). The Web and especially search engines -- with Google at the top — fall into this category. In the context of the Web, MIQ becomes Web IQ, or WIQ, for short.

BACKDROP

PREAMBLE

In moving further into the age of machine intelligence and automated reasoning, we have reached a point where we can speak, without exaggeration, of systems which have a high machine IQ (MIQ). The Web and especially search engines — with Google at the top — fall into this category. In the context of the Web, MIQ becomes Web IQ, or WIQ, for short.

WEB INTELLIGENCE

- *Existing search engines have many remarkable capabilities. However, what is not among them is the deduction capability — the capability to synthesize an answer to a query by drawing on bodies of information which reside in various parts of the knowledge base.*

CONTINUED

- ***A question-answering system is by definition a system which has deduction capability. One of the principal goals of Web intelligence is that of evolving search engines into question-answering systems. Achievement of this goal requires a quantum jump in the WIQ of existing search engines.***

BASIC PROBLEM

question-answering system

search engine

- identification of query-relevant information
- relevance-ranking of query-relevant information

+

- deduction from query-relevant information

meta-deduction

QUANTUM JUMP IN WIQ

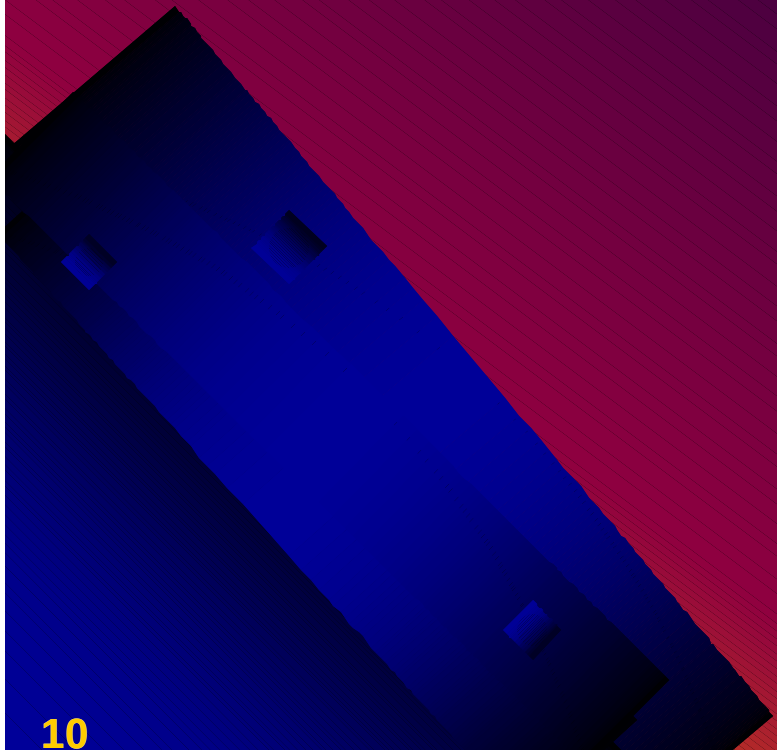
- ***Can a quantum jump in WIQ be achieved through the use of existing tools such as the Semantic Web and ontology-centered systems--tools which are based on bivalent logic and bivalent-logic-based probability theory?***

CONTINUED

- *It is beyond question that, in recent years, very impressive progress has been made through the use of such tools. But, a view which is advanced in the following is that bivalent-logic-based methods have intrinsically limited capability to address complex problems which arise in deduction from information which is pervasively ill-structured, uncertain and imprecise.*

WORLD KNOWLEDGE

The major problem is World Knowledge



WHAT IS WORLD KNOWLEDGE?

- *world knowledge is acquired through experience and education*

examples

- *usually it is hard to find parking near the campus between 9 and 5*
- *big cars are safer than small cars*
- *few professors are rich*

WORLD KNOWLEDGE AND THE WEB KEY POINTS

- *world knowledge plays a pivotal role in human cognition*
- *in particular, world knowledge forms the basis for disambiguation, decision-making, deduction and search*
- *specific: Helsinki is the capital of Finland*
- *general: Icy roads are slippery*

WORLD KNOWLEDGE: EXAMPLES

specific:

- *if Robert works in Berkeley then it is likely that Robert lives in or near Berkeley*
- *if Robert lives in Berkeley then it is likely that Robert works in or near Berkeley*

generalized:

if A/Person works in B/City then it is likely that A lives in or near B

precisiated:

Distance (Location (Residence (A/Person), Location (Work (A/Person) isu near

protoform: *F (A (B (C)), A (D (C))) isu R*

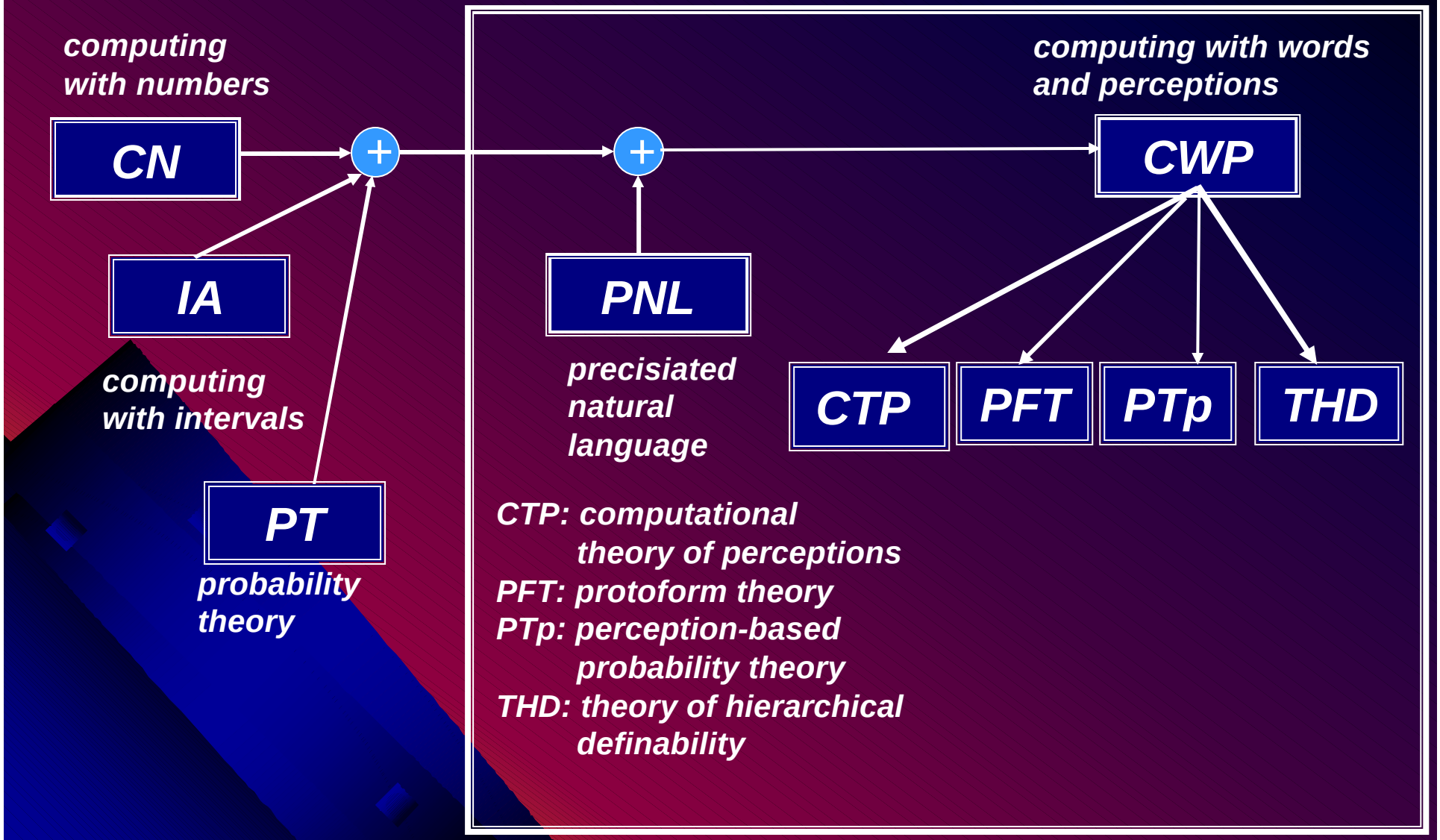
CONTINUED

- *the Web is, in the main, a repository of specific world knowledge*
- *Semantic Web and related systems serve to enhance the performance of search engines by adding to the web a collection of relevant fragments of world knowledge*
- *the problem is that much of world knowledge, and especially general world knowledge, consists of perceptions*

CONTINUED

- *perceptions are intrinsically imprecise*
- *imprecision of perceptions stands in the way of representing the meaning of perceptions through the use of conventional bivalent-logic-based languages*
- *to deal with perceptions and world knowledge, new tools are needed*
- *of particular relevance to enhancement of web intelligence are Precisiated Natural Language (PNL) and Protoform Theory (PFT)*

NEW TOOLS


computing with numbers
CN
IA
computing with intervals
PT
probability theory
PNL
precisiated natural language
computing with words and perceptions
CWP
CTP
PFT
PTp
THD
CTP: computational theory of perceptions
PFT: protoform theory
PTp: perception-based probability theory
THD: theory of hierarchical definability

LIMITATIONS OF SEARCH ENGINES TEST QUERIES

1. How many Ph.D.'s in computer science were produced by European universities in 1996?
2. Age of the President of Finland?
3. Name of the King of Finland?
4. Largest port in Switzerland?
5. Smallest port in Canada?
6. Number of lakes in Finland?

TEST QUERY (GOOGLE)

- *distance between largest city in Spain and largest city in Portugal: failure*
- *largest city in Spain: Madrid (success)*
- *largest city in Portugal: Lisbon (success)*
- *distance between Madrid and Lisbon*

  (success)

TEST QUERY (GOOGLE)

- *population of largest city in Spain: failure*
- *largest city in Spain: Madrid, success*
- *population of Madrid: success*

TEST QUERY (GOOGLE)

- *smallest port in Canada: failure*

Searched the web for smallest port Canada. Results 1 - 10 of about 77,100. Search took 0.43 seconds.

[PDF]Canada's Smallest Satellite: The Canadian Advanced Nanospace ...
File Format: PDF/Adobe Acrobat - View as HTML
... leading the design, development, testing, and operations of Canada's smallest satellites
having ... two imager lenses and the information and power test port. ...
cubesat.calpoly.edu/reference/canx_paper.pdf - Similar pages

Bw Poco Inn And Suites in Port Coquitlam, Canada
... 1000mt N//Bustop Crnr Coast Meridan/Lougheed Hwy Bus Coquitlam Taxi/Port Coquitlam/2km
W ... Of Largest Meeting Room - 3420 Sq Ft Capacity Of Smallest Meeting Room ...
www.travel-hotels-europe.co.uk/hotels/dist5/175892/moreinfo.htm - 9k - Cached - Similar pages

CONTINUED

- *Ramada Hotel & Conference in Edmonton, Canada*
  ... Coffee Direct Dial Telephone Hair Dryer Iron/Ironing Board Modem/Data Port Connection
  On ... Of Largest Meeting Room - 9877 Sq Ft Capacity Of Smallest Meeting Room ...
  www.travel-hotels-europe.co.uk/hotels/ dist4/141937/moreinfo.htm - 10k - Cached - Similar pages
  [More results from www.travel-hotels-europe.co.uk]
- *Port Alberni, Canada Hotel Information, Rate Comparison: Direct ...*
  Port Alberni, Canada, featured hotel: Best Western Barclay ... refurbished rooms centrally
  located in port alberni 87 ... 3105 sq ft capacity of smallest meeting room ...
  www.hotels-shopper.com/CA/YPB.html - 35k - Cached - Similar pages
- *Port Dover, Ontario Canada bed and breakfasts - in top 10% in ...*
  ... Heritage Homestead Bed and Breakfast - Simcoe, Ontario, Canada, ... Lake Erie's ports,
  including Port Dover just ... the original builder) is the smallest, though its ...
  www.bbontario.com/heritagehomestead.cfm - 14k - Cached - Similar pages

CONTINUED

Canada / New England Port Cities
Philipsburg, St. Maarten. Half-French/half-Dutch and wholly delightful St. Maarten
is the smallest territory in the world to be shared by two sovereign states. ...
164.109.173.140/destinations/ports/na_saa.htm - 5k - Cached - Similar pages

Sealetter Cruise Port Review: Do-It-Yourself Victoria BC Canada
... arrives at Vancouver Island, at a port called Swartz ... the grand architecture of Canadian
Pacific hotels across Canada. ... in the day when the crowds are smallest. ...
www.sealetter.com/Jun-98/doitvict.html - 22k - Cached - Similar pages

Best Western Toronto Airport in Mississauga, Canada
... Accessible Iron/Ironing Board Microwave - Upon Request Modem/Data Port Connection
Pay-Per ... Of Largest Meeting Room - 2000 Sq Ft Capacity Of Smallest Meeting Room ...
www.world-stay.com/hotels/en/dist4/209801/moreinfo.htm - 9k - Cached - Similar pages

TEST QUERY (GOOGLE)

- *largest port in Switzerland: failure*

Searched the web for largest port Switzerland. Results 1 - 10 of about 215,000. Search took 0.18 seconds.

Sponsored Links

Virtual Switzerland
Concierge, tourist and travel information. Zurich offices.
www.weequalize.com/
Interest:

See your message here...

THE CONSULATE GENERAL OF SWITZERLAND IN CHINA - SHANGHAI FLASH N ...
... 1993, is one of the largest port constructions in ... rear basis of the deepwater port,
bearing comprehensive ... Consulate General of Switzerland for business related ...
www.sinoptic.ch/shanghaiflash/2003/200303.htm - 20k - Sep 2, 2003 - Cached - Similar pages

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EMBASSY OF SWITZERLAND IN CHINA - CHINESE BUSINESS BRIEFING N ° ...

EMBASSY OF SWITZERLAND. ... Tianjin opens container shipping route to Europe Tianjin Port,
the largest port city in north China, opened a direct container shipping ...
www.sinoptic.ch/cbb/2003/cbb030224-030302.htm - 38k - Sep 2, 2003 - Cached - Similar pages
[More results from www.sinoptic.ch]

Andermatt, Switzerland Discount Hotels - Cheap hotel and motel ...

... people do, and you'll get the quaint stereotype of Switzerland that the ... Although GOTHENBURG
is Scandinavia's largest port, shipbuilding has long since taken a ...
www.eztrip.com/ANDERMATT_CH_INTL.html - 16k - Cached - Similar pages

Port Washington personals online dating post

... Port Washington largest online dating ... date are right in Port Washington. ... Saskatchewan
, Leask Saskatchewan , Switzerland , Switzerland , Hopedale , Hopedale ...
online-dating-services.communityfriends.net/ dating-service-forums/4581.html - 11k - Cached - Similar pages

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AZ of Tourism - Holiday and Vacation guide.

Offers comprehensive and continuously updated information on tourism, accommodation and entertainment for many major world cities and allows people to book ...

www.a-zoftourism.com/atoz-of-cities-in-UK.htm - 41k - Cached - Similar pages

SAIF - Sveriges Akademiska Idrottsförbund

... Austria Finland Georgien Hungary Netherlands (Holland) Japan Sweden Switzerland Preliminary schedule ... role in merchandising, and hosts the largest port in Sweden ...

www.studentidrott.nu/floorball/index.asp - 22k - Sep 2, 2003 - Cached - Similar pages

Hotels Rotterdam. Tourism Rotterdam. Accommodation Rotterdam. ...

... largest city of the Netherlands and the world's largest port. ... The port has several natural advantages, the most ... from as far away as Switzerland, France and ...

www.hotels-holland.com/info/Rotterdam/rotterdam.htm - 9k - Cached - Similar pages

RELEVANCE

- *a concept which has a position of centrality in search is that of relevance*
- *and yet, there is no definition of relevance*
- *relevance is a matter of degree*
- *relevance cannot be defined within the conceptual structure of bivalent logic*
- *to define relevance, what is needed is PNL (Precisiated Natural Language)*

EXAMPLE: DECISION PROBLEM

- *should I insure my car against theft?*
- *decision-relevant information: probability that my car may be stolen?*
- *query: ?q: what is the probability that my car may be stolen?*
- *query-relevant information: information about my car and me; information in police department and insurance company files*
- *the answer yielded by bivalent-logic-based probability theory is: the probability that my car may be stolen is between 0 and 1*

RELEVANCE FUNCTION

Rel (q/p)= degree to which p constrains the meaning of q, with p and q expressed as generalized constraints

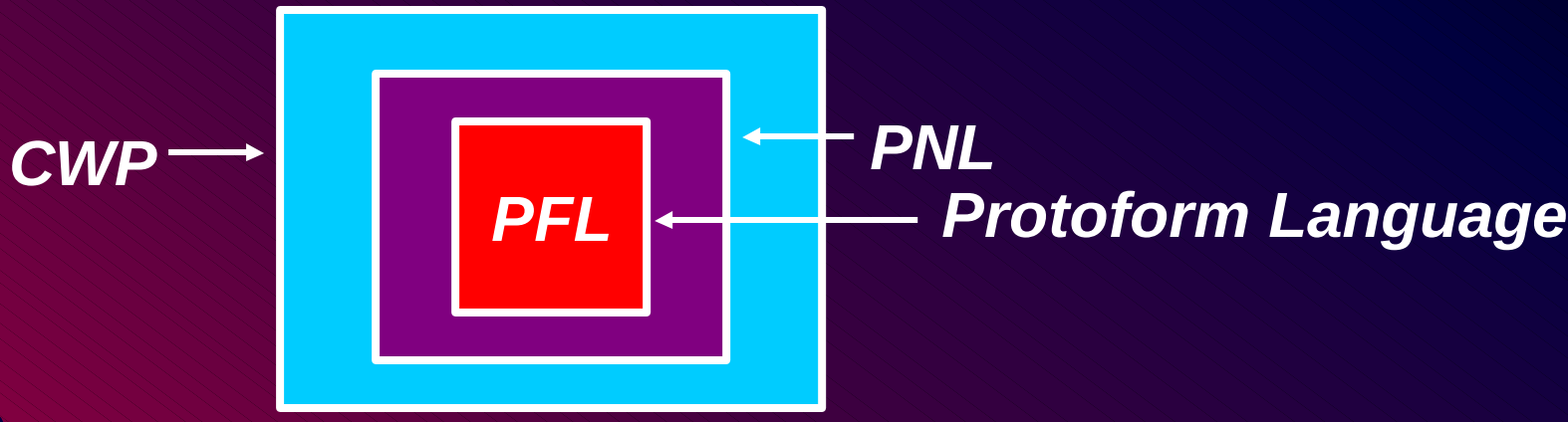
compositionality:

can Rel (q/p^r) be expressed as a function of

Rel (q/p) and Rel (q/r)?

PROTOFORM LANGUAGE

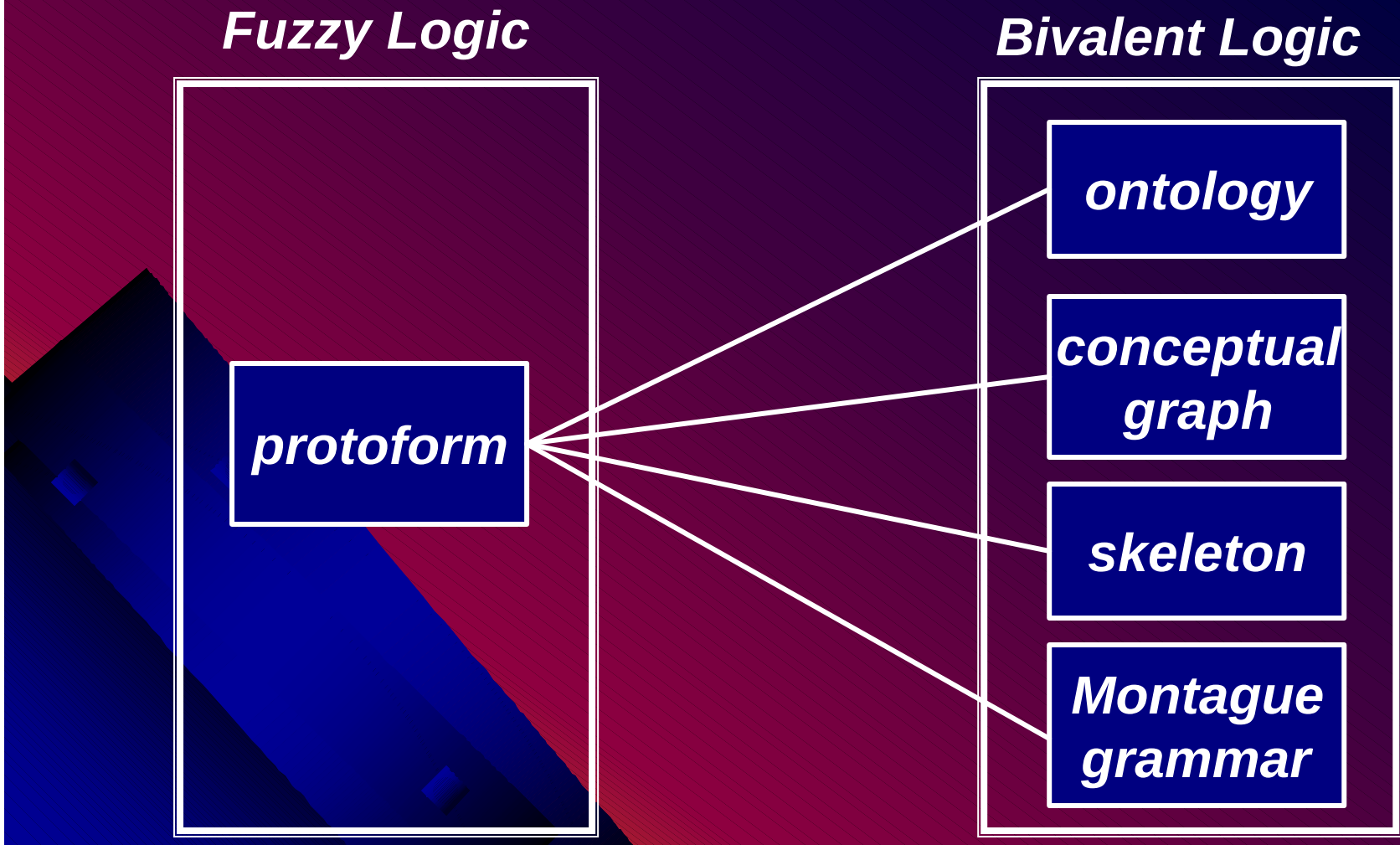
THE CONCEPT OF A PROTOFORM



WHAT IS A PROTOFORM?

- *protoform = abbreviation of prototypical form*
- *informally, a protoform, A, of an object, B, written as A=PF(B), is an abstracted summary of B*
- *usually, B is lexical entity such as proposition, question, command, scenario, decision problem, etc*
- *more generally, B may be a relation, system, geometrical form or an object of arbitrary complexity*
- *usually, A is a symbolic expression, but, like B, it may be a complex object*
- *the primary function of PF(B) is to place in evidence the deep semantic structure of B*

THE CONCEPT OF PROTOFORM AND RELATED CONCEPTS



TRANSLATION FROM NL TO PFL

examples

Most Swedes are tall → *Count (A/B) is Q*

Eva is much younger than Pat → *(A (B), A (C)) is R*

Age *Eva* *Age* *Pat* *much younger*

usually Robert returns from work at about 6pm →

Prob {A is B} is C

usually

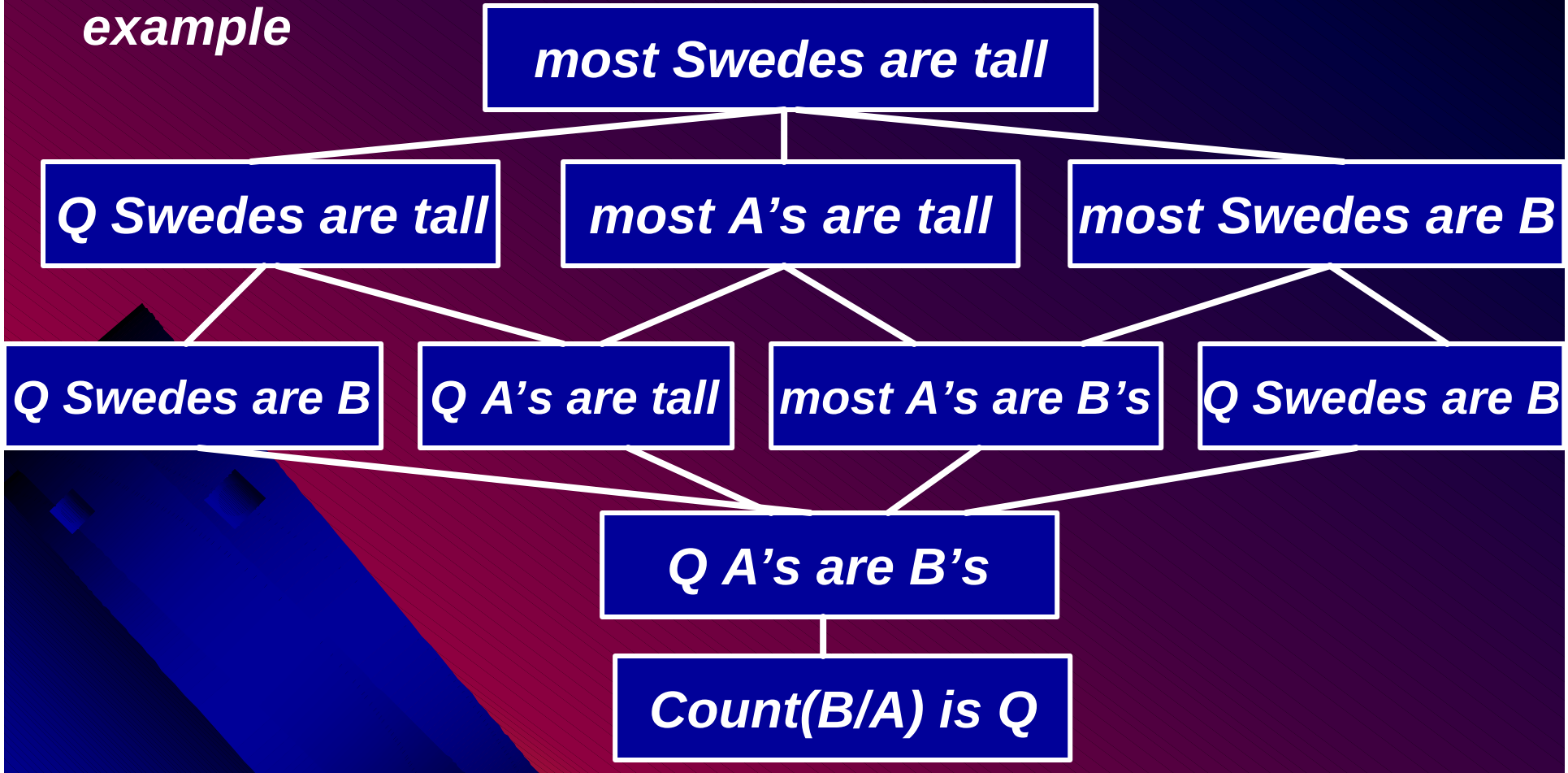
about 6 pm

Time (Robert returns from work)

MULTILEVEL STRUCTURES

- An object has a multiplicity of protoforms
- Protoforms have a multilevel structure
- There are three principal multilevel structures
- Level of abstraction (a)
- Level of summarization (s)
- Level of detail (d)
- For simplicity, levels are implicit
- A terminal protoform has maximum level of abstraction
- A multilevel structure may be represented as a lattice

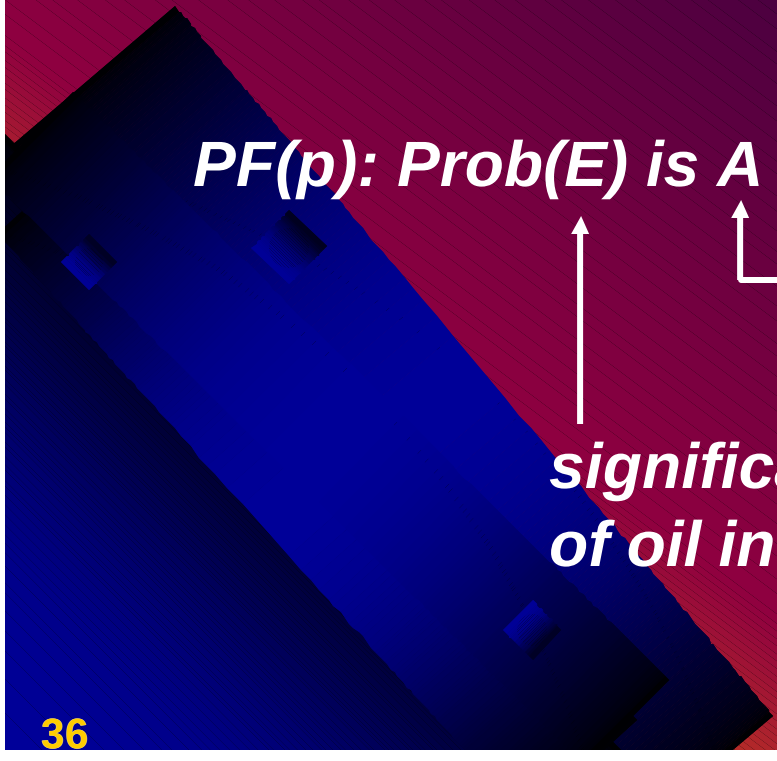
ABSTRACTION LATTICE



LEVELS OF SUMMARIZATION

example

p: it is very unlikely that there will be a significant increase in the price of oil in the near future



PF(p): Prob(E) is A

very.unlikely

significant increase in the price of oil in the near future

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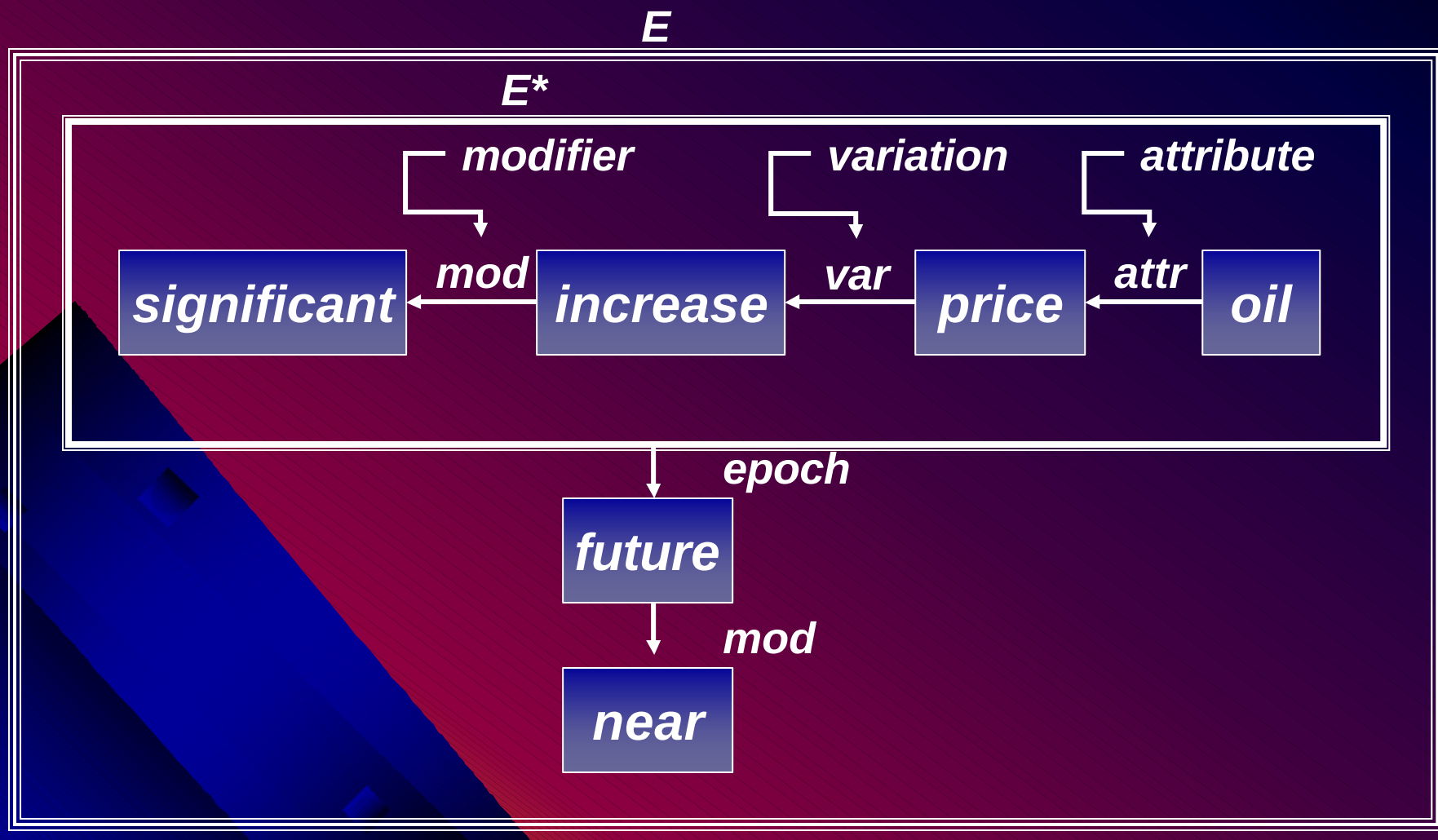
semantic network representation of E



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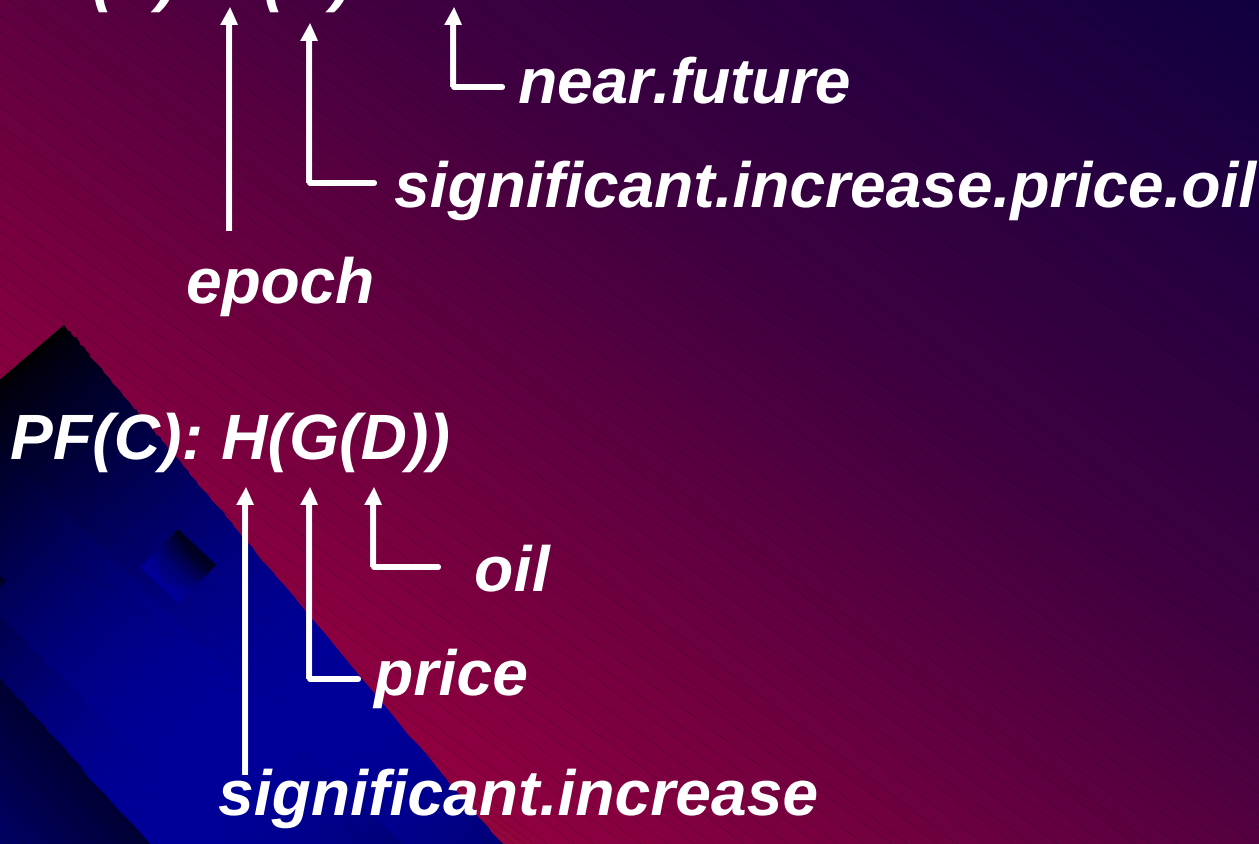
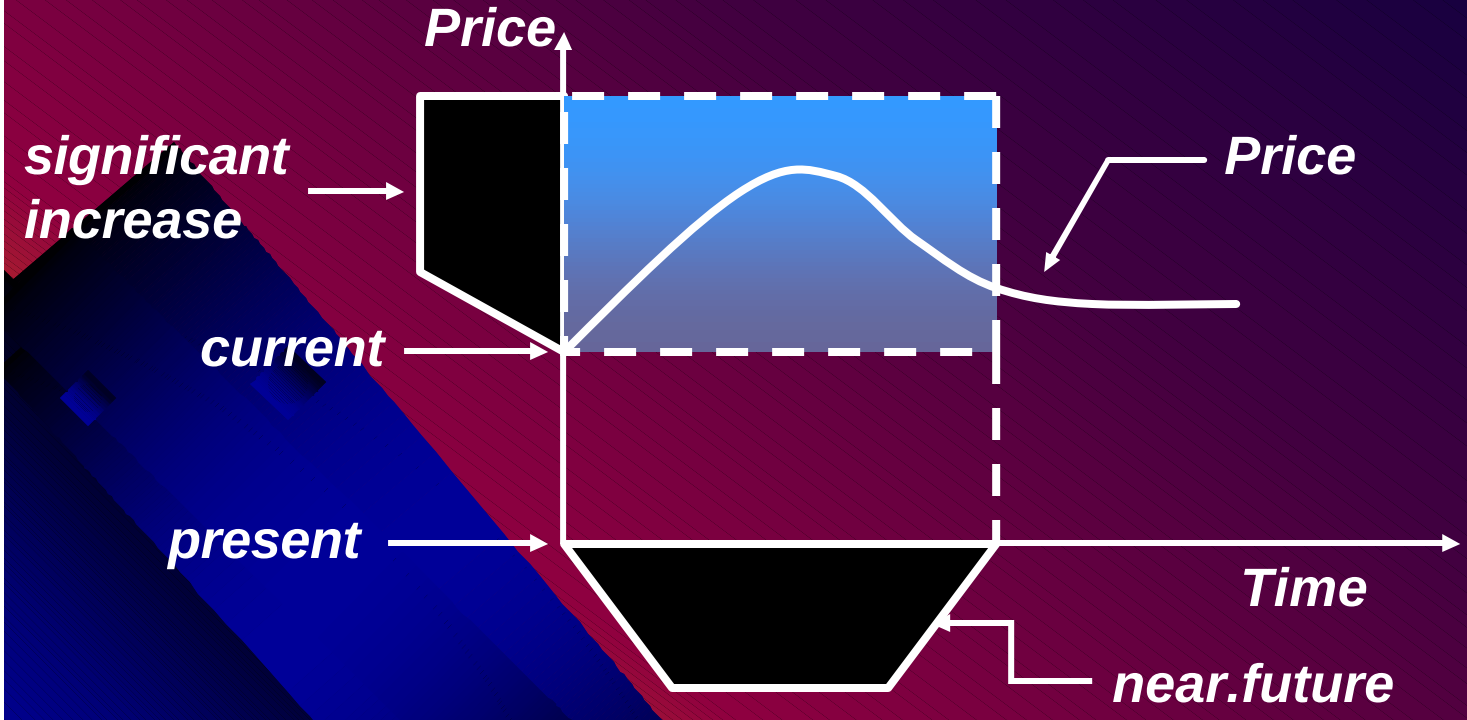

PF(E): B(C) is D
near.future
significant.increase.price.oil
epoch
PF(C): H(G(D))
oil
price
significant.increase

CONTINUED

Precisiation (f.b.-concept)

E*: Epoch (Variation (Price (oil)) is significant.increase)
is near.future



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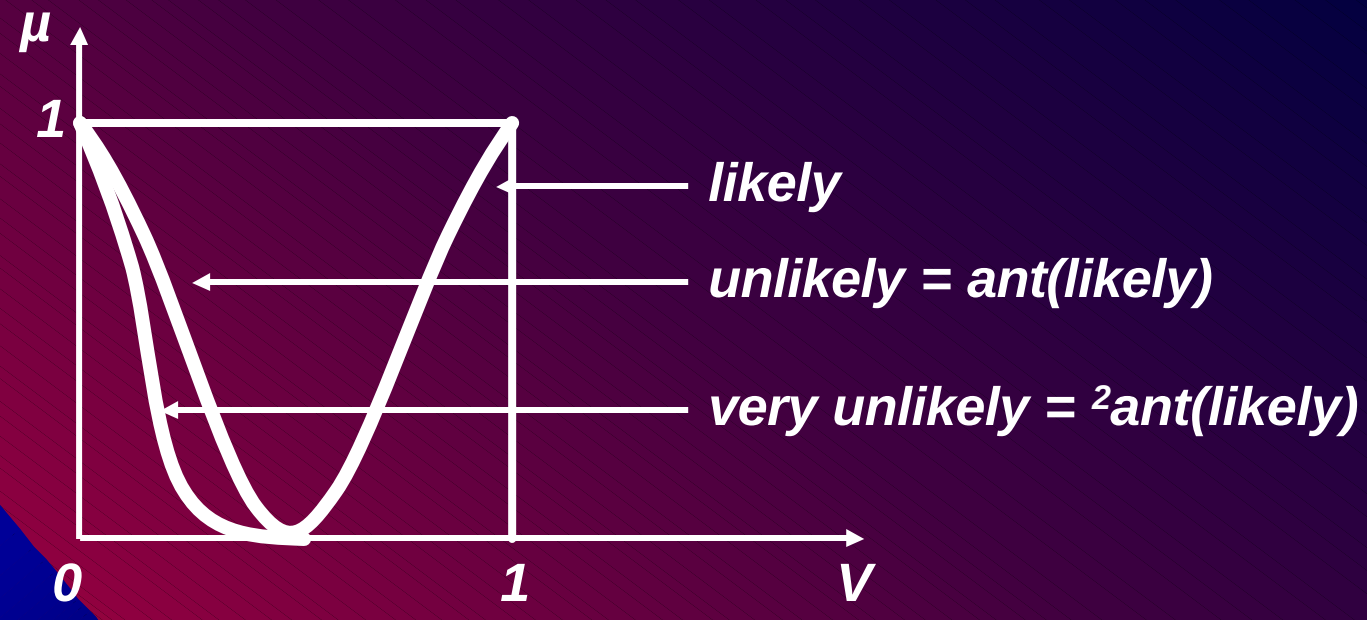
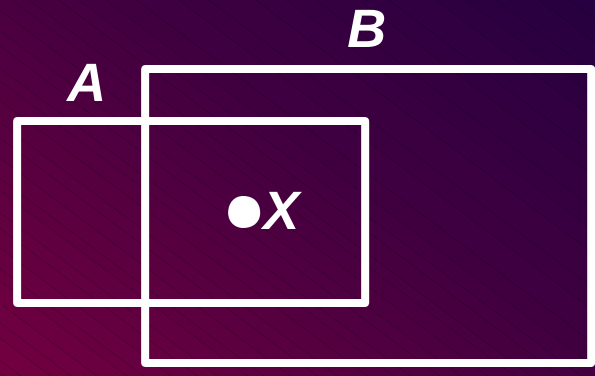
precisiation of very unlikely



$$\mu_{very.unlikely}(v) = (\mu_{likely}(1-v))^2$$

PROTOFORM OF A QUERY

- *largest port in Canada?*
- *second tallest building in San Francisco*



?X is selector (attribute (A/B))

2nd tallest *height* *buildings* *San Francisco*

THE TALL SWEDES PROBLEM

p: most Swedes are tall

Q: What is the average height of Swedes?

Try

p ⟶ p**: Count (B/A) is Q*

q ⟶ q**: F(C/A) is ?R*

Swedes

height attribute

functional of height attribute

*answer to q** cannot be inferred from p***

level of summarization of p has to be reduced

PROTOFORMAL SEARCH RULES

example

query: What is the distance between the largest city in Spain and the largest city in Portugal?

protoform of query: ?Attr (Desc(A), Desc(B))

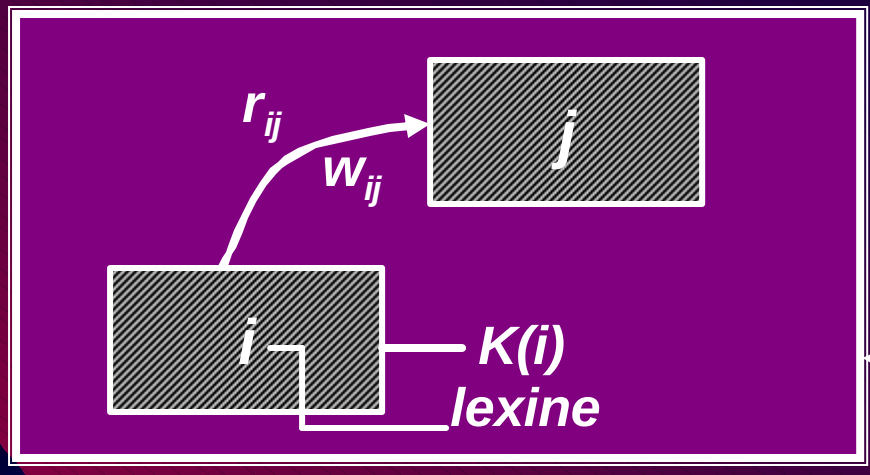
procedure

query: ?Name (A)|Desc (A)

query: Name (B)|Desc (B)

query: ?Attr (Name (A), Name (B))

ORGANIZATION OF WORLD KNOWLEDGE
EPISTEMIC (KNOWLEDGE-DIRECTED) LEXICON (EL)
(ONTOLOGY-RELATED)

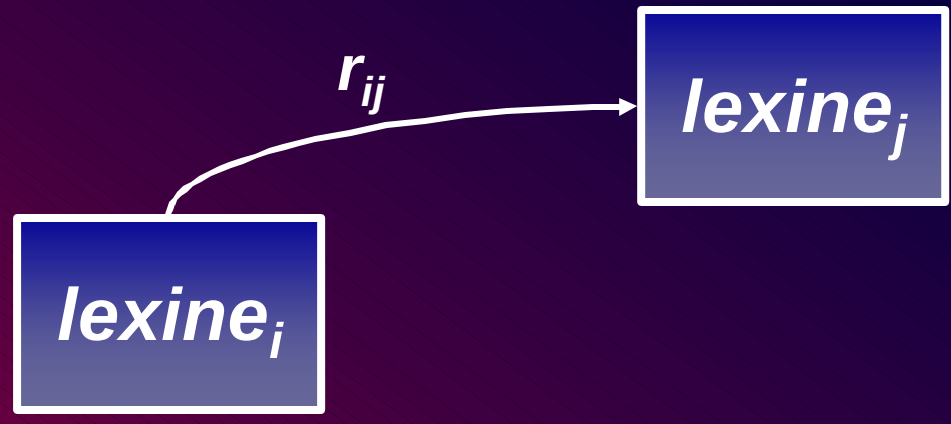


w_{ij}= granular strength of association between i and j

←network of nodes and links

- i (lexine): object, construct, concept (e.g., car, Ph.D. degree)
- K(i): world knowledge about i (mostly perception-based)
- K(i) is organized into n(i) relations R_{ii}, …, R_{in}
- entries in R_{ij} are bimodal-distribution-valued attributes of i
- values of attributes are, in general, granular and context-dependent

EPISTEMIC LEXICON



r_{ij}:		
	i is an instance of j	*(is or isu)*
	i is a subset of j	*(is or isu)*
	i is a superset of j	*(is or isu)*
	j is an attribute of i	
	i causes j	*(or usually)*
	i and j are related	

EPISTEMIC LEXICON

FORMAT OF RELATIONS

perception-based relation

lexine	A_1	…	A_m
	G_1		G_m

← attributes

← granular values

example

car	Make	Price	
	ford	G	
	chevy		

G: 20*% \ Ð 15k* + 40*% \ [15k*, 25k*] + • • •

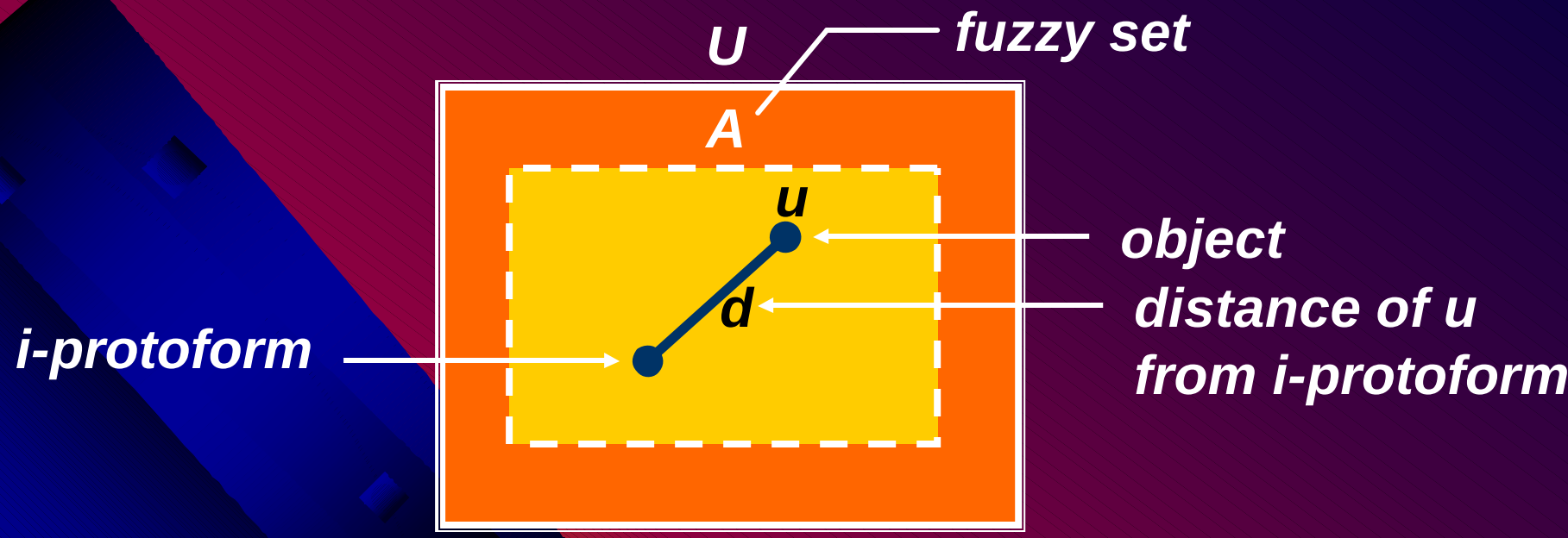
granular count

PROTOFORM OF A DECISION PROBLEM

- *buying a home*
- *decision attributes*
  - *measurement-based: price, taxes, area, no. of rooms, …*
  - *perception-based: appearance, quality of construction, security*
- *normalization of attributes*
- *ranking of importance of attributes*
- *importance function: w(attribute)*
- *importance function is granulated: L(low), M(medium), H(high)*

THE CONCEPT OF i-PROTOFORM

- *i-protoform: idealized protoform*
- *the key idea is to equate the grade of membership, $\mu_A(u)$, of an object, u, in a fuzzy set, A, to the distance of u from an i-protoform*
- *this idea is inspired by E. Rosch's work (ca 1972) on the theory of prototypes*



- *d is defined via PNL*

EXAMPLE: EXPECTED VALUE (f.f-concept)

- *X: real-valued random variable with probability density g*

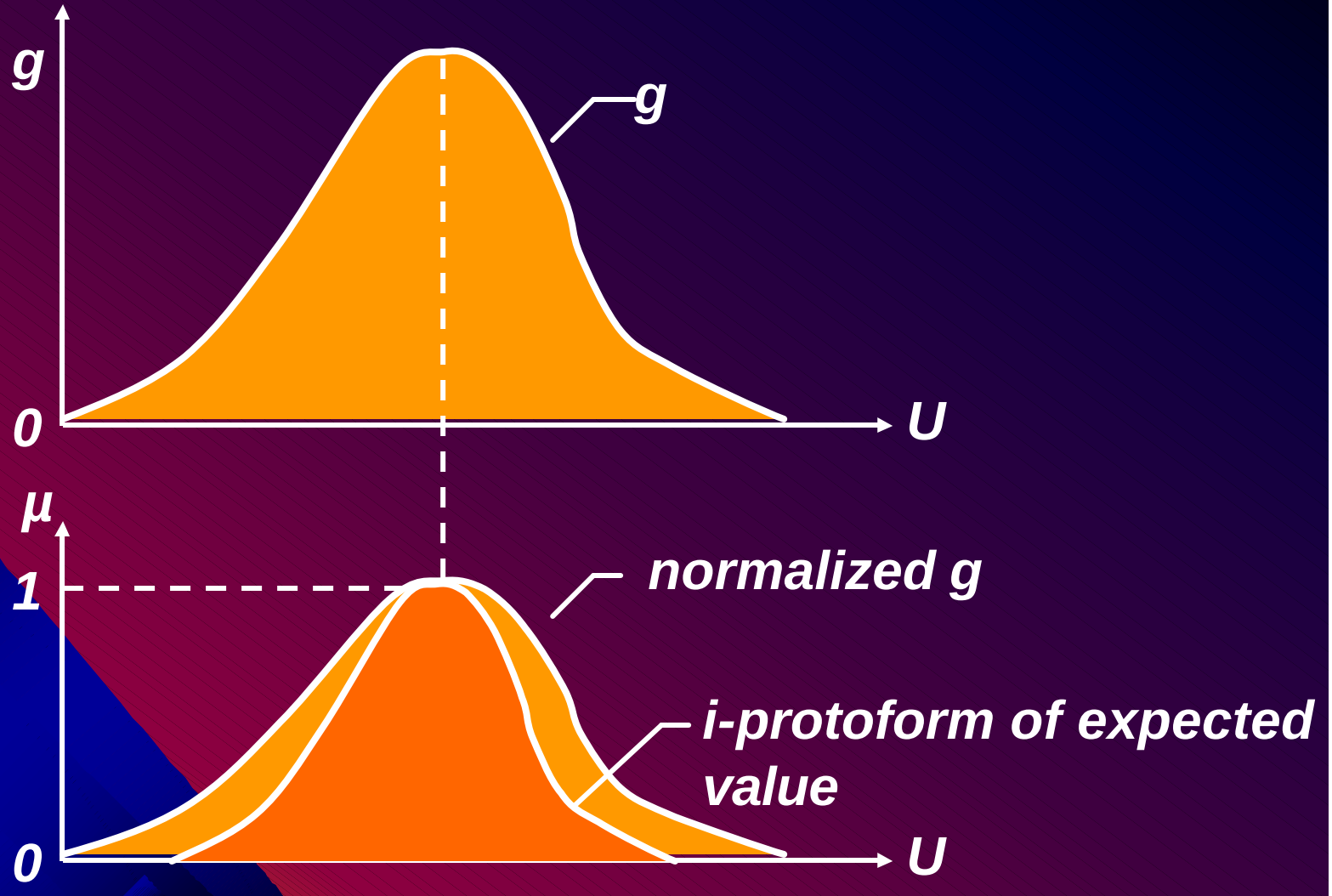
  standard definition of expected value of X

$$E(X) = \int_U u g(u)\,du$$

E(X) = average value of X

- *the label "expected value" is misleading*

i-PROTOFORM-BASED DEFINITION OF EXPECTED VALUE



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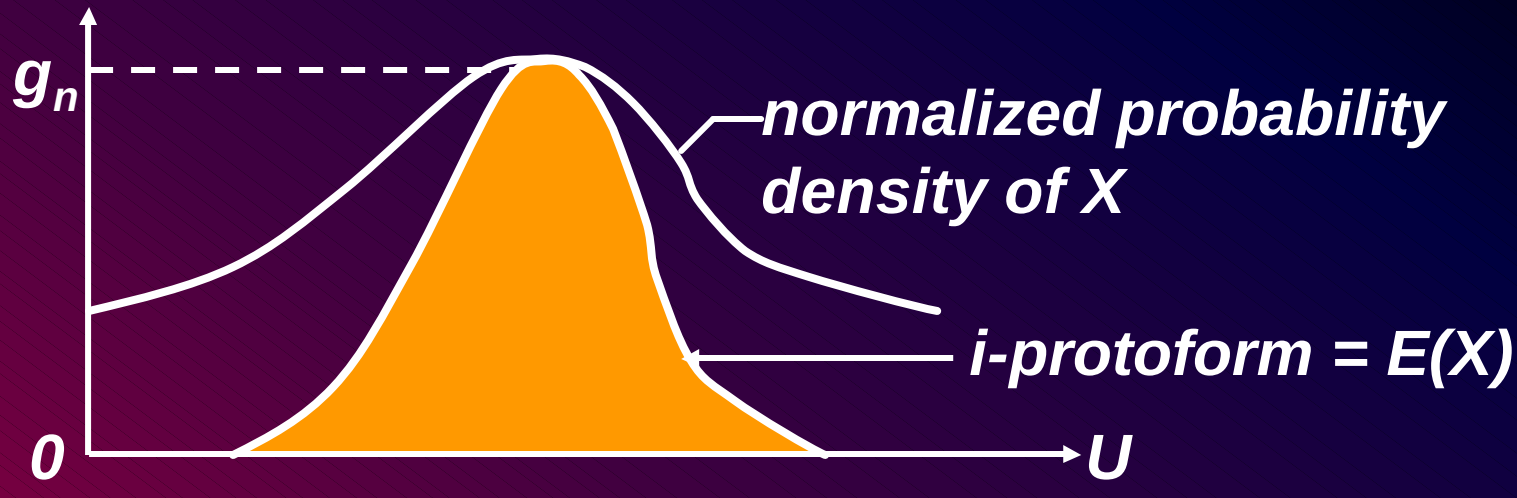


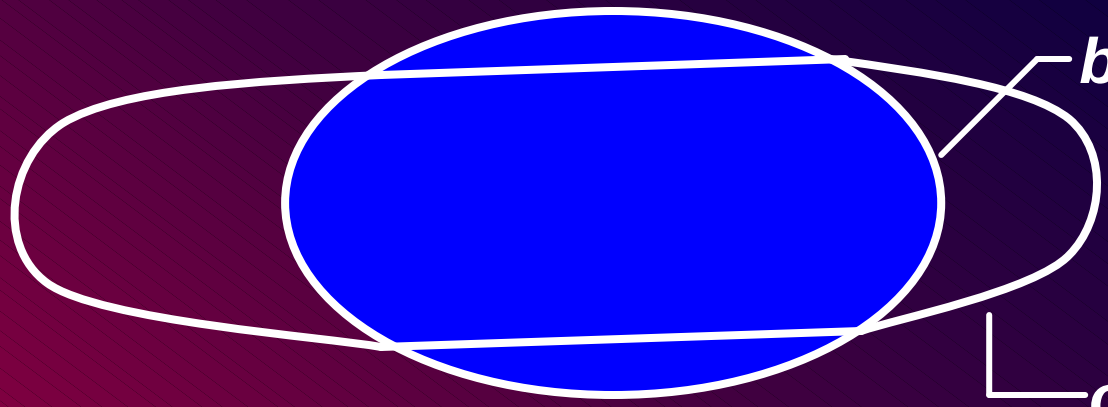
- *E(X) is a fuzzy set*
- *grade of membership of a particular function, E*(X), in the fuzzy set of expected value of X is the distance of E*(X) form best-fitting i-protoform*

I. PROTOFORMS OF GEOMETRICAL FORMS

- *line*
- *square*
- *circle*
- *ellipse*

- *i.protoform of an oval object is an ellipsoid*
- *degree of ovalness = distance from best-fitting ellipsoid*

OVALNESS



PROTOFORM EQUIVALENCE

- *A key concept in protoform theory is that of protoform-equivalence*
- *At specified levels of abstraction, summarization and detail, p and q are protoform-equivalent, written in PFE(p, q), if p and q have identical protoforms at those levels*

Example

p: most Swedes are tall

q: few professors are rich

- *Protoform equivalence serves as a basis*
- *for protoform-centered mode of knowledge organization*

PF-EQUIVALENCE

Scenario A:

Alan has severe back pain. He goes to see a doctor. The doctor tells him that there are two options: (1) do nothing; and (2) do surgery. In the case of surgery, there are two possibilities: (a) surgery is successful, in which case Alan will be pain free; and (b) surgery is not successful, in which case Alan will be paralyzed from the neck down. Question: Should Alan elect surgery?

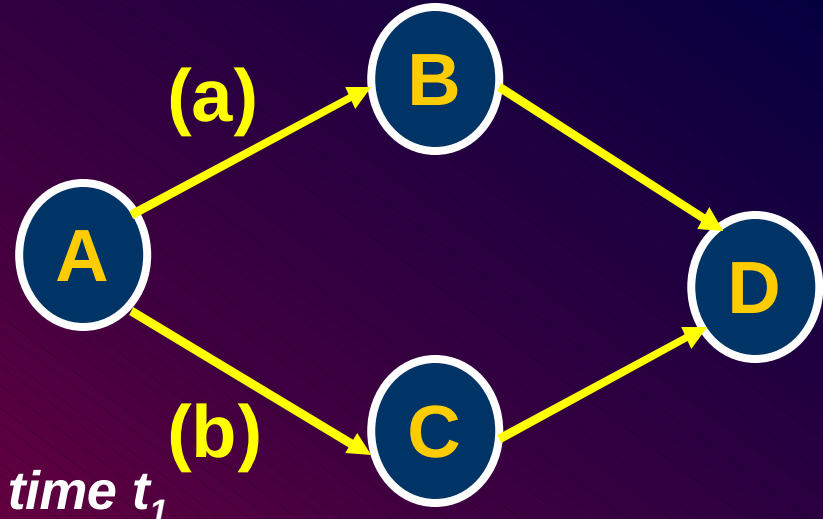
PF-EQUIVALENCE

Scenario B:

Alan needs to fly from San Francisco to St. Louis and has to get there as soon as possible. One option is fly to St. Louis via Chicago and the other through Denver. The flight via Denver is scheduled to arrive in St. Louis at time a. The flight via Chicago is scheduled to arrive in St. Louis at time b, with a<b. However, the connection time in Denver is short. If the flight is missed, then the time of arrival in St. Louis will be c, with c>b. Question: Which option is best?

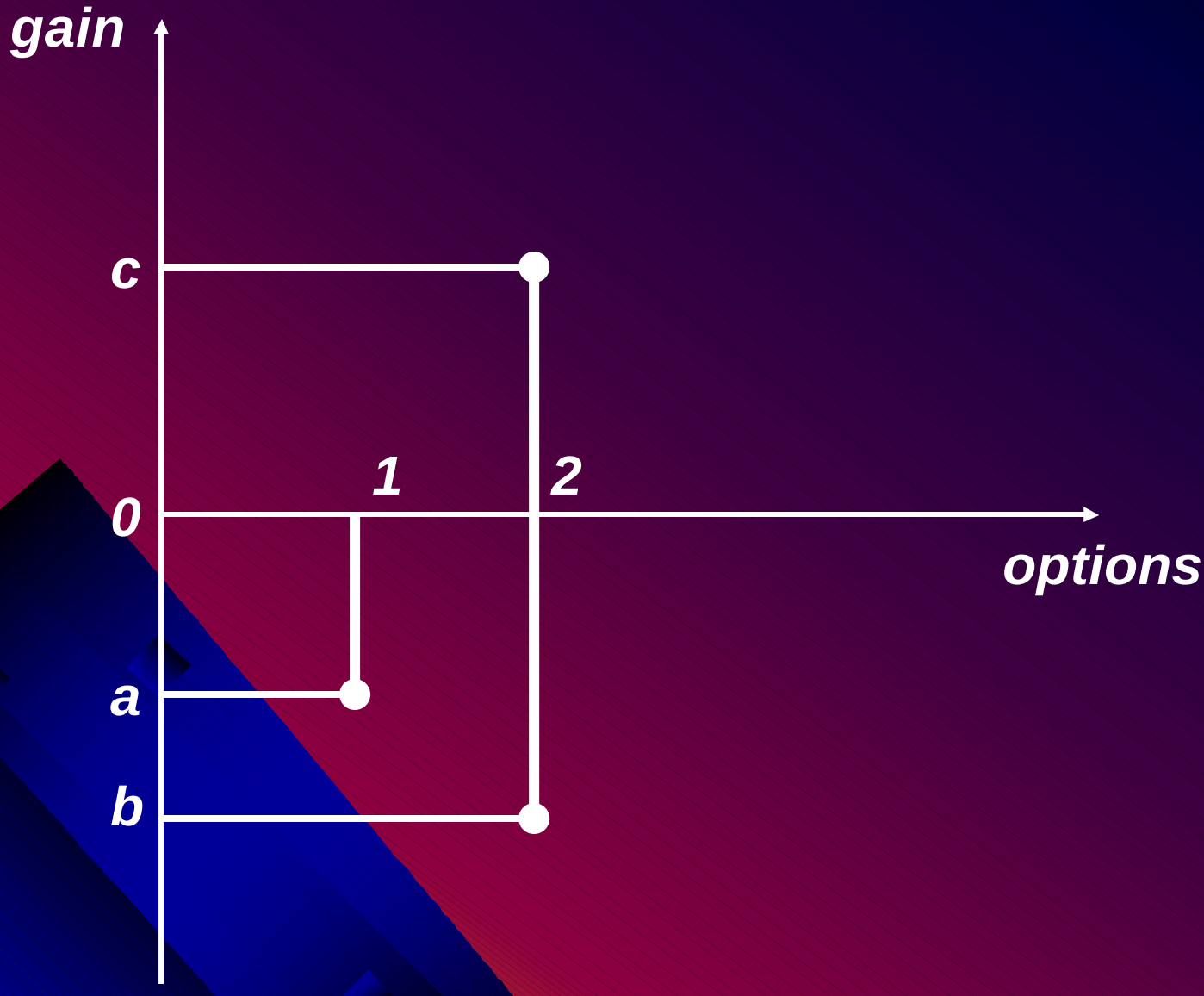
THE TRIP-PLANNING PROBLEM

- *I have to fly from A to D, and would like to get there as soon as possible*
- *I have two choices: (a) fly to D with a connection in B; or*
  (b) fly to D with a connection in C

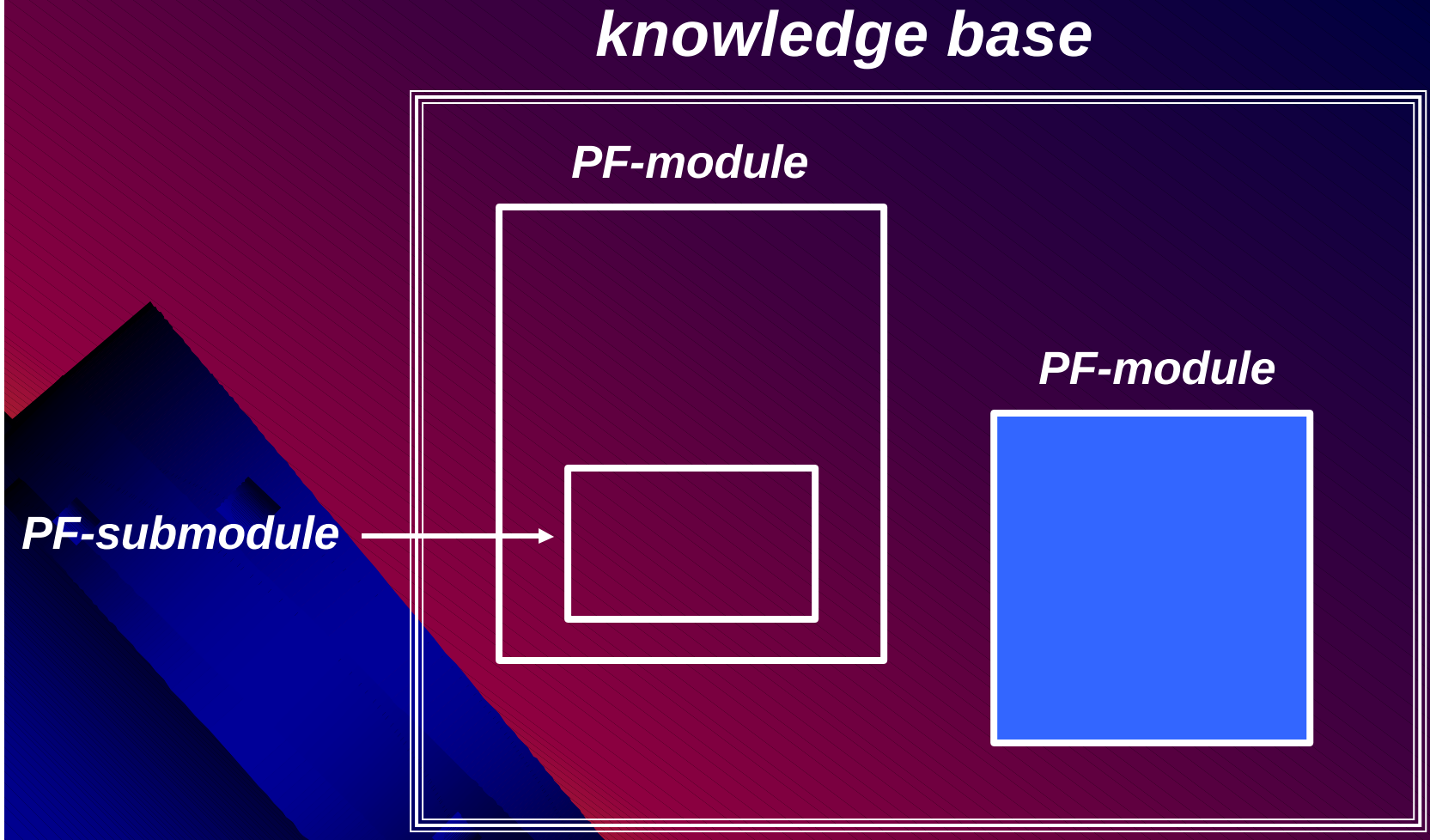


- *if I choose (a), I will arrive in D at time t_1*
- *if I choose (b), I will arrive in D at time t_2*
- *t_1 is earlier than t_2*
- *therefore, I should choose (a) ?*

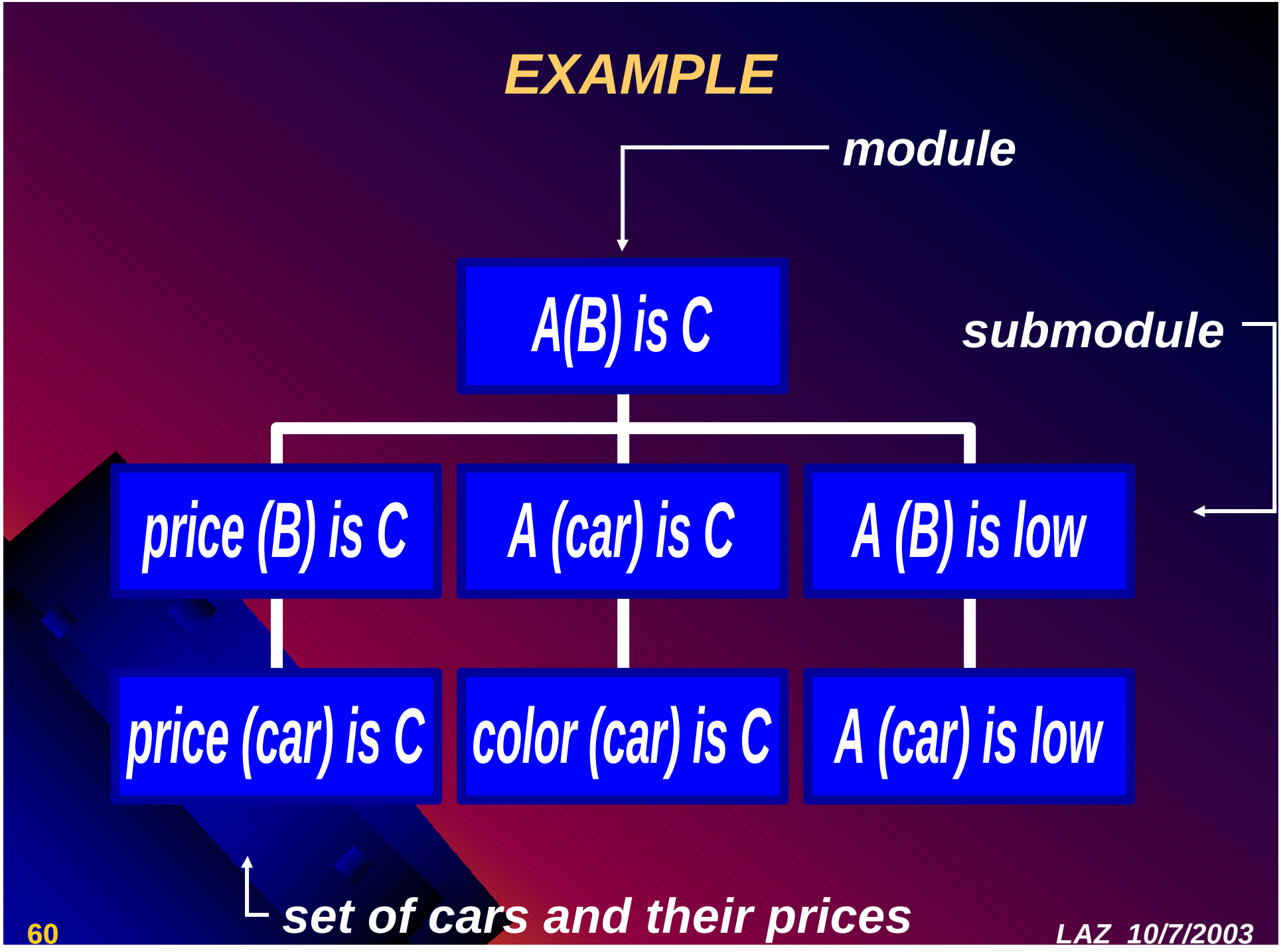
PROTOFORM EQUIVALENCE



PROTOFORM-CENTERED KNOWLEDGE ORGANIZATION



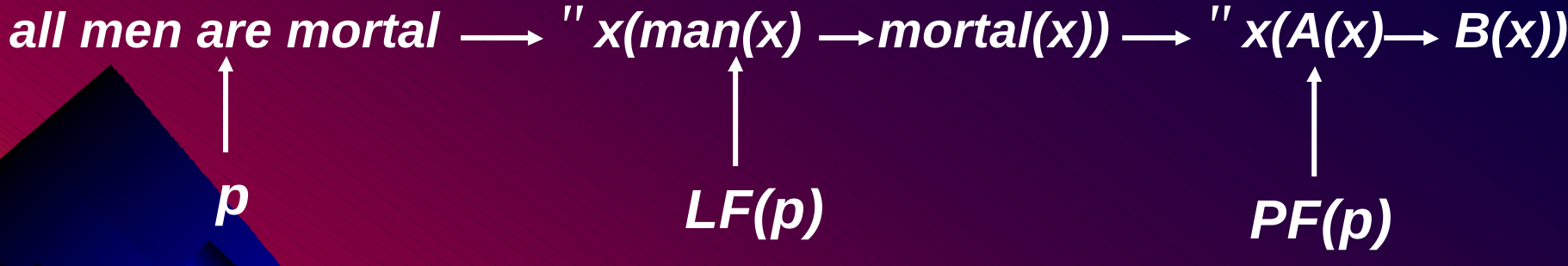
EXAMPLE


module
A(B) is C
submodule
price (B) is C
A (car) is C
A (B) is low
price (car) is C
color (car) is C
A (car) is low
set of cars and their prices

PROTOFORM-BASED DEDUCTION

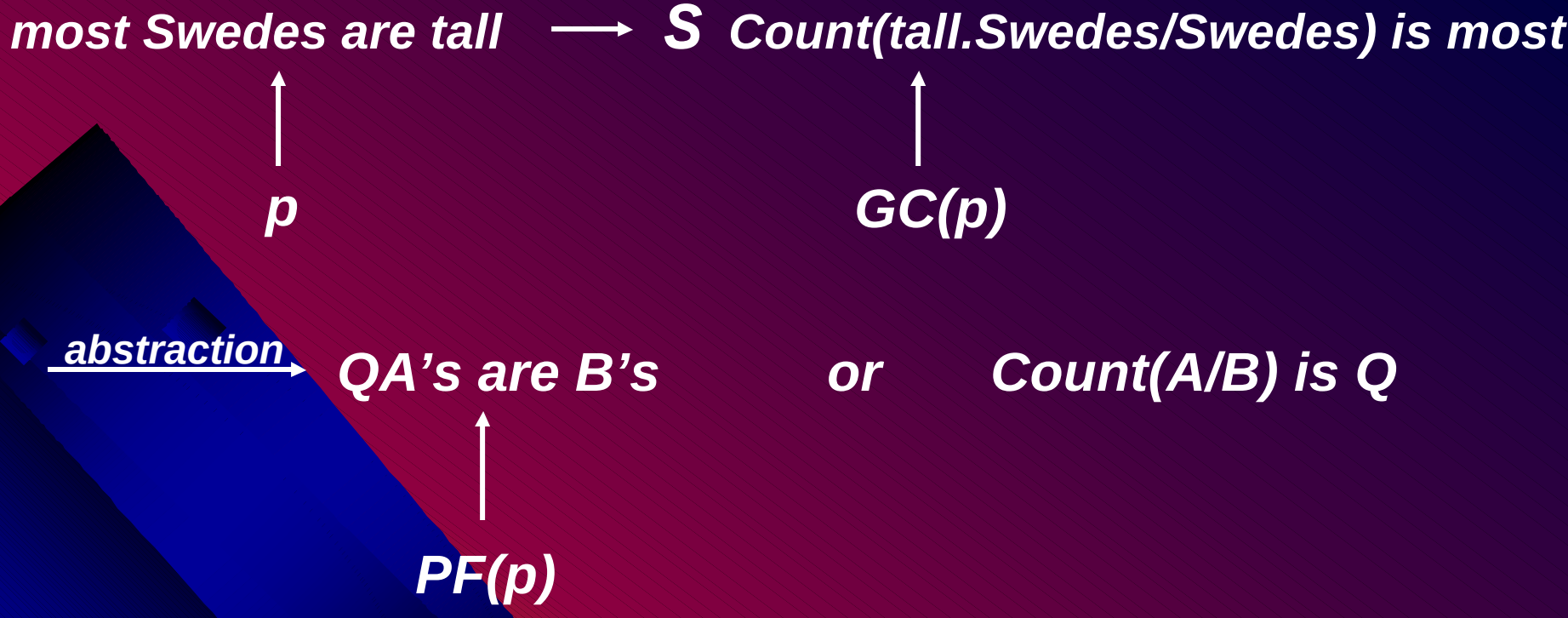
PROTOFORMS AND LOGICAL FORMS

- *p = proposition in a natural language*
- *if p has a logical form, LF(p), then a protoform of p, PF(p), is an abstraction of LF(p)*

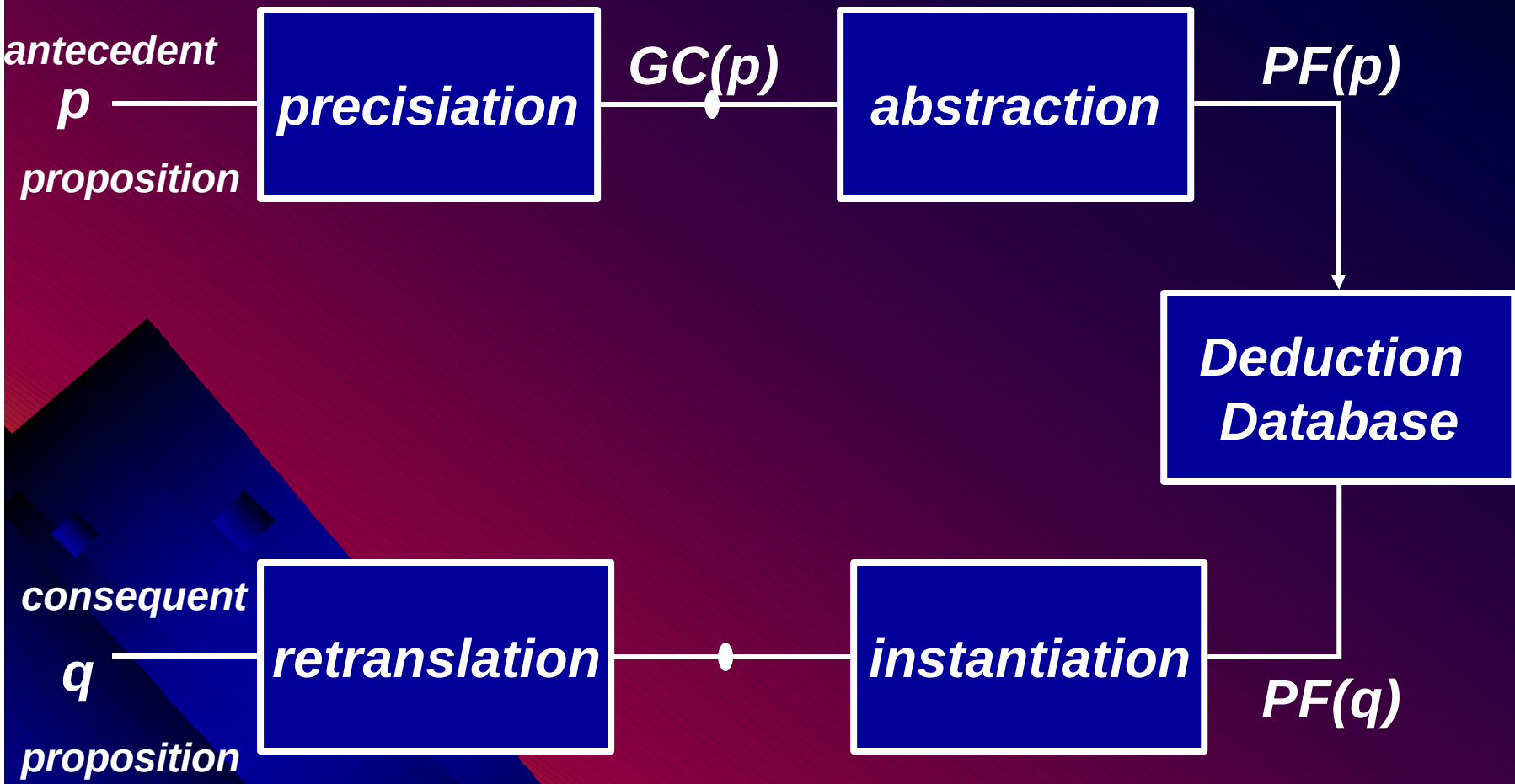


CONTINUED

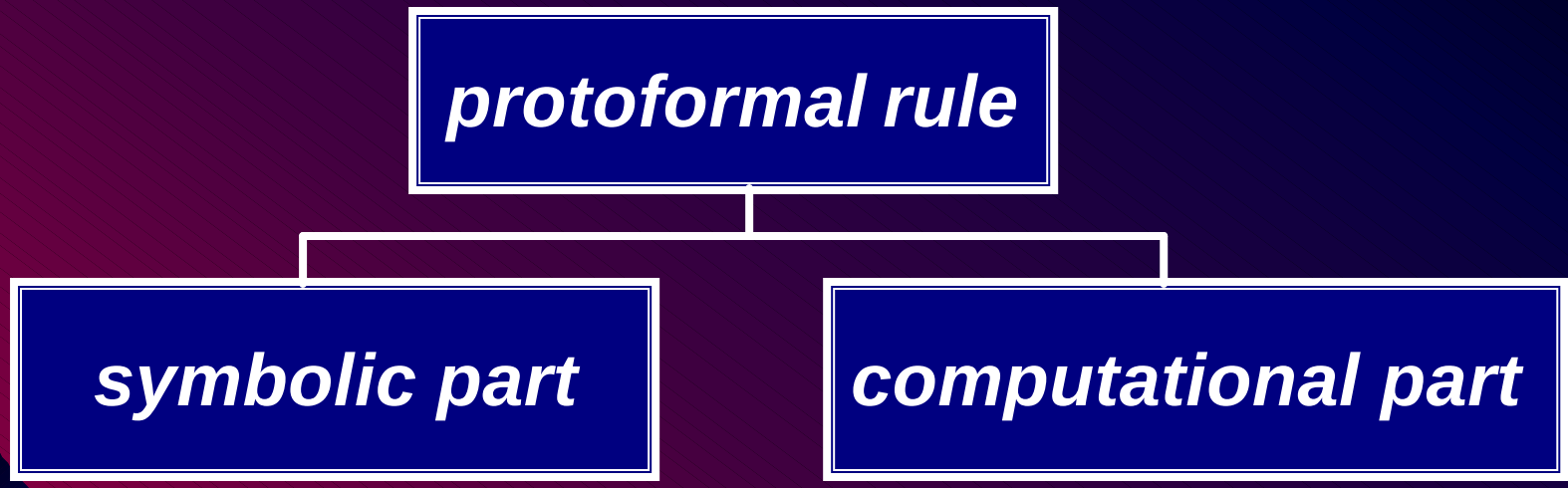
- *if p does not have a logical form but is in PNL, then a protoform of p is an abstraction of the generalized constraint form of p, GC(p)*



PROTOFORMAL (PROTOFORM-BASED) DEDUCTION



FORMAT OF PROTOFORMAL DEDUCTION RULES



PROTOFORM DEDUCTION RULE: GENERALIZED MODUS PONENS

fuzzy logic

classical

$$\frac{A \qquad A \rightarrow B}{B}$$

X is A
If X is B then Y is C
Y is D

← *symbolic*

computational 1 → $D = A \circ (B \times C)$ *(fuzzy graph; Mamdani)*

computational 2 → $D = A \circ (B \rightarrow C)$ *(implication; conditional relation)*

PROTOFORMAL RULES OF DEDUCTION

examples

$$\frac{X \text{ is } A \qquad (X, Y) \text{ is } B}{Y \text{ is } A \circ B}$$

$$\mu_{A \circ B}(v) = \max_u (\mu_A(u) \wedge \mu_B(u,v))$$

symbolic part

computational part

$$\frac{\text{Prob } (X \text{ is } A) \text{ is } B}{\text{Prob } (X \text{ is } C) \text{ is } D}$$

$$\mu_D(u) = \max_q \left(\mu_B \left(\int_U \mu_A(u) g(u) du \right) \right)$$

subject to:

$$v = \int_U \mu_C(u) g(u) du$$

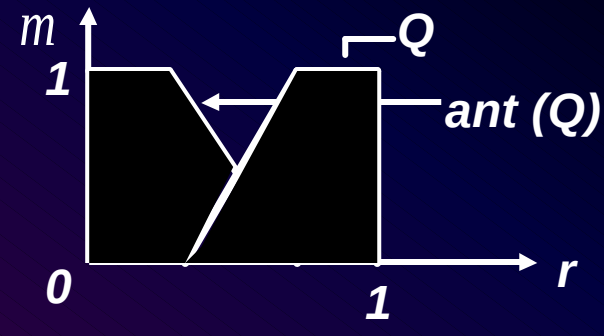
$$\int_U g(u) du = 1$$

COUNT-AND MEASURE-RELATED RULES

crisp

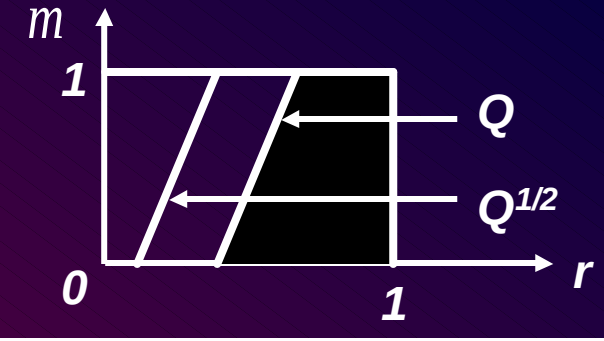
Q A's are B's

ant (Q) A's are not B's



Q A's are B's

$Q^{1/2}$ A's are ^{2}B's



most Swedes are tall

ave (height) Swedes is ?h

⟶

Q A's are B's

ave (B|A) is ?C

$$\mu_{ave}(v) = \sup_a \mu_Q\left(\frac{1}{N} ? _i \mu_B(a_i)\right)$$

, $a = (a_1, \ldots, a_N)$

$$v = \frac{1}{N}\left(\sum_i a_i\right)$$

CONTINUED

$not(QA's\ are\ B's) \longleftrightarrow (not\ Q)\ A's\ are\ B's$

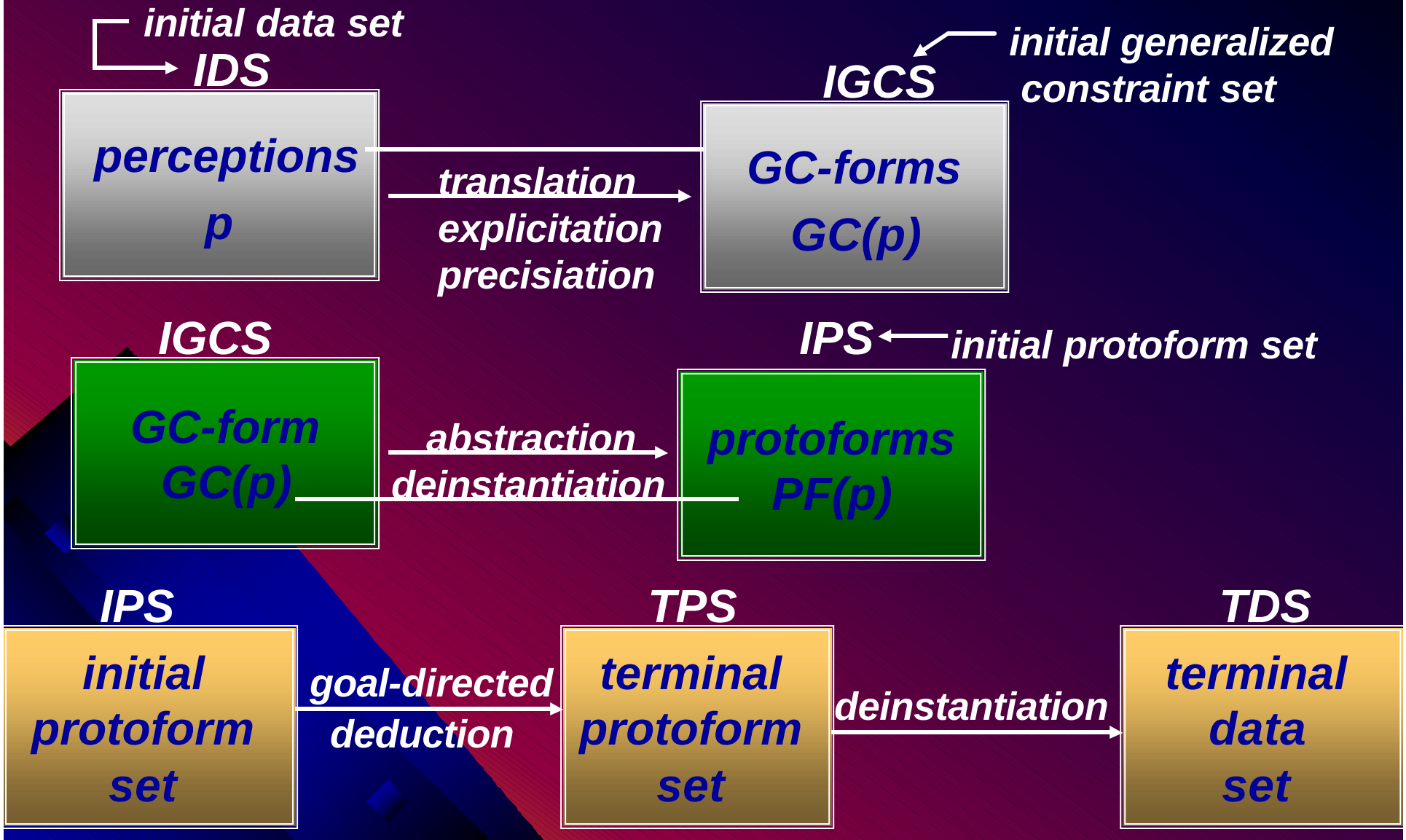
Q_1 $A's\ are\ B's$
Q_2 $(A\&B)'s\ are\ C's$

Q_1 Q_2 $A's\ are\ (B\&C)'s$

Q_1 $A's\ are\ B's$
Q_2 $A's\ are\ C's$

$(Q_1 + Q_2 - 1)\ A's\ are\ (B\&C)'s$

REASONING WITH PERCEPTIONS: DEDUCTION MODULE



PROTOFORMAL CONSTRAINT PROPAGATION

p	GC(p)	PF(p)
Dana is young	Age (Dana) is young	X is A
Tandy is a few years older than Dana	Age (Tandy) is (Age (Dana)) +few	Y is (X+B)

X is A
Y is (X+B)

Y is A+B

→ Age (Tandy) is (young+few)

$$\mu_{A+B}(v) = \sup_u(\mu_A(u) + \mu_B(v-u))$$

THE TALL SWEDES PROBLEM

p: most Swedes are tall

Q: What is the average height of Swedes?

Try

p → p**: Count (B/A) is Q*

q → q**: F(C/A) is ?R*

- *Swedes*
- *height attribute*
- *functional of height attribute*

*answer to q** cannot be inferred from p***

level of summarization of p has to be reduced

CONTINUED

$p \xrightarrow{\text{precisiation}}$ p* = Prop(tall.Swedes/Swedes) is most

$q \xrightarrow{\text{precisiation}}$ q* = Ave.height is ?R

$p^* \xrightarrow{\text{abs}}$ p**: Prob F(B/A) is ?Q

$q^* \xrightarrow{\text{abs}}$ q**: Ave F(B/A) is ?R

protoformal deduction rule

symbolic: $\dfrac{\text{Prop (F(B/A)) is Q}}{\text{Ave F(B/A) is R}}$

computational:

$$\mu_{ave}(v) = \sup_g \mu_Q\left(\int_0^M \mu_B(u)g(u)du\right)$$

subject to

$$v = \frac{I}{M}\int_0^M g(u)du$$

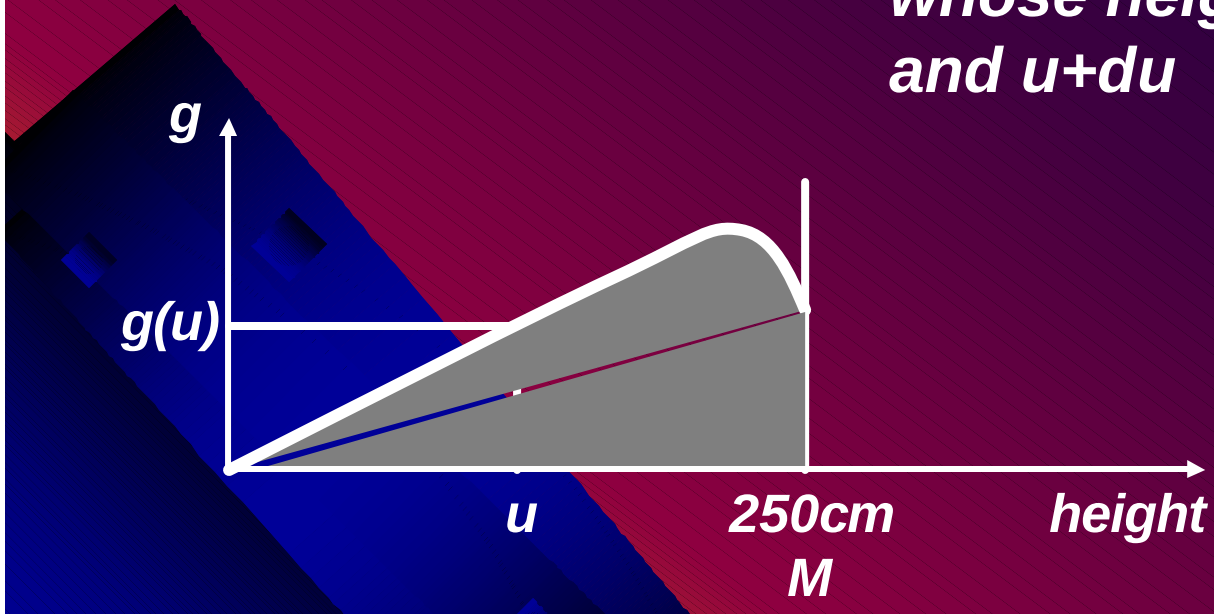
CONTINUED

- *example*

  IDS p: Most Swedes are tall

  TDS q: What is the average height of Swedes?

  g(u)= count density *g(u)du= number of Swedes whose height is between u and u+du*



PARTICULARIZATION (LAZ 1975)

P: population of objects

R: relation describing P

example

R: population of Swedes

R [Height; weight; age; …]

$R^{+:}$ particularized R

$R^{+:}$ [Height is tall]: population of tall Swedes

CONTINUED

p ⟶ p = Count(Swedes[Height is tall]/Swedes) is most*

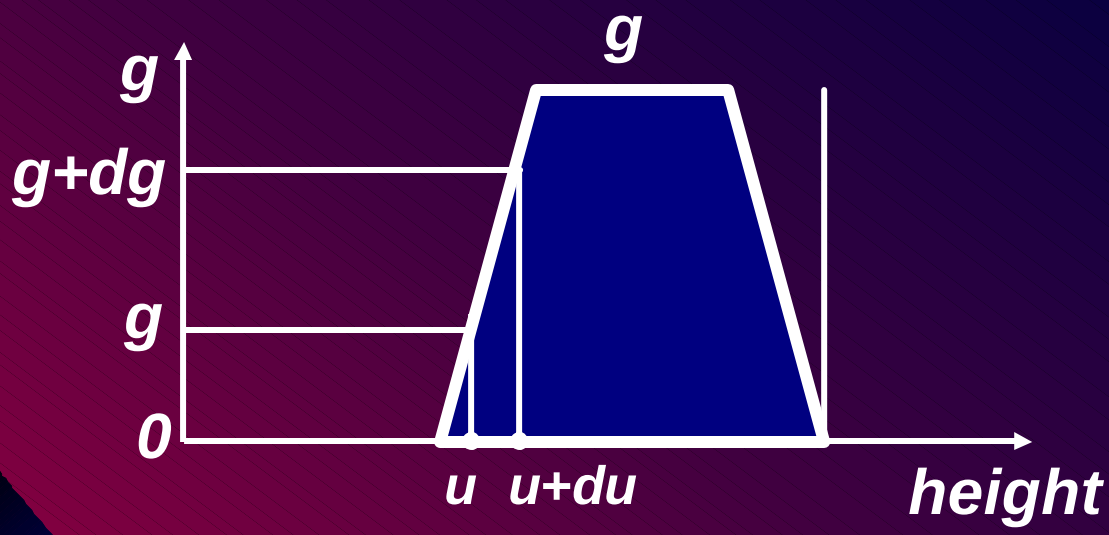
*p**: Count(R[A is B]/R) is Q*

q ⟶ q**: ? Ave (R[A is B]; A)*

rule:

Count(R[A is B]/R) is Q *Ave(R[A is B] is ?C*

CONTINUED



g(u) = height distribution

$$\frac{I}{M} ? \int_0^M g(u)\mu_{tall}(u)du \text{ is most}$$

$$\frac{I}{M} ? \int_0^M g(u)du \text{ is ?C}$$

CONTINUED

$$\mu_C(v) = \sup_g \mu_Q\left(\int_0^M g(u)\mu_Q(u)du\right)$$

subject to

$$v = \frac{I}{M}\int_0^M g(u)du$$

EXAMPLE OF DEDUCTION

most Swedes are tall

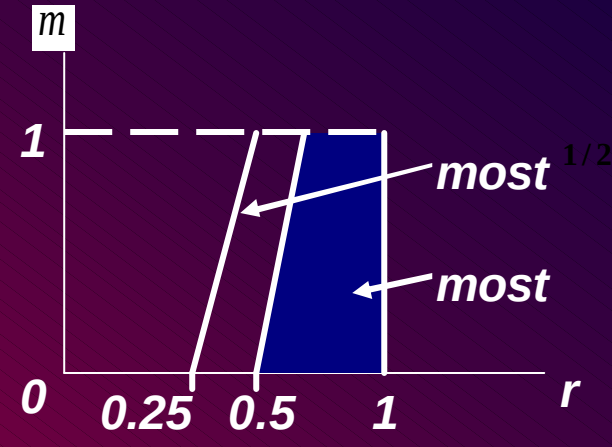
? R Swedes are very tall

most Swedes are tall —s/a-transformation→ Q A's are B's

Q A's are B's

$Q^{1/2}$ A's are ^{2}B's

$most^{1/2}$ Swedes are very tall



PROTOFORMAL DEDUCTION
THE ROBERT EXAMPLE

- *The Robert example is intended to serve as an illustration of protoformal deduction. In addition, it is intended to serve as a test of ability of standard probability theory, PT, to operate on perception-based information*

IDS: Usually Robert returns from work at about 6 pm

TDS: What is the probability that Robert is home at about t pm?

SOLUTION

1. **Precisiation**

   p: usually Robert returns from work at about 6 pm

   p ® p*: Prob(Return.Robert.from.work is about.6 pm

   X A

   is usually)

   B

2. **What is the probability that Robert is home at about t pm?**

   q ® q*: Prob(Robert.home.at.about.t pm) is ? D

   Y C D

3. **Abstraction**

   p* ® p**: Prob(X is A) is B

   q* ® q**: Prob(Y is C) is ?D

CONTINUED

4. Search in Deduction Database

- desired rule: $\frac{\text{Prob(X is A) is B}}{\text{Prob(Y is C) is ?D}}$

- top-level agent reports that desired rule is not in DDB, but that a variant rule,

$$\frac{\text{Prob(X is A) is B}}{\text{Prob(X is C) is ?D}}\ ,$$

is in DDB

- Can the desired rule be linked to the variant rule?

CONTINUED

5. Computation

$$\frac{\text{Prob(X is A) is B}}{\text{Prob(X is C) is ?D}}$$

computational part (g: probability density of X)

$$\mu_D(u) = \sup_u (\mu_A(\int_{12\,pm}^{12\,am} \mu_B(u)g(u)du))$$

subject to

$$v = \int_{12\,pm}^{12\,am} m_B(u)q(u)du$$

$$\int_{12\,pm}^{12\,am} g(u)du = 1$$

CONTINUED

6. **Search for linkage**

- **If Robert does not leave his home after returning from work, then**

Robert is at home at about.t pm =

Robert returns from work at.or.before t pm

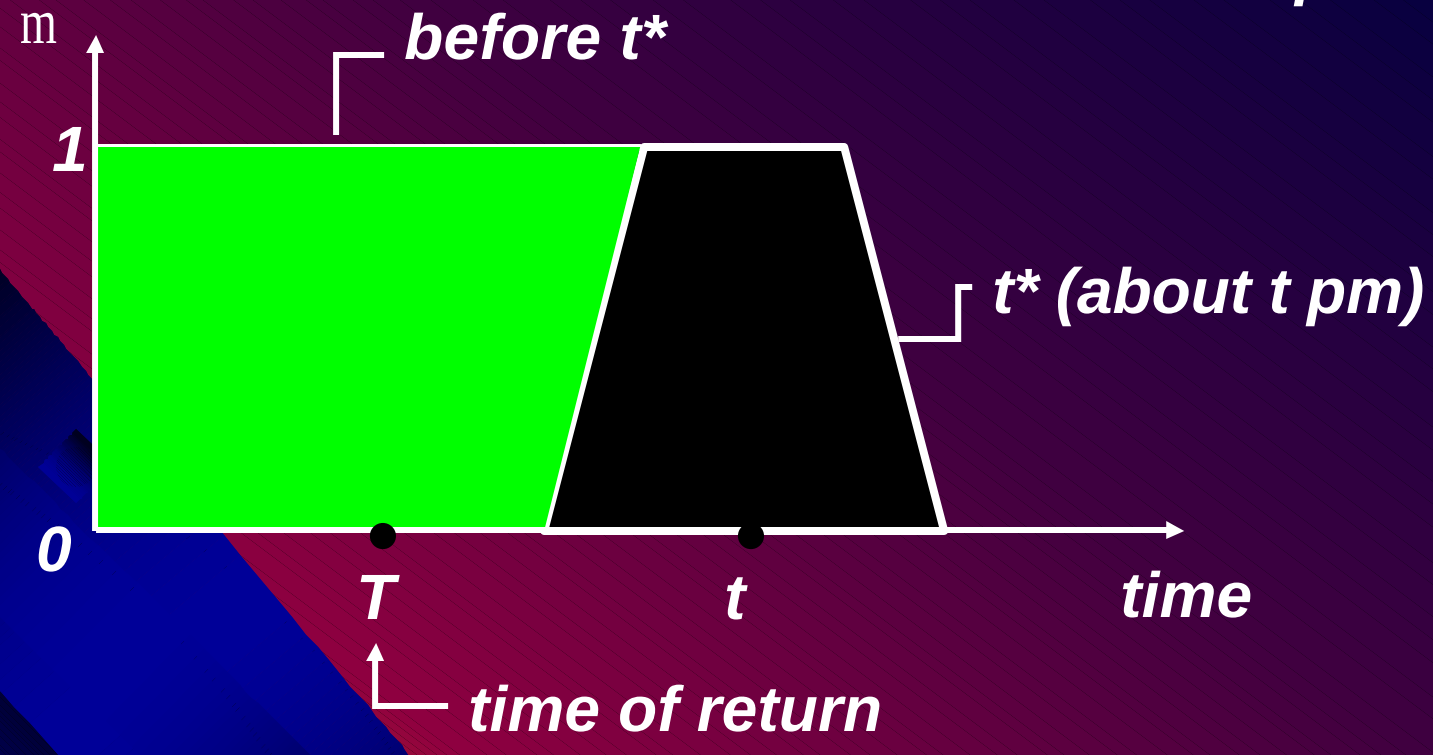
consequently

Y is about t pm = X is £ about.t pm

THE ROBERT EXAMPLE

event equivalence

Robert is home at about t pm = Robert returns from work before about t pm



Before about t pm = = o about t pm

CONTINUED

7. *Answer*

$$\mu_D(v) = \sup_g \left(\mu_{usually} \left(\int_{12am}^{12pm} \mu_{about.tpm}(u) g(u) du \right) \right)$$

subject to

$$v = \int_{12am}^{12pm} \mu_{about.tpm}(u) g(u) du$$

$$\int_{12am}^{12pm} g(u) du = 1$$

8. *Instantiation: D = Prob {Robert is home at about t}*

X = Time (Robert returns from work)

*A = 6**

B = usually

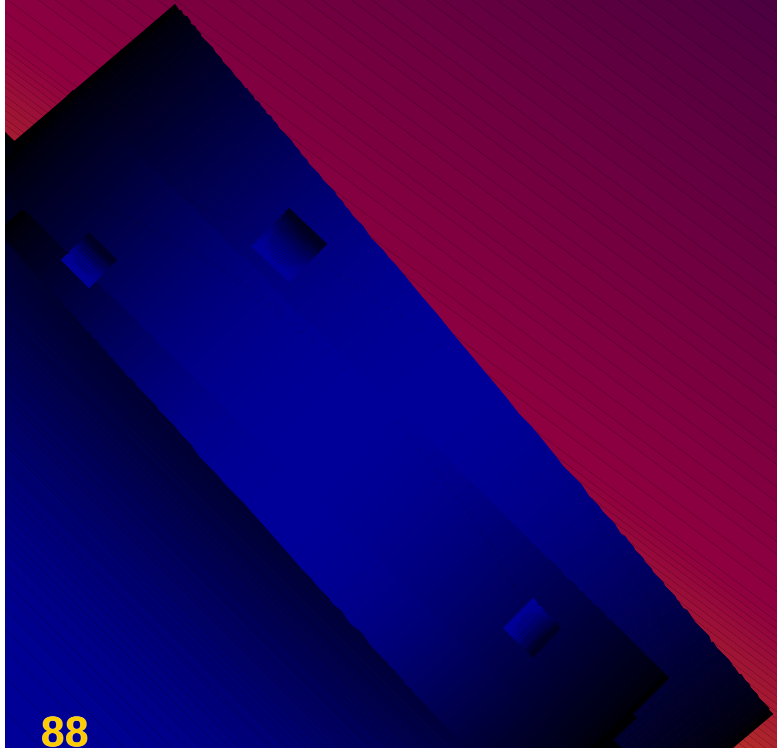
*C = £ t**

CONCLUSION

- *addition of significant question-answering capability to search engines is a complex, open-ended problem*
- *incremental progress, but not much more, is achievable through the use of bivalent-logic-based methods*
- *to achieve significant progress, it is imperative to develop and employ techniques based on computing with words, protoform theory, precisiated natural language and computational theory of perceptions*

CONTINUED

- *Actually, elementary fuzzy logic techniques are used in many search engines*



USE OF FUZZY LOGIC* IN SEARCH ENGINES

Search engine	Fuzzy logic in any form
Excite!	X
Alta Vista	
HotBot	X
Infoseek	X
Lycos	No info
Open Text	
Web Crawler	X
Yahoo	
Google	No info
Northern Light Power	X
Fast Search Advanced	X

* (currently, only elementary fuzzy logic tools are employed)

CONTINUED

- ***But what is needed is application of advanced concepts and techniques which are outlined in this presentation***