Computing with Words

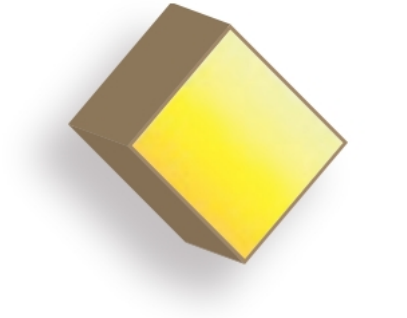
A closer look into using the natural language to compute

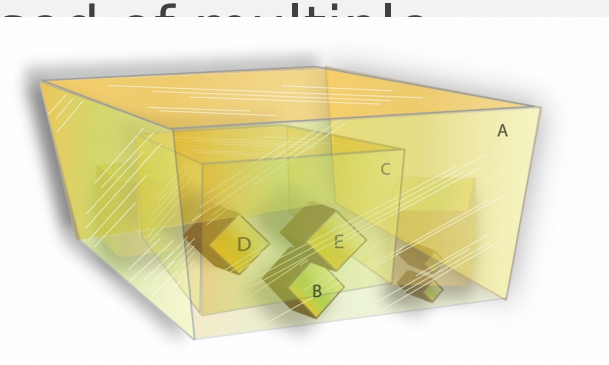
“Fuzzy Logic = Computing with Words”
Lotfi A Zadeh

Presented by Sharleen Fisher

What is granularity?

- Granule: A cluster of points grouped by similarity
  - A word *w* is a label of a granule *g*
- Two types of data:
  - Atomic data: Singular and indivisible
  - Composite data: Comprised of multiple





What is CWW?

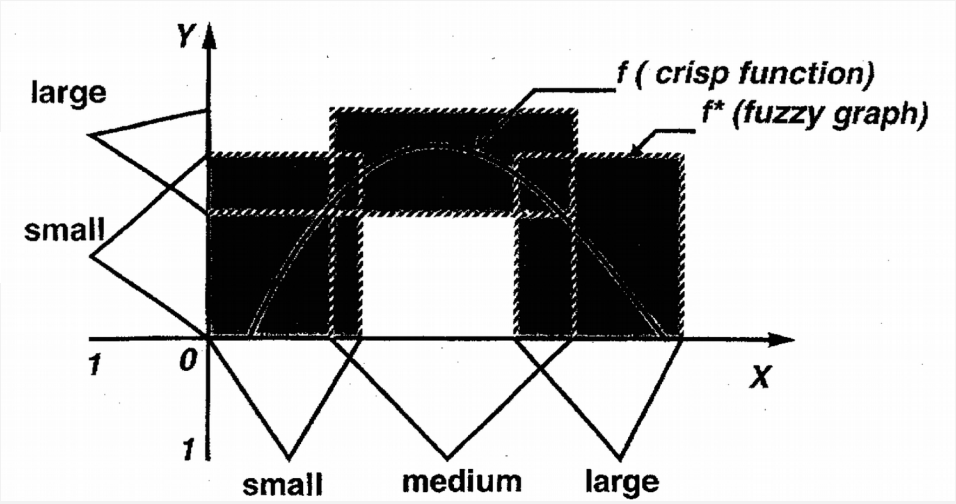
- Rooted in:
  - Linguistic variables and granulation
    - “Outline of a new approach to the analysis of complex systems and decision processes,” ***IEEE Trans. Syst., Man, Cybem.,*** vol. 3, L. Zadeh
  - Concepts of fuzzy constraint and fuzzy constraint propagation
    - “Calculus of fuzzy restrictions,” in ***Fuzzy Sets and Their Appli- cations to Cognitive and Decision Processes***, L. A. Zadeh, K. S. Fu, M. Shimura
    - “A theory of approximatereasoning,”***Machine Intelligence 9,*** J. Hayes, D. Michie, and L. I. Mukulich

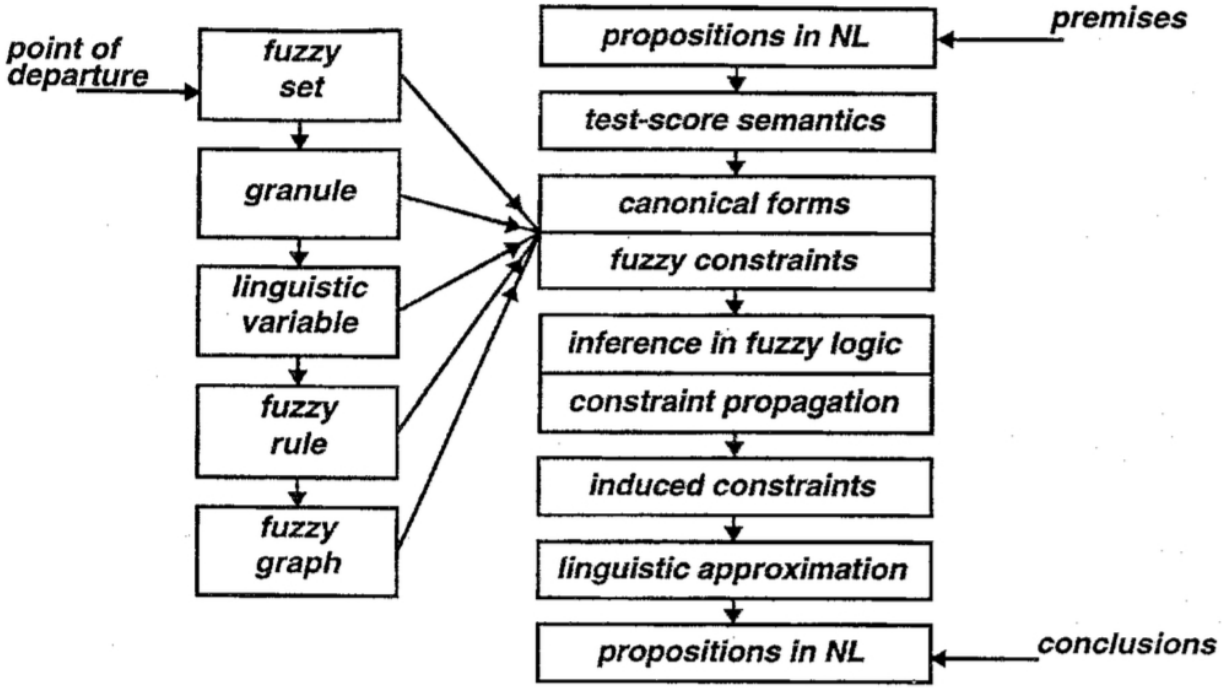
A Basic Problem

Assume that a function f, $f: U \to V$, $X \in U$, $Y \in V$ is described in words by the fuzzy IF-THEN rules

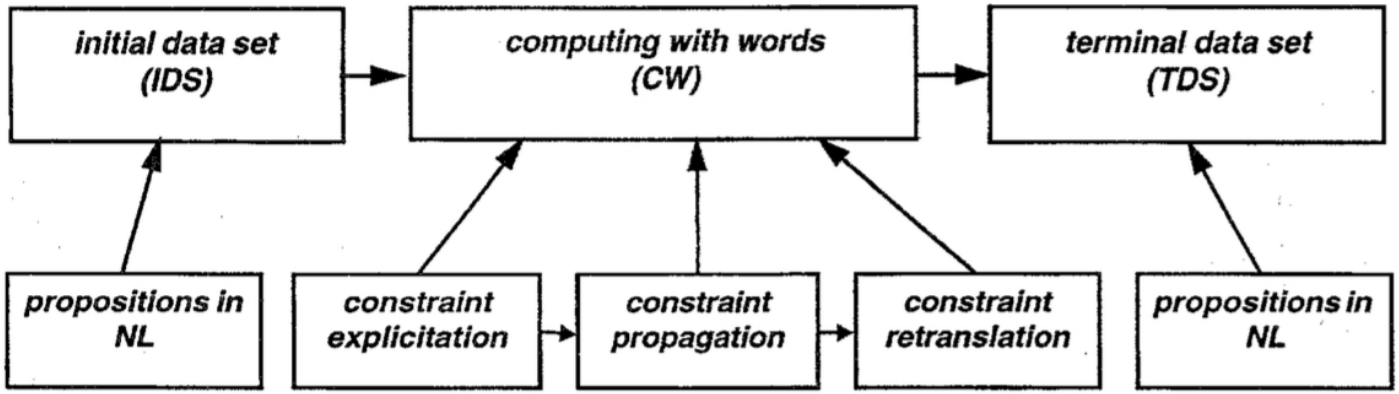
f: if X is small then Y is small
if X is medium then Y is large
if X is large then Y is small.

$$f^* = \text{small} \times \text{small} + \text{medium} \times \text{large} + \text{large} \times \text{small}.$$




point of departure
fuzzy set
granule
linguistic variable
fuzzy rule
fuzzy graph
propositions in NL
premises
test-score semantics
canonical forms
fuzzy constraints
inference in fuzzy logic
constraint propagation
induced constraints
linguistic approximation
propositions in NL
conclusions

(a)


initial data set (IDS)
computing with words (CW)
terminal data set (TDS)
propositions in NL
constraint explicitation
constraint propagation
constraint retranslation
propositions in NL

(b)

Canonical Form

- Formal expression of a mathematical object
  - In this case, an object of natural language

$$p \rightarrow X \text{ is } R$$

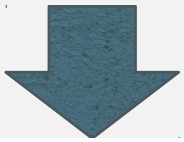
  - X: Constrained variable
  - R: Constraining fuzzy relation

Explanatory Database

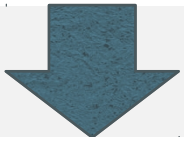
- A collection of relations including:
  - Names
  - Attributes
  - Domains
- Returns constrained variable X and the constraining variable R
- EDI = Explanatory Database Instantiated

Canonical Form Conversion

p = Mary is not very young.

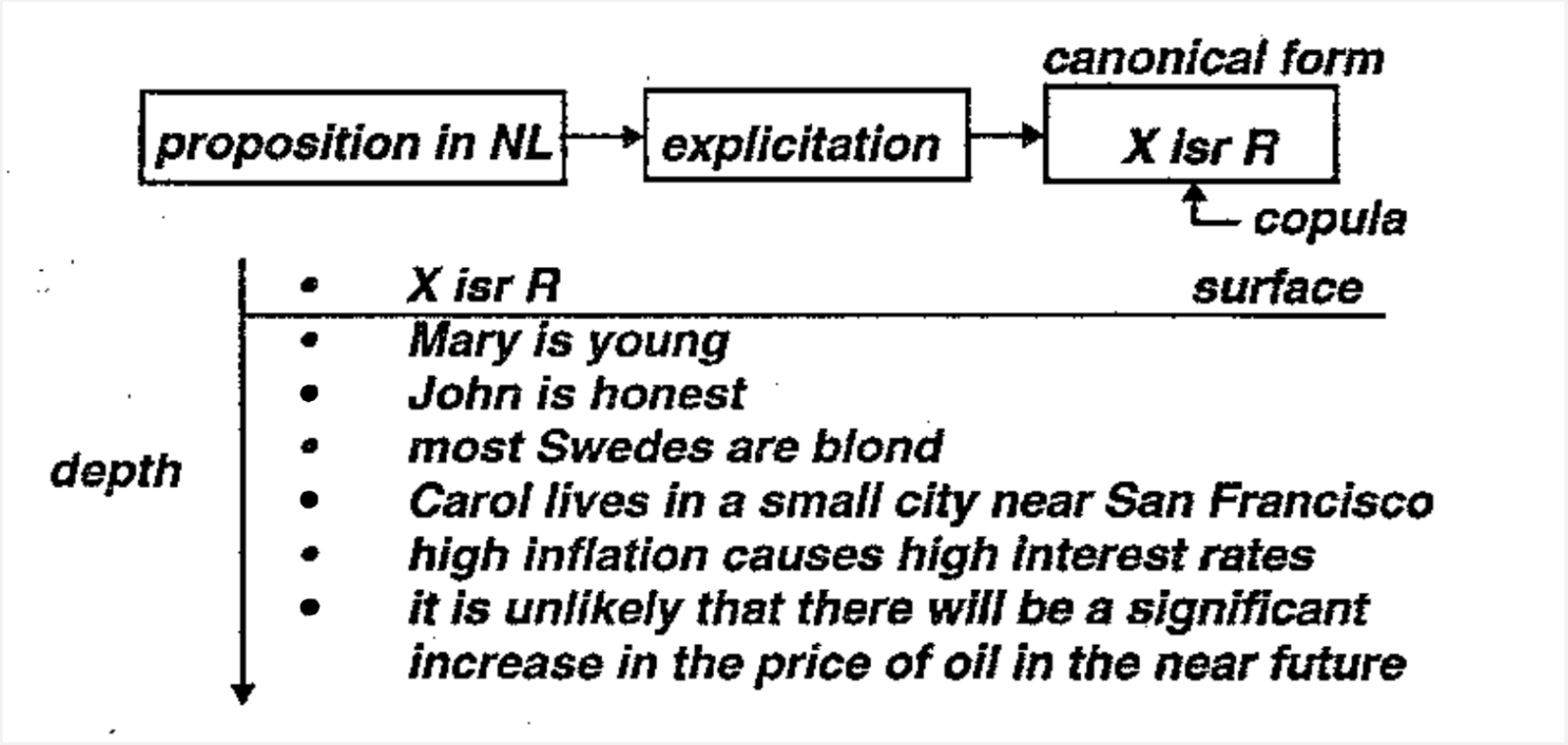


$$\text{ED} = \text{POPULATION}[\text{Name; Age}] + \text{YOUNG}[\text{Age; } \mu]$$



$$X = \text{Age(Mary)} =_{\text{Age}} \text{POPULATION}[\text{Name} = \text{Mary}].$$

$$R = ({}^2\text{YOUNG})' \qquad R = \text{YOUNG}[\text{Age; } 1 - \mu^2].$$


canonical form
proposition in NL
explicitation
X isr R
copula
surface
depth
X isr R
Mary is young
John is honest
most Swedes are blond
Carol lives in a small city near San Francisco
high inflation causes high interest rates
it is unlikely that there will be a significant increase in the price of oil in the near future

A More Complex Canonical Form Example

p = Carol lives in a small city near San Francisco

$$\begin{aligned} \text{ED} = \text{POPULATION}&[\text{Name; Residence}] \\ &+ \text{SMALL}[\text{City; } \mu] \\ &+ \text{NEAR}[\text{City 1; City 2; } \mu]. \end{aligned}$$

$$\begin{aligned} X &= \text{Residence}(\text{Carol}) \\ &=_{\text{Residence}} \text{POPULATION}[\text{Name} = \text{Carol}] \end{aligned}$$

$$R = \text{SMALL}[\text{City; } \mu] \cap_{\text{City1}} \text{NEAR}[\text{City 2} = \text{San Francisco}].$$

Constraints

$$X \text{ isr } R$$

e:	equal (abbreviated to =)
d:	disjunctive (possibilistic) (abbreviated to blank)
c:	conjunctive
p:	probabilistic
λ:	probability value
u:	usuality
rs:	random set
rsf:	random fuzzy set
fg:	fuzzy graph
ps:	rough set (Pawlak Set)

Conjunctive Example

- Conjunctive: Expresses if grade of membership of u in R is m, then $X = u$ has th

p = John is proficient in English, French, and German

X isc R

Proficiency(John) isc (Fluent/English + Semi-Fluent/French + Basic/German)

Fuzzy Constraint Propagation

- Rules of Interference in Fuzzy Logic
- Rules Governing Fuzzy Constraint Modification

Conjunctive Rule 1:

$$\frac{X \text{ is } A \qquad X \text{ is } B}{X \text{ is } A \cap B}.$$

Disjunctive Rule 1:

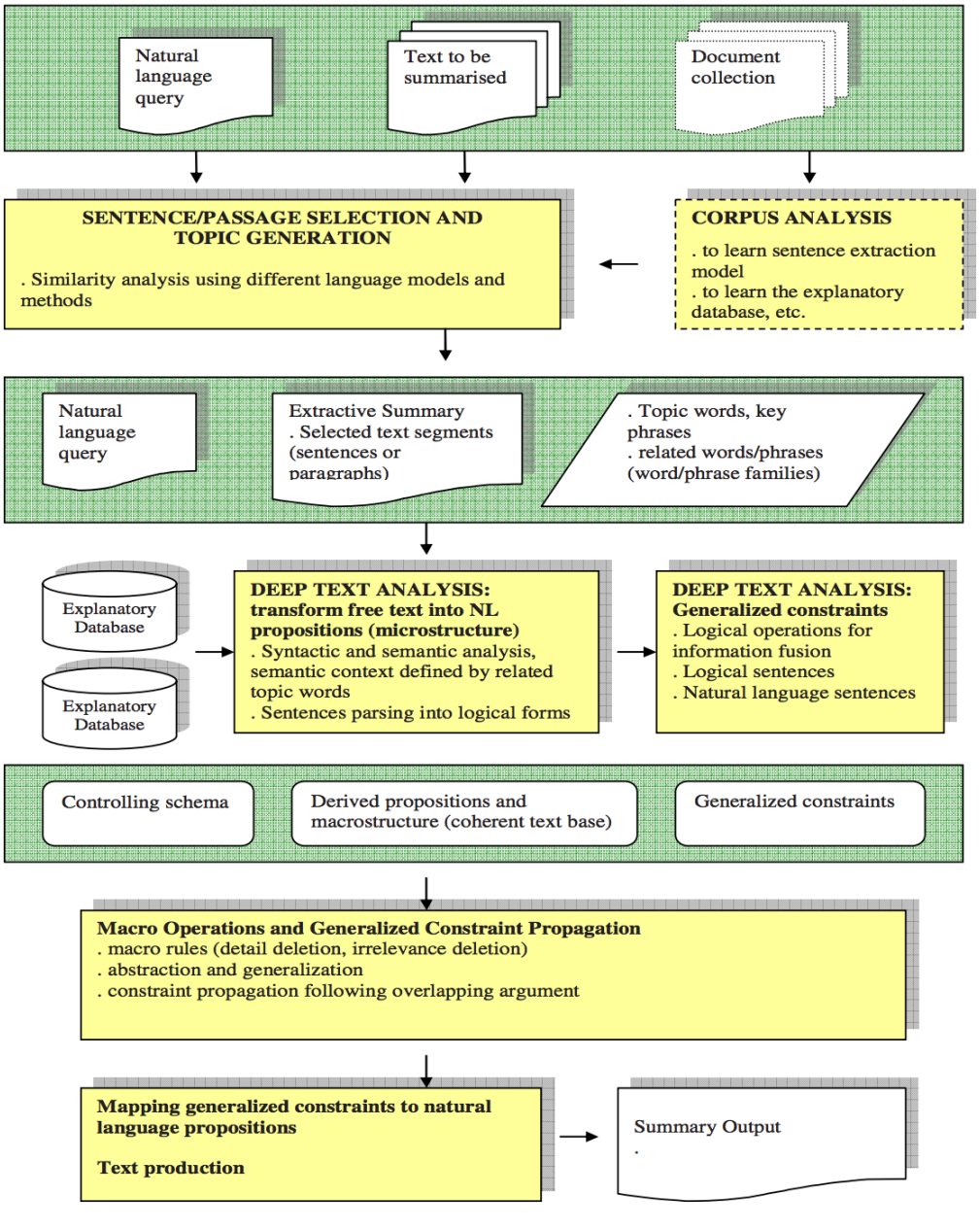
$$X \text{ is } A$$

or

$$\frac{X \text{ is } B}{X \text{ is } A \cup B}.$$

Application of CWW

- “Computing with Words Using Fuzzy Logic: Possibilities for Application in Automatic Text Summarization” (2007), Shuhua Liu


Natural language query
Text to be summarised
Document collection
SENTENCE/PASSAGE SELECTION AND TOPIC GENERATION
. Similarity analysis using different language models and methods
CORPUS ANALYSIS
. to learn sentence extraction model
. to learn the explanatory database, etc.
Natural language query
Extractive Summary
. Selected text segments (sentences or paragraphs)
. Topic words, key phrases
. related words/phrases (word/phrase families)
Explanatory Database
Explanatory Database
DEEP TEXT ANALYSIS: transform free text into NL propositions (microstructure)
. Syntactic and semantic analysis, semantic context defined by related topic words
. Sentences parsing into logical forms
DEEP TEXT ANALYSIS: Generalized constraints
. Logical operations for information fusion
. Logical sentences
. Natural language sentences
Controlling schema
Derived propositions and macrostructure (coherent text base)
Generalized constraints
Macro Operations and Generalized Constraint Propagation
. macro rules (detail deletion, irrelevance deletion)
. abstraction and generalization
. constraint propagation following overlapping argument
Mapping generalized constraints to natural language propositions
Text production
Summary Output
.

Questions?