



Introduction to Artificial Intelligence

Lecture 9

Knowledge representation- Semantic nets

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Introduction to Artificial Intelligence

Knowledge representation

- Associationist knowledge
semantic nets, conceptual dependencies
- structured knowledge
frames, scripts
- alternative approaches



- الفرضية التي ينطلق منها تمثيل المعارف هي أن أية عملية ذكية موصوفة مؤلفة من مركبات بنيوية يستخدمها المراقب الخارجي لوصف هذه الفعالية من خلال معارفه ومفاهيمه لهذه العملية.
- وتلعب استقلالية التوصيف الدلالي دوراً رئيسياً في وصف السلوك الذي تعرضه هذه المعرفة.
- **ترتيب الأغراض والعلاقات التي تربط بينها جزء أساسي من التفكير البشري.**
- معظم فعاليات التفكير والاستنتاج تحدث على مستوى الأصناف.
- تقدم الأصناف إمكانية تنظيم وترتيب وتبسيط قاعدة المعارف من خلال الوراثة **inheritance**.



Associationist Theories



نظرية الارتباط

- The meaning of an **object** in terms of a network of associations with other objects
- When humans perceive and reason about an object, that perception is the first mapped into a concept
- This concept is part of the entire knowledge of the world and is connected through appropriate relationships to other concepts
- The relationships form an understanding of the properties and behavior of objects
- For example snow can be associated with cold, white, snowman, slippery and ice

- يأخذ الغرض معناه من خلال شبكة من الارتباطات مع أشياء أخرى
- عندما يدرك الإنسان شيئاً ما ويفكر فيه، فإن هذا الإدراك يُحوّل أولاً إلى مفهوم
- يُعد هذا المفهوم جزءاً من مجمل معرفة العالم، ويرتبط بمفاهيم أخرى من خلال علاقات مناسبة تُشكّل هذه العلاقات فهما لخصائص الأشياء وسلوكها
- على سبيل المثال، يمكن ربط الثلج بالبرد، واللون الأبيض، ورجل الثلج، والزلق، والجليد





main idea: the meaning of a concept comes from the way it is connected to other concepts.

in understanding language and/or reasoning in complex environments, we make use of the rich associativity of knowledge

When Timmy woke up and saw snow on the ground, he immediately turned on the radio.



- تركز على
 - تصانيف الأغراض
 - العلاقات بين الأغراض
 - المفردات البيانية:
 - تمثل الأغراض كعقد.
 - ونمثل العلاقات الثنائية بأحرف ذات علامات Labeled Edges.

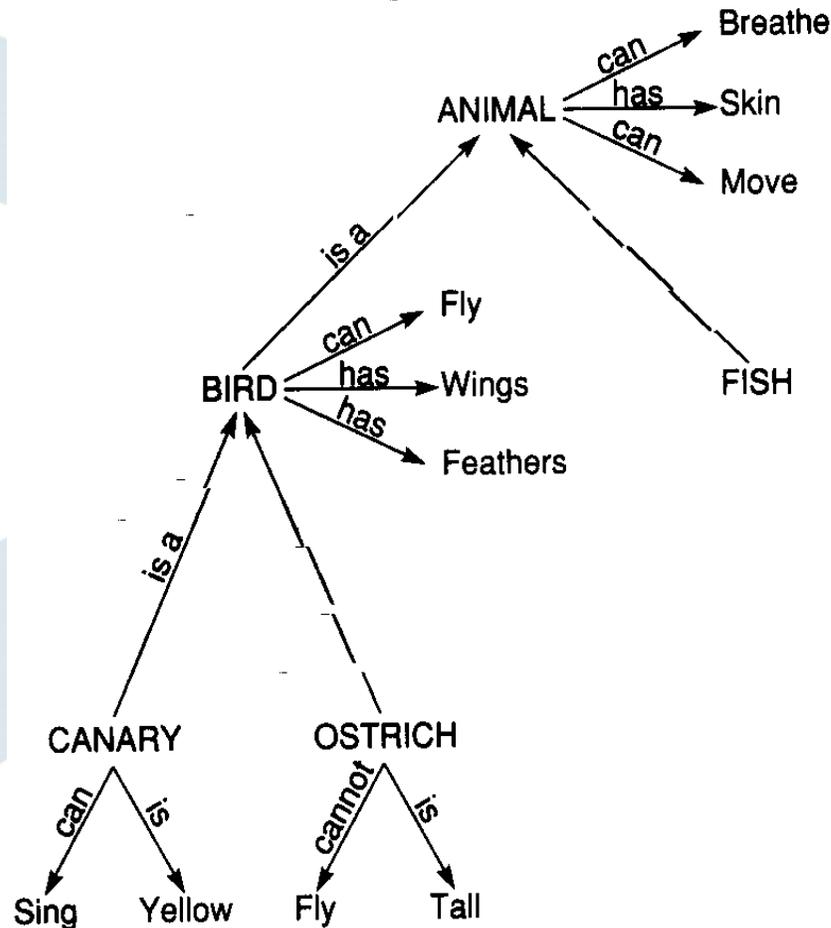


Canary and ostrich are birds which are an animal, that have skin and can breath and move. Birds can fly and has wings and feathers. Canary can sing and is yellow. Ostrich cannot fly and is tall. Fish can breath and move and has skin.





in addition to data retrieval, semantic nets can provide for *deduction* using inheritance



since a canary is a bird, it *inherits* the properties of birds (likewise, animals)

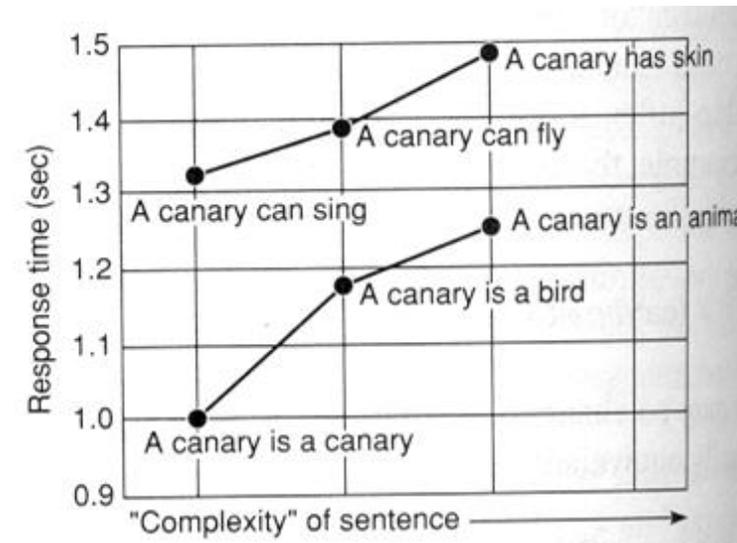
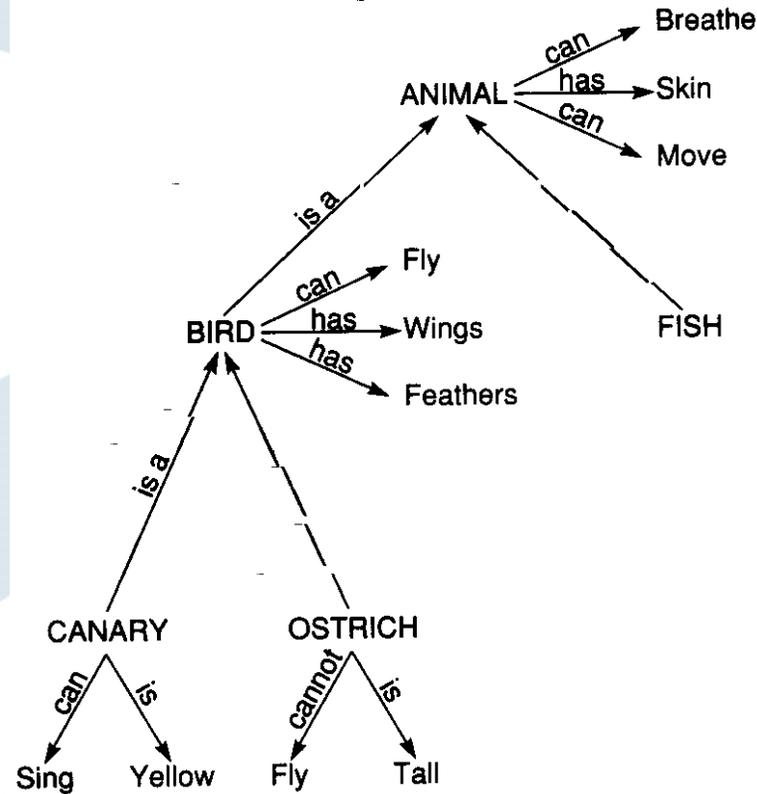
e.g., canary can fly, has skin, ...

to determine if an object has a property,

- look for the labeled association,
- if no association for that property, follow *is_a* link to parent class and (recursively) look there



Quillian and Collins (1969) showed that semantic nets with inheritance modeled human information storage and retrieval





- Knowledge organization has been formalized in inheritance systems
- Inheritance systems allow to store information at the highest level of abstraction which reduces the size of knowledge base and helps prevent update inconsistencies
- Inheritance also helps to maintain the consistency of the knowledge base when adding new classes and individuals





- *semantic network* encompasses a family of graph-based representations
- These representations differ chiefly in the names that are allowed for nodes and links and the inferences that may be performed on these structures
- A common set of assumptions and concerns is shared by all network representation languages
- Represents knowledge as a graph with the nodes corresponding to facts or concepts and the arcs to relations or associations between concepts
- both nodes and links are generally labeled

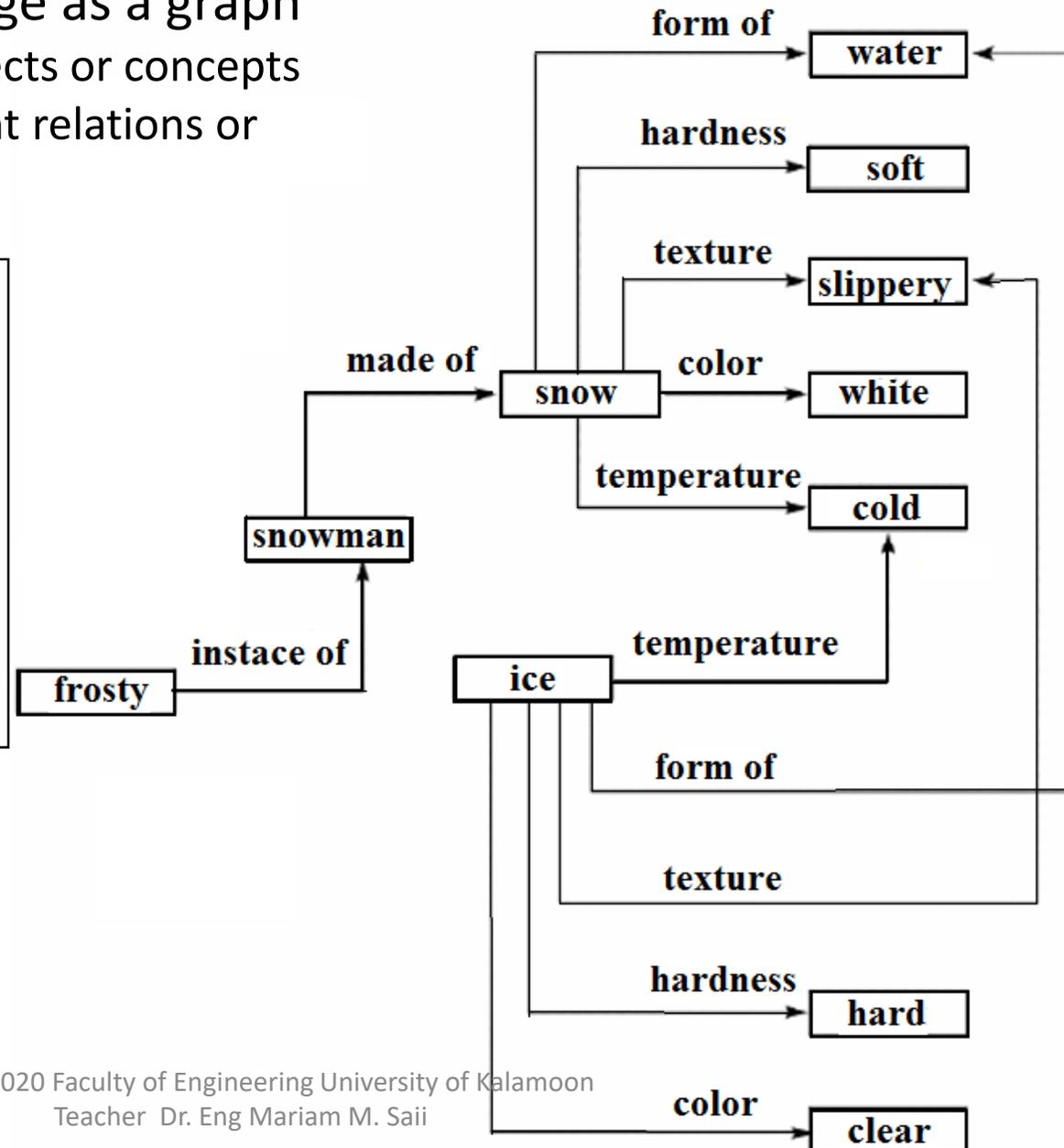


can represent knowledge as a graph

- nodes represent objects or concepts
- labeled arcs represent relations or associations

Snow formed of water. His hardness is soft. His texture is slippery. His color is white. His temperature is cold.

Frosty is a state of snow man, which is made of snow. Ice formed of water. His hardness is hard. His temperature is cold. His color is clear.

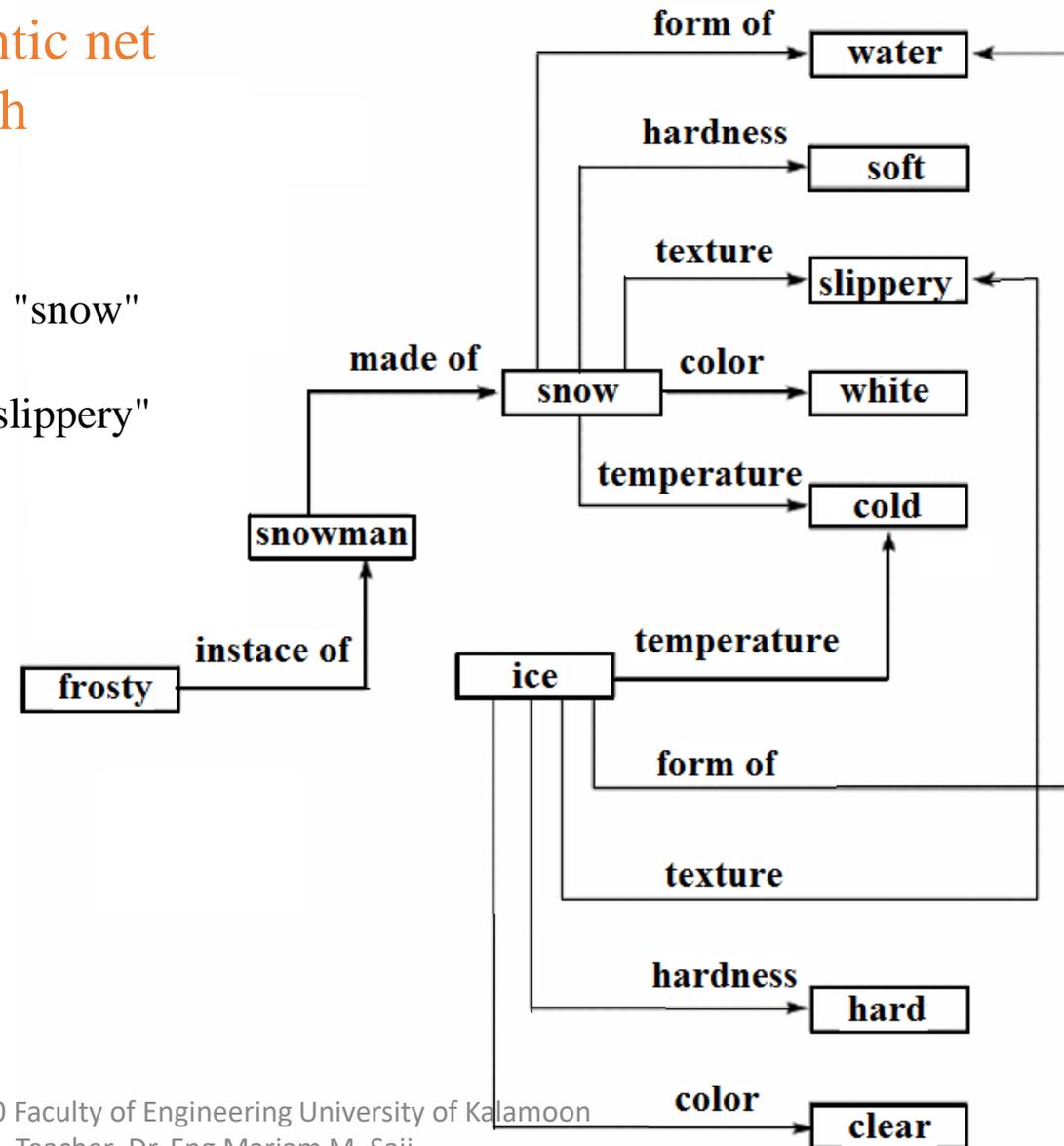




retrieving info from a semantic net
can be seen as a graph search
problem

to find the texture of snow

1. find the node corresponding to "snow"
2. find the arc labeled "texture"
3. follow the arc to the concept "slippery"





- Case relationships include
 - ✓ –agent
 - ✓ –object
 - ✓ –instrument
 - ✓ –location
 - ✓ –time
- A sentence is represented as a verb node, with various case links to nodes representing other participants in the action
- It is called a *case frame*
- In parsing a sentence, the program finds the verb and retrieves the case frame for that verb from its knowledge base
- It then binds the values of agent, object, etc. to the appropriate nodes in the case frame





not surprisingly, early semantic nets did not scale well

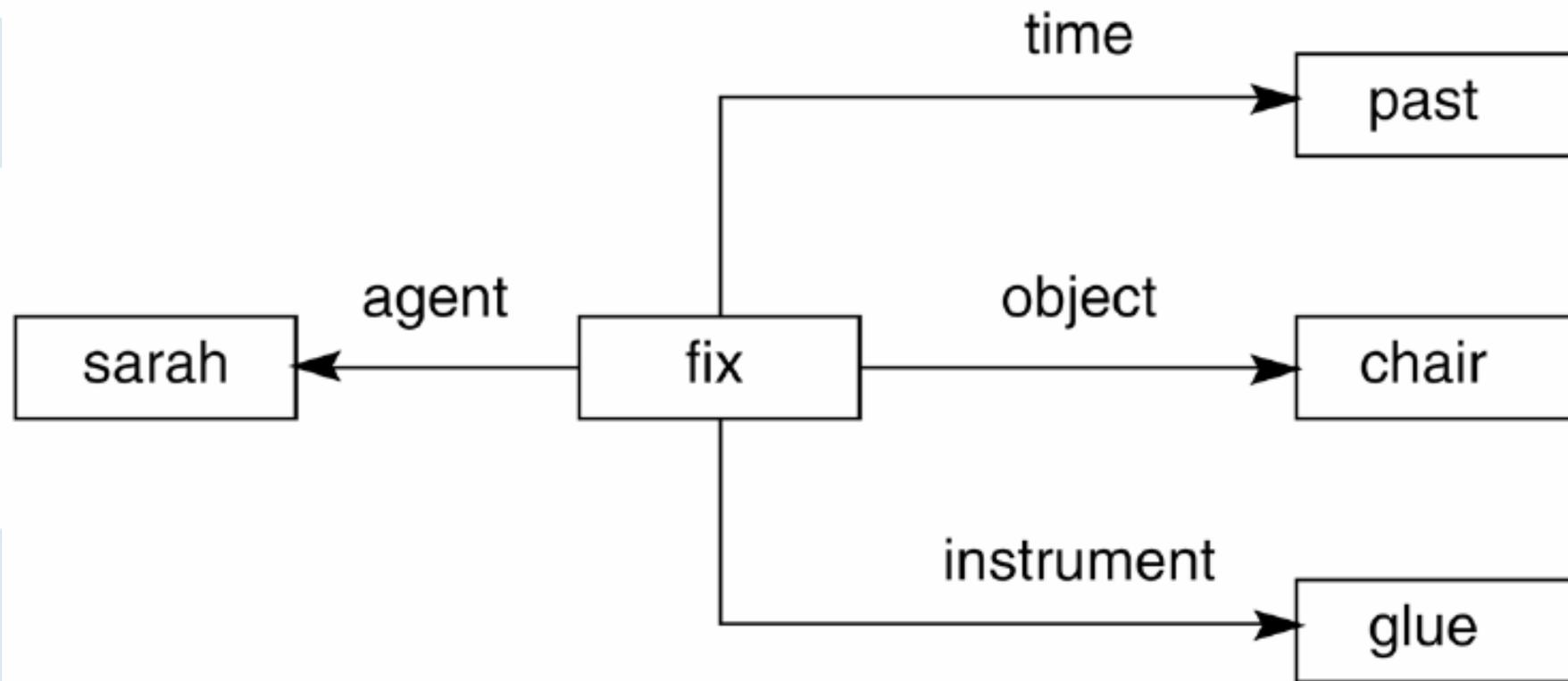
- most links were general associations
- no real basis for structuring semantic relations

much research has been done in defining richer sets of links

- rely on richer formalism, not richer domain knowledge



Case frame representation of the sentence "Sarah fixed the chair with glue."





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much research has been done in defining richer sets of links

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Conceptual Dependency Theory (Schank, 1973)

- attempts to model the semantic structure of natural language
- 4 primitive conceptualizations, from which meaning is built

ACT	action
PP	objects (picture producers)
AA	modifiers of actions (action aiders)
PA	modifiers of objects (picture aiders)

primitive actions include: ATRANS (transfer a relationship, e.g., give)
 PTRANS (transfer physical location, e.g., move)
 MTRANS (transfer mental information, e.g., tell)



conceptual dependency relationships

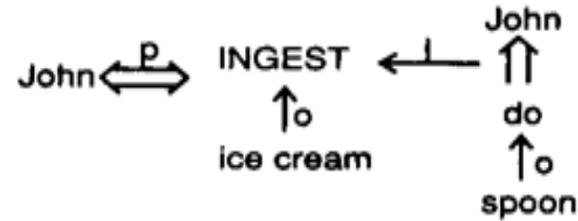
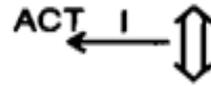
1.	PP ↔ ACT	John $\overset{P}{\longleftrightarrow}$ PTRANS	John ran.
2.	PP ↔ PA	John ↔ height (>average)	John is tall.
3.	PP ↔ PP	John ↔ doctor	John is a doctor.
4.	PP ↑ PA	boy ↑ nice	A nice boy
5.	PP ↑↑ PP	dog ↑↑ John POSS-BY	John's dog
6.	ACT $\overset{o}{\longleftarrow}$ PP	John $\overset{p}{\longleftrightarrow}$ PROPEL $\overset{o}{\longleftarrow}$ cart	John pushed the cart.
7.	ACT $\overset{R}{\longleftarrow}$ $\begin{cases} \rightarrow \text{PP} \\ \rightarrow \text{PP} \end{cases}$	John $\overset{p}{\longleftrightarrow}$ ATRANS $\overset{R}{\longleftarrow}$ $\begin{cases} \rightarrow \text{John} \\ \rightarrow \text{Mary} \end{cases}$ ↑ book	John took the book from Mary.



conceptual dependency relationships

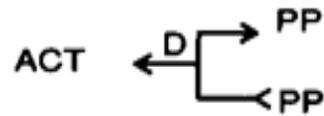


8.



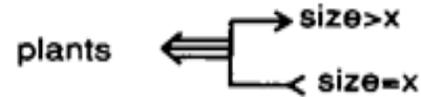
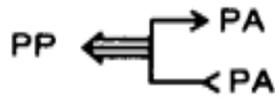
John ate ice cream.

9.



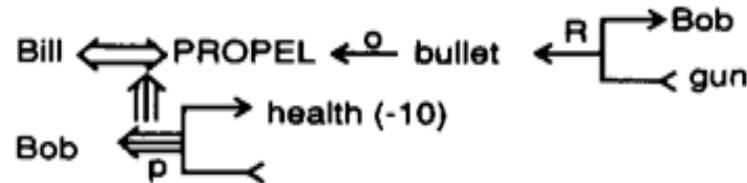
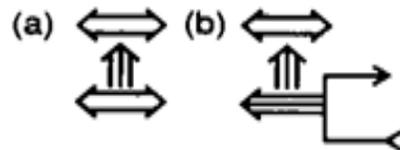
John fertilized the field.

10.



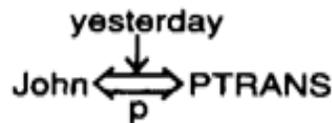
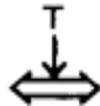
The plants grew.

11.



Bill shot Bob.

12.



John ran yesterday.



conceptual dependency relationships

tense/mode modifiers

p past
 f future
 t transition
 ? interrogative
 / negative

...

PP \Leftrightarrow ACT indicates that an actor acts.

PP \Leftrightarrow PA indicates that an object has a certain attribute.

ACT \xleftarrow{O} PP indicates the object of an action.

ACT \xleftarrow{R} PP indicates the recipient and the donor of an object within an action.

ACT \xleftarrow{D} PP indicates the direction of an object within an action.

ACT $\xleftarrow{1}$ \Updownarrow indicates the instrumental conceptualization for an action.

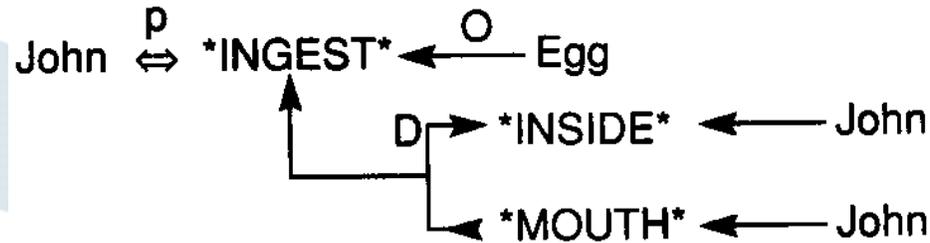
X
 \Uparrow
 Y indicates that conceptualization X caused conceptualization Y. When written with a C this form denotes that X COULD cause Y.

PP \Leftrightarrow PA2 indicates a state change of an object.

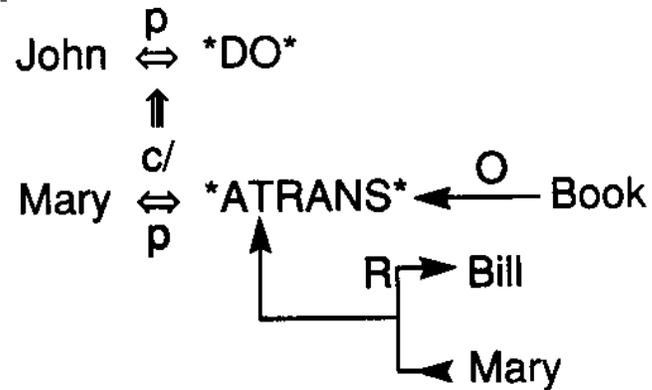
PP1 \leftarrow PP2 indicates that PP2 is either PART OF or the POSSESSOR OF PP1.



conceptual dependency (CD): Example



John ate an egg.



John prevented Mary from giving a book to Bill.



CD for natural language understanding



in the context of natural language understanding, the Conceptual Dependency representation has interesting properties:

- knowledge is represented using conceptual primitives
- actual words/phrases are not stored directly
- ideally, representation is independent of the original language (could be English, French, Russian, ...)

John sold Mary a book.

Mary bought a book from John.

Mary gave John a check for the book.

these sentences describe the same event – a CD representation would reduce these to the same conceptual symbols

ADVANTAGE: syntax is minimized, semantics matters

RESULT: CD representation is good for understanding or paraphrasing sentences



MARGIE (Schank, 1973)



MARGIE: Memory, Analysis, Response Generation in English

the system combined a

- parser (English → CD)
- generator (CD → English)
- inference engine (inferred info from CD)

MARGIE in inference mode

INPUT: John gave Mary an aspirin.

OUTPUT1: John believes that Mary wants an aspirin.

OUTPUT2: Mary is sick.

OUTPUT3: Mary wants to feel better.

OUTPUT4: Mary will ingest the aspirin.

MARGIE in paraphrase mode

INPUT: John killed Mary by choking her.

OUTPUT1: John strangled Mary.

OUTPUT2: John choked Mary and she died because she could not breathe.



Frames (Minsky, 1975)



in contrast to distributed knowledge networks, can instead organize knowledge into units representing situations or objects

When one encounters a new situation (or makes a substantial change in one's view of a problem) one selects from a memory structure called a "frame." This is a remembered framework to be adapted to fit reality by changing details as necessary.

-- Marvin Minsky

HOTEL ROOM

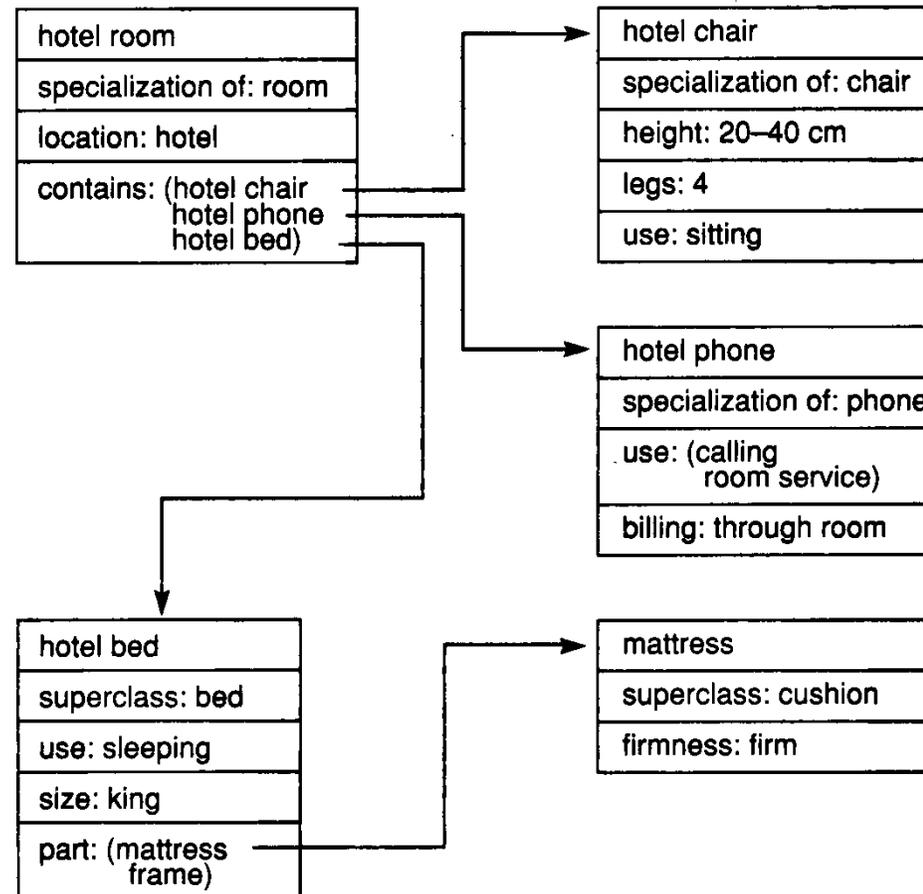


Frames Example



a frame is a structured collection of data

- has *slots* (properties) and *fillers* (values)
- fillers can be links to other frames



Implementation comments



DISCLAIMER: again, this implementation is simplistic

- need to be able to differentiate between instances and classes
- need to differentiate between properties of a class and properties of instances of that class
- need to handle multiple inheritance paths
- as is, not backtrackable

The structured nature of frames makes them easier to extend

- can include default values for slots
- can specify constraints on slots
- can attach procedures to slots

BASEBALL PLAYER
is_a : athlete
height: 6 ft bats: {left, right, switch} hits : 0 atBats : 0 batting avg: hits/atBats ...



Benefit of Conceptual dependency



- By providing a formal theory of natural language semantics, it reduces problems of **ambiguity**.
- The representation itself directly captures much of natural language semantics, by attempting provide **canonical form for the meaning of sentences**. That is, all sentences that have the same meaning will be represented internally by **syntactically identical, not just semantically equivalent, graphs**



Conceptual dependency theory of four primitive conceptualizations

ACTs	actions
PPs	objects (picture producers)
AAs	modifiers of actions (action aiders)
PAs	modifiers of objects (picture aiders)

For example, all actions are assumed to reduce to one or more of the primitive ACTs. These primitives, listed below, are taken as the basic components of action, with more specific verbs being formed through their modification and combination.

ATRANS	transfer a relationship (give)
PTRANS	transfer physical location of an object (go)
PROPEL	apply physical force to an object (push)
MOVE	move body part by owner (kick)
GRASP	grab an object by an actor (grasp)
INGEST	ingest an object by an animal (eat)
EXPEL	expel from an animal's body (cry)
MTRANS	transfer mental information (tell)
MBUILD	mentally make new information (decide)
CONC	conceptualize or think about an idea (think)
SPEAK	produce sound (say)
ATTEND	focus sense organ (listen)



Implementation comments



DISCLAIMER: this semantic net implementation is simplistic

- need to be able to differentiate between instances and classes
- need to differentiate between properties of a class and properties of instances of that class
- need to handle multiple inheritance paths
- as is, not backtrackable

Quillian used an intersection algorithm to find word relationships

- given two words, conduct breadth first search from each node
- look for common concepts (intersection nodes from the searches)



conceptual dependency relationships (Schnak and Reiger 1974)

$PP \leftrightarrow ACT$ indicates that an actor acts.

$PP \Leftrightarrow PA$ indicates that an object has a certain attribute.

$ACT \overset{O}{\leftarrow} PP$ indicates the object of an action.

$ACT \overset{R}{\leftarrow} PP$
 $\quad \quad \quad \rightarrow PP$ indicates the recipient and the donor of an object within an action.

$ACT \overset{D}{\leftarrow} PP$
 $\quad \quad \quad \rightarrow PP$ indicates the direction of an object within an action.

$ACT \overset{1}{\leftarrow} \updownarrow$ indicates the instrumental conceptualization for an action.

X
 \updownarrow
 Y indicates that conceptualization X caused conceptualization Y. When written with a C this form denotes that X COULD cause Y.

$PP \Leftrightarrow PA2$
 $\quad \quad \quad \rightarrow PA1$ indicates a state change of an object.

$PP1 \leftarrow PP2$ indicates that PP2 is either PART OF or the POSSESSOR OF PP1.



Some basic conceptual dependencies and their use in representation



1. PP ↔ ACT

John ↔ PTRANS

John ran.

2. PP ↔ PA

John ↔ height (> average)

John is tall.

3. PP ↔ PP

John ↔ doctor

John is a doctor.

4. PP
↑
PA

boy
↑
nice

A nice boy

5. PP
↑↑
PP

dog
↑↑ POSS-BY
John

John's dog

6. ACT ←^o PP

John ↔^p PROPEL ←^o cart

John pushed the cart.

7. ACT ←^R [PP
PP]

John ↔^p ATRANS
↑^o book
←^R [John
Mary]

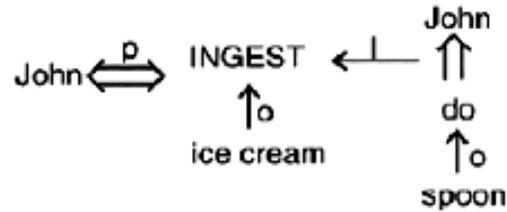
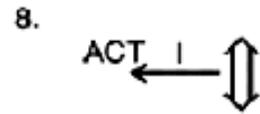
John took the book from Mary.

tense/mode modifiers

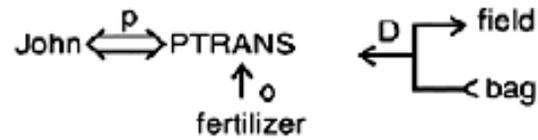
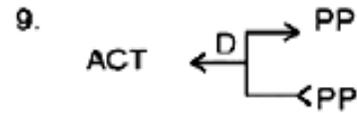
p past
f future
t transition
? interrogative
/ negative



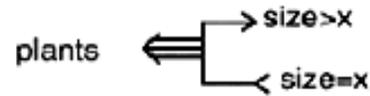
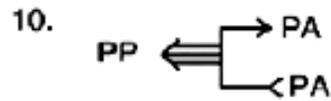
Some basic conceptual dependencies and their use in representation



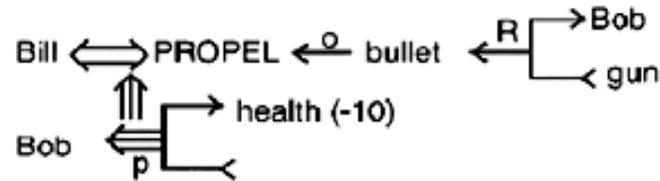
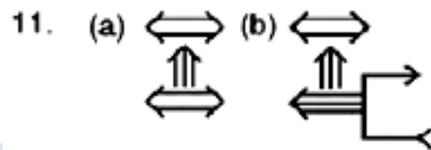
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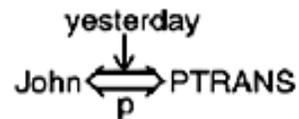
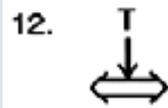
John fertilized the field.



The plants grew.



Bill shot Bob.



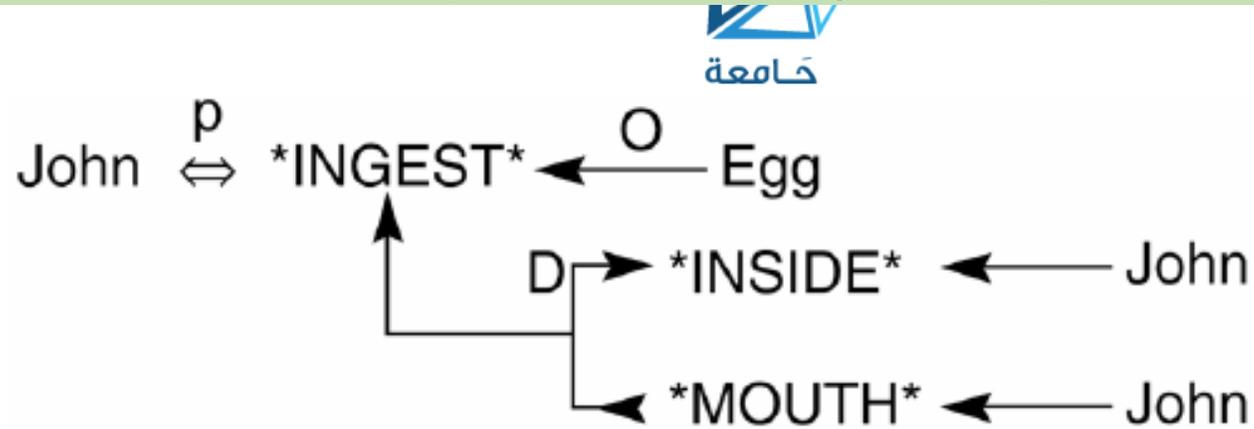
John ran yesterday.

tense/mode modifiers

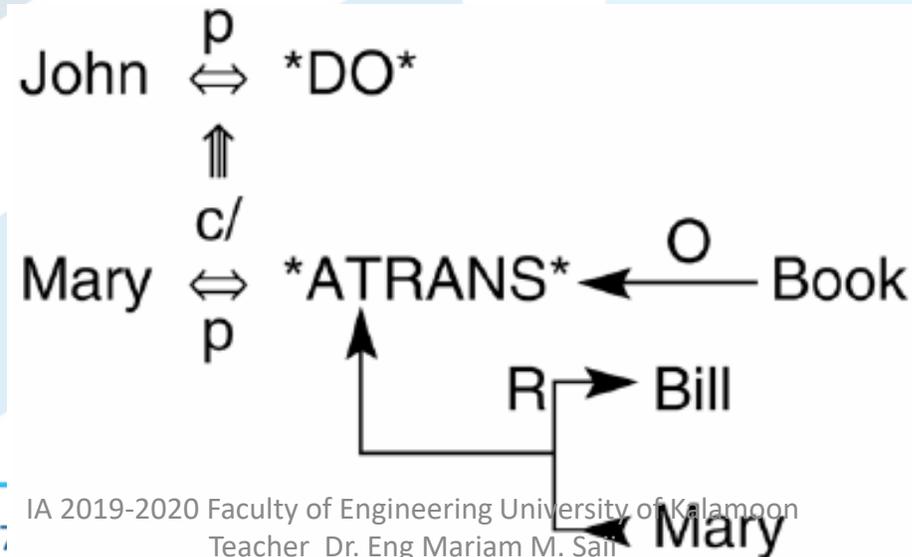
- p past
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- t transition
- ? interrogative
- / negative
- ...



Conceptual dependency representing “John ate the egg”
(Schank and Rieger 1974).



Conceptual dependency representing “John prevented Mary from giving a book to Bill”
(Schank and Rieger 1974).



CD for natural language understanding



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ADVANTAGE: syntax is minimized, semantics matters

RESULT: CD representation is good for understanding or paraphrasing sentences



Questions



Example

John went to a restaurant last night. He ordered steak. When he paid he was running out of money. He hurried home since it had started to rain.

Questions

Did John eat dinner last night? Did John use cash or a credit? How could John get a menu? What did John buy?

Example

Sue went to lunch. She sat a table and called a waiter, who brought her a menu. She ordered a sandwich.

Questions

Why did the waitress bring Sue a menu? Was Sue in a restaurant? Who paid? Who was the “she” who ordered the sandwich?



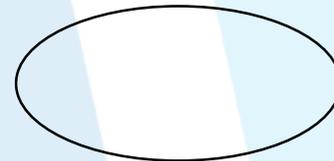
Conceptual Graphs: A Network Language



- An example of a network representation language
- Conceptual Graph
 - finite, connected, bipartite graph
- Nodes of the graph
 - concepts or conceptual relations
- Do not use labeled arcs; instead the conceptual relation nodes represent relations between concepts



concept



concept relation



Conceptual Graphs: Example



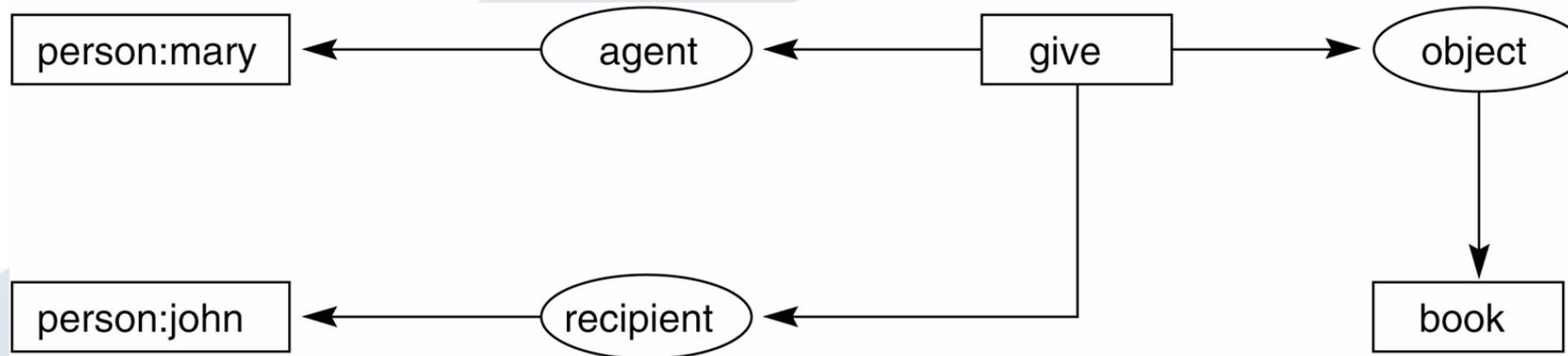
Present the following statement using Conceptual graph.

1. Mary gave John a book.
2. The dog named Emma is brown.
3. A dog named Emma is brown.
4. The dog scratches its ear with its paw
5. A particular (but named) dog is brown
6. John gave Tom an ice-cream
7. Basket ball player are tall
8. John took the big knife from the big man



Conceptual Graphs: Example

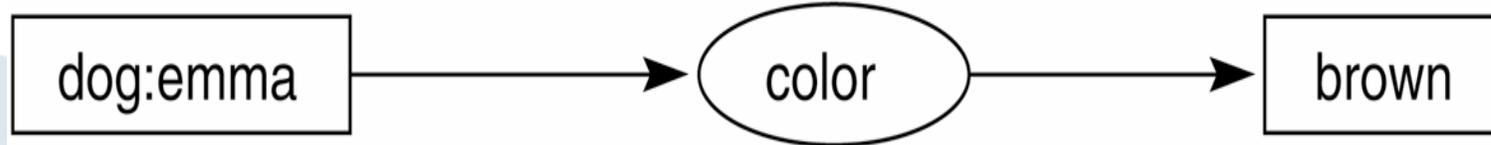
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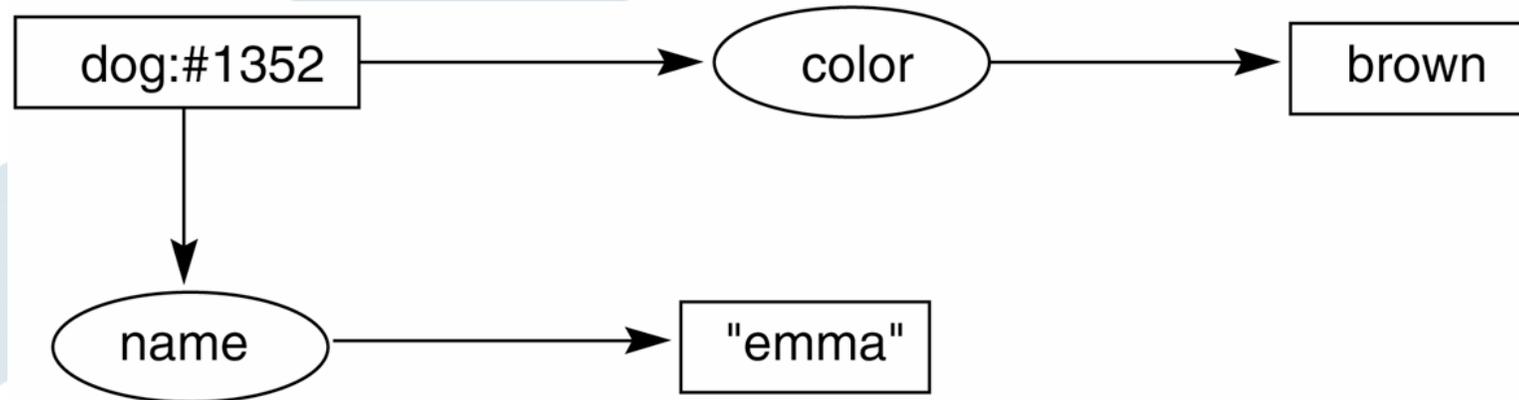
Conceptual Graphs: Example



1. The dog named Emma is brown.



2. A dog named Emma is brown.

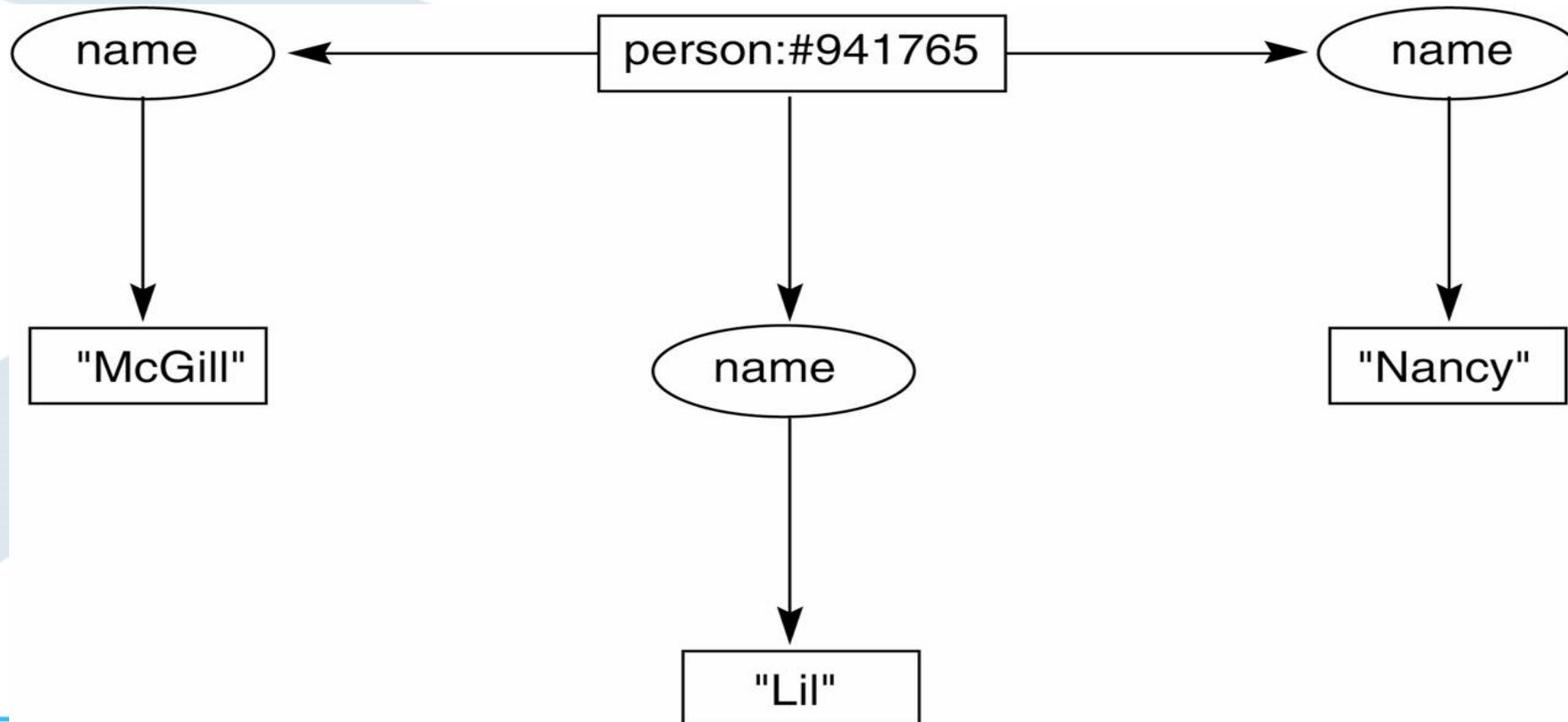


3. A particular (but named) dog is brown



Conceptual Graphs: Example

Conceptual graph of a person with three names.



Conceptual Graphs: Example

The dog scratches its ear with its paw

