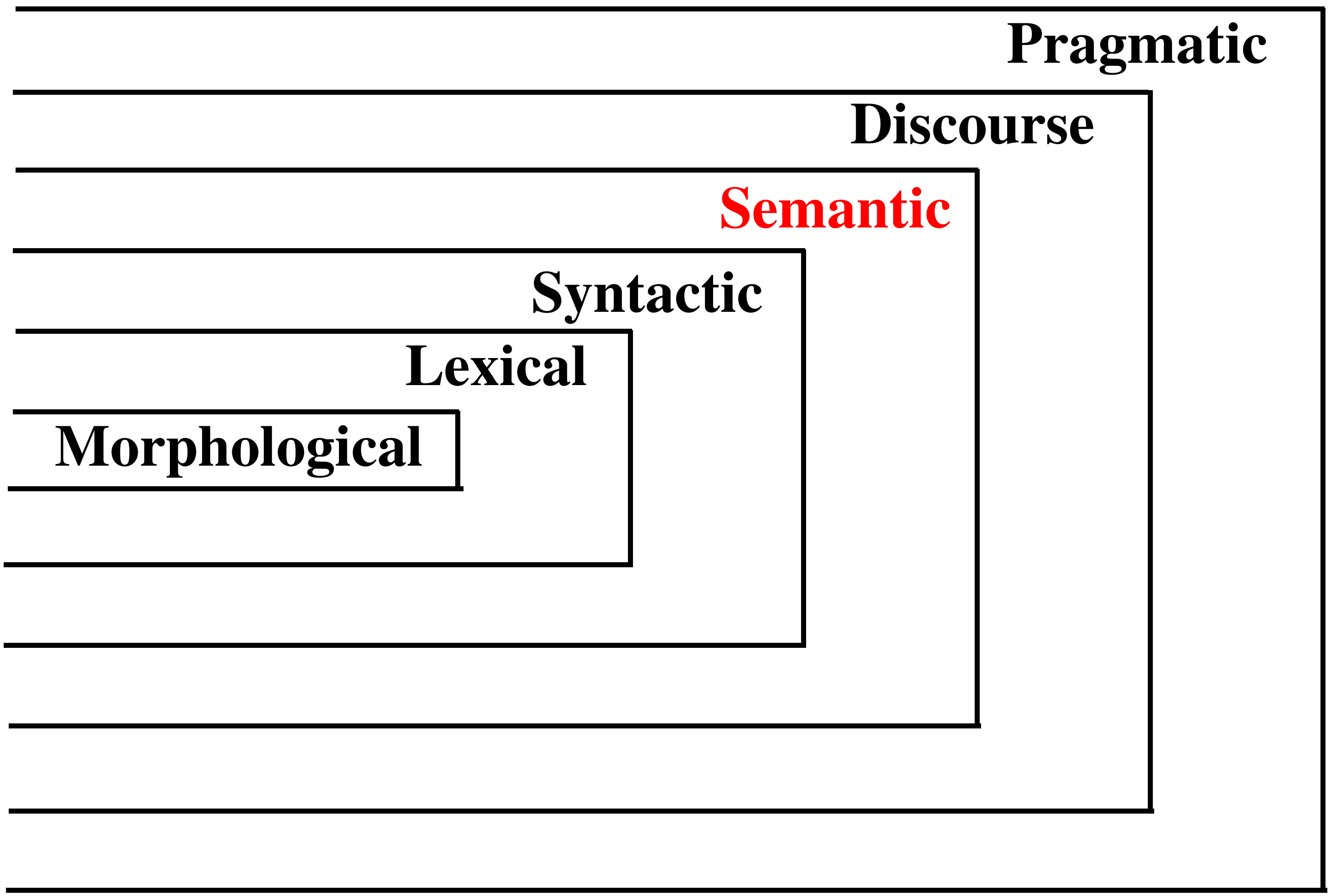
Semantic Representations

Synchronic Model of Language



Semantic Representation

- Descriptions of the world that a system can use to perform human-like tasks

- Some possible knowledge representation approaches:
  - First Order Logic
  - Semantic Nets
  - Conceptual Dependency
  - Frames
  - Rule-Based
  - Conceptual Graphs
  - Case Grammer

Why do we need semantic representations?

- To link the surface, linguistic elements to the non-linguistic knowledge of the world
  - Many words, few concepts
- Structures composed from a set of symbols
  - All languages have a predicate-argument structure
  - Correspond to relationships that hold among concepts underlying constituent words and phrases of a sentence, and then across sentences
- To represent the variety at the lexical level at a unified conceptual level
  - Unambiguous representations; canonical forms
- Can be used to reason, both to verify what is true in the world and to infer knowledge from the semantic representation

First Order Logic

- Also known as Predicate Calculus
- A symbolic language whose symbols have precisely stated meanings and uses
  - The symbols can be used as meanings in the real world
  - Typically express properties of entities in the world
- First Order Logic (FOL) often used in AI systems found in such applications as robotics and computational control systems
  - Allows a natural language interface to such systems
- Example – *if Socrates is a man, then Socrates is a mortal*

  Man (Socrates) -> Mortal (Mortal)

FOL language

- FOL uses terms to represent objects in the real world
  - Constants are specific objects in the world
    - Socrates, Pastabilities
  - Functions represent concepts about objects
    - LocationOf (Pastabilities)
  - Variables are used to stand for any object
    - X
- FOL uses predicates to state relations between objects
  - If Serves is a predicate taking a restaurant and a type of food as arguments, we can state that a particular restaurant serves a type of food
    - Serves (Pastabilities, VegetarianFood)

FOL language, cont.

- FOL uses connectives *and* and *or* to combine statements
  - Serves (Pastabilites, VegetarianFood) ^ IsExpensive(Pastabilities)
- FOL uses the implication connection to mean if the first statement is true, then the second one is also true
  - Serves(Pastabilities, VegetarianFood) => Restaurant(Pastabilities)
  - Is this true?
- FOL uses the existential quantifier to assert that an object with particular properties exists

  ∃ x Restaurant(x) ^ Serves(x, VegetarianFood)
- FOL uses the universal quantifier to assert that particular properties are true for all objects
  - (forall) x Restaurant(x) => Serves(x, VegetarianFood)

  (this is definitely false because not all restaurants serve vegetarian food)

Example

A person born in the United Kingdom after commencement shall be a British citizen if at the time of birth his father or mother is:

a. a British citizen; or
b. settled in the United Kingdom

Which can be represented as:

((x was born in the U.K.)
^ (x was born on date y
^ (y is after or on commencement)
^ (z is a parent of x)
^ (z is a British citizen on date y))
=> (x is a British citizen)

Reasoning with FOL

- FOL allows inference to make conclusions of new information
  - Inference rule is called “modus ponens”, informally is if-then reasoning

    if we know that A is true and we know that A => B is true,

    we can conclude that B is true

Events in First Order Logic

- So far the predicates have captured state, properties that remain unchanged over some period of time
- Events denote changes in some state and can have a host of participants, props, times and locations.
- One way to give events in FOL is to state the existence of an event that has all the participants, etc.

I ate a turkey sandwich for lunch at my desk on Tuesday.

∃ e Eating(e) ^ Eater(e, Speaker) ^ Eaten(e, TurkeySandwich)
^ Meal(e, Lunch) ^ LocationOf(e, Desk) ^ Time(e, Tuesday)

Difficulties with First Order Logic

- Problem for NLP:
  - ‘semantics’ of logic does not necessarily equate to ‘meaning’ in the real world
  - Not everything is as clear cut as required by a formal logic
  - May not be enough “real world” predicates in the FOL system to capture semantics of text
    - This is a problem for all the semantic representations
    - Semantic systems better developed for objects and actions
    - Not as well developed to represent ideas and beliefs

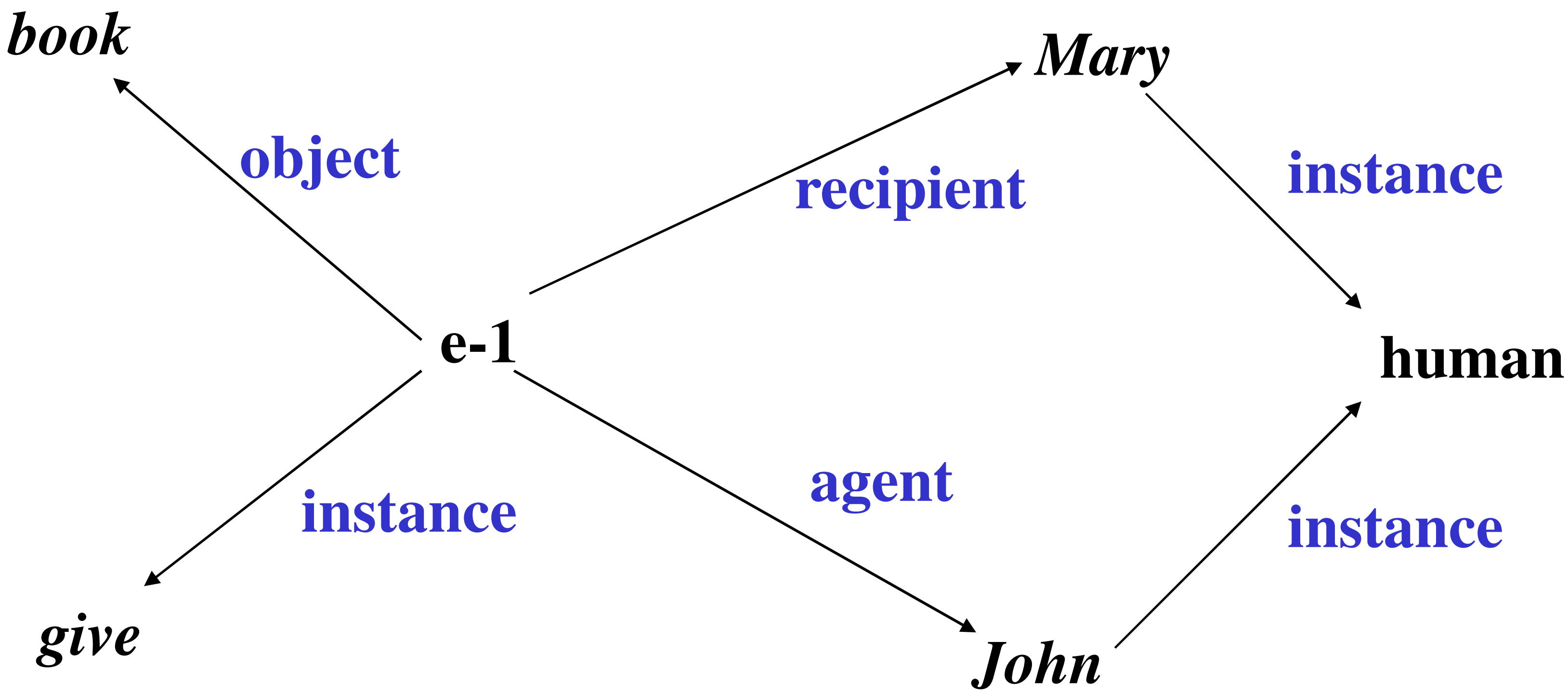
In-class exercise.

Semantic Networks

- Developed specifically for dealing with knowledge about the real world

- Consist of:
  1. A network or graph of nodes joined by links where:
     - nodes represent concepts (e.g. BOOK, GREEN)
     - links (labelled, directed arcs) represent relations (e.g. ISA)
  2. A set of interpretive processes that operate on the network
  3. A parser

John gives a book to Mary.



Semantic Network

Semantic Networks (cont'd)

- Proposed as model of human memory, **but** based very heavily on organization & layout of dictionary entries
- Each node basically corresponds to a <u>word concept</u>
- Provide for:
  - '*type*' nodes which link to other nodes which define its meaning
  - '*token*' nodes which represent individual instances of the '*type*'
- First introduced notion of '*inheritance*'
  - Allows a type node to inherit properties from superclass nodes in definitions
- Claimed to be able to express anything that can be expressed in natural language

Example: Linear Representation of Legal Definitions

Case – a question to be decided in court

Court – a room or building in which law cases can be heard and judged

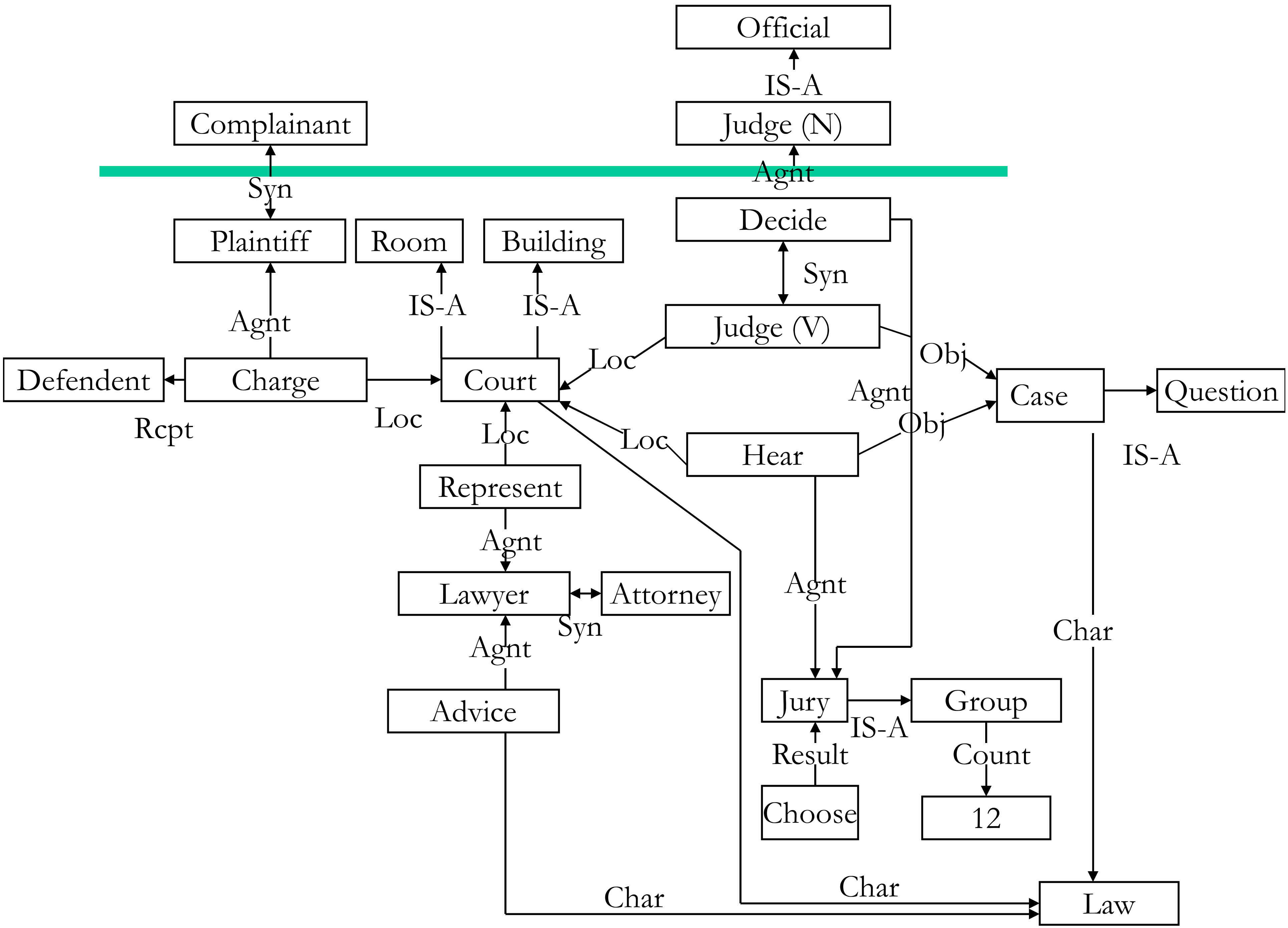
Defendant – a person against whom a charge is brought in a court of law

Judge – a public official who has the power to decide questions brought before a court of law

Jury – a group of 12 people chosen to hear all the details of a case in a court of law and give their decision on it

Lawyer – attorney; a person whose business is to advise people about laws and represent them in court

Plaintiff – complainant; a person who brings a charge against someone


Official
IS-A
Complainant
Judge (N)
Agnt
Syn
Decide
Plaintiff
Room
Building
Syn
IS-A
IS-A
Agnt
Judge (V)
Obj
Defendent
Charge
Court
Loc
Case
Question
Agnt
Rcpt
Loc
Obj
Loc
Loc
Hear
IS-A
Represent
Agnt
Agnt
Lawyer
Attorney
Char
Syn
Agnt
Jury
Group
Advice
IS-A
Result
Count
Choose
12
Char
Char
Law

Frames

- A type of structured representation or *schema*
- Introduced by Marvin Minsky in 1975
  - "A Framework for Representing Knowledge"
  - Most widely referenced paper on knowledge representation
  - Explicitly attempts to represent human processing
- Based on common sense knowledge
- A way of grouping information about an entity or an event or a state in terms of a record of 'slots' and 'fillers'
  - One slot filled by the name of the object that the node stands for
  - Other slots filled with value of various common attributes associated with such an object

Frames (cont'd)

- Enables reasoning about classes of objects by using stereo-typical representations of knowledge which are modified to capture the complexities of the real world
  - Properties in the higher levels of the system are fixed (and inheritable), but the lower levels can be filled with specific values from the instance

- Frame systems consist of collections of frames which are linked together by shared slots
  - Lower level frames inherit properties of higher level frames

FRAMES & INHERITANCE

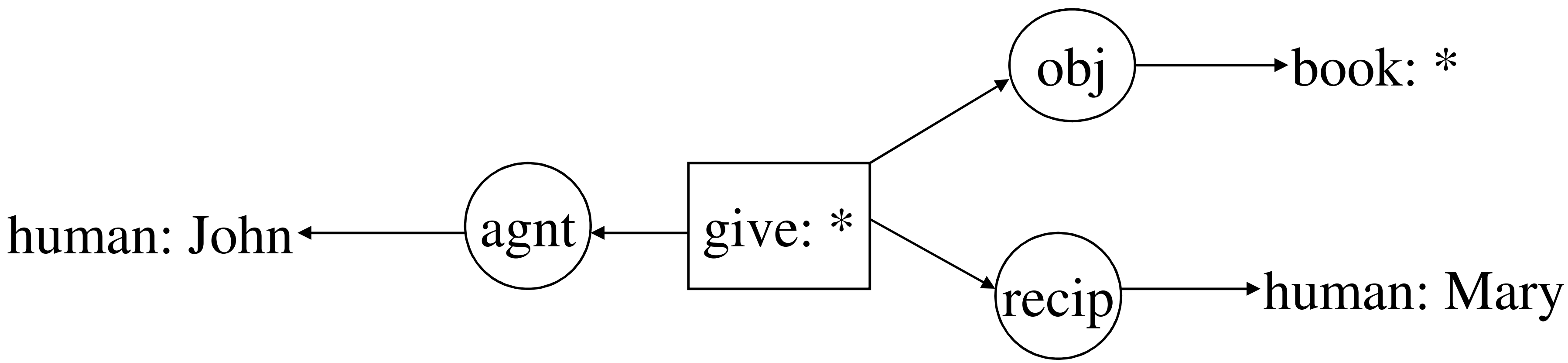
FRAMENAME	MAMMAL
SLOT1	BODYCOVER
SLOT 2	BIRTH: LIVE
SLOT 3	SEX: MALE OR FEMALE

FRAMENAME	DOG
SLOT1	IS-A: MAMMAL
SLOT 2	OFFSPRING: PUPPIES
SLOT 3	VOCALISATION: BARK

FRAMENAME	DOG
SLOT 1	BODYCOVER: FUR
SLOT 2	BIRTH: LIVE
SLOT 3	SEX: MALE OR FEMALE
SLOT 4	OFFSPRING: PUPPIES
SLOT 5	VOCALISATION: BARK

Conceptual Graphs

- Introduced by John Sowa of IBM in 1984
- Utilizes two types of nodes
  - Concepts
  - Unlabelled relations
- A more flexible, extensive, and precisely defined knowledge representation
  - Notation has full representative power of FOL
  - Mapping into logic is fully defined
  - Notation can cope with modal statements
  - Resolves confusion between 'isa' and 'instanceof' relations by maintaining a type hierarchy external to the network



Conceptual Graph Representation

Conceptual Graphs (cont'd)

- Defines operations on CGs which are useful in reasoning
  - *Maximal join* – looks for the greatest match between two conceptual graphs (a generalization of the unification operation)
  - Developed a methodology for performing first-order deductive reasoning
  - Primitives of the theory are:
    - Concept types
    - Concepts
    - Conceptual relations

Conceptual Graphs (cont'd)

- Concept-**types**
  - Represent classes of entity, attribute, state, or event (e.g. CAT, SIT, READ, PRICE, JUSTICE)
  - Broadly correspond to nouns, adjectives, verbs
  - Comprise a type-hierarchy (a partial ordering)
    - CAT < MAMMAL < ANIMAL < PHYSICAL-OBJECT
    - Represents the subsumption relation between concept-types usually represented by IS-A relations in semantic networks
    - Does not include other relations (e.g. agent) in type hierarchy

Conceptual Graphs (cont'd)

- Concepts
  - An instantiation of a concept-type by adding a *referent field* (a unique ID e.g. 'Fred')

- Conceptual Relations
  - The roles that concepts play in relation to each other:
    - ATTR BIG is an *attribute* of MAN
    - AGNT MAN is an *agent* of DRINK
    - OBJT WHISKEY is an *object* of DRINKING
    - MANR SLOW is a *manner* of DRINKING
    - LOC An EVENT takes place in a *location*
  - In language, conceptual relations are indicated by word order, case endings, prepositions, etc.