Semantic Nets, Frames, World Representation

CS – W4701

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Knowledge Representation as a medium for human expression

- An intelligent system must have KRs that can be interpreted by humans.
  - We need to be able to encode information in the knowledge base without significant effort.
  - We need to be able to understand what the system knows and how it draws its conclusions.

Knowledge Representation

- Logic (prepositional, predicate)
- Network representation
  - Semantic nets
- Structured representation
  - Frames
- Issues in KR
  - Hierarchies, inheritance, exceptions
- Advantages and disadvantages

Propositional Logic

- It is raining ➔ **RAINING**
- It is sunny ➔ **SUNNY**

We can deduce whether a certain proposition is true or false

- Socrates is a man ➔ **SOCRATESMAN**
- Plato is a man ➔ **PLATOMAN**

We can not draw any conclusions about Similarities between Socrates and Plato

Predicate Logic

- Socrates is a man ➔ **MAN (SOCRATES)**
- Plato is a man ➔ **MAN (PLATO)**

Now the structure of representation reflects the structure of knowledge

- All Romans were either loyal to Caesar or hated him ➔

$$\forall x ROMAN \rightarrow loyalto(x, Caesar) \vee hate(x, Caesar)$$

It is difficult to represent knowledge in predicate logic with only *THERE EXISTS, ALL, AND, OR*

Semantic Networks

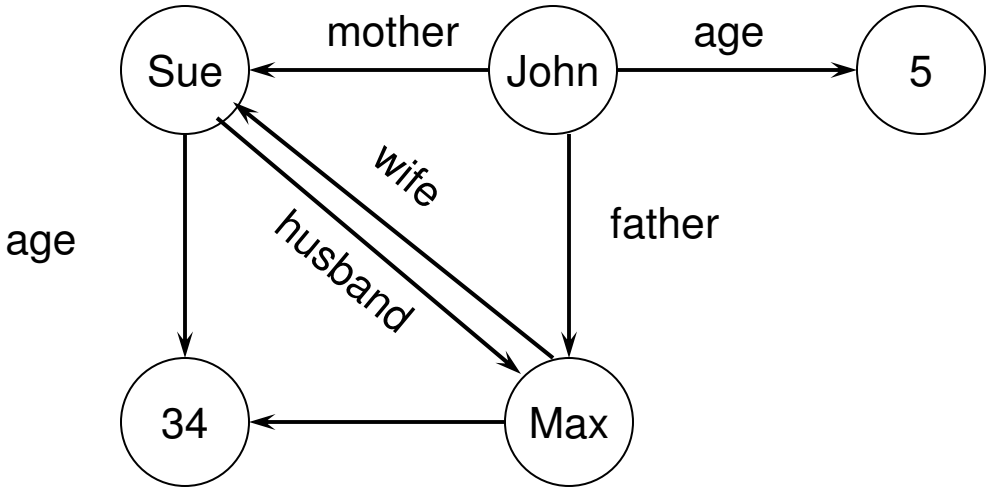
- First introduced by Quillian back in the late-60s

  M. Ross Quillian. "Semantic Memories", In M. M. Minsky, editor, *Semantic Information Processing,* pages 216-270. Cambridge, MA: MIT Press, 1968

- **Semantic network** is simple representation scheme which uses a graph of labeled nodes and labeled directed arcs to encode knowledge
  - Nodes – objects, concepts, events
  - Arcs – relationships between nodes
- **Graphical depiction** associated with semantic networks is a big reason for their popularity

Nodes and Arcs

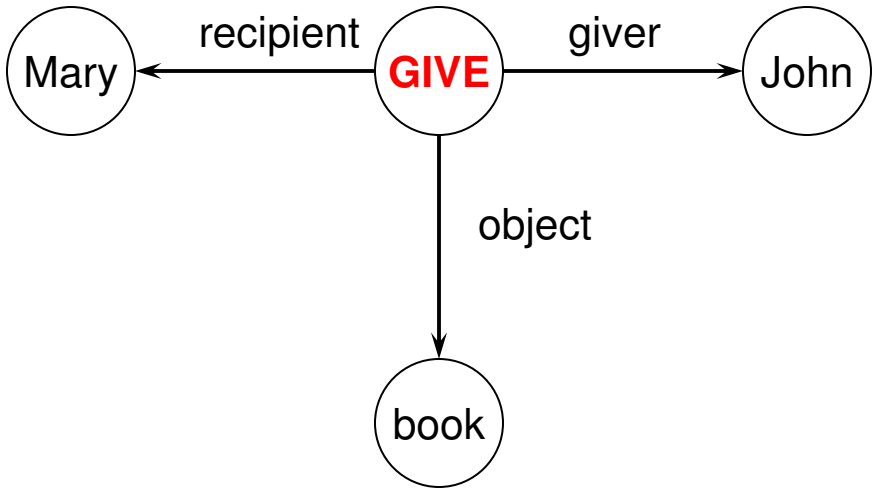
- Arcs define binary relations which hold between objects denoted by the nodes.



mother (john, sue)
age (john, 5)
wife (sue, max)
age (max, 34)
…

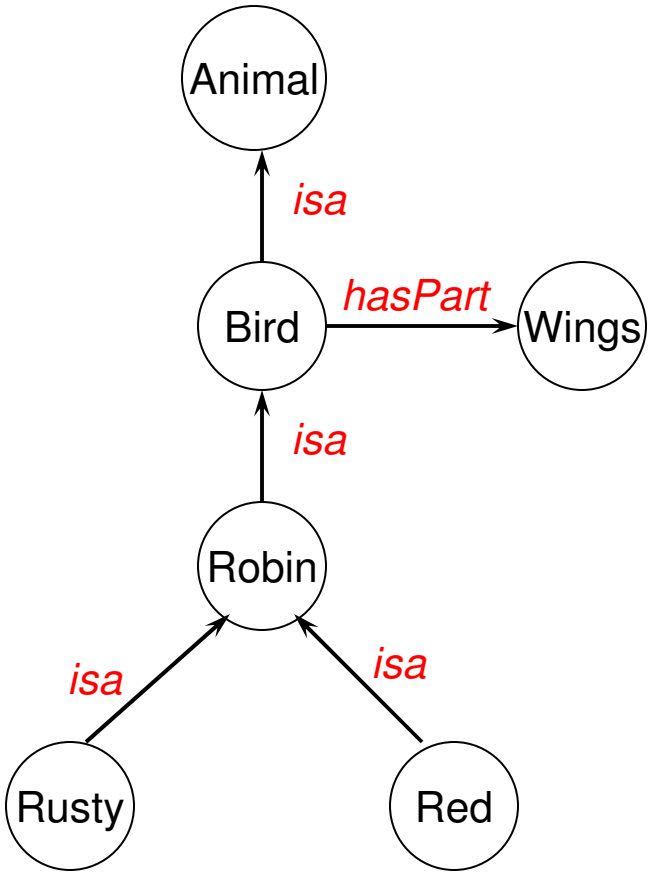
Non-binary relations

- We can represent the generic *give* event as a relation involving three things:
  - A giver
  - A recipient
  - An object



Inheritance

- Inheritance is one of the main kind of reasoning done in semantic nets
- The **ISA** (is a) relation is often used to link a class and its superclass.
- Some links (e.g. **haspart**) are inherited along **ISA** paths
- The semantics of a semantic net can be relatively informal or very formal
  - Often defined at the implementation level

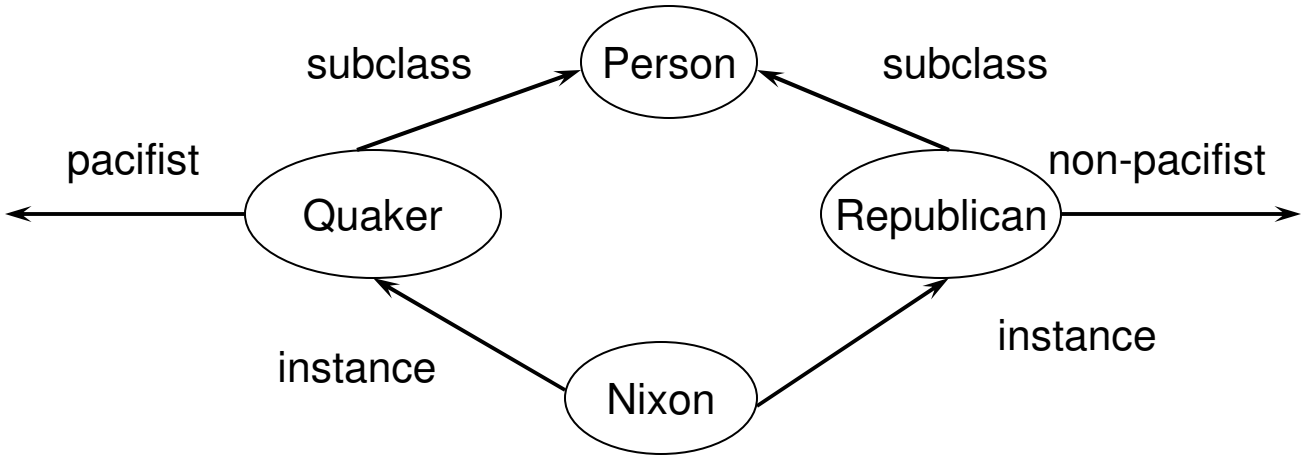


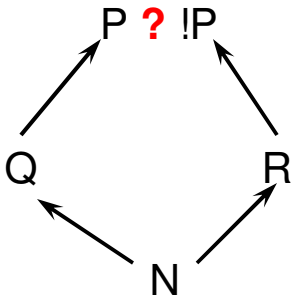
Multiple Inheritance

- A node can have any number of superclasses that contain it, enabling a node to inherit properties from multiple *parent* nodes and their ancestors in the network. It can cause conflicting inheritance.

Nixon Diamond

(two contradictory inferences from the same data)





Example

Advantages of Semantic nets

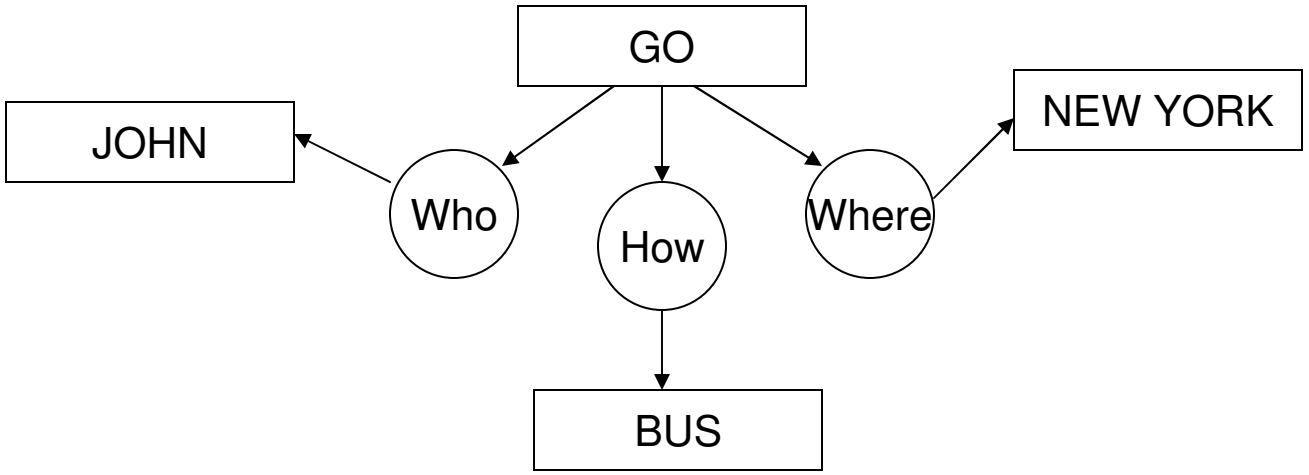
- Easy to visualize
- Formal definitions of semantic networks have been developed.
- Related knowledge is easily clustered.
- Efficient in space requirements
  - Objects represented only once
  - Relationships handled by pointers

Disadvantages of Semantic nets

- Inheritance (particularly from multiple sources and when exceptions in inheritance are wanted) can cause problems.
- Facts placed inappropriately cause problems.
- No standards about node and arc values

Conceptual Graphs

- *Conceptual graphs* are semantic nets representing the meaning of (simple) sentences in natural language
- Two types of nodes:
  - *Concept nodes*; there are two types of concepts, individual concepts and generic concepts
  - *Relation nodes*(binary relations between concepts)



Frames

- Frames – semantic net with properties
- A frame represents an entity as a set of slots (attributes) and associated values
- A frame can represent a specific entry, or a general concept
- Frames are implicitly associated with one another because the value of a slot can be another frame

3 components of a frame

- frame name
- attributes (slots)
- values (fillers: list of values, range, string, etc.)

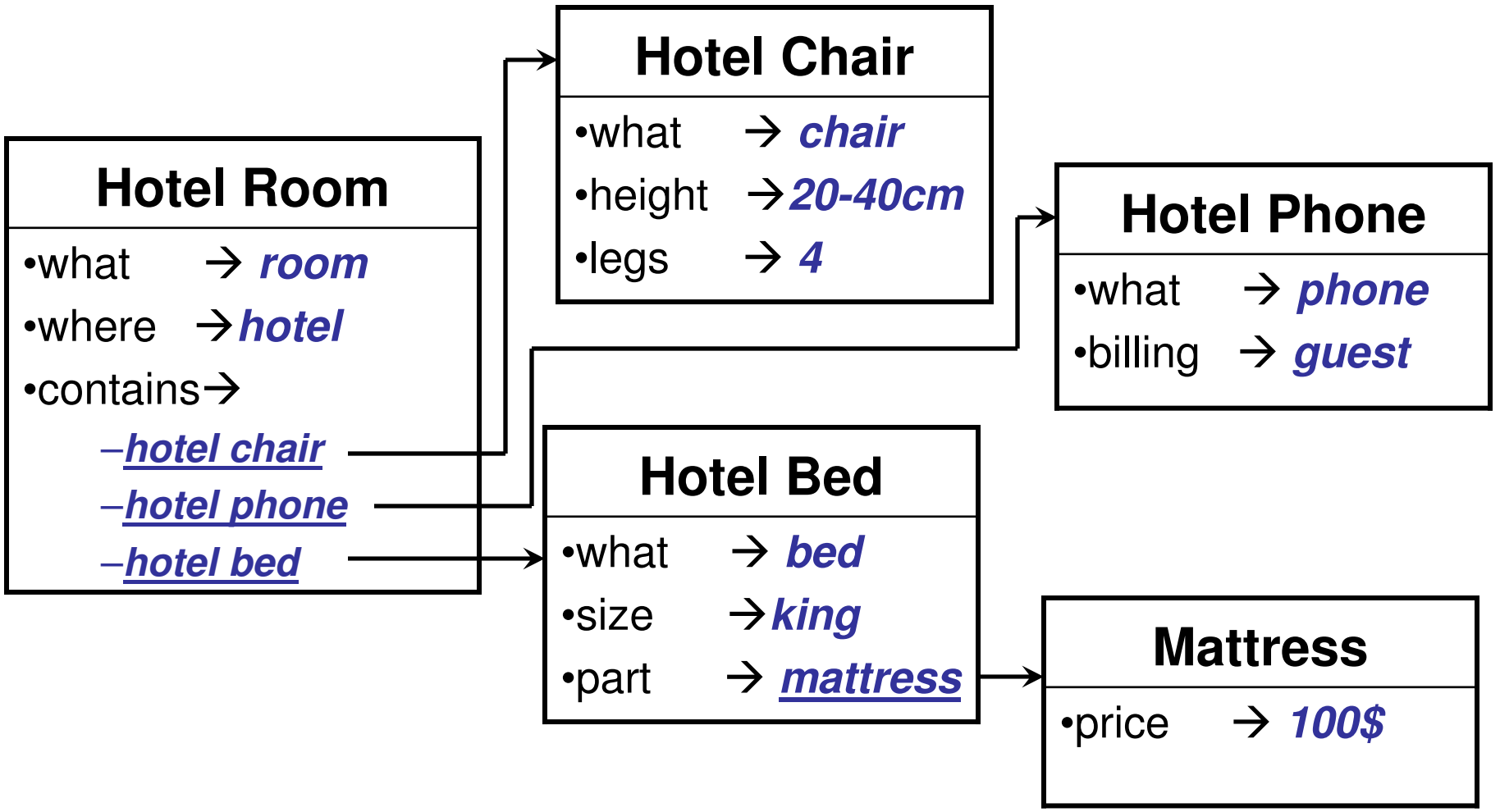
Book Frame	
Slot →	***Filler***
•Title →	***AI. A modern Approach***
•Author →	***Russell & Norvig***
•Year →	***2003***

Features of Frame Representation

- More natural support of values then semantic nets (each slots has constraints describing legal values that a slot can take)
- Can be easily implemented using object-oriented programming techniques
- Inheritance is easily controlled

Inheritance

- Similar to Object-Oriented programming paradigm



Modern Data-Bases combine three approaches:
conceptual graphs, frames, predicate logic
(relational algebra)

Example

Benefits of Frames

- Makes programming easier by grouping related knowledge
- Easily understood by non-developers
- Expressive power
- Easy to set up slots for new properties and relations
- Easy to include default information and detect missing values

Drawbacks of Frames

- No standards (slot-filler values)
- More of a general methodology than a specific representation:
  - Frame for a class-room will be different for a professor and for a maintenance worker
- No associated reasoning/inference mechanisms

Description Logic

- There is a family of frame-like KR systems with a formal semantics
  - KL-ONE, Classic
- A subset of FOL designed to focus on categories and their definitions in terms of existing relations. **Automatic classification**
  - **Finding the right place in a hierarchy of objects for a new description**
- More expressive than frames and semantic networks
- Major inference tasks:
  - Subsumption

    Is category C1 a subset of C2?
  - Classification

    Does Object O belong to C?

KL-ONE (Brachman, 1977)

- Bi-partite view of knowledge representation
    1. Descriptions
    2. Assertions

- Entities can be “described” without making any particular assertions about them

- Descriptions are made from other descriptions using a very small set of operators

KL-ONE basics

- Structured inheritance network
- Basic elements:
  - Concepts: Things in the world
    - Generic concepts
    - Individuals
  - Roles: Conceptual properties of an entity
    - parts, attributes, function arguments, linguistic cases
  - Structured descriptions: Relations among roles

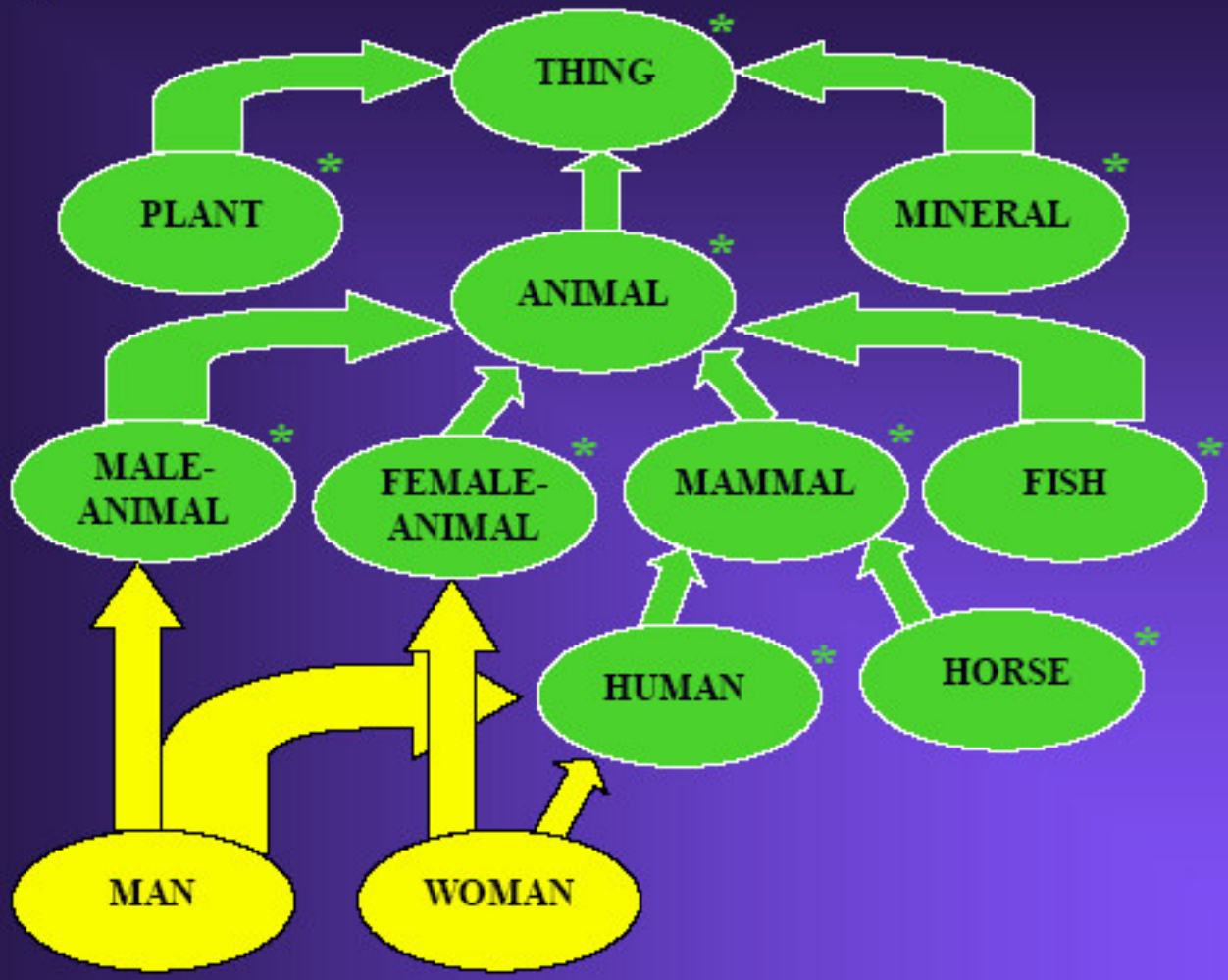
Kinds of concepts

- Defined
  - Have explicit necessary and sufficient properties (roles)
  - Often are specializations of primitive concepts
- Primitive
  - Have no sufficient properties
  - May have other, necessary properties
  - Correspond to *natural kinds*

A KL-ONE Network

- Can be viewed as a kind of semantic network
- Preserves a complex set of relations among descriptions as concepts become more general and more specific
- Clarifies which concepts *subsume* other concepts
- Requires a *classifier* to take new descriptions and to place them where they belong, maintaining all appropriate relationships

A simple KL-ONE network of Generic Concepts

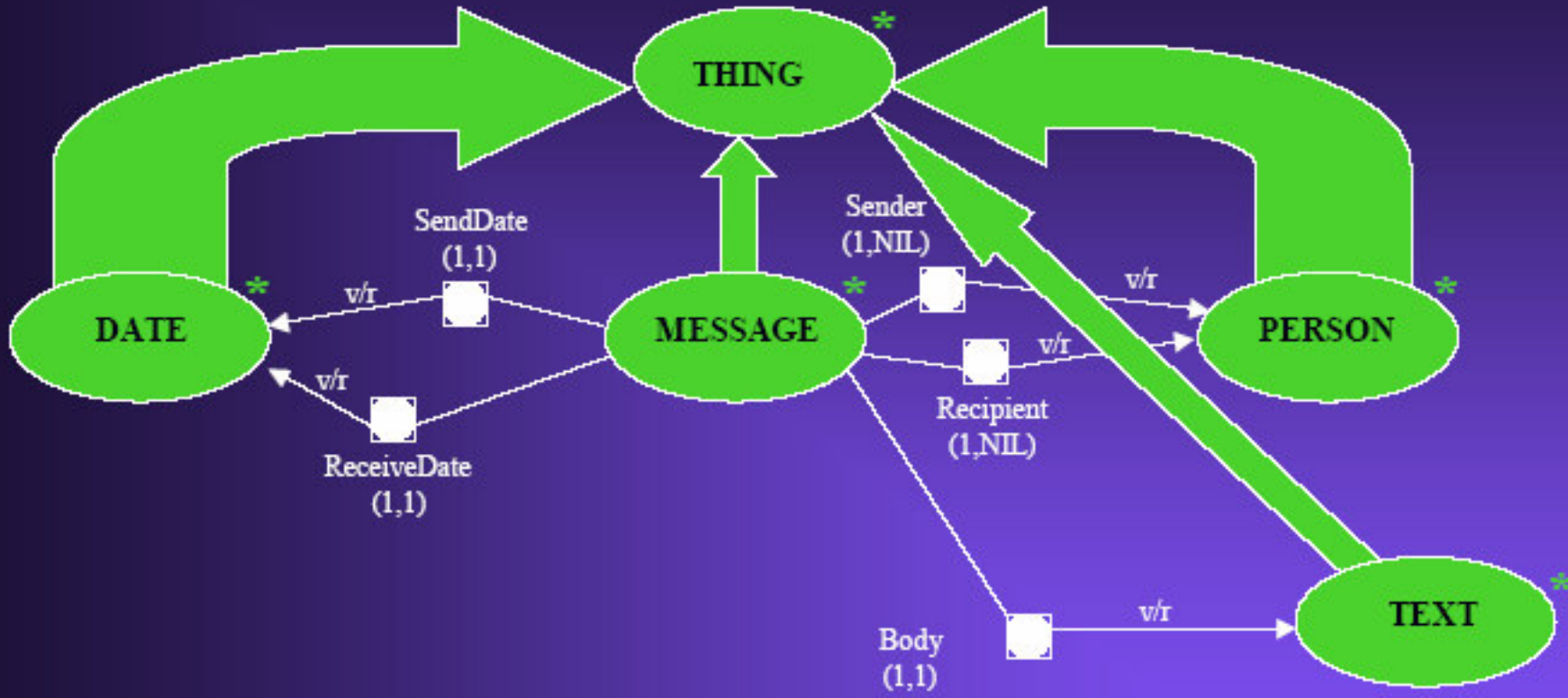


Defined concepts are in yellow;
Primitive concepts are in green.

KL-ONE "Roles"

- Are like *properties* of frames
- Capture the notion that, at different times, a functional role may be played by different entities
- Include value restrictions, which are *necessary* type restrictions on role fillers
- Include number restrictions, which are *necessary* restrictions on cardinality (min, max)

The Primitive Concept MESSAGE



A MESSAGE is, among other things, a THING with at least one Sender, all of which are PERSONs, at least one Recipient, all of which are PERSONs, a Body, which is a TEXT, a SendDate, which is a DATE, and a ReceivedDate, which is a DATE.

OVERFLOW

- Semantic nets: originally developed for mapping sentences (NLP). Example with Shank's graphs.