COMP219: Artificial Intelligence

Lecture 18: Expert Systems and Ontologies

Overview

- Last time
  - Structured objects for knowledge representation

- Today
  - Expert systems
    - General features and architecture
  - One of the most important expert systems: MYCIN
  - General problems with rule-based expert systems
  - Ontologies

- Learning outcome covered today:

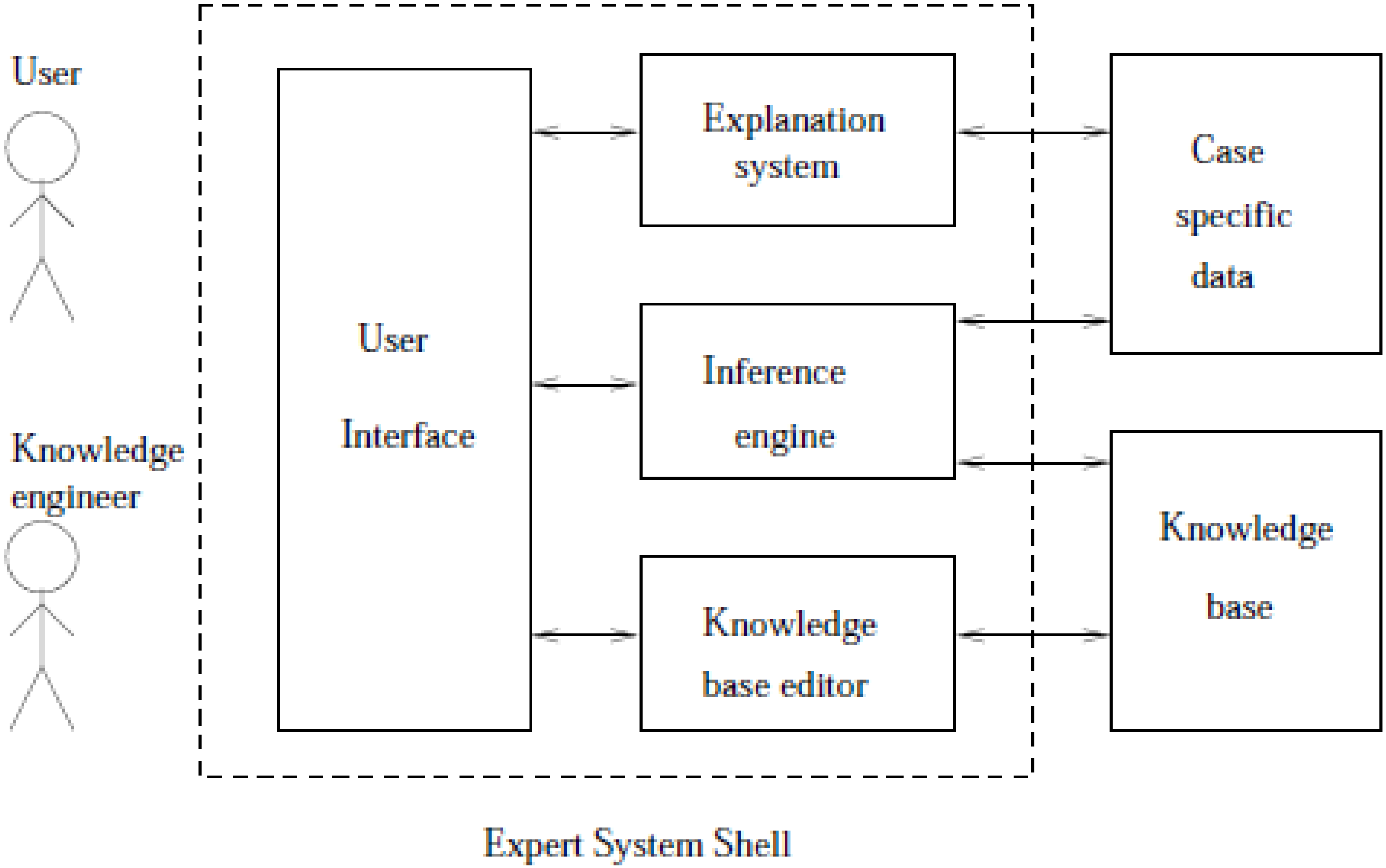
  Identify or describe some of the major applications of AI;

What is an Expert System?

- A expert system is a computing system that is capable of expressing and reasoning about some domain of specialist knowledge
- Typical domains are
  - medicine (INTERNIST, MYCIN, . . .)
  - geology (PROSPECTOR)
  - chemical analysis (DENDRAL)
  - configuration of computers (R1)
  - law (British Nationality Act)

- The purpose of the expert system is to be able to solve problems or offer advice in that domain
- Rule-based expert systems were the big AI success story in the 80s, but later fell from favour

Architecture of an Expert System



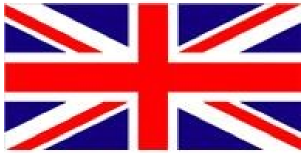
Architecture of an Expert System

- Knowledge base holds the expertise that the system can deploy
  - Constructed by the knowledge engineer in consultation with the domain expert
- Most common KR scheme used is rules, and most ES use backward chaining
- Other KR schemes can be used: Frames (Internist); Semantic networks (Grebe); Bayesian networks (Prospector)
- In use, some facts are added to the working memory that represent *observations* about the domain
  - Typically user-supplied in response to questions

Architecture of an Expert System

- Inference engine makes inferences from the case specific data and the knowledge in the knowledge base
  - Leads to more questions as sub-goals are generated
- Backward chaining identifies what the system needs from the user
  - Some ES use a mixture of forward and backward chaining
- User interface for interaction

Legal Expert System



- citizen(X) :- bornIn(X,uk).
- citizen(X) :- father(Y,X), bornIn(Y,uk).
  - User: citizen(me)?
  - System: where were you born?
  - User: Malta.
    - Add bornIn(me,malta). First rule fails.
  - System: who is your father?
  - User: Colin
  - System: where was Colin born.
  - User: London.
    - Add bornIn(colin,uk), using fact in(london,uk). Succeeds
  - System: Yes.

MYCIN

- One of the most important expert systems developed was MYCIN, a system for diagnosing and treating bacterial infections of the blood

- The name comes from the fact that most of the drugs used in the treatment of bacterial infections are called "*Something*"mycin

- MYCIN is intended to be used by a doctor, to provide advice when treating a patient

- The idea is that MYCIN can extend the expertise of the doctor in some specific area

Rules in MYCIN

- Internally held in a Lisp-like syntax, but of the form

```
IF
1. The gram stain of the organism is gramneg,
   and
2. The morphology of the organism is rod, and
3. The aerobicity of the organism is anaerobic
THEN
there is suggestive evidence (0.6) that the
identity of the organism is bacteroides.
```

- Antecedent can contain both AND and OR conditions

A Rule with OR Conditions

- A rule about treatment

```
IF
1. The therapy under consideration is:
       cephalothin, or
       clindamycin, or
       erythromycin, or
       lincomycin, or
       vancomycin
   and
2. Meningitis is a diagnosis for the patient
THEN
It is definite that the therapy under
consideration is not a potential therapy.
```

Certainty Factors

- MYCIN needs a way to handle uncertainty, inherent in medical diagnosis
- Uses certainty factors (CFs), values between +1 and −1, about its conclusions
  - Positive value = suggestive evidence in support of the conclusion
  - Negative value = suggestive evidence against the conclusion
- Example: data of a particular organism relating to its Gram stain, morphology and aerobicity

```
GRAM = (GRMNEG 1.0)
MORPH = (ROD 0.8)
AIR = (ANAEROBIC 0.7)
```

Certainty Factors

- Each statement and rule has a certainty factor
- Statement AND statement – use the minimum of the two CFs
- Statement OR statement – use the maximum of the two CFs
- Rule: CF(antecedent) * CF(conclusion)
  - Combining conclusions from two rules:
    (CF(conclusion1)+CF(conclusion2)) minus
    (CF(conclusion1)*CF(conclusion2))
- Does NOT correspond to probability theory, but simple and tractable. Initial numbers not probabilities anyway!

Example

- R1: If P (0.4) and Q (0.7) then R (0.8)
- R2: If S (0.2) or T (0.5) then R (0.9).
- P and Q = 0.4
- S or T = 0.5
- R1 gives R = 0.32
- R2 gives R = 0.45
- Overall: 0.77 – 0.144 = 0.626

How MYCIN Works

- MYCIN has a four stage task
  1. decide which organisms, if any, are causing significant disease
  2. determine the likely identity of the significant organisms
  3. decide which drugs are potentially useful
  4. select the best drug, or combination of drugs
- Rules for each stage are in different partitions
- The control strategy for doing this is coded as meta-knowledge

Main Rule

```
IF
1. There is an organism which requires
   therapy, and
2. Consideration has been given to possible
   other organisms which require therapy
THEN
1. Compile a list of possible therapies, and
2. Determine the best therapy.
ELSE
Indicate that the patient does not require
therapy.
```

- Starts with some clinical observations: blood test results
- Backward chains until it needs more information
- Asks user (who may need to do further tests)
- When a sub-goal is complete, e.g. the organism is identified, moves on to next sub-goal

Example Consultation

```
1) Patient's name: (first-last)
** FRED BRAUN
2) Sex
** M
3) Age
** 55
4) Are there any illnesses for Fred Braun
   which may be related to the present illness,
   and from which organisms have been grown
   in the microbiology laboratory?
** Y
-------- CULTURE-1 ----------
5) From what site was the specimen for
   CULTURE-1 taken?
** BLOD
= BLOOD
6) Please give the date and time
   when CULTURE-1 was obtained.
** JUN 20 1977
```

Explanation dialogues could also be generated to show how MYCIN arrived at its conclusions.

Evaluation of MYCIN

- Evaluated by comparing its performance to 8 members of Stanford medical school: 5 faculty members, one research fellow in infectious diseases, one physician and one student
- They were given 10 randomly selected case histories and asked to come up with diagnoses and recommendations
- MYCIN performed as well as any of the Stanford medical team and considerably better than the physician or student

Use of MYCIN

- MYCIN has never been used in clinical practice due to:
  - expense of computing power required at the time
  - the amount of time and typing required for a session
  - incompleteness of the knowledge base
  - issues relating to professional responsibility; what if it was wrong?
- MYCIN was *enormously influential*
  - Almost all practical expert systems of the 80s and 90s used ideas from MYCIN
  - Fielded in domains where complete knowledge was available, responsibility issues less (not life critical, advice), and as computer power became cheap (micro computers)

Advantages of Expert Systems

- Declarative information: programming an ES involves capturing the expert's knowledge; not like programming a conventional system
  - failure to draw a conclusion; missing knowledge
  - drawing the wrong conclusion; a faulty statement
- Interface: user-friendly; inferences drawn are intended to be similar to those drawn by the experts
  - Promotes ease of maintenance by users
- Explanation: the ability to explain their conclusions
- Easy to extend and maintain: provided the domain does not change

Problems with Expert Systems

- Problems with construction
  - Knowledge acquisition bottleneck
  - Machine learning
- Problems with representation
  - What does “significant evidence” mean?
  - Handling uncertainty
- Problems with acceptance
  - Operational issues
  - Legal issues
  - Trust
- Problems with domain
  - Brittleness
  - Common sense knowledge (see CYC)

Ontologies

- Ontologies address some of the problems identified in semantic nets by providing *a formalisation of a conceptualisation of a domain* (Thomas Gruber)

- Ontologies are intended to
  - Provide a common well-defined vocabulary for understanding a domain
    - To share between people and software agents
  - Record design decisions
    - To make assumptions explicit
    - To facilitate merging and re-use

- An ontology for a KBS serves many of the purposes of a Data Dictionary for a DB

Winston's ZOOKEEPER

```
Z1: mammal(X):-hair(X).
Z2: mammal(X):-givesMilk(X).
Z3: bird(X):-feathers(X).
Z4: bird(X):-flies(X),
       laysEggs(X).
Z5: carnivore(X):- mammal(X),
          eats(X,meat).
Z6: carnivore(X):- mammal(X),
          teeth(X,pointed),
          has(X,claws),
          eyes(X,forwardPointing).
Z7: ungulate(X):- mammal(X),
         has(X,hoofs).
Z8: ungulate(X):- mammal(X),
         chewsCud(X).
Z9: cheetah(X):-carnivore(X),
        colour(X,tawny),
        spots(X,dark).
Z10: tiger(X):-carnivore(X),
        colour(X,tawny),
        stripes(X,black).
Z11: giraffe(X):-ungulate(X),
        legs(X,long), neck(X,long),
        colour(X,tawny),
         spots(X,dark).
Z12: zebra(X):-ungulate(X),
        colour(X,white),
        stripes(X,black).
Z13: ostrich(X):-bird(X),
         not flies(X), legs(X,long),
         neck(X,long),
       colour(X,blackandwhite).
Z14: penguin(X):-bird(X),
         swims(X),
         not flies(X),
         colour(X,blackandwhite).
Z15: albatross(X):- bird(X),
          flies(X,well).
```

Works well enough.
But: is it a satisfactory knowledge base?

Exercise

- Do you think the Zookeeper knowledge base is satisfactory? If not, why not?

Problems

- Animals divided into mammals and birds:
  - Standard zoological taxonomy – but is this exhaustive and disjoint?
- Mammals are divided into carnivores (what they eat) and ungulates (have hooves, what their feet are like).
  - Why this distinction? Exhaustive? Disjoint?
- Birds are not divided. Why not?
- Stripes are black and spots are dark. Same?
- Colour can be white or blackandwhite. Pattern?
- Albatross flies well. What counts as well?
- Lays eggs?
  - Observable? Only applies to females?

Consider the 20 Predicates

- Some present alternatives, enabling grouping
  - skin covering {hair,feathers}
  - colour{white, tawny,black and white}
  - markings{spots,stripes}
  - movesBy{swims,flies}
  - feet{hoofs,claws}
- Sometimes only one option is given
  - teeth{pointed,?}
  - eats{meat,?}
  - legs{long,?}
  - neck{long,?}
  - stripes{black,?}
  - spots{dark,?}
  - flies{well,?}
  - eyes{point forward,?}

inconsistencies

incompleteness

gaps

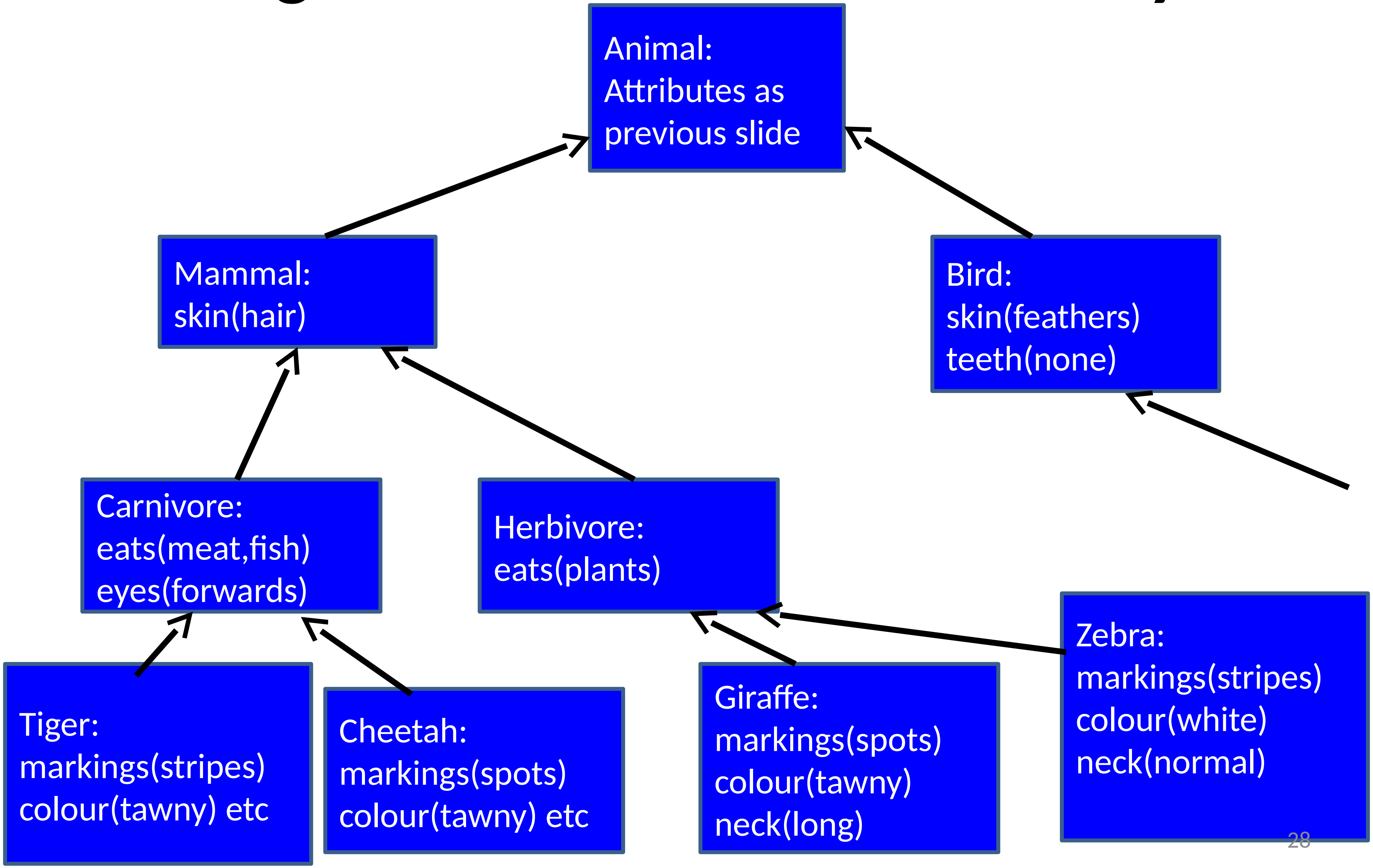
Domain Vocabulary

- Let’s devise a vocabulary for the domain:
  - What attributes do we want?
  - For these attributes: what values are ***possible***?
- Will form the basis of entity-attribute-value triples to use in our rules

So: (added values in blue)

- skin covering {hair, feathers}
- colour{white, tawny, black, other}
- markings{spots, stripes, irregular}
- movesBy{swims, flies, neither}
- feet{hoofs, claws, toes}
- teeth{pointed, rounded, none}
- eats{meat, plants, fish}
- legs{long, normal}
- neck{long, normal}
- markingColour{dark, light} %replaces spots and stripes
- eyes{point forward, sideways}

Organise into an Is-A hierarchy



Strict Specialisation

- The slot fillers are possible values not defaults
- As we go down the hierarchy we can only
  - Add attributes
    - e.g. A soldier has a rank a person does not
  - Remove values
    - Soldier has rank {private, sergeant, captain, general}
    - Officer has rank {captain, general}

- Strict Specialisation enables us to give a formal description, e.g. in first order logic:

  $\forall x \cdot officer(x) \Rightarrow (rank(x,captain) \lor rank(x,general))$

- However, Description Logic usually used (expressive KR scheme with tractable inference)

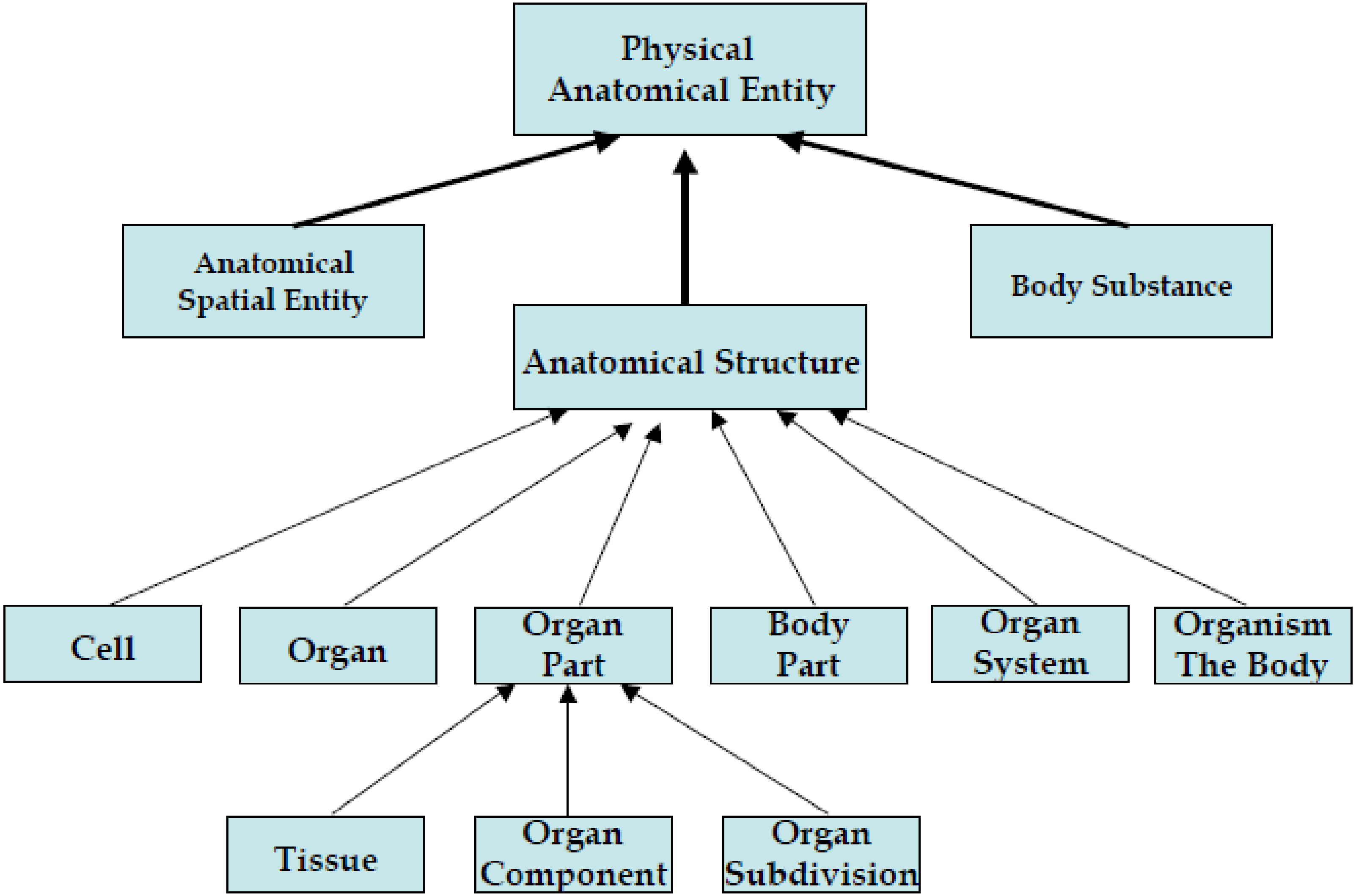
Current Work on Ontologies

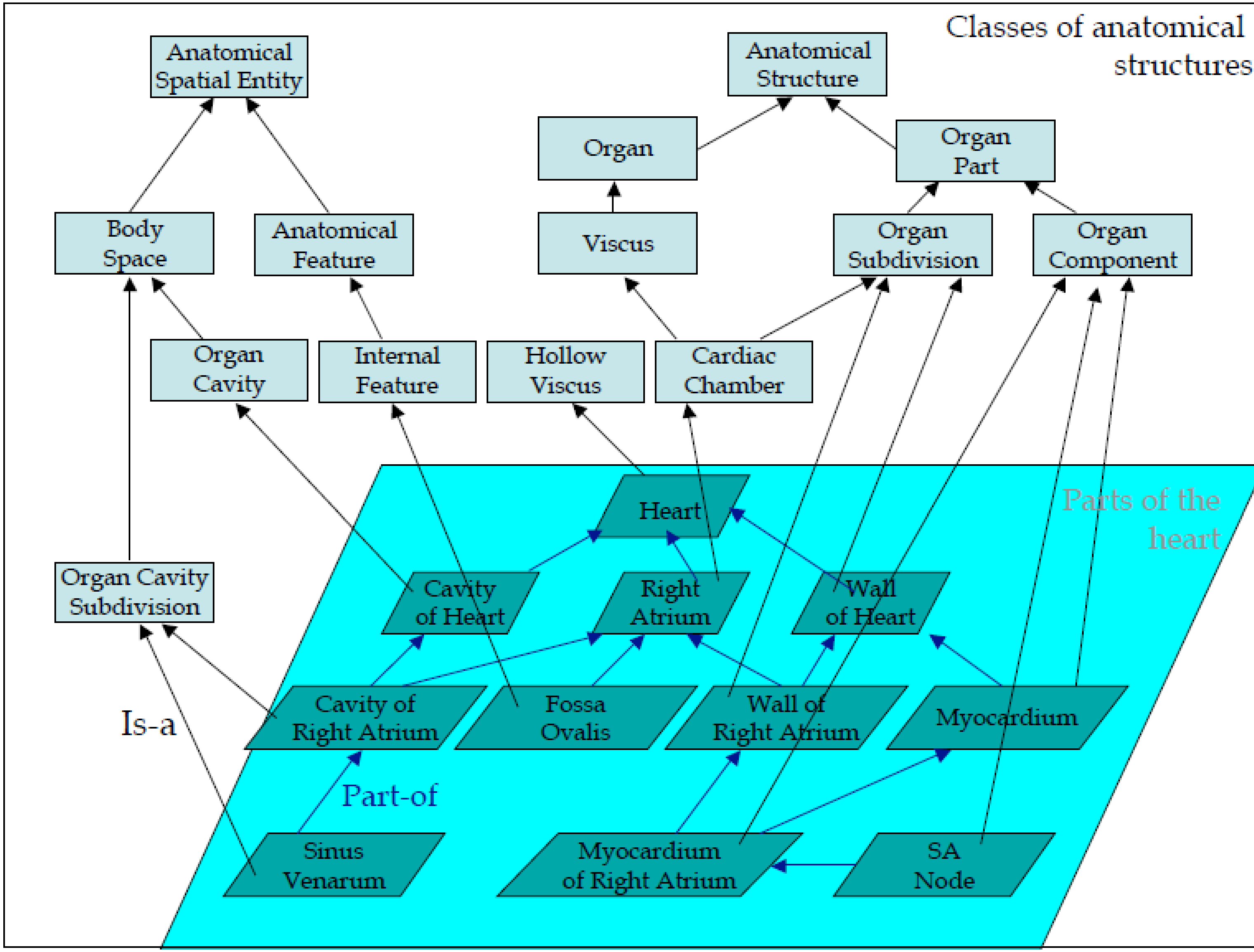
- Many substantial ontologies have been developed
- Especially in the medical domain
- Example: SNOMED
  - *"SNOMED Clinical Terms (SNOMED CT) is a dynamic, scientifically validated clinical health care terminology and infrastructure that makes health care knowledge more usable and accessible. The SNOMED CT Core terminology provides a common language that enables a consistent way of capturing, sharing and aggregating health data across specialties and sites of care."*

Place of Ontologies in Modern AI

- Specific domain ontologies: but general purpose – supposed to support many applications
  - The US National Center for Biomedical Ontology
  - SNOMED CT (311,000 medical concepts)
  - The Gene Ontology GO
  - Foundational Model of Anatomy (75,000 anatomical classes)
  - SUMO Ontology
    - "The goal . . . is to develop a standard upper ontology that will promote data interoperability, information search and retrieval, automated inferencing, and natural language processing."
- Knowledge about everything!
  - CYC, OpenCyc
- Semantic Web: Annotate Web pages with concepts defined in ontologies available on the Web
  - Improve accuracy of Web searches
  - Web searches will be able to generalise/specialise queries

Top level of the Foundational Model of Anatomy




Classes of anatomical structures
Anatomical Spatial Entity
Anatomical Structure
Organ
Organ Part
Body Space
Anatomical Feature
Viscus
Organ Subdivision
Organ Component
Organ Cavity
Internal Feature
Hollow Viscus
Cardiac Chamber
Parts of the heart
Heart
Organ Cavity Subdivision
Cavity of Heart
Right Atrium
Wall of Heart
Is-a
Cavity of Right Atrium
Fossa Ovalis
Wall of Right Atrium
Myocardium
Part-of
Sinus Venarum
Myocardium of Right Atrium
SA Node

Summary

- Expert systems were an important development in AI
- ES were mainly built using rules as their form of KR
- The MYCIN system is one of the best known examples of an ES
- Although ES have been influential, they have a number of disadvantages that led to them falling from popularity

- Ontologies provide a formalisation of a conceptualisation of a domain
- Ontologies have been successfully applied in the real world
- Ontologies can be given well-defined semantics using description logics
  - Covered in COMP321

- Next time
  - Logic

Acknowledgements

- The slides on the “Foundational Model of Anatomy” are from public material from
  - The Structural Informatics Group at the University of Washington (http://sig.biostr.washington.edu/)
  - A talk on Ontologies in Biomedicine by Mark Musen of Stanford University (http://med.stanford.edu/profiles/Mark_Musen/)