Ontology

Topics of this lecture

- What is ontology?
- Semantic network
- Frame
- Structural knowledge
- Declarative knowledge
- Procedural knowledge

- オントロジーとは？
- 意味ネットワーク
- フレーム
- 構造的知識
- 宣言的知識
- 手続き的知識

What is ontology?

- Ontology is a term used by philosophers to mean the most "**essential existence**" in the universe.
- For example, if A can be derived from or produced by B, A is NOT essential. Here B can be a single "existence" or a set of "existences".
- An existence may not be an "object". In fact, a group of philosophers believe that all existences are produced by a "spirit". These philosophers are called "**spiritualists**".

What is ontology?

- On the contrary, some philosophers believe that the universe is made up of various materials or objects, and they are called "**materialists**".
- Objects defined in a **cyber-space** are not essential from the point of view of its creator (human), but "the agents" (AI) living in that space may "think" they are.

https://www.canstockphoto.jp/

Ontology engineering

- In **ontology engineering**, we do not care what is the “origin” of the universe, but care about the “true meanings” of concepts. With the true meanings, we can define knowledge that can be shared, understood, and used by anybody (with different culture backgrounds9 in the world.
- For this purpose, researchers are trying to **represent knowledge graphically**, and open it to the world. People can then improve the **knowledge graph or ontology graph** from different angles. Hopefully, after many years, some of the knowledge can be universally useful. This kind of knowledge will be language (platform) independent.

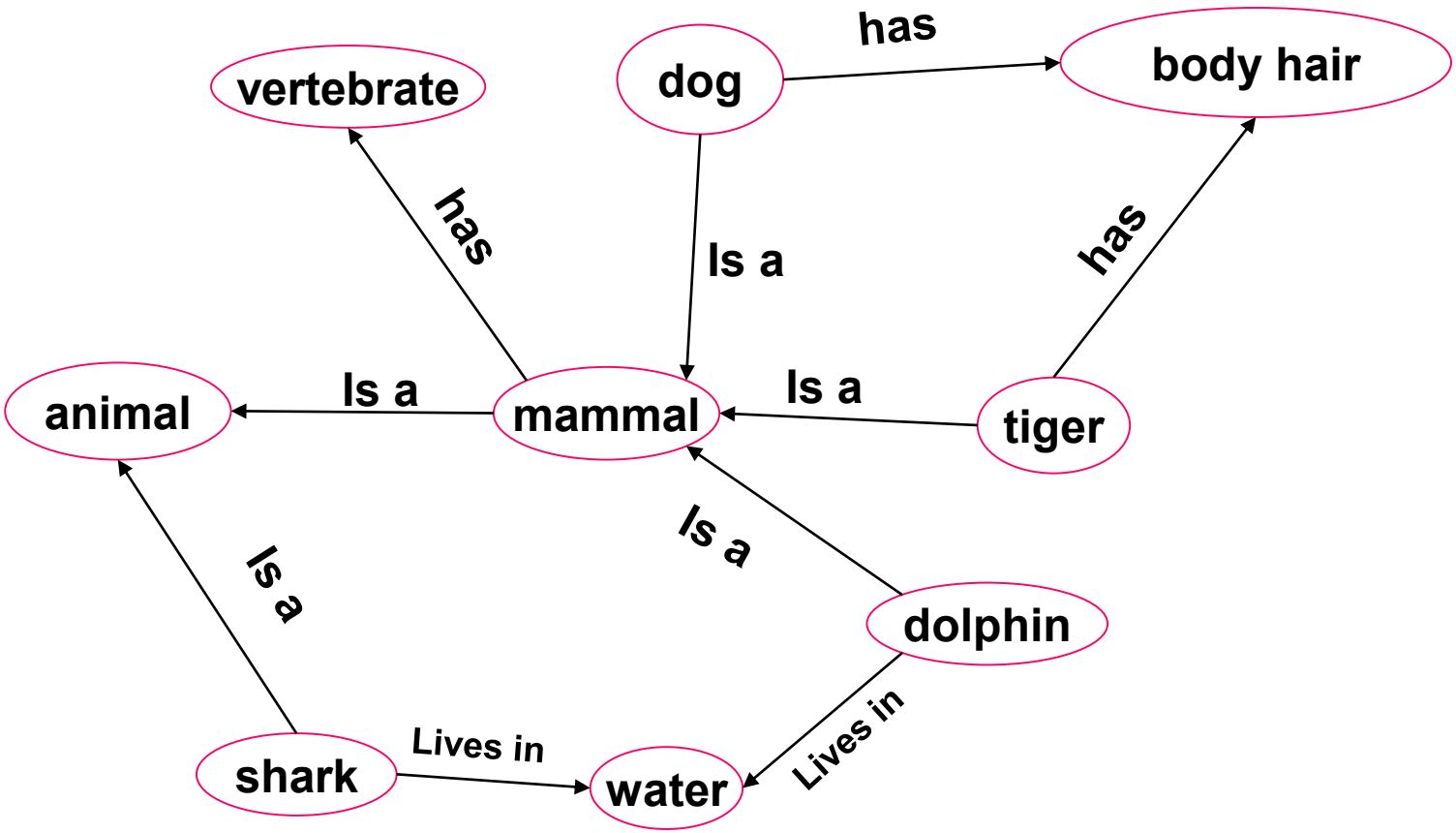
Basic idea of ontology engineering

- In ontology engineering, knowledge is represented using a graph.
- Each node of the graph represents a “concept”, and the edge between two nodes represents the relation between the two concepts.
- **A concept defines a group of existences**. The form (shape or outlook), properties, states, etc. of these existences are memorized (capsulized) in the corresponding node.
- The relation between two concepts may include causal relation, inclusion relation, membership relation, etc.
- Using an ontology graph, other people can understand the corresponding knowledge easily, and can improve freely.

Semantic network

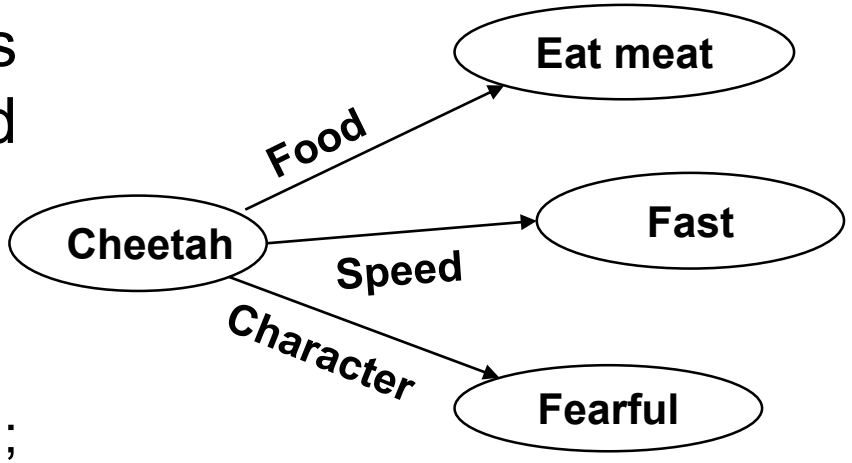
- Semantic network is a special case of ontology graph. In a semantic network, the knowledge is represented by a directed graph.
- In each node, a concept is defined by
  - Concept (object) name;
  - Attributes; and
  - Attribute values.
- An edge defines the relation between two concepts.

Example of semantic network



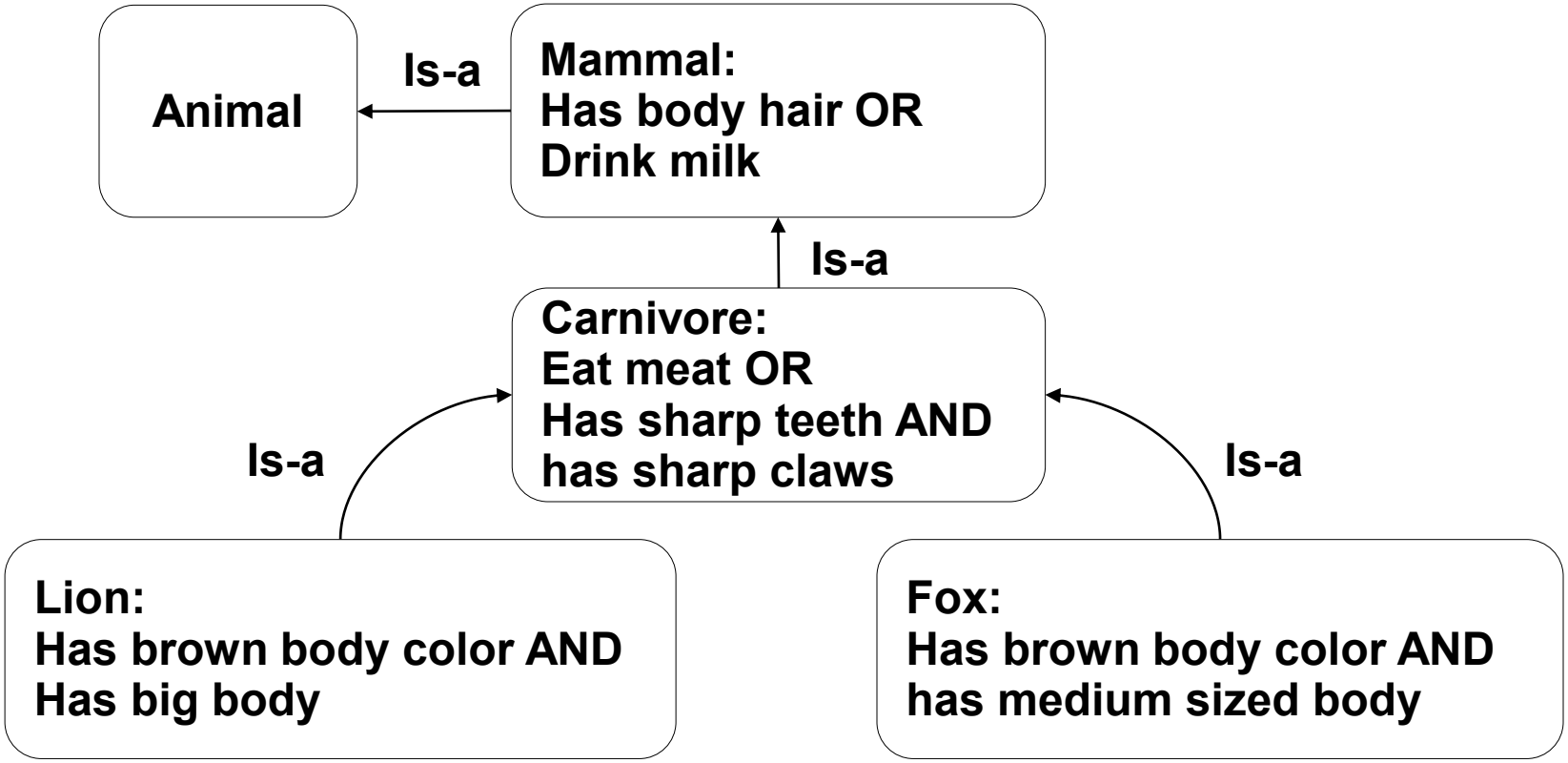
Example of a concept

- The concept “cheetah” has the following attributes and corresponding values:
  - A1=food; Value=meat;
  - A2=speed; Value=fast;
  - A3=character; Value=fearful;
- Fuzzy values are often used here to make them more understandable.



Semantic network for animals

(part of Fig. 4.4 in p. 79)



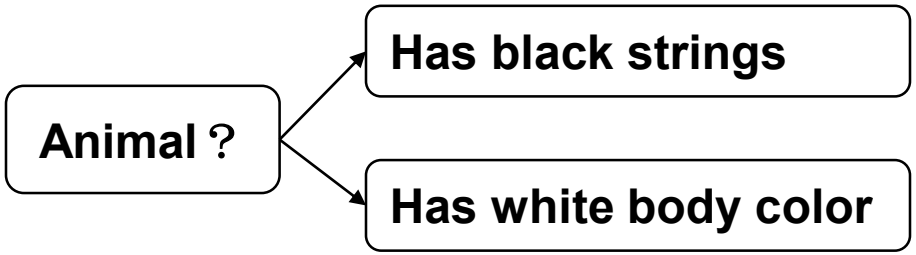
Reasoning based on semantic network

- Questions to ask
  - Does lion has a big body?
  - Is fox an ungulate?
  - Does deer ruminate?
  - Is swallow black?
  - Does zebra has an odd number of toes?
  - **What is the type of an animal who has**
    - **black strings and**
    - **a white body color?**

Use ontology as a knowledge base to answer questions, to confirm your decisions, etc.

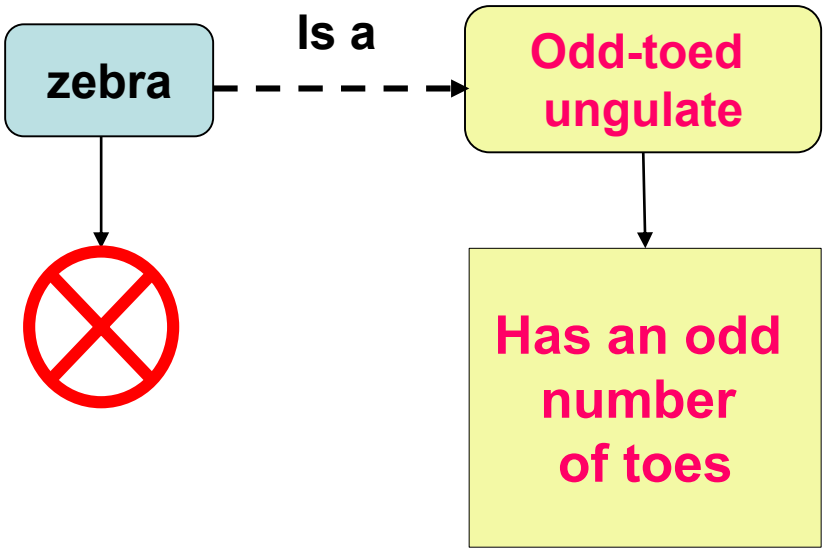
Reasoning based on semantic network

- Reasoning is equivalent to graph matching.
- A ***question network*** is generated for each question.
- We get an answer when the question network matches to a sub-graph of the semantic network.



Reasoning based on inheritance

- **Does zebra has an odd number of toes?**



A sub-concept inherits all properties of its upper (parent) concept.

Although the concept "zebra" does not contain the property mentioned in the question, its upper concept (super-set) contains the needed property. Therefore, the answer should be YES.

From semantic network to frame

- Frame was proposed by Minsky in 1975 as an extension of the semantic network. Frame is more powerful for knowledge representation.

Slot	Value	Type
Cheetah		ID (name) of this frame
Is-a	Carnivore	Pointer to the parent frame
Food	meat	Attribute and value
Speed	Fast	Attribute and value
Character	Fearful	Attribute and value

Frames are more similar to web pages (1)

Living being	
is-a	*Thing*
Attribute	Live
Attribute	Re-producible
Attribute	Die

Animal	
is-a	*Living being*
Attribute	Move
Attribute	Eat
Attribute	Breath

Poch	
is-a	*Dog*
Popular	1
Size	Small
Origin	Japan

Cheetah	
is-a	*Animal*
Food	Meat
Character	Fearful
Speed	Fast

Dog	
is-a	*Animal*
Food	Omnivorous
Character	Friendly
Speed	Medium

Sahha	
is-a	*Cheetah*
Popular	2
Size	Medium
Origin	Sahara

Frames are more similar to web pages (2)

Animal	
is-a	*Living being*
Attribute	*Head*
Attribute	*Body*
Attribute	*Move*

Head	
Front	*Face*
Tow sides	*Ears*
Upper side	*Forehead*
Lower side	*Neck*

Face	
Upper side	*Eyes*
Lower side	*Jaw*
Middle	*Nose*

Difference frames are connected via "hyper-links".
Different relations can be defined naturally.

Reasoning based on frames

- Similar to semantic network, to answer a question, we try to match the question to the frames. An answer can be obtained directly if a frame matches the question.
- In case there is no frame that can match the given question completely, we may try to look at the parent frames, and get the answer based on inheritance.
- To improve reasoning efficiency, some heuristics are needed to select the frame to match. For example, we may start reasoning from the “most satisfiable frame” defined in Eq. (4.2) in the textbook.

The functional frames

- In addition to static concepts, procedures (functions or methods) for conducting certain tasks can also be embedded into a frame.
- That is, frame can be used to represent both declarative knowledge and procedural knowledge.

Know what to do and how to do!

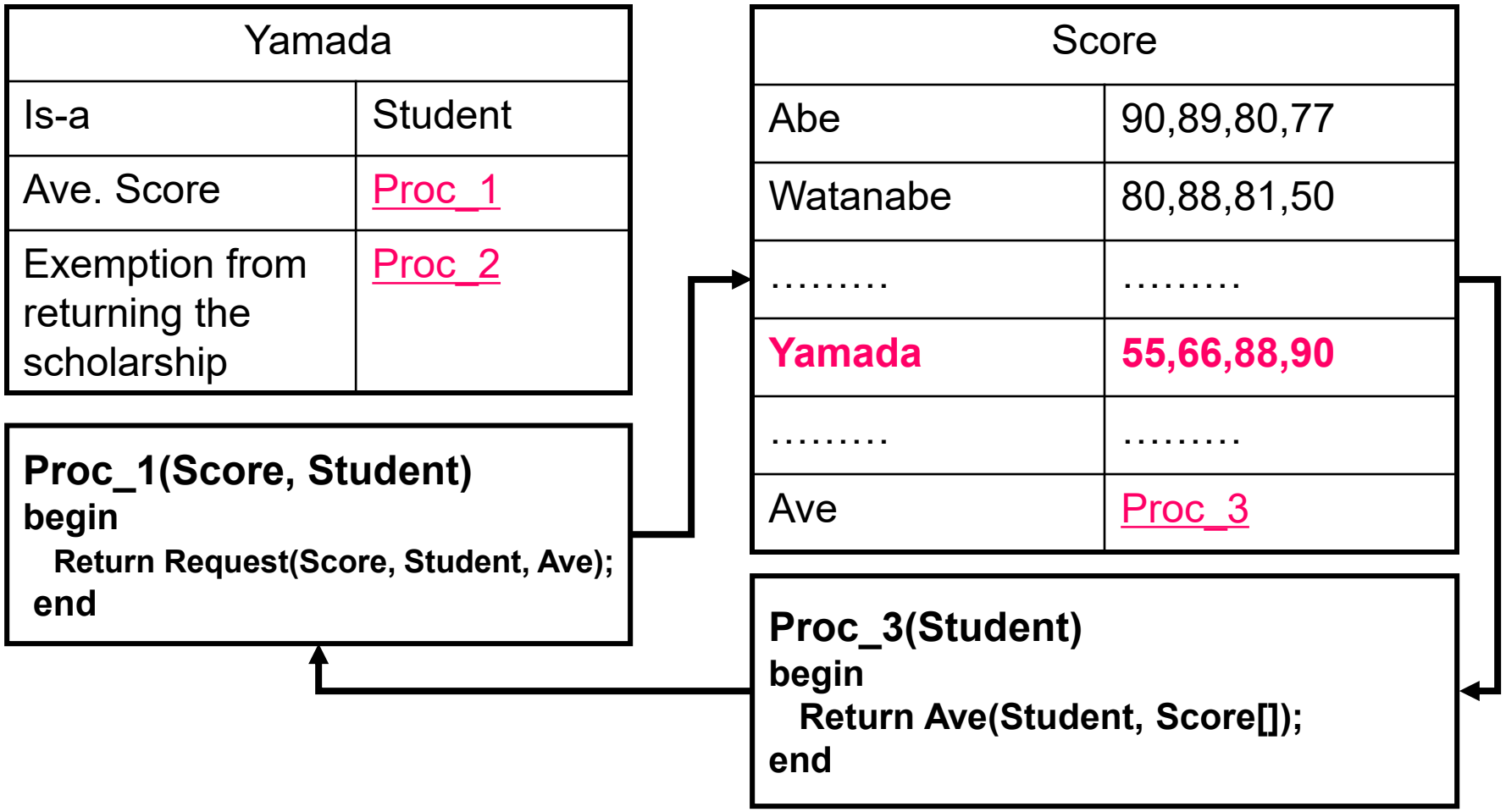
Demon or agent

- The procedures are often called demons or agents.
- They are activated automatically when certain conditions are satisfied.
- Example of conditions
  - If needed,
  - if added,
  - if removed,
  - if modified,
  - etc.

- Example: If the GPA of a student is needed, and the value does not exist yet, a procedure can be called to find the value.

Yamada	
Is-a	student
GPA	**If-needed:** Proc_1
Earlier graduation	**If-needed:** Proc_2

An example



An example

- For the question “what is the average score of Yamada”,
  - The system tries to find the frame of “Yamada” and then his average score;
  - If the average score exists, return the value and stop.
  - Otherwise, call Proc_1;
  - Proc_1 sends a request to the frame “Score” with a student name and the name of the slot (or attribute);
  - Proc_3 is activated because it is needed;
  - Proc_3 finds the average value of the specified student and replies to Proc_1 (of the specified student);
  - Proc_1 receives the value from Proc_3, and return it to the user.

Properties of frame

- A frame system has the same ability as a semantic network for representing declarative knowledge.
- It can also represent procedural knowledge by using demons (agents, functions, or methods).
- That is, a frame system can not only reason with existing knowledge, but also produce new knowledge when needed.
- In other word, the concept represented by a frame (or node if we consider the frame system a knowledge graph) can be dynamically modified based on new data (or new situation).

Homework for lecture 6 (1)

(submit the answer during the exercise class)

- Try to solve Problem 4.4 in the textbook, in p. 81.
- That is, for the knowledge base given by Table 4.2 (p. 67), draw the corresponding semantic network.
- You can use Japanese or English.

Homework for lecture 6 (2)

- Download the skeleton, and complete the program to implement a simple “student management frame system”.
- Conditions for exemption from returning the scholarship are given as follows:
  - If the average score is top 5: full exemption
  - If the average score is between top 6 to top 10: half exemption
  - Otherwise: No exemption.
- After finishing the program, try to add some data into “data_06.txt” and add the expected answer in “answer_06.txt”. Confirm if the results of your program are the same as expected.

Quizzes of today

- What are the meanings of “node” and “edge” in a semantic network?
- How to define a concept?
- Prove “Fox has sharp teeth” using the semantic network of Fig. 4.4 (p. 79) in the textbook.

- What is the main difference between a semantic network and a frame system?
- What is a demon in a frame system?