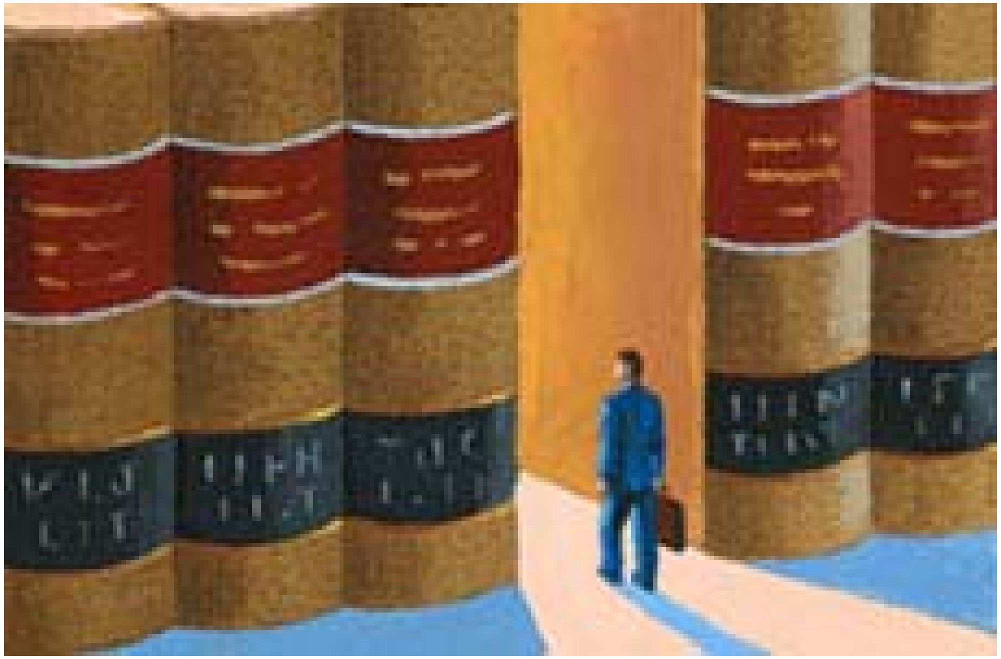
# D. Wissensrepräsentation



# Prinzipien der Wissensrepräsentation

Davis, Shrobe, and Szolovits (1993) discussed **five principles for a knowledge representation**:

1. A knowledge representation is a **surrogate**,
2. a **set of ontological commitments**,
3. a **fragmentary theory of intelligent reasoning**,
4. a **medium for pragmatically efficient computation**,
5. and a **medium of human expression**.

- The way a knowledge representation focuses on these principles characterizes its spirit.
- Each knowledge representation is a trade-off between these principles.

# Knowledge representation as surrogate

„Knowledge representation is most fundamentally a *surrogate,* a substitute for the thing itself, used to enable an entity to determine consequences by thinking rather than acting. [...] Reasoning is a process that goes on internally [of a person or program], while most things it wishes to reason about exist only externally.“

# Knowledge representation as as set ontological commitments

A knowledge representation “is a *set of ontological commitments*, i.e., an answer to the following question: ‚In what terms should we think about the world? [...] In selecting any representation, we are [...] making a set of decisions about how and what to see in the world. [...] We (and our reasoning machines) need guidance in deciding what in the world to attend to, and what to ignore.“

# Knowledge representation as theory of intelligent reasoning

„The initial conception of a knowledge representation is typically motivated by some insight indicating how people reason intelligently, or by some belief about what it means to reason intelligently at all. [...]

It is a *fragmentary theory of intelligent reasoning*, expressed in terms of three components:

(i) the representation's fundamental conception of intelligent reasoning;

(ii) the set of inferences the representation *sanctions;*

(iii) and the set of inferences it *recommends.*

The authors consider five fields which have provided notions of intelligent reasoning:

- Mathematical Logic (e.g., Prolog)
- Psychology (e.g., frames)
- Biology (e.g., neural networks)
- Statistics (e.g., bayesian networks)
- Economics (e.g., rational agents)

(Siehe drei Folien weiter.)

# Knowledge representation as medium for efficient computation

Knowledge representation „is a *medium for pragmatically efficient computation*, i.e., the computational environment in which thinking is accomplished. One contribution to this pragmatic efficiency is supplied by the guidance a representation provides for organizing information so as to facilitate making the recommended inferences.“

# Knowledge representation as medium of human expression

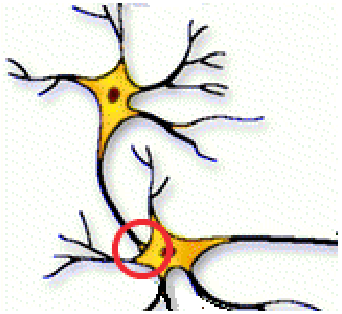
„Knowledge representations are [...] the medium of expression and communication in which we tell the machine (and perhaps one another) about the world. [...]

Knowledge representation is thus a medium of expression and communication for the use by *us*. [...]

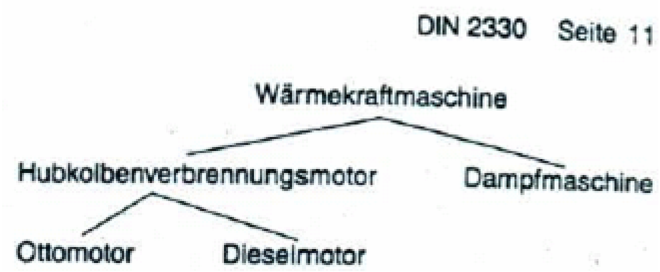
A representation is the language in which we communicate, hence we must be able to speak it without heroic effort."

# Wissen

Es gibt verschiedene Wurzeln der Wissensverarbeitung, die zu unterschiedlichen Modellen von Wissen führen:



- Biologie: Vernetzung
  → neuronale Netze
- mathematische Logik: Deduktion
  → Logikkalküle, Prolog
- Statistik: Unsicherheit
  → Fuzzy-Logik, Bayessche Netze
- Psychologie: Begriffe
  → wissensbasierte Systeme
- Ökonomie: Ziele, Bewertungen
  → Agenten



## Neuronale Netze

- Wir werden in dieser Vorlesung den Schwerpunkt auf die begriffliche Wissensrepräsentation legen.
- Vorher aber ein kleiner Ausflug in die neuronalen Netze, um die Verschiedenheit der Ansätze zu beleuchten.
- Neuronale Netze werden detailliert in der Vorlesung „Knowledge Discovery“ besprochen.

# (Künstliche) Neuronale Netze

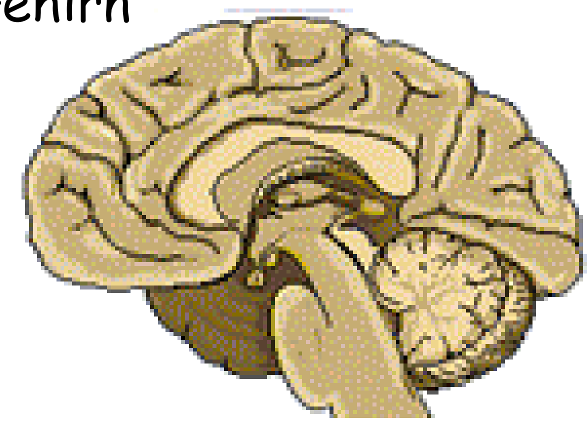
sind massiv parallel verbundene Netzwerke aus

- einfachen (üblicherweise adaptiven) Elementen in
- hierarchischer Anordnung oder Organisation,

die mit der Welt in der selben Art wie biologische Nervensysteme interagieren sollen. [Kohonen 1984]

## Vorbild Biologie

Gehirn



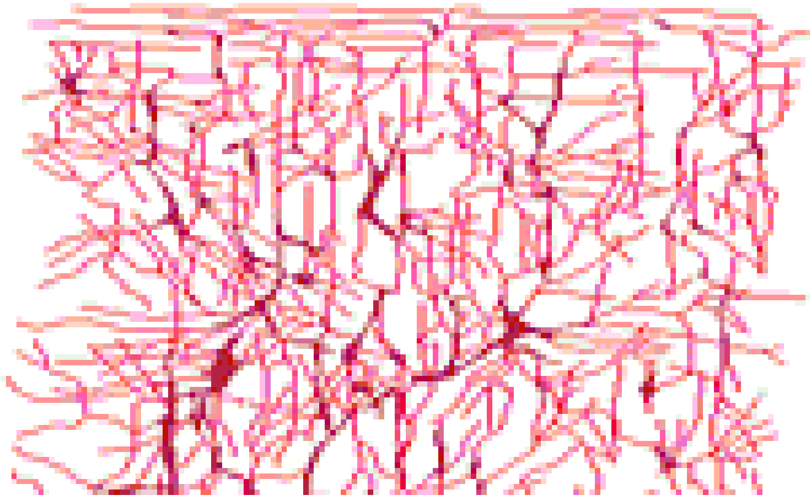
Das Gehirn besteht aus

- ca. $10^{11}$ Neuronen, die mit
- ca. $10^{4}$ anderen Neuronen
- ca. $10^{13}$ Synapsen

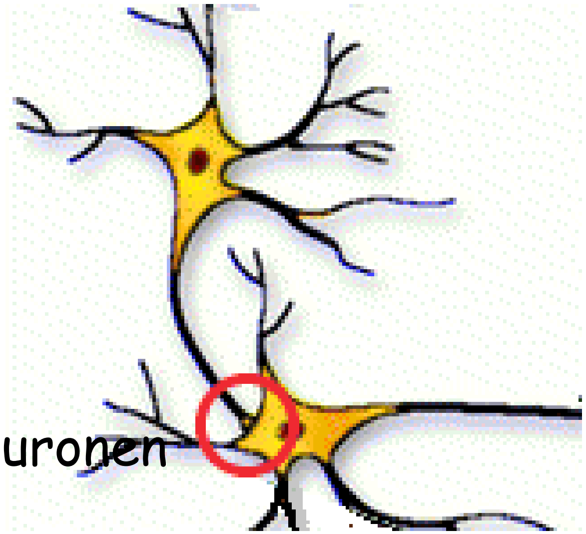
verschaltet sind.

In der Vergangenheit wurden Forscher aus den verschiedensten Fachgebieten durch das biologische Vorbild motiviert.

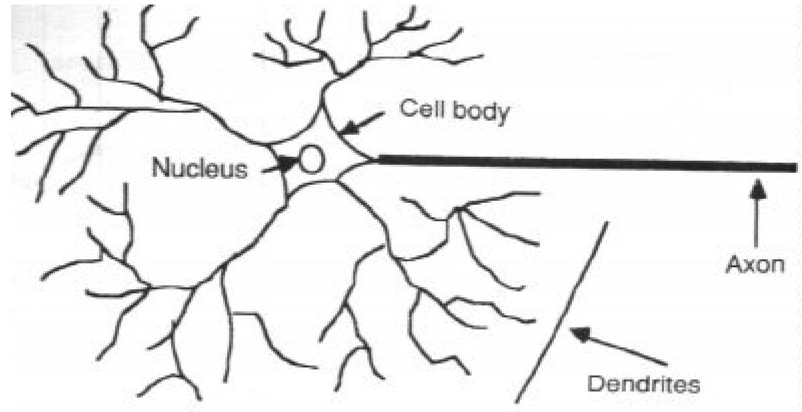
Geflecht aus Neuronen

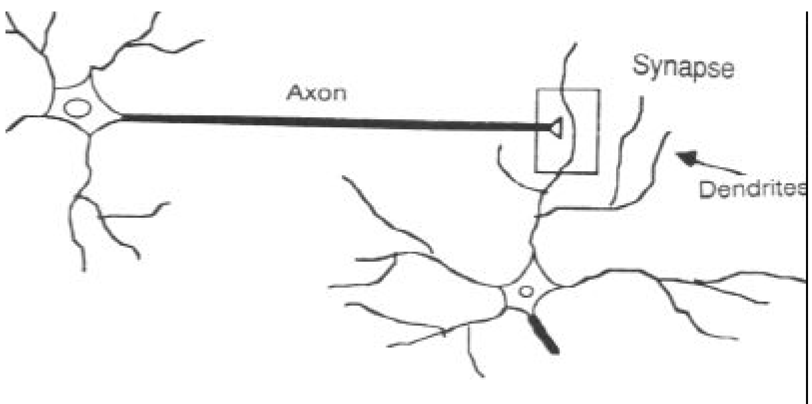


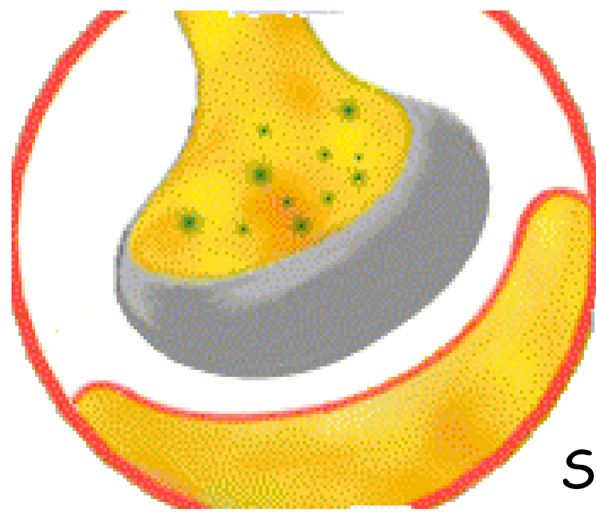
## Vorbild Biologie



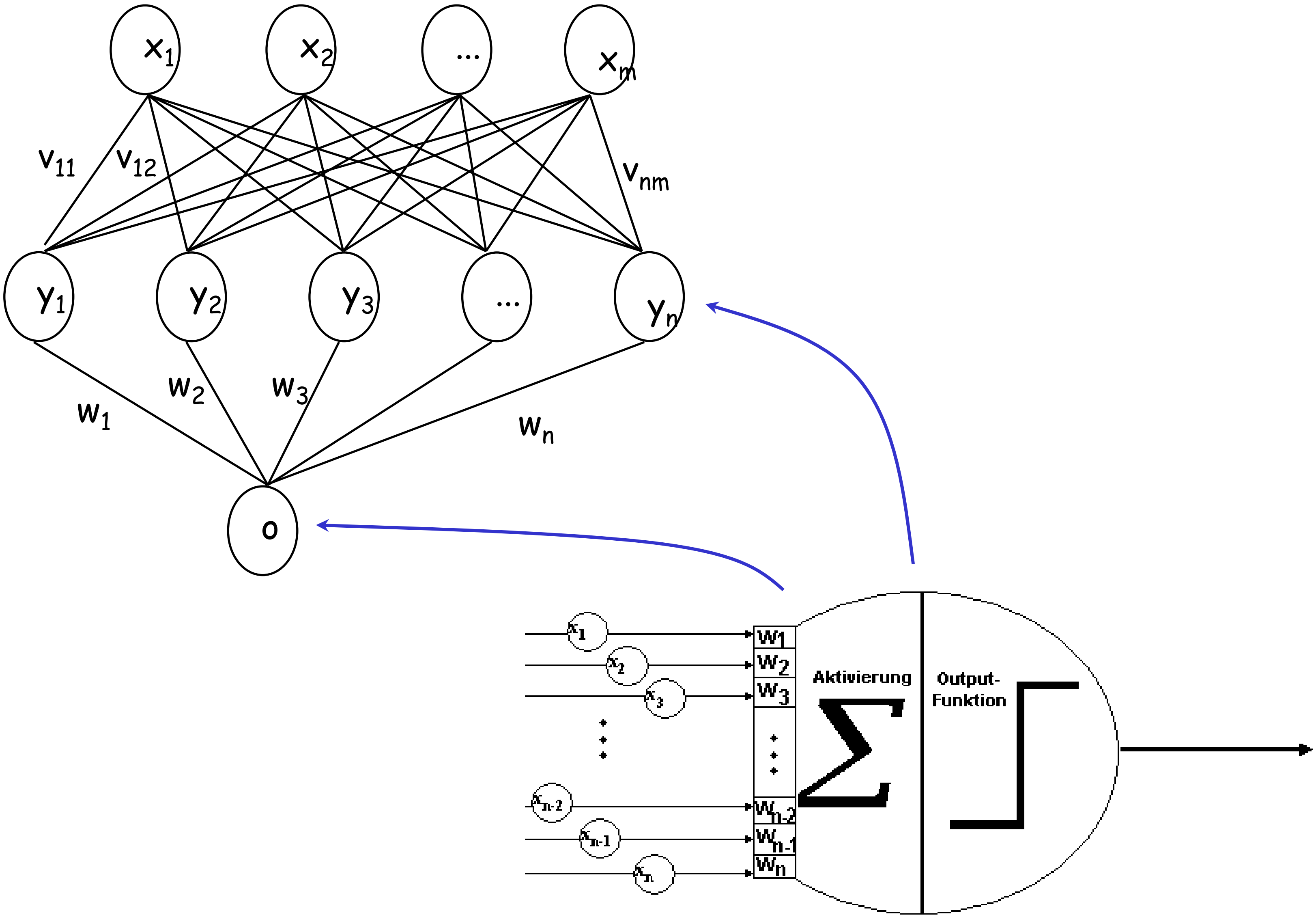
Neuronen



Synapse


x1
x2
...
xm
v11
v12
vnm
y1
y2
y3
...
yn
w1
w2
w3
wn
o
x1
x2
x3
xn-2
xn-1
xn
W1
W2
W3
Wn-2
Wn-1
Wn
Aktivierung
Output-
Funktion

# Neuronale Netze

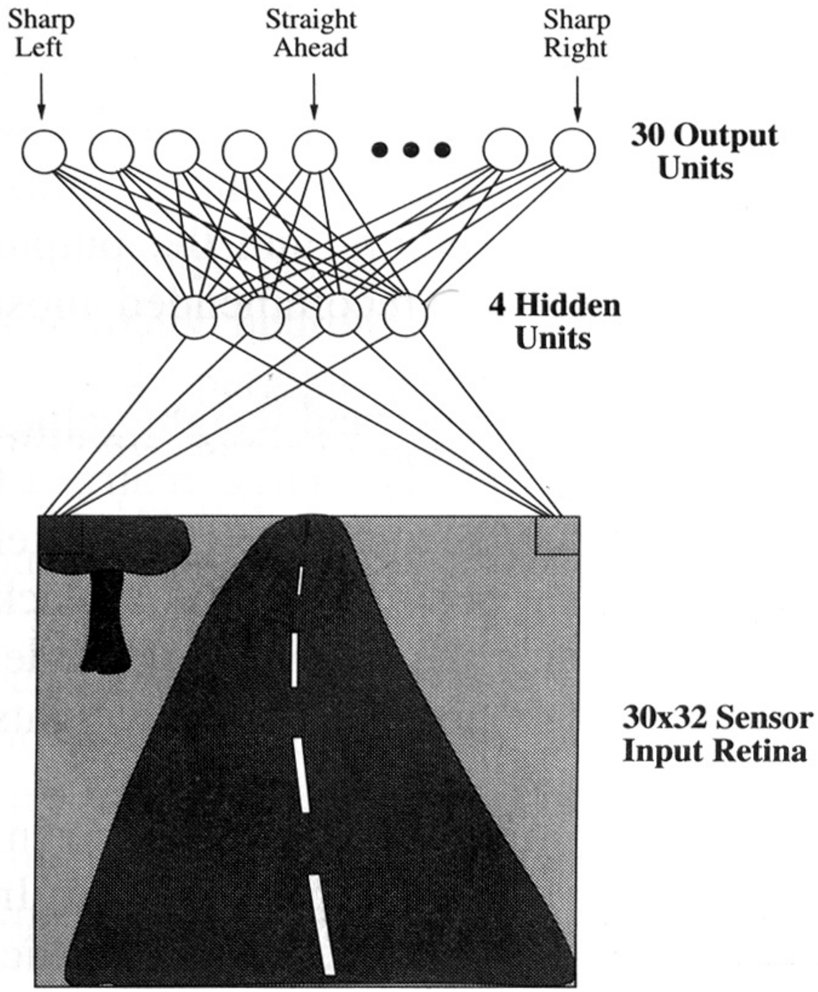
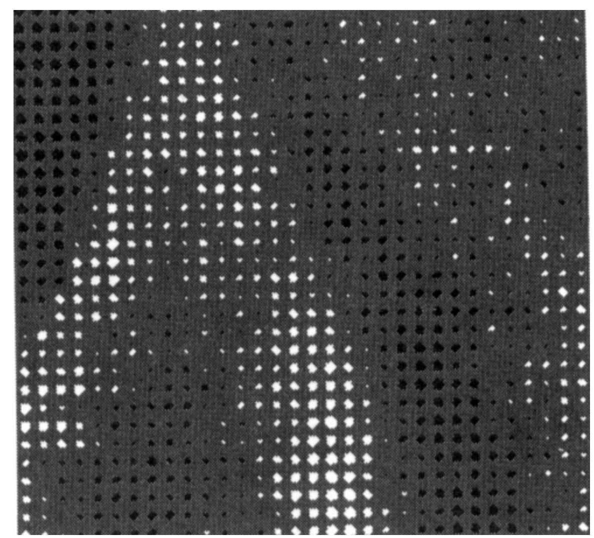



Figure 1: Neural Network learning to
steer an autonomous vehicle (Mitchell 1997)



# Neuronale Netze

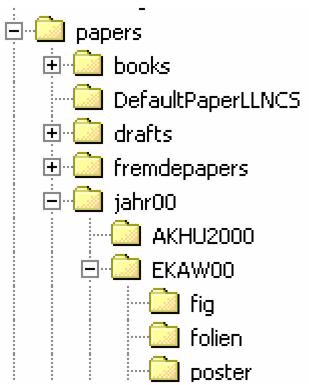
Wofür nutzt man sie?

- Forschung:
  - Modellierung & Simulation biologischer neuronaler Netze
  - Funktionsapproximation
  - Speicherung von Informationen
  - …

- Anwendungen (z.B.):
  - Interpretation von Sensordaten
  - Prozeßsteuerung
  - Medizin
  - Elektronische Nase
  - Schrifterkennung
  - Risikomanagement
  - Zeitreihenanalyse und -prognose
  - Robotersteuerung

## Begriffliches Wissen

- Wir werden in dieser Vorlesung den Schwerpunkt auf die begriffliche Wissensrepräsentation legen.
- Die psychologische Perspektive führt zu begrifflichen Modellen von Wissen:
  - Semantische Netze
  - Frames
  - Begriffliche Graphen
  - Formale Begriffsanalyse
  - Beschreibungslogiken
  - Ontologien/Semantic Web



## Was ist ein Begriff?

**Begriff.** Denkeinheit, die aus einer Menge von Gegenständen unter Ermittlung der diesen Gegenständen gemeinsamen Eigenschaften mittels Abstraktion gebildet wird.

**Benennung.** Aus einem Wort oder mehreren Wörtern bestehende Bezeichnung.

**Definition.** Begriffsbestimmung mit sprachlichen Mitteln.

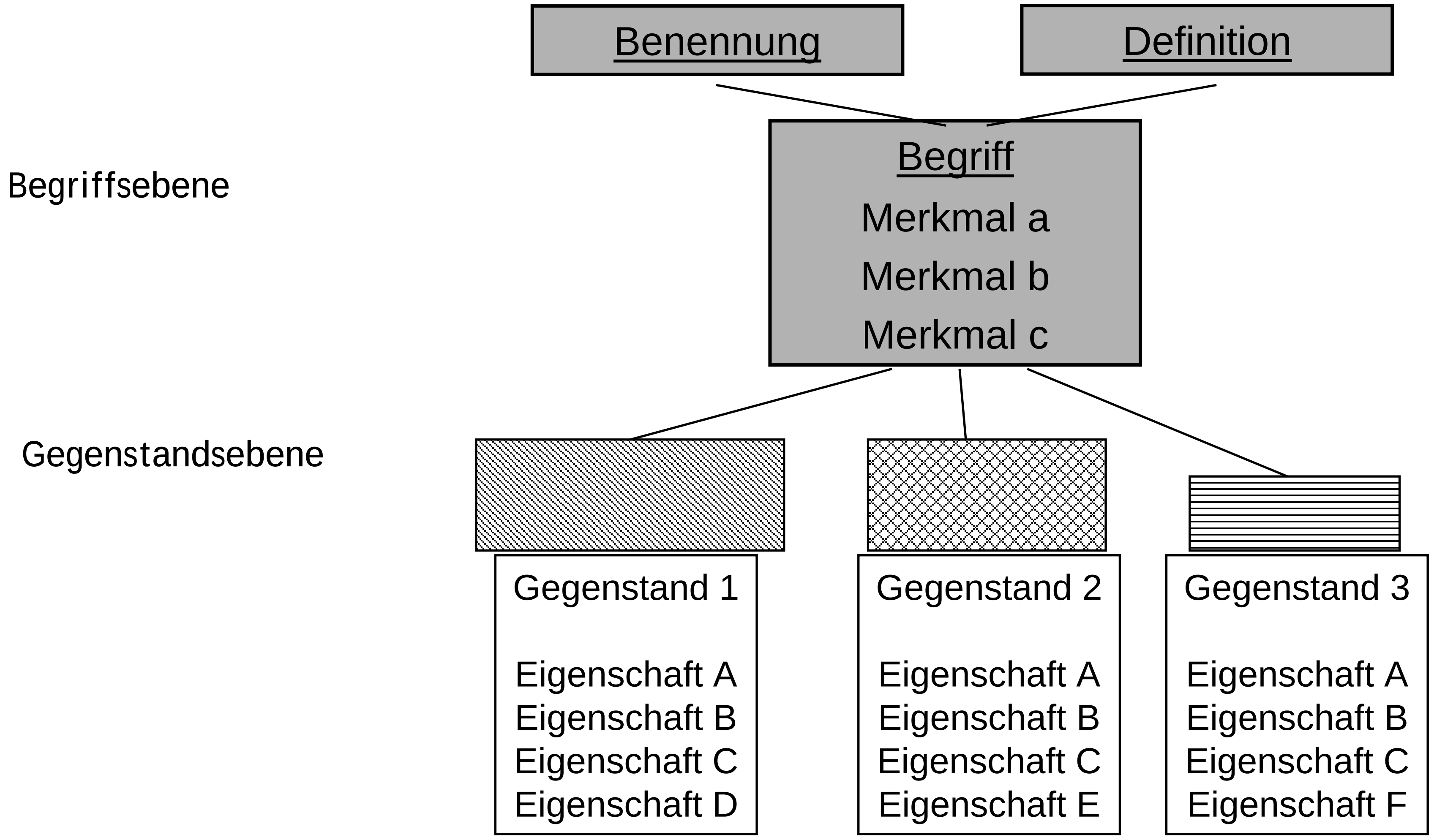
[DIN 2342 Teil 1, Begriffe der Terminologielehre - Grundbegriffe, 10.92]

The set of *characteristics* that come together as a unit to form the *concept* is called the *intension*. The *objects* viewed as a set and conceptualized into a *concept* are known as the *extension*. The two, *extension* and *intension*, are interdependent. For example, the *characteristics* making up the *intension* of ‚lead pencil' determines the *extension*, those *objects* that qualify as lead pencils and vice versa.

[ISO 704: Terminology Work: Principles and Methods, ISO 2000]

# Begriffliche Wissensrepräsentation

DIN 2330: Begriffe und Benennungen. Allgemeine Grundsätze



# Begriffliche Wissensrepräsentation

Wir stellen nun kurz ein paar Formalismen zur Repräsentation begrifflichen Wissens vor:

- **Natural Language**
- **Concept hiararchies**
- **Existential Graphs**
- **Semantic Networks**
- **Frames**
- **Conceptual Graphs**
- **Description Logics**

Letzteren werden wir im Verlauf der Vorlesung wiederbegegnen als formale Grundlage für Wissensrepräsentation im WWW.

(siehe u.a. J. Sowa: Semantic Networks. http://www.jfsowa.com/pubs/semnet.htm )

**Advantages of natural language:**

- Very expressive.
- Easy to understand for humans.

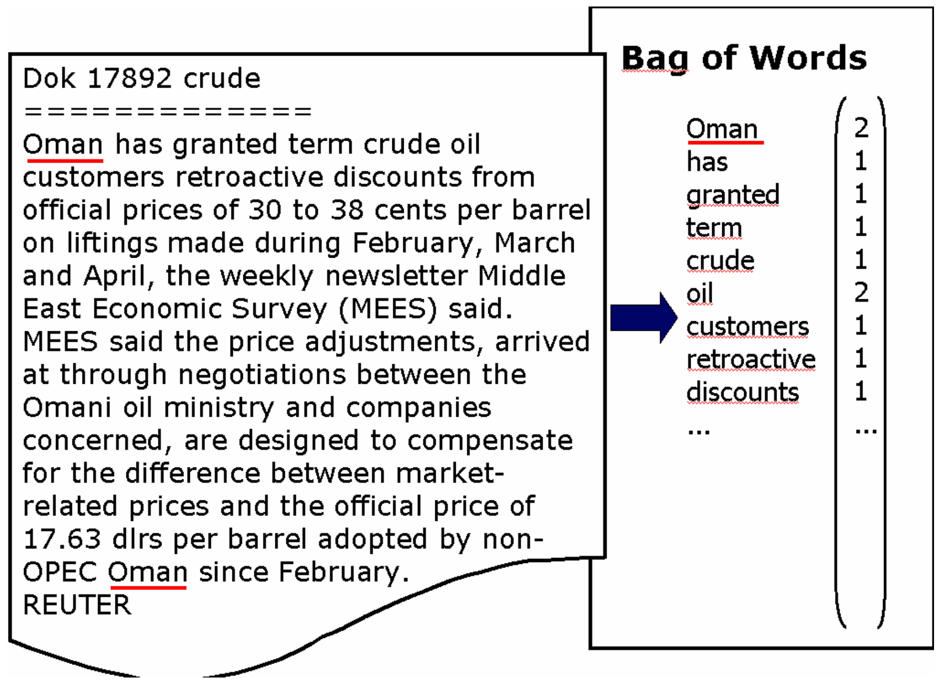
**Problems with natural language (for automatic processing):**

- Natural language is often ambiguous.
- Semantics are not formally defined.
- There is little uniformity in the structure of sentences.

# Knowledge Representation by Natural Language

**Excursion: Workaround for Information Retrieval and Text Mining:**

- "Bag of Words" Model (see lecture on Information Retrieval)
- (Is not considered as 'Knowledge Representation' in the narrow sense.)




- Advantages:
  - *easy computation* in a vector space
  - "similarity" between documents can be *measured*
- Disadvantage:
  - internal *structure and meaning* of the text *gets lost*

# Concept hierarchies

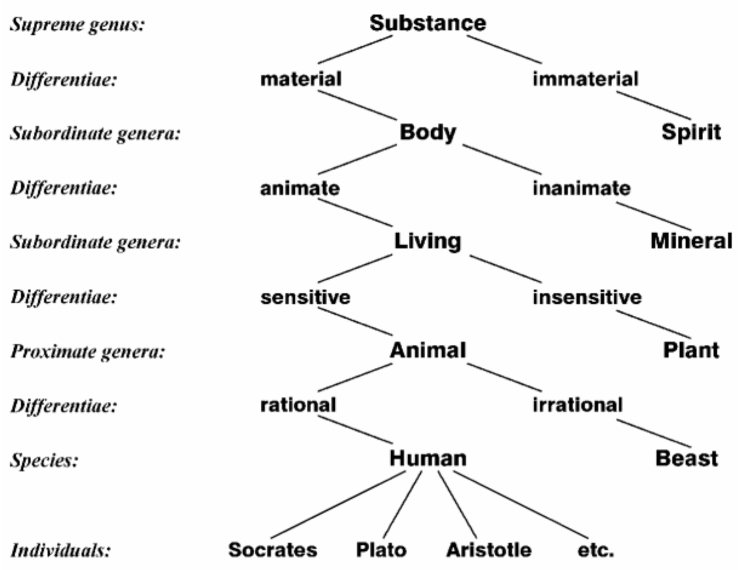
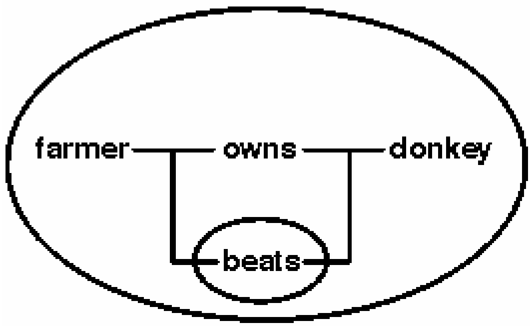



Figure 1. Tree of Porphyry, as drawn by Peter of Spain (1329)

- going back to Aristotle/Porphyry

- Advantages:
  - easy to understand
  - widely used
- Disadvantage:
  - not very expressive (but sufficient for many applications – eg, the file system on your PC)

# Existential Graphs




"If a farmer owns a donkey, then he beats it."

- Introduced by Charles S. Peirce in 1897(!).

- Advantages:
  - intuitive reading
  - intuitive calculus
  - formal semantics (but hard to extract from Peirce's manuscripts)

- Disadvantage:
  - non-linear notation difficult to represent in the computer

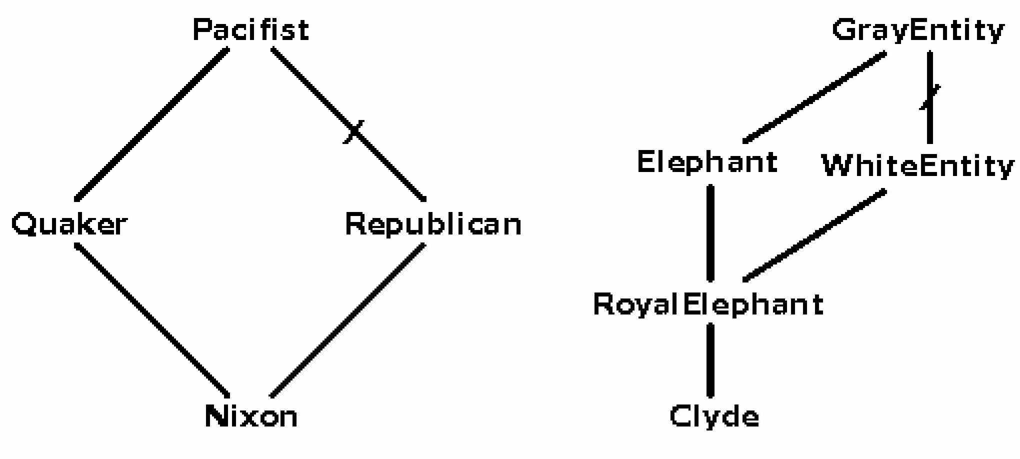
# Semantic Networks

- "Semantic Nets" were first invented for computers by Richard H. Richens of the Cambridge Language Research Unit in 1956 as an „interlingua“ for machine translation of natural languages.

- They were developed by Robert F. Simmons in the early 1960s and later featured prominently in the work of M. Ross Quinlan in 1966.

- Did not provide clear, formal semantics. → Different implementations could treat the same data differently!

# Semantic Networks



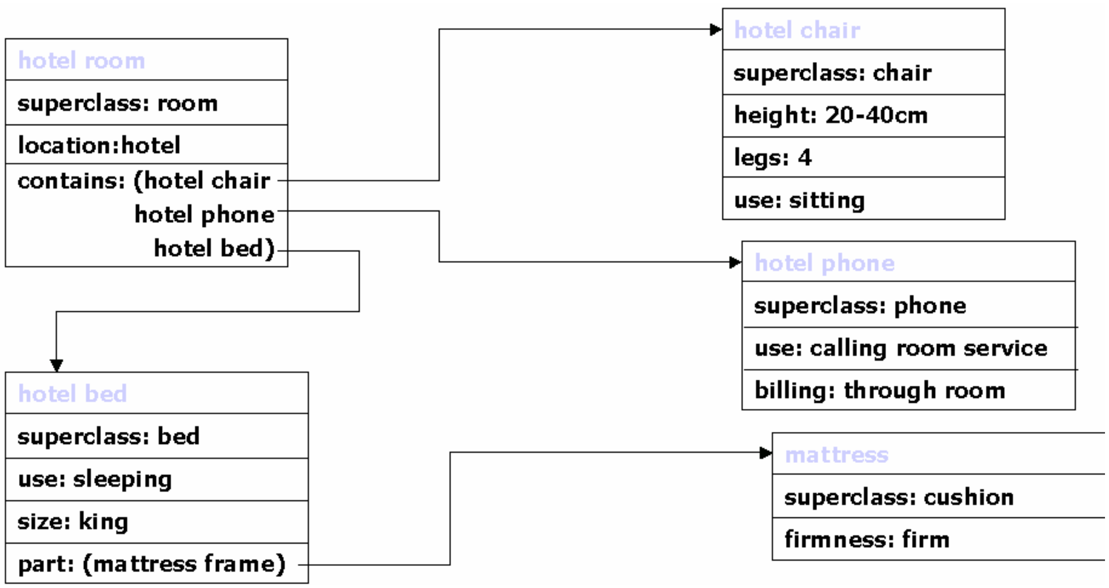

The example above shows default reasoning: Usually, elephants are grey.

- Problem: How are royal elephants treated? → The formalism is ambiguous. Different implementations may treat the same data differently. A formal semantic would answer this question.

- Later, Description Logics where introduced to overcome this problem by introducing such a semantic.

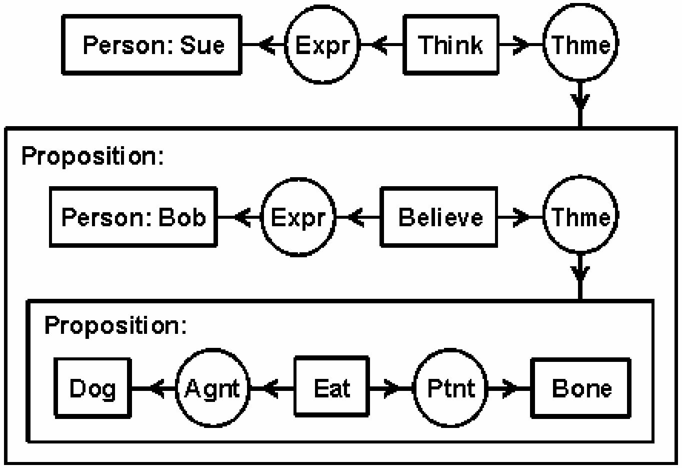
# Frames

- Much like a semantic network except each node represents prototypical concepts and/or situations.
- Each node has several property *slots* whose values may be specified or *inherited* by default.
- Frames are similar to object-oriented modelling




- Advantages:
  - is intuitive for many users
- Disadvantages
  - formal semantics are missing

# Conceptual graphs




- Based on Peirce’s existential graphs
- Aim at providing a formal semantics, by mapping to predicate logic.

- Advantages:
  - intuitive reading
  - expressive (beyond first order logic, see example above)
  - provides linear notation for easier computation

- Disadvantages:
  - mapping to predicate logic is not (yet) well defined → formal semantics are still missing

# Description Logics

$$
\begin{aligned}
\mathsf{Woman} &\equiv \mathsf{Person} \sqcap \mathsf{Female} \\
\mathsf{Man} &\equiv \mathsf{Person} \sqcap \neg\mathsf{Woman} \\
\mathsf{Mother} &\equiv \mathsf{Woman} \sqcap \exists\mathsf{hasChild}.\mathsf{Person} \\
\mathsf{Father} &\equiv \mathsf{Man} \sqcap \exists\mathsf{hasChild}.\mathsf{Person} \\
\mathsf{Parent} &\equiv \mathsf{Father} \sqcup \mathsf{Mother} \\
\mathsf{Grandmother} &\equiv \mathsf{Mother} \sqcap \exists\mathsf{hasChild}.\mathsf{Parent} \\
\mathsf{MotherWithManyChildren} &\equiv \mathsf{Mother} \sqcap \geqslant 3\ \mathsf{hasChild} \\
\mathsf{MotherWithoutDaughter} &\equiv \mathsf{Mother} \sqcap \forall\mathsf{hasChild}.\neg\mathsf{Woman} \\
\mathsf{Wife} &\equiv \mathsf{Woman} \sqcap \exists\mathsf{hasHusband}.\mathsf{Man}
\end{aligned}
$$

- Beschreibungslogiken sind eine Familie von entscheidbaren Fragmenten der Prädikatenlogik.
- Im Gegensatz zu Frames und semantischen Netzen bieten sie eine formale Semantik.
- Erster Vertreter: KL-ONE (1985)
- Heutzutage Grundlage für das Semantic Web (→ Kapitel E & F)

## Conclusion

- There are many formalisms for representing conceptual knowledge.
- Depending on the purpose, a different formalism might be the most suitable.
- In this light, we will discuss (in the next section) three formalisms in more details that were established for the (Semantic) Web: XML, RDF, OWL.