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Rationalistic approaches to IS modeling: analogy and reference models

1 Motivation 1

1.1 Analogical thinking, a cognitive strategy 1

Cognitive dilemma 1

(Neolithic) Humans need(ed) information (knowledge)
to quickly master new situations,
but humans cannot know every object of cognition.
They have too compare them with well-known situations.
=> the cognitive necessity of comparisons:
analogical thinking / reasoning

Purpose of analogical thinking:
Quick extension of the knowledge about some new situation
based upon a comparison, upon analogy,
no logical conclusion, but a heuristic strategy.

Procedure:
1. Situation
A new and a well-known object of cognition (requires memory!)
coincide in some features.
2. Assumed consequence (analogical knowledge transfer)
Assumption of analogy:
They coincide in all their "important" features,
at least one more feature.

Assumption of a strong analogy starting from a weak one,
assumption of an extensibility of an existing analogy.
(In German: Analogieschluss = Schluss auf stärkere Analogie)

The correctness of assumptions of analogy cannot be proved.

1.1 Analogical thinking, a cognitive strategy 2

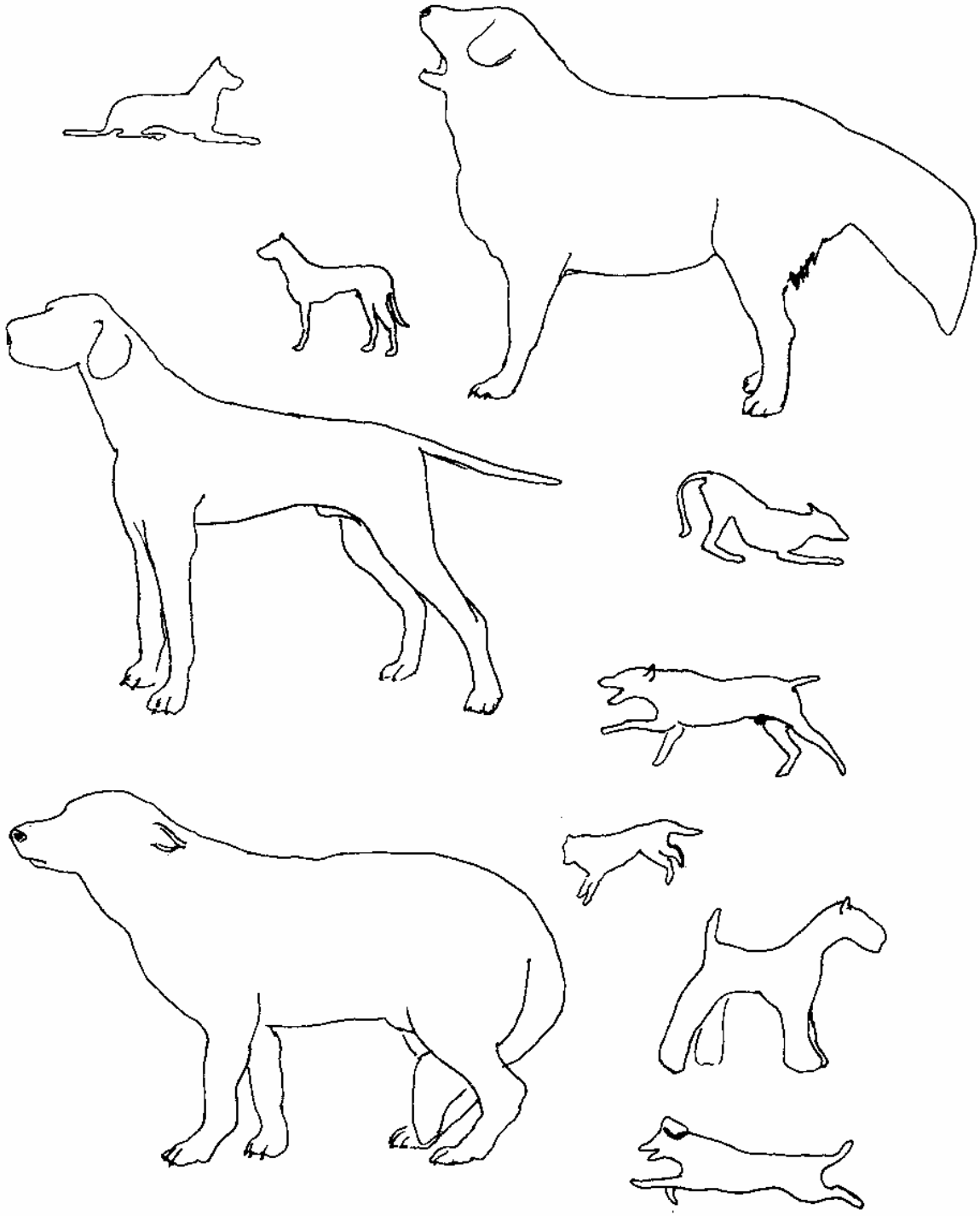

Abb. 13: Beispiel für Gestaltwahrnehmung des Menschen. Jede dieser Figuren erkennen wir als „Hund", obwohl es sich nur um grobe Umrißzeichnungen handelt. Wir abstrahieren die für Hunde essentiellen Merkmale, die „Hundegestalt", und erkennen diese auch in vereinfachenden Abbildungen, sofern nur die betreffenden Merkmale herausragen.

Assignment of individuals to a type using key features (Wuketits, Entdeckung des Verhaltens, 1995, 71)

1 Motivation 3

1.2 Examples for analogical thinking in IS 1

- **Data Mining** techniques (statistical and non-statistical), knowledge discovery in databases: similarities of data objects are used for inductive type construction.
- Transfer of **reference models** to "analogical" application fields;
  cf. purchase and sales depts. in a company
  (vs. the second source of modeling: observation / interview)
- Taxonomy in OO class models (**generalization**)
- Almost all IS models are **type models**.
  We don't model an individual customer, but a customer type.
  We don't model individual sales processes, but a sales process type.
  (Exception: model of an individual machine)
- The concept of analogy can be used for static and dynamic situations, e.g. data structures and process structures.
- Pattern recognition
- Design patterns
- etc.

1 Motivation 4

1.2 Examples 2 – Two sources for model design

Popper's World 1 (reality): empiristic method/approach
Organization, company, department
observation and interviews (W3)
of employees by a model designer
(contrary to natural sciences: only observation)
preliminary description in pre-formal models: natural language
abstraction
check whether terminology is mathematically well-defined
final type construction
formalization (degree of pre-formalization is different)
reduction to axioms

often used for peripheral areas of models
often used for individual parts of an organization
(nominalist point of view: enumeration of individual objects)

Popper's World 3 (models, concepts, ideas): rationalistic method
reference models
activation in a model designer's brain
analogy-based transfer

often used for central areas of models
often used for standard parts of an organization, e.g. accounting
(universalist point of view: search for general principles)

Final step: integration of individual and reference models.

All steps have to be taken in World 2.

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1.2 Examples 3 – Two sources for model design

external world ↓ World 1 objects of cognition	phenomenon, individual experience ↓ World 2 knowledge of an individual subject of cognition			model, theory ↓ World 3 common knowledge
	perception, cognitive processes (empiristic) ↓ reconstruct. of World 1 →	memory	learning rationalistic ↓ activations of World 3 ←	
←	↓ creation, induction ↓ design, influence ←	← new ideas, knowledge	→ publi-cation	→

Bi/trilateral semiotic sign		
materialized signifiant, vox	code of interpretation	signifié, conceptus W2|W3
object of cog.		

Model as complex bi/trilateral semiotic sign		
materialized model repre sentation	code of interpretation	model meaning W2|W3
object of cog.		

1 Motivation 6

1.2 Examples – Variables, type models 3

IS experts do not design models of single real objects, such as of individual customers, of the processing of individual orders, (that is up to the organization's employees)
but general models, such as
the common properties of all of the customers,
of the processing of all of the orders.
This fact is the basis for the rationalization potential of IS.

Models with variables: type / class models:
(intensional set definition, that is, no enumeration)

– data model of a set of analogous / equivalent real objects:
tuple of attributes (variables); entity type; OO-class
e.g. customers in general

– function model (algorithm) for a set of equivalent problems:
e.g. algorithm for the calculation of the greatest common divisor of two natural numbers (variables) in general
e.g. algorithm for the processing of orders in general

Models without variables: individual / instance models:

– data model of a single real object:
tuple of attribute values (constants); entity; OO-instance
e.g. one individual customer

– function model for a single problem:
e.g. for the calculation of the greatest common divisor of the two natural numbers 12 and 30 (constants)
e.g. for the processing of order no. 4711

2 Analogy – coincidence of feature values 1

Relation between two objects of cognition
(segments of reality, models; objects, data, processes):
Similarity, comparability, compatibility, associability,
equivalence (in terms of mathematics; → equivalence relation)
– some equal / common features
(tertium comparationis: base of comparison)
– some different features

Example: debtor and creditor management in a company
common: flow of data, goods, money between business partners
different: flow direction (inward, outward),
incoming / outgoing orders,
status of goods (raw material, final product)

Distinction:
– functional analogy: two processes deliver the same result
irrespective of the way of constructing the result
(→ functional model)
Example: copying a text with a copying machine vs. by hand
– structural analogy: two objects of cognition coincide
in selected structural components

We restrict ourselves to the latter kind of analogy.

In biology, analogy has a special meaning (vs. homology):
two recent similar morphological forms
without phylogenetic relationship, without a common ancestor
Examples:
– fins of whales and fish
– wings of bats, birds and flying reptiles

2 Analogy – coincidence of feature values 2

Formalization of the principle of analogy
in order to make models more transparent and better comparable

Feature *F* (based on theory of gestalt):
– dimension *D*
– value *V*
(cf. attributes and attribute values in data modeling)

Example: Feature *F* (*D* color, *V* red)

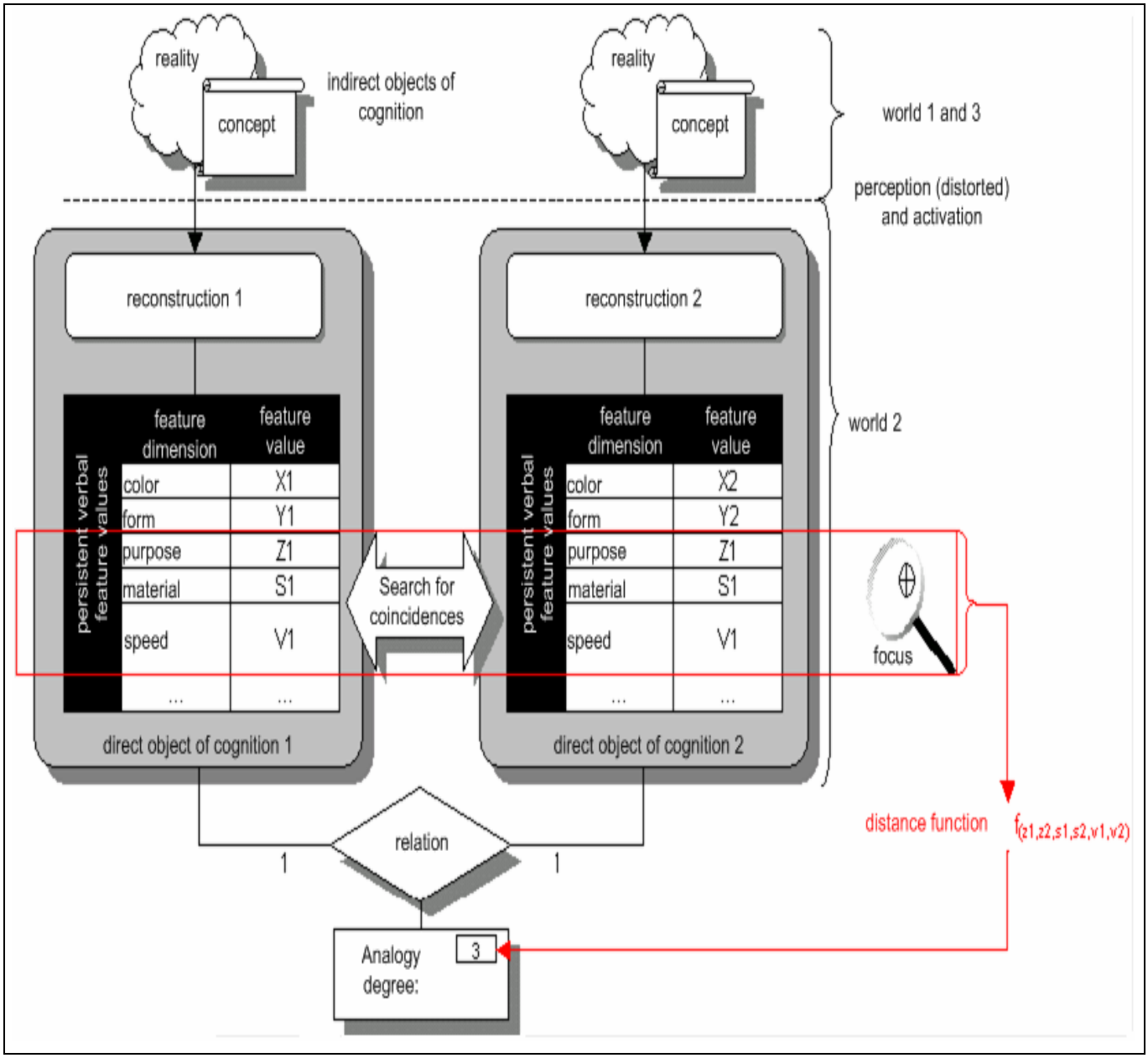
Degree of analogy
between two objects of cognition based on *n* features
calculated by using a weighted measure / function of proximity / similarity:

$$f(V_{11},V_{12},V_{21},V_{22},..,V_{n1},V_{n2}) = \sum_{\substack{i=1..n \\ V_{i1}=V_{i2}}} W_i$$

Pick out the common features in the above set of *n* features.

Two (or *m*) objects of cognition are defined as analogous iff they have
– equal essential (distinctive) features
(are considered as relevant for the comparison)
– different / equal accidental (non-distinctive) features
(don't play any role for the comparison)

2 Analogy – coincidence of feature values 3



Analogies are based upon coincidences of feature values (Holl / Auerochs, Analogisches Denken, 2004, Fig. 2)

3 Analogical thinking 1

3.1 Type construction – induction 1

Type (some sort of a model):
– constituted by equal / common essential features
– found via induction from similar objects of cognition
– a verbal description (umbrella term) can be constructed comprising just the analogous objects of cognition belonging to this type
– different or equal accidental features (e.g. size, number of employees of an organization etc.)

Example:
Customer and supplier (business partners) with
– essential features: name, address, contact person, turnover etc. (short for formal Boolean features (name-yes-no, yes) etc.)
– accidental features: receiver or sender of orders

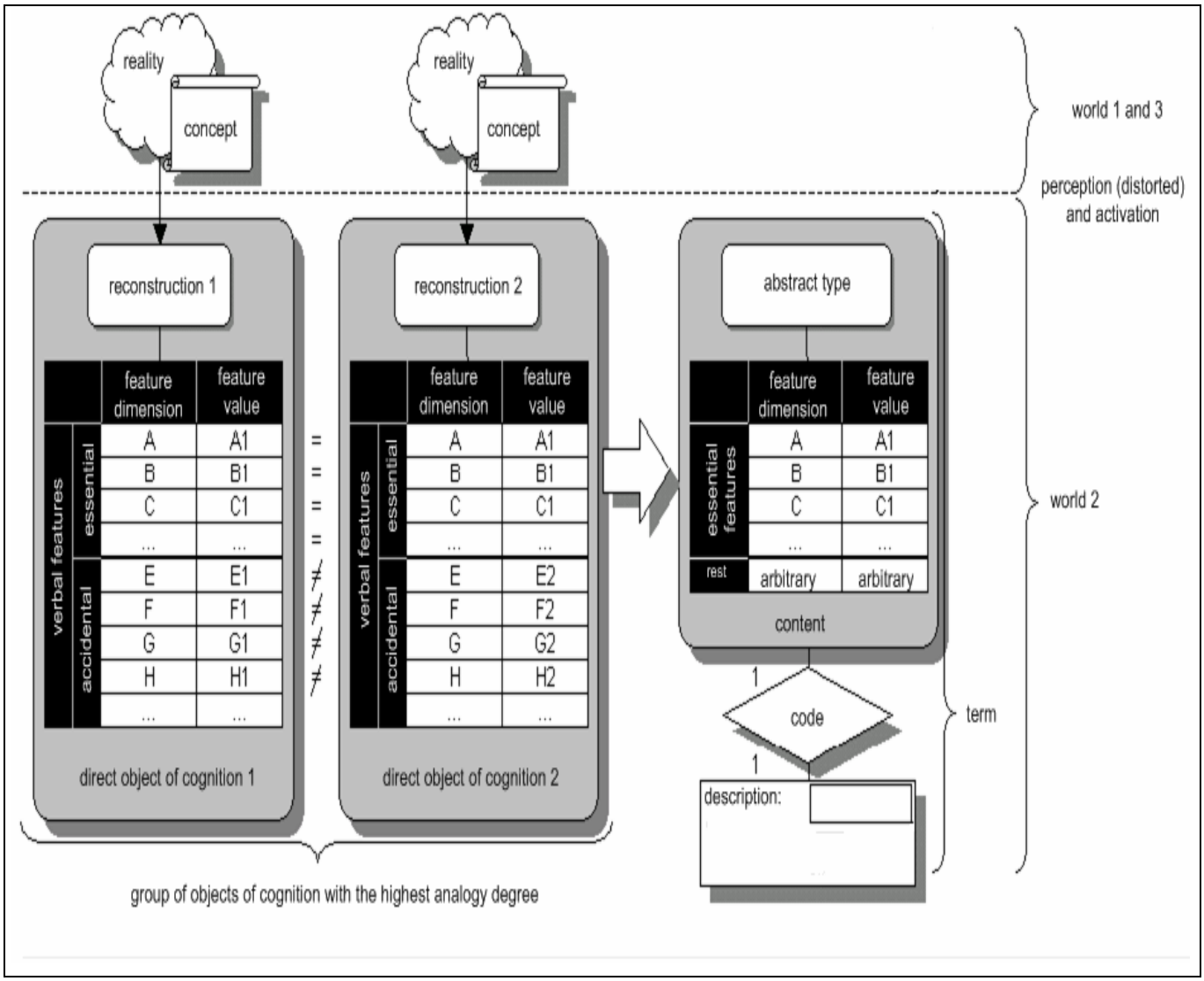
Type construction is done in every natural language where the essential features often remain implicit.

It can be formalized to serve scientific purposes.

Up until now, we distinguish between two kinds of features:
– essential features: common / equal (within a type), distinctive (towards other types)
– accidental features: common or not common non-distinctive

3 Analogical thinking 2

3.1 Type construction – induction 2



Induction step due to postulated analogy
(Holl / Auerochs, Analogisches Denken, 2004, Fig. 3)

3 Analogical thinking 3

3.1 Type construction – induction 3

**An object of cognition can be assigned
to different essential features, that is, to different types,
depending on the compared object of cognition.**

Analogy is always relative to a given set of essential features.

Example:
**Customer 1 – customer 2: customers with
more than 10,000 $ turnover a year**
**Customer 1 – customer 3: customers with
A-rating**
Customer 1 – customer 4: regular customers

Weak analogy: “few” essential features
Strong analogy: “many” essential features

**“An analogy can be more or less detailed and
hence more or less informative.”
(Konrad Lorenz, Analogy as a source of knowledge, 1974, 186)**

3 Analogical thinking 4

3.2 Levels of analogy

Analogy can be defined between objects of cognition on various levels of cognition/existence, between
– 1 objects of cognition of World 1
– 2 types, (parts of) models (World 3 objects of cognition)
– 3 objects of cognition of World 1 and types (World 3)

A type is also an object of cognition!

Examples (case 1):
Socrates, Aristotle;
this swan, that swan
customer 1, customer 2

Example (case 2):
philosopher, human;
ostrich, swan, bird
customers, suppliers

Examples (case 3):
Socrates, humans;
this swan, swans
customer 1, customers

3 Analogical thinking 5

3.3 Reasoning – deduction 1

1 Classification using essential features
2 Transfer using a pars-pro-toto strategy

Example (case 3) with true conclusion:
modus ponens (a sort of a syllogism = logical conclusion)
Humans are mortal.
common accidental (non-distinctive) feature of a type
Classification:
Socrates is a human.
coincidence object of cognition - type
in essential features (or key features, see 4)
Transfer:
Socrates is mortal.
common accidental feature of an object of cognition
(or essential feature if one starts with key features)

Example (case 3) with false conclusion:
Every swan is white.
This bird is a swan.
This bird is white.

Example (case 2) with false conclusion:
A swan can fly.
Ostrich and swan are analogous (are birds).
An ostrich can fly.

Correctness of assumptions of analogy:
– ⇔ adequacy of selected essential features (or key features)
– cannot be proved.
Risk: This kind of thinking can be a cognitive trap!

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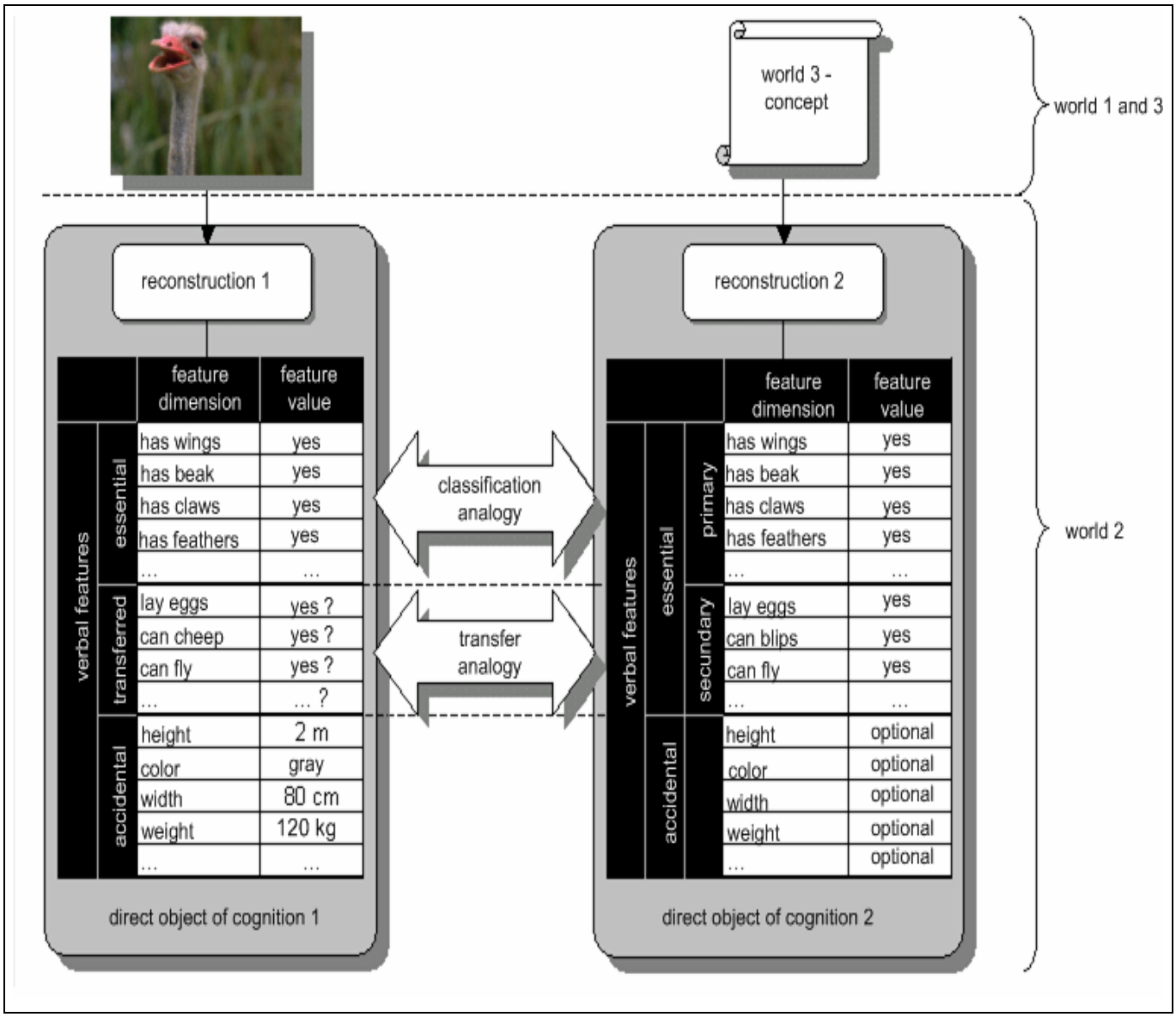
3.3 Reasoning – deduction 2



Deductive conclusion with the help of analogy
(Holl / Auerochs, Analogisches Denken, 2004, Fig. 4)

Up until now, we distinguish between <u>three kinds of features</u>:
– essential features (classification)
– common accidental features (transfer)
– different accidental features

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3.4 Relation between analogy and induction / deduction

Induction
(due to cognitive dilemma 1)
Starting from some similar / analogous objects of cognition of the same type,
that is objects of cognition with the same essential features,
a theory / model of a common accidental feature is derived.
This is a creative, heuristic (not logical) procedure!

Deduction
Situation:
There is a theory about a common accidental feature of a type.
Classification: The type and some other object of cognition coincide in their essential features.
Transfer – analogical assumption – (logical) conclusion:
Type and object of cognition are analogous,
that is, they coincide in all their essential features,
therefore, the theory applies for the object of cognition.
(analogical transfer of common accidental features)

Or even in a weaker form (see 4):
Classification: The type and some other object of cognition coincide in key features.
Transfer – analogical assumption – (logical) conclusion:
Type and object of cognition are analogous,
that is, they coincide in all their key features,
therefore, the theory applies for the object of cognition.
(analogical transfer of common accidental features and secondary essential features)

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3.5 Popper's fallibilism 1

Verification / falsification (Karl Popper)

As we do not know all the objects of cognition of a given type, inductively derived theories cannot be proved;
cf. *every swan is white*, *every bird can fly*

That is – as we already know –
the correctness of assumptions of analogy cannot be proved and
the correctness of logical deductions
starting from an inductively derived (only falsifiable) theory cannot be proved.
The results cannot be more true than the pre-conditions.

Deduction works correctly only with well-defined mathematical objects.

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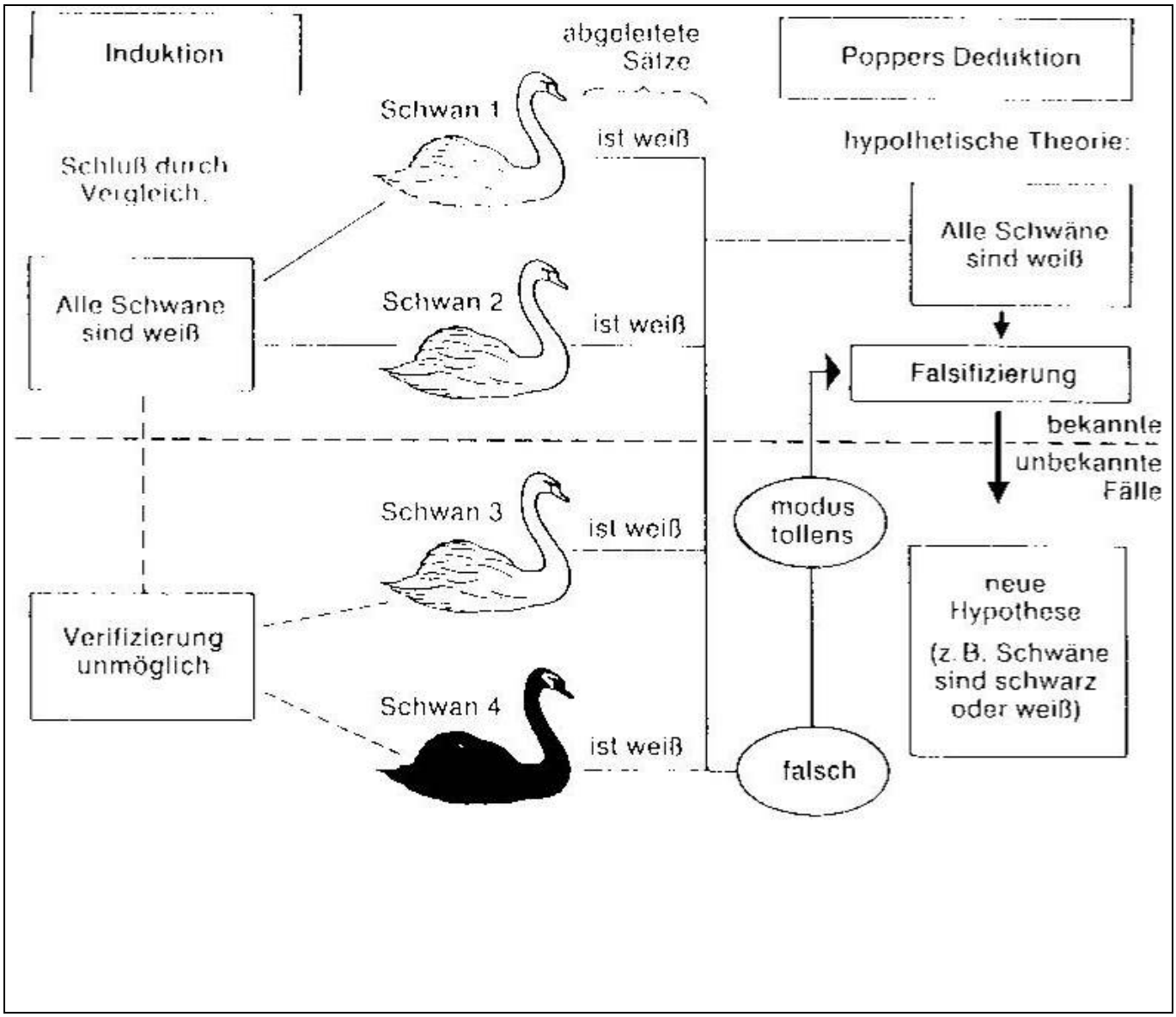
3.5 Popper's fallibilism 2



Can swans be black?
(dtv-Atlas Philosophie, *, 228)**

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3.5 Popper's fallibilism 3

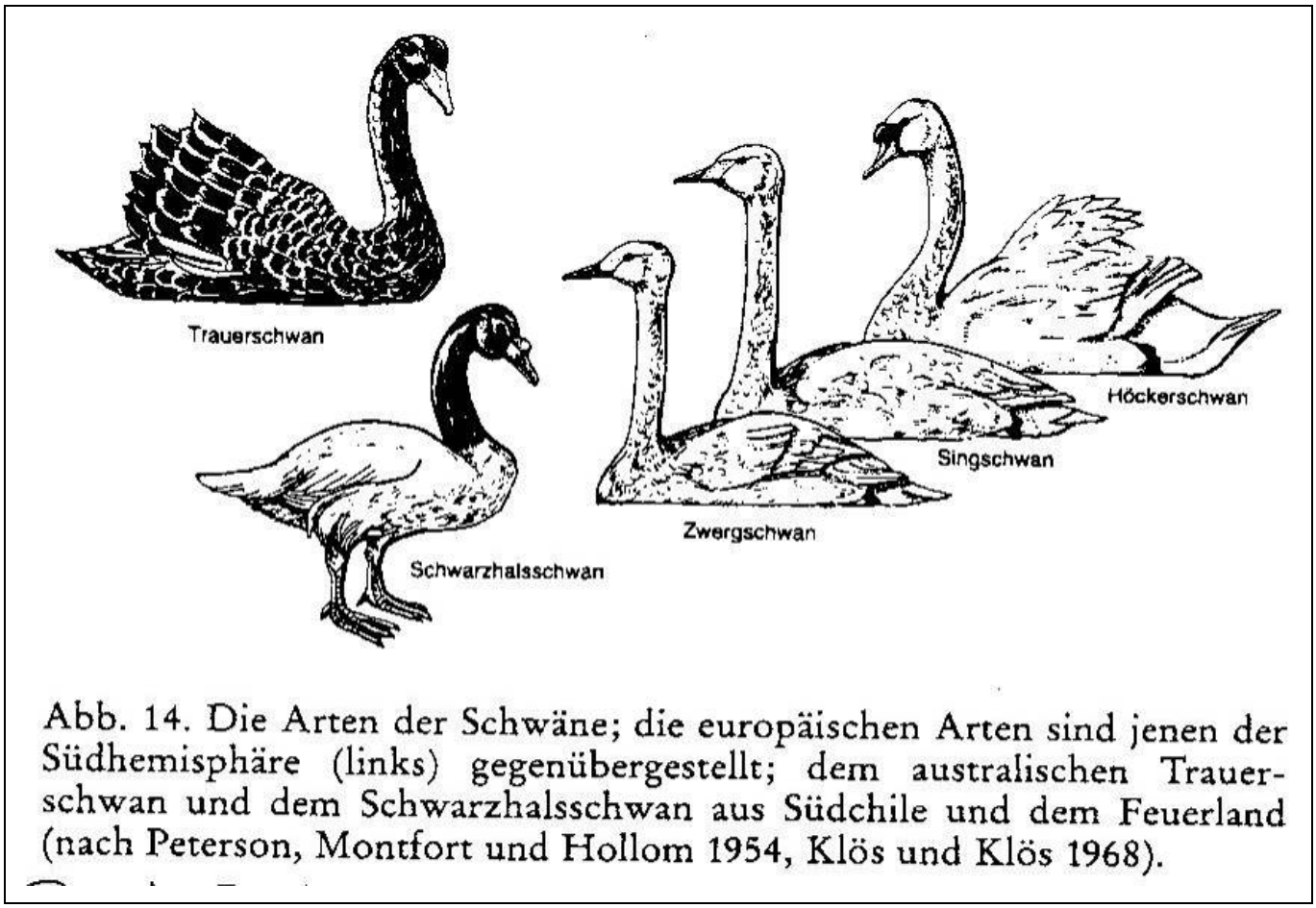


Abb. 14. Die Arten der Schwäne; die europäischen Arten sind jenen der Südhemisphäre (links) gegenübergestellt; dem australischen Trauerschwan und dem Schwarzhalsschwan aus Südchile und dem Feuerland (nach Peterson, Montfort und Hollom 1954, Klös und Klös 1968).

The genus "swan"
(Riedl, Biology of knowledge, 1984, 83)

4 Key feature based analogical thinking 1

Cognitive dilemma 2

(Neolithic) Humans need information to master these situations in the most adequate possible way, but
every object of cognition has numerous features,
among them not easily observable ones and even hidden ones.
The complete observation of all the essential features of an object of cognition is impossible,
it would take too much time or even destroy the object,
but quick reactions are necessary for survival.
cf. lion in the bush, roars, but is not visible

=> the cognitive necessity of partial comparisons
based upon only few features ("key features")

The cognitive strategy of analogical thinking is originally a heuristic cognitive pars-pro-toto (part instead of total) strategy based upon so-called key features
(Konrad Lorenz, Die angeborenen Formen möglicher Erfahrung, 1943, 240: key stimuli, pars-pro-toto reactions)

Key features (directly perceptible, e.g. optical):
– considered as important in the sense of the theory of gestalt
Konrad Lorenz 1959:
"Gestalt perception as source of scientific knowledge."
– (un)consciously, heuristically defined by observer/scientist
– not type-immanent, depending on object and observation

Example:
Customers and suppliers are
companies connected with our own company
by business transactions (data, goods, money)

4 Key feature based analogical thinking 2

Highly significant essential features can serve as key features.

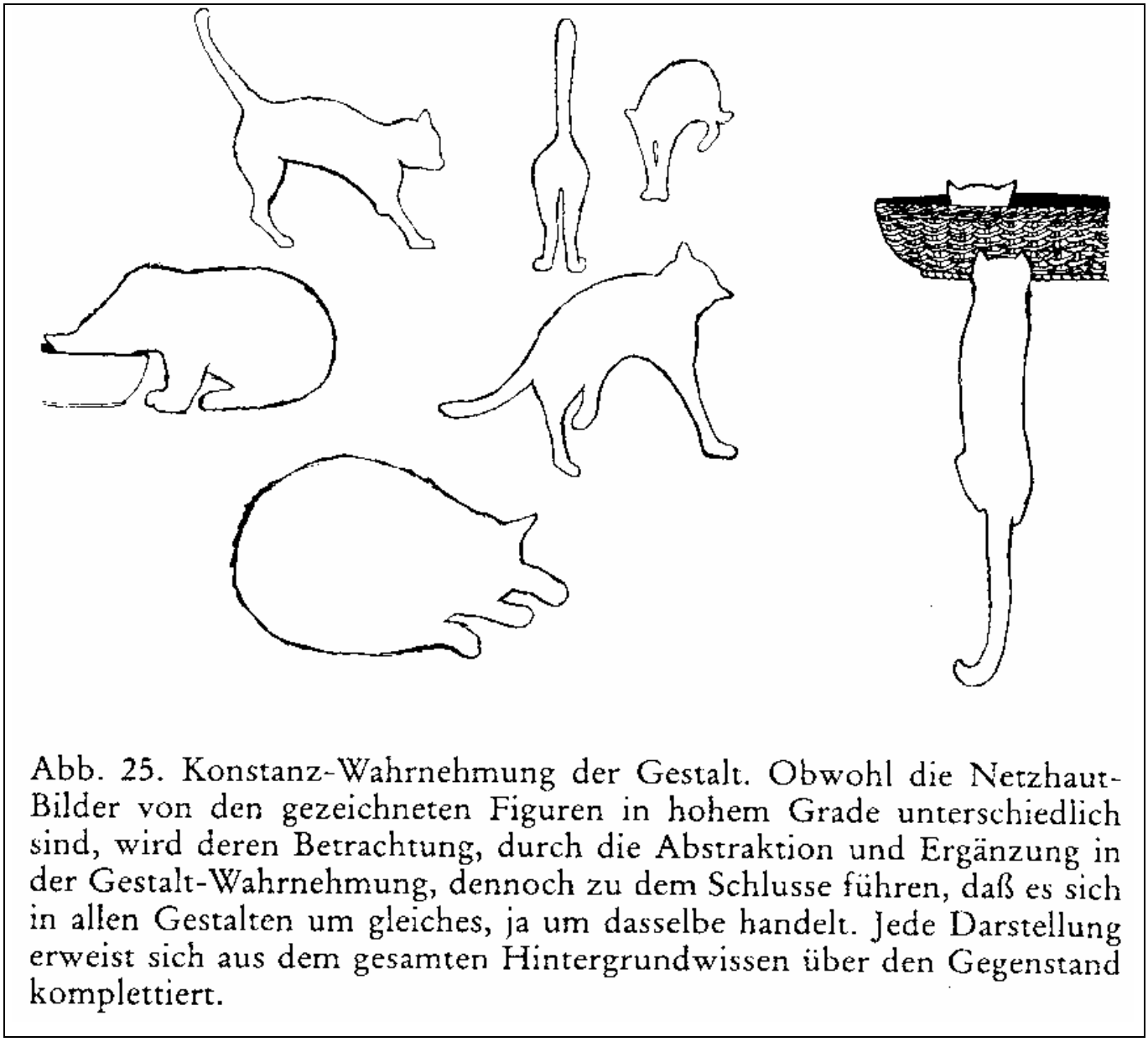


Abb. 25. Konstanz-Wahrnehmung der Gestalt. Obwohl die Netzhaut-Bilder von den gezeichneten Figuren in hohem Grade unterschiedlich sind, wird deren Betrachtung, durch die Abstraktion und Ergänzung in der Gestalt-Wahrnehmung, dennoch zu dem Schlusse führen, daß es sich in allen Gestalten um gleiches, ja um dasselbe handelt. Jede Darstellung erweist sich aus dem gesamten Hintergrundwissen über den Gegenstand komplettiert.

One animal or different animals?
(Riedl, Biology of knowledge, 1984, 167)

4 Key feature based analogical thinking 3

At last, we distinguish between four kinds of features:
– primary essential features (suitable as key features)
– secondary essential features (not suitable as key features)
– common accidental features (transfer)
– different accidental features

Example: human

Primary essential features (suitable as key features)
– shape of the body
– shape of the face
– movement on two legs
– ability to speak

Secondary essential features (not suitable as key features)
– cortex of the brain

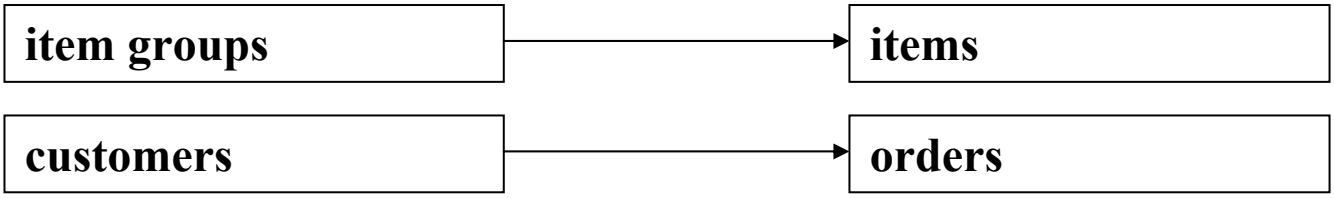
Common accidental features
– mortality

Different accidental features
– color of hair
– color of skin
– height
– sex

Essential features are common /equal and distinctive.
Accidental features are common or not and non-distinctive.
Secondary essential features and common accidental features can be used for analogical transfer.

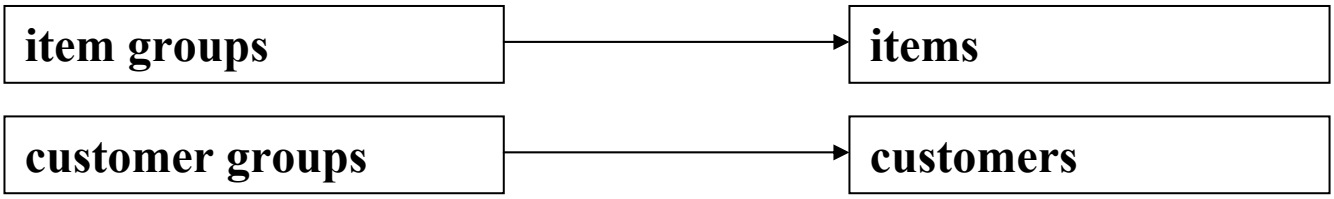
5.1 Data models: What degrees of analogy occur?

1 mere syntactic

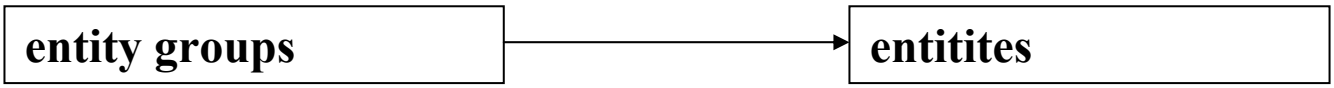


analogy: one-to-many relationship

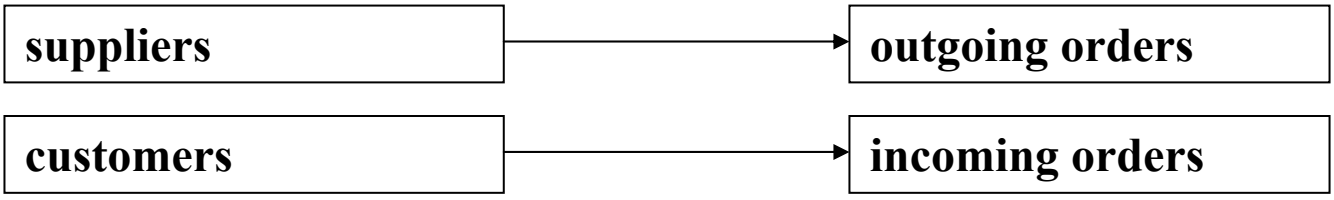
2 low degree, weak semantic



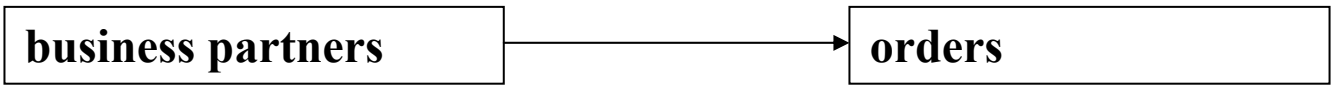
umbrella terms:



3 high degree, strong semantic



umbrella terms:



5.1 Data models:
generic models; reference models

Two data models are analogous iff

(1) they are syntactically equal, that is
the structures of entity types and relationships are equal,
the mere diagrams without text coincide

(2) they are semantically analogous in the same degree, that is
syntactically corresponding entity types
are analogous in the same degree, that is
an umbrella term can be constructed
for each pair of corresponding entity types

Example

creditor	debtor	umbrella terms generic model
supplier groups ↓ suppliers ↓ outgoing orders ↓ order lines ↑ raw materials ↑ material groups	customer groups ↓ customers ↓ incoming orders ↓ order lines ↑ products ↑ product groups	business partner gr. ↓ business partners ↓ orders/contracts ↓ order lines ↑ items ↑ item groups

→ one-to-many relationship

5.1 Data models: What about partial analogies?

Complete model analogies are rare, that is syntactic equality is often not complete.

Example 1:
Number of order lines
orders with only one or with more order lines

customers **library users**	→	**orders** **-**	→	**order lines** **borrow transactions**	←	**products** **books**

Example 2:
Individual identifiability of items
individually identifiable items (library books, cars) or not individually identifiable items

borrow transactions **order lines**	←	**books (copies)** **-**	←	**books (titles)** **products**

5.2 Main functional areas of a company

Company management
Information management
Financial management, investments
Personnel management = human resources management
Accounting (ledger, accounts receivable, accounts payable)
Marketing, distribution, sales, order management
Materials management, inventory, purchasing, procurement
Production
Quality assurance/management
Product development, research and development
Customer support/service

Decomposition into smaller functional areas
which can be assigned to
employees (employee groups) in a matrix

6 References

pdf-files of my own publications: see my homepage.

Holl, Alfred:
Empirische Wirtschaftsinformatik und evolutionäre Erkenntnistheorie.
In: Becker, Jörg et al. (ed.): *Wirtschaftsinformatik und Wissenschaftstheorie. Bestandsaufnahme und Perspektiven*.
Wiesbaden: Gabler 1999, 163-207, ISBN 3-409-12002-5.
English translation on my homepage.

Holl, Alfred; Auerochs, Robert:
Analogisches Denken als Erkenntnisstrategie zur Modellbildung in der Wirtschaftsinformatik.
In: Frank, Ulrich (ed.): *Wissenschaftstheorie in Ökonomie und Wirtschaftsinformatik. Theoriebildung und –bewertung, Ontologien, Wissenmanagement.*
Wiesbaden: DUV 2004, 367-389, ISBN 3-8244-0738-8.