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Critical-Realistic Software Engineering: Epistemology-Based IS Modeling Critique of IS modeling

Information Systems
as empirical science and
Evolutionary Epistemology

**“From our studies, my impression is that
the American IS researchers develop hypotheses,
the German IS researchers get surveys done and
the Scandinavians think a lot.“**

C. Avgerou, LSE, ECIS 1996, AIS Panel on European Research Traditions in IS

IV. Which problem areas of IS require an application of epistemology? Which answers do critical realism and evolutionary epistemology give? Which advantages and which consequences for IS are the result?

Selected examples, approaches for explanation and proposals for solution

1. result of observation: knowledge (W2/3)

2. object of observation (W1) **3. observer (subject W2)**

4. observation process (W1-W2)

IV.1 What are the particularities of the human cognitive power? How does the human being gain objects of cognition? What are the qualities of human knowledge? Two epistemological dilemma: Problem of isomorphy and problem of isolation/separability

Overview

IV.1.1 Dilemma 1: Necessity of filtering, interpreting, abstracting, inductive cognitive processes: Problem of isomorphy world – model; problem of completeness of models

- **Observations (although the contrary is expected)**
- **Explanation by critical realism**
- **Explanation by evolutionary epistemology**
- **Consequences for IS**

IV.1.2 Dilemma 2: Necessity of structuring the world and its lack of non-ambiguity: Problem of isolation/separability

IV.1.1 Problem of isomorphy 1

Observations
permanent search for new modeling methods
no one-to-one mapping of reality by OO models

Critical realism
complex distortion by cognitive processes ==>
1. not necessarily equality of structure
between object domains and models
2. distinction required:
reality-immanent categories - descriptive categories
3. incomplete observability
incomplete models
4. missing provability of models

There is no empirical knowledge without distortion by perception!
The only way to acquire knowledge about W1 is via W2!
(1st epistemological dilemma → II.4.3)

Evolutionary epistemology
biological purpose of knowledge:
guaranty of survival,
descriptive functional models (e.g. law of gravity)
not: understanding of the world in detail,
explanatory models with equal structure
(e.g. the exact mechanism of gravitation)

IV.1.1 Problem of isomorphy 2

Consequences for IS

1. Tension reality - model is not solvable as a principle
approximations require a well-reasoned set of methods
two starting points:
reference models and analogy (→ V.3)
pre-models in natural language and their formalizing

2. awareness of non-perfect models with errors

3. With regard to the same application field, compare:
– alternative models under the same modeling aspect
– models under different modeling aspects (data, functions etc.)
the approaches have to be consistent (hypothesis of consistency)
cf. tale of the elephant and the four wise men (→ IV.3.2.1)
vs. valid incoherent theories in physics
(e.g. wave-particle-dualism of the light),
no coherent super/umbrella theory
That is: IS object domains are 'simpler' than physical ones.

4. terminological distinction: W1 categories – W3 categories

5. missing universality of mathematics, no positivism of maths

Remark 1 (agile SW development → IV3.1.1)
To press application fields into modeling notations makes the consequences of the problem of isomorphy even worse.
Notations have to be adapted to application fields. (cf. EPC)

Remark 2 (ambiguity of modeling → II.2.2)
There are different ways of modeling an application field.

IV.1.2 Problem of isolation/separability 1

Observations
trouble with not effective isolated SW solutions
trouble with the limitation of systems

Critical realism
1. complexity reduction by creating segments and structures
2. there are natural system-like structures
with strong internal and weak external connections
but: there aren't any natural closed systems,
only open systems [informational systems in IS]
==> systems: descriptive categories, not reality-immanent
it is the observer who defines system boundaries

There is no empirical knowledge without isolation of systems!
(2nd epistemological dilemma)
Isolation is the pre-condition for
– the mere cognition of objects
– the transfer of feature sets, the perception of "gestalts"
– the comparison of objects
(Lorenz "The innate forms of possible experience" 1943: 319)

Evolutionary epistemology
1. cerebral cortex as carrier of cognitive processes
has its origin in optical neural centers;
consequence: cognitive strategies are transferred from
primary objects of cognition
visual-tangible (physical solids), simple,
few interactions, 'mesocosmic'
to secondary objects of cognition
socio-economical, sub-atomic particles, complex,
numerous interactions, macro/microcosmical
2. small segments are better suitable as basis of analogy

IV.1.2 Problem of isolation/separability 2

Consequences for IS

1. at least: SA context diagram or UML use case diagram
with system surroundings and external connections
2. better: magnifying glass model:
soft, blending system boundary
with precision/magnification decreasing towards the rim
3. clear idea of the system's purpose and objectives

Remark 1 (ambiguity of segmentation)
There are different ways of decomposing an object domain.

Example: magnet: optical field vs. magnetic field

Remark 2 (abstraction levels)
Humans cannot understand complex systems at first glance
==> complexity reduction by decomposition
is necessary on different abstraction levels
==> problem of isolation occurs on every abstraction level

Remark 3 (process – system)
Processes can be interpreted as (linear) systems,
therefore, there are equivalences
– open process ~ open system
– process boundary ~ system boundary (defined by observer)
– process decomposition ~ system decomposition (→ IV.3.1.2)

IV.2 What are the particularities of the IS objects of cognition with respect to formalization? Inhomogeneity, heteronomy; pre-formalization, suitability for formalization; compatibility of IT tool and IT application field; temporal dynamics

Overview

IV.2.1 What are the particularities of the IS objects of cognition?
Inhomogeneous, autonomous-heteronomous object domains;
'human factor';
communication as basis for observation

IV.2.2 How can IS objects of cognition be discriminated
with respect to formalization?
Different degree of pre-formalization,
suitability for formalization and effort of formalization

IV.2.3 What is the purpose of the formal optimization
of business processes?
Compatibility of tool and application field,
principle of key and lock

IV.2.4 How is the temporal behavior of IS objects of cognition?
Temporal dynamics; Changed requirements management

IV.2.1 What are the particularities of the IS objects of cognition? Inhomogeneous, autonomous-heteronomous object domains; 'human factor'; communication as basis for observation

Observations
There are no 100 % IT solutions.
The deployment of IT infrastructure does not necessarily imply its successful use by the end user.

Critical realism
An enterprise, a human artifact, as object of cognition is different from segments of nature which are observed in natural sciences:
– **autonomous natural parts: humans, scarcely formalizable**
– **heteronomous artificial parts: math. structures, formalizable**

Evolutionary epistemology
Human cognitive strategies start at homogeneous simple objects, but homogeneity is less probable in large, complex objects.

Consequences for IS
IS expert should learn and be aware of that non-formalizable humans (individualistic view of humans) control data processing in enterprises.
Consequences:
– **participative strategies, fair explanations for end users**
– **organization consulting for various optimization approaches:**
– – **non-formal optimizations: group dynamics, fear of IT, organization/human resources psychology**
– – **formal optimizations without IT: e.g. card index**
– – **formal optimizations with IT**

IV.2.2 How can IS objects of cognition be discriminated with respect to formalization? Different degree of pre-formalization, suitability for and effort of formalization

Observations

It is more difficult to model small enterprises than large ones.
SW development for accounting is easier than for production.
Suitable descriptive categories are often unknown in enterprises and model designers have to start from scratch to define them.
It is difficult to estimate the time necessary for formal modeling.

Critical realism

With regard to formalization, IS object domains differ in:

- **pre-formalization**
- **suitability for formalization**
  (cf. deterministic vs. (non-) deterministic, chaotic domains)
- **effort of formalization**

→ not pre-formalized, scarcely formalizable object domains
→ partly pre-formalized object domains: implicit formal models
→ well pre-formalized object domains: explicit formal models

Evolutionary epistemology

primary cognitive strategies:

- **all objects of cognition are of the same kind, uniform (with regard to suitability for formalization)**
- **objects of cognition do not overlap**
  vs. magnetic and gravitational fields

Both assumptions do not apply for complex objects:
e.g., difficult formalization of production; personal union; optical objects and functional objects need not coincide

IV.2.2 How can IS objects of cognition be discriminated with respect to formalization? Different degree of pre-formalization, suitability for and effort of formalization 2

Consequences for IS

Examine object domains with respect to 3 views of formalization.
Respect the results in time and project management.
Pre-formalized domains are starting points for IT (accounting).
Don’t force formalization, allow chaotic oscillations (production).
Check terminology used in enterprises with regard to suitability for formalization.

Remark (structuring)

These considerations apply for pre-structures, suitability and effort for structuring as well.

IV.2.3 What is the purpose of the formal optimization of business processes? Compatibility of tool and application field, principle of key and lock

Observations
The effect of exclusive IT deployment is often overestimated.
Even well-modeled SW often does not fit an enterprise.

Critical realism
IT tools are formal and fit only formal application fields.
They cannot cure disastrous organization.
Straight keys cannot be put into crooked locks.

Evolutionary epistemology
Originally: Adapt tools to their application fields.
IT: In addition, adapt application fields to tools (formalization)

Consequences for IS
IT deployment requires formalization of the application field
Formalize (straighten) lock before modeling a formal key:
survey of the current state:
– describe and model the lock
analysis of the current state:
– Is the lock pre-formalized (straight) or not (crooked)?
– How, to what extent can the lock be formalized (straightened)?
conceptual model of the planned state:
– formal model of the lock (enterprise/department)
– formal model of the key (IT/SW system)

Remark (further particularities of objects of cognition)
incomplete observability

IV.2.4 How is the temporal behavior of IS objects of cognition? Temporal dynamics; changed requirements management 1

Observations
SW does not meet requirements after long programming periods.

Critical realism
Every segment of the reality contains internal temporal dynamics, which can partly be deterministic and partly chaotic.
Prognoses of its future behavior are only partly reliable, especially if a segment is disturbed.

Evolutionary epistemology
Primary objects of cognition are quite static (solids).
This assumption is transferred to secondary objects of cognition (e.g. socio-economical domains) where it is not valid.

Consequences for IS
in general:
1. keep your model of the planned state valid
by quickly including changes in the application field in order to avoid using models of a past reality for programming
2. keep your models and your SW easily changeable in order to be able to easily change models and SW
in the case of changes in the application field

IV.2.4 How is the temporal behavior of IS objects of cognition? Temporal dynamics; changed requirements management 2

Consequences for IS
in detail:
changed requirements management
overlapping phases and iterations in phase concepts
dynamic design concepts
permanent check of changes in the application field
permanent contact to the future users
participative strategies
evolutionary SW development
well-documented and easily adaptable SW
some aspects of 'extreme programming'
(user participation, quick development, small projects)

Remark (dynamics due to external influences)
The effects of the internal temporal dynamics of segments of reality and their treatment
correspond more or less to the externally induced dynamics
due to changes of the environment (e.g. laws) and
due to the influence of an observer (IV.4).

IV.3 How do subjects of cognition treat objects? Particularities of human thinking during model construction; individualistic view of humans

Overview: 3 levels of features: general features (all humans) and individual features (accessible and not accessible to consciousness)

IV.3.1 How do humans think generally, how should they think? Essential properties of human thinking

IV.3.1.1 How can human cognitive processes be put in a linear temporal sequence and how can they be structured? Flexible phase concepts, levels of design

IV.3.1.2 Why is process decomposition more difficult than data decomposition? Static forms can be analyzed more easily than dynamic forms

IV.3.1.3 Why do humans have difficulties with formalization, mathematization etc.? These skills are not primarily necessary for survival

IV.3.2 What circumstances exert an influence on individual human thinking? Accidental properties of human thinking depending on disposition

IV.3.2.1 Why are models of different subjects of cognition not necessarily consistent? Psychic-intellectual-social disposition of subjects of cognition

IV.3.2.2 Why are humans not fond of model description? Concentration on primary results

<u>IV.3.1.1 How can human cognitive processes be put in a linear temporal sequence and how can they be structured? Flexible phase concepts, levels of design</u>

<u>Observations</u>
lack of success of at least strictly serial phase concepts
many different phase concepts

<u>Critical realism</u>
Temporal structuring (decomposition)
– leads to critical cases and overlaps (swed. gråzoner**)**
– is not possible in an non-ambiguous way

<u>Evolutionary epistemology</u>
1. Multidimensional thinking is an advantage for survival.
→ Several decision levels are regarded in parallel, not in sequence
2. Human cerebral cortex has an optical-tangible orientation.
→ Easier to decompose spatial domains than temporal ones.
cf. (IV.3.1.2)

<u>Consequences for IS</u>
Phase concepts are standards not respecting cognitive processes.
1. Use iterative, <u>flexible phase concepts adaptable to the particularities of projects</u> in a differentiated way, allow overlapping phases.
2. Replace design phases (analysis vs. implementation) by discrete <u>design levels</u> (information-relevant vs. implementation-relevant).

<u>Remark</u> (further particularities of human thinking)
formalization, mathematization, reduction to axioms,
treatment of critical cases → <u>requirements engineering</u>

IV.3.1.1 How can human cognitive processes be put in a linear temporal sequence and how can they be structured? Flexible phase concepts, levels of design 2

Remark:

**It is not the task of a project
to prove the applicability and quality
of a modeling technique/method or notation.**

**The other way round:
Methods and notations should support
modeling within a specific project,
therefore, they should be adapted
to the particular requirements of a specific project.**

cf. 'agile SW development' [Chris Rupp, Sophist]

IV.3.1.2 Why is process decomposition more difficult than data decomposition? Static forms can be analyzed more easily than dynamic forms (theory of gestalt)

Observations
Data modeling and static object modeling more often lead to uniform results than function and (business) process modeling.

Critical realism
Structuring, decomposition and division into discrete segments
quite easy for spatial domains (snapshots)
→ data models
quite difficult for temporal domains (processes)
→ process models

Evolutionary Epistemology
Observations are due to properties of human brain:
Human cerebral cortex has an optical-tangible orientation.

Consequences for IS
Start modeling with the temporally least dynamic aspects:
data model or static object model.
Feature-based event-driven process chains (→ V.4.3)
as process-oriented equivalent to normalization in data modeling

IV.3.1.3 Why do humans have difficulties with formalization, mathematization etc.? These skills are not primarily necessary for survival

UNDER CONSTRUCTION

IV.3.2.1 Why are models of different subjects of cognition not necessarily consistent? Psychic-intellectual-social disposition

Observations
Versed IS experts try to press enterprises in standards,
in reference models (hermeneutic circle).
Inexperienced IS experts do not recognize hidden standards.

Critical realism
There is no knowledge without subjects of cognition,
no models without model designers.
The subject's properties always play an important role
(especially in the case of logical induction during modeling):
– psychological disposition: emotional relation to object etc.
– intellectual disposition: prejudices, pre-knowledge etc.
– social disposition: colleagues, ability to work in teams etc.

Evolutionary epistemology
Reactions depend on pre-knowledge.
Humans react on known situations in an analogical way,
on unknown situation in a spontaneous and creative way.
What is known and unknown, however, depends on the subject.
"Naive" observers do not realize these interrelations.

Consequences for IS
Strive for sharpened awareness of epistemological constraints.
Give up the illusion of a model's objectivity and independence.
Give up the illusion of the observer's neutrality.
Be aware of your (pre-)dispositions. (Wuketits, Lorenz 234)**.**
Try to find a balance between reference and individual model.

→ Exemplum of "The blind men and the elephant" V.1

IV.3.2.2 Why are humans not fond of model description? Concentration on primary results

Observations
Documentations are often missing or just bad.

Critical realism
'Una palabra mal colocada estropea el más bello pensamiento.'
'Bad wording destroys the best idea.' (Voltaire)

Evolutionary epistemology
Humans concentrate on activities
which are primarily necessary for survival.

Consequences for IS
coding conventions
source list layout
mnemonic names (transparency by underline, capitalizing)

functions: names consist of verb + object
CAUTION: singular and plural often identical in German
Kunden löschen
– operational decomposition:
administrate data → record data, change data, delete data
– object-oriented decomposition:
administrate data → administrate customers, suppliers, products
– (remark: fine decomposition leads to OO functions)
function blocks: BEGIN, END, names of local variables
include a reference to the block name (scope recognizable)
DB tables, files, screens and other complex variables:
names of attributes include a reference to the table name:
formal abbreviation + semantic name
primary and reference keys recognizable by their names

IV.4 What is the relation between subject and object? Interdependency, mutual influence

Observations
Demand for checking questions after analysis of current state
Unrealistic, strange results of an external analysis

Critical realism
1. An observer acts on and changes an object of cognition and, therefore, becomes part of the observed object domain:
Interviews with observer lead to internal considerations (different understanding, optimizations, fear of rationalization)
(cf. Heisenberg's relation)
2. The observed object retro-acts and changes the observer:
During the observation period, the observer learns more about the object of cognition.
The interpretations of the first partial object can be done in a completely different way as those of the last one.

Feed-back loop (circular process) instead of independency
missing self-containedness of objects of cognition
no strict S – O separation/independency ➔ against positivism

Evolutionary epistemology
Naive-realistic cognitive strategies have their origin in 'mesocosmic' physical solids you can see and touch.
These strategies are not suitable for other objects of cognition, such as sub-atomic particles and social structures.

Consequences for IS
long observation periods, evolutionary SW development
changed requirements management,
participative strategies