Towards an Ontology for Information Systems Development

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Outline

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1. Introduction

In the last four decades a large number of approaches have been suggested in the literature to perceive ISD:

- ISD is seen as
  - a transformation process (e.g. Saeki et al. 1993),
  - a decision-making process (e.g. Jarke et al. 1990; Rolland et al. 1995),
  - a problem-solving process (e.g. Sol 1992; Jayaratna 1994),
  - a learning process (e.g. Iivari 1990; Ramesh et al. 1994),
  - a political process (e.g. Keen 1981; Newman et al. 1990) etc.
- An ISD process is structured according to the water fall model, the spiral model, the fountain model, a prototyping model, an evolutionary model, etc.
- Features of IS are modeled according to structured, functional, object-oriented, feature-oriented, agent-oriented, aspect-oriented, etc. approaches.

1. Introduction (Continues..)

To promote a common understanding of research subjects and results, a shared conceptualization of ISD is needed.

That conceptualization should be based on a view on ISD that more comprehensive than the existing ISD artifacts suggest.

ISD should be conceived as a context with all its facets.

1. Introduction (Continues..)

An ontology is a kind of framework unifying different viewpoints, thus functioning like a lingua-franga (Chandrasekaran et al. 1999). It is an explicit specification of a conceptualization of some part of reality that is of interest (Gruber 1993).

The purpose of this paper is to present an ISD ontology based on a contextual approach.

The ontology provides a vocabulary with explicit definitions and meta models represented in a UML-based language.

The ISD ontology is not yet a complete ontology.

1. Introduction (continues..)

There are some well-known artifacts: e.g.

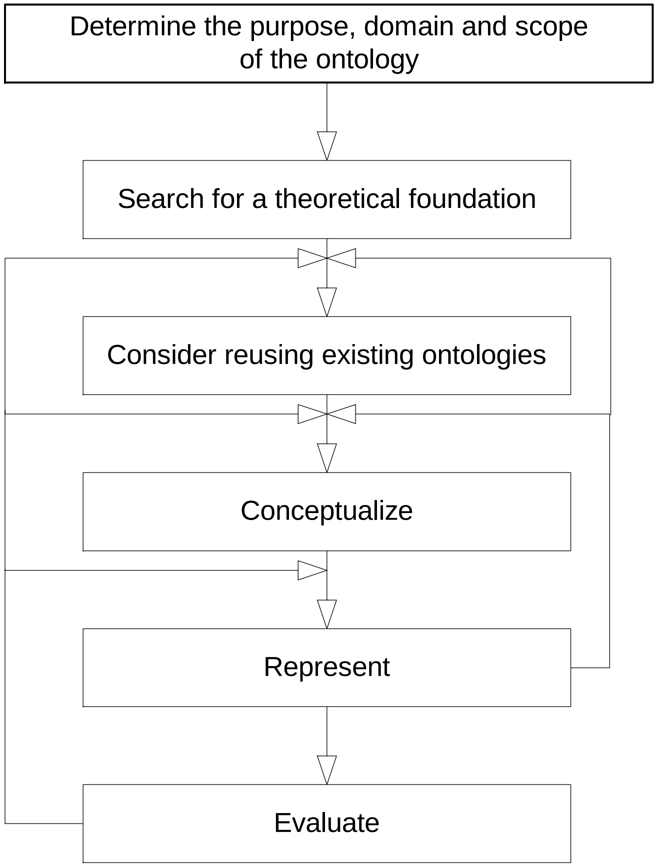
- FRISCO Framework (Falkenberg et al. 1998)
- Bunge-Wand-Weber model (e.g. Wand et al. 1989, Wand et al. 1990)
- ontologies for some parts of SE: e.g. Falbo et al. 1998; Kitchenham et al. 1999; Ruiz et al. 2004; Kishore et al. 2004;
- ISD frameworks, meta models and references models: e.g. Olle et al. 1988; Iivari 1990; Heym et al. 1992, Krogstie 1995; NATURE Approach (Grosz et al. 1997), Song 1997; Saeki 1998, Harmsen 1997; OPF (Firesmith et al. 2001),…

1. Introduction (continues..)

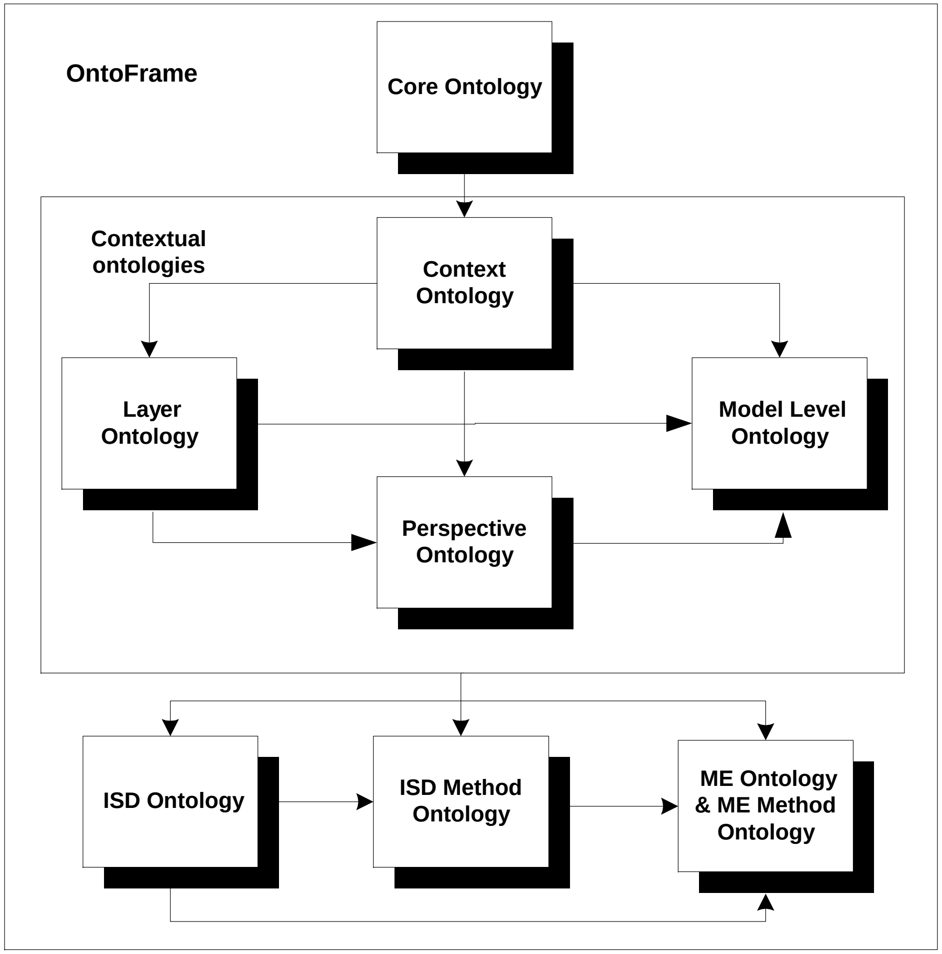
The ISD ontology is intended for

- *descriptive purposes:* to provide concepts and constructs for conceiving, understanding, structuring and presenting contextual phenomena in ISD
- *analytical purposes*: to provide a conceptual foundation to analyze and compare existing ISD artifacts
- *constructive purposes*: to support the engineering of new ISD artifacts (i.e. ISD models, techniques and methods)

1. Introduction (continues..)

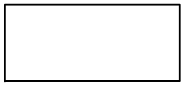
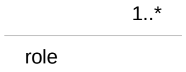
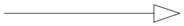
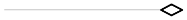
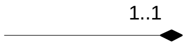

Determine the purpose, domain and scope of the ontology
Search for a theoretical foundation
Consider reusing existing ontologies
Conceptualize
Represent
Evaluate

The process of ontology engineering



Ontological framework (OntoFrame)

Ontology representation language

Concepts	Definition	Notation
Class	A description of a set of concepts that share the same predicates.	
Association	An semantic connection between two classes, each one associated in a specific role (ClassRole). For each association end a range of allowed cardinalities is specified with the multiplicity.	
Generalization	A taxonomic association between a more general class and a more specific class.	
Aggregation	A special form of association that specifies a whole-part relationship between a whole and its part in such a way that the parts in the whole are inter-related.	
Composition	A special form of aggregation which requires that a part instance is included in at most one whole at a time, and that the lifetimes of the parts are coincident with the lifetime of the whole.	

2. Contextual Approach

Based on a large literature review about the notion of context in several disciplines (i.e. knowledge representation and reasoning, pragmatics, computational linguistics, sociolinguistic, organizational theory and information systems), we came to the following generic definition:

> *A context* means a whole that is composed of things connected to one another with contextual relationships. A thing gets its meaning through the relationships it has to the other things in that context.

To recognize a proper set of contextual concepts we drew upon relevant meaning theories. Each of them consider a context from a different viewpoint:

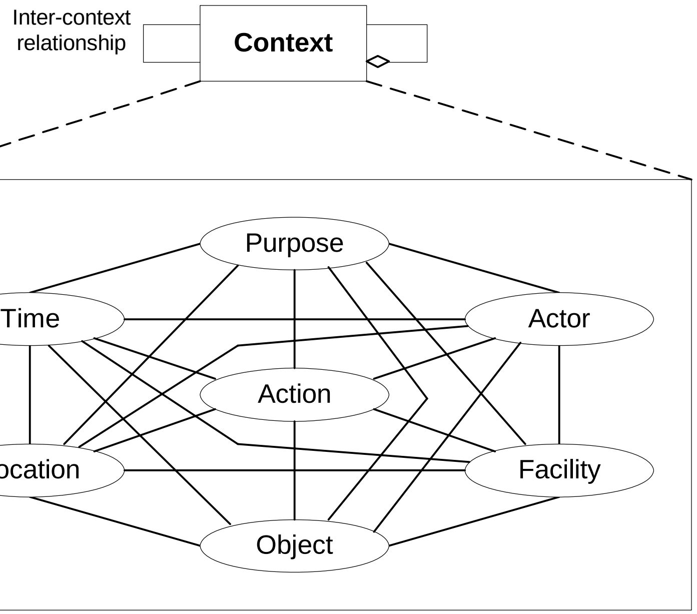
- *Sentence context*: semantics (e.g. case grammar, Fillmore 1968),
- *Conversation context*: pragmatics (e.g. Levinson 1983),
- *Action context*: activity theory (e.g. Engeström 1987).

Domains	**Case grammar (Fillmore 1968)**	**Pragmatics (Levinson 1983)**	**Speech act theory (Searle 1979)**	**Activity theory (Engeström 1987)**
Context		context	context	activity
Purpose			illocution	goal
Actor	agentive	person deixis	speaker, hearer	subject
Action	main verb, factitive	verb	speech act	action, operation
Object	objective, dative			object
Facility	instrumental			tool
Location	locative	place deixis	place	
Time		time deixis	time	

2. Contextual Approach (continues..)

Based on these theories we define the Seven S’s Scheme:

F*or Some* purpose, *Somebody* does *Something* for *Someone,* with *Some* means, *Sometimes* and *Somewhere*.



2. Contextual Approach (continues..)

According to the *contextual approach*, individual things in reality are seen to play specific roles in a certain context, and/or to be contexts themselves. The contexts can be decomposed into more elementary ones and related to one another through inter-context relationships.

The contextual approach has been earlier applied to

- *enterprises*: to engineer a context-based enterprise ontology (Leppänen 2005b)
- *method engineering* (ME): to built a conceptual framework for the analysis of ME artifacts (Leppänen 2005a)

2. Contextual Approach (continues..)

Based on the contextual approach, we define ISD and the ISD ontoogy as follows:

Information system development (ISD) is a context in which *ISD actors* carry out *ISD actions* to produce *ISD deliverables* contributing to a renewed or a new IS, by means of *ISD facilities*, in a certain organizational and *spatio-temporal* context, in order to satisfy ISD stakeholders' *goals*.

The *ISD ontology* provides concepts and constructs for conceiving, understanding, structuring and representing contextual phenomena in ISD.

2. Contextual Approach (continues..)

The ISD ontology has been engineered

- *deductively:*

  Searched for disciplines and theories that address social and organizational contexts, and derived a basic categorization of concepts into contextual domains from them.

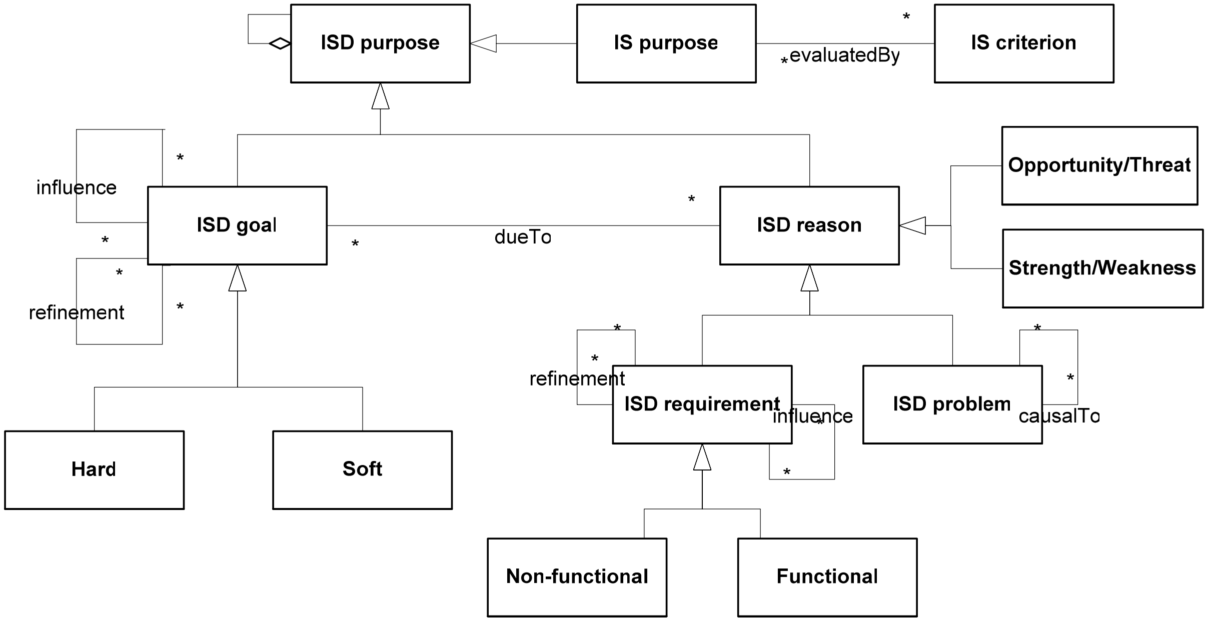
- *inductively:*

  Enriched the contents and structure of each contextual domain by a thorough analysis of existing artifacts, and by selecting, integrating and adapting those concepts that were found to be applicable.

  Also closely examined empirical studies on ISD practice.

3. ISD Purpose Domain

The *ISD purpose domain* embraces all those concepts and constructs that refer to goals, motives, or intentions of someone or something in the ISD context.



3. ISD Purpose Domain (continues..)

An *ISD goal* expresses a desired state or event with qualities and quantities, related to the ISD context as a whole, or to some parts thereof.

ISD reasons are expressed in terms of requirements, problems, opportunities, threats, etc

Some of the ISD purposes concern an IS. They are called *IS purposes*, and they are further sub-divided into *IS goals* and *IS reasons*.

An *IS criterion* is a standard of judgment presented as an established rule or principle for evaluating some feature(s) of an IS in terms of IS purposes.

3. ISD Purpose Domain (continues..)

ISD goals / ISD requirements are related to one another with

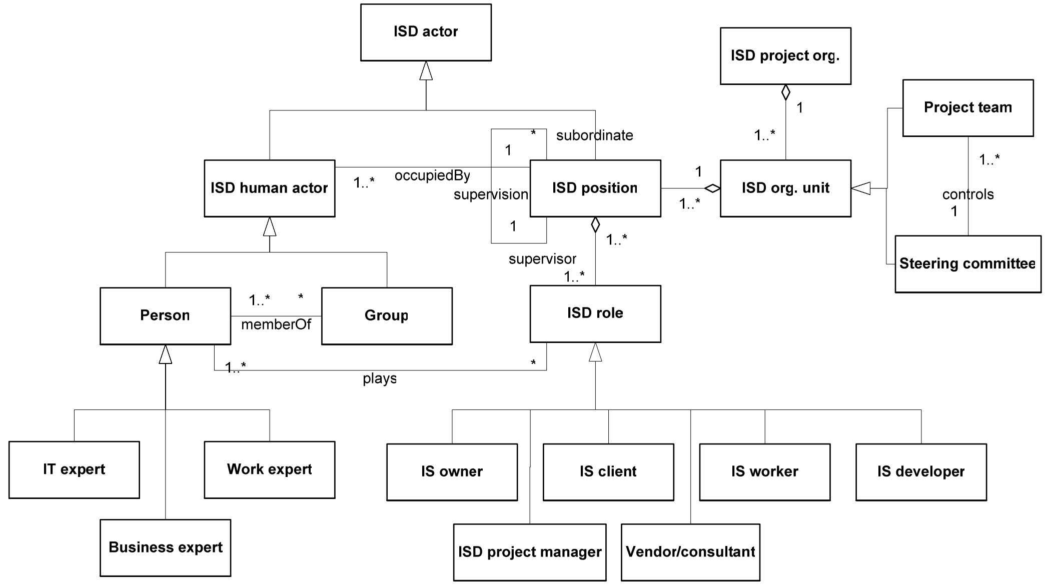
- *Refinement relationships*: an ISD goal can be reached when certain ISD goals below it in the ISD goal hierarchy are fulfilled (e.g. Rolland et al. 1998).
- *Influence relationships*: an ISD goal has impacts, positive or negative, on the achievement of another ISD goal (e.g. Kavakli et al. 1999). The ISD goals with negative interrelationships are referred to as conflicting requirements.

ISD problems are related to one another with:

- *CausalTo relationships*: the appearance of one ISD problem is at least a partial reason for the occurrence of another ISD problem

4. ISD Actor Domain

The *ISD actor domain* consists of all those concepts and constructs that refer to human and active part of the ISD context.



4. ISD Actor Domain (continues…)

An *ISD position* is a post of employment

- identified with a title,
- occupied by a human ISD actor
- composed of the defined ISD roles
- equipped with a set of skill or capability characterizations.

A *capability* means a skill or attribute of personal behavior, according to which behavior can be logically classified (Acuna et al. 2004).

An *ISD role* is a collection of ISD responsibilities and authorities, stipulated in terms of ISD actions.

4. ISD Actor Domain (continues…)

The ISD roles are categorized in many ways in the ISD literature:

- Social roles:
    - Problem solving process (Vessey et al. 1994): problem owner, problem solver,
    - Change process (Rettig et al. 1993): change facilitator, change implementator
    - Political process (Robey 1984): self-interest agent, principal
    - Learning process: mentor, student or apprentice

- Technical roles:
    - From the stakeholder view
    - From the software business view
    - From the organizational view

4. ISD Actor Domain (continues…)

We distinguish between six ISD roles (cf. Checkland 1988, Baskerville 1989; Sabherwall 1995, Mathiassen 1998):

- An *IS owner* has the responsibility for, and the authority of, making decisions on the IS as though it were his/her property.
- An *IS client* is the ISD role player for whom the IS is to be developed.
- An *IS worker* works with the current IS, and/or will work with the new IS, in order to provide IS clients with information.
- An *IS developer* works for satisfying needs and requirements put forward by ISD actors in the other roles.
- An *ISD project manager* makes plans on how to organize an ISD effort.
- A *vendor / consultant* role is played by a person from outside the organization.

4. ISD Actor Domain (continues…)

The categorization of ISD persons based on their expertise:

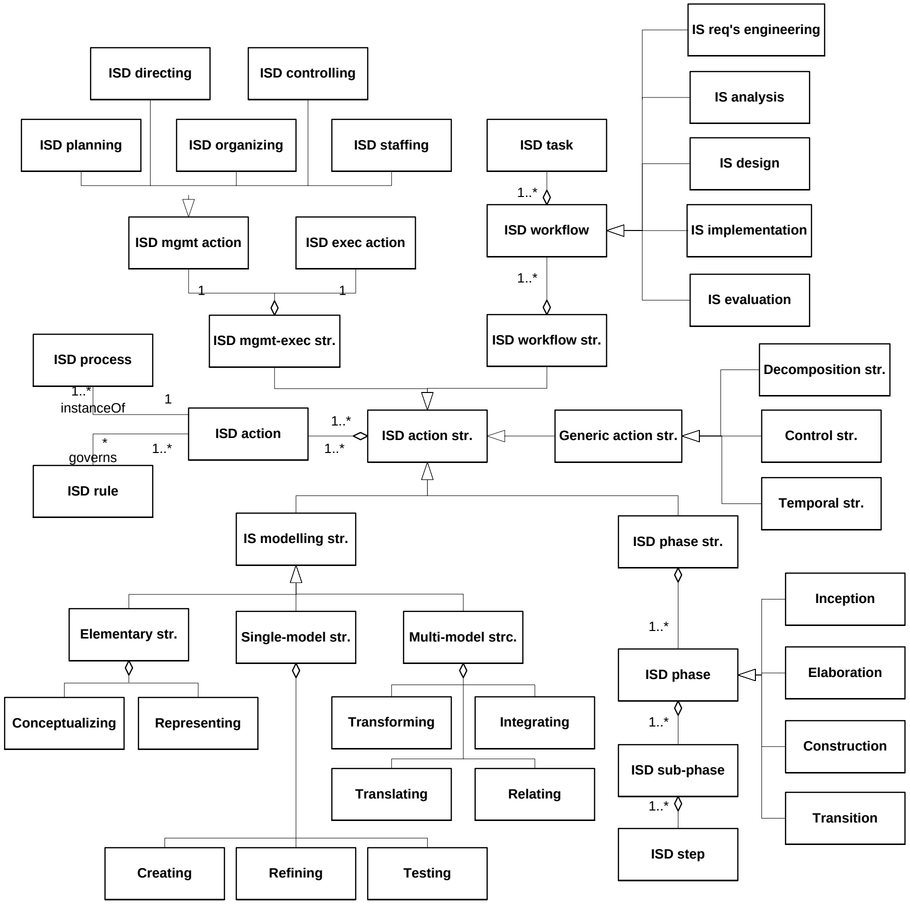
• *IT experts* are persons whose education, skills, experience, as well as their former positions, are related to information technology and/or ISD methods.

• *Business experts* are knowledgeable in business strategies, policies, markets, competition, trends, legislation, etc., in other words, in matters relating to how to make business, in general or in the organization.

• *Work experts* master daily routines, e.g. in making orders, invoicing, production planning, inventory control, goods deliveries, etc.

5. ISD Action Domain

The *ISD action domain* comprises all those concepts and constructs that refer to deeds or events in the ISD context.



5. ISD Action Domain (continues…)

Three generic action structures:

- decomposition structure,
- control structure: sequence, selection, iteration
- temporal structure: overlapping, parallel, disjoint

Four fundamental ISD action structures:

- ISD management – execution structure
- ISD workflow structure
- ISD phase structure
- IS modeling structure

5. ISD Action Domain (continues…)

(1) ISD management – execution structure

- ISD management actions (Thayer 1987):
  - ISD planning
  - ISD organizing
  - ISD staffing
  - ISD directing
  - ISD controlling
- ISD execution actions

5. ISD Action Domain (continues…)

(2) ISD workflow structure (Jacobson et al. 1999):

- IS requirements engineering
- IS analysis
- IS design
- IS implementation
- IS evaluation

An *ISD workflow* is a coherent composition of ISD actions, which are organized to accomplish some ISD process. They share the same target of action and produce valuable results for ISD actors.

5. ISD Action Domain (continues…)

(3) ISD phase structure (Jacobson et al. 1999):

- Inception
- Elaboration
- Construction
- Transition

An *ISD phase* means ISD actions that are executed between two milestones. By these actions a well-defined set of goals is met, ISD deliverables are completed, and decisions are made on to move or not to move into the next phase.

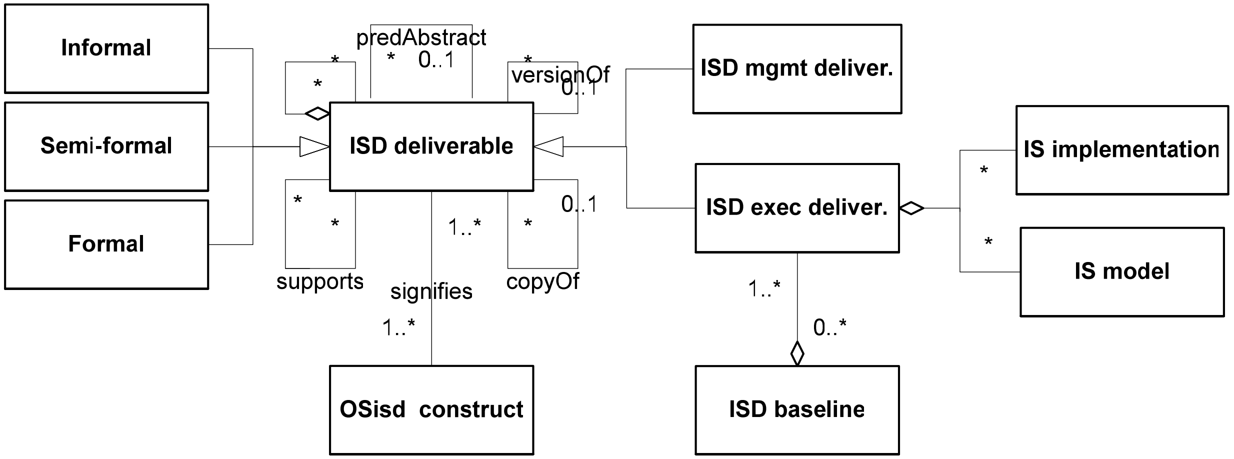
5. ISD Action Domain (continues…)

(4) IS modeling structure

- Elementary modeling action structure:
  - Conceptualizing
  - Representing
- Single-model action structure:
  - Creating
  - Refining
  - Testing
- Multi-model action structure:
  - Transforming
  - Translating
  - Relating
  - Integrating

6. ISD Object Domain

The *ISD object domain* comprises all those concepts and constructs that refer to something which ISD actions are directed to.



6. ISD Object Domain (continues…)

On the elementary level, an *ISD deliverable* is an assertion, a prediction, a plan, a rule, or a command, concerning the ISD itself, the existing IS, the new IS, the object system (OS), or the utilizing system.

OS_{ISD} construct denotes some part(s) in the object system of the ISD.

The main categorization:

• *ISD management deliverables:* plans for, decisions on, directives for, and assessments of goals, positions, actions, deliverables, locations, etc. in the ISD context.

• *ISD execution deliverables*: descriptions and prescriptions about why, what, and how information processing is carried out, or is to be carried out, in the current IS, or in a new IS, respectively.

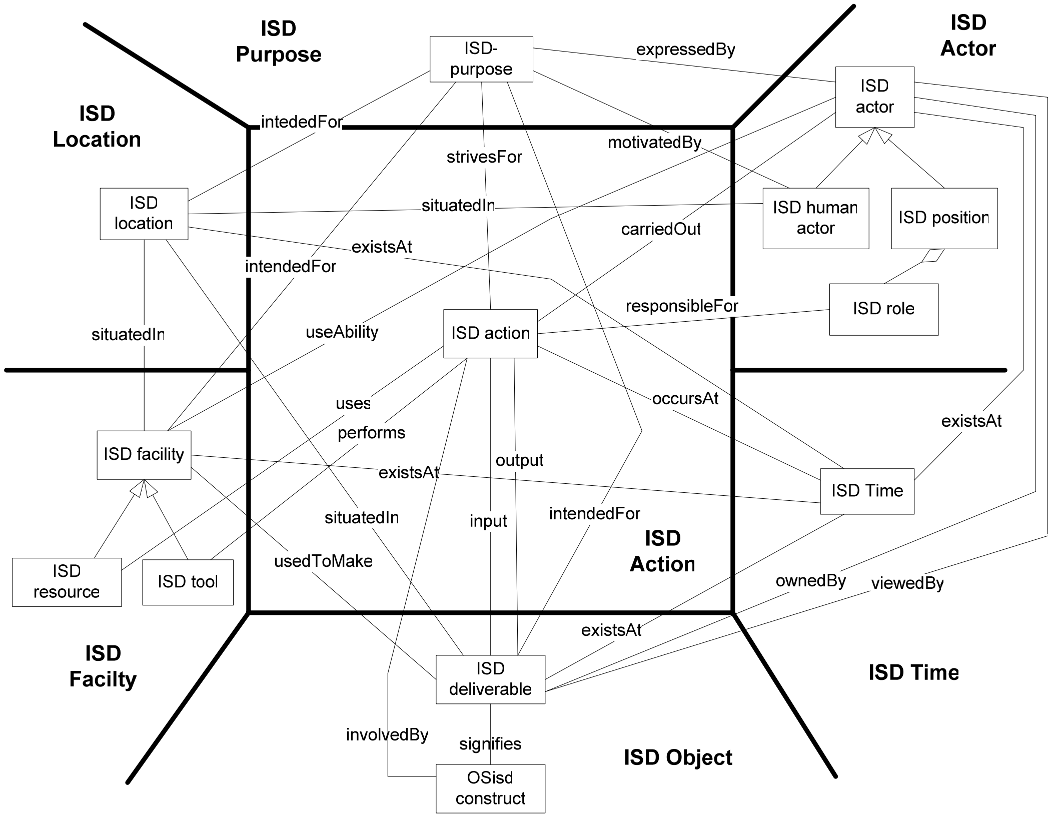
6. ISD Object Domain (continues…)

The ISD execution deliverables include *IS models* (e.g. class diagrams, component diagrams) and their *implementations* (e.g. software components, data bases).

The ISD deliverables are related to one another through the following relationships:

- Composed of
- Input to, or a prescription for (i.e. the supports relationship)
- Version of
- Copy of
- More abstract than (i.e. the predAbstract relationship).

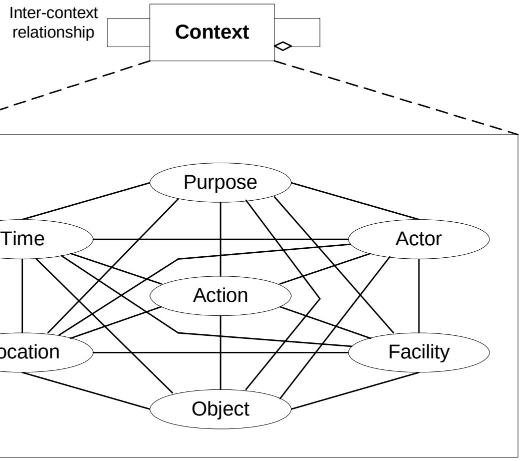
7. ISD Inter-Domain Relationships



8. Discussions and Implications

We have suggested a coherent, consistent and comprehensive conceptualization of ISD in the form of ISD ontology.

The ISD ontology is based on an integrated view through which ISD is conceived as an aggregate of contexts. This provides groundwork for the specification, analysis and integration of more specific views.



8. Discussions and Implications (continues..)

Quality criteria of ontologies (e.g. Gruber 1995; Uschold 1996; Weinberger et al. 2003; Burton-Jones et al. 2005):

- consistency
- coherence
- comprehensiveness
- clarity
- accuracy
- extendibility
- applicability

8. Discussions and Implications (continues..)

The ultimate test of the quality of an ontology is its **applicability**.

The ISD ontology is intended for descriptive, analytical and constructive use. We have applied the ISD ontology

- to analyze and compare a set of existing frameworks, meta models and reference models for ISD and ISD methods (Leppänen 2005a, Leppänen 2005b)
- to engineer an ISD ontology and a methodical skeleton for method engineering (Leppänen 2005a).

8. Discussions and Implications (continues..)

Comparative analysis of ISD artifacts:

- The artifacts analyzed :
  - Harmsen 1997; Heym et al. 1992; Iivari 1990; NATURE Approach; Saeki et al. 1993; Saeki 1998; Song et al. 1992; Song 1997;
- An overall analysis concerned
  - Purposes, theoretical bases, ISD approaches applied, representation forms and acts of validation
- A domain-specific analysis:
  - An in-depth analysis of the concepts and constructs of the ISD artifacts based on the four domains of the ISD ontology

The summary of the overall analysis (1)

Reference	Artifact	Purpose	Theoretical basis	ISD approach	Representation	Validation
This work	ISD ontology	For understanding the ISD domain, and for analyzing and constructing other artifacts for the ISD domain	Theories underlying the contextual approach, ISD theories, ISD methods	Contextual approach	Definitions in English, meta models in a graphical notation	Used as a basis in an comparative analysis and in the construction of the methodical skeleton of ME
Harmsen (1997)	Ontology (MDM) and a process classification system	For assembling a situational method from building blocks called method fragments	Literature on existing ISD methods	Not recognizable	Definitions in English, supported with the use of first order predicate calculus	Implemented as a prototype of the Method Base System that has been used in some empirical studies
Heym *et al.* (1992a)	Framework, reference model	For describing, understanding, and comparing ISD methods	Not mentioned	Not recognizable	Definitions in English, the reference model in a graphical notation	Used as the data model of the MERET tool which has been deployed in several organizations
Iivari (1990a, 1990b)	Hierarchical spiral model	For providing an abstract explanatory model for the IS/SW design process	Socio-cybernetics, Information economics	Transformation, learning process, and decision-oriented approaches	Definitions in English	Not mentioned

The summary of the overall analysis (2)

Reference	**Artifact**	**Purpose**	**Theoretical basis**	**ISD approach**	**Representation**	**Validation**
NATURE Team (1996), Grosz *et al.* (1997)	Process meta-model	For defining way-of-working in requirements engineering	Theory of plans	Decision-oriented approach	Definitions in English, partly in a graphical notation	Widely used in succeeding projects; Prototype
Saeki *et al.* (1993), Saeki (1998)	Meta model	For representing software specification and design methods	Not mentioned	Transformation approach	Definitions in English, partly in a graphical notation	Used to develop representations of ISD methods; Prototype
Song *et al.* (1992), Song (1997)	Framework	For identifying method components (Song *et al.* (1992); For integrating software methods (Song 1997)	Abstracted from existing methods	Transformation approach	Definitions in English, partly in a graphical notation (Song 1997)	Not mentioned

The summary of the analysis of the concepts of the ISD action domain (1)

References/ Concepts	**ISD Ontology**	**Harmsen (1997)**	**Heym *et al.* (1992)**	**Iivari (1990)**	**NATURE Team (1996)**	**Saeki *et al.* (1993)**	**Song *et al.* (1992)**
Generic concept	ISD action	Process fragment	Process	Design act	Action	Procedure	Action
Sub-concepts	ISD workflow ISD phase ISD process	Process role Basic action	Phase Activity	Main phase Subphase Design act			Step
ISD management - execution structure	Mgmt action: - ISD planning - ISD organizing - ISD staffing - ISD directing - ISD controlling Execution action		Decision Planning Control		Plan Execution		
ISD workflow structure	ISD worflow: - IS req's engineering - IS analysis - IS design - IS implementation - IS evaluation	Action type: - Planning - Analysis - Synthesis - Evaluation - Implementation - Evolution	ISD stage: - Analysis - Design - Construction design - Construction - Test and installation - Maintenance				

The summary of the analysis of the concepts of the ISD action domain (2)

References /Concepts	**ISD Ontology**	**Harmsen (1997)**	**Heym *et al.* (1992)**	**Iivari (1990)**	**NATURE Team (1996)**	**Saeki *et al.* (1993)**	**Song *et al.* (1992)**
ISD phase structure	ISD phase: - Inception - Elaboration - Construction - Transition		Phase	Phase structure: - Org. design - Conceptual / infological design - Datalogical/ technical design - Implementation			
IS modeling structure	Conceptualizing Representing Creating Refining Testing Transforming Translating Integrating Relating		Abstraction Checking Review Form conversion	Diagnosis/ Design Verification / Validation, Observation / Analysis, Manipulation / Refinement	Transformation		Create Modify

The summary of the analysis of the concepts of the ISD action domain (3)

References / Concepts	**ISD Ontology**	**Harmsen (1997)**	**Heym *et al.* (1992)**	**Iivari (1990)**	**NATURE Team (1996)**	**Saeki *et al.* (1993)**	**Song *et al.* (1992)**
Control structures	sequence selection iteration	precedence (Process fragment, Process fragment) choice(Process fragment, Process fragment)	sequence refinement jump branching path unifying path iteration	iteration	precedence alternative	precede	
Abstraction structures	partOf isA memberOf instanceOf	contents	aggregation	component of		has	part of is a

Inter-domain relationships	input (ISD deliverable, ISD action)
	output (ISD action, ISD deliverable)
	involves(ISD action, OS$_{ISD}$ construct)
		prerequisite (Process fragment, Product fragment)
		manipulation (Process fragment, Product fragment, Process role)
			input usage (Deliverable, Process)
			output usage (Process, Deliverable)
					change (Action, Product)	input (Product part, Procedure)
						output (Process, Product part)
							input (Artifact, Action)
							output (Action, Artifact)
							affect(Artifact, Action)
							influence(Representation, Action)

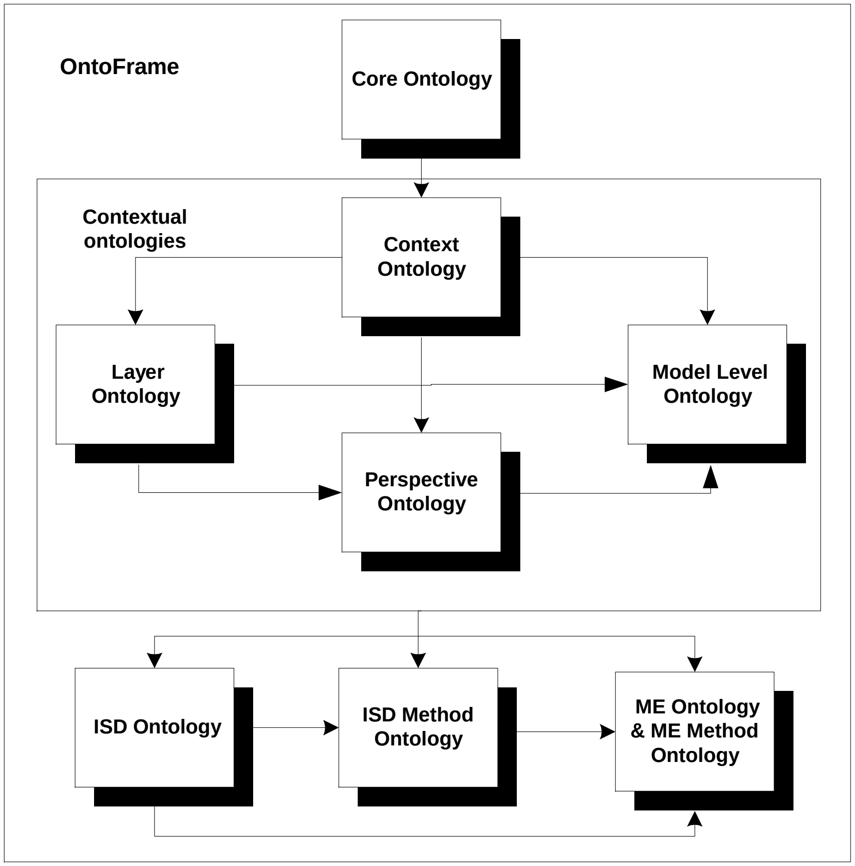
8. Discussions and Implications (continues..)

Findings from the analysis:

- The artifacts mostly lack a theoretical background.
- They have commonly been abstracted from existing ISD methods.
- They are narrow-scoped as to their contextual concepts; e.g.
  - only two artifacts (Harmsen 1997; Nature Team 1996) provide some concepts for the ISD purpose domain.
  - only two artifacts (Harmsen 1997; Heym et al. 1992) clearly offer concepts for the ISD actor domain.
  - only four artifacts (Harmsen 1997; Heym et al. 1992; Iivari 1990; Song et al. 1992) address the ISD object domain adequately.
- Emphasis on the ISD action domain in all the ISD artifacts.

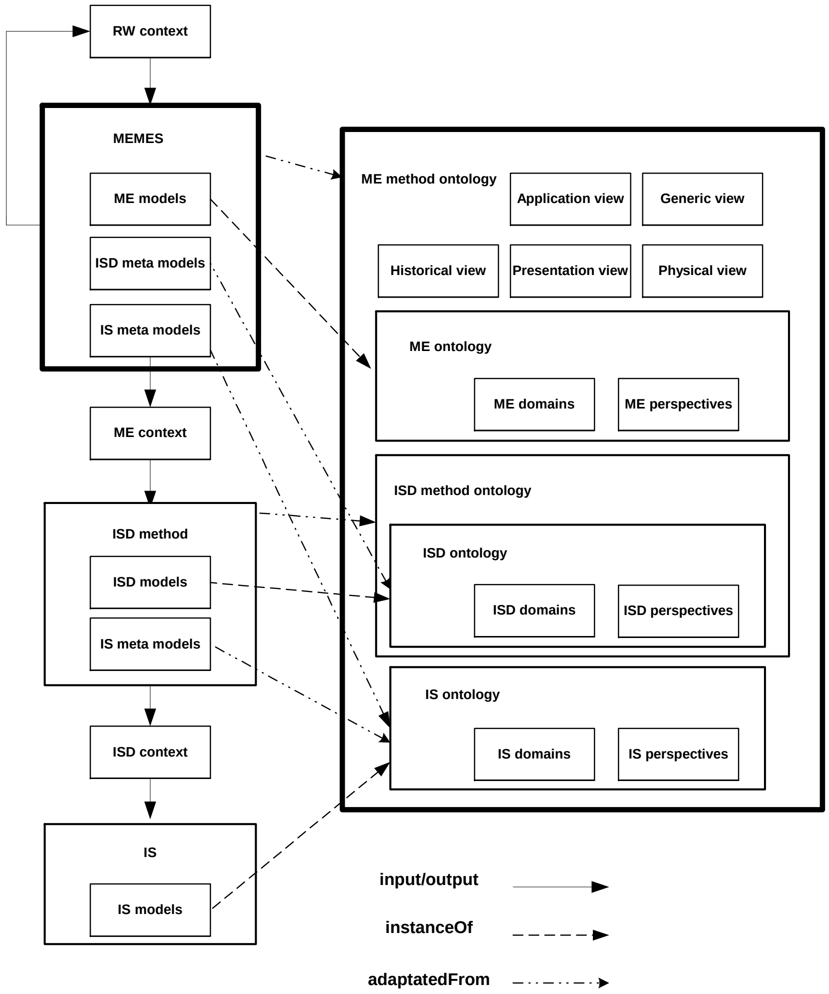
8. Discussions and Implications (continues..)

For constructive use (1)



8. Discussions and Implications (continues..)

For constructive use (2)



8. Discussions and Implications (continues..)

Experience from the use of the ISD ontology

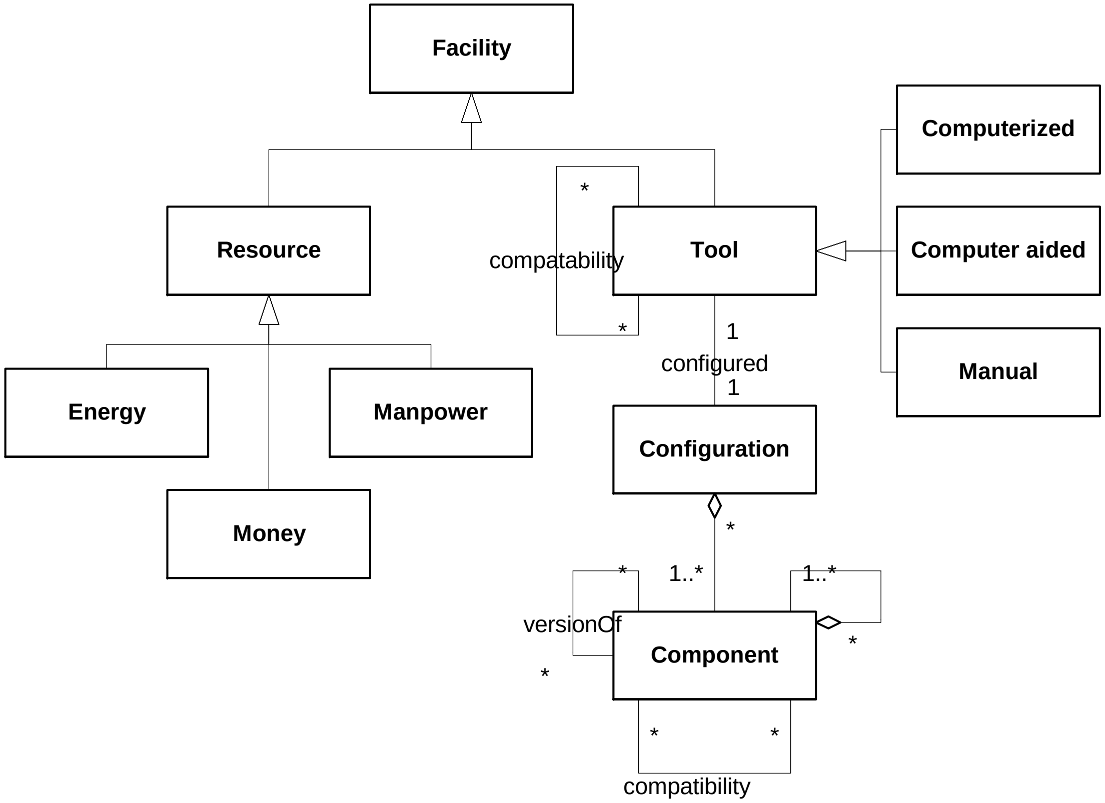
- for the analytical purposes:
  - The ISD ontology, composed of a large array of concepts and constructs within four concetxtual domains, provided a comprehensive foundation for the recognition, categorization, analysis and comparision of the concepts and constructs in the ISD artifacts.
  - The ISD ontology helped form conceptions of coverage, emphases, strenghts and weaknesses of the ISD artifacts in terms of contextual aspects of ISD.

- for the constructive purposes:
  - The ISD ontology offered a rich set of concepts and constructs for specifying and elaborating the semantic content of an ISD method
  - The ISD ontology helped distinguish and structure approaches, actions and deliverables of method engineering

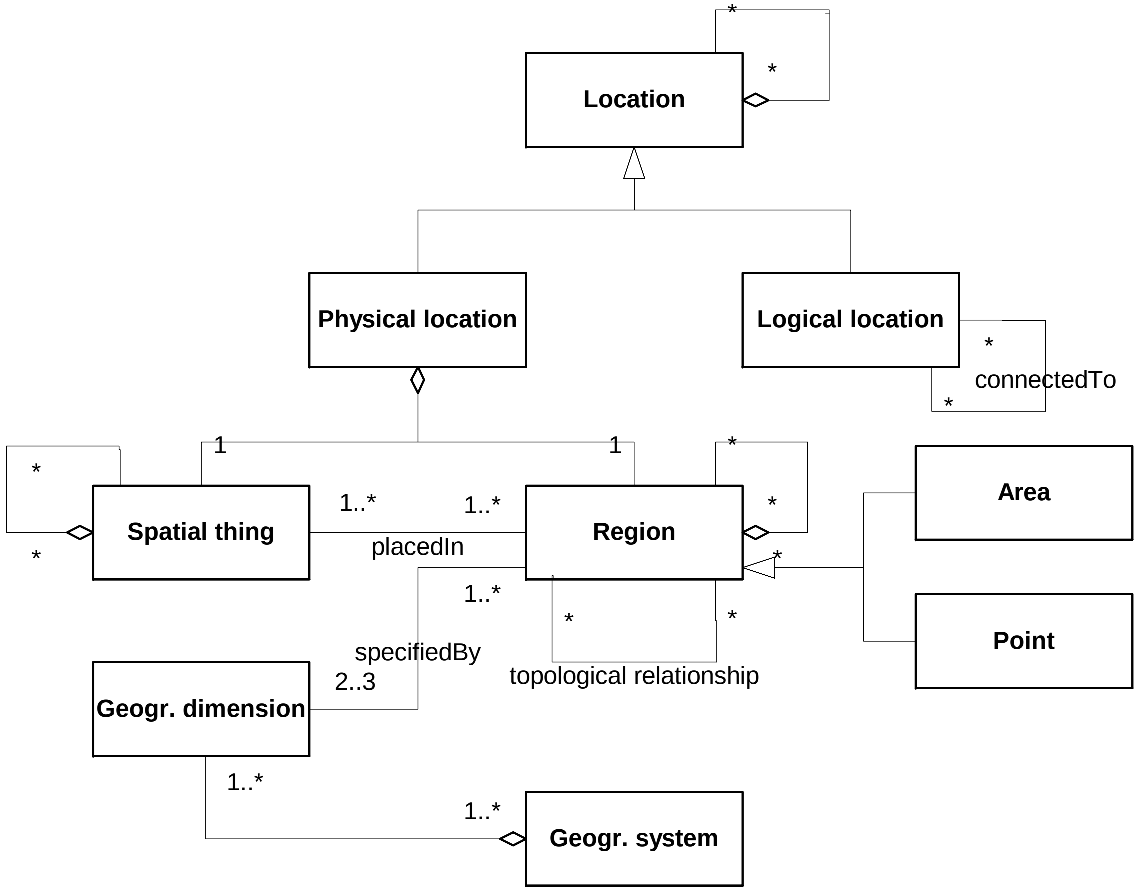
8. Discussions and Implications (continues..)

Future research

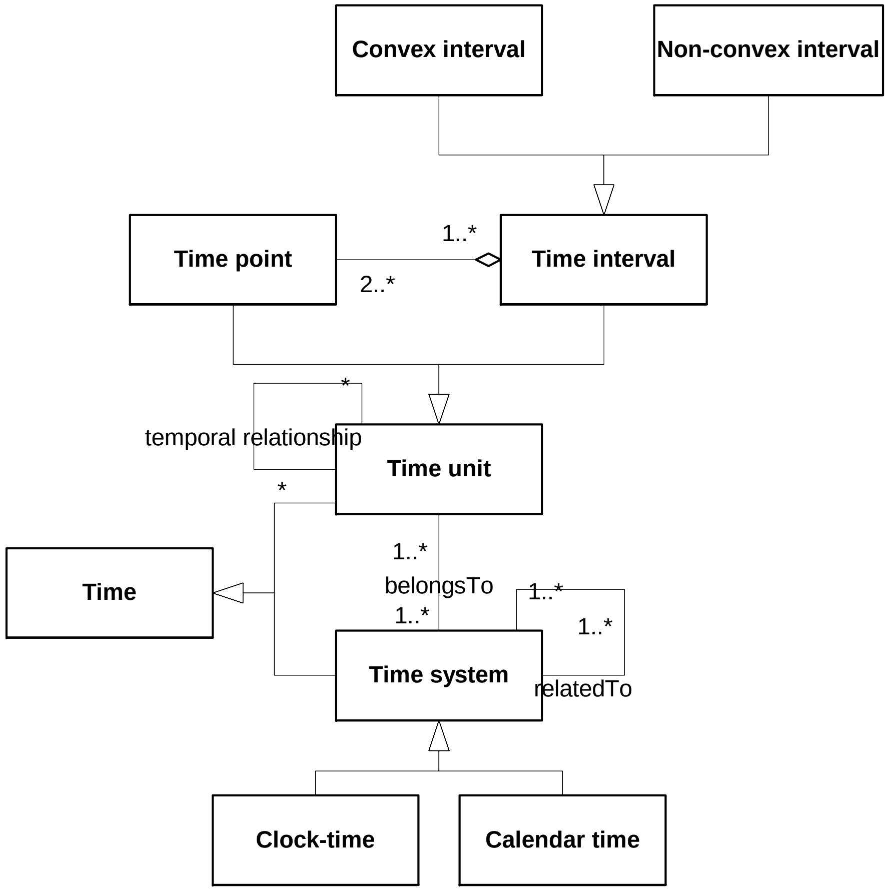
- To enhance the ISD ontology with missing ISD domains and more specialized concepts and constructs.
- To expand the ISD with more elaborated rules for ISD contexts.
- To deploy the ISD ontology to analyze and integrate conceptual models underlying empirical studies (cf. Kitchenham et al. 1999).
- To deploy the ISD ontology to analyze existing ISD approaches



Facility Domain



Location Domain


Convex interval
Non-convex interval
Time point
1..*
Time interval
2..*
*
temporal relationship
Time unit
*
1..*
Time
belongsTo
1..*
1..*
1..*
Time system
relatedTo
Clock-time
Calendar time

Time Domain