Spatio-temporal Ontology for defining the quality of an application

Bérengère Vasseur[*], Daniel van de Vlag[**], Alfred Stein[**], Robert Jeansoulin[*], Arta Dilo[**]

[*]*Laboratoire des Sciences de l'Information et des Systèmes*
LSIS, Université de Provence, 39, rue Joliot-Curie, 13453 Marseille cedex 13
berengere.vasseur@lsis.org , robert.jeansoulin@cmi.univ-mrs.fr

[**]*ITC, Department of Earth Observation Science, Hengelosestraat 99, P.O. Box 6, 7500 AA Enschede, The Netherlands*
vandevlag@itc.nl, stein@itc.nl, dilo@itc.nl

ABSTRACT. Decision making in geographical information systems is based on models of observed processes. These have their own concepts and objects, that could be different from those used for the data. This raises the question of fitness for use between the problem to be solved and the available data. Use of ontologies has resulted into a new approach to qualifying and quantifying fitness for use. So far, temporal aspects have been poorly integrated . The purpose of this paper is to provide a methodology for this purpose.. We integrate : 1- quality elements described by ISO standards and 2- a features ontology concerning a possibly dunamic application . Integration is carried out by means of a matrix of quality. Satisfying each box of the matrix with a quality close to the required one represents an approximation between the two ontologies. We apply this methodology to an application in coastal movement in the Netherlands, whereby beaches are subject to nourishment due to severe erosion. In this application, the problem ontology addresses erosion uses knowledge to anticipate the event of beach nourishment. For that purpose, it describes the quality of his application, given the selected data.

***KEYWORDS**: spatio-temporal ontology, fitness for use, fuzzy objects, temporal objects, data quality.*

1. Introduction

Evolution of technology and new means of communication allow the representation of more complex geographical phenomena. Data from various sources, and various scales are now available at lower cost, in digital form, and it is easy to combine and use them to answer a given problem. Moreover, the number of users have increased and, in the same time, their expertise in treatment and data interpretation has degraded (Rindfuss 1998). Hence, one can ask what is the value of a decision based on data that deciders little know about (Hunter 2001). This raise the problem of fitness for use between the data ideally required to respond to a problem and the existing one.

The use of an ontological approach to link quality elements from ISO to the features of the application, can help assessing fitness for use between a problem and some data, but in a certain extent only.

First, ontological approach is very useful to describe the fitness for use of an application. More precisely, an ontology can be defined as a an explicit specification of a conceptualization, which give the definitions of classes, relations, functions, and other objects (Gruber 1993), (Guarino 1995). It guides the design of a GIS database, and provide a common framework that is exchangeable and comprehensible by others (Jeansoulin et Wilson 2002). Hence, by adopting this approach, the characteristics of an application are specified (object, relation, attribute, etc), and it become possible to specify the conformance quality level expected for the important features of an application. However, ontological approaches representing space and time are not frequently used yet, although this dimension is essential to analyze and understand dynamic geographical problems (Claramunt 1997), (Galton 2000), (Frank, subm).

Second, standards of quality, such as ISO provide a good base for better qualifying and quantifying the fitness for use. It enables data producers to express how well their product meets the criteria set forth in its product specification, and data users to establish in what extent a dataset meets their requirements (ISO 2003). However, standards come from discussions and negotiations supported explicitly and implicitly by certain institutions, and, in that sense, give a partial representation of reality (Goodchild and Jeansoulin 1998). In that sense, ISO quality standards concerns a-temporal applications, but do not take into account temporal applications, with the study of events and processes working on them.

Hence, to look at the full dimensions of the problem, it should be relevant to get a methodology that would qualify and quantify the quality of the data and models describing events and processes happening on them.

Finally, our objective of research relates to the description of a spatio-temporal application in term of quality. First, we take into account ISO elements and sub elements of quality as a starting point, and extend them for describing the dynamic geographical problems. Second, we follow an ontological approach, considering the dimension of time, for better specifying the characteristics of an application, and attaching quality elements. In our approach, we consider that the user is an expert in the field of application, and has the best data to represent his problem (Vasseur 2003) (Van de Vlag et al. subm). The methodology is applied to an application in coastal movement within the Netherlands, whereby beaches are subject to nourishment due to severe erosion The characteristic of this study lies in the "fuzzy" nature of the objects, and their dynamism. Those aspects are studied still little in the conceptual representation of the geographical applications by ontologies.

2. Research methodology

To qualify fitness for use, we integrate: the different ontology features, and the "quality elements", described by the standards, in particular ISO. *Table 1* presents the matrix of quality describing a dynamic problem.

2.1. *Ontology features*

The definition of ontological features (objects, attributes, relations, states, processes, and events) is important to understand dynamic geographical problems. First, these objects have a name, a format, and some attributes such as spatial, or thematic attribute that characterize it (Guptill et Morrison 1995). For example, the spatial attributes describe the geometry of crisp or fuzzy objects, such as roads or buildings, or dunes or forests. Moreover, thematic attributes describe quantitative or qualitative properties of an object. For example, this information give an information about a size of an object, a difference in temperature, a difference in ratio, or a pixel classification (Laurini R. 1992). The objects and their attributes are bound by relations. These relations are for instance topological relations, logical (ex: constraints of integrity, of cardinality, or fixed by the expert). The objects, attributes and relations do not change in time (stay in the same state), unless they are affected by a process (Galton 2000). Indeed, the concept of process makes it possible to understand changes occurring in nature, like erosion for example. Lastly, an event, is defined as a complete set of changes occurring at a place on a given time, driving to a new state (Claramunt et al., 1998), (Frank subm). Hence, by defining these characteristics, it become easier to qualify and thereafter quantify their quality, and, finally, aggregate quality level of the application in his whole..

2.2. *Quality elements and subelements*

Several quality elements in the sense of "fitness for use" are suggested by the organizations of standardization (ISO 2003) (FGDC 2000) (CEN/TC-287 1994/1995). More precisely, the recognized external quantitative data quality elements that measure fitness for use concern the following parameters: completeness, logical consistency, and accuracy (Fisher 2003). These parameters are defined as follow, according to ISO (*see* JOOS 2003). We give a definition of data elements and data sub-elements taken from ISO 2003, in order to give a good overview of the quality parameters to take into account in our approach.

- *Completeness:* presence and absence of features, their attributes and relationships
  - *Commission:* excess data present in a dataset
  - *Omission:* data absent from a dataset

- *Logical consistency:* degree of adherence to logical rules of data structure, attribution and relationships (data structure can be conceptual, logical or physical)
  - *Conceptual:* adherence to rules of the conceptual schema
  - *Domain:* adherence of values to the domain of values
  - *Format*: degree to which data is stored in accordance with the physical structure of the dataset
  - *Topological:* correctness of the explicitly encoded topological characteristics of a dataset.

- *Positional accuracy:* accuracy of the position of features
  - *Absolute or external:* closeness of reported coordinate values to values accepted as or being true

Relative or internal: closeness of the relative positions of features in a dataset to their respective relative positions accepted as or being true
Gridded data position: closeness of gridded data position values to values accepted as or being true

- *Temporal accuracy:* accuracy of the temporal attributes and temporal relationships of features
Accuracy of a time measurement: correctness of the temporal references of an item (reporting of error in time measurement)
Temporal consistency: correctness of ordered events or sequences, if reported
Temporal validity: validity of data with respect to time

- *Thematic accuracy*
Accuracy of quantitative attributes: and the correctness of non-quantitative attributes and of the classifications of features and their relationships.
Classification correctness: comparison of the classes assigned to features or their attributes to a universe of discourse (e.g. ground truth or reference dataset),
Non-quantitative attribute correctness: correctness of non-quantitative attributes
quantitative attribute accuracy: accuracy of quantitative attributes

- *Other elements: to define*
New data quality element(s) may be named and defined if the quality elements listed in this international standard do not sufficiently address a component of quality.

2.3. Quality matrix

The matrix of quality represented on *table 1*, can be used to characterize a state but also characterize a process and event. The relevant cases of the matrix, which link an attribute of quality to some ontology features, have to be defined when existing. We will name those cases "quality features". Moreover, different quality features may have some influences between a case and another, and should be defined when existing. Finally, several matrices could be used to reflect the quality of a process or an event of a dynamic application, as we will see in Ameland application.

Table 1: Quality matrix for defining a State, a Process, or an Event

	Ontology features			
Quality elements *« y »*	Spatial	Thematic	Temporal	Relation
Completeness				
Logical consistency				
Positional accuracy				
Temporal accuracy	***Define the quality features when applicable***			
Thematic accuracy *non quantitatif* *quantitatif accuracy*				
…				

This matrix in *table 1* indicates, on the first line, the characteristics of the application and on the left-hand column, the elements of quality of interest for the application.

- *Notations*

The notation of the ontology features and quality elements that characterize the “quality features” with their notation are indicated on table 1. We employ the following notation to characterize “quality features” noted “$\partial_y(x)$”, where “*x*” indicate the ontology features , and “ *y* ” indicate the quality elements. Also, we use the notation $\check{Z}(t)$ to illustrate the evolution of “quality features” between different states.

- *Inferences*

We indicate the inferences the following way: *B is inferred by A:* $B \rightarrow A$,

Finally, we have to fill the cases of the matrix when applicable, qualify the “quality features”, and indicate explicitely the inference rules.

This methodology is illustrated through Ameland application, in Netherlands, and is presented thereafter in *section 3* entitled Application Ameland.

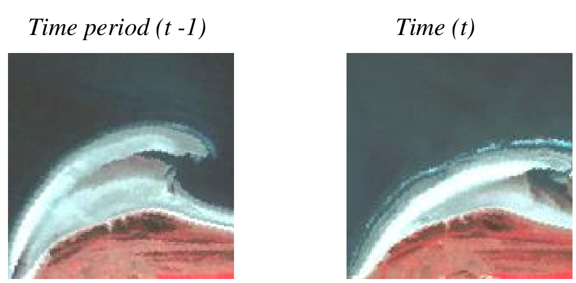
3. Application Ameland

The application is studied by the International Institute for Geo-Information Science and Earth Observation ITC), in co-operation with Rijkswaterstaat and RIKZ in Holland (Van de Vlag et al., 2003).

We illustrate our methodology through the application of Ameland in Holland. It relates to a coastal area in the north of Holland, where erosion and sedimentation of the beaches influence its morphology. This has an economic impact on the management of the beach and public safety (Roelse 2002). Therefore, the expert wishes to model the best possible the ‘process’ of erosion, and event of nourishment at a certain period. The interest of this application is to take into account the "fuzzy" nature of objects, and their “dynamism" in time. The *figure 1* illustrates the evolution of the beach between two different periods of time.

We present, first of all, the ontological features of the modelisation of the process of erosion, and the event of beach nourishment. Later on, we explain the quality problems and the resulting quality matrix.

Figure. 1. Evolution of the beach between two different period of time



3.1. Ontological features

3.1.1. Beach object (table 2.1)

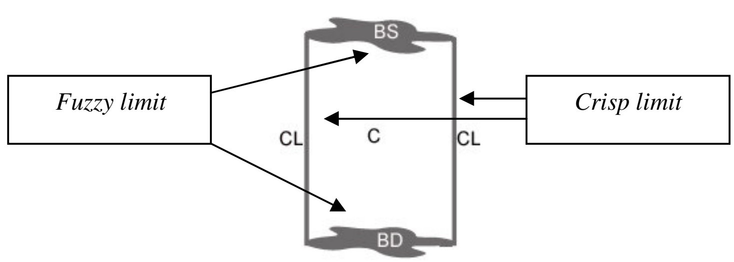
The problem concerns the localization of areas that need nourihment with sand. These areas are objects of interest for this study, and are called beach objects. Beach objects are defined according to a certain number of constraints related to the elevation (over the sea), wetness index (dry places), and vegetation index (non vegetated places). For defining beach objects, different sources of information are used, which are Digital Elevation Model *DEM* (1980 to 2002) and *Landsat TM images* (1989 to 2000). The determination of beach objects, according to the data *(DEM),* is carried out by applying a membership function μ_e to the elevation model, for selecting places that have an elevation around 0 and 1. In addition, the dry and nonvegetated places are identified, using *Landsat TM*. More precisely, dry object is defined by membership function μ_w on wetness values, such that the wetness index μw is almost negative. Non-vegetated object is defined by applying a membership function *(MF)* μ_v on *NDVI* values: *NDVI* index has to be almost negative. Hence, the delimitation of the beach object must satisfy the constraints of elevation μ_e, dryness μ_w, and of nonvegetation μ_v, as it is shown by the following equation *(equation 1).*

$$\mu(x,y,t)= min\{\mu_e (x,y,t), \mu_v(x,y,t), \mu_w(x,y,t)\} \quad (1)$$

3.1.2. Spatial attributes (table 2.2)

First, the determination of beach object provides the study aera, and determines the fuzzy limits that change over time, between sea and beach (*BS*), and beach and dune (*BD*). Moreover, to identify places that require nourishment at a certain period of time, the beach object is partitioned into study units called compartments (*C*). The creation of compartments takes into account the ground reality of beach object, but also takes into account some constraints that come form the Dutch government *(Rijkswaterstaat).* This is related to the places of sand discharge which are carried out according to some limits fixed by the government (*CL*), and also related to places where elevation measures are taken. Those crisp limit are fix in time, perpendicular to the littoral, and large of 100-200 meters. In conclusion, the compartments of the beaches are delimited by static limits CL.geo, and dynamic fuzzy limits (*BS (t), BD (t)*). These limits are illustrated in *figure 2*.

Figure 2. Limits of the object "compartment"



3.1.3. Thematic and quantitative attributes (table 2.3)

The most important attribute of the application is the volume of sand per compartment *C.vol (t)* which is determined by the following functin.

$$C.vol(t) = \iint e(x,y,t)\, \mu^C (x,y,t)\, dxdy \quad (2)$$

$$= \iint e(x,y,t)\, \chi^C(x, y)\, min\{\mu_e (x,y,t), \mu_v(x,y,t), \mu_w(x,y,t)\}\, dxdy \quad (3)$$

The calculation of this volume depends on elevation *e*, and also on the membership function μ^C of beach compartment, which is defined from fixed crisp departments limits χ^C and membership functions on elevation μ_e , vegetation index μ_v , and wetness index μ_w as seen in *3.1.1.*

3.1.4. Relations

- Topological relations (table 2.4)
The compartment must be adjacent. In addition, there exist one or two fuzzy limits per compartment between the zone of beach and sea, and a fuzzy limit by compartment between the zone of beach and sea.

- Temporal topological relation (table 2.5)
CL.geo limits remain fixed in time. On the other hand, the limits *BS(t)* and *BD(t)* change from one state to another. The limit *BD* is more stable than *BS*.

- Temporal quantitative relation (tableau 2.6)
The most important quantitative relation is the evolution of sand volume per compartment between two periods: *C.vol (t) - C.vol (t-1).*

3.1.5. State, process, and event

- State (table 2.7)
There exists in our application several data defining different states. These states are used to approximate the continuous model of the process of erosion and beach nourishment. However, data must be sufficient and complete to ensure the model built on them is a good approximation of reality.

- Process of erosion (table 2.8)
A process of erosion exists between two periods (t) and (t-1), when the slope of volume evolution is negative (C.vol (t) - C.vol (t-1) < 0) and that current volume is below the reference value measured in 1990.

- Event of compartment nourishment (table 2.9)
Two constraints determine it. The first constraint is that a compartment, or a group of adjacent compartments, are exposed to structural erosion. The second constraint, for a compartment or a group of adjacent compartments, is that the volume of sand needed for nourishment, i.e., the volume of sand lost in erosion, should exceed 0.2 Mm^3.

Table 2 summarizes the ontological features of the application, which should be taken into account for defining the application quality.

Table2: ontological features of Ameland application

« Features»	Notation	Ontological features of Ameland application
2.1. Beach object	*e*: elevation μ: MF of beach μ_e: MF on elevation μ_w: MF on wetness index μ_v: MF on vegetation index	Characterization of beach object, using an MF μ^C, that takes into account MF on elevation μ_e,, MF on wetness index $\mu_{w,}$ and MF on vegetation index μ_v. $\mu^C(x,y,t) = min\{\mu_e(x,y,t), \mu_w(x,y,t), \mu_v(x,y,t)\}$ $\mu_e(x,y,t)$ / *e around [0, 1],* $\mu_w(x,y,t)$ / *wetness index almost negative* $\mu_v(x,y,t)$ / *NDVI almost negative*
2.2. Spatial attributes	Compartment limits Crisp limits : *CL* Fuzzy limits : *BS.(t) , BD.(t)*	- *CL*, fixed, perpendicular to the littoral - *BD(t)* *ti ∈ [1989-2000], {BD.elev (t) around [0, 1m], and NDVI almost}* - *BS(t)* *ti ∈ [1989-2000], {BD.elev (t) around [0, 1m], and wetness index almost negative}*
2.3. Thematic and quantitative attributes	C.vol(t)	$C.vol(t)=\iint e(x,y,t)\ \mu^C(x,y,t)\ dxdy$
2.4. Topological relation	*Rt*	Adjacency of compartments, one limit beach dune, one or two limits beach sea
2.5. Temporal topological relation	*Rt(t)*	- *CL fixed;* - *BS(t) et BD(t) dynamic*
2.6.Temporal quantitative relation	*Rq(t)*	Evolution of *C.vol (t)- C.vol (t-1)*
2.7. State	*St*	Several data defining different states. These states are used to approximate the continuous model of the erosion process .
2.8. Process of erosion	*P*	Approximation of the "states" to a continuous model of erosion. $C.vol(t) - C.vol(t-1) < 0$ *et* $C.vol(t) < C.vol(1990)$
2.9. Event of compartment nourishment	*Ebn*	Constraint n.1 : Process of erosion Constraint n.2 : The second constraint, for a compartment or a group of adjacent compartments, is that the volume of sand necessary for beach nourishment should exceeds 0.2 Mm^3. $\sum_n C_n.vol(t) \geq 200\ 000\ m^3$

3.2. Quality matrix

3.2.1. Quality matrix for a state

Table 3 indicates the quality features of interest for defining a state, as well as existing inferences. Thise are noted the following way: *B is inferred by A: B* → *A* .

Table 3: matrix of quality for a state – Ameland application

	Ontology features for a state – Ameland application (compartment, state t)					
Quality elements	Limits	Elevation	Wetness index	Vegetation index	Volume	Topo Rel
Logical consistency Topology						Rtopo
Positional accuracy	∂_S (CL) ∂_S (BD (t)) ∂_S (BS (t))					
Thematic accuracy		$\partial c(\mu e)$	$\partial c(\mu w)$	$\partial c(\mu v)$		
Quantitativ accuracy		$\partial q(e)$			$\partial q(vol)$	

The matrix of quality shown on *Table 3* indicates, for a given state, and for a given compartment, the various quality characteristics, and existing inferences.

To reach a desired quality for compartment volume $\partial q(vol)$, we have to check on the quality of features that affect it, which are:

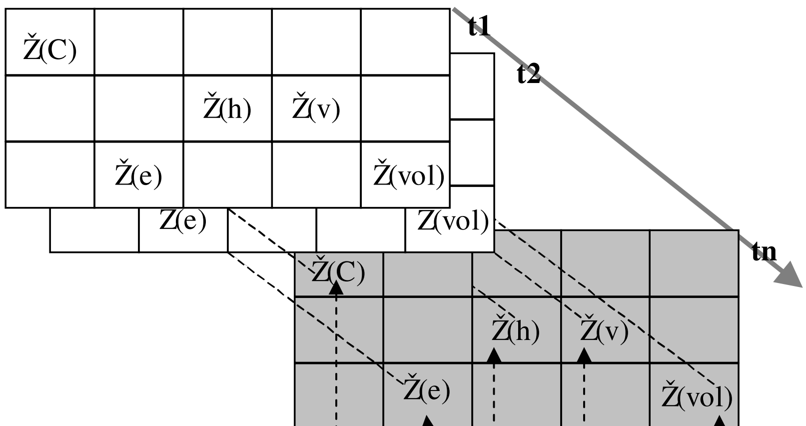
- the quantitative accuracy of elevation $\partial q(e)$.
- the qualitative accuracy of MF on elevation $c(\mu e)$, MF on wetness index $\partial c(\mu_w)$, and MF on vegetation indexes $\partial c(\mu_v)$, which affects the calculation of volume through the *variable* μ.

In addition, the thematic accuracy of classification of the beach object $\partial_C(\mu_e, \mu_w, \mu_v)$ infers the positional accuracy of the spatial fuzzy limits $\partial_S(BS(t), BD(t))$. Finally, the topological constraints Rtopo have also to be respected.

3.2.2. Quality matrix for an event and process

Different states are used for defining the process of erosion, and model it. Hence, the matrix takes into account different states to qualify the quality. More precisely, the most important quality element is the logical temporal accuracy *∂lt(μw(t))*, applied to various features, that make it possible to measure the evolution of volume in time. This is highlighted by the temporal matrix below *(table 4).*

Table 4: matrix of quality for a process and event – Ameland application



	Ontology features for a process and model – Ameland application (compartment, different states ti)				
Eléments de qualité	Rel State	Rel C limits	Rel wetness index	Rel vege index	Rel volume
Completeness	б$_C$				
Logical consistency topological		∂ls(CL) ∂ls(BD(t)) ∂ls(BS(t))			
Logical consistency Temporal			∂lt(μw(t))	∂lt(μv(t))	
Thematic accuracy quantitatif			∂q(e)		∂q(vol (t))

The matrix of quality shown on *Table 4* indicates, for a process and event, and for a given compartment, the various quality characteristics of interest, and existing inferences.
We use the notation Ž(t) to illustrate the evolution of quality features between different states.

The decomposition of the erosion model emphasizes several quality elements that have to be taken into account for defining quality of processes and events in the Ameland application. The Landsat images used to specify these various states were not taken at the same time in the year, neither in the month, nor in day-time. In this sense, the effects of tide and season are not same, which can influence wetness index and vegetation index. Also, that can influence the analysis of the evolution of fuzzy limits per compartment, and thereafter the evolution of the volume of sand. Hence, it is better to concider these problems of temporal quality for better modelling the erosion process.

More precisely, the calculation of volume is an agregate, since it is an integral on time and space:

- Over time,

One requires that the valid values for e, $\mu_W(t)$ *and* $\mu_V(t)$ in a sufficient number (σ_C), and are sufficiently well distributed over the period, so that approximate calculation of the volume is correct: these conditions define "temporal consistency" for each three variable $\{\partial q(e), (\partial lt(\mu_w(t)), \partial lt(\mu_v(t))\}$.

More precisely, for the temporal consistency of the fuzzy limits $(\partial lt(\mu_w(t)), \partial lt(\mu_v(t))$

- for wetness, there are two temporal factors that are important which are the relative hour compared to the last tide, and the recent weather events. According to the importance taken in calculation, this information will have to be required in the “éphémérides” (certainly possible and inexpensive), in order to "validate" each value, the condition being of having the maximum of observation in similar situation of tide;
- for the vegetation, the relative date in the season is important: the constraint is to have the maximum of observations in the same season.

- On space,

It is necessary to examine these conditions variable by variable: the condition is that the limits of *CL* limits do not move $(\partial ls(CL))$, the limits *BS.(t)* and *BD(t)* change from one state to another, and that the limit *BD* is more stable than *BS* $(\partial ls(BD(t)), \partial ls(BS(t))$.

4. Conclusions

This paper describes a spatio-temporal application of ontologies by presenting a quality matrix for a state, that is extended to also include processes and events. Its main advantage is that it formalizes the processes and that it is comprehensible by those who are not specialist in the field of application. Moreover, it takes into account the current standards of quality, within a larger framework, as such integrating the temporal dimension and fuzzy objects. Finally, information on the application quality is presented including some rules of inference.

We found that influences exist between different quality features. It is important to qualify these for better identifying those features that are relevant for the application. This enables to derive rules to aggregate the quality of different features that are relevant for an application.

Ontologies are also useful to create object compartment . Indeed an ontology of application is the formal representation of a reality which , in our application, is also a practical reality.

Finally, our methodology aims to reach the best possible agreement between the needs expressed by a geographical application concerning vague objects by nature, and available numerical data. It is discussed how our interpretation of ontologies as points of view on a reality, corresponds to other points of view. It takes into account any explicit note on differences between two imperfect representations and also allows one to reduce these.

We applied this methodology to objects with unspecified limits in a dynamic context. As such it resulted into a clear and transparent matrix of related objects and quality standards in a dynamic way.

Acknowlegment

The authors make a point of thanking the European Community, for its financing, through contract IST-1999-14189, project REV!GIS of the program IST 'Future & Emerging Technologies"(June 2000, June 2004)

References

CEN/TC-287 (1994/1995). WG 2, Data description: Quality. Working paper N. 15, August 1994. PT05, Draft Quality Model for Geographic Information, Working paper D3, January 1995.

Claramunt Christophe, P. C., Thériault Marius (1997). "Design Patterns for spatio-temporal Processes."

FGDC (2000). Content Standard for Digital Geospatial Metadata Workbook**,** 122 p.

Fisher (2003). Data quality and Uncertainty: Ships passing in the night. ISSDQ'2003 Proceedings, Hong Kong.

Frank, U. (subm). "A linguistically justified proposal for a spatio-temporal ontology"

Galton, A. (2000). Qualitative Spatial Change. New York, Oxford University Press.

Goodchild, M. et Jeansoulin R. (1998). Data Quality in Geographic Information. from Error to Uncertainty. (Jeansoulin & Goodchild,. eds) Paris, Editions Hermès, 192 p.

Gruber, T. R. (1993). "A Translation Approach to Portable Ontology Specifications." Knowledge Acquisition 5 (2). pp 199-220.

Guarino (1995) edited by N.Guarino and R.Poli, "Formal Ontology, conceptual analysis and knowledge representation." International Journal of Human and Computer Studies.

Guptill, C. et Morrison L (1995). Elements of spatial data quality. New York, Elsevier Science inc, 201p.

Hunter, G. J. (2001). "Spatial Data Quality Revisited." Symposium, Rio de Janeiro, Brazil, 4-5 October 2001.

ISO (2003). "ISO/TC 211 Geographic information/Geomatics - 19113, 1914, Geographic information quality; evaluation procedures.

Jeansoulin, R. et Wilson, N. (2002). "Quality of Geographic Information: Ontological approach and Artificial Intelligence Tools in the REV!GIS project." 8th EC-GI&GIS Workshop, Dublin 3-5.

Joos, G. 2003. Standardization of data quality measures. In: Proceedings of the 2nd international symposium on spatial data quality '2003'. Eds. Shi, W., Goodchild M.F. and Fisher, P.F. pp 205-209.

Laurini R. et Thompson D. (1992). Fundamentals of spatial information systems, the APIC series number 37, Academic Press, 680 p.

Rindfuss, S. (1998). People and pixels, linking remote sensing and social science, national research council, national academy press, 244 p.

Roelse (2002). Water en Zand in Balans. Evaluatie zandsuppleties na 1990; een morfologische beschouwing. Internal Report Rijksinsituut voor Kust en Zee, Middelburg, The Netherlands.

Van de Vlag D., Vasseur B., (subm). "An application of problem and product ontologies for coastal movements."

Vasseur, B. a. (2003). "Ontological Approach of the Fitness of Use of Geospatial Datasets." In Proceedings of 6th AGILE Conference, Published by Presses Polytechniques et Universitaires Romandes: pp: 497-504.