Located and temporal based services for nature-society interaction regulation

Cyril Faucher[a,*], Cyril Tissot[b], Jean-Yves Lafaye[a], Frédéric Bertrand[a], David Brosset[b], and Mathias Rouan[b]

[a]L3i (Informatique, Image, Interaction), University of La Rochelle, France; [b]LETG Géomer UMR 6554, CNRS, France

(Received xx Month 2010; final version received xx Month 2010)

With the surge of mobile devices and applications, knowledge base browsing and querying facilities must be adapted to new kinds of users and services. Space and time databases are concerned and, as such, are the subject of this paper. Within a mobile context, data retrieval services must take the location of the call into consideration as regards space and time, insofar many pieces of information do depend on 'where' and 'when' constraints. We present here with a general object model dedicated to specifying time properties. The novel aspects of our proposal consist of three main points. First, the temporal object model stands as a pivot model, and all the more leverages interoperability between software applications, since it extends common standards such as ISO 19108 and iCalendar. Second, we accompany the object model with a formal grammar close to natural languages, which helps end users in managing and checking temporal object instances. Last, our proposal focuses on intensional temporal expressions instead of extensional sets of concrete calendar dates. This allows to express semantic aspects – namely for periodic (cyclic) events – which remain hidden and not computable when only series of dates are given.
We evoke two kinds of applications for which our model is beneficial; one concerns services called by human users and the other addresses calls placed by software agents e.g., in a multi agent system for instance within a simulation context.

Keywords: intensional temporal expression; located based temporal services; nature-society interaction; multiagent system; visual analytics

1. Introduction

The development of dynamic models of nature-society interactions (Le Tixerant et al. 2010) requires consideration of the multi-scale character of these interactions in spatial as well as temporal terms (Peuquet 1994). The above point of view applies in case of users calling for services whose outputs depend on the context of the call, and especially, for our concern, on location and time. The required services must query the model in order to correctly integrate the spatial and time local parameters of the call, before returning a consistent response to the user. This remark is a plain and common one as regards located services, but time issues and their often tight interconnection with geographic positions make things less straightforward to manage. As a matter of fact, we advocate for paying consideration to time based services as well as to – and in connection with – location based services.

The running example in this paper deals with seashell digging. Then, as an example, high and low tides constitute a most relevant global natural phenomenon, which generates many periodical located occurrences (Andrienko, Andrienko, and Gatalsky 2003; Roth and Ross 2009). It seems clumsy to store the entire time datasets for tides – low and high – for each day and location. Hence the benefit of recording

* Corresponding author. Email: cyril.faucher@univ-lr.fr

abstract, concise and intensional periodic time expressions (Carnap 1947) instead of their extensional counterparts.

This point gains in importance with the expansion of mobile and ubiquitous systems, which leads to an increased volume of such space and time located queries. Of course, information about local time and space can directly be captured from the mobile device, which places the call. Moreover, an abstract – say object – model embedding intensional temporal expressions is a very convenient frame for ensuring interoperability, especially with applications in charge of displaying the retrieved information (e.g., maps) on Smartphones.

Another application field refers to simulation framework based on located multiagent systems (MAS) (Weiss 2000; Shoham and Leyton-Brown 2009). Users are no longer human agents, but state machines. The system consists of a Knowledge Base (KB), and located clients query the KB so as to determine their behaviour at runtime. In this case, it is usual to deal with discrete systems and asynchronous agents, making it cumbersome if not intractable to store calendar datetimes with multiple contexts and granularities. Additionally, recording, but datetime occurrences hides a lot of semantic issues, namely about periodicity.

In this paper, we provide a generic UML (Unified Modelling Language[1]) Class model (OMG 2009) for specifying temporal knowledge. UML is a specification language for modelling objects. The ISO 19100 series standard[2], we will reference below, is specified with UML (ISO/TC211 2010). Moreover, we reused types of time characterized in (Isard 1970) like: linear time, cyclic time, ordinal time, and time as distance. Our approach keeps close to the natural language and to the domain/business model. However, one important point is that, in contrast with natural languages, our specification language is unambiguous.

Our contribution must be seen as a forehand basic step towards any of the four main threads in the Visual Analytics Agenda (Thomas et al. 2005; Andrienko et al. 2007). In fact, the common pivot UML model allows designing interoperable applications in the fields of analytical reasoning, visual representation and user interaction, data transformation *via* Model Driven Engineering (MDE) (Bézivin 2005; Schmidt 2006), and production/dissemination. Moreover, it leverages the operational bridging of these threads to one another.

As regards the paper organization, the next Section elicits our contribution to the Visual Analytics Agenda. Then, Section 3 is dedicated to presenting the example applied to professional seashell digging; it shows that coping with temporal expressions is mandatory at various stages, and suggests in which ways these expressions can be exploited. Section 4 presents excerpts of the object model, which are central parts of our proposal. Section 5 evokes how the underlying Smartphone applications and the multiagent system interact with the Temporal Model. We conclude by listing the key issues of our work and outline the future developments.

2. Interaction with the Visual Analytics Agenda

Our work has been initialized and deliberately achieved within a wide general application context, yet we intend to outline below why it can fruitfully and specifically apply to visual analytics. Let us adopt the classification of the R&D Agenda and successively address its four identified threads (Thomas et al. 2005).

As regards analytic reasoning, either human or software agents need to access prior asserted pieces of information before processing logical or empirical reasoning and inference, and possibly contribute to decision making. Whatever the goal:

assessment, forecasting or developing and testing options, these agents must browse and select relevant information and data. The object model we have designed provides a context-independent way to depict the domain temporal knowledge. As a pivot model, it also provides a seamless access to various knowledge and data warehouses, whichever the language in use (SQL, RDF, XML). It is also beneficial when willing to integrate temporal and spatial knowledge. The last thread is also directly concerned by these facilities: within a dissemination process, the requirements remain the same as above, but in that case, the display of results targets end users instead of intermediate agents.

Likewise, the pivot model can help bridging the domain temporal knowledge to computer-mediated representation frameworks that bear human interactions and tease intuition. In fact, it provides a set of classes and methods that directly interoperate with visualization API specifications. This is a significant contribution to the visualization and interaction techniques.

With regard to the third thread, model driven engineering allow customized data transformation based on model mapping. So as to apply these most effective techniques, having a consensual shared domain model at one's disposal is mandatory. Here, the temporal object model allows to transform model elements as well as data instances from any modelling space (source) into any other (target). For instance, *via* a common intermediate object representation, data from XML and RDF resources can be integrated so as to feed widgets Class instances in a visualization application.

In all the cases above, the pivot model allows to leverage software design and data integration, by means of interoperability, reusability, maintainability and ease of verification and validation.

3. The Telline (Donax Trunculsus) use case

This section presents a use case dedicated to providing time specification facilities for the modelling of marine fishing activities. The final goal is to provide the user with a language that handles a large set of abstract temporal expressions, in particular periodic (cyclic) ones (e.g., *"each first Wednesday in the month"*).

More precisely, the example simulates the professional Telline (*Donax trunculus*, edible saltwater clam) digging process in Douarnenez bay[3] (France). Telline digging appeared during the 1970's in Douarnenez and proved to be highly profitable, what led to a rapid Telline's stock exhaustion (Guillou 1982). In order to achieve a sustainable regulation of the activity, the administration drafted orders for ruling the access to fishing areas, by restricting the digging duration and imposing a feedback about captures. This use case reveals the actual complexity of the digging activity calendar and requires a specification on how multi-scaled spatio-temporal constraints on this activity can impact the resource stock.

3.1 Activity temporal modelling

Temporal modelling consists of building a Temporal Potential Practice (TPP), which results from compiling various constraints (see Figure 1):

- For each registered digging field, the law specifies 'allowed', 'restricted' or 'prohibited' digging periods.
- Sea state and tide, as well as temperature, constrain the accessibility to digging areas.
- The bacteriological quality of water also has an impact on fishing rights.

All of these constraints are related to several periodical factors. With regards to the registered digging field of Douarnenez-Camaret, in addition to other constraints ('Weather condition', 'Tidal coefficient' and 'Sale price'), it is stipulated that:

"digging is <u>*prohibited*</u> *each year, from 9 p.m. to 6 a.m. between July 1st and August 31st. Out of these periods, digging is* <u>*allowed*</u> *from 3 hours before low tide up to 3 hours after the same low tide (according to the tide almanac in Douarnenez). Otherwise, it is* <u>*restricted*</u>*".*

This rule is depicted on the TPP in Figure 1, by the first constraint time-zones named 'Regulation'. Figure 1 uses a time wheel representation (Peuquet 2002; Moellering 1976; Edsall and Sidney 2005) to show periodical properties like regulation and tide indicator. The tide period is '12h50' and for other constraints the cycle is annual. The time wheel corresponds to a homogeneous area as regards the various parameters. It accounts for a set of mean conditions computed over several consecutive years and provides a mean pattern for the parameters that impact on Telline seashell digging. Local conditions possibly add some corrections to the mean effect.

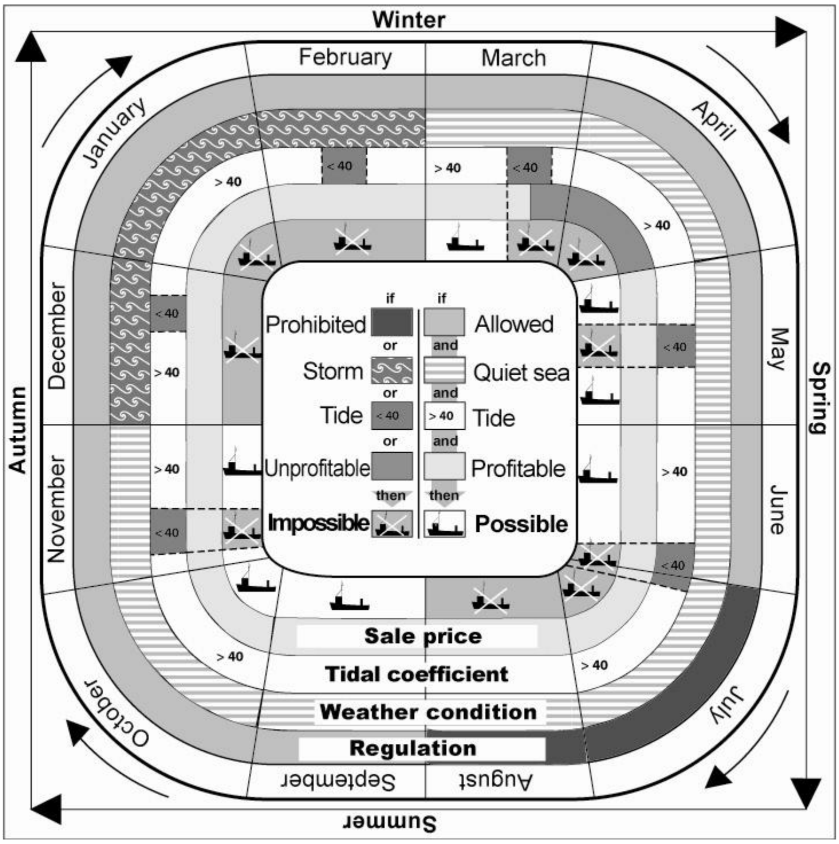

Figure 1. Temporal Potential Practice for *Donax trunculus* digging.

Specifying and setting the multiagent behaviour requires that temporal knowledge and databases be queried at runtime in order to update the modelled environment, agent states, and interactions. This is a complex issue, since all basic temporal rules must be coded as well as their exceptions, including relative time positions of events (weather, oceanography, administrative decisions, etc). Dealing here with time occurrence semantics is much better than dealing with time occurrence data.

3.2 Activity spatial modelling

Spatial analysis methods permit the building of a Spatial Potential Practice (SPP) for the activity. The SPP results from the superimposition of geographical information layers that account for the set of geographical constraints upon the activity. With regards to *Donax trunculus*, the SPP consists of the registered digging areas boundaries, the bathymetry, the sedimentary nature of the intertidal zone, and also of the digging areas accessibility (paths, roads, docks, etc). All constraints are likely to evolve either in a deterministic, stochastic (predictable – e.g., environment change) or chaotic way (unpredictable – e.g., pollution accident). Managing these evolutions (effects) implies that the source events calendar (causes) is managed accordingly. Due to the marine environment complexity, a minimum amount of information has been defined for running the simulation process. In particular, the physical characteristics of the environment (such as bathymetry, submarine geomorphology, tides and weather conditions) and the activity regulatory constraints are required.

The constraints that impact on the spatial development activities are specific to each activity. They tally with thematic layers formatted in a Geographic Information Base (GIB) processed by GIS. GIS spatial analysis functions are used to superimpose the various GIB layers on a single layer finally accounting for all of the practice conditions. This analysis layer contains a set of polygons, which specify whether the modelled activity is likely to be developed or not, and thus describes the SPP.

4. Periodical (cyclical) Phenomenon Modelling

We propose a general UML object model for specifying temporal events properties i.e., the Temporal Occurrence Model. Many instances of this model are taken into consideration within the process. More precisely, there is one special instance for each pair of (activity, location). Periodic characteristics are based on such temporal basic concepts as Instant and Period as well as on secondary concepts with their related properties, which can be found in several well known standards such as iCalendar (Dawson and Stenerson 1998) or OWL-Time (W3C 2006).

4.1 Motivations for creating a Domain Specific Language for temporal expressions

Time can be considered from many viewpoints: mathematics, philosophy, economics, meteorology, etc. Our motivation is to design a language, which can help specifying non ambiguous models likely to be easily understood and managed by human beings, and also to be processed efficiently by computers. So, we accompany our model with a textual grammar (see Subsection 4.8), which is close to the natural language.

The model is designed to apply to a very wide scope. The object model can capture both concrete (extensive set of calendar dates) and comprehensive time expressions (abstract specification of a set of periodic/cyclic occurrences). We do not address signal processing (Fourier transform), even if we eventually do split complex time properties of events into a set of simple ones. Instead, we intend to keep close to natural languages. One of our goals is to provide a means to compute and reason about temporal occurrences initially extracted from textual (English, French) specifications (Faucher et al. 2010).

Standards like the ISO 19108 (ISO 2002) or iCalendar still have some lacks with regards to our requirements. In fact, both periodical restriction on existing periodical rule and relative positions between occurrences need to be handled. With respect to interoperability among the various applications (e.g.: Smartphones, MAS, knowledge base query engine, GIS access, etc) we rely upon Model Driven Engineering techniques, which is a most convenient paradigm for achieving the implementation of the required models and data transformers.

4.2 Temporal Occurrence Model basics

We selected the ISO 19108 standard as a reference for modelling the basic concepts: Instant and Period. The main reasons for this choice are the following:

- The object representation of the ISO 19108 proves to be well suited for being used with MDE as a pivot representation between software applications that have to deal with the various technical spaces (Bézivin 2005) in use.
- The ISO 19100 series treats of geographical information issues that are commonly associated with temporal features.
- Having a pivot object model at one's disposal leverages the mapping of temporal concepts in hand with items from other application and domain oriented time specification languages.
    - Namely OWL-Time for specifying an ontology including time issues, for expressing logical time rules and for performing formal reasoning about time properties.
    - SQL-Time for relational database querying, according to time constraints. iCalendar for scheduling applications that deal with both periodic and non periodic event occurrences.

4.3 Periodic Rule Model

Within the scope of the present paper, and for the sake of brevity, we only discuss selected excerpts of our model[4]. Let us first focus on the central concept in Figure 2. The PeriodicRule class is the root element of our model for defining periodicity issues about a PeriodicTemporalOccurrence.

A PeriodicTemporalOccurrence is a set of PeriodicRules. Each aggregated element indicates a simple periodic phenomenon (i.e., only one Frequency). The composition of all elements in the set results in the sum of the simple periodic components.

Consequently, the first property of a PeriodicRule is its Frequency. According to a common definition (DiBiase et al. 1992), a Frequency is a pair of values respectively indicating the number of occurrences (times attribute) that happen during a given time span (referenceDuration role). As shown in Figure 2, referenceDuration ends in a Duration data type. This might be too restrictive in practice, since only durations can then be referenced. Thus, in our proposal, we give access to the whole set of AbsoluteTemporalExpressions for specifying the start and the end of the desired interval. Intrinsic periodic CalendarPeriodicDescriptors can be specified as discussed in Subsection 4.4 *via* the role periodicTimeInterval (e.g., "*each Monday*", "*each first Tuesday*").

A PeriodicRule owns an optional ruleExtent that defines the interval during which the rule is valid. This property is needed when checking if a concrete date is consistent with the given rule or not. The optional startTime attribute is specified for one frequency, in order to anchor the first periodic phenomenon occurrence on a concrete calendar i.e., to define its phase once its frequency is known.

As mentioned above, if no referenceDuration is given for a PeriodicRule, then a PeriodicTimeInterval must be specified with two properties, namely begin and end, which are AbsoluteTemporalExpression (see Subsection 4.4). Of course, constraints are to be checked e.g., begin precedes end for all occurrences, and both begin and end should have the same frequency, but begin and end occurrences may present a phase difference. This means that the length of PeriodicTimeInterval occurrences are not necessarily equal to one another (e.g., PeriodicTimeInterval occurring *"from the first Tuesday to the last Monday of each month"*). The class PeriodicRelativePosition is used to specify a PeriodicInstant in relation with one previously defined (see Subsection 4.6).

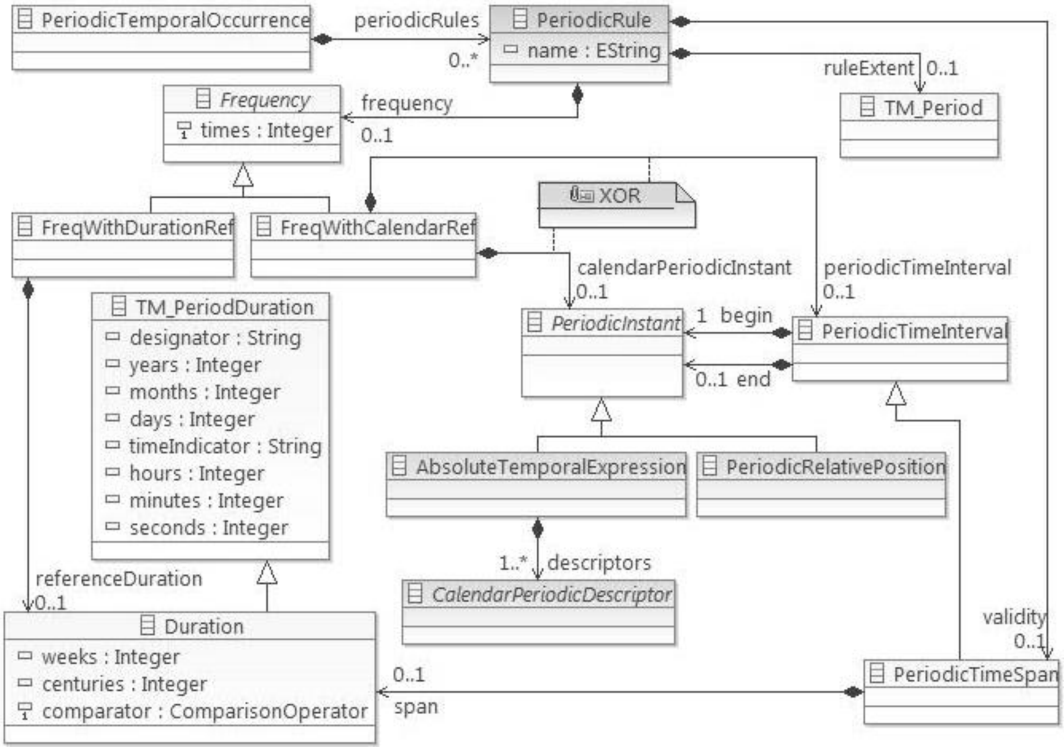

Figure 2. Excerpt of the Periodic Temporal Occurrence model.

4.4 Calendar Periodic Descriptor

The model excerpt shown in Figure 3 provides means for specifying the major calendar units when dealing with time issues.

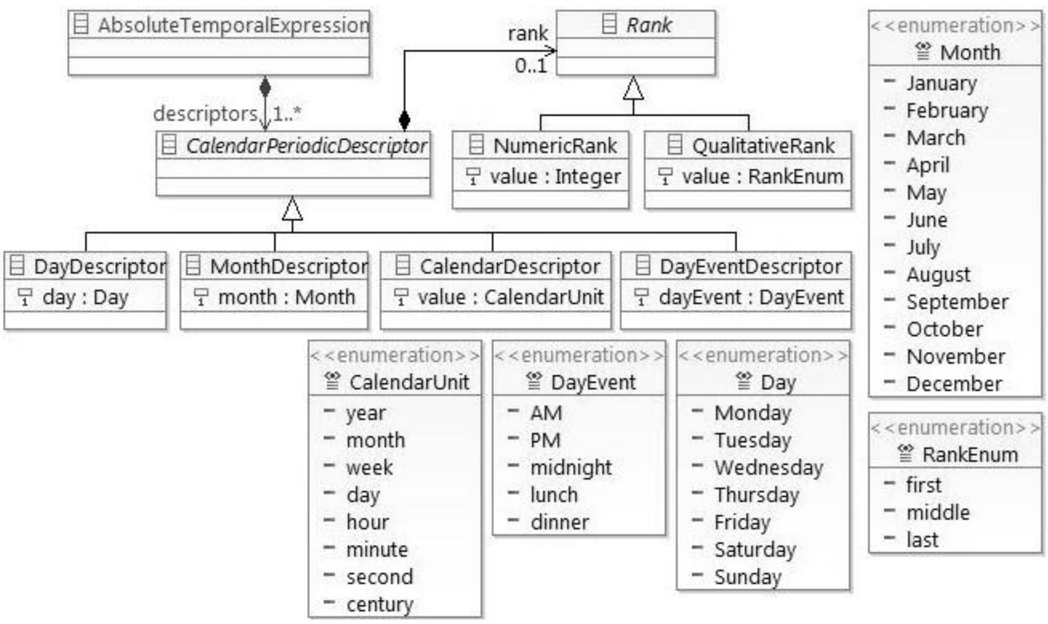

Figure 3. Excerpt of the Calendar Periodic Descriptor model.

Calendar units actually are abstractions that implicitly account for the essential periodic nature of calendar items, hence the name of the root class: CalendarPeriodicDescriptor. The Instant/Period duality clearly appears here as an artifact of the granularity. One can either specify: *"the event takes place in May"* or *"the event occurs between May 1st and May 31st"*. Even though the two assertions have equivalent semantics; they effectively refer to different underlying concepts. When the Instant viewpoint prevails, days in a week and months in a year are identified by their name (Monday, March, etc). On the contrary, week, month and year rather refer to a sliding period with a more or less precise duration: week is a period of 7 days, month a period of 28/.../31days, and so on.

Instants may also be specified by adding a NumericRank to a calendar unit e.g., "*3rd Sunday*, *28th week*". Adding a rank to a calendar item changes the viewpoint to this item. In fact, as mentioned above, month refers to a sliding period, while "*3rd month*" refers to the third month in the year and is actually a synonym of March, which indicates an instant. This also applies to unlabeled units such as: the "*2nd week*" of a month or the "*2nd week*" of a year.

4.5 Rule Extent and Periodic Time Span

A periodic phenomenon is basically infinite. For practical use, time boundaries should be provided, at least for identifying the starting point. The ruleExtent role specifies the period during which the PeriodicRule applies. The association end is a TM_Period with a beginning and an optional end. It is not required that the boundaries correspond to exact occurrences. The semantics of ruleExtent is that all occurrences are valid inside the extent and invalid otherwise.

A fixed time extent may prove insufficient to capture some situations, which are not scarce among periodic events. As a matter of fact, the extent should itself often be periodic. This, for instance is the case in the following assertion: "*the event occurs each first week of the month from March to September"* (see Figure 4).

Therefore, a PeriodicTimeSpan is defined to specify a periodic time restriction: "*from March to September*", which occurs each year. An additional ruleExtent could assert that the rule applies for example from 2010 to 2015. The PeriodicTimeSpan is expressed as a special PeriodicTimeInterval. For sake of simplicity, no inner PeriodicTimeSpan should be nested in a primary one.

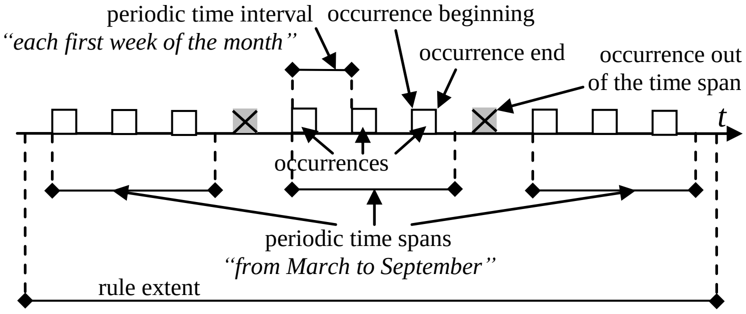

Figure 4. Periodic Rule with a Periodic Time Span in practice.

4.6 Relative Temporal Occurrence

TopologicalPrimitive is provided by the ISO 19108 in order to capture the pairwise relationship between primitives. We added the concept of FeatureRelativePosition (see Figure 5) to provide facilities for specifying the sets of occurrences of temporal objects in relation to one another. Therefore, it is possible to specify relative positions between periodic expressions such as *"3 hours before low tide"*. This expression is regarded as a PeriodicRelativePosition and 'low tide' as a referred PeriodicRule. The term 'before' comes from the Allen's temporal relations (Allen 1983). '3 hours' is the gap between the two specifications. The Allen's relations are used here to define relative positions between (temporal occurrences of) events. This is a static piece of information, used only once when defining the relative position of a 'relative' event. The interaction with the expert is limited to the event definition.

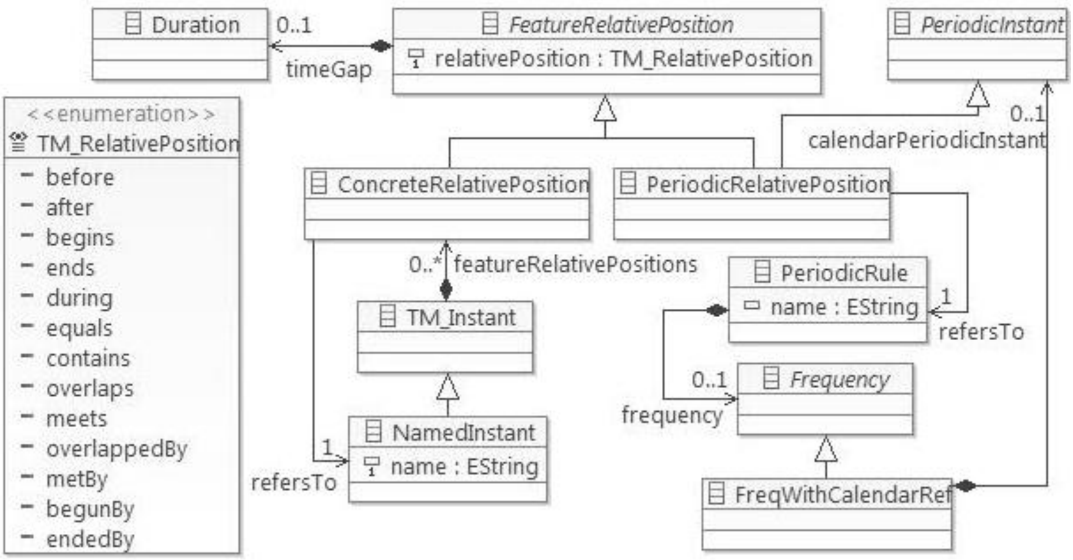

Figure 5. Excerpt of the Temporal Relative Position model.

4.7 Management of exceptions

Once a set of occurrences is specified (either concrete or periodic), it is possible to restrict the general definition by specifying TemporalExceptions. Basically, temporal exceptions (Figure 6) specify a set of occurrences in the same way as done for TemporalOccurrences, unless nested exceptions are not allowed within a TemporalExceptions specification. The set of exception occurrences is finally withdrawn from its parent TemporalOccurrence set definition. It is for instance possible to specify an exception such as: *"except on Tuesday between 11 a.m. and 3 p.m."*.

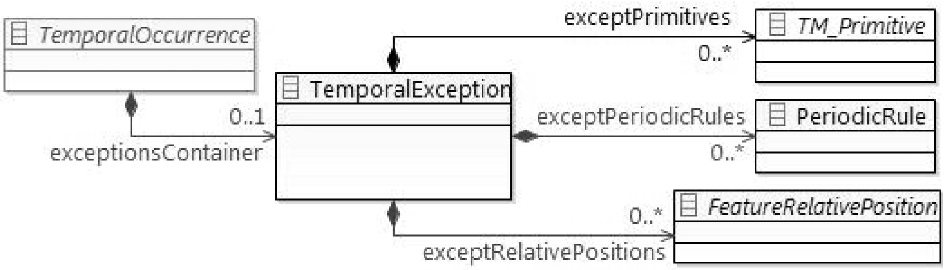

Figure 6. Excerpt of the Temporal Exception model.

4.8 Temporal Occurrence Textual Grammar

In connection with the Temporal Model, a textual grammar has been specified. It allows an automated translation of any rule in the model into an equivalent counterpart expressed in natural language, which can immediately be understood by the user, thus allowing a direct checking of the modelled data validity. Figure 7 shows an example of the grammar output with respect to the *Donax trunculus* use case.

"1 time(s) during one 12 hours 50 minutes period" specifies the frequency. 'Night' and 'seashell of *Donax trunculus* digging' concepts are used in order to specify exceptions with relativePositions (night digging is prohibited).

```
//night definition following the regulation
The event "night" occurs periodically according to the rule(s) below
    - rule: (identified by night)
        from each 21th hour of each day
        to each 06th hour of each day
    end of the periodic temporal occurrence description
end of the event

//low tide in Douarnenez
The event "low tide" occurs periodically according to the rule(s) below
    - rule: (identified by low_tide_Douarnenez) 1 times during one 12hours 50minutes period
    //The first occurrence of low tide
    and starts on "2010-07-15T14:23:00"
end of the periodic temporal occurrence description
end of the event

//seashell of Donax trunculus digging
The event "Telline seashell digging" occurs periodically according to the rule(s) below
    //3 hours before the begin of the "low tide"
    //3 hours after the end of the "low tide"
    //low tide is defined as a periodical instant
    //then the begin and end of the "low tide" are the same instant
    - rule: from 3 hours before low_tide_Douarnenez to 3 hours after low_tide_Douarnenez
    //Exceptions, except the night
    except a relative position  equals night
    and except from each July to each August
end of the periodic temporal occurrence description
end of the event
```

Figure 7. Use of the Grammar: file edition for the *Donax trunculus* use case.

5. Managing temporal regulation of nature-society interaction

This Section describes the implementation of a Located Time Based Service (LTBS) which interacts with two use cases. The first one concerns a Smartphone application and the second one concerns the 'HUman Dynamic Activity' framework (DAHU) (Tillier and Tissot 2010; Tissot et al. 2004), which is used for simulating the *Donax trunculus* digging activity.

5.1 A Located Time Based Service (LTBS)

We have designed a Located Time Based Service as an external and independent component that can be shared by various remote applications, provided they refer to the same TemporalModel (see Section 4). Clients can call the LTBS, which will retrieve pieces of temporal information anchored at a special location. Figure 8 describes the Client/LTBS component architecture.

The main use cases for the LTBS are the following:

- Modelling temporal rules for nature-society interactions in a given location.
- Answering queries to the TemporalModel and check that one Instant/Period is consistent with the knowledge base (existing rules).
- Providing the Temporal Potential Practice (i.e., optionally compute the concrete with the series of dates when the practice is allowed *vs* prohibited).

We consider two types of clients: human clients equipped with Smartphones or software agents like in DAHU framework. As regards Smartphones, we have designed a mobile application implemented on the Android operating system. Figure 9 shows the graphical interface we implemented with the Android Virtual Devices tool[5]. According to the standard scenario, the user successively selects the type of activity he is interested in (e.g., Telline digging), then the datetime and location (i.e., area where the practice takes place).

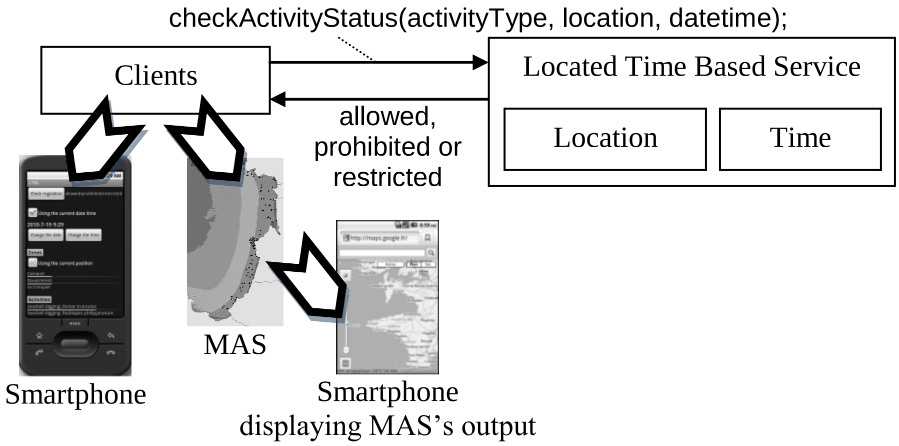

Figure 8. Clients/LTBS architecture.

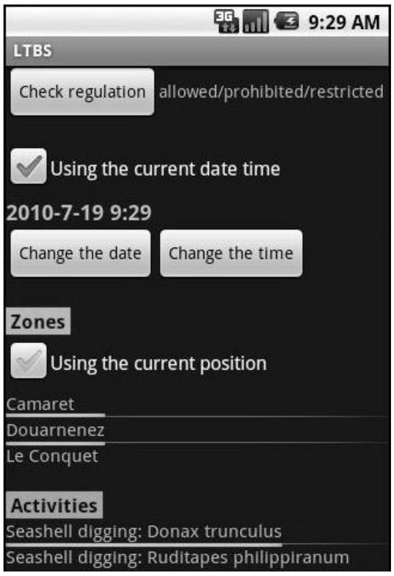

Figure 9. LTBS application for Android.

Of course, the datetime and the location can directly be determined by the mobile phone when equipped with a GPS chip. Then checking the *"Check regulation"* button returns the status of the activity i.e., either 'allowed', 'prohibited' or 'restricted'. Calls and data exchanges are performed with a Web Service (SOAP).

Likewise, in case of the DAHU MAS simulator, software agents are assumed being bound to special locations. Their state evolves along the simulation process, and they can at any time retrieve pieces of information actually depending on time and location. For instance – back to the seashell digging use case – let us consider an agent, which represents a registered digging area. It is bound to an object in the TemporalModel which embeds its dynamic behaviour in accordance with the current set of administrative rules.

When the MAS queries the status of the digging area during a given period, it sends a request (with this period as an input parameter) to the LTBS, which returns 'allowed', 'prohibited' or 'restricted'. According to the answer, the MAS can then go one step ahead in the simulation process. The previous version of DAHU dealt with temporal properties expressed in extension. Thus, during a simulation, DAHU interacted with the database containing all the concrete instants at which a given activity was performed. Presently, the database only records intensional periodic expressions. DAHU queries this database *via* the LTBS.

Another kind of request would, for instance, ask for a time interval during which the practice is allowed e.g., *"from 11.18 a.m. to 5.18 p.m."*, assuming the tide is low at 2.18 p.m. in the corresponding area. DAHU can list all Spatial Potential Practice areas within the current context and display it on a Smartphone. The latter is likely to be either exploited by further simulation computations or visualized on a map representation for various analysis and decision processes.

5.2 The simulation framework: DAHU

DAHU simulation framework is based on a multiagent system structure, but presents significant differences as regards how to formalize the relations between agents and the modelled environment. The multiagent system is in charge of simulating the anthropogenic activities and their interaction with the environment. The system is based on a distributed intelligence model that gathers all the relevant actors at the scale of the fishing area. Locality is handled through patterns composed of coded polygons respectively delimiting homogeneous areas for digging techniques, physical and biological characteristics and target species.

The aim is less to represent the progress of virtual activities on a theoretical territory, than to propose a descriptive tool founded on the analysis of existing (scientific and administrative) data in order to infer a valid reality model (Le Tixerant et al. 2010). Unlike the MAS in (Bousquet and Le Page 2004), which is devoted to analysing the evolution of landscapes based on economy production scenarios, DAHU considers space as a simulation constraint. Thanks to this approach, DAHU can be viewed as a distributed artificial intelligence system based on the coupling of quantitative and qualitative models with a GIS (Tissot et al. 2004).

Within the *Donax trunculus* digging context, the approach we suggest is based on the constitution of a distributed artificial intelligence system. This architecture meets the need of building models under spatio-temporal constraints in order to simulate the progress and impact of fishing activities at the spatial potential practice scale. The approach is built on a technical description of the modelled activities. The aim is to constitute a series of archetypes[6] integrating all properties related to the production directions, to the spatial organisation levels they are associated with and to the species involved.

The agents implemented in the model are of three kinds:

(1) Marine District agents, which enclose fishing activity. Their function is also regulatory insofar as they can forbid *Donax trunculus* digging for a given period following coastal water pollution of telluric or marine origin;

(2) Fishermen Agents. They are formalised on the basis of archetypes deriving from technical description. From a spatial standpoint, they are associated with allowed fishing areas. They determine fishing resource pressure according to physical and biological constraints of fishing areas;

(3) Fishing Area representing the fishing resource production unit. A set of characteristics determine their potential production capacity. According to environmental constraints (water temperature, sea floor sedimentological properties) and regulation constraints this potential production capacity evolves.

These three groups are maintained at generic specification levels and have no specificity connected to the spatial establishment of modelled activities. Conversely, they integrate the ability to react and adapt to the evolution of their environment, the latter resulting from a combination of natural and anthropogenic constraints associated with a territory. In order to set these agents back in a known spatio-temporal context, several compartments were created in the framework. They aim at organizing the various procedures used by the model to reproduce the operation of aqua cultural activities under the constraints influencing their development.

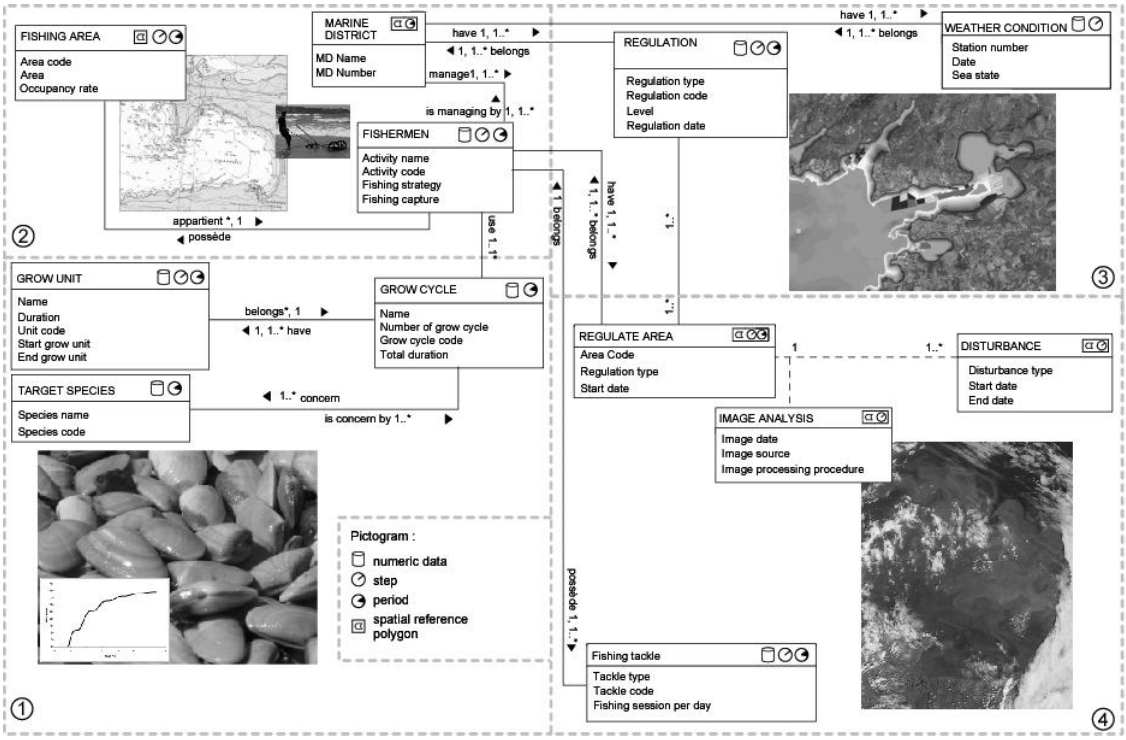

Figure 10. Structure of the seashell digging model into the DAHU framework.

Figure 10 illustrates this relational pattern with a four-cell structure, each of which plays a very specific role in the development of simulations:

- the first cell includes all descriptors that characterize agents derived from production archetypes. It creates connections between fishing strategies and target species;
- the second cell manages the connection between these data and their spatial reference entity (fishing area, marine district). It also includes all the coding keys for linking the various compartments of the model;
- the third cell integrates spatio-temporal constraints that determine the legal conditions for fishing activities;
- the fourth cell includes geographic information sources that can reproduce the impact of accidental or chronic disturbance on fishing activities (pollution incidents resulting in the alteration of water quality, for instance).

Each agent in the simulation framework, is associated with a *thread* including technical data and spatio-temporal constraints. According to its Class, an agent presents with reaction capacities. The agents are first stimulated by the ‘perception’ of the environmental conditions; then, they react according to a predefined reflex behaviour before producing a response, which is the simulation’s outcome.

5.3 Simulation output analytics

Figure 11 accounts for the average distribution of the fishing pressure in the area. Aerial photographs have been taken and analyzed during year 1997 (and this will be iterated in 2010). Dots represent the relative fishing stress according to simulation output. This kind of output gives initial elements to explore data (Andrienko and Andrienko 2005; Weaver et al. 2007; Chen, MacEachren, and Guo 2008). Within the *Donax trunculus* digging context, the approach is built with a double aim:

- the first aim is to show the variability of the activity's development according to instituting fishing areas with restricted or prohibited access and to biophysical constraints;
- the second goal is to produce a fishing assessment in order to estimate a level of pressure on stock (number of fishermen present in an area over a given period).

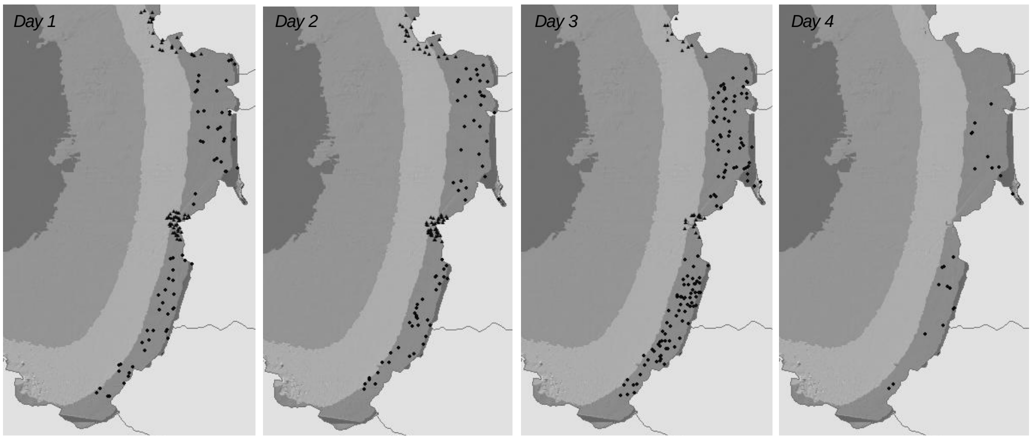

Figure 11. Simulation output with DAHU (*Donax trunculus* digging from 2005-01-03 to 2005-04-03).

6. Conclusion and future work

This paper presents an approach allowing to inform a mobile user about the authorization (or prohibition) to carry on regulated activities. This information is provided by a service based on the position of the user in both space and time. Given one spatio-temporal position it is possible to query a database consisting of the set of rules governing the activity in the corresponding location, and for instance to return the set of dates when the activity is permitted/prohibited.

We specified a conceptual model, which captures the temporal semantics of a part of the complex rules that govern some nature-society interactions. This object model extends the temporal model defined in the ISO 19108 standard. It allows to represent periodic temporal expressions possibly including exceptions, which can themselves be periodic. Periodic temporal expressions are intensional. This is a most concise way for specifying temporal data while retaining the full semantics of periodicity, which would be lost if dealing with extensional datasets.

Using our model also provides facilities for exporting the expressions towards other standards such as iCalendar and OWL-Time. The object model is accompanied by an equivalent formal textual grammar, which provides a concrete syntax for temporal expressions. This allows an automated translation of model elements into a set of textual expressions close to the natural language, and proves to be very convenient when communicating with a human operator, either for an acquisition or a validation process of complex temporal expressions.

We used the service model combined with a simulation framework where the end user is a software agent endowed with an autonomous behaviour. The simulation, aims at inferring, validating and exploiting a model for the impact of a given nature-society interaction upon its environment. The output of the simulation process is a set of maps that can be used by experts so as to predict the dynamics of the nature-society interaction within the frame of a given regulated ecosystem.

Our work in progress consists in designing an ontology that can express the common knowledge about time and calendars and then permit – thanks to convenient rules – to infer pieces of knowledge about temporal expressions. The challenge is to cope with intensional expressions in order to avoid the combinatorial explosion attached to extensional datasets calculus. From a practical viewpoint, our approach provides the user with friendly interfaces that accept queries expressed in a controlled natural language. Since the formal grammar of this query language directly translates into model elements (from our temporal model) and eventually can retrieve the corresponding sets of structured instances, the whole chain of operations between the located query and the display of the response on the user device can be automated.

Acknowledgements

This work is partially granted by the French National Research Agency (ANR-Contint, RelaxMultiMedias 2 project). We would like to thank Matthieu Le Tixerant and Fanny Kerninon.

Notes

1. UML is a refinement of earlier Object Oriented Design and Object Oriented Analysis methodologies
2. ISO 19100 meant to standardize all aspects of geographic information
3. Douarnenez Bay: http://www.geonames.org/maps/google_48.167_-4.417.html
4. TM_ is a prefix chosen by ISO and means these classes come from the ISO 19108 standard
5. Android Virtual Devices tool: http://developer.android.com/guide/developing/tools/avd.html
6. Invariant model comprising a set of descriptors to characterise one or several activities with identical production processes

References

Allen, James F. 1983. "Maintaining knowledge about temporal intervals." *Communications of the ACM* 26:832-843.

Andrienko, Gennady L. et al. 2007. "Geovisual analytics for spatial decision support: Setting the research agenda." *International Journal of Geographical Information Science* 21:839-857.

Andrienko, Natalia V., Gennady L. Andrienko, and Peter Gatalsky. 2003. "Exploratory spatio-temporal visualization: an analytical review." *Journal of Visual Languages & Computing* 14:503-541.

Andrienko, Natalia V., and Gennady L. Andrienko. 2005. *Exploratory analysis of spatial and temporal data: a systematic approach*. Springer Berlin Heidelberg.

Bousquet, François, and Christophe Le Page. 2004. "Multi-agent simulations and ecosystem management: a review." *Ecological Modelling* 313-332.

Bézivin, Jean. 2005. "On The Unification Power of Models." *Software and System Modelling* 4:171-188.

Carnap, Rudolf. 1947. *Meaning and Necessity*. University of Chicago Press.

Chen, Jin, Alan M. MacEachren, and Diansheng Guo. 2008. "Supporting the Process of Exploring and Interpreting Space-Time Multivariate Patterns: The Visual Inquiry Toolkit." *Cartography and Geographic Information Science* 35:33-50.

Dawson, F, and D Stenerson. 1998. *Internet Calendaring and Scheduling Core Object Specification (iCalendar) - RFC2445*.

DiBiase, David, Alan M. MacEachren, John B. Krygier, and Catherine Reeves. 1992. "Animation and the role of map design in scientific visualization." *Cartography and Geographic Information Science* 19:201-214.

Edsall, R.M., and L.R. Sidney. 2005. "Applications of a cognitively informed framework for the design of interactive spatio-temporal representations. "p. 730 in *Exploring geovisualization*, *International Cartographic Association*, J. Dykes, Alan M. MacEachren, and M. J. Kraak. Amsterdam, The Netherlands: Elsevier Science.

Faucher, Cyril, Charles Teissèdre, Jean-Yves Lafaye, and Frédéric Bertrand. 2010. "Temporal Knowledge Acquisition and Modeling. "p. 10 in *EKAW 2010 - Knowledge Engineering and Knowledge Management by the Masses*, vol. 6317, *LNCS*. Lisbon, Portugal: Springer-Verlag.

Guillou, J. 1982. "Variabilité des populations de Donax trunculus et Donax vittatus en baie de Douarnenez." *Netherlands Journal of Sea Research* 16:88-95.

ISO/TC211. 2010. "ISO 19100 Models." http://www.isotc211.org/hmmg/HTML/index.htm.

ISO. 2002. *Text of 19108 Geographic information - Temporal schema*.

Isard, W. 1970. "On notions of models of time." *Papers in Regional Science* 25:6-31.

Le Tixerant, Matthieu, Françoise Gourmelon, Cyril Tissot, and David Brosset. 2010. "Modelling of human activity development in coastal sea areas." *Journal of Coastal Conservation*.

Moellering, H. 1976. "The potential uses of a computer animated film in the analysis of geographical patterns of traffic crashes." *Accident Analysis & Prevention* 8:215-227.

OMG. 2009. *OMG Unified Modelling Language (OMG UML), Version 2.2*.

Peuquet, Donna J. 1994. "It’s about time: A conceptual framework for the representation of spatiotemporal dynamics in geographic information systems." *Annals of the Association of American Geographers* 84:441-461.

Peuquet, Donna J. 2002. *Representations of Space and Time*. Guilford Press.

Roth, Robert E., and Kevin S. Ross. 2009. "Extending the Google Maps API for event animation mashups." *Cartographic Perspectives* 64:21-40.

Schmidt, Douglas C. 2006. "Model-Driven Engineering." *IEEE Computer Society*.

Shoham, Yoav, and Kevin Leyton-Brown. 2009. *Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations*. Cambridge University Press.

Thomas, James J. et al. 2005. *Illuminating the Path: The Research and Development Agenda for Visual Analytics*. James J. Thomas and Kristin A. Cook. Chicago, USA: IEEE Computer Society Press.

Tillier, Ion, and Cyril Tissot. 2010. "Modelling Nature-Society interactions and spatial use conflicts in coastal areas coupling MAS with GIS. "p. 20 in *Geomatic Solutions for Coastal Environments*, M Maanan and M Robin. Nova Science Publishers.

Tissot, Cyril, Matthieu Le Tixerant, Françoise Gourmelon, and Iwan Le Berre. 2004. "Modelling interactions between human activities and coastal zone environment. "in *Littoral 2004*. Aberdeen, Scotland: Cambridge Publications.

W3C. 2006. *Time Ontology in OWL*.

Weaver, Chris et al. 2007. "Visual exploration and analysis of historic hotel visits." *Information Visualization* 6:89-103.

Weiss, Gerhard. 2000. *Multiagent systems, A modern approach to distributed artificial intelligence*. The MIT Pr. Gerhard Weiss. The MIT Press.