Benefits of a periodic temporal model for the simulation of human activities

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Introduction

Within a decision process about space and time data, visualization may be seen as twofold. On the one hand, visualization reflects a synthetic point of view and expresses semantic aspects of the current results; on the other hand, it stands as a support for the analyst's intuition and suggests novel hypothesis or further computations. In any case, visualization exploits data and knowledge that should be recorded somewhere. Often, large and possibly high dimensional sets of data are to be processed for analysis, reasoning and decision making. It is clear that time datasets made of calendar elements (concrete dates) hide a great deal of the semantics that can be extracted by *ad hoc* methods and expressed in natural or specific languages.

In this paper, we provide a general UML [8] object model for specifying temporal knowledge. We of course account for usual time stamps and durations referring to sets of calendar data, but also focus on specifying concise representations for many kinds of periodic events - somewhat in the same way the Fourier transform can compress signals - except that 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.

The model we propose, extends the ISO19108 [5] and iCalendar [3] standards so that periodic temporal expressions could be expressed in intension [9] while the equivalent set of concrete extensions (calendar expression) is always likely to be exactly computed on demand either in a batch or 'on the fly' process.

The ISO19108 standard is dedicated to Geographic Information Systems (GIS) and provides means for specifying series of concrete time-occurrences, but does not address capturing information about periodicity. iCalendar can be used to specify periodic expressions but does not bear relative time expressions such as '3 hours before the tide is low'.

Dealing with intensional temporal periodic expressions is a means for compressing data without loss of information. Moreover, from an experimental viewpoint, human beings do act within a natural environment which is strongly subject to periodic phenomena, hence the need for modelling periodic event occurrences.

The first part of the paper is dedicated to presenting an application example with a multiagent simulation system applied to professional seashell digging. It shows that coping with temporal expressions is mandatory at various stages of the process, and suggests in which ways these expressions can be exploited. The second part of the paper presents excerpts of the object model which is a central part of our proposal.

The third part shows how the underlying Multi-Agent System and the Temporal Model are coupled. We conclude and summarize the benefits of a periodical temporal model for the simulation of human activities

1 The Telline *(Donax trunculus)* use case

This paper presents a contribution about a special use case dedicated to providing time specification facilities for a Multiagent simulation System (MAS [4], [11]) applied to 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, especially including periodic ones.

More precisely, the example at hand simulates the professional Telline (*Donax trunculus*) digging process in Douarnenez bay (Brittany, France).

Telline digging rose around the 70's in Douarnenez and proved to be highly profitable, hence the stock rapid exhaustion. In order to achieve a sustainable regulation of the activity, the prefect made a set of orders for ruling the access to fishing areas, by restricting the digging duration and imposing a feed back about captures.

This use case shows an actual complexity of the digging activity calendar and requires specifying how multi-scaled spatio-temporal constraints on the digging activity impact upon the resource stock.

1.1 Activity temporal modelling

Temporal modelling consists in building a Potential Practice Schedule (PPS) which results from compiling various constraints (see Fig. 1):

i) For each registered digging field, the law specify either, 'allowed', 'restricted' or 'prohibited' digging periods.

ii) Sea state and tide, as well as temperature, constrain the accessibility of digging areas.

iii) The bacteriological quality of water also impacts upon fishing rights.

All of these constraints are related to several periodical factors.

As regards the registered digging field of Douarnenez-Camaret, in addition to other constraints, it is stipulated that: '*digging is <u>prohibited</u> each year, from 9 pm to 6 am between July 1st to August 31st. Out of these periods, digging is <u>allowed</u> from 3h 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 PPS in Fig.1, by the first constraint time-zones filled in green and red.

Specifying and setting the multiagent behaviour requires that temporal knowledge and data bases be queried at runtime, so that the environment, the agents states and interactions be updated. 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.

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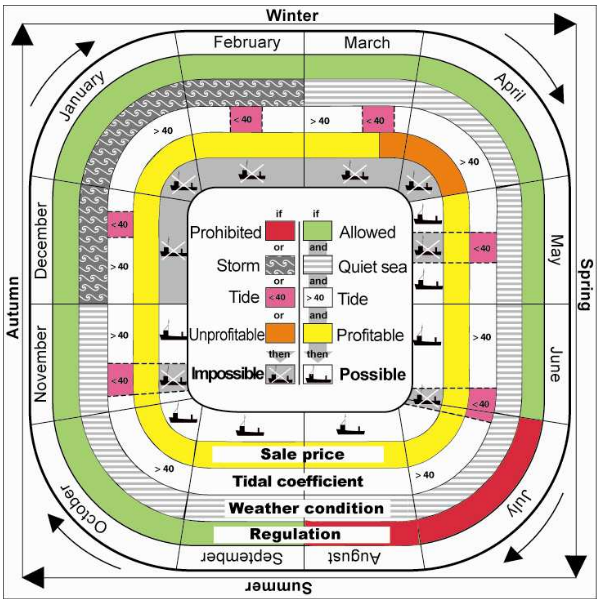

Fig. 1. Potential Practice Schedule for *Donax trunculus* digging.

1.2 Activity spatial modelling

Spatial analysis methods permit to build a Potential Practice Territory (PPT) for the activity which results from the superimposition of geographical information layers that account for the set of geographical constraints upon the activity. As regards *Donax trunculus*, the PPT 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, parkings, etc). All constraints are likely to evolve either in a deterministic, stochastic (predictable – eg.: environment change) or chaotic way (unpredictable - eg.: pollution accident). Managing these evolutions (effects) implies the source events calendar (causes) is managed accordingly.

1.3 Simulating the activity under spatio-temporal constraints

The *Donax trunculus* digging activity simulation is achieved within the 'HUman Dynamic Activity' framework (DAHU [1], [6], see Fig. 2). The multiagent system is in charge of simulating the anthropogenic activities and their interaction with the environment. The system grounds on a distributed intelligence model which gathers all the relevant actors at the scale of the fishing area.

Patterns are composed of coded polygons specifying the digging techniques, the physical and biological characteristics of the digging area and of the target species.

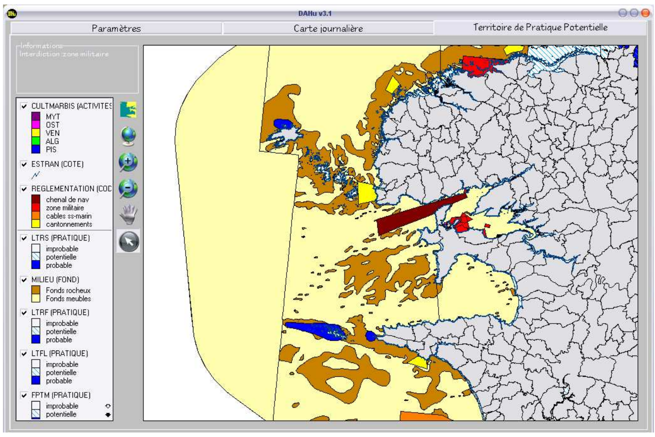

Fig. 2. Output of a simulation with DAHU.

A special GUI allows the user to adapt the parameters for specifying the spatial and time extents for the simulation. Thus, results are returned as interactive maps at different scales.

2 Periodical Phenomenon Modelling

We propose a general UML object model for temporal events properties. Here, we use an instance of this model and specify the special case of factors that may impact upon the behaviour of agents in the MAS.

Periodic characteristics ground 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 or OWL-Time [10].

Time can be considered from many viewpoints: mathematics, philosophy, economics, meteorology, etc. Our motivation is to present with a language which can help specifying non ambiguous models likely to be both easily understood and managed by human beings, and also to be efficiently processed by computers. So, we accompany our model proposal by a textual grammar (Subsection 2.6) which is close to the common natural language.

With respect to interoperability between the various applications at hand (MAS, knowledge base query engine, GIS access, etc), we rely upon Model Driven Engineering techniques (MDE [2]) for implementing the needed data transformers.

2.1 Temporal Occurrence Model basics

We selected the ISO19108 standard as a reference for modelling the basic concepts: Instant and Period. The main reasons for this choice are the following:

i) The object representation of the ISO19108 proves to be well fitted for being used in MDE as a pivot representation between software applications that have to deal with the various technical spaces in use.

ii) Having a pivot object model at one's disposal, leverages the mapping of the temporal concepts at 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 performing formal reasoning about time properties; SQL-Time for relational database querying, according to time constraints. iCalendar for scheduling applications that deal with concrete event occurrences, eventually bonded to calendar date and time.

2.2 Periodic Rule Model

Within the scope of the present paper, we can only give an excerpt of our model. Let's first focus on the central concept in Fig. 3. The PeriodicRule class is the root element for defining periodicity issues about a PeriodicTemporalOccurrence. Nb.: the concepts prefixed by TM_ come from the ISO19108 standard.

A PeriodicTemporalOccurrence is an aggregation 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. This decomposition of a PeriodicTemporalOccurrence into elementary PeriodicRules is homologous to the spectral analysis in signal processing.

Consequently, the first property of a PeriodicRule is its Frequency. Frequency is not mandatory, since a periodicity may sometimes simply be described through specifying intrinsic periodic CalendarPeriodicDescriptors as discussed in Subsection 2.3 *via* the role ruleOccurrencePosition (e.g.: 'each Monday').

According to a common definition, a frequency is a pair of values respectively indicating the number of occurrences (times attribute) that happen during a special unit of time (referenceDuration role). As shown in Fig. 3, referenceDuration ends in a Duration datatype. This might be too restrictive in practice, since only elementary standard calendar units could then be referenced. So, our proposal allows a customised definition of the referenceTimeInterval which gives access to the whole set of AbsoluteTemporalExpressions for specifying the beginning and the end of the desired interval. In this case, both properties (begin, end) are mandatory.

The facilities for defining a referenceTimeInterval are widened by providing a FeatureRelativePosition. In short, a featureRelativePosition permits to define one instant (either primitive or periodic) in relation with another previously specified one. The specification of relative positions is discussed in Subsection 2.4.

The optional startTime attribute is specified for one frequency, in order to anchor the initial/first periodic phenomenon occurrence in a concrete calendar, i.e.: to define its phase once its frequency is known.

If no frequency is given for a PeriodicRule, then a PeriodicTimeInterval must be specified with two properties, namely begin and end, which are AbsoluteTemporalExpression (see Subsection 2.3). 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 with a phase difference. This means that the lengths of the occurrences of a PeriodicTimeInterval are not necessarily equal. Example: a PeriodicTimeInterval occurring 'from the first Tuesday to the last Monday of each month'.

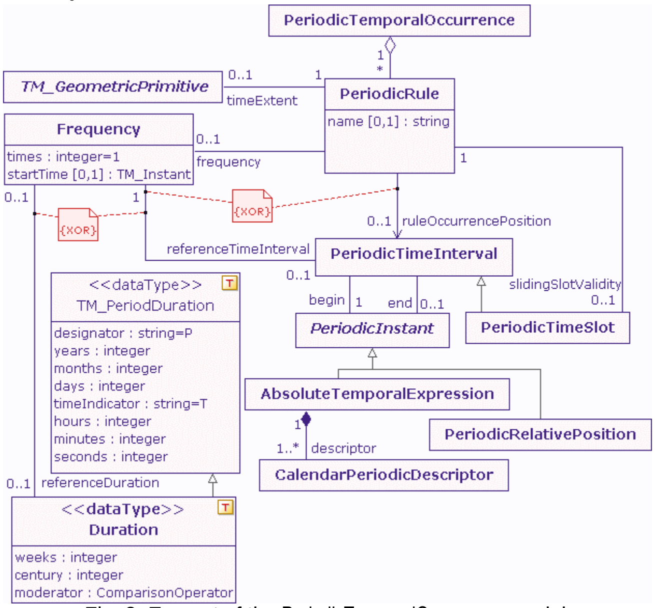

Fig. 3. Excerpt of the PeriodicTemporalOccurrence model.

2.3 Calendar Periodic Descriptor

The model excerpt shown in Fig. 4 provides means to specify the major calendar units in use when treating of time issues. Calendar units actually are abstractions that implicitly account for the essential periodic nature of calendar items, hence the name of the root class: CalendarPeriodicDescriptor.

Each sub-element in CalendarPeriodicDescriptor corresponds to a special granularity. 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'. Despite 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 4/5 weeks, and so on.

Instants may also be specified by adding a numeric rank to a calendar unit: e.g.: '3rd Sunday, 28th week'. Adding a rank to a calendar item, changes the viewpoint upon 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 actually is a synonym to 'March' which indicates an instant. This also applies to unnamed units such as: the '2nd week' (in a month).

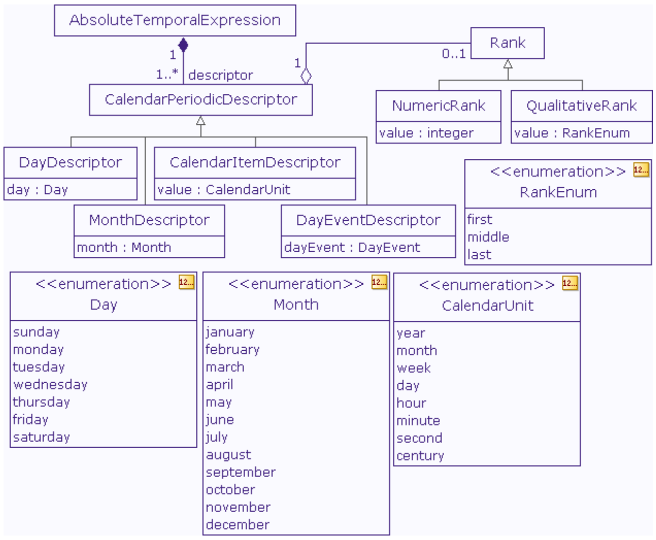

Fig. 4. Excerpt of the CalendarPeriodicDescriptor model.

2.4 Relative Temporal Occurrence

TopologicalPrimitive are provided by the ISO19108 in order to capture the pairwise relationship between primitives. We added the concept of RelativePosition to provide facilities for specifying the sets of occurrences of temporal objects in relation with one another. Therefore it is possible to specify an expression such as '3 hours before low tide'. The term 'before' comes from the Allen's temporal relations [7].

2.5 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 specify a set of Occurrences in the same way as what has been done for TemporalOccurrences, unless nested exceptions are not allowed within a TemporalExceptions specification. The set of exception occurrences finally is withdrawn from its parent TemporalOccurrence set definition. It is then possible to specify an exception such as: 'except on Tuesday between 11 am and 3 pm'.

2.6 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 to be immediately understood by the user thus allowing a direct checking of the modeled data.

Fig. 5 shows an example of the grammar output with respect to the *Donax trunculus* use case.

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

```
//Concept of night
The periodic temporal occurrence "night"
according to the rule(s) below (identified by night)
  1 times during one 1 days period having an occurrence position
    from each 21th hour to each 06th hour
end of the periodic temporal occurrence description

//Concept of low tide
The periodic temporal occurrence "low tide"
according to the rule(s) below (identified by low_tide)
end of the periodic temporal occurrence description
```

```
//Concept of seashell of Donax trunculus digging
The periodic temporal occurrence "Donax trunculus"
according to the rule(s) below
  1 times during one 1 days period
  //3 hours before the begin of the "low tide" -> 3 hours after the end of the "low tide"
  using a time slot as from 3 hours before low_tide to 3 hours after low_tide
  //Exceptions
  except a relative position without gap equals night
  and except having an occurrence position
    from each 0th hour of each Saturday to each 24th hour of each Saturday
  and except having an occurrence position
    from each July to each August
end of the periodic temporal occurrence description
```

Fig. 5. Use of the Grammar: *Donax trunculus* use case.

3 Coupling Multiagent System with the Temporal Model

Fig. 6 describes the interactions between DAHU MAS and the Temporal Model. 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 when an activity was performed. Presently, the database only records the intension of periodic expressions. DAHU queries this database, and if necessary, the TimeManager is called to transform the abstract result into a set of concrete dates.

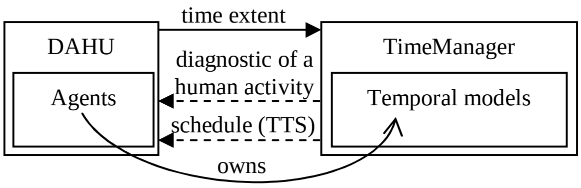

Fig. 6. Interactions between the DAHU MAS and the TimeManager.

In DAHU new architecture the Time Manager stands as an independent component that can be shared by various extraneous applications provided they refer to the same Temporal Model.

The main use cases for the TimeManager are the following:
i) Model temporal rules for the human activities in the simulation.
ii) Query the Temporal Model and check that an Instant/Period is consistent with the knowledge base (Rules).
iii) Provide the Potential Practice Schedule (i.e. optionally compute the concrete dates when the practice is allowed or prohibited).
Thanks to the TimeManager, the MAS can check guards for practice simulated actions, and control the agent's behaviour.

For instance, getting back to the seashell digging use case, let's consider an agent which represents a registered digging area. It is bond to an object in the Temporal Model which embeds its dynamic behaviour in accordance with the current set of administration rules. This object is linked to a set of instances in the Temporal Model.

When the MAS queries for the status of the digging area during a given period (timeExtent), it sends a request (with the timeExtent as an input parameter) to the TimeManager which returns either 'allowed', 'prohibited' or 'restricted'. According to the answer, the MAS can then go one step ahead in the simulation process.

Another kind of request would for instance return a time interval during which the practice is allowed: e.g.: from 11.18 am to 5.18 pm, assuming the tide is low at 2.18 pm in the corresponding area.

So, DAHU can list all Potential Practice Territories within the current context. The latter is likely to be either exploited by further simulation computations, or visualized on a map representation for various human analysis and decision processes.

4 Conclusion

In this paper, we presented an extension to the ISO19108 standard for specifying precise periodical temporal expressions. The various rules that govern human activities prove to be so awkward that a conceptual model is needed for capturing and recording this richness. A rough series of calendar dates cannot express the underlying knowledge about periodicity, frequency and relative positioning between phenomena.

Besides, we showed the beneficial use of temporal expressions given in intension rather than listed in extension, and provided a general UML object model that applies whatever the domain. Thanks to this approach, the data is much more concise, what is profitable for persistency, query and computation issues.

Moreover, within the scope of simulation processes, computation is only performed when necessary in a given context while it is actually not very feasible that all extensions be once and for all computed within every possible context.

Clearly, using intensional expressions captures and records the semantics of the data – here: the semantics of administrative rules for seashell digging.

The Temporal Model deals with periodical relative time expressions with possible exceptions (themselves possibly periodical). It copes with concrete time dates as well, and within this domain, it coincides with the ISO19108 standard. It also proposes consistent extensions which moreover prove their consistency with other standards such as iCalendar and OWL-Time.

We accompany our model by a textual grammar counterpart. It allows an automated translation of the model elements into natural language expressions that are useful for designing user interfaces either to query or populate the model, and check recorded instances.

Our proposal stands as a pivot model that can help to build various applications, components or highly interoperable services. In the Telline example the MAS, the query engine, the TimeManager, the natural language generator, the GIS and the graphical interface for map visualisation do interact *via* the common pivot model.

Now, our work in progress consists in designing an ontology that can account for inference rules and would exploit the common knowledge about time and calendars, in tight connection with the domain knowledge expressed in the domain model and in the Temporal Model. So, formal reasoning facilities will be offered to leverage decision making processes.

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