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Description Logics for Fishery Time

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Abstract

Understanding time in fisheries is executed by analyzing data which are picked up from investigated documents to make significant decisions. When data are big enough, time information of objects definitely becomes hard to represent to get knowledge quickly and temporal relationships are more difficult for observing. This article concentrates on introducing Description Logics (DLs) which is extended by rules as an appropriate knowledge representation formalism for managing fishery time.

A DL knowledge base for fisheries is installed with relations between areas and creatures, creatures and catchers, catchers and time for catching, time and opened areas, catchers and tools. To build this model, we use Protégé for illustrating an ontology of fisheries through data got from the document of Vietnamese mangrove fisheries. This document is published by the Vietnam Academy of Agricultural Sciences in 2015 with statistics in detail. The research shows the way to represent fishery time by DLs.

Keywords: Description Logics, temporal fishery representation, DLs for time.

1. Introduction

Marine resources have significant biological productivity, especially the value of creatures. With roles of making and growing creatures, the sea has been providing the great amount of annual economic value of creatures and bringing the high power of economy for communities living by fishing.

To protect marine products, fisheries need to be managed seriously. For Kevern and Serge (2009), some of the basic solutions for managing fisheries showed are:

- Regulating time for opening areas and periods for each vessel in catching.
- Regulating the quantities of creatures caught in each area.
- Claiming restrictions about the size of fishing tools for vessels, small crafts and fishers.

Therefore, the process of fishery management is going to be based on some essential elements and relationships of them in order to guard the diversity of species as well as sustainable productivity for fishermen. The elements in the fishery model are species, fishing tool, catcher, fishing area, time and different levels of interaction between them. However, the management always has a lot of challenges which come from the complex interactions of elements in the fisheries and diversity of these elements.

The following partial list sketches some of the issues with respect to each element:

- Species: All creatures have an economic valuation in the sea.
- Fishing tool: Some of the methods mainly used in fisheries.
- Time: Periods are suitable for fishing and protecting resources simultaneously.
- Fishing area: These areas are locations having zones for the living of sea creatures.
- Catcher: Objects operate fishing gears.

Besides issues from interactions of elements and representing information, interactions of time and its representation in fisheries have also the significant part. Managing time in fisheries minimizes conflicts and protects fish stocks from becoming over-exploited. However, this task is almost only solved by manual searching. Solving it requires an appropriate formalism for representing and reasoning with data and domain knowledge. For that reason, the key idea in this paper is to describe time and its interaction in fisheries by DLs. We choose DLs because they are more advantageous than Semantic Nets and Frames in minimizing ambiguities by adhering to FOL semantics while retaining as much intuitively as possible. DLs make an open world assumption, therefore allowing for incomplete knowledge. They also make an open domain assumption, which allows the set of specified individuals to be incomplete.

Protégé software can be considered as a tool to transform this model into the fishery ontology for illustrating.

We arrange the article as the following structure: Description logics (section 2) are represented before the knowledge bases of fisheries (section 3). The next section is experiments for fishery time in Protégé (section 4) and conclusions

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in the last section (section 5).

2. Description logics

2.1. Overview

DLs is one of the latest terminologies in a family of knowledge representation. Before a couple of words "description logics" becomes popular, it is said as phrases "knowledge representation languages" or "concept languages" (Franz et al, 2002; Franz et al, 2007).

DLs can be used to represent the conceptual knowledge of an application domain in a structured and formally well-understand way by classification of concepts and individuals. The result from the classification of concepts is subconcept/ superconcept relationships (called subsumption relationships) between the concepts of a given terminology as well as acknowledgment for structuring the terminology in the form of a subsumption hierarchy. This hierarchy provides valuable information about connections of different concepts and it is able to speed up other inference services. Determining whether this instance relationship is implied by the description of the individual and the definition of the concept is the other result from the classification of individuals. Furthermore, instance relationships may trigger the application of rules that insert additional facts into the knowledge base.

2.2. Knowledge bases

Knowledge representation systems based on DLs provide tools for creating knowledge bases, reasoning their contents and running them.

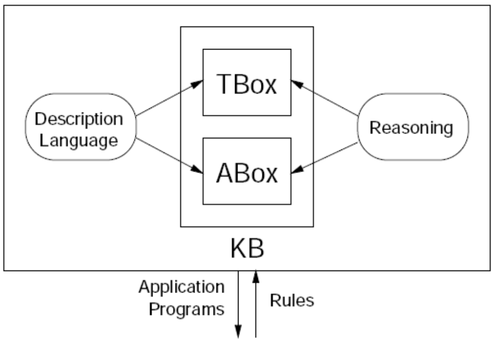

Figure 1. The architecture of a knowledge representation based on DLs

A DL knowledge base usually consists of two parts. The terminological part (TBox), which defines concepts and also states additional constraints on the interpretation of these concepts, and the assertional part (ABox), which describes individuals and their relationships to each other and to concepts. In addition, through reasoning services, we can get the right knowledge. Besides storing terminologies and assertions, DL systems also offer services that reason about them such as reasoning tasks to determine whether a description is satisfiable or whether one description is more general than another one.

2.3. Description languages

Complex concepts in DLs are built by $\mathcal{AL}$ (attributive language) or extend languages of $\mathcal{AL}$ called description languages from the family of $\mathcal{AL}$–languages (Franz et al, 2002; Franz et al, 2007). Besides, there are also many languages from the family of calculus with different expressive power ($\mathcal{SHIO}$, $\mathcal{SHION}$…) (Yu, 2008). Starting with description bases and rules for building concepts, description languages help to make new concepts in knowledge-based systems.

2.3.1. Basic description language $\mathcal{AL}$

$C, D \rightarrow A$ |	(atomic concept)
$\top$ |	(universal concept)
$\bot$ |	(bottom concept)
$\neg A$ |	(atomic negation)
$C \sqcap D$ |	(intersection)
$\forall R.C$ |	(value restriction)
$\exists R.\top$ |	(limited existential quantification)

Table 1. The syntax rule of attributive language

Basic elements of the $\mathcal{AL}$ are concepts and roles of atomic concepts. Complex descriptions are formed by associations of the elements through constructors. In abstract notation, the letters A and B are used for atomic concepts, the letter R for atomic roles, and the letter C and D for concept descriptions. Concept descriptions in $\mathcal{AL}$ are formed according to the following syntax rules in Table 1. (Franz et al, 2002).

2.3.2. The family of $\mathcal{AL}$ languages

Figure 2 lists some elements of the family $\mathcal{AL}$-languages (Yu, 2008). $\mathcal{ALC}$ is a combination between three letters in which the letters $\mathcal{AL}$ stand for attributive language and the letter $\mathcal{C}$ for the complement. Besides $\mathcal{ALC}$, other letters indicate various DL extensions including the following:

- $\mathcal{I}$ for inverse roles.
- $\mathcal{F}$ for functional restrictions.
- $\mathcal{H}$ for role hierarchy
- $\mathcal{Q}$ for qualified number restrictions

DL Name	Propositional constructs			Universal/ Existential Restriction	Functional Restriction	Qualified Number Restriction	Role Hierarchy	Inverse Role	Transitive Role	Nominal
	$\sqcap$	$\sqcup$	$\neg$	$\forall R.C$ $\exists R.C$	$\leq 1R$ $\geq 1R$	$\exists\leq nR.C$ $\exists\geq nR.C$	$R_1 \sqsubseteq R_2$	R^-	S	$\{o\}$
$\mathcal{ALC}$		✓		✓						
$\mathcal{ALCI}$		✓		✓				✓		
$\mathcal{ALCFI}$		✓		✓	✓			✓		✓
$\mathcal{ALCHIQ}$		✓		✓		✓	✓	✓		

Figure 2. Some language elements of the family $\mathcal{AL}$ - laguages

3. The fishery knowledge base

In this section, a knowledge base for fisheries is launched with DLs. Foundations of fisheries are represented in the TBox T. The ABox A attaches information about fishing activities in Vietnamese mangrove forests from the documentary about fisheries (Nguyen et al, 2015). It is later enhanced by new assertion obtained through ABox inference. The description of the rule base R for inferring will be shown here.

3.1. TBox

The fishery knowledge base is a collection of definitions of concepts of fisheries, their relations

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and inclusion relations between the concepts. Those concepts are creature, tool, area, catcher and time. Basically, marine creatures consist of fish, crustacean and mollusc (Nguyen et al, 2015). Crustacean has three groups being crab, shrimp and prawn (Marine Education Society of Australasia, 2015) as a number of mollusc groups namely shellfish, snail and squid (Malaysia Biodiversity Information System, 2015).

Hierarchy All axiom concepts are arranged in different levels of a specialization structure is called a hierarchy. A hierarchy of fisheries is illustrated as a diagram in Figure 3(a). Each group of creatures contains another lower level of it as representative information.

Inclusions are described in the following way. For example, "All fish is creatures"

$$\text{Fish} \sqsubseteq \text{Creature}$$

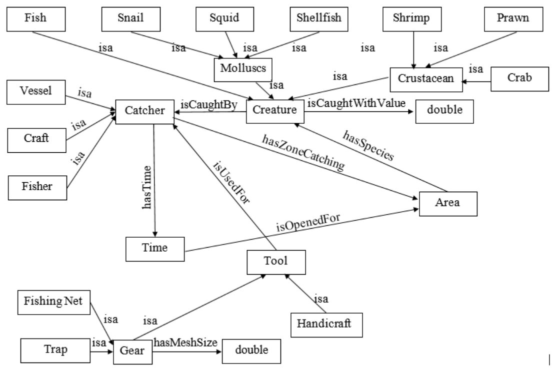
A concept is equivalent to the composition of other concepts below it in the hierarchy is represented through sufficient conditions for being that concept.

The description of "A fauna consists of fish, shrimp, squid, sea snail, shellfish and crab" is:

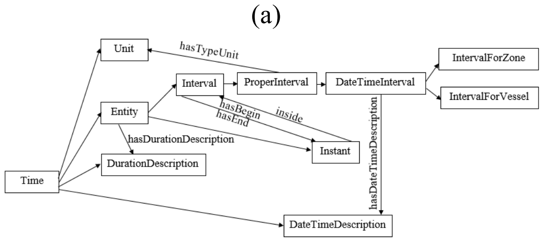
$$\text{Fauna} \equiv \text{Crustacean} \sqcup \text{Fish} \sqcup \text{Mollusc}$$

Disjointness between subconcepts can be clearly expressed. "Mollusc is disjoint with Fish and Crustacean"

$$\text{Mollusc} \equiv \neg\text{Fish} \sqcap \neg\text{Crustacean}$$



(a)



(b)

Figure 3. Fisheries TBox; (a) Hierarchy, (b) Subsumption hierarchy

Time representation Time is the indefinite continued progress of existence and events in the past, present, and future regarded as a whole. Time is formed by instants and intervals while intervals are periods between beginning instants and ending instants. There are many instants being inside an interval. Normally, intervals have positive values, the zero value is specified for two instants overlapping each other. In this research, only positive time intervals are considered as figure 3(b). Besides, each time period has to have units itself.

Description of duration is used for representing intervals with time arguments in the annual fishing cycle. For example, an interval may have duration as 2 days, or 1 day and 10 hours, or 1 month.

Description of date-time is used for specifying exact time to intervals that have positive time length through its subconcepts (12 months).

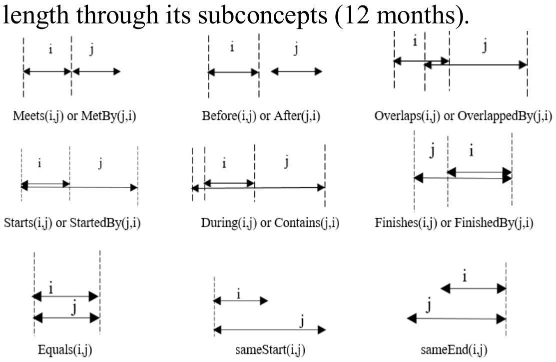


Figure 4. Relationships between intervals

Relations between intervals can be seen in figure 4. Their relative orientations are illustrated on the timeline with two intervals namely i and j. A description of the arrangement of a temporal individual with respect to another comprises ABox role, assertions.

Restrictions By using concepts and time roles, restrictions are formulated on the set of possible models. The restrictions are divided into two groups: time restrictions and fishery building regulations. First, the time restrictions are written in DLs as follows:

"An interval has a starting and ending instant"

$$\text{Interval} \sqsubseteq \exists\text{hasEnd.Instant} \sqcap \exists\text{hasBegin.Instant}$$

"All instants are inside intervals "

$$\text{Instant} \sqsubseteq \forall\text{inSide.Interval}$$

"Each entity has a description about duration with time arguments"

$$\text{Entity} \sqsubseteq \exists\text{hasDurationDescription.DurationDescription}$$

"Each date time interval has a description about its date time"

$$\text{DateTimeInterval} \sqsubseteq \exists\text{hasDateTimeDescription.DateTimeDescription}$$

"Every proper interval has at least one unit "

$$\text{ProperInterval} \sqsubseteq \exists\text{hasTypeUnit.Unit}$$

Second, the fishery building regulations represented are:

"Total of time periods for catching of each vessel is greater than 1 and less than 4"

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$$\text{Vessel} \sqsubseteq \exists_{\geq 1}\text{hasTime.IntervalForVessel} \sqcap \exists_{\leq 4}\text{hasTime.IntervalForVessel}$$

"Time periods for vessels are during the time of their zones"

$$\text{IntervalForVessel} \sqsubseteq \forall\text{During.IntervalForZone}$$

"An interval of the vessel does not overlap, is not before and after an interval of its zone"

$$\text{IntervalForVessel} \sqsubseteq \forall\text{Overlap.}\neg\text{IntervalForZone} \sqcap \forall\text{Before.}\neg\text{IntervalForZone} \sqcap \forall\text{After.}\neg\text{IntervalForZone}$$

"Starting interval of a zone is the same as or before one of the starting interval of vessels"

$$\text{SIntervalForZone} \sqsubseteq \exists\text{sameStart.SIntervalForVessel} \sqcup \exists\text{Before.SIntervalForVessel}$$

"Ending interval of a zone is the same as or after one of the ending interval of vessels"

$$\text{EIntervalOfZone} \sqsubseteq \exists\text{sameEnd.EIntervalOfVessel} \sqcup \exists\text{After.EIntervalOfVessel}$$

Besides managing fisheries involves many restrictions, regulating the quantity of fish caught is one of the restrictions for ensuring sustainable and responsible fisheries. Regulating type of gear and its size as well as specifying closed seasons and closed areas are incredibly important restrictions to protect sustainable utilization of the resources.

3.2. ABox

A delegate chosen from the statistic document published about the fisheries at Vietnamese (Nguyen at el, 2015) to illustrate ABox is the information of Metapenaeus Affinis, a type of prawn caught at Hung Hoa, an area of mangroves in Vietnam. Temporal individuals are supposed optional inputs and their relationships are built to support for inferring through rules.

In Hung Hoa, Metapenaeus Affinis is caught by vessels and crafts having gears (gill-net, drift-net, weir and cage) at Hoa Lam and Phong Dang with opened time from January until June and from October to November, respectively. (Nguyen et al, 2015). The opened time of Hoa Lam and Phong Dang is intervals, namely Interval1 and Interval2. Supposing Vessel1, Vessel2 and Vessel3, Vessel4, Vessel5 caught at Hoa Lam. Vessel1 caught 5.4 kg in Interval01, Vessel2 caught in Interval02, Vessel3 caught in Interval03, Vessel4 caught in Interval04 and Vessel5 caught in Interval05 with:

Interval01: from Jan 1st to Mar 31st
Interval02: from Feb 12th to May 21st
Interval03: from Apr 1st to May 31st
Interval04: from Apr 1st to Jun 15th
Interval05: from Feb 12th to May 21st
Interval06: Apr 1st
Interval07: Jun 15th

From these details, a small part of ABox is:

A = { Metapenaeus affinis : Prawn,
HungHoa : Area,
Vessel1, Vessel2, Vessel3, Vessel4, Vessel5 : Vessel,
(Metapenaeus affinis, HungHoa): isSpeciesOf,
(HungHoa, HoaLam) : hasPart,
(Interval1, HoaLam) : isOpenedFor,
(Vessel1, interval01) :hasTime,
(Interval01, Interval03) : Meets,
(Interval01, Interval02) : Overlaps,
(Interval06, Interval03) : Starts,
(Interval07, Interval04) : Finishes,
…}

"Metapenaeus affinis in Hung Hoa is caught at HoaLam or PhongDang"

$$\text{MetapenaeusAffinisInHungHoa} : \text{isSpeciesOf.(HoaLam} \sqcup \text{PhongDang}$$

"Vessel1 catches 5.4 kg for Metapenaeus Affinis at HoaLam"

$$\text{Vessel1: caught.MetapenaeusAffinis} \sqcap = 5.4\ \text{isCaughtWithValue} \sqcap \text{hasZoneCatching.HoaLam}$$

"Interval01 of Vessel1 overlaps Interval02 of Vessel2".

$$\text{Interval01} \equiv \text{Overlaps.Interval02}$$

"Interval01 of Vessel1 meets Interval03 of Vessel3 "

$$\text{Interval01} \equiv \text{Meets.Interval03}$$

3.3. Rules

From the time relationships represented, temporal rules can be created to serve for managing fisheries:

"If an interval x_3 meets intervals x_1 and x_2, represented with relationship sameStart(x_1,x_2)"

$$(x_1, x_2)\text{: sameStart} \leftarrow (x_3, x_1)\text{: Meets} \wedge (x_3, x_2)\text{: Meets} \wedge x_1\text{: Interval} \wedge x_2\text{: Interval} \wedge x_3\text{: Interval}$$

"If an interval x_3 before an interval x_1 and the interval x_1 is before an interval x_2. So the interval x_3 is before the interval x_2 and represented with relationship Before(x_3,x_2)"

$$(x_3, x_2)\text{: Before} \leftarrow (x_3, x_1)\text{: Before} \wedge (x_1, x_2)\text{: Before} \wedge x_1\text{: Interval} \wedge x_2\text{: Interval} \wedge x_3\text{: Interval}$$

"If an interval x_1 has the same starting interval x_3, x_2 is after an interval x_1, x_2 and x_3 have the same ending interval. Therefore, x_2 has the fishing

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interval x_3, represented with relationship Finishes(x_2,x_3)"

$$(x_2, x_3): \text{Finishes} \leftarrow (x_2, x_1): \text{After} \wedge (x_1, x_3): \text{sameStart} \wedge (x_2, x_3): \text{sameEnd} \wedge x_1: \text{Interval} \wedge x_2: \text{Interval} \wedge k: \text{Interval}$$

Some other rules for fishing can also be shown below:

"If a species lives in an area, this species certainly lives in the superconcept of the area"

$$(x_1, x_3): \text{hasSpecies} \leftarrow \text{Contain}(x_1, x_2) \wedge \text{hasSpecies}(x_2, x_3) \wedge x_1: \text{Area} \wedge x_2: \text{Area} \wedge x_3: \text{Creature}$$

"If x_1 is one of the following elements: Fishing net (drag-net, gill-net); trap (cage, drift-net, weir); handicraft (spear, harpoon), x_1 becomes a fishing tool."

$$x_1: \text{Tool} \leftarrow (\, x_1: \text{Rear} \leftarrow x_1: \text{fishingNet} \vee x_1: \text{Trap}\,) \vee x_1: \text{Handicraft}$$

can be rewrited is:

$$x_1: \text{Tool} \leftarrow x_1: \text{fishingNet} \vee x_1: \text{Trap} \vee x_1: \text{Handicraft}$$

"The species which is crab is also Crustacean" is:

$$\text{hasPart}(?z, ?y) \leftarrow x: \text{Crab} \wedge y: \text{Creature} \wedge z: \text{Crustacean} \wedge \text{hasPart}(?z, ?x) \wedge \text{hasPart}(?x, ?y)$$

4. Experiments

In this section, we use Protégé version 4.3 - a free, open source platform to represent the knowledge base that is described above. Information about fisheries in Vietnam (Nguyen et al, 2015) is the background to build an ontology of fisheries. After that, temporal rules are built to infer relationships of relevant interval and instant elements.

Example 1. If interval i meets interval j, then j and k have the same starting interval, represented with relationship Meets(i,k).

Rule statement:

Meets(?i, ?j), sameStart(?j, ?k) -> Meets(?i, ?k)

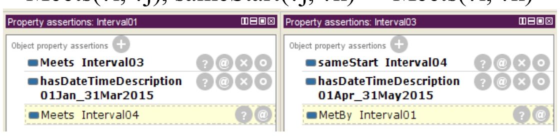

Figure 5. Result for example 1

Interval01 meets Interval03, Interval03 and Interval04 have the same starting interval. Therefore, Interval01 meets Interval04.

Example 2. If an interval i meets interval k and overlaps interval j, then interval j and interval k have the same ending interval, During(k,j) is the relationship for representation.

Rule statement:

Meets(?i, ?k), Overlaps(?i, ?j), sameEnd(?k, ?j) -> During(?k, ?j)

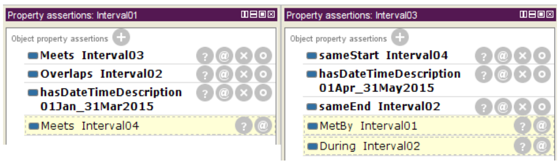

Figure 6. Result for example 2

Interval01 meets Interval03 and overlaps Interval02 while Interval03 and Interval02 have the same ending interval. As a result, Interval03 is during Interval02.

Example 3. If interval i and j have the same starting interval, interval i and j have all the same duration with units (month, week, day) respectively, sameEnd(?j,?i) is represented for this relationship.

Rule statement:

hasUnitType(?i, unitMonth), hasUnitType(?i, unitWeek), hasUnitType(?j, unitDay), hasUnitType(?j, unitMonth), hasUnitType(?j, unitWeek), sameStart(?i, ?j), days(?i, ?l), days(?j, ?l), months(?i, ?m), months(?j, ?m), weeks(?i, ?k), weeks(?j, ?k) -> sameEnd(?j, ?i)

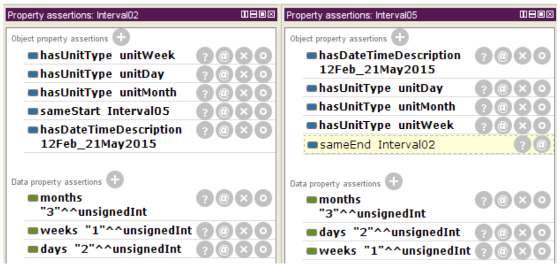

Figure 7. Result for example 3

Interval02 and Interval05 have the same starting interval and duration for fishing (3 months, 1 week, 2 days). So Interval02 and Interval05 have the same ending interval.

5. Conclusions

In this research, we proposed an approach to DLs for time in fisheries. This model describes relationships between of two temporal objects. From here, there are many relationships between other temporal objects can be reasoned by rules. After denoting the fishery knowledge base into Protégé for experiments, we get some favorable results about reasonings for temporal relationships. We believe this contribution can solve problems about representing temporal objects and relationships between them in fisheries.

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