Narrative Geospatial Knowledge about Taiwanese Aboriginal Settlements — A Case Study

(Extended Abstract)

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Outline

- Motivation
- Background
- Ontology
- Web Ontology Language
- Implementation
- Conclusion and Future works

Motivation

An efficient expression and reasoning system to display the Taiwan aboriginal settlements, including current settlements, historical settlements and migration history.

Motivation

Narrative geospatial descriptions from ethnographies are different from conventional GIS:

- Expressed in everyday vocabularies
- Use of relative phrases
- Precise positions are often unspecified
- Can be conflicting, incomplete, and missing.

To display and reason these narrative geospatial descriptions, we turn to ontologybased approach.

The ethnography used in this paper

Liao, Shoucheng Liao (Masaw Mowna)1977, 1978 The migration and distribution of the EastSedeq Atayal(I)(II). Bulletin of the Institute of Ethnology, Academia Sinica,(44):61206,(45):81212.

- It describes settlement location and migration history of an ethnic group of Taiwan aborigines
- The geographical distribution is relatively simple, but the migration history is rich
- The author was not only a researcher but also a native
- There are plenty of other documents to help us verify the result.

The Kele settlement

established in 1930s, from 6 original settlements.

the narrative

The land of Batakan ... is located at the left bank of midstream Liwu River, and is south of Sanjhuei Mountain. It is above the cliff on the riverbank opposite to now Jinheng Station on Central CrossIsland Road...

The semantic of narrative

- Suppose we read following sentences.
  - Taipei is south of Keelung.
  - Taoyuan is south of Taipei.
  - Tamsui is located at right bank of Tamsui River.
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But not every knowledge can be encoded easily.

Ontology

So how to do it ?

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- An ontology is an explicit and formal specification of a conceptualization.
  - Tom Gruber, Toward principles for the design of ontologies used for knowledge sharing. 1993
- Ontology consists of concepts (of some domain) and the relationship between them.
  - Concepts (classes of objects): student, animal, car ...
  - Relationship: Hierarchies of classes.

Ontology:example

We all know :

- math, history, and computer courses are all course.
- students and teachers are persons.
- A student is the person who takes some courses.
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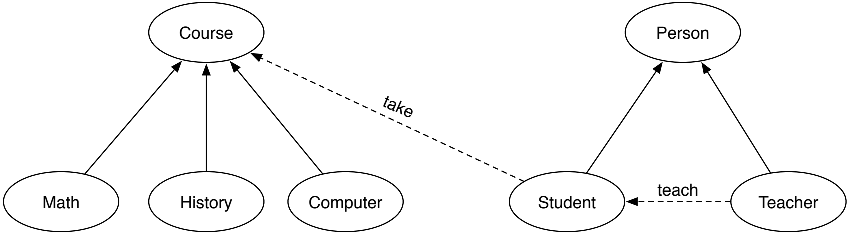

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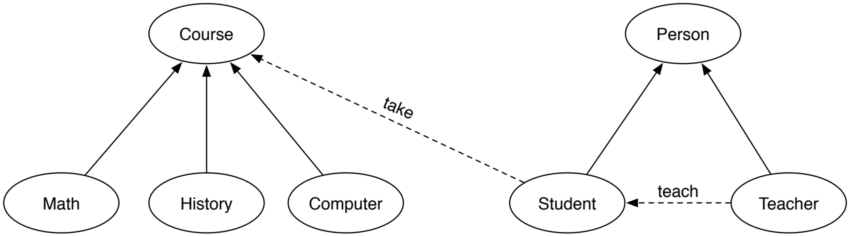

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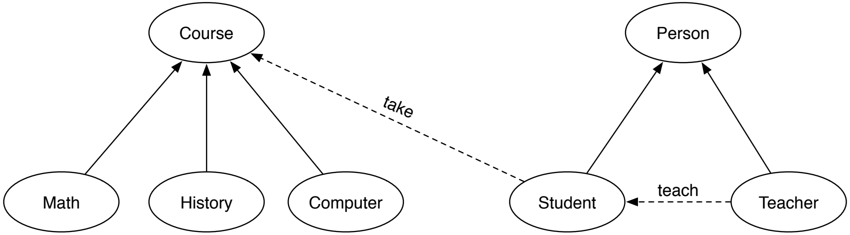

How to encode ontology ? The semantic web technology is employed.

Semantic Web

The semantic web aimed at building a software agent that help us dealing with web pages automatically. The languages proposed for now are following.

- XML, a well-known data encoding language which has lots of tools can be used to process it.
- RDF, a data model language that models objects relation and is in XML syntax.
- RDF Schema, a vocabulary description language that describes the properties and classes hierarchy. The basic ontology language.
- OWL, a richer vocabulary description language that adds more vocabulary for describing properties and classes.

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We will focus on OWL.

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OWL is the tradeoff between the expressiveness and the computability.

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Two kinds of axioms in description logic.

- subclass axiom, use to denote the classes' subsuming relation.
- equivalence axiom, use to denote the equivalence relation between classes.

Description logic: example

The encoding of the example above in description logic.

Class	Course.		
Class	Math	$\sqsubseteq$	Course.
Class	History	$\sqsubseteq$	Course.
Class	Computer	$\sqsubseteq$	Course.
Class	Person.		
Class	Student	$\sqsubseteq$	Person $\sqcap$ (take some Course).
Class	Teacher	$\sqsubseteq$	Person $\sqcap$ (teach some Student).
Class	MathTeacher	$\equiv$	teacher $\sqcap$ (prepare some Math).
Prop	take(Person, Course).		
Prop	teach(Person, Course).		
Prop	prepare(person, Coruse).		

Property setting

The property(relation,role) can have following setting,

- Transitive: p(x,y) and p(y, z) implies p(x, z)
- Symmetric: p(x, y) implies p(y, x)
- Functional: p(x, y), for every domain value x can have only one range value y.
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Those settings will be very helpful while reasoning.

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hasChild(?x, ?y) -> parent(?x) ^ child(?y)
```

The concept definition(1)

The concepts encoded in our paper will be shown bellow.

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Class	Geo.		
Class	People.		
Class	Place.		
Class	Settlement	$\sqsubseteq$	Place $\sqcap$ (populatedBy min 1).
Class	River	$\equiv$	Place $\sqcap$ (originateFrom min 1) $\sqcap$ (endAt exactly 1) $\sqcap$ (hasUpstream exactly 1) $\sqcap$ (hasMidstream exactly 1) $\sqcap$ (hasDownstream exactly 1).
Class	Upstream	$\sqsubseteq$	Place $\sqcap$ (hasPosition min 1).
Class	Downstream	$\sqsubseteq$	Place $\sqcap$ (hasPosition exactly 1).
Class	Midstream	$\sqsubseteq$	Place $\sqcap$ (meet some Upstream) $\sqcap$ (meet some Downstream).
Disjoint			Upstream, Midstream, Downstream.

The concept definitions(2)

$$
\begin{aligned}
&\texttt{Class} \quad \text{Point} && \equiv \text{Geo} \sqcap (\text{hasHeight } \texttt{exactly } 1) \sqcap \\
& && \quad (\text{hasLatitude } \texttt{exactly } 1) \sqcap \\
& && \quad (\text{hasLongitude } \texttt{exactly } 1). \\
&\texttt{Class} \quad \text{Landmark} && \equiv \text{Place} \sqcap (\text{hasPosition } \texttt{exactly } 1). \\
&\texttt{Class} \quad \text{Bridge} && \sqsubseteq \text{Landmark}. \\
&\texttt{Class} \quad \text{Station} && \sqsubseteq \text{Landmark}. \\
&\texttt{Class} \quad \text{PlaceGroup} && \sqsubseteq \text{Place}. \\
&\texttt{Class} \quad \text{Pair} && \sqsubseteq \text{PlaceGroup} \sqcap (\text{consistOf } \texttt{exactly } 2). \\
&\texttt{Class} \quad \text{Divider} && \sqsubseteq \text{Place} \sqcap (\text{inBetween } \texttt{some } \text{Pair}). \\
&\texttt{Class} \quad \text{Rivercross} && \sqsubseteq \text{Place} \sqcap (\text{hasPosition } \texttt{exactly } 1) \sqcap \\
& && \quad (\text{hasInflow } \texttt{min } 2)
\end{aligned}
$$

The property definitions

`Prop`	populatedBy(Settlement, People).		
`Prop`	hasPosition(Place, Point).		
`Prop`	locatedAt(Place, Place).		
`Prop`	consistOf(PlaceGroup, Place).		
`Prop`	southOf(Place, Place)	[transitive]	northOf^{-1}.
`Prop`	westOf(Place, Place)	[transitive]	eastOf^{-1}.
`Prop`	southWestOf(Place, Place)	[transitive]	northEastOf^{-1}.
`Prop`	southEastOf(Place, Place)	[transitive]	northWestOf^{-1}.

The property definitions

Prop	originateFrom(River, Point).		
Prop	endAt(River, Point).		
Prop	meet(Place, Place)	[symmetric].	
Prop	hasInflow(RiverCross, River).		
Prop	oppositeTo(Place, Place)	[symmetric].	
Prop	inBetween(Divider, Pair)		separatedBy^{-1}.
Prop	bankOf(Place, River).		
Prop	leftBankOf(Place, River)	$\sqsubseteq$	bankOf.
Prop	rightBankOf(Place, River)	$\sqsubseteq$	bankOf.

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Batakan, Bolowan, Kalugi, Lausi, Lodox	:	Settlement.
Mogolisi, Sikilian, Sowasal, Tomowan	:	Settlement.
Dalama, Laosi, Liwu, Mokelisi	:	River.
Puluowan, Sikalahan, Tuosai, Wahei-er	:	River.
MidLiwu, MidTuosai	:	Midstream.
DownLiwu, DownTuosai, DownSikalahan	:	Downstream.
Liwu_Wahei-er, Liwu_Laosi, Liwu_Tuosai, Tuosai_Dalama	:	Rivercross.
Jhongyangjian, Jiming, Mantou, Sanjhuei, Ta	:	Mountain.
MantouSide	:	Mountainside.

Assertion: relations of individules

hasMidstream	(Liwu, MidLiwu).
hasMidstream	(Tuosai, MidTuosai).
hasDownstream	(Liwu, DownLiwu).
hasDownstream	(Tuosai, DownTuosai).
hasDownstream	(Sikalahan, DownSikalahan).
hasInflow	(Liwu_Wahei-er, Liwu).
hasInflow	(Liwu_Wahei-er, Wahei-er).
hasInflow	(Liwu_Laosi, Liwu).
hasInflow	(Liwu_Laosi, Laosi).
hasInflow	(Liwu_Tuosai, Liwu).
hasInflow	(Liwu_Tuosai, Tuosai).
hasInflow	(Tuosai_Dalama, Tuosai).
hasInflow	(Tuosai_Dalama, Dalama).
hasSide	(Mantou, MantouSide).

The reasoning

The most important thing of using description logic to encode knowledge is the automatic reasoning. The automatic reasoning in our paper can be characterize using following example.

- Reason through the property setting.
- Query by defining concept.
- SWRL helps the reasoning.
- The layer of GIS.

The reasoning: the setting of Property

The properties of each Property could derive some implicit relations. For example, given

- southOf is inverse of northOf and vice versa.
- southOf, northOf are transitive function.
- southOf(a, b) and northOf(c, b) are in knowledge base.

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- southOf(a, b) and southOf(b, c) implies southOf(a, c).

The reasoning: query by defining concepts

The query of ontology could be the declaration of equivalence axiom since it states the sufficient and necessary condition for each of them. For example

- `Class` MountainPlace $\equiv$ Place $\sqcap$ (locatedAt some Mountain).
- `Class` WestOfLaosi $\equiv$ Place $\sqcap$ (westOf has Laosi).

The reasoning: the help of SWRL(1)

Some knowledge is not explicitly defined in OWL, we have to extract them from knowledge base by using SWRL rules. For example, the narrative sentence states

- There are two places A and B which are separated by a place D.

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We defined the ontology for that as bellow.

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\begin{array}{llcl}
\texttt{Class} & \text{Divider} & \sqsubseteq & \text{Place} \sqcap (\text{inBetween } \texttt{some} \text{ Pair}). \\
\texttt{Class} & \text{Pair} & \sqsubseteq & \text{PlaceGroup} \sqcap (\text{consistOf } \texttt{exactly } 2). \\
\texttt{Class} & \text{PlaceGroup} & \sqsubseteq & \text{Place}.
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- $\text{Pair}(p) \wedge \text{Divider}(d) \wedge \text{inBetween}(d, p) \wedge \text{consistOf}(p, x) \wedge \text{consistOf}(p, y) \wedge \text{differentFrom}(x, y) \rightarrow \text{oppositeTo}(x, y)$.

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- If the divider is a river, and one of them is located at one side of river bank, we can deduce the opposite place must be in the other side.
- $\text{Pair}(p) \wedge \text{River}(r) \wedge \text{inBetween}(r, p) \wedge \text{consistOf}(p, x) \wedge \text{consistOf}(p, y) \wedge \text{differentFrom}(x, y) \wedge \text{leftBankOf}(x, r) \rightarrow \text{rightBankOf}(y, r)$.

The reasoning: the layer of GIS system(1)

Give the following assertions from narrative sentences.

$$\begin{aligned} \text{westOf} \quad & (\text{Kalugi}, \text{Liwu\_Wahei-er}). \\ \text{wastOf} \quad & (\text{Heliou}, \text{Lausi}). \end{aligned}$$

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- The settlement in our definition are all located by the relative direction of some landmarks.

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$$\begin{aligned} \text{westOf} & \quad (\text{Kalugi}, \text{Liwu\_Wahei-er}). \\ \text{wastOf} & \quad (\text{Heliou}, \text{Lausi}). \end{aligned}$$

We want to know the relative direction of kalugi and Lausi. Is it possible ?
No.
We miss some relative direction of those places.
What can we do ?

- The settlement in our definition are all located by the relative direction of some landmarks.
- Landmarks are the places has exact position. (Mountain, rivercross, police station...)

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- Landmarks are the places has exact position. (Mountain, rivercross, police station...)
- GIS system can compute their relative direction.

The reasoning: the layer of GIS system(2)

Therefore, if GIS system compute following relative direction for us.

$$\text{westOf}\quad(\text{Liwu\_Wahei-er}, \text{Heliou}).$$

By transitive property, we can know the relative direction of Kalugi and Lausi.
westOf(Kalugi, Liwu_Wahei-er),
westOf(Liwu_Wahei-er, Heliou),
westOf(Heliou, Lausi)
imply westOf(Kalugi, Lausi)

Conclusion and Future works

What we had learned

- The design of Ontology should
  - be as compact as possible. (less error prone, easy assertion)
  - contain implicit information as much as possible. (produce knowledge automatically)
- OWL DL is not easy to encode useful knowledge base without the help of SWRL.
- The narratives are vague, implicit, and inconsistent which sometimes make it hard to be encoded.

Future Work

- Use OWL 2 to encode more complete ontology.
- Cooperate to a GIS system for computing more relative relations.