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AN ALGEBRAIC MODEL OF COMPLEX TEMPORAL OBJECTS

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ABSTRACT

The Spatio-temporal object is a kind of complex temporal objects. Here, four basic constructors, i.e., tuple, set, list and temporal, are introduced to construct an algebraic model of complex temporal objects. Transformations from various traditional temporal relational models to the temporal object model are illustrated. The study has shown that the algebraic model of complex temporal objects has more advantages over temporal relational models in complex structures and temporal semantics modelling.

1 INTRODUCTION

Complex object modeling is a fundamental property of third-generation database systems or object-oriented database systems[1,2]. In GIS, the spatio-temporal object is a typical kind of complex objects[7]. Spatio-temporal complex objects have common structure properties of multi-hierarchies, variable length, and sequence. For example, in node-arc-polygon structure like spatial data models, a polygon consists of a variable length sequence of arcs at the first level, a arc consists of a variable length sequence of points at the second level, a changeable geographical entity is composed of a sequence of valid status at the different times.

In order to support complex object modeling, object-relational data model and object-oriented data model are widely developed presently. In theory, extended relational algebra and object algebra are proposed as their formal descriptions.

Storage structure of temporal data somewhat implies explicit representation of time-varying semantics in data models. As illustrated by Snodgrass[3], time-varying semantics modeling should be solved at the algebraic level. Referring to temporal relational algebra that extends time-varying semantics to traditional relational algebra, here we attempt to develop temporal object algebra that extends time-varying semantics to an emerging object algebra. Temporal object algebra as an algebraic model of complex temporal objects is of initial exploration to theory of temporal object databases.

2 AN ALGEBRAIC MODEL OF COMPLEX TEMPORAL OBJECTS

Here, we adopt Pistor and Q.M. Chen's algebraic model of objects[4,5,6], which constructs complex objects with three constructors of set, tuple and list. Furthermore, we introduce temporal constructor in complex temporal objects modeling to model time-varying semantics explicitly. The four constructors are named set, tuple, list and temporal.

Assume that there exists a set A with a finite number of attribute items $a_1, a_2, \ldots, a_n$, i.e., $A=\{a_1, a_2, \ldots, a_n\}$, elements in set A are distinguished from each other.

Definition 1 Complex objects in temporal databases consist of :
a) Atom objects. Atom objects, including number, char, logical, date, time value, are not divided any more. Atom objects have the specific meaning in the application area.
b) Tuple objects(Figure 1). A tuple object is denoted by
$$O=[a_1:O_1, a_2:O_2, \ldots, a_n:O_n]$$
where O_i is the value object of attribute name a_i, [ ] is tuple constructor.
c) Set objects(Figure 2). A set object is denoted by
$$O=\{O_1, O_2, \ldots, O_n\}$$
where O_i is a value object, { } is set constructor.
d) List objects(Figure 3). A list object is denoted by
$$O=<O_1, O_2, \ldots, O_n>$$
where O_i is a value object, < > is list constructor.
e) Temporal objects(Figure 4). A temporal object is denoted by
$$O=[O, \mathbf{T}]^t$$
where O_i is a value object, $\mathbf{T}$ is a valid timestamp, $[\ ]^t$ is temporal constructor.
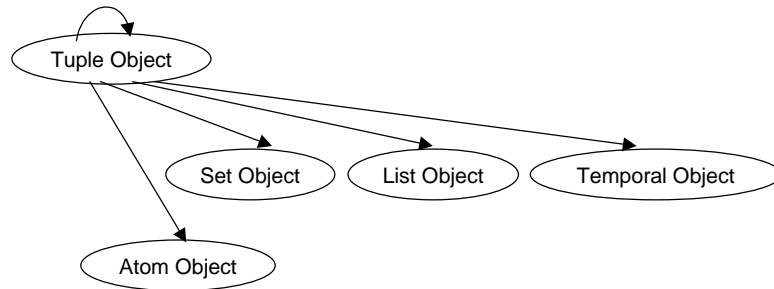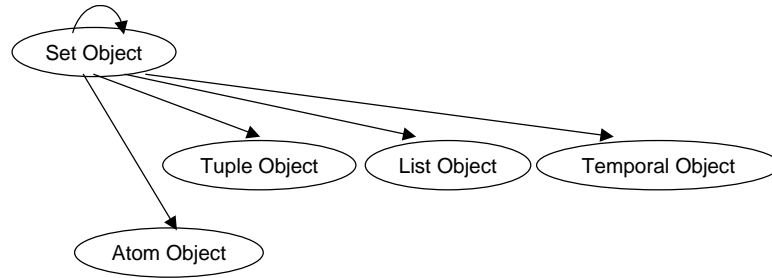
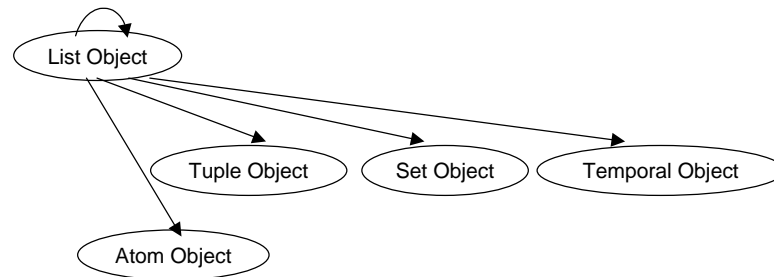Figure 1 Construction of tuple objects

Figure 2 Construction of set objects

Figure 3 Construction of list objects
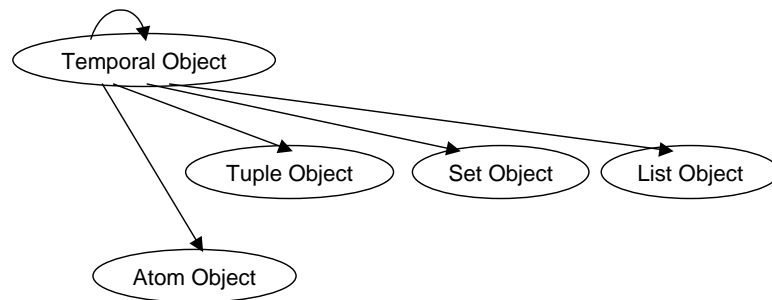
Figure 4 Construction of temporal objects

f) "Inconsistency" and "undefinition". "Inconsistency" and "undefinition" are two special objects denoted by $\top$, $\bot$ respectively.

g) NULL. The NULL object is denoted by one of $\oslash$, [ ], { }, < >, [ ]^t freely.

To explain the semantics of $\top$ and $\bot$, definition 2 is given.

Definition 2

a) For tuple object O with the set S of attribute items, $\forall x[x \notin S \Rightarrow O.x = \bot]$;

b) $< O1,...,\bot,...,On >= \bot$

c) $\{O1,...,On,\bot\} = \{O1,...,On\};$

d) $[\bot, \mathbf{T}] = \bot;$

e) $[...,ai : \top,...] = \top$

f) $\{...,\top,...\} = \top$

g) $<...,\top,...> = \top$

h) $[\top, \oslash]^t = \top$

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Definition 3 A static object is an atom object or object which is only constructed by tuple, set or list constructor. According to constructors at the top level, static objects can be categorized into static tuple objects, static set objects and static list objects respectively. A dynamic object is object which used temporal constructor in the process of self-construction. According to constructor used by the value object at the top level, dynamic objects are categorized into dynamic tuple objects, dynamic set objects and dynamic list objects respectively.

Definition 1 and Definition 2 form an algebraic model of complex temporal objects basically.

3   ALGEBRAIC TRANSFORMATIONS FROM VARIOUS TEMPORAL RELATIONAL MODELS TO THE TEMPORAL OBJECT MODEL

The following corollary fellows from the above definitions.

Corollary 1 A normal relational model, a non-first normal (NF2) relational model, a nested relational model and an attribute-timestamped relational model and a tuple-timestamped relational model are special cases of the temporal object model.

Proof:

1)   A normal relation is a set of tuples, where every attribute field of tuple gets value of an atom object. A normal relational database is a set of normal relations. A normal relational model can be transformed to the temporal object model in Figure 5.

2)   A non-first relation is a set of tuples, where every attribute field of tuple gets value of a set of atom objects or a tuple object constructed with atom object-valued attribute fields. A NF2 relational database is a set of NF2 relations. In fact, a normal relation can be viewed as a simple NF2 relation where every attribute field of tuple gets value of a set of an atom object. A NF2 relational model can be transformed to the temporal object model in Figure 6.
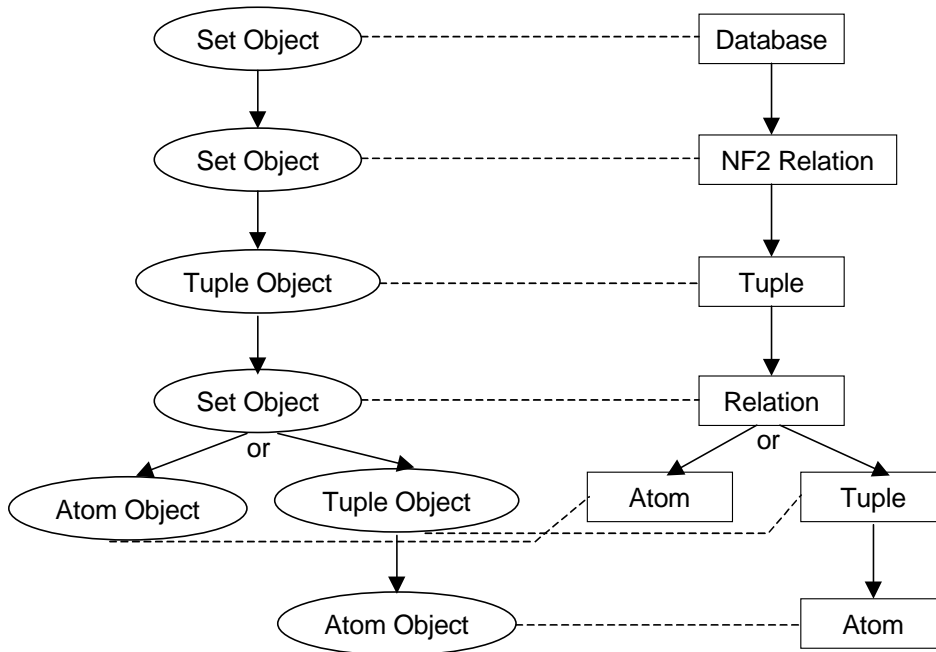

Figure 5 Transformation from the normal relational model (right) to the temporal object model (left)
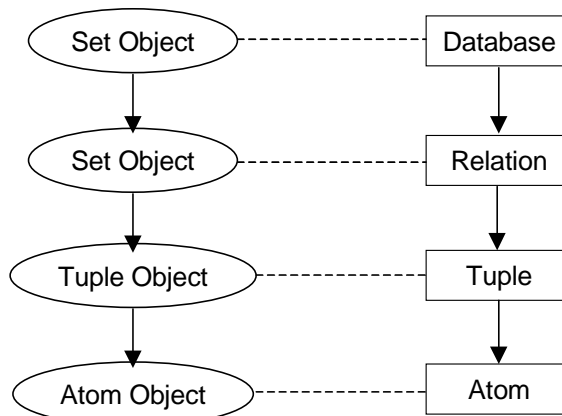

Figure 6 Transformation from the NF2 relational model (right) to the temporal object model (left)
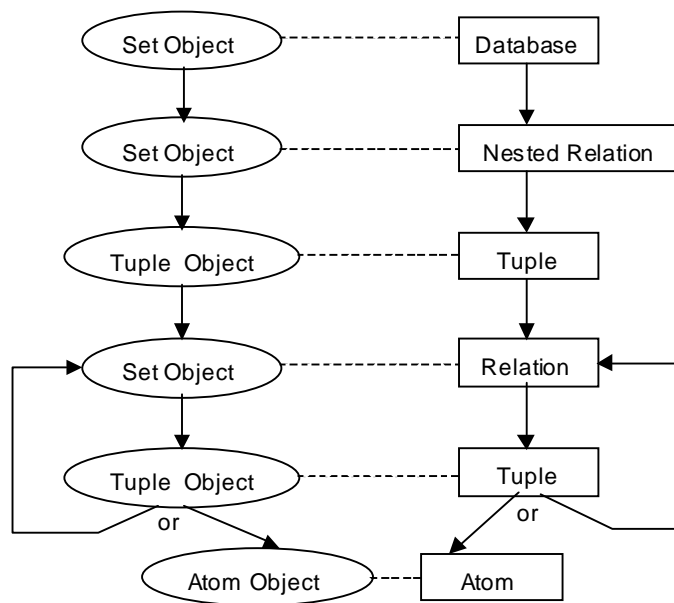
Figure 7 Transformation from the nested relational model (right) to the temporal object model (left)
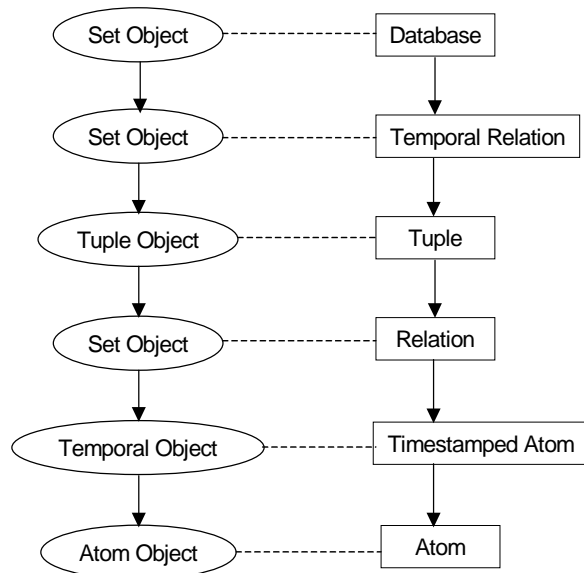

Figure 8 Transformation from the attribute-timestamped relational model (right) to the temporal object model (left)
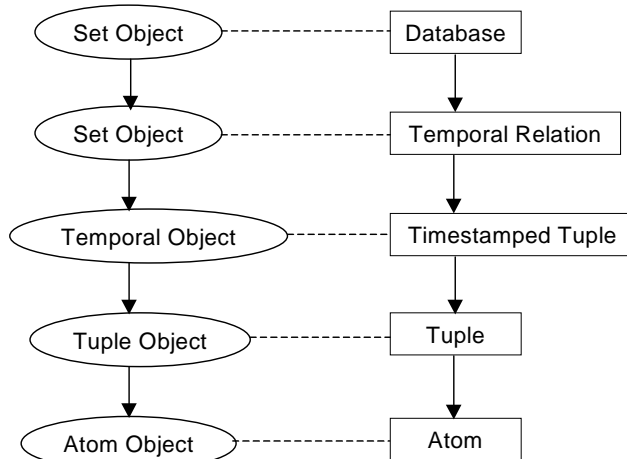

Figure 9 Transformation from the tuple-timestamped relational model (right) to the temporal object model (left)

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3) A nested relation is a set of tuples, where every attribute field of tuple gets value of set of tuples nestedly. A nested relational database is a set of nested relations. In fact, a NF2 relation can be viewed as a simple nested relation with one level nested depth. The object of a nested relation is constructed alternatively by set and tuple constructors. A nested relational model can be transformed to the temporal object model in Figure 7.

4) An attribute-timestamped relation is a set of tuples, where every attribute field of tuple gets value of a set of timestamped atom objects. In fact, an attribute-timestamped relation can be viewed as a special NF2 relation. An attribute-timestamped relational model can be transformed to the temporal object model in Figure 8.

5) A tuple-timestamped relation is a set of tuples composed of a single field. This single field is a timestamped tuple. In fact, a tuple-timestamped relation can be viewed as a special normal relation which has a specific meaning field "Valid time". A tuple-timestamped relational model can be transformed to the temporal object model in Figure 9.

4   CONCLUDING REMARKS

Temporal relational algebra, as a formal description of temporal relational models, is studied for ten years or so. But temporal object algebra, as a promising algebraic definition of complex temporal object model, is first advanced[7]. As shown above, the algebraic model of complex temporal objects has more advantages over temporal relational models in complex structures and temporal semantics modeling.

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