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A META-DATABASE FOR A DATABASE DESIGN METHOD

by

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Abstract

The aim of this paper is four-fold. First, it presents a data model. Second, a database design method SDDM (Sentential Database Design Method) based on the data model is proposed. Third, the schema of the database which support the above design method is shown. Fourth, the above stated database design method was followed, though manually, to design the above schema itself.

The database above will contain the various information concerning to those resources such as files, processes, information requirements, attributes and domains which are used in an information system. Thus it is called a meta-database.

1. Introduction

Many authors speak of data models. But few of them (except e.g. [Moulin 1976], [Flory 1978]) also speak of database design methods closely connected to them. Much less the authors who speak of the meta model of their models and methodology. A data model stated without its meta model tends to be ambiguous since the description of it is stated using natural but sometines ambiguous language.

We state both the data model (called TH model) and corresponding database design method (called SDDM) as one system. We intend to use a particular database describing those resources such as files, processes, information requirements, attributes and domains which are used in an information system.

Thus the database is called a meta-database. It is also called a data dictionary/directory ([Hotaka 1976], [Tsubaki 1980]). The meta-database is a kind of database. Therefore we will show that it can be designed by the database design method SDDM. The schema of the meta-database is described by TH model.

Describing a model and a corresponding design method using the constructs of the model itself justifies the strength and consistency of the model and the corresponding design method. The design procedure of the meta-database may be used as an example of the application of the design method SDDM.

In section 2, TH model is introduced as a tool for a database design method. Section 3 briefly sketches the design procedures of SDDM. From sections 4 to 6, ordinary design procedures of SDDM are followed to obtain the schema of the meta-database. Information requirements are stated in 4, reduction of information requirements to sentences in 5, file synthesis and schema diagram in 6 respectively.

2. Data Model

Only very short explanation of the data model is given here. The model is called TH model and was explained elsewhere ([Hotaka 1981]).

The basic components of the model are <u>entity</u>, <u>entity type</u> and <u>name</u>. The set of all entities constitutes the <u>entity set</u> ES and the set of all entity types <u>entity type set</u> TS. To an entity type $T \in TS$ corresponds a set of entity E. Suppose $e \in E$ then we say e belongs to T, or e is an occurrence of T, and is denoted by $e \prec T$. Let $S(T) = \{e | e \prec T\}$. Then E can be written $E = S(T)$.

In order to represent entities and entity types in a database, we must correspond each of them to a name. The set of all names is called name set and is denoted by NS. It is not always easy to establish a correspondence from ES or TS to NS. But, in the following, we shall confine ourselves only to those cases where unambiguous correspondence exists.

(Assumption 1)
TS has one-to-one correspondence to a subset of NS.

(Assumption 2)
For every $T \in TS$, the set $\{e \mid e \in ES$ and $e \lessdot T\}$ has one-to-one correspondence to a subset of NS.

These assumptions are not automatically satisfied. We shall pay special attention so that these assumptions are valid during the whole life cycle of the database. Under the assumptions 1 and 2, we will make no distinction between an entity or an entity type with its corresponding name.

Suppose e_i $(i=1,\ldots,n)$ be an entity. We sometimes corresponds a list $(e_1,e_2,\ldots,e_n;\ r_1,r_2,\ldots,r_n)$ to an entity e belonging to an entity type T. We call e a list abstract entity (an aggregate), and the correspondence is shown by

$$e <\overset{=}{_L} (e_1,e_2,\ldots,e_n;\ r_1,r_2,\ldots,r_n).$$

$r_i(i=1,\ldots,n)$ is called a role. We assume $r_i \neq r_j$ if $i \neq j$ $(i,j=1,\ldots,n)$. T is called a list abstraction or an aggregation. Each of aggregations belongs to an entity type AGGREGATION. A role is a kind of an entity and is supposed to belong to an entity type ROLE. When roles $r_1,r_2,\ldots,r_n$ are natural numbers $1,2,\ldots,n$, we simply write

$$e <\overset{=}{_L} (e_1,e_2,\ldots,e_n).$$

When a set $\{e_1,\ldots,e_n\}$ corresponds to an entity e belonging to an entity type T, this correspondence is shown by

$$e <\overset{=}{_S} \{e_1,\ldots,e_n\}$$

and e is called a set abstract entity. T is called a set-abstraction. Each of set abstractions belongs to an entity type SET-ABSTRACTION. If e is a list abstract entity or a set abstract entity, it is called an abstract entity.

(Assumption 3)
No entity is two differnt abstract entities at the same time.

I.e., an entity is not a list abstract entity and set abstract entity at the same time. Also if $e <\overset{=}{_L} (e_1,\ldots,e_n;\ r_1,\ldots,r_n)$ and $e <\overset{=}{_L} (f_1,\ldots,f_m;\ s_1,\ldots,s_m)$ then $n = m$, $e_i = f_i(i=1,\ldots,n)$ and $r_i = s_i(i=1,\ldots,n)$.

An entity $e \lessdot T_1$ may sometimes be thought to belong to another entity type T_2 at the same time. To avoid complexity, we assume the following

(Assumption 4)
If $S(T_1) \cap S(T_2) \neq \emptyset$ then $S(T_1) \subset S(T_2)$ or $S(T_1) \supset S(T_2)$ holds.

If $S(T_1) \subset S(T_2)$ then T_1 is called a subtype of T_2. In this case, the same naming rule of T_2 can be applied to T_1. Therefore arbitrary definition of subtype satisfies Assumption 2. Each of subtypes belongs to an entity type SUBTYPE. If $S(T_1) \cap S(T_2) = \emptyset$, the newly generated entity type T which corresponds to $S(T_1) \cup S(T_2)$ has the unique naming rule. For example, $e_1(\in T_1)$ and $e_2(\in T_2)$ may be named $T_1.e_1$ and $T_2.e_2$ respectively. Analogously we can define an entity type T which corresponds to $S(T_1) \cup \ldots \cup S(T_n)$ when $S(T_i)$'s are mutually disjoint. We call T a generalization of $T_1, \ldots, T_n$. Each of generalizations belongs to an entity type GENERALIZATION. Note that we use the terminology "generalization" in somewhat restricted sense in order to preserve the property stated in Assumption2.

Entities may represent any object observed in the real world. Sometimes even an entity type is considered to be an entity. This situation arises in designing a meta-database.

Later, it will be shown that each of four entity types such as AGGREGATION, SET-ABSTRACTION, SUBTYPE and GENERALIZATION is also a subtype of an entity type DOMAIN. At the same time, each of entities such as AGGREGATION, SET-ABSTRACTION, SUBTYPE, GENERALIZATION and DOMAIN itself belongs to the entity type DOMAIN. The same name such as AGGREGATION and DOMAIN is used differently (Fig. 1).

3. Sentential Database Design Method

The logical database design method SDDM was explained in [Hotaka 1981]. Here, we sketch the method briefly for self-containedness. The design procedures are roughly in three steps.

[Information requirement step]
First, information requirements are enumerated. Each requirement is identified and written out on a R-record (a piece of paper or a database record depending on the situation). There should not be inconsistencies among information requirements. Each of information requirements belongs to an entity type REQUIREMENT.

[Reduction step]
Each information requirement must finally be satisfied by the data stored in the target database. We arbitrarily pick up an information requirement and investigate if it can be answered from the data which has already been incorporated in the database. If it cannot be answered, we create new data types as many as required which together with the data already in the database answer the information requirement. Sometimes, the information requirement is too large so it cannot be answered by the data directly. In these cases, designers break it down into several smaller information requirements.

In SDDM, a data type is prepared in the form of a simple sentence type. The definition of the simple sentence type requires analogous procedures which appear in defining Boyce-Codd normal form of the relational database theory. We omit detailed discussions but give sufficient condition under which a sentence type becomes a simple sentence type.

a sufficient condition for a sentence type to be a simple sentence type

A sentence type is a simple sentence type when it cannot be decomposed into smaller sentence types without losing semantics.

For example, a sentence type

(1) PART x has WEIGHT y and is supplied by the SUPPLIER z who is in CITY u.

can be decomposed into following two sentence types:

(2) PART x has WEIGHT y.

and

(3) PART x is supplied by the SUPPLIER z who is in CITY u.

Hence the sentence type (1) is not a simple sentence type, but the sentence type (2) is obviously a simple sentence type since it cannot be decomposed into smaller sentence types without losing semantics. The above condition resembles to the irreducible relations ([Hall 1976]), atomic sentence, elementary sentence and semantically irreducible sentence (the last three appeared in [Nijssen 1977]). Each of simple sentence types belongs to an entity type SENTENCE.

Those underlined capital letter words such as PART, WEIGHT, SUPPLIER etc. appeared in the above sentences are called attributes. Each of attributes belongs to an entity type ATTRIBUTE. No two same attributes should appear in a simple sentence type, whereas an attribute may appear in more than one simple sentence types.

Corresponding to an attribute A an entity type T exists. Each attribute value of a simple sentence type F belongs to this entity type. This entity type is called the domain of A and is denoted as T = dom(A, F). Note that an attribute alone cannot uniquely determine the corresponding domain. Each of domains belongs to an entity type DOMAIN.

Occurrences of a simple sentence type constitutes a file. A non-redundant set of attributes of a simple sentence type whose respective values uniquely identifies a sentence occurrence is called a key of the simple sentence type. We assume the uniqueness of the key in the simple sentence. Each constituent attribute of the key in the sentence is called part-of-key and belongs to an entity type PART-OF-KEY.

During the reduction, relationships among entity types such as list abstraction (aggregation), set abstraction, generalization and subtype are identified.

derived sentence (data), terminal sentence

Suppose all of the information requirements are reduced to a set of simple sentence types. But the database design may have not been finished yet. Sentence occurrences of a simple sentence type F simply cannot be obtained in the organization or the enterprise. Designers must think out other simple sentence types whose occurrences derive the occurrences of the sentence type F. The sentence type F is called derived sentence (or data) type. Each of derived sentence types belongs to an entity type DERIVED-SENTENCE. DERIVED-SENTENCE is a subtype of an entity type SENTENCE. We assume the derivation is realized through a process, which belongs to an entity type PROCESS.

(Assumption 5)
A derived sentence is assumed to be produced by only one process.

The reduction of sentence types continues as long as not-yet-reduced derived sentence types remain. The reduction ends at the point where the occurrences of a reduced sentence type are directly observable in the organization or the enterprise. The sentence type for which no reductions are necessary is called terminal sentence type. In other words, reductions ends when terminal sentence types are met.

(File synthesis step)
Occurrences of a simple sentence type F could be interpreted to correspond one-to-one to occurrences of an entity type T. The entity type T is called the key entity type of the simple sentence type F. Simple sentence types of the same key entity type will be collected to compose a simple sentence type. Thus files corresponding to key entity types are built.

It is up to designers' choice how files corresponding to derived sentence types are hold. They may be calculated each time they are used or they may have been produced beforehand periodically.

4. Information Requirement Step

Information requirements for the meta-database are as follows:

R1: Suppose an information requirement is given. What terminal sentence types are used to answer this requirement?
R2: What processes and terminal sentence types are used to derive a derived data?
R4: To what entity types does a component of a list abstract entity belong? What role does a participating entity type play?
R5: To what entity type does a component of a set abstract entity belong?
R6: From which entity types is a generalized entity type generated?
R7: Of which entity type is an entity type subtype?
R8: What is the key of a simple sentence type?
R9: What is the key entity type of a simple sentence type?
R10: Given a simple sentence type F, enumerate these simple sentence types each of whose key entity type coincides with that of F.
R11: What is the domain of an attribute which appears in a simple sentence type?
R12: Suppose the semantics of an entity type has been changed. Which requirements are affected by this change?
R13: Delete these simple sentences which no requirements or derived sentences use.

5. Reduction Step

Each of the information requirements stated above will be reduced to appropriate simple sentence types.
Note) Only those attributes whose names are different from those of their domains are listed with domains.

R1 reduces to F1, F2, F3.

F1: REQUIREMENT x uses a simple SENTENCE y.
key: (REQUIREMENT, SENTENCE)
key entity type: REQ-SENTENCE

F2: MASTER-REQUIREMENT x uses a SUB-REQUIREMENT y.
dom (MASTER-REQUIREMENT, F2) = REQUIREMENT
dom (SUB-REQUIREMENT, F2) = REQUIREMENT
key: (MASTER-REQUIREMENT, SUB-REQUIREMENT)
key entity type: MREQ-SREQ

F3: DERIVED-SENTENCE x uses SENTENCE y.
DERIVED-SENTENCE is a subtype of SENTENCE.
key: (DERIVED-SENTENCE, SENTENCE)
key entity type: DERIVATION

R2 reduces to F3, F4.
F3: stated earlier.
F4: DERIVED-SENTENCE x is produced by a PROCESS y.
key: DERIVED-SENTENCE
key entity type: DERIVED-SENTENCE

R3 reduces to F3.
F3: stated earlier.

R4 reduces to F5.
F5: DOMAIN x plays ROLE y in AGGREGATION y.
AGGREGATION is a subtype of DOMAIN.
key: (DOMAIN, ROLE, AGGREGATION)
key entity type: DOM-ROLE-IN-AGG

R5 reduces to F6.
F6: SET-ABSTRACTION x represents a set in DOMAIN y.
SET-ABSTRACTION is a subtype of DOMAIN.
key: SET-ABSTRACTION
key entity type: SET-ABSTRACTION

R6 reduces to F7.
F7: GENERALIZATION x generalizes DOMAIN y.
GENERALIZATION is a subtype of DOMAIN.
key: (GENERALIZATION, DOMAIN)
key entity type: GEN-DOM

R7 reduces to F8.
F8: SUBTYPE x is a subtype of DOMAIN y.
SUBTYPE is a subtype of DOMAIN.
Note) The above two sentences have different meaning. The former is a sentence type and the latter states the relationship between the entity type SUBTYPE and the entity type DOMAIN.
key: SUBTYPE
key entity type: SUBTYPE
Note) DOMAIN is an entity type, whereas each entity type such as REQ-SENTENCE, MREQ-SREQ, AGGREGATION and DOMAIN itself is an occurrence of an entity type DOMAIN.

R8 reduces to F9.
F9: ATTRIBUTE x in a SENTENCE y is part-of-key.
key: (ATTRIBUTE, SENTENCE)
key entity type: PART-OF-KEY
PART-OF-KEY is a subtype of ATTR-SENTENCE.

R9 reduces F10.

F10: Key entity type of SENTENCE x is KEY-ENTITY-TYPE y.
dom (KEY-ENTITY-TYPE, F10) = DOMAIN
key: SENTENCE
key entity type: SENTENCE

R10 reduces to F10.

F10: stated earlier.

R11 reduces to F11.

F11: The domain of ATTRIBUTE x in a SENTENCE y is DOMAIN z.
key: (ATTRIBUTE, SENTENCE)
key entity type: ATTR-SENTENCE

R12 reduces to F1, F10, F11.

F1, F10, F11: stated earlier.

R13 reduces to F2, F3.

F2, F3: stated earlier.

All of the above simple sentence types are also terminal sentences, hence the reduction is completed.

6. File Synthesis and Schema Diagram

Sentences of the same key entity type are collected and the names of the key entity types themselves are adopted as the names of files. We get the schema analogous to the relational schema. An underlined attribute is part-of-key.

REQ-SENTENCE (REQUIREMENT, SENTENCE)
MREQ-SREQ (MASTER-REQUIREMENT, SUB-REQUIREMENT)
DERIVATION (DERIVED-SENTENCE, SENTENCE)
DERIVED-SENTENCE (DERIVED-SENTENCE, PROCESS)
DOM-ROLE-IN-AGG (DOMAIN, ROLE, AGGREGATION)
SET-ABSTRACTION (SET-ABSTRACTION, DOMAIN)
GEN-DOM (GENERALIZATION, DOMAIN)
SUBTYPE (SUBTYPE, DOMAIN)
PART-OF-KEY (ATTRIBUTE, SENTENCE)
SENTENCE (SENTENCE, KEY-ENTITY-TYPE)
ATTR-SENTENCE (ATTRIBUTE, SENTENCE, DOMAIN)

Schema diagram is shown in Fig. 2. We used similar representation adopted by [Abrial 1974].

7. Concluding Remarks

An integrated database management system will treat both the meta-database and the corresponding database equally. In that case, the meta-database becomes the integrated data dictionary (IDD). It seems that description of the model by the concepts of the model itself clears many ambiguous properties of the model and its associated database design method. This self-describability might be used to check if a data model is built complete.

In this paper, the database design method SDDM is applied using only manual procedures. But the supporting aid will be developed using the ordinary database facility in near future.

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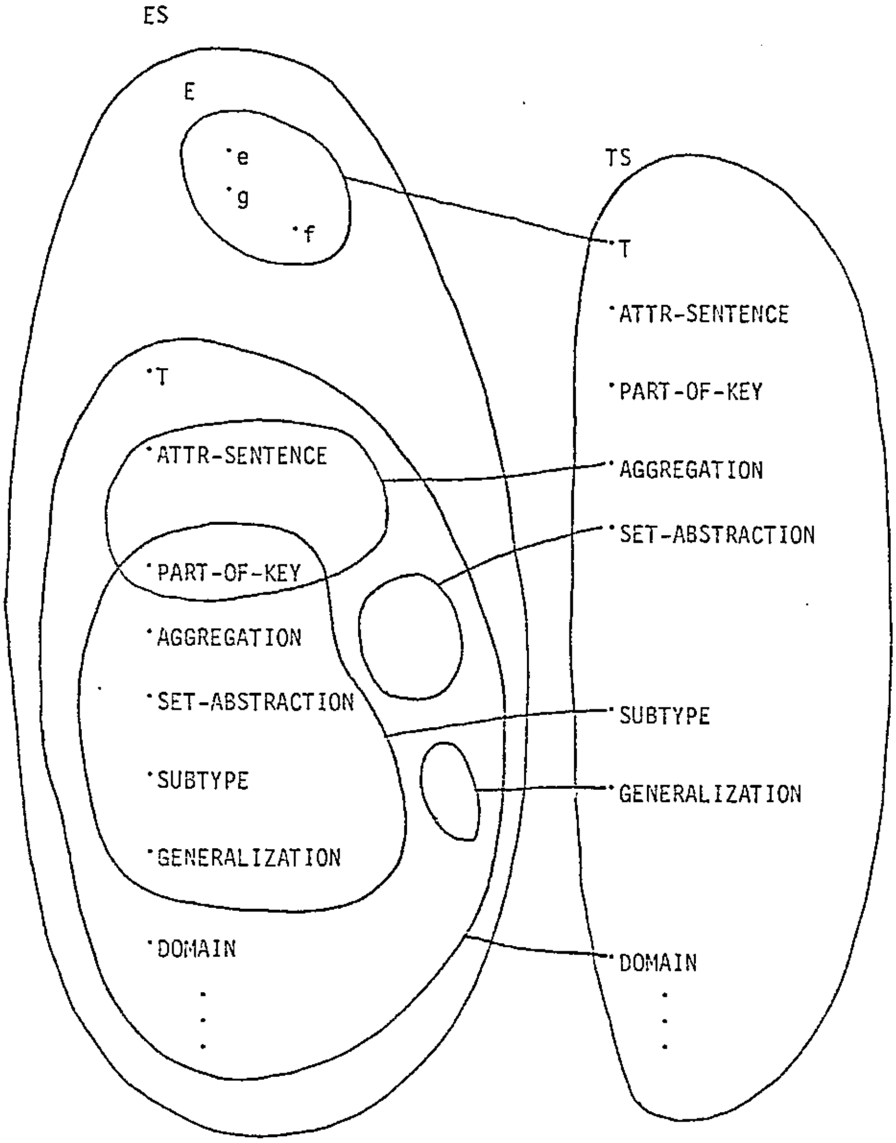

Fig. 1 Relationships between entities and entity types

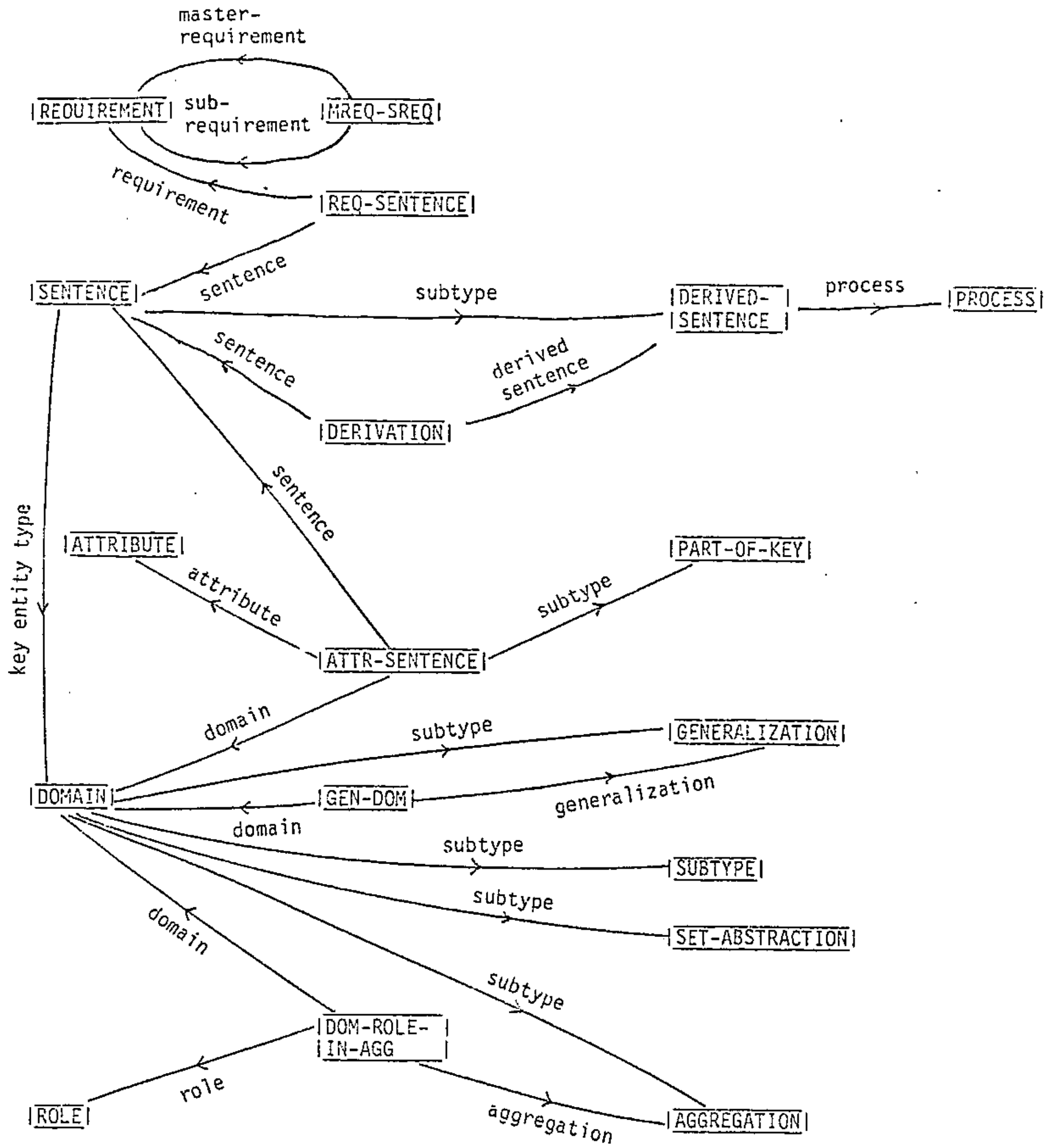

Fig. 2 The schema diagram of the meta-database

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