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A Common Data Model For Meta-Data in Interoperable Environments

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Abstract

A Common Data Model is a unifying structure used to allow heterogeneous environments to interoperate. An Object Oriented common model is presented in this paper, which provides this unifying structure for a Meta-Data Repository Visualisation Tool. The creation of this common model from the Meta-Data held in component databases is described. The role this common model has in interoperable environments is discussed, and the physical architecture created from the examination of the Meta-Data in the Repository common model is described.

1 Introduction

Many Interoperable Database Management systems utilise a Common Data Model as a single structure which all of the components use, allowing application programs to access data transparently i.e. the Data Model in the component databases are transparent. The common model is not only a conflict resolution structure but also a way to describe the complete data resource held in many heterogeneous data sources. This paper focuses on the common model of a Meta-Data Repository Visualisation Tool being designed and built for the HPC/SEA/IRISS project [1].

HPPC/SEA/IRISS is a Eureka project which is concerned with applications that manipulate large volumes of data. Issues in IRISS centre around areas such as decision support, on-line transaction processing and system interoperability, with a special focus on obtaining optimum performance. In this project the partners are aiming to provide an architecture which is capable of supporting the necessary data volumes and levels of processing required to support both mission critical applications and decision support applications. IRISS is based on a former UK Advanced technology project, IDIOMS [2], which was a two year project to develop a database engine with supporting decision support prototype software, scaled to the requirements of TSB PLC (a leading

UK Bank). The underlying machine used in the IRISS project is the IDIOMS database Machine.

New technologies are required to support the demands of inter-application data sharing. The requirement is a new lightweight mechanism that allows dynamically constructed data to be transferred between any set of applications and a set of databases anywhere on the network running in any environment. This is currently achieved through the use of middleware which provides the overall support for standard interfaces. There is a requirement for database tools to manage this middleware. Consequently one of the major project tasks concerns the provision of a set of portable reusable tools to be used in heterogeneous environments to aid database administration, to help optimise the database through monitoring and visualisation facilities and to interface different databases. This is the task in which the LPAC (London Parallel Application Centre) group is involved; the tools we are developing include a database monitoring tool and the Repository. The Repository together with Strand Software Technologies Clearinghouse system [3] will be the 'glue' which ties all the disparate databases together. A key element of the Repository is the common model.

The organisation of the paper is as follows. Section 2 describes the Repository. Section 3 describes the Clearinghouse system. Section 4 describes the common model and its component parts. The role of the common model in interoperable environments is described in section 5. Section 6 describes the physical architecture of an interoperable environment created by the examination of Meta-Data in the Repository common model. A summary is given and further work needed is described in section 7.

2 The Meta-Data Repository Visualisation Tool

We have defined three main components of the Repository; an extraction component, a semantic match tool and a graphical data visualisation tool. Figure 1 shows the relationship between the various components.

Extraction tools examine the Meta-Data and redefine its information in terms of our common model. The semantic match tool takes this Meta-Data and resolves semantic heterogeneity between the various Meta-Data. The visualisation component will provide interaction facilities for the extraction and semantic match components, as well as visualising the Meta-Data. The Repository will connect with the Clearinghouse middleware system, using an Application Programming Interface, but has been designed using an object model so that it will easily connect to an Object Request Broker based middleware product. Once heterogeneity has been resolved, the operational architecture for the interoperable environment can be generated (see section 6) using the Meta-Data created during the Schema Integration process and held in the Repository common model.

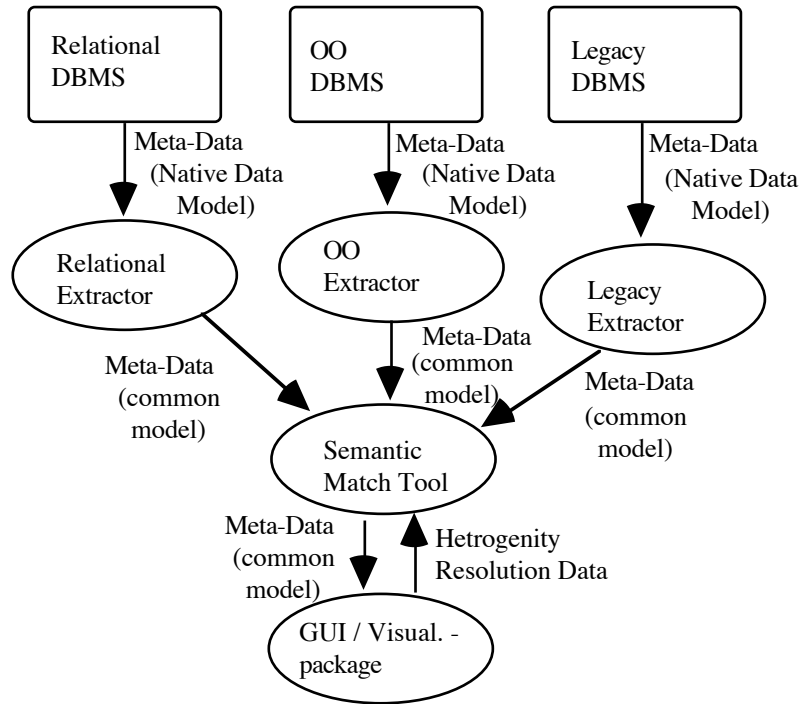


FIGURE 1 - Repository Structure

3 The Clearinghouse System

The Clearinghouse system [3] is essentially a distributed event manager, where data is pro-actively sent to clients. There are four main components to the Clearinghouse system; the register, exchanges, probes and database agents. The register records the location of Clearinghouse elements for client programs as well as storing other details. An exchange holds information on a single, simple data model and with which client programs connect to when given the location by the register. Probes are reactive process which map data from one data model to another and connect exchanges together. Database agents enable the clearinghouse system to connect with component databases. We have conceptually designed the common model using the Object-Oriented model, but physical storage of translation, functions etc. use Clearinghouse.

4 Description of the Common Data Model

The Common Data Model is a recommended structure by which interoperable environments can unify their disparate component databases, with varying native data models. The actual model is given in Appendix II and the Object Notation [4] used is given in Appendix I. This common model is the logical representation of Meta-Data. The basis of this model is formed from inspection of Meta-Data in relational and

legacy databases. Example coverage included the IBM IMS® system [5] and the relational databases INGRES® [6] and ORACLE® [7]. The model to be used in the common model is Object Oriented which has the advantages; it provides a number of useful abstraction mechanisms such as inheritance and aggregation, permits behaviour of objects to be captured through methods, non-traditional databases can be integrated using behavioural mappings and given that storage and retrieval is supported by the underlying model efficiency is not greatly degraded [8]. The Object Oriented model is becoming the dominant model in interoperable systems; previously many systems used the relational model [9]. We have identified four main Meta-Data classes; Objects, Constraints, Security and System. Each of these Meta-Data are described below.

4.1 Objects

The Object class refers to Meta-Data that users of all types use directly in support of their functions e.g. end users need to know about the Meta-Data for the data that their application program use to complete their task. The objects can be Tables, Views, Reports, Forms, records, segments etc. The definition of Object has been defined to take account of the various types of structures which are encountered in the many native data models we examined. For example relational databases are made up of relations (tables), which are in turn made up of attributes; hierarchical databases have trees which are made up of segments, which are made up of attributes and links to other segments. It is apparent that we can model these native data models using Object Orientation. We use the process of *Aggregation* [4] to build up Object Oriented representations of these native models. The process of *Generalisation* [4] is used to build objects in the common model using the different representations built by the Aggregation process. The advantage of this definition of Object is that the native data model can be modeled naturally, while isomorphism's for the common model can be formed from those disparate models. An isomorphism is defined by Hofstadter [10] is an information preserving-transformation where "two complex structures can be mapped onto each other, in such a way that to each part of one structure there is a corresponding part in the other structure, where 'corresponding' means that the two parts play similar roles in their respective structures". Isomorphism creation can be done by defining the *extent* which is the ability to define the set of objects which *belongs-to* a class [8]. The relation *belongs-to* means that an operation can be done on a class "if it is an instance of that class or any of its subclasses" [8]. We use the term isomorphism to mean the mapping of disparate data models to a single Object Oriented data model in order to allow interoperation between them. Thus there are a number of mappings needed to build isomorphism's. These Isomorphism's are built by resolving heterogeneity using the match tool component of the Repository.

4.2 Constraint

Constraint Meta-Data refers to constraints on Object Meta-Data such as unique data within fields or a threshold for object occurrences e.g. an attribute NUM_COMPONENTS would have the constraint > 0 . This Meta-Data can be built into the system, as found with IMS [5] or user defined. There appears to be occasions when Constraint Meta-Data is defined on a on Object at the same time as Security e.g. in ORACLE 6 the Meta-Data attribute CONSTRAINT_COLUMNS refers to constraint definitions on accessible tables. The extraction component of the Repository has to be built with such information in mind.

4.3 Security

Security Meta-Data refers to the users ability to access to a particular object or objects, more specifically identifies permissions to read, write, or update objects or groups of users ability to access an object. As noted above the distinction between Security and Constraint Meta-Data can sometimes be blurred. The security mechanism is visible for an Object in the example given above, therefore the extraction process can easily be implemented to accommodate such information. Where Security mechanisms are built in to a Database Management System e.g. IMS [5] the distinction between Security and Constraint Meta-Data could be harder to determine. This has implications for the extraction tool where specific extractions will need to be built for a given database, particularly for legacy systems such as IMS [5].

4.4 System

System Meta-Data refers to system administration data for databases. Examples of this type of data are the physical storage for an object, object location, information needed for recovery, network information (topology, site, address), logical to physical mapping and performance.

4.5 Aggregate Classes

It should be noted that System, Security and Constraint Meta-Data applies to the aggregate classes i.e. the attributes of a tables as well as the table itself. This means that each sub-class may have its own Constraints, Security and System related Meta-Data. A further important point is that there may be missing information in our representation i.e. NULL data.

5 The Role of the Common Model in Interoperable Environments

In [11] Seth and Larson describe a five level schema architecture for use in Federated Database systems. Pitoura et al [8] take this architecture and adapt it to include the data models for each schema. In this section we describe the role of the common model in an interoperable environment in all levels of this five level architecture.

The Local Schema of the pre-existing component database system uses the native data model. The extraction process (or the Schema Translation process [11]) takes Meta-Data from this Local Schema and converts it into the common model of the Component Schema. The relevant sub-class of that native data model is used to populate the Component Schema. It should be noted that this is not the only strategy. The Jupiter system [12] defines a Participation Schema in the place of the Component Schema. Murphy and Grimson argue that to make available only those parts of a Local Schema through the Export Schema (in our terms partial extraction) is more pragmatic. Our approach is to populate the Component Schema with all the relevant Meta-Data, so that the Meta-Data is available when a new federation is needed and no extra request by a Database Administrator is needed to put the extra data in the system. While this is a much more user friendly option, it is at the cost of extra redundancy of Meta-Data in the Repository. However, Meta-Data will not be large relative to the data which it describes. The local Database Administrator manages the Component Schema.

Once the Component Schema is set up, any Export Schema can be defined for use in Federated Schemas as and when they are required. The Export Schema common model is a view over a subset of the Component Schemas common model; only that which is required by the federation. It is the task of the local Database Administrator to define this Export Schema, using negotiation with the Federated Database Administrator (the negotiation process [11]).

When the Export schema common model's have been defined, the Federated Database Administrator can create the Federated Schema common model by using the process of Schema Integration [11] to unify the Export Schema common model's. An important issue is the decidability of conflict-freeness when integrating schemas. Conflict-freeness between any two schemas is defined as the ability to determine that the structure of the schemas do not conflict in any way. When conflict-freeness cannot be decided between schemas the resultant effect is to render the integration of those schemas problematic and any interoperation between them cannot be relied upon. Convent [13] formally argues that conflict-freeness in the integration of two relational schemas is undecidable. If he is correct, it could have serious consequences for the

ability to prove the conflictfreeness of any two schemas with any given data model. However, Convent has only proved that conflictfreeness is undecidable at the level of expressiveness for schema integration which he believes is the minimum needed . No proof is given for the level of expressiveness he uses in the paper. It is therefore hard to accept the validity of his proof one way or another, with knowing more about the level of expressiveness needed for schema integration. For the sake of brevity the reader is referred to Convents paper [13] for examples. In any case the formal model which Convent uses [14] requires the use of a data model with clear formal semantics; the latter will not probably not exist for legacy systems. We therefore believe that a formal model must be derived in order reason about conflictfreeness of heterogeneous integrated schemas. Unfortunately the lifetime of this project precludes the authors from attempting this.

After the Federated Schemas have been defined with some level of expressiveness which is conflict free, External Schemas with any data model can be defined as views over those federations.

6 Physical Architecture for Interoperable Environments

The physical architecture of a interoperable environment (or Federated Database system) is very dependant on the middleware to be used to implement it. Examples are Clearinghouse [3] and CORBA [15]. We need to hide the details of the architecture such that either of these systems could be used to implement the Repository. Our aim is to provide some middleware portability. We present a architecture for Clearinghouse in Figure 3, which we believe could be useful. The Clearinghouse notation used is Strand Software Technologies' [3] which can be found in Appendix III.

Two levels of the 5-level architecture are represented by Clearinghouse exchanges, which contain the common model at that level. The probes between these exchanges represent a mapping between each of exchanges of the various levels of the architecture. The Repository will set up the exchanges with the relevant common model and the probes with the model to model mappings, so that data can pass through them in an operational environment. A view over the Component Schema is provided for Export Schema implementation. An alternative would be to have an exchange to handle the Export Schema, but this would mean that transactions would need to pass through an extra exchange, with resultant loss of performance. The Federated exchange provides a External Schema view using the Clearinghouse Application Programming Interface for client programs. The advantage of the architecture in Figure 3 is that there are no circular relationships between the exchanges, and therefore the risk of race conditions is greatly reduced.

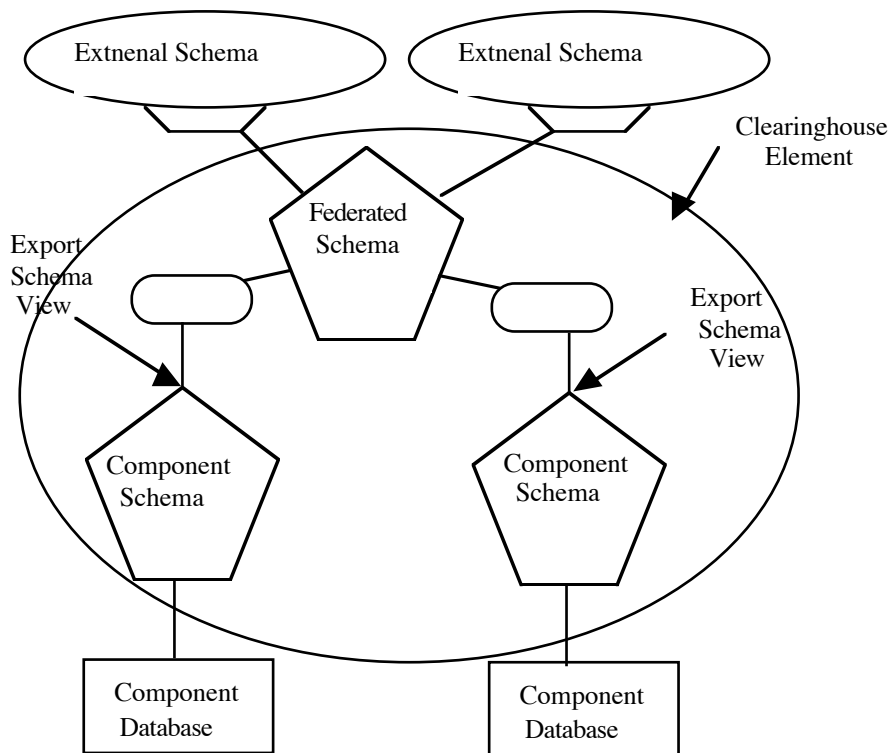


FIGURE 3 - Physical Architecture for Interoperable Environments

An alternative to Clearinghouse is CORBA [15]. We can replace the Clearinghouse element shown in figure 3 by Object Request Brokers and provide a standard interface with which to access the data. Given that our design will be based on the Object-Oriented model, this would be a minor task. It should be noted however, that some addition to CORBA would be needed to provide the same functionality as Clearinghouse. This is because of the pro-activity of Clearinghouse which propagates events around connected exchanges. The ISIS system [16] could provide the pro-activity needed in conjunction with an Object Request Broker by using the concept of process groups, in which processes notify each other of events as and when they occur.

7 Summary & Further Work

We have described the Common Data Model which will be used as the common structure in the Meta-Data Repository Visualisation Tool being designed and implemented for the purposes of the HPPC/SEA/Iriss project. Four main classes for Meta-Data for a Object-Oriented common model have been identified; Object, Constraints, Security and System. We believe the definition of Object is flexible enough to model the structures of all types of databases. The role of the common model in Federated Databases is discussed for each of the levels of Seth and Larsons 5-Level schema architecture [11]. We present an architecture created from Meta-Data in the Repository common model which we believe is race condition free (Clearinghouse

only). We have designed the Repository using the Object Oriented model such that an Object Request Broker product could be used in place of the Clearinghouse. The importance of isomorphism creation is stressed in the paper. Information preserving transformations are regarded as central to the success of integrating heterogeneous databases. We have identified the need to derive a formal model in order to reason about the decideability of conflict-freeness when integrating schemas in heterogeneous environments. We hope that we will be able to undertake this task in the near future. We are currently implementing the Repository using the common model structure described in this paper. Extraction tools will take information from the native database and put it in a suitable form for the common model. The semantic match tool will provide the method for building federations. The GUI/visualisation tool will allow the user to resolve heterogeneity interactively, as well as visualise the Meta-Data in the Repository using a representation of the common model structure. The resultant operational architecture for the Interoperable system can then be created from the Meta-Data held in the repository; this will be an automatic process.

Acknowledgement

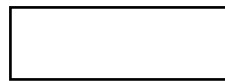
We are grateful to David Streader for helping us to clarify the concept of isomorphism's.

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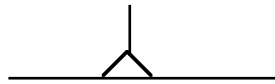
APPENDIX I - OBJECT MODEL NOTATION USED



Class



Association of classes



Generalisation (Inheritance)

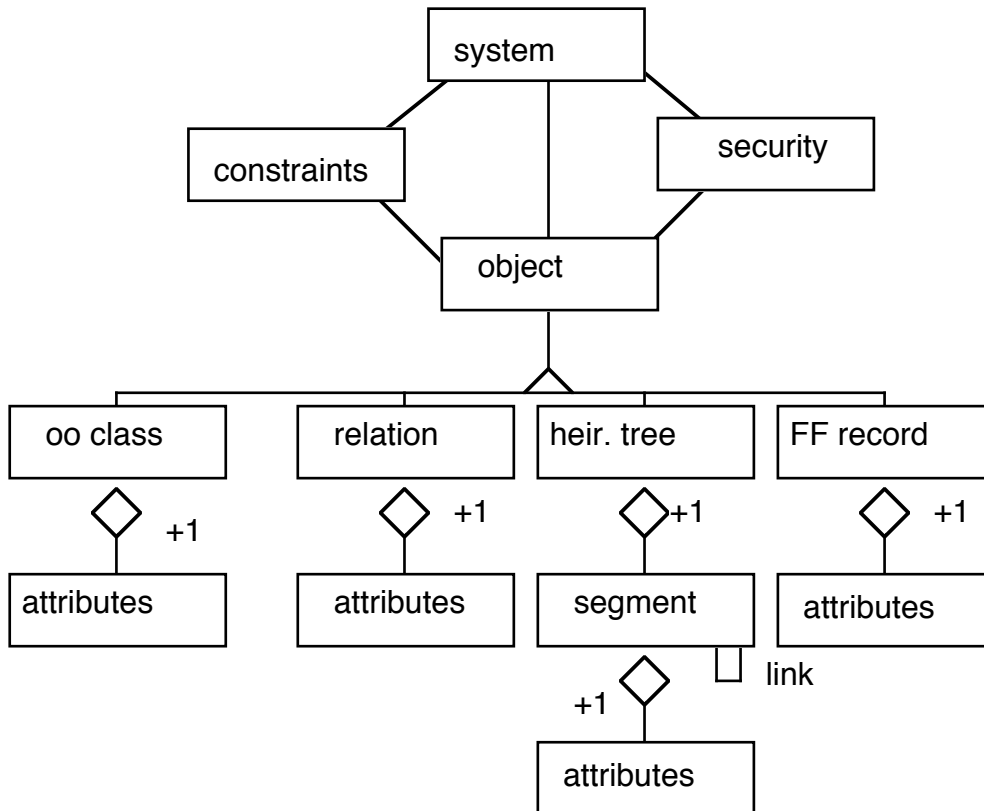


Aggregation

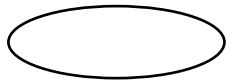
+1

One or more associations

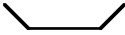
APPENDIX II - THE COMMON DATA MODEL



APPENDIX III - CLEARINGHOUSE NOTATION



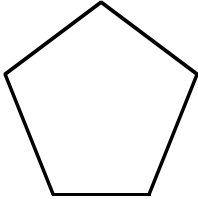
A Client Program



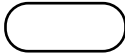
Clearinghouse API



Connection to an Exchange



Clearinghouse Exhchange



Clearinghouse Probe



Component Database
(with Native Data Model)