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An Object-Oriented Multi-Mediator Browser

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ABSTRACT

The area of data integration has gained increased popularity in recent years. A data browser is described for a data integration system where an intermediate layer of distributed mediators is used to query and integrate data from heterogeneous data sources. The data sources can be regular relational databases but also other data producing programs. They often have complex data representations and are often object-oriented (OO). The mediator database layer is therefore also object-oriented for a high abstraction level. An OO query interface is used to access the mediator layer from application programs and users. For a scalable and component based architecture the mediators can be used as servers for other mediators. This leads to a distributed mediator architecture where mediator servers interact with other mediators and data sources. The OO multi-mediator browser GOOVI is presented, which enables maintenance of such distributed mediator databases. With GOOVI all autonomous mediators in a federation can be viewed, queried, and updated. This multi-mediator browser also provides user interfaces for integrating data through OO views. The paper describes the architecture and functionality of GOOVI.

1. Introduction

With the mediator/wrapper approach to data integration [Wie92] *wrappers* define interfaces to heterogeneous data sources while *mediators* are virtual database layers where queries and views to the mediated data can be defined. The mediator approach to data integration has gained a lot of interest in recent year [BE96,G97,HKWY97,LP97,TRV98]. Early mediator systems are central in that a single mediator database server integrates data from several wrapped data sources. In the work presented here, the integration of many distributed sources is facilitated through a scalable distributed mediator architecture where views are defined in terms of object-oriented (OO) views from other mediators and where different wrapped data sources can be plugged in. This allows for a component-based development of mediator modules, as early envisioned in [Wie92].

GOOVI (Graphical Object-Oriented View Integrator) is is a graphical user interface for managing a federation of mediator servers in the mediator system Amos II [RJ01,RJK00,JR99a]. Amos II is a distributed OO mediator system that allows OO views in mediator servers to be defined in terms of views in other mediator servers on the net. Data sources are wrapped by embedding them in Amos II mediator servers through foreign data source interfaces [RJ01,JR99a]. The primary GOOVI user is a mediator administrator who defines and modifies distributed mediators and who investigate properties of them. Such a mediator administrator needs to find mediators in a federation, to inspect and modify the schema of each individual mediator, to inspect and update the contents of each mediator, and to define integrating views of data from other mediators. The actual wrapping of data sources requires some programming and is outside the scope of this paper.

An overview is presented of the distributed architecture of GOOVI along with examples of interactions with the system to illustrate its functionality. The purpose of GOOVI to manage a federation of distributed mediator servers requires a unique combination of facilities.

For finding relevant mediators in a federation GOOVI provides interfaces to browse some general meta-mediator properties of the federation members, such as their names and locations. The autonomy of the individual mediator servers must be respected and therefore no central schema is maintained.

To inspect the schema of each autonomous mediator, GOOVI provides a very easy way to graphically browse several AMOS II mediator databases in a distributed federation. The type hierarchies of different mediators can be visualized in separate windows. GOOVI also has primitives for schema modification for each browsed mediator.

For manipulating the contents of the mediator databases, individual database object instances in each mediator database can be both inspected and modified, similar to OO database browsers. The interface illustrates on a high level the relationships between database objects in a single mediator. Furthermore, it allows OO multi-database queries to be submitted to any mediator server in the federation. The results of the queries are presented as browser objects too, for convenient further browsing. Separate browser and query window groups can be opened for browsing different autonomous Amos II mediators in a federation.

For combining data from different mediators GOOVI provides a graphical interface to define OO multi-mediator views. Such a view definition facility must include primitives for reconciling differences between data in different mediators. The multi-database integration primitives of Amos II [JR99a,JR99b] provides such functionality.

This paper first discusses related work. Then the style of interactions with GOOVI is presented in Section 4. Section 5 describes how to define multi-mediator views, followed by an overview of the implementation in Section 6.

2. Related work

Most commercial relational databases provide graphical database browsers. A few systems address browsing of OO databases [MDT88,F89,AGS90,CHMW96,CA96]. As in Pesto [CHMW96] the results of queries to individual mediators in GOOVI are returned as database structures that can be examined by GOOVI as any other database objects. This is called *query-in-place* in Pesto. As in Jasmine [CA96] we use an interface style with a Windows oriented look-and-feel. However, unlike Jasmine (and like Pesto) our query interface is stream oriented to allow for retrievals of large sets of data. Furthermore, GOOVI allows multi-mediator queries to be submitted to any mediator in a federation and the resulting objects from different databases to be inspected.

Browsers for centrally integrated XML sources are proposed in [B99][MP00]. A major difference between GOOVI and all other known database browsers is that GOOVI is designed for browsing *federations* of distributed OO mediators. This puts new requirements on the browser to be able to separately visualize data from several autonomous OO mediators in a federation and to be able to graphically define reconciling views of data from several of them. GOOVI therefore allows the user to open separate OO *mediator browser windows* for each member in the federation. Separate windows, e.g. for querying and data integration, can be associated with each such database browser window. A *connection manager* allows the user to select among the members of the federation to open up new database browser windows.

Furthermore, *data integration windows* can be defined where OO multi-mediator views can be defined that derive and reconcile data from several mediator servers [JR99a,JR99b].

The interaction between GOOVI and the mediator in the federation respects the autonomy of the members. This means that, unlike other database browsers, GOOVI does not presuppose any central database, mediator, or global conceptual schema. The only requirements are that the databases in the federation are wrapped in Amos II mediators and that they are registered with a meta-mediator called the *mediator name server*. The mediator name server is an ordinary mediator server having name, location and some other *meta-mediator properties* of the members in a federation. However, the mediator name server contains only very limited information about the members of the federation; it respects the autonomy of the members and it is *not* a full central data dictionary.

3. Browsing Multi-mediators

A federation of Amos II servers may contain many mediator servers distributed on a computer network. Each mediator server is an autonomous database server supporting the OO query language AmosQL of Amos II having a syntax and semantics similar to the OO parts of SQL-99 [RJ01,RJK00]. The mediator servers have primitives for communicating with other mediator servers and for wrapping external data sources. Foreign data can be made accessible to the federation by developing an interface, called a *wrapper*, for each kind of data source where simple query algebra operations are executed on external data elements. We have successfully developed wrappers for ODBC, STEP/EXPRESS, XML, web-based search engines and currency exchange services, etc.

If a data source has no own query processing capabilities, as e.g. STEP/EXPRESS and basic XML, the processing of the imported data is done transparently inside Amos II in a streamed fashion or through materialization in the mediator database, depending on the data source.

However, if the data source accepts queries, as e.g. ODBC and search engines, there is also a need to develop query *translators* that translate (rewrite) AmosQL queries into execution plans containing query fragments submitted to the foreign query engine for evaluation.

From a mediator administrator's perspective the mediator layer appears as a federation of distributed and autonomous mediator servers each using the same OO data model and query language, where some mediators wrap one or several data sources while other combine data through OO views over data from other mediators.

Figure 1 illustrates one such scenario where we have five mediator servers named *WC*, *NAMESERVER*, *TORE*, *HOLIDAYFLIGHGTS_INC*, and *FLYGRESOR_AB*[1] running somewhere on the network. The mediator named *NAMESERVER* is a mediator server knowing the locations, names, and other properties of the mediator servers in the federation, i.e. the *mediator name server*.

Mediator servers will query the mediator name server using AmosQL when they need to know meta-properties of members in the federation. Notice here that this architecture does not include any global conceptual schema; every autonomous mediator server has its own local OO schema and the mediator name server knows only very general meta-properties of the other mediator servers. The different mediators and databases can be located anywhere on the Internet and, since they are autonomous, the number of mediators in a federation can be very large.

In the example, *TORE* does not have any local database, but only OO view definitions of data in other mediators. *WC*, *HOLIDAYFLIGHGTS_INC*, and *FLYGRESOR_AB* wrap regular databases (e.g. relational databases). The mediator *USER* represents the view of the federation for a particular user. The user can browse and store private data in a local database. It is also used internally by GOOVI for caching data extracted from other databases. The user can ask GOOVI what mediator servers are available in the federation. GOOVI will send queries to the name server to find this out.

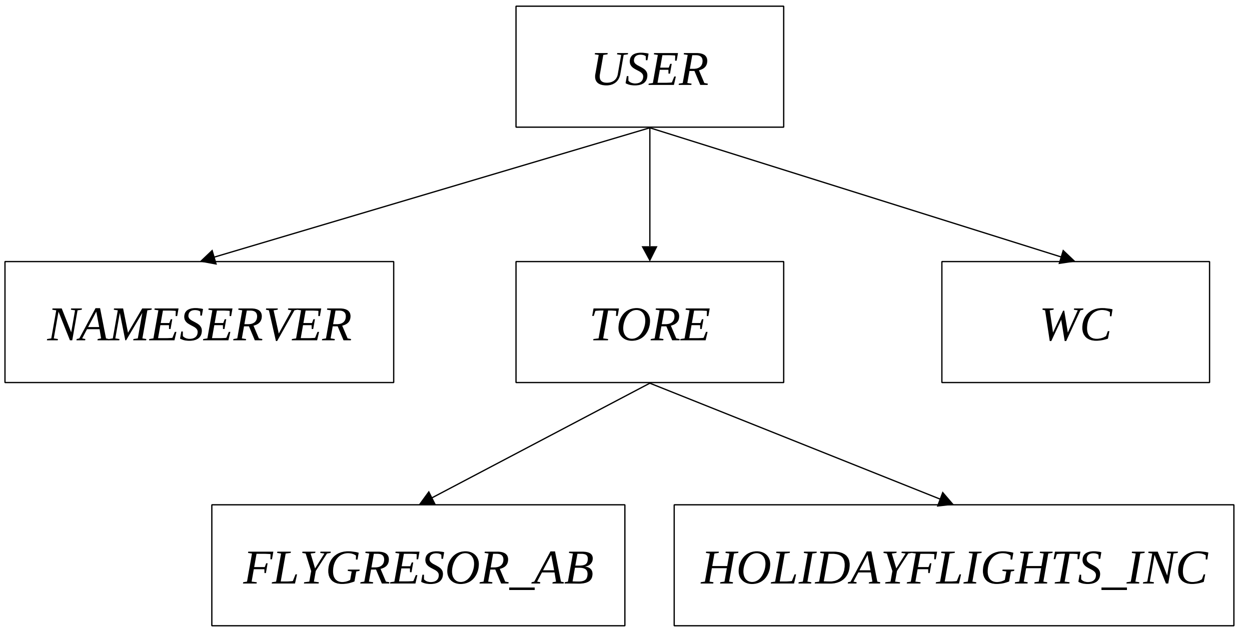
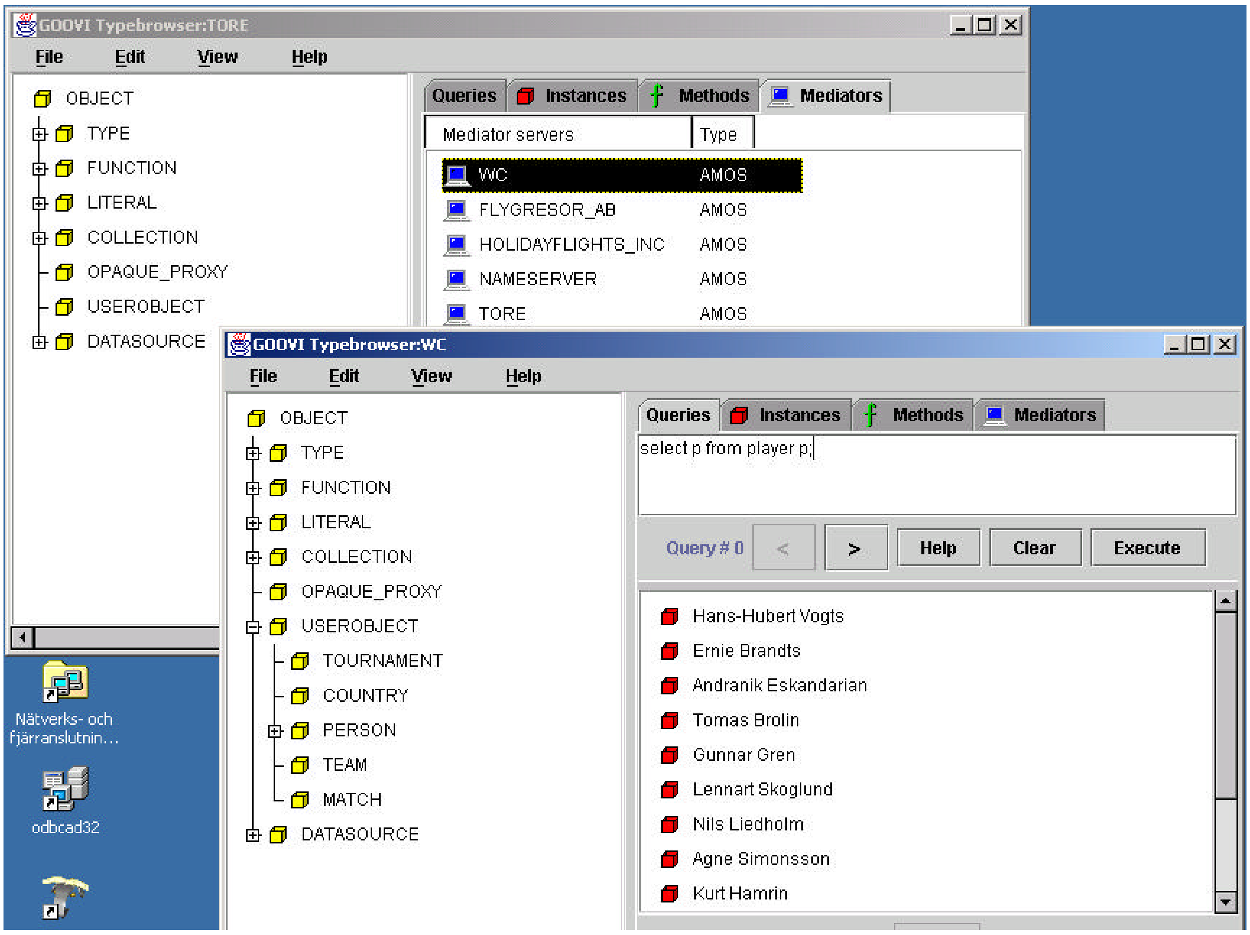


Figure 1: Multi-Mediator Scenario

Figure 2 shows an example of a GOOVI interaction in our multi-mediator scenario. In the example two multi-mediator type browser windows are open, the top one connected to the *TORE* mediator and the bottom one to the mediator server named *WC* for which also a query is stated. The result of the query is presented as a scan of objects of type *PLAYER*. Furthermore, Figure 2 also shows how the user can ask GOOVI what mediator servers are available in the

[1] Air Travel Inc. in Swedish.

federation by opening a *mediator browser* to the right. GOOVI has here internally queried the name server mediator for the names, locations, ports, etc. of the mediator servers in the federation. Through the mediator browser dialog the user can open separate type browser windows on any mediator server in the federation.



Mediator servers	Type
WC	AMOS
FLYGRESOR_AB	AMOS
HOLIDAYFLIGHTS_INC	AMOS
NAMESERVER	AMOS
TORE	AMOS

```
select p from player p;
```

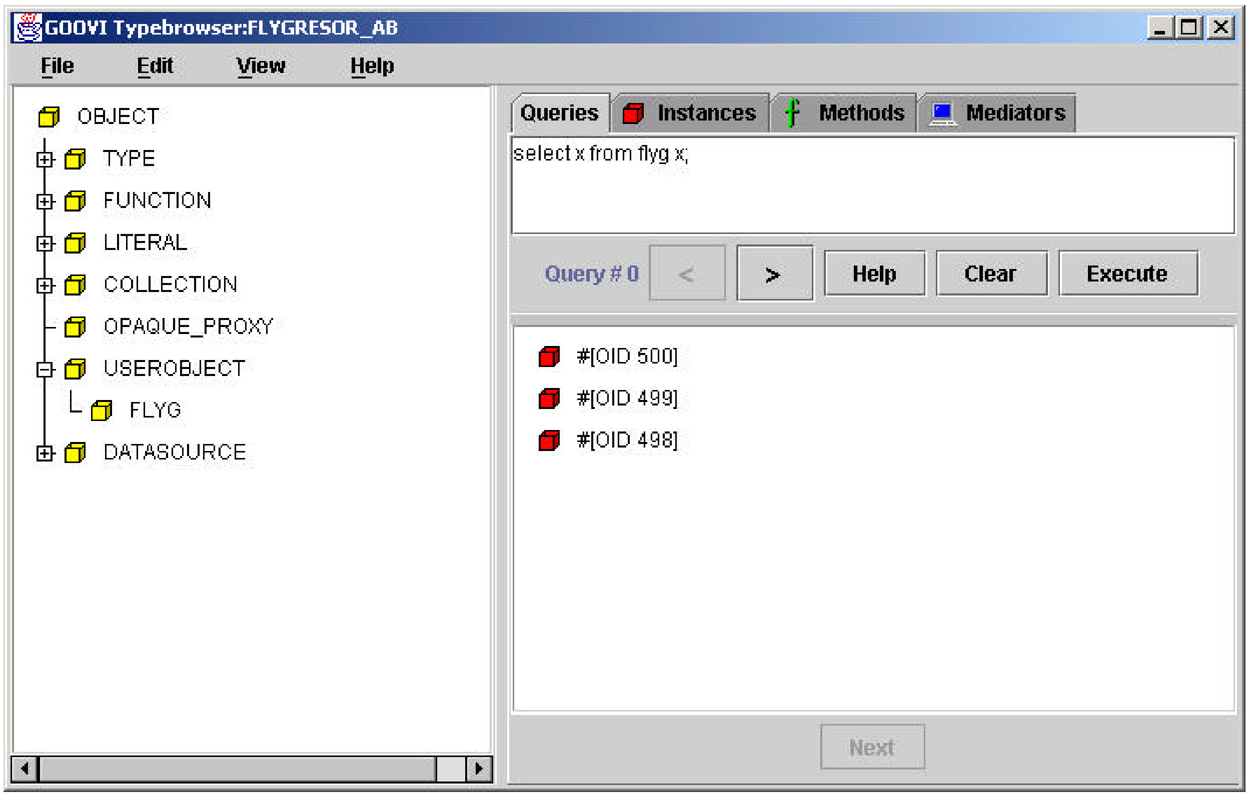
```
Hans-Hubert Vogts
Ernie Brandts
Andranik Eskandarian
Tomas Brolin
Gunnar Gren
Lennart Skoglund
Nils Liedholm
Agne Simonsson
Kurt Hamrin
```

Figure 2: GOOVI Interaction

When the mediator browser is opened it has to contact the mediator name server to obtain the set of mediators in the federation. The mediator name server can be located anywhere on the net and the user is therefore first asked to specify its network location to GOOVI. The members of the federation can be located anywhere on the net too. Through queries to the mediator name server the mediator browser can present the user with a menu of the members of the federation.

3.1 The Type Browser

The *type browser window* graphically displays the type hierarchy for a particular mediator server. Initially the type browser window for the mediator is displayed. The approach of having the type hierarchy as the main view of an OO database is a natural choice since the types and their relationships are central for an OO database. It was also chosen, e.g., in Jasmine [CA96] and Iris [F89].



select x from flyg x;

#[OID 500]
#[OID 499]
#[OID 498]

Figure 3 The GOOVI Type Browser

Figure 3 shows the type browser window for a mediator database *FLYGRESOR_AB*, wrapping a data source containing flight data for a Swedish travel agent. The window is divided vertically in two parts with a left panel showing the type hierarchy and a right panel having a number of tabs for inspecting different properties of the mediator. There is also a menu bar on top with functions for creating new types, viewing, searching, editing, etc. Some of the menu-items have keyboard shortcuts.

When opening browsers of several autonomous AMOS II mediator servers, separate and independent type browser windows appear on the screen for each mediator, as shown in Figure 2. Every type browser window thus has a one-to-one relation to a connection to an AMOS II database in the federation. This helps the user to keep track of what mediator databases are being inspected. By closing the corresponding type browser window the connection is also closed along with all other dialogs associated with the closed type browser. The type browser window thus serves as a grouping of all GOOVI dialogues associated with a particular mediator server. The name of the AMOS II database (e.g. *FLYGRESOR_AB*) is stated in the title of the type browser. When the last type browser window is closed GOOVI is exited after a confirmation.

3.2 The Query Editor

The *query editor* allows execution of queries and browsing the resulting scans displayed in a graphical format. The entities of query results are inspectable and have a consistent appearance as other database objects for generality and user orientation. We have chosen to specify queries as text input to browser forms rather than using elaborate mouse selection as in some other database query tools [CA96, CHMW96], the reason being that we believe that a somewhat trained person, such as a mediator/database administrator, is more efficient with typing OO queries than elaborate mouse selections. Future studies should investigate how to combine our text based interface with a graphical query language, e.g. along the lines of Pesto [CHMW96].

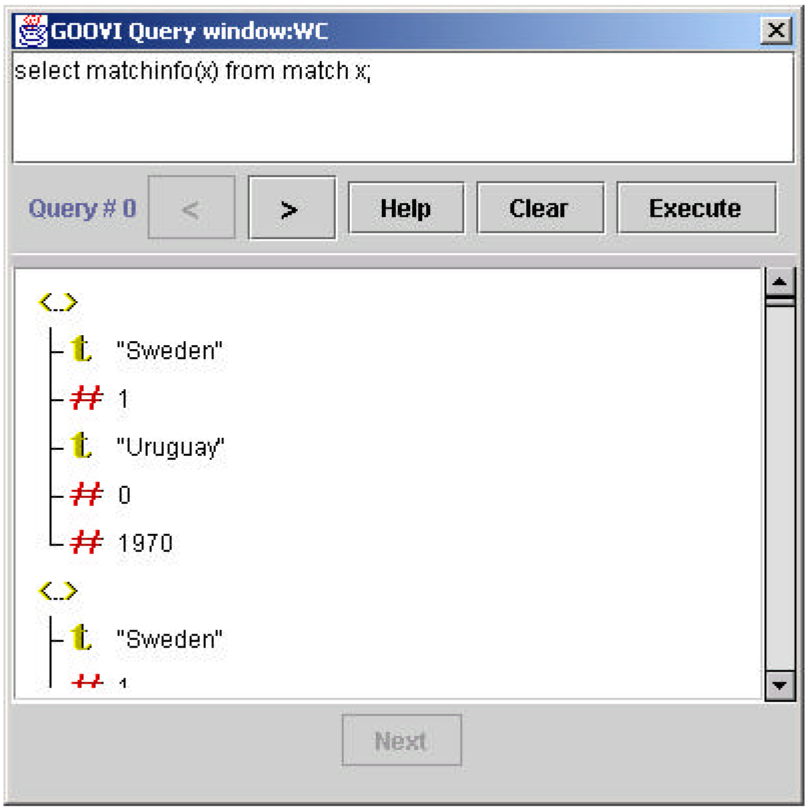
In the query editor AmosQL queries can be entered textually. A history of queries makes it possible to browse previously stated queries to edit or redo them. We do not save the query results in the history for memory and performance reasons. It is however possible to open new independent query editor windows for any query where a piece of the latest result is then visualized. Figure 4 shows an example of such a separate query window. This gives the user the choice to have several active queries and their results on the desk top to be used for inspection, copying, and pasting between query results and browsed objects.

The query editor is divided into three parts. First there is a label that states a numeric query history identifier. Then there are buttons to move backward and forward in the history and for help and (re-)execution of the current query.

Below the button panel there is a text area where queries can be entered textually or edited using the standard OS clipboard. Further below there is an outliner that displays the result when the ‘execute’ button is pressed.

The result of an AMOS II database query consists of a *scan* of objects where the objects are visualized by dark (red) icons, as in Figure 2 and 3. For objects having names the browser maintains the correspondence between the OID and its name and the object’s name is displayed as in Query#1 of Figure 2. The name of an object is specified in the mediator through a user defined *name* function. The results of queries are connected to the clipboard for general cut-and-paste between different GOOVI windows.

The result of a query can also be a scan of tuples, which are then visualized graphically to indicate their structure, as shown in Figure 4. Each tuple can have sub-tuple nestings to any level. Such a scan is visualized as a tree. If there are sub-tuples inside the elements of a scan special *collection icons* are created. This gives a nice presentation of most data structures retrieved from AMOS II database.


GOOVI Query window:WC

```
select matchinfo(x) from match x;
```

```
<..>
├ "Sweden"
├ # 1
├ "Uruguay"
├ # 0
└ # 1970
<..>
├ "Sweden"
├ # 1
```

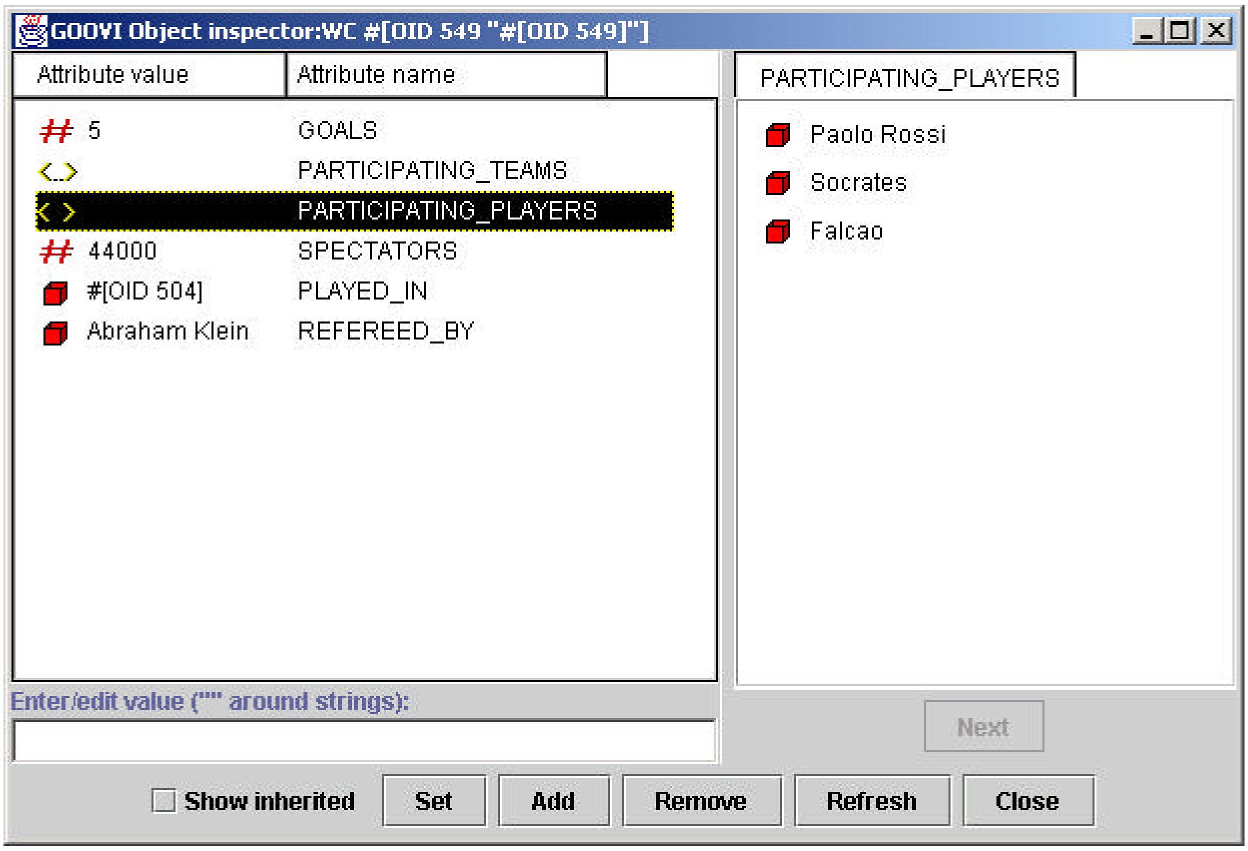
Figure 4 Scan visualization.

Fig. 4 shows the result trees from a query that returns rows of tuples containing string and integer elements. The collection icons (indicated <..>) indicate tuples. If one of the elements in the tuple in the example had been a vector (ordered collection), e.g. if the two countries were put in a vector this would result in clickable nodes in this position.

This outliner is streamed and only a predefined (default 20) set of result elements are displayed initially. To get the next set of elements in the scan the ‘Next row’ button is used located at the very bottom of the query editor.

3.3 The Object Inspector

The object inspector window is opened if the user double clicks on an icon for an Amos II object. The object inspector allows displaying and editing the values of the attributes of the selected object.


GOOVI Object inspector:WC #[OID 549 "#[OID 549]"]
Enter/edit value ("" around strings):
Next
Show inherited
Set
Add
Remove
Refresh
Close

Attribute value	Attribute name
5	GOALS
<..>	PARTICIPATING_TEAMS
< >	PARTICIPATING_PLAYERS
44000	SPECTATORS
#[OID 504]	PLAYED_IN
Abraham Klein	REFEREED_BY

PARTICIPATING_PLAYERS
Paolo Rossi
Socrates
Falcao

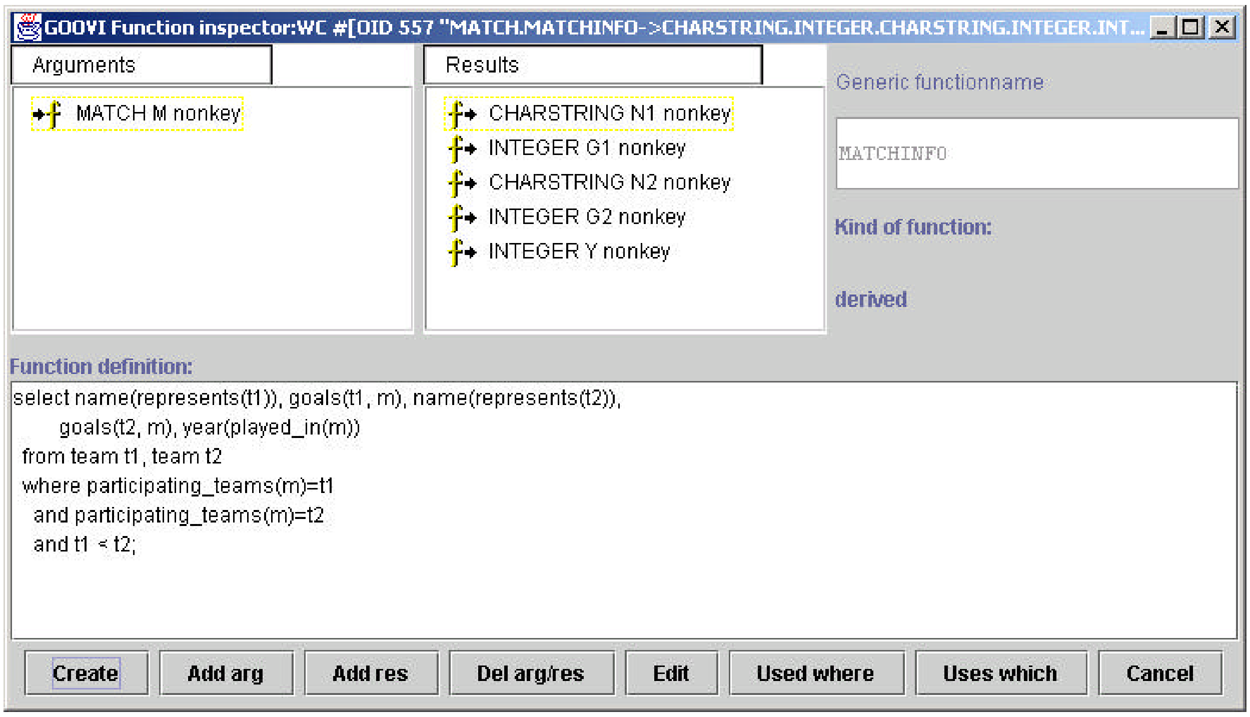
Figure 5 Object Inspector

Fig. 5 is an example of the object inspector in GOOVI. The *attribute* column displays the result of the function named in the *attribute-name* column. The object inspector also allows updates of database attributes.

Collection attributes are displayed as icons. As collections can be large, they are not immediately displayed, but retrieved in chunks by double-clicking on a collection icon.

3.4 The Function Inspector

The *function inspector* allows to view/edit arguments, results and source code of Amos II functions (Fig. 6). These definitions are stored in the database as (meta-) objects of type *FUNCTION* and are retrieved by the function inspector through queries to the database schema returning such meta-objects and their properties. Amos II functions can be of several kinds and the inspected function's type is indicated at the bottom of the function inspector window.


GOOVI Function inspector:WC #[OID 557 "MATCH.MATCHINFO->CHARSTRING.INTEGER.CHARSTRING.INTEGER.INT...

Arguments

MATCH M nonkey

Results

CHARSTRING N1 nonkey
INTEGER G1 nonkey
CHARSTRING N2 nonkey
INTEGER G2 nonkey
INTEGER Y nonkey

Generic functionname

MATCHINFO

Kind of function:

derived

Function definition:

```
select name(represents(t1)), goals(t1, m), name(represents(t2)),
      goals(t2, m), year(played_in(m))
 from team t1, team t2
 where participating_teams(m)=t1
  and participating_teams(m)=t2
  and t1 < t2;
```

Figure 6 Function Inspector

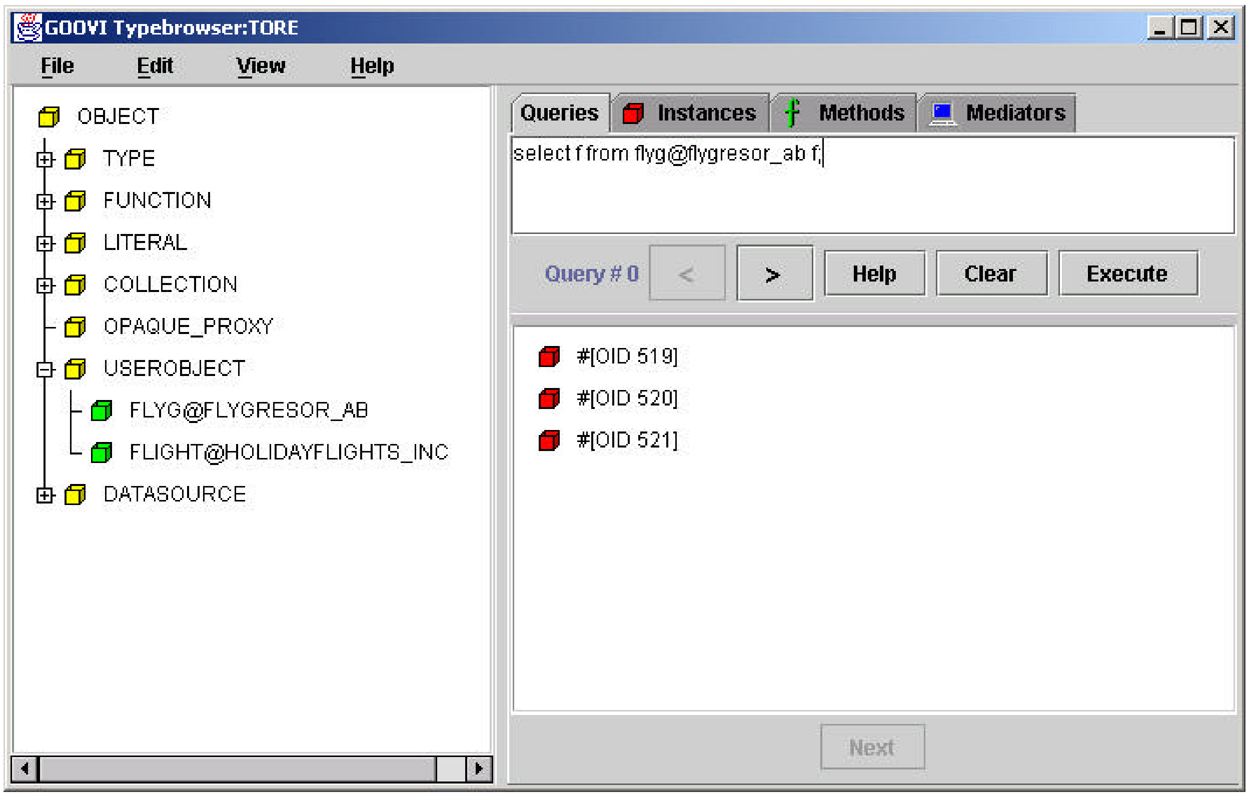
The example illustrates a *derived function* defined in terms of other AmosQL functions through an AmosQL query. Functions can also be stored in the database or defined in some external programming language [RJ01]. Roughly speaking attributes in OO languages correspond to stored functions, while methods correspond to derived and foreign functions.

4. Database integration with GOOVI

In order to combine data from different mediators, GOOVI allows importation of meta-objects, such as types (classes) and functions (method, attributes), from one AMOS II server to another. This is achieved by first selecting type and function definitions for exportation from one mediator and then importing them to another one.

To demonstrate the database integration support of GOOVI, assume we are in a tourist office and want to book flights. We have access to two databases, a British one called *HOLIDAYFLIGHTS_INC* and a Swedish one called *FLYGRESOR_AB*. The first database has a type called *FLIGHT* with the attributes: *flight_no, price, origin* and *destination*. The price is given in British pounds. The latter database has a type called *FLYG* with the attributes*: flyg_no, pris, start* and *destination. Pris* holds the price in Swedish crowns.

The first step is to import these types into the mediator *TORE*. We first have to select them for exportation from the mediators *HOLIDAYFLIGHTS_INC* and *FLYGRESOR_AB*. We therefore open a type browser for the *HOLIDAYFLIGHTS_INC* database and mark the type *FLIGHT*. Then we choose FILE->EXPORT in the menu bar. A dialog will confirm that the type is now ready for exportation. Next we go to the type browser for the mediator *TORE* and choose FILE->IMPORT. A dialog will confirm that the type was imported and it is called *FLIGHT@HOLIDAYFLIGHTS_INC* and automatically placed under type *USEROBJECT*. The same procedure is then repeated to import the type *FLYG* from the mediator *FLYGRESOR_AB* and then we have the situation shown in Fig. 7.



```
select f from flyg@flygresor_ab f;
```

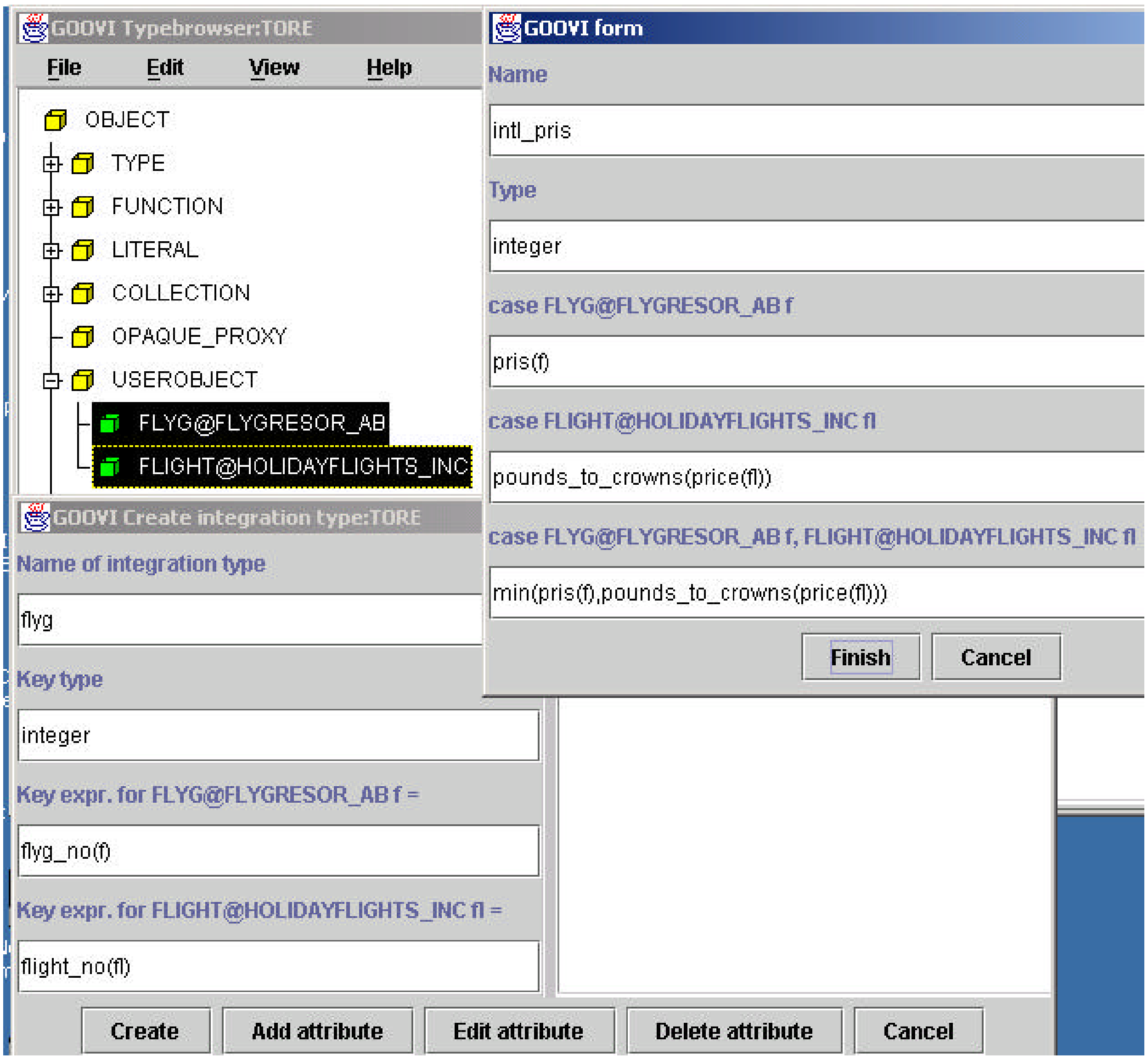
```
#[OID 519]
#[OID 520]
#[OID 521]
```

Figure 7 Mediator view after imports

An imported type can be used in database queries as other types, as also illustrated in Figure 7. The instances of an imported type are represented as *proxies* describing its origin. If more than one type is imported it is possible to state multi-database queries and views that join data from different mediator databases. However, OIDs are unique within each mediator and such joins can therefore not compare OIDs but have to join on literal properties only.

To reconcile overlapping and conflicting data from several mediators, an *integration union type*, IUT, [JR99a] can be defined. IUTs define types whose extents are proxies of objects from other mediators and where the same entities may be found in more than one source but with different, and sometimes conflicting, properties.

To illustrate how IUTs are defined with GOOVI, we mark the two imported types in the mediator *TORE* and choose FILE->NEW->INTEGRATION TYPE. In Fig. 8 we see the so created *create integration* type dialog.


GOOVI Typebrowser:TORE

File Edit View Help

OBJECT
TYPE
FUNCTION
LITERAL
COLLECTION
OPAQUE_PROXY
USEROBJECT
FLYG@FLYGRESOR_AB
FLIGHT@HOLIDAYFLIGHTS_INC

GOOVI form

Name: intl_pris

Type: integer

case FLYG@FLYGRESOR_AB f: pris(f)

case FLIGHT@HOLIDAYFLIGHTS_INC fl: pounds_to_crowns(price(fl))

case FLYG@FLYGRESOR_AB f, FLIGHT@HOLIDAYFLIGHTS_INC fl: min(pris(f),pounds_to_crowns(price(fl)))

Finish Cancel

GOOVI Create integration type:TORE

Name of integration type: flyg

Key type: integer

Key expr. for FLYG@FLYGRESOR_AB f = flyg_no(f)

Key expr. for FLIGHT@HOLIDAYFLIGHTS_INC fl = flight_no(fl)

Create Add attribute Edit attribute Delete attribute Cancel

Figure 8 Integration Union Type creation

The first two fields in the IUT creation dialogue to left are the name and the key type of the IUT identifying equivalent objects from different mediators. In our example two objects are considered equivalent if their flight numbers (represented as integers) are the same. The flight number for *FLYG@FLYGRESOR_AB* is defined by the function *flyg_no* while the corresponding function for *FLIGHT@HOLIDAYFLIGHTS_INC* is *flight_no.* The next fields state the *key expression* for the two types to integrate which map instances of the integrated types to the common key. GOOVI generates unique variable names to be used in the integrating expressions. We specify there that the *flyg_no* of the mediator *FLYGRESOR_AB* corresponds to *flight_no* in *HOLIDAYFLIGHTS_INC.*

To specify how to define object attributes of the IUT in terms of attributes from different mediators, one needs to define the attributes of the IUT by pressing ‘add attribute’ and filling in the popup form seen to the right in Fig. 8. Here the attribute *intl_pris* of the IUT is derived from the prices in *FLYGRESOR_AB* and *HOLIDAY_FLIGHTS_INC*. Different expressions are used if a flight exists in one of the two databases or in both. In this example the lowest price is chosen if the flight exists in both databases. The function *pounds_to_crowns* is a function defined in the mediator to convert British pounds to Swedish crowns. If real-time access to the current exchange is required, this function can be defined in the mediator by wrapping, e.g., access to web-based currency exchange information[2]. The attributes *name*, *origin*, and *destination* are defined in the same way. Finally ‘create’ is pressed to create the IUT *PRIS* in mediator *TORE*. It can then be browsed and queried as any other type. Updates of IUTs are currently not allowed.

5. Implementation

GOOVI is implemented in Java. Sun’s Java Native Interface JNI [SUN99] is used to tightly connect the Java Virtual machine (VM) to the AMOS II mediator database engine, which is written in C. The interface is completely query based by sending Amos II queries and function calls to the database engine for execution. This is possible since all system objects (including types and methods) are represented as database objects that can be queried using AmosQL. While end users usually query the contents of the mediator databases, GOOVI mainly submits to the Amos II kernel meta-queries about the structures of mediators in a federation. AmosQL update statements are sent to Amos II when the user creates or updates objects, while AmosQL meta-data definitions are send when new types and functions are created.

Program errors in Java applications, such as GOOVI, cannot crash the Amos II kernel system. The reason is that Java applications run in a separate thread from the kernel and the Java VM traps all Java program errors. Furthermore, the high level AmosQL based interface from Java prohibits calls to the Amos II kernel that can adversely affect it.

The Amos II kernel in its turn has TCP/IP based primitives for efficient communication with the name server and other mediator servers in the federation. Several novel techniques [JR99a,JR99b,JR00,RJ01] are used for efficiently executing multi-mediator queries over several distributed mediator servers. The techniques are based on installing optimized query plans on different mediators and then shipping bulks of data between them. For good performance we have therefore chosen to let GOOVI (and other Java applications) to communicate with the mediators in a federation through a local database rather than to directly communicate with each mediator.

[2] For example, we have successfully developed such a wrapper for www.swissquote.ch.

Figure 9 illustrates how GOOVI is interfaced with the local Amos II database system and how the system communicates with Amos II servers in the federation through the local mediator database system.

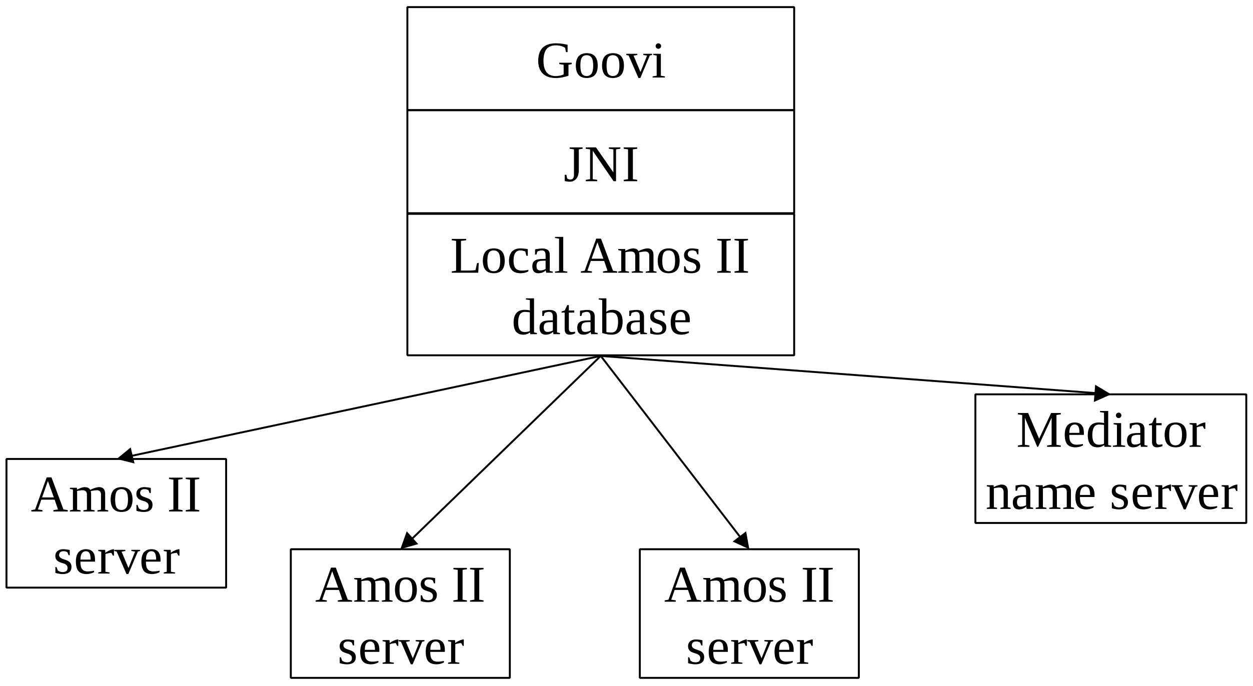


Figure 9: Connecting GOOVI to Amos II mediator databases

A possible disadvantage with the current approach is that some Amos II kernel code must be installed on the machine where GOOVI runs in order to provide the C-based interface to the Amos II kernel. However, we are working on a pure Java client-server interface to the local Amos II database, which would make it possible to run GOOVI as a Java applet, at the expense of much higher communication costs between GOOVI and the local database.

6. Conclusions

The architecture and appearance of the OO multi-mediator browser GOOVI was described. The purpose of GOOVI is to be able to browse, query, and integrate federations of autonomous mediator servers in a computer network. The data integration facilities allow the definition of OO views that integrate data from several mediator servers. Each mediator server is autonomous and there is no global conceptual schema of all mediators in a federation. Instead a meta-mediator, the *mediator name server*, knows locations, names and some other meta-data about the members in a federation. The interface between GOOVI and a federation of mediators is implemented by internally querying the mediator name server for meta-properties using an OO query language and then use these meta-properties to connect to individual members in the federation. All communication between the browser and the mediator engine is thus made through the query language. This is possible since meta-objects are first class objects too.

The user can open a group of windows connected to a type browser window for each selected member of a mediator federation. In these windows type structures are investigated, queries are specified, and integrating OO views are defined. Database objects returned from queries are displayed graphically and can be browsed and used in other queries, etc.

GOOVI is the first OO multi-database browser that addresses graphical integration of multiple mediators. Such a tool is very useful for the mediator developer when integrating data from a federation of databases wrapped in mediators.

In summary, GOOVI has the following unique properties:

- It is an OO multi-database browser where several OO databases can be browsed separately.

- It can graphically integrate data from multiple distributed mediators in a federation.

- It respects the autonomy of the mediators in the browsed federation; it is thus not based on the availability of any global conceptual schema.

- Every object on any level in the federation is transparently inspectable, including mediators, type definitions, function definitions, and the database contents.

A limitation with the current GOOVI version is that many mediator definitions, e.g. queries and view properties, are not entered graphically, but as editable text string. Some system, e.g. Pesto and Jasmine, makes e.g. query specification fully graphical. Sometimes text is more convenient to enter than graphical interactions. This issue should be investigated further even though it does not alter the main principles of the system, which is the focus of this paper.

The use of Java as an implementation language provides a portable implementation and a rich library of user interface primitives. A uniform query based Java application program interface provides a flexible and high-level interaction between GOOVI and the Amos II kernel. The system is fully implemented under Windows 98/NT/2000 and downloadable from *http://www.dis.uu.se/~udbl/amos*. A Unix version of the Amos II kernel is also available with which Windows-based GOOVI clients can communicate with Unix based mediator servers.

7. REFERENCES

[AGS90] R.Agrawal, N.Gehani, J.Srinivasan: ODE-View: The Graphical Interface to ODE. *Proc. ACM SIGMOD Conf.,* May 1990.

[B99] L.Bouganim, T. Chan-Sine-Ying, T-T.Dang-Ngoc, J-L.Darroux, G.Gardarin, F.Sha: MIROWeb: Integrating Multiple Data Sources Trough Semistructured Data Types. *Proc. 25th Intl. Conf. On Very Large Databases (VLDB'99),* Edinburgh, Scotland, 1999.

[BE96] O. Bukhres, A. Elmagarmid (eds.): *Object-Oriented Multidatabase Systems.* Pretince Hall, 1996.

[CA96] Computer Associates corporation: *Jasmine Version 1.2 Tutorial*, 1996.

[CHMW96] M.Carey, L.Haas, V.Maganty, J.Williams: PESTO: An Integrated Query/Browser for Object Databases. *Proc. 22nd Conf. On Very Large Databases (VLDB'96),* 203-214, 1996.

[F89] D.H.Fishman, J.Annevelink, E.Chow, T.Connors, J.W.Davis, W.Hasan, C.G.Hoch, W.Kent, S.Leichner, P.Lyngbaek, B.Mahbod, M.A.Neimat, T.Risch, M.C.Shan, W.K.Wilkinson: Overview of the Iris DBMS, in W.Kim, F.H.Lochovsky (eds.*): Object-Oriented Concepts, Databases, and Applications*, ACM Press, 1989.

[HKWY97] L. Haas, D. Kossmann, E.L. Wimmers, J. Yang: Optimizing Queries across Diverse Data Sources. *23rd Intl. Conf. on Very Large Databases (VLDB'97),* 276-285, 1997

[G97] H. Garcia-Molina, Y. Papakonstantinou, D. Quass, A. Rajaraman, Y.Sagiv, J. Ullman, V. Vassalos, J. Widom: The TSIMMIS Approach to Mediation: Data Models and Languages. *Intelligent Information Systems (JIIS),* Kluwer, 8(2), 117-132, 1997

[JR99a] V.Josifovski, T.Risch: Functional Query Optimization over Object-Oriented Views for Data Integration. *Journal of Intelligent Information Systems (JIIS),* Vol. 12, No. 2-3, 1999

[JR99b] V.Josifovski, T.Risch: Integrating Heterogeneous Overlapping Databases through Object-Oriented Transformations. *25th Conf. on Very Large Databases (VLDB'99),* 435-446, 1999.

[JR00] V.Josifovski, T.Risch: Query Decomposition for a Distributed Object-Oriented Mediator System . To be published in *Distributed and Parallel Databases J.,* Kluwer, 2000.

[MDT88] A.Motro, A.D'Atri, L.Tarantino: The Design of KIVIEW: An Object-Oriented Browser. *Proc. 2nd Intl. Conf. On Expert Database Systems*, April 1988.

[LP97] L.Liu, C.Pu: An Adaptive Object-Oriented Approach to Integration and Access of Heterogeneous Information Sources. *Distributed and Parallel Databases,* Kluwer, 5(2), 167-205, 1997.

[MP00] K.Munroe, Y.Papakonstantinou: BBQ: A Visual Interface for Browsing and Querying XML, *Proc. Visual Database Systems (VDB) 2000*.

[RJ01] T.Risch, V.Josifovski: Distributed Data Integration by Object-Oriented Mediator Servers. To be published in *Concurrency - Practice and Experience J.*, John Wiley & Sons, 2000.

[RJK00] T.Risch, V.Josifovski, T.Katchanouov: *AMOS II Concepts*, Department. of Information Science, Uppsala University, 2000, (available at http://www.dis.uu.se/~udbl/amos/).

[SUN99] Sun corporation: JNI - *Java Native Interface*, 1999 (http://www.javasoft.com/products/jdk/1.1/docs/guide/jni/index.html).

[TRV98] A. Tomasic, L. Raschid, P. Valduriez: Scaling Access to Heterogeneous Data Sources with DISCO. *IEEE Transactions on Knowledge and Date Engineering*, 10(5), 808-823, 1998

[Wie92] G Wiederhold: Mediators in the Architecture of Future Information Systems. *IEEE Computer*, 25(3), 38-49, 1992.