1. Introduction

Open source database management systems (OSS-DBMSs) have a long history as open source software (OSS) comparable to the well-known UNIX toolkits and Linux. The different systems offer different features, but they all continue to be developed in the direction of the functions and performance of commercial DBMSs.

Some DBMSs that were developed and marketed as commercial products have recently been released as OSS. These days, there is nothing preventing a DBMS from being used in a commercial IT system simply because it is open source. One cannot hide from the fact that OSS-DBMSs have the capability to replace commercial DBMSs. Indeed, their use will be a key factor in reducing the cost of IT systems.

2. OSS-DBMS trends

The well-known OSS-DBMSs that are receiving the most attention are compared in Table 1.

2.1 PostgreSQL

PostgreSQL [1] is an OSS-DBMS project that grew out of work begun by Dr. M. Stonebreaker of the University of California, Berkeley and has the same roots as Ingres. It is based on POSTGRES Version 4.2 and continues to be developed by the open source community. PostgreSQL supports SQL92/99 [2] of the database language SQL (structured query language) specified by the ISO (International Organization for Standardization) and other state-of-the-art functions. In terms of functionality, it is unsurpassed, even by commercial DBMSs. It is covered by the BSD (Berkeley Software Distribution) license [3], which places no restrictions on use, modification, or distribution for any private, commercial, or educational use.

2.2 MySQL

MySQL [4] is an OSS-DBMS that was started in 1995 by Michael Widnies of the TcX Data Konsalt company in Sweden. It is currently being developed by MySQL AB, also in Sweden. MySQL development emphasizes performance, so it has fewer functions than commercial DBMSs. Nevertheless, it is regarded as offering particularly fast query processing and is widely used as a database back-end for Web servers. The licensing terms allow users to select either the GPL (GNU General Public License) [3] or a commercial (paid) license.
### 2.3 Firebird

Firebird [5] is an OSS-DBMS that is being developed by the OSS community on the basis of the InterBase 6.0 source code released by Borland in 2000. Functionally, Firebird conforms fully to SQL92 Entry Level 1, and most of SQL99 has also been implemented. It is a lightweight program that features easy setup and management. The licensing terms are specified by IPL (InterBase Public License) [3] and it can be used without charge even for commercial purposes.

### 2.4 Ingres

Ingres [6] is an OSS-DBMS that was announced for release as open source in May 2004 by Computer Associates International. The source code was released in October 2004. Tracing back through its history reveals that Ingres and PostgreSQL have the same roots. The licensing terms are specified by CA-TOSL (CA-Trusted Open Source License) [6], which allows incorporation into the products of other companies under the condition that the Ingres source code is supplied along with the product.

### 2.5 Derby (Cloudscape)

Derby [7] is a Java-based DBMS for which IBM released the source code to the Apache Software Foundation (ASF) in August 2004. It features a small program size of about 2 megabytes. The licensing terms are specified by Apache license version 2.0 [8] and it can be used without charge even for commercial purposes.

The source code for Ingres and Derby has only recently been released, so it is not yet clear how future development will proceed, that is to say, whether OSS development communities will form or whether a particular company will undertake development, etc. Nevertheless, a clear start has been made and these systems will probably establish a position for themselves among the OSS-DBMSs.

### 3. Overview of OSS-DBMS functionality

Here, we take PostgreSQL as an example of an OSS-DBMS that offers a large function set to show what functions these programs implement. The many functions of a DBMS can be categorized as 1) query processing functions for searching and updating the database, 2) transaction support functions, and 3) operation support functions.

1. **Basic search and update functions**
   - Although the current SQL standard is SQL99, the function set has expanded greatly, so “SQL99 Core Features” are being recommended for implementation as the basic function set. PostgreSQL 7.4 implements about 90% of the core features, excluding only those functions that are seldom used. In terms of support for SQL, this system is in no way inferior to commercial DBMSs.
   - In this respect too, a practical stage of implementation has been reached.

<table>
<thead>
<tr>
<th>Latest stable version (As of January 20, 2005)</th>
<th>PostgreSQL</th>
<th>MySQL</th>
<th>Firebird</th>
<th>Ingres</th>
<th>Derby</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ver. 8.0.0</td>
<td>Ver. 4.1.9</td>
<td>Ver. 1.5.2</td>
<td>Ingres r3</td>
<td>Ver. 10.0.2.2</td>
<td></td>
</tr>
<tr>
<td>License terms</td>
<td>BSD license</td>
<td>GPL or commercial</td>
<td>IPL</td>
<td>CA-TOSL</td>
<td>Apache license, version 2.0</td>
</tr>
<tr>
<td>Main target platforms</td>
<td>Linux, Solaris, AIX, HP-UX, FreeBSD, etc.</td>
<td>Linux, Windows, Solaris, AIX, HP-UX, FreeBSD, etc.</td>
<td>Linux, Windows, Solaris, HP-UX, FreeBSD, MacOS X</td>
<td>Linux, Windows, UNIX, OpenVMS</td>
<td>Java-based</td>
</tr>
<tr>
<td>Features</td>
<td>Implements the important functions of SQL92/SQL99</td>
<td>Functionally inferior to commercial DBMS, but processing speed is high (query processing is particularly fast)</td>
<td>Functionality fully conforms to the SQL92 entry level. SQL99 is also implemented for the most part.</td>
<td>Functionality fully conforms to the SQL92 entry level. Has the same origins as PostgreSQL.</td>
<td>Small program size (about 2 MB) allows application to small-scale systems.</td>
</tr>
</tbody>
</table>
(2) Transaction support functions

One purpose of using a DBMS is to implement transactions. The essential properties of a transaction (atomicity, consistency, isolation, and durability) are implemented by PostgreSQL to the extent shown in Table 2.

One point to note in Table 2 is the implementation of a multiple version concurrency control (MVCC) mechanism to achieve highly efficient transaction execution while maintaining isolation. Another point is the implementation of a write ahead logging (WAL) mechanism, which protects the results of transactions in the event of a system crash or other failure. In addition, the most recent version 8.0, which was released on January 19, 2005, implements a point in time recovery (PITR) mechanism that uses backup files and log records to recover a database after a disk crash or other media failure. In this respect as well, this system is approaching the same level as commercial DBMSs.

(3) Operation support functions

As utility functions for supporting operation, OSS-DBMSs are also equipped with the basic ones for backing up the database and issuing warnings when errors occur, etc.

Commercial DBMSs, on the other hand, have recently been focusing on providing complete sets of maintenance tools in addition to these basic functions. In this respect, OSS-DBMSs have yet to catch up with commercial DBMSs.

4. Using OSS-DBMS in the development of XML-DBMS

Here, we describe an example of an R&D activity with OSS-DBMS in NTT Cyber Space Laboratories. As a format for message exchange in transactions between companies on the Internet, standards based on XML (extensible markup language) are becoming mainstream. Anticipating an increasing demand for storage and retrieval of XML data in its native form, NTT Cyber Space Laboratories has been conducting research and development of XML-DBMSs.

There are two approaches to storing XML data with a DBMS. One is to store the XML data with its own structure, which is known as a native XML-DBMS. The other approach is to alter the structure of the XML data so that it can be stored in a relational DBMS (RDBMS), which has a proven record of reliability. Here, we describe Xmics/PostgreSQL [9], which is the application of PostgreSQL to the latter approach.

There are three general methods for storing XML data in a relational database (RDB), as described below (Fig. 1).

1) Store the XML data in its entirety in one column and create indexes only for the elements that serve as search keys.
2) Store it with the elements of the XML data mapped to columns of their respective tables.
3) Separate the elements into nodes and links based on the XML tree structure model and store them in respective tables.

Table 2. PostgreSQL transaction functions.

<table>
<thead>
<tr>
<th>Property</th>
<th>Explanation</th>
<th>Supporting functions</th>
<th>Extent of implementation*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomicity</td>
<td>This means that either all of the database operations in a transaction must be completed or none of them will be completed.</td>
<td>SQL statements such as BEGIN, COMMIT, and ROLLBACK for specifying the beginning and end of a transaction are available.</td>
<td>Good</td>
</tr>
<tr>
<td>Consistency</td>
<td>Transaction operations on a database that is in a consistent state (i.e., having no contradictions) must leave the database in a consistent state when the transaction is completed.</td>
<td>SQL statements such as ASSERTION are available for detecting violations of consistency when the database is updated.</td>
<td>Good</td>
</tr>
<tr>
<td>Isolation</td>
<td>Even when multiple transactions are executed in parallel, they are seen as having been executed sequentially, so that no abnormalities result.</td>
<td>The MVCC function is implemented for efficient execution of transactions.</td>
<td>Good</td>
</tr>
<tr>
<td>Durability</td>
<td>Once a transaction has been completed and the result committed as correct, the result will persist in the event of any kind of failure.</td>
<td>The WAL function, which allows the database content to be restored to normal even after a system crash, is implemented. In the recent version 8.0, recovery from media failure is also possible.</td>
<td>Fair (v. 7.4) Good (v. 8.0)</td>
</tr>
</tbody>
</table>

* compared with commercial DBMSs
Here, we explain the first two methods. The first is suitable for storing and retrieving all of the XML data as a whole and offers fast operation for that purpose. Another advantage of this method is that it can handle semi-structured XML data, which is known as “schemaless” or “self-describing”. For partial operations such as retrieving or updating only part of the XML data, however, this method takes a lot of time. In contrast, in the second method, although it takes time to input all of the data because the XML structure must be reconstructed, subsequent partial operations can be performed at high speed. Furthermore, SQL operations can be used after the data has been stored, which has the advantage of reducing the need to add to the RDBMS.

The value of using each method depends on the application program and the XML data, so is desirable for the DBMS to support both, allowing the user to select one or the other.

Xmics/PostgreSQL has functions that support both methods and they can also be used in combination. For example, method 2 can be used to update a certain range of the data in a set of XML data, and the remaining data set can be stored as a whole by method 1.

Xmics/PostgreSQL is implemented as a middleware component between the application program and PostgreSQL and another component that extends the functions of PostgreSQL (Fig. 2). This provides the application program with access to what it sees as an XML-DBMS rather than an RDB. Furthermore, a schema conversion tool that automatically creates an RDB schema from the XML schema is also provided. Although the basic technology of the Xmics/PostgreSQL system can be applied to a general-purpose RDBMS, the fact that the PostgreSQL source code is open allows optimization of the processing within PostgreSQL, making it possible to implement a fast and reliable XML-DBMS that is also highly cost effective.

5. Future development

NTT Cyber Space Laboratories will continue to improve the performance, reliability, utility, and operability of OSS-DBMSs and increase the added value of their functions in order to gain expertise in making use of them and extending their range of application.

References

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