Development of a Distributed Database System for Borehole Data using Free and Open Source Software

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Abstract
A web-based distributed database system has been developed with an aim of continuing delivery of geological data even if a large-scale disaster occurs. The distributed database system has an advantage that the system remains available if an individual database is down. The software which composes the system is Free and Open Source Software (FOSS). The distributed database is constructed by combination of PostgreSQL and pgpool-II. PostgreSQL is a powerful relational database management system. Pgpool-II has some modes for management of a distributed database. It is possible to create a real-time backup on two or more databases by Replication mode. Data can be split among multiple databases by Parallel query mode. The prototypes of a distributed database system for sharing borehole data have been successfully implemented by using Replication mode and Parallel query mode respectively.

1. Introduction

Geological information is one of the important spatial information supporting construction of secure and safe society. Since Japan is a country with many natural disasters, geological information is essential as basic elements for measures against them. Recently, geological data, such as borehole data and geological maps, and hazard maps for natural disasters are published via the internet by the national government, local governments, and research institutes in Japan. Most web systems that deliver such geological information consist of a centralized database, which are located and maintained in one location (e.g. Kawabata and Murata, 2008, Kurahashi et al., 2008 and Kimura et al., 2012). It is easy to manage the centralized database system because all data resides in a single location. However, if one database breaks, the entire system will be down. Actually, some systems delivering geological data could not be available for several days or weeks after the 2011 off the Pacific coast of Tohoku Earthquake because the centralized database was down. In the present study, a distributed database system has been developed to continue delivering geological data even if a large-scale disaster occurs. The distributed database system has an advantage that the system remains available although an individual database is down. PostgreSQL and pgpool-II (pgpool Global Development Group, 2013) which can be downloaded over the internet for free are utilized to construct a distributed database system. PostgreSQL is a powerful relational database management system. Pgpool-II has functions for management of multiple PostgreSQL servers.

2. Advantages of a Distributed Database

A system using a centralized database cannot be available if the database is down. A distributed database solves the problem. The main advantages of the distributed database are shown below:

- Increase of reliability and availability: the system remains available even if an individual database is down.
- Protection of data: all of the data will not be lost at once because database servers are located in multiple locations.
- Improvement of performance: load is balanced because a query is executed in parallel.
- Reflection of organizational structure: each distributed database is located in the related departments.

3. A Distributed Database by pgpool-II

Pgpool-II works between PostgreSQL servers and a PostgreSQL database client. In the present study, two modes shown below are used to manage the distributed database.

3.1 Replication Mode

It is possible to create a real-time backup on two or more databases by Replication mode. The synchronization of data is performed by sending a same INSERT/UPDATE/DELATE query to all PostgreSQL servers at the same time (Figure 1). The service can continue even if one of those servers is down. A SELECT query used to select data from the database is sent to a master server when both the master server and the slave server are available (Figure 2). The system remains available by sending the SELECT query to the slave server if the master server is down. The master server is used again if it is recovered.

3.2 Parallel Query Mode

Data can be split among multiple databases by Parallel query mode. The System Database is required to use parallel query. It contains distribution rules to send partitioned data to an appropriate server. An INSERT query used to insert data to the database is executed according to the rules (Figure 3). A SELECT query is executed on every server, and returns an integrated result to a client (Figure 4). If large-scale data is searched, the overall execution time will be reduced. If a database server is down, it is cut off from the system automatically and the system remains available using the remaining database server.

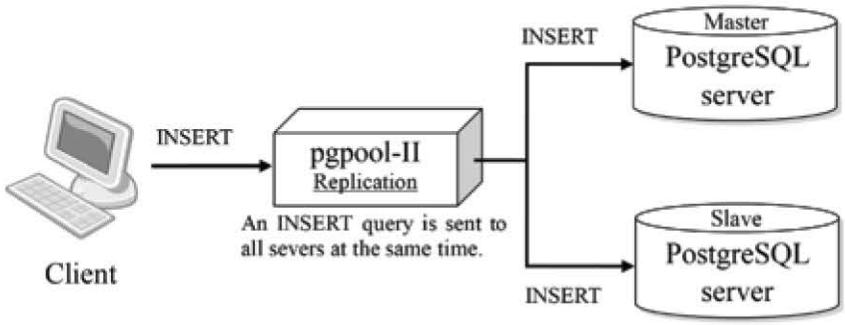

Figure 1: An INSERT query in Replication mode

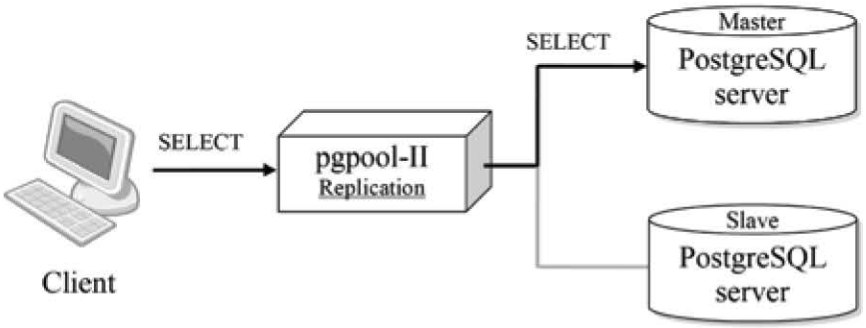

Figure 2: A SELECT query in Replication mode

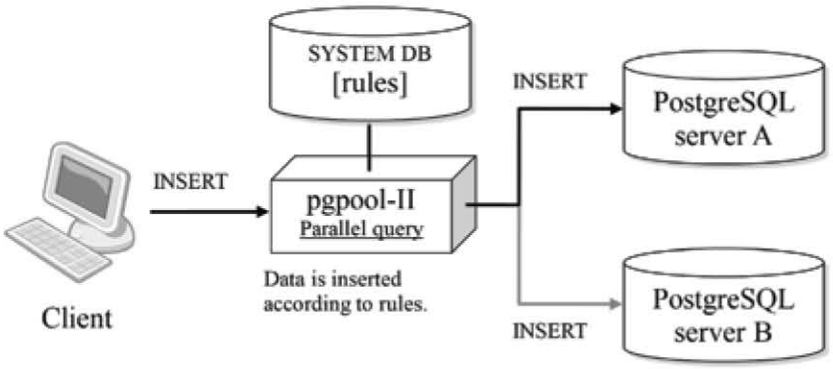

Figure 3: An INSERT query in Parallel query mode

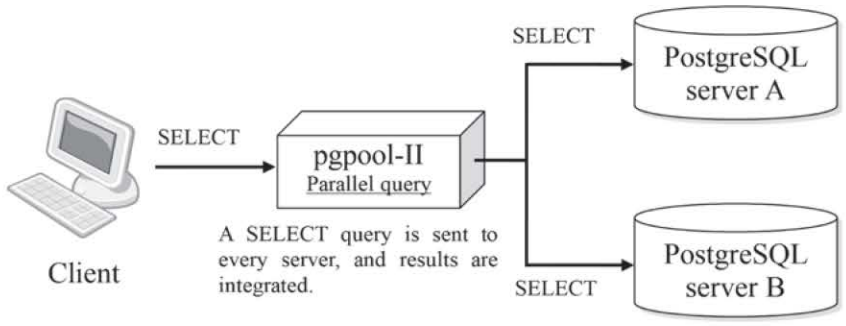

Figure 4: A SELECT query in Parallel query mode

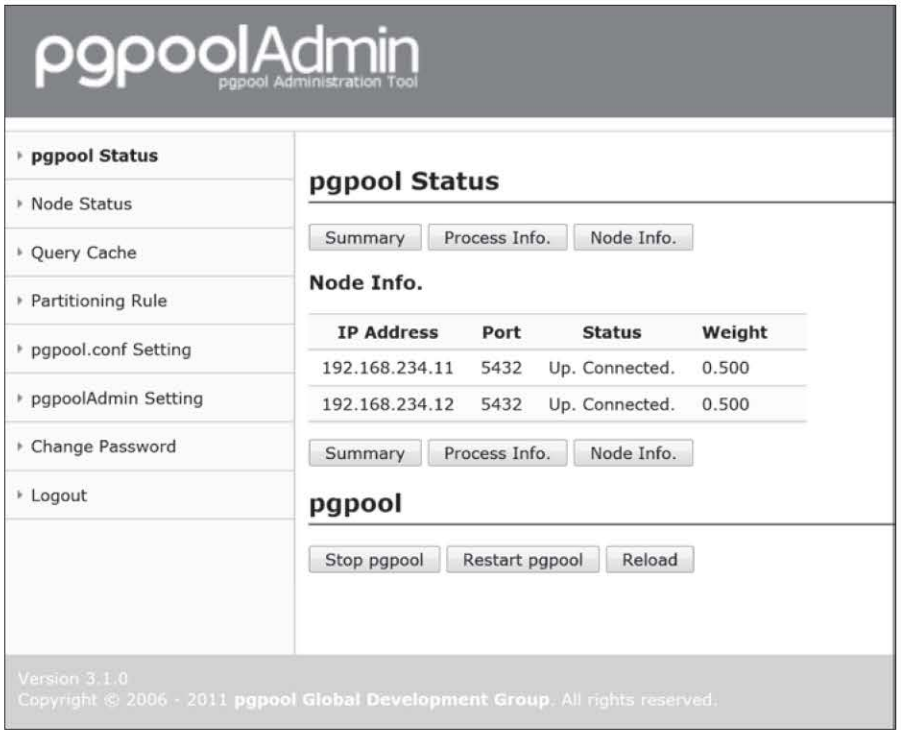

Figure 5: Pgpool Status shown in pgpoolAdmin

PgpoolAdmin is a management tool for pgpool-II. It is possible to monitor, start, stop and change settings of pgpool-II on the browser. An image of pgpoolAdmin is shown in Figure 5.

4. Prototype Systems for Borehole Data

Two prototypes of a distributed database system for sharing borehole data have been developed by extending Web-GIS system for management of geological data developed by Nemoto and Kimura, (2010). They were constructed using Replication mode and Parallel query mode respectively. CentOS Linux was selected as the development environment. The software used for prototypes is shown in Table 1.

All software is FOSS that can be downloaded over the Internet. OpenLayers is a JavaScript library to load, display and render maps from spatial data on web pages. The front-end for access to PostgreSQL was coded using the Hypertext Preprocessor (PHP).

4.1 Borehole Data

Four hundred borehole data owned by Kochi Prefecture and one thousand borehole data owned by Kochi City were used for validation of the system. The borehole data was downloaded from Web-GIS developed in Kochi ubiquitous demonstration project for disaster prevention (Nakada, 2011 and http://www.geonews.jp/kochi/).

Table 1: Software configuration

Software		Download Site
Relational database management system	PostgreSQL	http://www.postgresql.org/
Distributed database management tool	pgpool-II	http://www.pgpool.net/
Management tool for pgpool-II	pgpoolAdmin	http://www.pgpool.net/
Web-GIS client	OpenLayers	http://openlayers.org/

Table 2: Table structure of borehole data

Field name	Data type	Description
name	text	XML file name
title	text	Survey title
address	text	Survey address
lng	double precision	Longitude coordinate
lat	double precision	Latitude coordinate
log	text	Borehole log file name

The format of borehole data is an XML based on the specification of the Ministry of Land, Infrastructure, Transport and Tourism of Japan. The data of file name, survey title, survey address, longitude, latitude, and borehole log file name extracted from XML file was inserted into the distributed databases (Table 2).

4.2 Installation and Configuration of pgpool-II

A distributed database system was constructed by using Linux servers in which Apache, PHP and PostgreSQL were installed and configured to accept connections from network. The construction procedure is shown below. One server is for pgpool-II server and the others are for PostgreSQL servers.

(1) Installation of pgpool-II: Pgpool-II is installed by executing commands in order of "configure", "make" and "make install" in pgpool-II server.
(2) Configuration for authentication: The user name and password are written in pcp.conf file.
(3) Preparation of database nodes: The backend PostgreSQL servers are set up for pgpool-II. If the hostnames of two PostgreSQL servers are "192.168.234.11" and "192.168.234.12" respectively, and the port number 5432 is assigned for both servers, pgpool.conf file is edited as follows:

```
backend_hostname0 = '192.168.234.11'
backend_port0 = 5432
backend_weight0 = 1
backend_hostname1 = '192.168.234.12'
backend_port1 = 5432
backend_weight1 = 1
```

The node ID for each server is specified by added positive integers at the end of each parameter string. The backend_weight parameter is ratio for load balancing.
(4) Configuration for each mode: For Replication mode, "replication_mode" is set to true in pgpool.config file. For Parallel query mode, "parallel_mode" is set to true.
(5) Configuration of parameters for Parallel query mode: The hostname, port number, database name, schema name, user name, and password for the system database are written in pgpool.conf.
(6) Starting of pgpool-II: pgpool-II starts by executing a command "pgpool".

The following website can be referred for the details of installation and configuration:http://www.pgpool-.net/docs/latest/tutorial-en.html

4.3 Prototype by Replication Mode

The distributed database system by Replication mode has been developed using one pgpool-II server and two PostgreSQL servers. After borehole data was inserted to the system, it was confirmed that all data were registered in both databases of PostgreSQL server. Two databases are synchronized by pgpool-II. If one server is down, this prototype remains available using the other server.

4.4 Prototype by Parallel Query Mode

The distributed database system by Parallel query mode has been developed using one pgpool-II server and two PostgreSQL servers. The pgpool-II server includes the system database. PostgreSQL server with node ID 0 has a database for borehole data owned by Kochi Prefecture, and PostgreSQL

server with node ID 1 has a database for borehole data owned by Kochi City. The first 5 characters of borehole file name owned by Kochi Prefecture are "BEDKP", and those owned by Kochi City are "BEDKC". As an owner can be distinguished by the file name, a distribution rule was registered as shown below:

```
CREATE OR REPLACE FUNCTION
pgpool_catalog.dist_def_bore(anyelement)
        RETURNS integer AS $$
            SELECT CASE WHEN $1
            LIKE 'BEDKP%' THEN 0
        ELSE 1
END;
$$ LANGUAGE sql;
```

This means that data in a borehole file is inserted in the server with node ID **0** if the file name starts with "**BEDKP**", and data is inserted in the server with node ID **1** if the condition is not satisfied. After all borehole data was inserted in pgpool-II server, it was confirmed that data were registered to the appropriate server according to the distribution rule. The positions of borehole data obtained by SELECT query displayed on the map (Figure 6). As a marker of the borehole position is clicked, attribute information is displayed in a pop-up window. Moreover, if "PDF" in attribute information is clicked, a borehole log is displayed (Figure 7). Results of a keyword search are shown in Figure 8. It shows that data was obtained from both databases by sending one SELECT query.

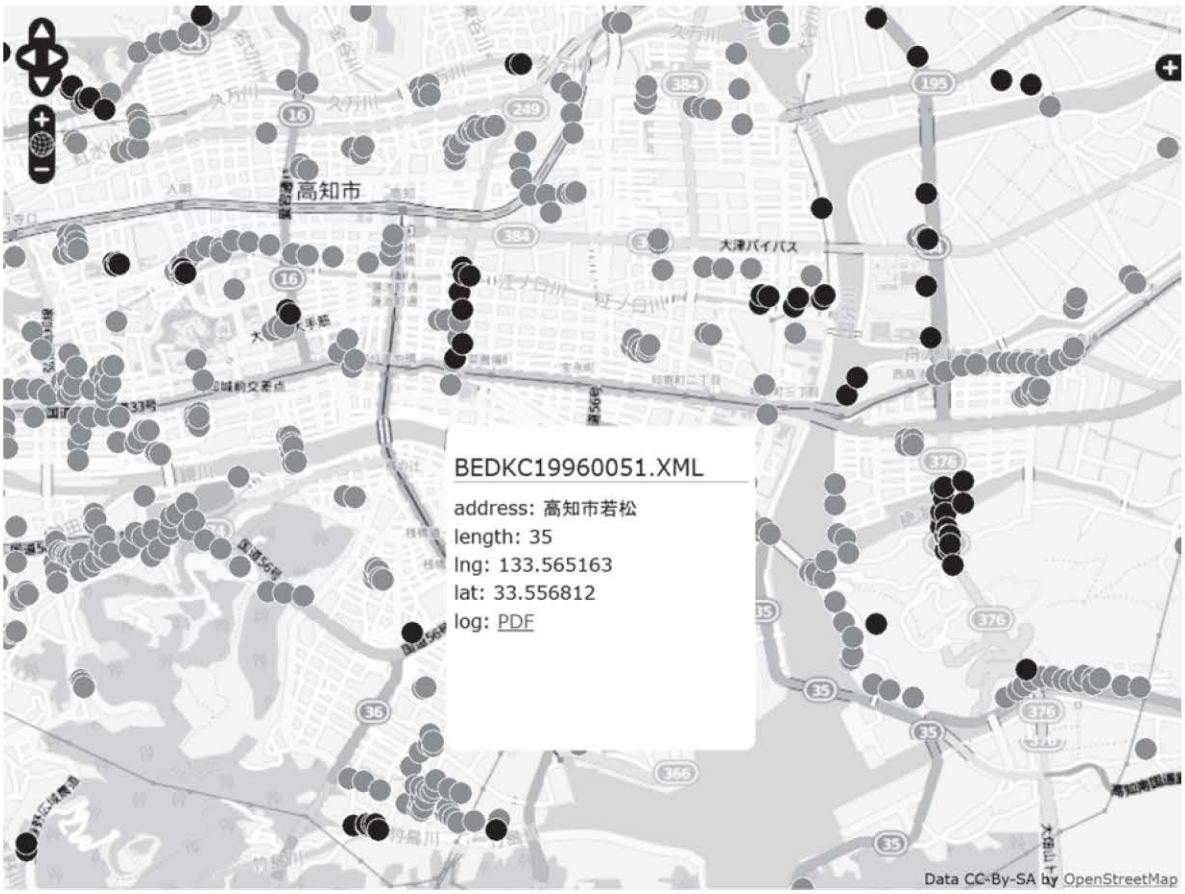

Figure 6: Positions of borehole data displayed on the map

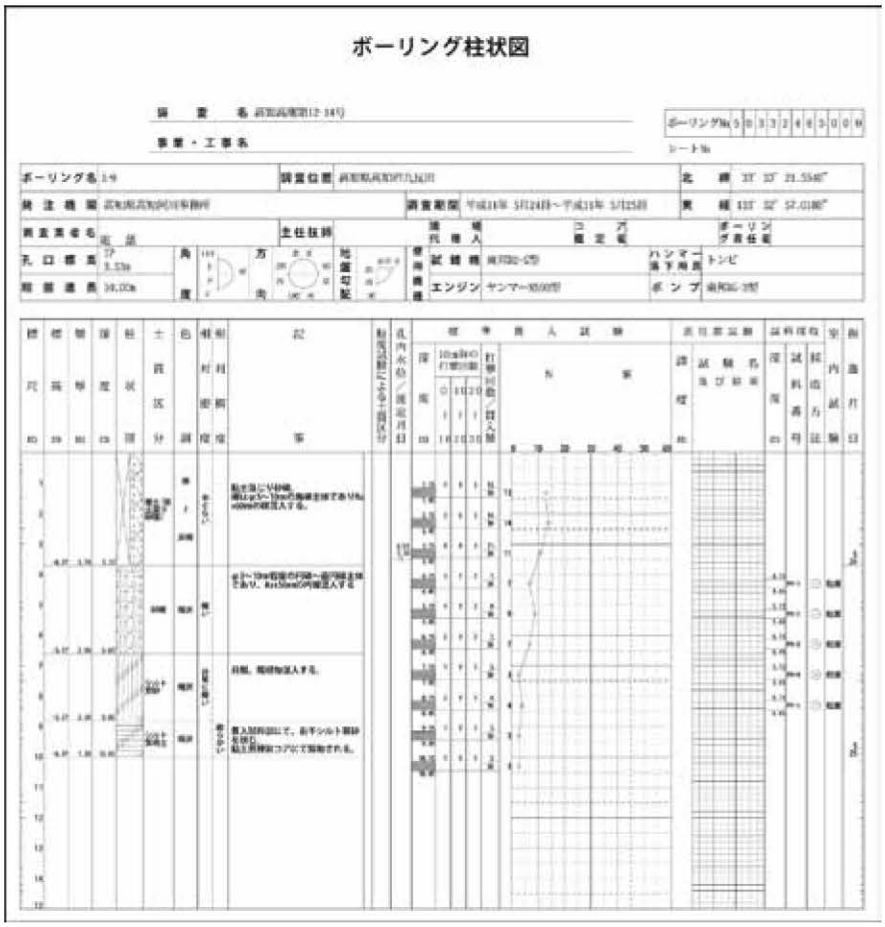

Figure 7: A borehole log

Keyword Search

XML file name Survey title Survey address

高知市 search

>> SELECT * FROM bore WHERE address LIKE '%高知市%'

Results:

XML file name	Survey title	Servey address	Coordinates
BEDKP19900006.XML	平成2年度高里沼1-2-1号都市計画街路大津白水線県単地質調査委託業務	高知県高知市大津	133.598422,33.570291
BEDKP19900014.XML	中小改第11-11号十市川地質調査委託業務　十市川改修工事	高知県高知市三里地区	133.587275,33.525912
BEDKP19990013.XML	激特第1-3-21号国分川(舟入工区)河川激甚災害対策特別緊急地質調査委託業務	高知県高知市大津	133.615132,33.576701
BEDKP19910017.XML	平成2年度　高知高潮第5-14号舟入川地質調査委託業務	高知県高知市大津	133.600048,33.572269
BEDKP19900013.XML	中小改第11-11号十市川地質調査委託業務　十市川改修工事	高知県高知市三里地区	133.587229,33.525746
BEDKC20030011.XML	下知下水処理場地盤調査委託業務	高知市小倉町	133.566810,33.560744
BEDKC19890042.XML	高須2号汚水幹線地質調査委託業務	高知市高須	133.576530,33.559219
BEDKC19840014.XML	上ノ橋地質調査委託業務	高知市大川筋	133.533312,33.564872
BEDKC19890044.XML	高須2号汚水幹線地質調査委託業務	高知市高須	133.578636,33.559304
BEDKC20040014.XML	高知市立新堀小学校屋内運動場改築工事地質調査委託業務	高知市はりまや町2丁目14-8	133.546449,33.561372

Figure 8. Results of a keyword search. First five in results were obtained from the database for Kochi Prefecture's data, and the rest were obtained from the database for Kochi City's data

5. Discussion and Conclusions

The distributed database systems with high availability has been developed by combination of PostgreSQL and pgpool-II. The user can use the systems without considering distribution of databases. The system using Replication mode has an advantage that it remains available even if one database server is down. The system using Parallel query mode has an advantage that all data is not lost at once. Although it might takes the cost for servers

in comparison to a centralized database, the advantages are great. If a centralized database is implemented by PostgreSQL, it is possible to extend it to a distributed database by using pgpool-II. The prototype system developed in the present study can be customized easily because it consists of FOSS. Further development and improvement of the system are necessary to manage and share various spatial data in addition to borehole data.

Acknowledgement
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References

Kawabata, D. and Murata, Y., 2008, Development of G-INDEX based on WebGIS. *Proc. 33rd International Geological Congress*, CD-ROM.

Kimura, K., Ooi, M. and Nemoto, T., 2012, Information System for Borehole Data in Japan. *Proc. 34th International Geological Congress*, CD-ROM.

Kurahashi, T., Sasaki, Y. and Inazaki, T., 2008, Development of Internet Web Service Providing Borehole Data, KuniJiban. *Proc. 33rd International Geological Congress*, CD-ROM.

Nakada, F., 2011, A Proposal on Sharing and Reusing Geotechnical Information Based on "Kochi Ubiquitous Demonstration Projects for Disaster Prevention". *Geoinformatics*, 22, 189-200.

Nemoto, T. and Kimura, K., 2010, Development of Web-GIS System for Sharing and Visualizing Geologic Data. *Proc. GIS-IDEAS2010*, 119-124.

pgpool Global Development Group, 2013, *pgpool-II manual*. http://www.pgpool.net/download.php?f=pgpool-en-3.3.0.pdf