# Global Digital Museum(5) Global Search

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## Introduction

A museum is a cultural place where shows a huge amount of a cultural heritage. Famous museums in the world usually have a high quality of contents that contains sculpture, ancient manuscripts, cultural photographs, historical goods and so on. Locations of museums are geographically dispersed in the world. Each museum has its own contents, and these contents are normally placed in the museum. For example, if you need to study the history and its related topics with museum contents, you have to go to museums. It is also difficult to find the specific content exactly when you are in the museum.

We are building the Global Digital Museum(GDM) that is the system for the digitized museum for museum education. The goal of the GDM is to establish the digitized museum where users can navigate and retrieve museum contents in digital and edit contents for their studies[1][2][3][4]. The GDM system is the distributed system that each host is interconnected via the Internet. The host is used for the same protocol to the access for the other host. Since there are multiple GDM hosts on the Internet, one of key functions in the GDM is the distributed search that calls Global Search to retrieve contents. To archive seamless access to multiple hosts, the system provides the single access image for the end user.

In this paper we describe the design and the development of the distributed search function in the GDM. The characteristic of the distributed search in the GDM is to find the nearest host on the network. As the function for finding the nearest host on the network is evaluated at each query and is stored, the nearest host is changed at the evaluation. The mechanism for the evaluation keeps a good transfer rate on the network.

## Background

The usage of the Internet is rapidly increasing these days. Although the Internet is widely used for many areas, the underlying network protocol that is the IP protocol still causes the packet loss because of misconfiguration of routers or the congestion on the network. The transport protocol that is the TCP has to guarantee the reliable service to recover the packet loss with the retransmission of the lost packet. As the result of the retransmission for lost packets, there is a performance degradation between end-to-end hosts on the network.

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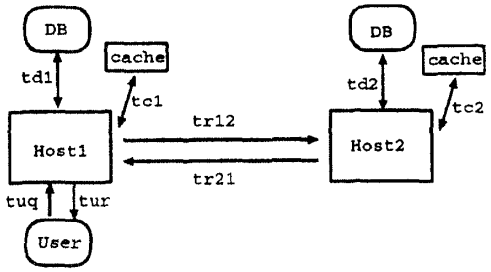


Figure 1: Cache and database

The unreliable network such as the Internet is the issue for the search and the retrieval function to degradate the performance. It is known that the Internet has the packet loss about 10% or above. If the distributed search takes time to retrieve data from the remote host, users have the unwanted long waiting time. The distributed database should be improved on the Internet.

The GDM system is used for the hyper-link database that consists of a node and a link. The hyper-link database is stored in the relational database. The node consists of the meta data that is information for the object and the object that is the text, the image and the video. The search is done for the meta data that has the related information of the object. The search result is sent back to user and it is stored in the local and remote cache file for the later use.

The set of the node and the link in the hyper-link database represents the museum contents. The part of the hyper-link database can be replicated to other host because of the performance improvement. This is the replication of the database.

## Cache for contents

The GDM system is used for the relational database to store the hyper-link database that manages museum contents. The cache function in the system is used to improve the performance for the search of remote hosts. The index of the cache file uses the simple hash file. The hash file is used for the search instead of the relational database. There are four methods for the access to the remote data. These are 1)local access time without cache, 2)local access time with cache, 3)remote access time without cache and 4)remote access time with cache.

Simple equations show the comparison among these four methods.

The figure 1 shows the configuration of the cache function. Let $t_{r12}$ be the transfer time from host1 to host2, and let $t_{r21}$ be the transfer time from host2 to host1. Let $t_{c1}$ and $t_{c2}$ be the retrieval time from the cache data on host1 and host2. Let $t_{d1}$ and $t_{d2}$ be the retrieval time from database on host1 and host2.

The search time of database is always less than that of local cache file ($t_{c1} \leq t_{d1}, t_{c2} \leq t_{d2}$). Let $t_{uq}$ and $t_{ur}$ be the query time from user and the reply time to user. The following equations are the processing time for each search. The processing time for local cache is $t_{lc}$, that for local database is $t_{ld}$, that for remote cache is $t_{rc}$ and that for remote database is $t_{rdc}$. Following equations are defined.

$$t_{lc} = t_{uq} + t_{c1} + t_{ur} \quad (1)$$

$$t_{ld} = t_{uq} + t_{d1} + t_{ur} \quad (2)$$

$$t_{rc} = t_{uq} + t_{r12} + t_{c2} + t_{r21} + t_{ur} \quad (3)$$

$$t_{rd} = t_{uq} + t_{r12} + t_{d2} + t_{r21} + t_{ur} \quad (4)$$

If the index for the cache is stored in local file, the fast retrieval can be done. Since the retrieval time for the remote and local host is almost same ($t_{c1} \approx t_{c2}$, $t_{d1} \approx t_{d2}$), the transfer time that is defined as $t_{r12}$ and $t_{r21}$ is critical for the performance. Those transfer times depend on the packet loss and the delay of the Internet. The packet loss causes the degradation of the performance and the transfer time on the Internet is longer than we expected. To improve the performance, recent queries should be placed in the local cache. If the cache data is searched, the data should be stored into the local database. The replication of the remote data also improves the performance of the transfer.

$$t_{lc} < t_{ld} < t_{rc} < t_{rd} \quad (5)$$

If the cache data exists in the local database or local cache files and another query is sent, the server can retrieve data from the local cache without the query to the remote host. In this cache hit case, as there is no actual data transfer on the Internet, the performance of the data transfer is improved. This is an efficient method at the low transfer rate or at the network that causes the packet loss.

## Replication

The replication of data in the hyper-link database is done by the retrieval of the museum content at the reply for the query. The local host retrieves the content from the remote host and to user. The content is stored to the cache file at the same time. When the retrieval from the remote host is the content that is requested at the previous time, the replicated data is sent back to the remote host. If the read-only or almost read-only contents are stored in the database, the replication of the database improves the performance.

The replicated data is expired at the original expiration time that comes with the content. The remote host also removes the replicated data for their space or the management for the host.

## Neighbor host

The distributed search is to search objects on multiple remote hosts. The simplest method of the distributed search is that the query is sent to multiple hosts at the same time and that replies for the query are got from those hosts. The nearest host has to be found out to retrieve contents with the good performance.

What's the neighbor host on the network? It isn't only the hop count on routers but also the bandwidth of the path. It's a distance between hosts on the network. The distance of the host on the network is defined as the function of the delay bound and the packet loss. The bandwidth is directly related to the packet loss. If the packet loss rate is high, the actual bandwidth of the network is decreased. Even if the bandwidth is high, there is a long delay of the path.

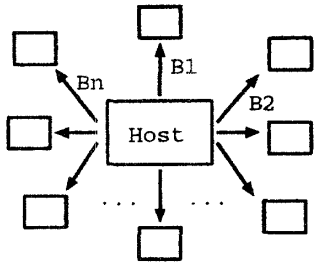


Figure 2: Finding the nearest host

The finding neighborhood with delay and packet loss is to use 1)the history of transactions and 2)the probe packet to investigate the current status of the network.

Each transaction of previous queries has time stamps for hosts. We can get both the transferred time and the transferred amount for the remote host, and calculate the transfer rate. If the transfer rate for the remote host is high, the remote host is the closer place than other hosts. The highest transfer rate will be the nearest host.

The packet loss rate is directly affected to the transfer rate. If the packet loss is high, the transfer rate is low. If the packet loss is low, the transfer rate is high. The delay investigation is the return value from the remote host. The most recent measurement is used for the delay estimation. The measurement value is expired at the certain time. As the delay is higher than other hosts, the distance is large. As the delay is lower than other hosts, the distance for the remote host is small.

The figure 2 shows the nearest host on the network. The bandwidth of remote host shows $B_1, B_2, ..., B_n$, and the minium bandwidth $B_m = (B_1, B_2, ..., B_n)$ is determined in previous transactions.

## Conclusion

The paper describes the global search in the GDM system. It focuses on the improvement of the search performance with both the cache for the index of the search result and the replication of the hyper-link database. The finding method of the nearest host is also described.

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