XML 기반 ACL로 통신하는 멀티에이전트 시스템을 이용한 P2P DICOM 시스템

(P2P DICOM System using Multiagent Systems Communicating with XML Encoded ACL)

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요 약 현재 병원에서 구축되어 사용되는 PACS 시스템은 대용량의 데이터를 취급하고, 의료 영상 정보의 관리도 서버에 집중되어 이루어짐으로 서버의 부하가 크다. 의료 영상은 DICOM 표준을 따라 만들어지고 운용되는데 크기가 크고 이동 빈도가 높은 의료 영상 데이터를 효율적으로 관리하기 위해 의료 정보의 분산된 관리 체계를 제시한다. 의료 정보의 분산 관리 및 전송은 네트워크의 부하와 서버의 부하를 줄여서 효율적 자원의 사용과 서버 시스템의 성능 향상이라는 효과를 가져올 것이다. DICOM PC to PC 컴포넌트는 요청한 질의를 처리하는 서비스 매니저와 파일의 전송을 담당하는 커뮤니케이션 매니저, 그리고 데이터의 저장과 시스템 동작을 담당하는 DICOM 매니저로 구성되어 있다. 각 컴포넌트는 에이전트로 구현이 되었다. 각 컴포넌트 간의 메시지 통신은 에이전트 통신 언어로 코드화된 XML 문서를 사용한다.

본 시스템은 기존의 DICOM 서버에서 요청 받은 질의를 수행하여 중앙집중적으로 처리했던 파일관리와 전송 방법을 각각의 PC에서 파일 관리 및 전송을 분산적으로 처리함으로써 서버가 처리하던 일의 과중을 분산 시켜서 의료 영상 전송과 관리에의 효율을 증대시킨다.

키워드 : 의료 영상 전송, 분산 관리, PACS, DICOM, PC to PC 질의 멀티 캐스트 방법, 멀티 에이전트 시스템, 에이전트 통신 언어(ACL), XML

Abstract We suggest a distributed communication and management methodology using PC to PC Query multicasting strategy for efficient management of medical images produced by DICOM(Digital Imaging and Communications in Medicine) Modalities. It is absolutely necessary to reduce strict degradation of PACS system due to large size of medical images and their very high transport rates. DICOM PC to PC Component is composed of a Service Manager to execute requested queries, a Communication Manager to take charge of file transmission, and a DICOM Manager to manage stored data and system behavior. Each Manager itself is a component to search for requested file by interaction or to transmit the file to other PCs. Distributed management and transformation of medical information based on PC to PC Query multicasting methodology will enhance performance of central server and network capacity, reducing overload on both. We organize three major components for system operation. Each component is implemented as Agent. Communication between agents uses XML encoded Agent Communication Language

Key words : Medical image communication, Distributed management, PACS, DICOM, Query multicasting methodology, Multiagent system, Agent Communication Language, XML

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1. Introduction

DICOM is the standard of medical imaging storage and communication established by the ACR(American College of Radiology) and NEMA(National Electrical Manufactures Association) in 1983.

The MultiAgent System is an integrated system through which autonomous agents communicate with each other, and share knowledge[1,2]. The MultiAgent System is composed of Agent Management, Agent message Communication, and Agent Message Transport in FIPA(Foundation for Intelligent Physical Agents)[1] Specification.

The Agent Management executes operation with AMS(Agent Management System), DF(Directory Facilitator) (Figure 1). AMS takes responsibility for agent management and DF takes a role of agent yellow page. To receive the services of an agent platform, the agent must register itself in the platform. The AMS performs agent registration process. After registration, the agent can communicate with other agents and advertise itself through DF. FIPA defines ontology and AMS/DF functionality related to agent management[3].

ACL(Agent Communication Language) is a language used for communication between agents[3]. In FIPA2000, DTD(Document Type Definition) for XML-encoded ACL is suggested[4].

XML(eXtensible Markup Language)is a markup language for documents containing structured information. Structured information contains both content(words, pictures, etc.) and some indication of what role that content plays(for example, content in a section heading has a different meaning from content in a footnote, which means something different than content in a figure caption or content in a database table, etc.). Almost all documents have some structure. A markup language is a mechanism to identify structures in a document[5].

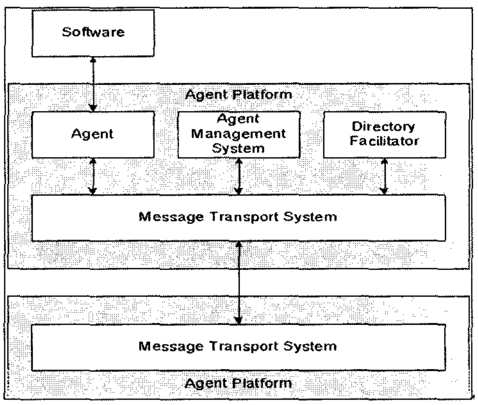

Fig. 1 Agent Management Reference Model

1) FIPA is a non-profit organization aimed at producing standards for inter operation of hetegeneous software agent

The PACS(Picture Archiving and Communications System) system built and used in hospitals nowadays has quite a significant overload on the central server because of both treatment of very large data and full management of medical images.

PACS is a system which transfers and stores medical images using DICOM standard. PACS has become more and more important for construction of complex hospital information system that stores and retrieves medical images, transfers them to diagnostic workstations, and manages medical information and communications between the Hospital Information System and the Radiology Information System[6,7,8]. PACS system that uses digital images instead of films and supports a continuum of information management with a database of medical image information has many benefits due to cost effectiveness. Operation of PACS is focused on the flow of DICOM files.

PACS system using DICOM puts a serious load on its central image server because it handles a large amount of data. Duplicated image transmission leads to serious degradation of the central image server and waste of the network bandwidth.

2. Related Works

We apply P2P(PC to PC) communication protocol for medical image file transfer mechanism in which DICOM PCs store image files for image users near by, but query UID(Unique Identifier)s of image files to the central image server in order to acquire, in case of not storing the necessary image files. Then the DICOM workstation queries to other workstations nearby to determine if it has the file UID. If it has the file UID, it transfers the file to the DICOM workstation with PC to PC file transfer protocol. This file transfer and management are executed focusing on movement of the medical image to be related with patients.

The CIS(Central Image Server) system stores medical images into databases in the central server of PACS only. When a Client requests the necessary images, the CIS processes the query and sends matched medical images to the client. There are heavy loads on CIS for query processing, database management, image UID management, and DICOM communication(send, receive DICOM files).

P2P System is the alternative of CIS.

1) File management: In CIS system, CIS only manages DICOM files. In P2P System(PC to PC Component System), each PC manages DICOM files. In this case, even P2P system needs more complicated management, it can reduce loads on system, and works more efficiently.

2) Image UID management: In CIS system, CIS only manages image UID. In P2P, each PC manages image UID. In this case, P2P system is more efficient in the face of system load and complexity.

3) Query Operation: In CIS system, CIS only processes requested query. In P2P, each PC processes its request query. In this case, P2P system is more efficient about system load and query processing by distributing them. But there are additional load on each PC to process queries.

4) DICOM communication: In CIS system, each PC serves DICOM Storage service as SCP (file receiver). In P2P, each PC serves DICOM Storage service as SCU (file sender) and SCP (file receiver). Because each PC roles as both sender and receiver with DICOM standard, clients can act as file senders and as a file receivers also. And this way of communication makes network efficiently than CIS that only server can send files.

There is a research that focused on the reducing loads of central image server, Distributed PACS.

Distributed PACS stores image data considering the task in distributed Storage system. each workstation has local image storage that acts as a temporal image storage like caches. local database stores data using Prefetching Algorithm. Prefetching algorithm is the method which get data from central server before they are requested and stored in local storage. In distributed PACS system, Data transfer takes long time, If there were no result about requests. And all of these are processed in server

In P2P system, query data transferred from neighborhood PC. It can reduce server dependency and can speed up the transferring rate. Because there is no result in neighborhood, In first time, when there are few images in local PC, each PC often accesses server to find requested image. when they have enough images, accesses to server can be reduced.

3. Scenario

The following Scenario(Figure 2) is a Case example of the needs for PC to PC multicasting methodology. It is made intentionally.

Patient A who has symptoms of a disease visits a department of family medicine in a Hospital. The General Practitioner advises the patient A to take a CT photograph at the department of radiology after performing the patients's physical examination. He guesses that the patient A may have liver cancer because the patient's symptoms are similar to those of a liver cancer patient. As soon as the patient A has his CT taken the department of diagnosis radiology, the acquired image is stored into the central DICOM server's storage system and radiologist diagnoses the CT images. The images are transferred to the department of internal disease with the radiologist's diagnostic letter of opinion. Internal disease doctor B accurately diagnoses the patient's symptoms with the patient's other physical examinations or laboratory results and radiologist's letter of diagnostic opinion. He temporarily hypothesizes that the patient has liver

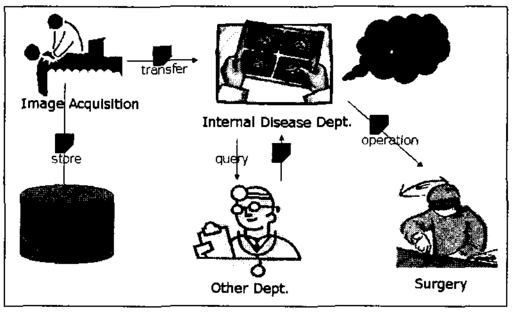

Fig. 2 Illustration of Scenario

cancer and collects the liver cancer patients' images into his private folder. He requests that several PCs and departments transfer liver cancer images similar to this patient's case and he awaits their response. Similar liver cancer images are transferred to internal disease physician B's PC. Internal disease physician B compares transferred images with the patient A's images exceedingly carefully. Finally he diagnoses that the patient A has liver cancer and says that patient A should have an operation will be executed as soon as possible. Patient A's images are transferred to the department of surgery and patient A's operation schedule is set in this department. Patient A's images from the department of diagnostic radiology are transferred to the surgery department via the internal disease department. While transferring, those images are stored into every diagnostic PC. Patient A's special diagnostic images are regarded now as new liver cancer images and they are transferred to another PC if requested from other internal disease department PCs or other department doctors.

As shown in the above clinical circulation, PC to PC DICOM image communication occurs very often. PC to PC communication, rather than the central image server, has benefits of reducing server load and of efficient network performance through image transfer from and to each diagnostic PC in every department of the hospital[9].

4. System Policy

If we support management of DICOM files based on P2P communication, the load of DICOM server is reduced enhancing the performance of distributed PCs and the efficiency of the network system is improved. The following criteria should be considered to enhance the performance of PACS.

1) Policy of file management: Since each diagnostic workstation does not have an infinite amount of storage, they may have medical images to be retrieved frequently by other diagnostic workstations or by themselves. Optimal distribution of medical images is that the central server of PACS allows only one time of retrieval to the distributed PC diagnostic workstation systems and each client retrieves the necessary images from the nearest diagnostic workstation systems. This reduces the load of the DICOM server in PACS and helps maximize the performance of the PACS. Since a series of medical images like MRI or CT tend to be accessed simultaneously, we try to manage DICOM files efficiently by grouping them based on their semantically continuous relationship.

2) Query: DICOM files are retrieved only via query and their relationship for management of DIOCM files also needs to be stored. However, it requires many resources to store many relationships. We must consider the trade-off between efficient query and quantity of resources.

3) Transmit and query method: Multicasting enables to send queries to distributed diagnostic workstations at the same time[10]. Since medical images are retrieved via patient information, its efficiency will be maximized when multicast packets are involved with information related to query, instead of simple UID of medical images.

4) Query response Policy: It is a more important problem to decide how long to wait after sending the specific or general query to distributed diagnostic workstations. While the fixed time waiting is not desirable in the dynamic environment of PACS, we measure statistically the response time from the time of multicasting a dummy message to the time of response by the last diagnostic workstation. We calculate it periodically so that the performance of the network system is continuously monitored. If we can't find the patient images from distributed diagnostic workstations after passing the statistical response time, we access the DICOM central server because distributed diagnostic workstations don't have it (Figure 3). If we receive multi responses from distributed diagnostic workstations, we select the diagnostic workstation to send the first response and retrieve the patient images because the diagnostic workstation is nearest or the performance of network subnet system including the best diagnostic workstation. The files of the patient images should be locked not to be removed from cache but to be

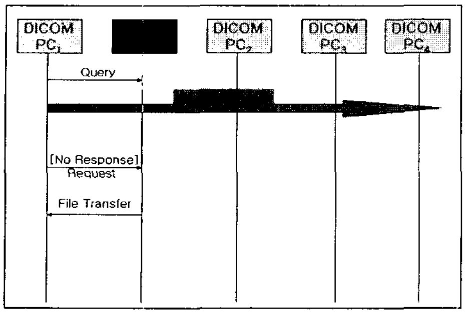

Fig. 3 Operations of P2P component image received from server

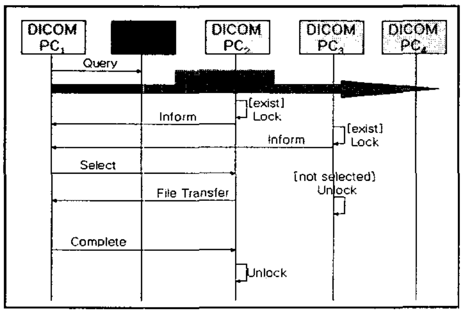

Fig. 4 Operation of P2P Component image received from other PCs

transmitted. We unlock them to complete their transmission[11]. In case a diagnostic workstation is not selected, even if it sent the response message that it is able to transmit the patient images, it unlocks the files of patient images after the statistical response time (Figure 4).

5. DICOM P2P System Component

Considering the above criteria, The DICOM P2P system consists of P2P Service Manager for query, Communication Manager for transmission of file, and DICOM Manager for management of the whole system communicating with those two managers. (Figure 5) Every diagnostic PC in the hospital sends DICOM P2P query or request to other PCs, transfers the images using this P2P protocol, and stores the DICOM file in its local database. DICOM files are transferred within the Intranet environment. DICOM Manager receives service requests from other PCs, analyzes requests, and updates management

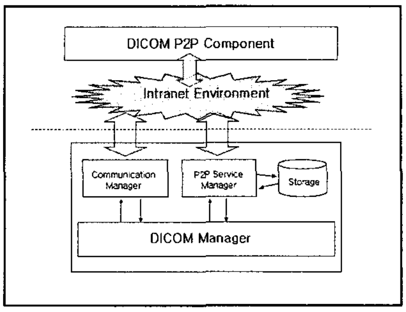

Fig. 5 Organization of DICOM P2P Component

information by P2P Service Manager. P2P Service Manager transmits service results to DICOM Manager to be able to access the database, if this service can be executed in his own PC. If not, (e.g. query file doesn't exist), this service is canceled. DICOM Manager updates management Information and transmits the executed results to the PC that requested the service via Communication Manager.

5.1 P2P Service Manager

P2P Service Manager analyzes the query from other PCs and responds to the query. Some of the examples of queries are as follows:

- Find images of given Patient ID
- Find images of given Modality UID
- Find images of given Image acquisition date

The patient information stored into the database for query operation has Patient Id, Series Number, Image Number, Modality UID, Image acquisition date, and body part. The P2P Service Manager finds the query images by accessing database and transfers the found medical information to DICOM Manager[12]. Otherwise, it broadcasts the query for images to other PCs.

5.2 Communication Manager

Communication Manager communicates with PCs to send image information transferred from DICOM Manager. The establishment of a connection between the two sides starts the transmission of DICOM files. DICOM service for establishing the connection is called an Association service. A PC that wants to establish the connection sends an association request and the opposite side sends an acceptance message and the connection establishment is complete. In the case of transferring a DICOM file, DICOM store service is executed. The sender side transfers move-request to pass the file and the receiver side signalizes its stand-by status by transmitting move-accept. Then the sender side transmits a store request and starts to transmit the file. The receiver side sends a store accepts when it is completed. The connection establishment is released by sending a release request from the sender side and by receiving a release acceptance from the receiver side[13].

5.3 DICOM Manager

The DICOM Manager administrates all the system components. The DICOM Manager sends image information to the Communication Manager. It also communicates with the P2P Service Manager about a send/receive query for finding medical image. It administrates all the information of the DICOM file in a current PC, information of files to send, and information of files to request transmission to another PC. It makes a scheduling for request of file transmission to many other PCs. Also, it manages a timer to prepare for non-response of a requested query.

6. Agent Communication

We used MAMI (Multiagent for Medical Information) as the agent platform for medical information. MAMI follows FIPA's agent management reference model.

Agents that reside in the inner platform are AMS, DF, ACC(Agent Communication Channel) and the Delegate agent (Figure 6). ACC exists in the previous specification, handles a special message transport such as an inter-platform communication. The message format used in MAMI is XML encoded FIPA ACL, and it adopts semantics of FIPA CAs (Communicative Act) and parameters[4]. Table1 shows meaning of parameters in FIPA ACL

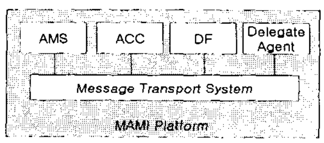

Fig. 6 MAMI Platform

Table 1 FIPA ACL Parameter

Parameter	Meaning
:sender	Id of sender
:receiver	Id of receive
:content	Message content
:reply-with	Used for identifying response of which message
:in-reply-to	Pair of reply-with
:envelope	Information need for message transport
:language	Language used in content
:ontology	Ontology in message
:reply-by	Response time
:protocol	Protocol in message
:conversation-id	Identify communications

XML encoded ACL's advantage are as follows.

-Development of parser is easy

-Making web friendly agent

-Document Based ACL

DICOM P2P components, as we described in Section 5, are implemented to agents on MAMI Platform. These agents communicate with each other using XML encoded ACL. The communication act model is described in Figure 7.

The flow of communication messages for valid specific operations is as follows.

An agent (DICOM P2P Component System A) that wants to find DICOM files multicasts <message> (Figure 8) which includes a query to search for theses.

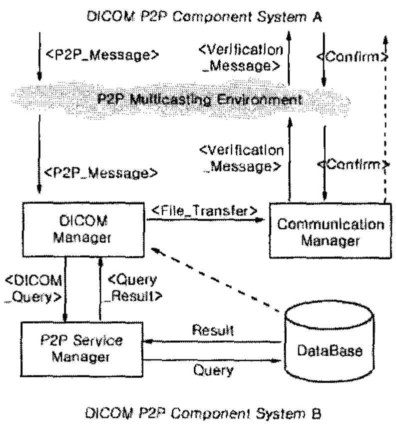

Fig. 7 Communication Message Flow

```
<message>
<messagetype>P2P_Message </messagetype>
  <sender>
     <agent-identifier>
              <sender_ip></sender_ip>
              <sender_name></sender_name>
     </agent-identifier>
  </sender>
  <receiver>
    <receiver_ip></receiver_ip>
    <receiver_name></receiver_name>
  </receiver>
  <language></language>
  <protocol></protocol>
  .....
  .....
  <content>
    <DICOM_query>
              <query_id></query_id>
              <modality_ID></modality_ID>
              <date></date>
              <patient>
                <patient_ID></patient_ID>
               <patient_name></patient_name>
              </patient>
    </DICOM_query>
  </content>
</message>
```

Fig. 8 <P2P_Message> main structure

The <sender> tag is information about agent that needs DICOM Image Files. The <receiver> tag is information about agent that receives this query message. If there is a specific agent to receive it, <receiver> includes this agent's information. But if there are no specific agents, the data of this part will be empty.

The DICOM Manager that receives the <message> checks the <receiver> field first. If the data field is empty, it receives the message unconditionally. If not, it compares information to itself.

After the complete checking, the DICOM Manager separates the <DICOM_query> part from the <message>, because the <sender> and the <receiver> are not needed for communication between the DICOM Manager and the P2P Service Manager.

The P2P Service Manager converts the <DICOM_query> message into database query.

<Query_Result>(Figure 9) is sent to DICOM Manager. If there is no query result, it sends empty message. When DICOM Manager receives <Query_Result> message, it makes <File_Transfer>(Figure 10) to send to Communication Manager.

It contains the query result (file location), sender, and receiver. The DICOM Manager sets <sender>and <receiver> again. In the <sender> field, the DICOM Manager sets information about itself and sets in the <receiver> field information about which the Agent sent the first message. If the query failed, the DICOM_Manager does not send the message to Communication Manager.

```
<message>
....
....
<content>
  <Query_Result>
          <SOPInstUID></SOPInstUID>
  </Query_Result>
</content>
</message>
```

Fig. 9 <Query_Result> message

```
<message>
....
....
  <sender>
    <agent-identifier>
      ...
  </sender>
  <receiver>
    ....
  </receiver>
  ....
  <content>
    <File_Transfer>
        <file_location></file_location>
    </File_Transfer>
  </content>
  </message>
```

Fig. 10 <File_Transfer> message

Communication Manager checks the <file_location> field about when to receive the <File_Transfer> in <message>. If the<file_location> is valid, the Communication Manager generates a <Verification_Message> (Figure 11).

```
<message>
  <sender>
  ....
  </sender>
  <receiver>
  ....
  </receiver>
  ....
  <content>
    <Verification_Message>
      <query_id></query_id>
    </Verification_Message>
  </content>
</message>
```

Fig. 11 <Verification_Message>

It simply consists of <sender>, <receiver>, and <query_id> from <DICOM_query> in <message>. Sending this message means a successful query and there are some results, because this is sent when the query has been completed.

The Agent that sent the first message waits for <Verification_ Message> from other Agents. When it receives the <Verification_Message>, it sends <Confirm> messages to the Agent that first sent the <Verification_Message>.

After receiving the <Confirm,> the message Communication Manager sends the DICOM Files to the requested Agent.

7. Simulations

With the Windows environment, main operations such as accessing to database, requesting and processing queries, and transferring DICOM files were implemented by C++ language and Visual Basic and MS SQL Server.

The simulation environment consists of 100 nodes that request medical images and each node executes varieties of operations described in Section 4. We assume that images requested by nodes have the normal distribution. Since images of patients who are taking medical treatment are accessed frequently, it is reasonable that images appear as normal distribution. The images' peak normal distribution curve shifts slightly into the right side along with the elapsed time. This gives simulation similar effects when new images are obtained and those images are used in medical treatment. Also we assume that there are 100 nodes, and 10 nodes, 10% of 100 nodes that each node requests images. 10% of total nodes send requests queries. When initial state, each PC accesses to server because it has no images. As time goes, each PC has images increasingly. So transferring images between PCs are happened more often than server. As I summed that resent files may requested more, this phenomenon looked more explicitly. Figure 12 and 13 show the results of a simulation. The X-axis represents time and the Y-axis represents the rate of the central server to be accessed when no nodes have requested images. As shown in figures, the central server access rate converges into certain rate after some period. Figure 12 shows the result when each node has 100 blocks for image storage, and 50/80% of probability of being online. It says that if there are more PCs that send queries and store images, dependency on server are reduced. Figure13 shows the result when each node has 50/100 blocks for image storage, and 80% of PCs are online. The cache that store data to local system reduces access to server. The number of the caches effects little on server dependency. Because there are little processing on data. We can expect that the number of accesses to server will reduce if there are many caches with data that will be stored to local database. Simulation results show that the perfor- mance is affected by each node's status on PC's online rather than storage space of each node. Although we try to simulate a real access pattern in Kyungpook National University Hospital in Daegu, Korea, there may be some differences from other hospitals. However, the simulation results show the proposed method can significantly reduce the central server load.

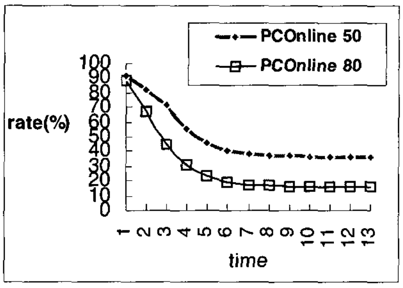

Fig. 12 Server dependence rate by online PCs' status

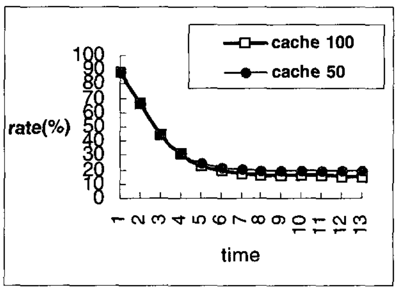

Fig. 13 Server dependence rate by node cache

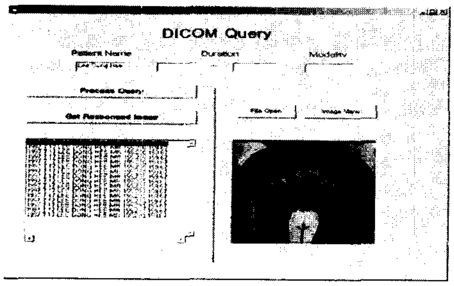

Fig. 14 DCIOM Query Operation Program

8. Conclusions and Future Works

Under the a P2P system environment, if a client requests query for specific DICOM file, the message is sent to other PCs simultaneously. Three Agents of our system send/receive message for operation and its results including DICOM files are sent to the requested client(PC).

DICOM P2P component makes each PC transmit medical images and manages them so that the load of the central server is more reduced and network bandwidth is better and more efficient. The DICOM P2P component consists of a service manager to execute a requested query, a communication Manager to take charge of file transmission, and a DICOM Manager to manage stored data and system behavior. Each Manager itself is a component to search for requested files by interaction or to transmit the file to other PCs.

Our three components implemented Agents operating on an MAMI Platform. Agents communicate with each other through XML encoded ACL of FIPA ACL Message Representation.

Role of each PC is important in this system that reduces load on server. Improvements for cache management, efficient database administration and query processing are needed, and we will research these distributed mechanism continuously.

With the help of Kyungpook National University Hospital in Daegu, Korea, we will apply this enhancement methodology to DICOM Web component system. This distributed DICOM web component system also will be integrated into our Web-based groupware component system and an intelligent agent platform for e-Health.

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