Distributed System with Portable Device Based on Gesture Recognition

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Abstract –In this study, the communication between a server and a client is controlled via a user's gestures. Because a laptop device is usually operated through a handheld device such as a keyboard, mouse, laser-tracked pen or stylus, nearby people is disturbed by sounds such as the tapping of a keyboard or the clicking of a mouse. Contrastingly, natural communication involves the use of noiseless hand and body gestures. Client operators can use the proposed portable device through gestures. By this proposed method, people around the client can avoid the disturbance from handheld devices. And, -an operator can use the portable device based on intuitive gesture recognition.

In studies using three-dimensional (3D) imaging, high-performance computing is often required. Therefore, we usually use large computers. Such computers occupy a large space in an operation room, and a patient feels overwhelmed by computers in the room. Although a portable device does not have high calculation performance, it is possible to process many calculations between distant places by using the proposed distributed system. A portable device in a distributed system can perform data processing without having many internal resources. Therefore, people around the client do not feel overwhelmed by the client. We conducted the experiment by using GPU. The server was downsized by GPU. And its calculation speed was faster than the conventional technology such as a CPU.

The working of the proposed portable device operated by gestures is demonstrated. And, we evaluated a data transfer time, and calculation time.

Keywords: gesture recognition, distributed system, portable device

1 INTRODUCTION

In case of the studies containing 3D imaging, the ability of high-performance computing is often required to the computers. For example, Optoacoustic imaging in the field of medical requires many optoacoustic wave equations to be solved. For the calculation processing, we usually use large size computers. Such computers occupy a large space in an operation room, and a patient feels overwhelmed by computers in an operation room. Specifically, quiet surroundings are strictly required in a medical diagnosis room. It is important that a patient does not feel overwhelmed by any imposing surroundings. By using the proposed distributed system, large servers and a portable sized client can be set in place in separate locations. Because it is possible to handle data transmission between these separate locations, a portable device in the distributed system can perform data processing without having significant resources. Therefore, the servers do not disturb people in the room where the portable device is being operated. Client operators perceive that one database performs all the processing [1]. Of course, many portable devices can exist in a network. Better and simpler software development tools, along with cheaper electronics, make it possible to embed web interfaces into small and inexpensive microprocessor-based devices. This paper proposes the concept of an imaging device that can be incorporated into a web interface. We propose and design a wired or wireless distributed data acquisition system. The networks include a wired or wireless portable device as the client.

There have been some studies related to wireless client devices. This type of a system can be used as tele-medical system. The client devices in this environment would monitor standard physiological signals: Electro-cardio-gram (ECG), Electro-encephalo-gram (EEG), oxygen saturation (SO2), breathing, temperature [2][3] etc. The data of acquisitions would be processed by the client device. Then the data is stored on their secondary storage until the server could download and display the data. The physician monitoring a patient, connected to the client devices, would carry around a his mobile device to investigate/monitor the measurement from the patient [4]. The major requirements of the monitoring devices in such a wireless distributed data acquisition system are long battery life, lightweight, small size and big storage capacity [5][6][7]. However, these devices mainly communicate with the server unidirectionally. Usually a client devices cannot have high calculation performance.

In this paper, we describe the study of a wired or wireless distributed-data-acquisition-system based on an intelligent portable device.

The next topic concerns the control of a device. The operator can communicate with machines via a handheld device like a keyboard, mouse, remote control, laser-tracked pen, or stylus. If the machine is operated with a handheld device, people around the machine are disturbed by the sounds of the tapping of the keyboard or clicking of the mouse. The operator may try to communicate with machines via speech or activity/gesture. Because a variety of spontaneous gestures, such as finger, hand, body and head movements are used to convey information in interactions among people, among these methods, gestures can be considered a natural communication channel [8]. However the communication between a server and a client is controlled by an operator. We propose the communication operated by gestures. By this method, an operator can use the portable device based on intuitive gesture recognition.

2 SYSTEM STRUCTURE

2.1 Client/Server Distributed System

We describe the structure of our proposed client/server distributed system. The portable device, as a client, transmits the acquired data to the server. The server constructs the 3D image from the acquired data. After processing, all or parts of the data in the server are transmitted to a client. Figure 1 shows the system organization.

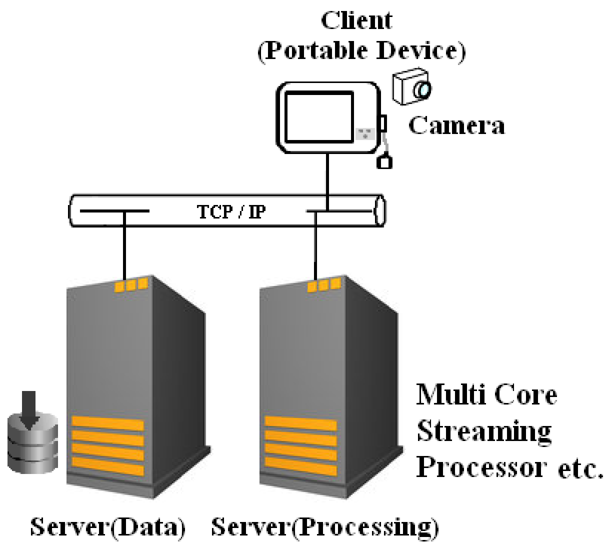

Figure 1: System Organization

The network is able to organize multi-clients/servers by sharing the data stored in servers. A monitor of client displays the functional 3D image. Volume rendering visualize a 3D dataset in a single image. Processing such images can be very compute intensive. And high quality renderings require the high calculation performance and the much storage spaces. 3D texture hardware can be addressed by three indexes (i, j, k). Index k is a depth of an image. In other words, it represents time series. Three indexes present a voxel (Volumetric Picture Element) cubic data set. A voxel is a volume element, representing a value on a regular grid in three dimensional spaces. Such images may be stored for viewing later or displayed in real-time. While simple images can be produced rapidly, more realistic and complicated higher-resolution images can now be produced in more reasonable amounts of the time. The desire to create high-quality work rather than simply wanting the same images created faster drives the need for increased computing power. The performance of a big server is typically limited by the performance of data room's cooling systems and the total electricity cost rather than by the performance of the processors. The computers, routers, power supplies and related electronics are typically mounted on racks in a server room or data center. Servers are currently too large to place in an operation room. Recently, one of our studies explored the feasibility of reprogramming modern video cards to perform rendering in the card's hardware. A GPU has many streaming processors [9]. If a GPU is used in the server, the calculation speed is faster than when the processing is performed by several multi-core-processors.

In this paper, we propose the recognition of gestures as a mean of command-input. The client merely consists of a camera (command-input-device), a data-acquisition-device and a monitor. The data-acquisition-device consists of a transducer (The transducer is the piezoelectric device that can measure sound levels.), analog-digital converters (A/D converters), the minimum amount of data memory (These is used for preserving digital data from channels of analog to digital converters.), and wired or wireless communication interface. In order that it can be embedded into a portable device, the monitor should be a type of flat-panel-display.

2.2 Data Flow

The portable devices record the data onto their temporary storage memory and transmit the data to the server using the “Transmission Data” command. The data flow of the portable device is shown in Fig. 2.

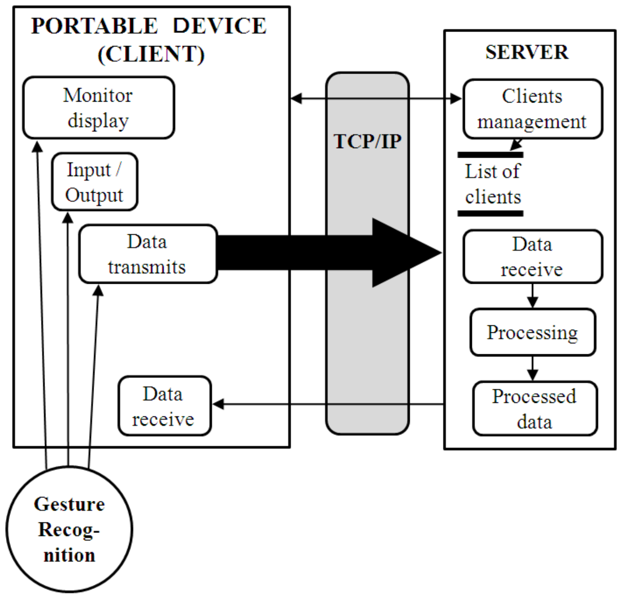

Figure 2: Data Flow of System

The sensor (such as a camera sensor, a time of flight measurement sensor, etc.) is fixed to the device, either internally or externally. The sensor (in this case, a camera) captures the image information in order to support the controlling of the device by gestures. The types of commands include I/O commands (such as data acquisition, monitoring, data transmission, etc.). The processing related to image recognition entails classifying gestures into different command types. These commands control sensors and actuators of the portable device. In other words, the gestures initiate controlling the events for the portable device. For example, a “Data-transmit” event transmits data, acquired by a transducer, transducer from the client to a processing-server. After the processing is completed by the processing-server, the client receives the voxel image data from the processing-server via a LAN or a WLAN.

Table 1: Assigned commands to gesture actions

Commands	Gesture Style	Direction
Acquire Data	Gripping Transducer	Client Only
Transmit Data	Assigning one finger	Client to Server
Display Image	Assigning two fingers	Server to Client
Display Information	Assigning three fingers	Server to Client

The complete system data flow is described as follows.

1. If the operator grips the transducer, the client starts the acquisition of data and stores the data to the memory in real time.

2. If a "Transmit Data" command is recognized by the Image Recognition Unit, the data is transmitted from the client to a processing server. After the processing server completes the reconstruction of a volumetric image from the data, the volumetric image is transmitted from the processing server to the client via a LAN or a WLAN

3. Finally, when a "Display Image" command is issued, display i/f outputs the volumetric image data to a client monitor.

2.3 Commands Based on Gesture Actions

We show the commands implemented for clients in Table 1. As mentioned above in Section 2.2, various command types are implemented in order to control the portable device. One command is used for acquiring data. The operator grips a transducer with hands to begin data acquisition. Another command is used for transmitting data. Commands for monitoring are used in order to display image or text information on the screen of a monitor.

If the portable device is operated with a handheld device such as a keyboard, mouse, laser-tracked pen, or stylus, people around the portable device are disturbed by the sounds of the tapping of the keyboard or the clicking of the mouse. Further, the operator must grip a transducer by hand for data acquisition. If he grips a handheld device in the other hand to communicate with the portable device, both his hands are now occupied.

Therefore, we use gesture recognition to enable the operation of the portable device. Object recognition in computer vision is the task of finding a given object in an image or video sequence. Humans recognize a multitude of objects in images with little effort, despite the fact that the image of the objects may vary somewhat in different viewpoints, in many different sizes, scale or even when they are translated or rotated. Objects can even be recognized when they are partially obstructed from view. This task is still a challenge for computer vision systems in general. However, we challenged to adapt the object recognition for the portable device.

2.4 Wireless Communication

The portable device, as a client, enables communication via a wireless port as well. A wireless portable device has many advantages, such as low power consumption, a small size, low cost, scalability, mobility, and flexibility.

We show the organization of a wireless system in Fig. 3. The system contains servers, portable devices, and an access point. Servers are placed in a fixed location. A processing server responds to requests from the portable device and reconstructs an image from the data acquired by the portable device that is placed in the operation room. The server returns a reconstructed image to the portable device after processing. The use of wireless communication provides more flexibility to the distributed system.

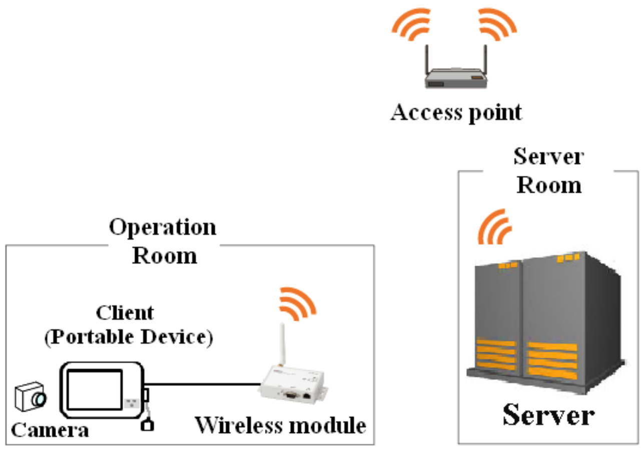

Figure 3: Wireless System Organization

3 DEVELOPMENT OF A PROPOSED PORTABLE DEVICE

3.1 Functional Prototype Device

We show the structure of a client in Fig. 4.

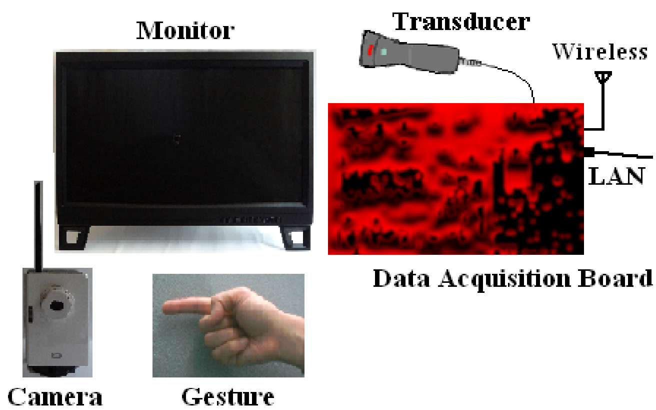

Figure 4: Functional prototype of the portable device

This is a functional prototype. The client consists of a camera as an input device, a data-acquisition-board, a monitor, and a transducer for scanning the object. The flat-panel-display device is used for monitoring the reconstructed image, but it has not yet been embedded into the portable device. The data-acquisition board has communication ports: both wired and wireless. Therefore, the client can work as a standalone device, without the need to be placed near the server. Furthermore, the client operator can easily control the device via gestures.

We show a functional block diagram of the data-acquisition board in Fig. 5.

The Data-Acquisition Board consists of A/D Converters, the Memory, the CPU Core, the Image Recognition Unit, the Display i/f, the LAN port and the WLAN port. The A/D converters are connected to a transducer. The Memory caches the acquired data. The Image Recognition Unit recognizes the pattern of gestures using feature descriptors. The Display i/f outputs the reconstructed image or text information. Finally, the wired or wireless LAN is used to communicate with servers. The wired LAN port is a 1 Gbps Ethernet port. The wireless LAN port is an 802.11n wireless port.

If the operator grips the transducer, the board initiates the data acquisition and stores it to the memory in real time. If a Transmit Data command is recognized by the Image Recognition Unit, the data is transmitted to a processing server. After the processing server finishes reconstructing a voxel image from the data, the board receives the reconstructed image data from the processing server via a LAN or a WLAN. When a “Display Image” command is issued, the Display i/f outputs the voxel image to a monitor.

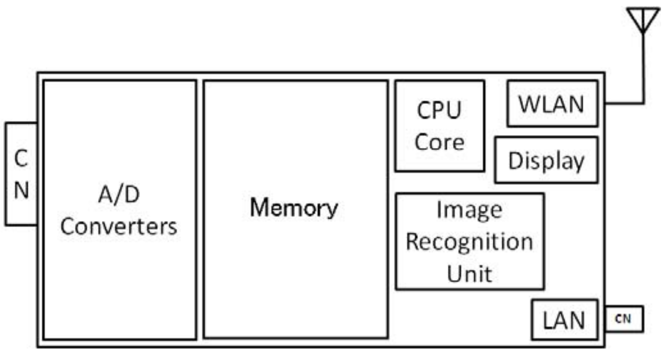

Figure 5: Functional block diagram of the board

3.2 Future Structure

We show a more suitable client structure in Fig. 6. The client consists of a camera as the input device, a monitor, and a transducer for scanning the object. The transducer has a data acquisition function and a WLAN function. The WLAN hardware inside the transducer is used for communication with servers. A transducer does not need to have cables. While the camera and the monitor are shown separate in this figure, these devices will be placed in the same casing in the future. An operator can hold the device by hand if the portable device is smaller and thinner. The operator can use the portable device by moving it. The portable device will recognize the direction of the movement of the background using its camera and perform the corresponding function. Other operators may hang the portable device on the wall, making gestures at the wall to control it. The portable device will recognize gestures and perform the corresponding function.

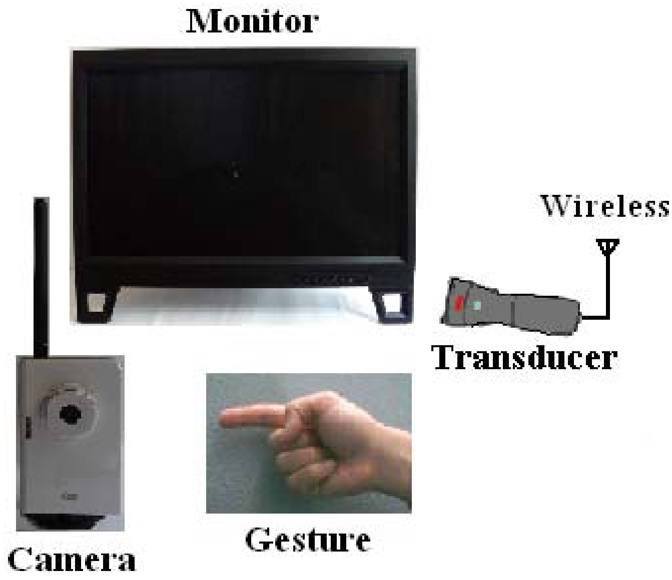

Figure 6: Functional parts for the suitable client

We describe a sample operation of the suitable client in Fig. 7.

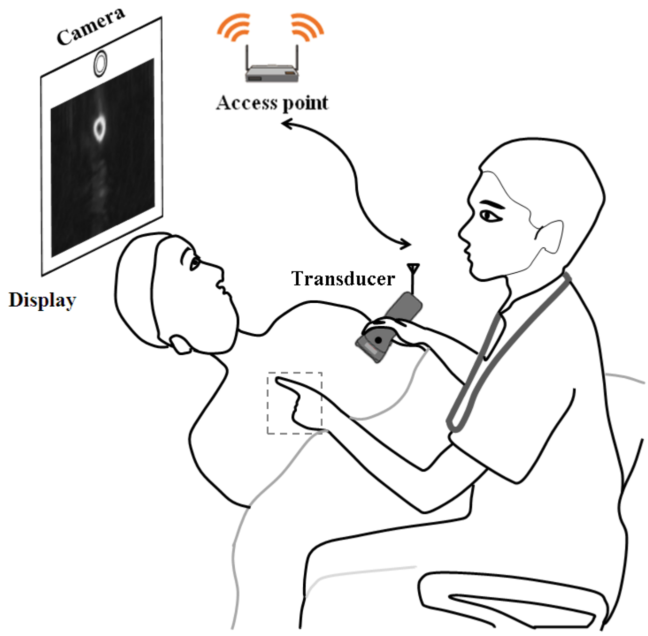

Figure 7: Assumed operation example of the suitable client

A monitor with a camera is hanging in an operation room. The transducer acquires the data because the operator grips the transducer. The operator makes a gesture with the left hand, to transmit the data. This gesture action is assigned the label “Transmit Data.” The transducer has a data acquisition function and a WLAN function. The WLAN inside the transducer is used to communicate with servers. The transducer communicates with an access point (the access point communicates with the servers), as shown in this figure. The transducer does not have cables.

3.3 Gesture Recognition

Portable devices should be easy to use. As a target goal, the operator should be able to operate the portable device using intuitive gestures. We use a histogram of oriented gradient descriptors in order to recognize gestures. Histogram of oriented gradient descriptors is feature descriptors used in computer vision and image processing for the purpose of object detection [10]. The technique counts occurrences of gradient orientation in localized portions of an image. This method is similar to that of edge orientation histograms, scale-invariant feature transform descriptors, and shape contexts, however differs in that it on a dense grid of uniformly spaced cells and uses overlapping local contrast normalization for improved accuracy. The essential thought behind the histogram of oriented gradient descriptors is that local object appearance and shape within an image can be described by the distribution of intensity gradients or edge directions. Since the histogram of oriented gradients descriptor operates on localized cells, the method upholds invariance to geometric and photometric transformations such changes would only appear in larger spatial regions.

Moreover, coarse spatial sampling, fine orientation sampling, and strong local photometric normalization permit the individual hand movements of operators to roughly classify a finger position.

We recorded 2D images of gestures with a camera. Then, the images were saved to memory. We created template patterns from the images. We input a complete image from a camera to classify the image. We recognized the pattern of each image using histograms of oriented gradient descriptors. The result is shown in Fig. 8. The black rectangle is drawn around a recognized pattern

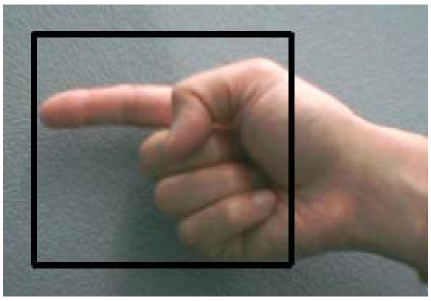

Figure 8: Example of Image Recognition for Classifying Gesture Actions

4 EVALUATION

4.1 Algorism of Optoacoustic Imaging

We selected optoacoustic imaging for the system evaluation. Optoacoustic imaging recently became the one of a subject of an emergency research in the field of medical diagnostics. We took a voxel image by using the distributed system including the portable device. Electromagnetic wave source are commonly used. The temporal shape and the duration of the optoacoustic yield information about the distribution of absorbed optical energy. The optoacoustic is measured outside the tissue and is used for generating tomography images of absorbing structures inside biological tissue [11]. The method of the optoacoustic signal detection is shown in Fig. 9 [12]. Optoacoustic imaging is a three-dimensional (3D) imaging technique since the scattered incident electromagnetic wave pulse generates thermo elastic pressure waves in absorbing structures located inside the whole irradiated volume. The detected acoustic pressure waves contain this 3D information which is utilized to reconstruct the distribution and shape of the absorbers in the irradiated volume. To acquire the amount of information necessary to reconstruct a 3D image, a method has to be used that efficiently samples the acoustic waves. One method is the measurement of two-dimensional (2D) snapshots of the pressure distribution in a plane at different delay times after the incident laser pulse. Based on such 2D measurements the pressure source can be reconstructed by using a radial back projection of the recorded pressure distributions from the detector plane into the source volume [13]. This is a very robust algorithm, which gives an image even if the number of collected 2D stress images and their resolution are low. Optoacoustic imaging has to solve many optoacoustic wave equations. We need huge power to solve these equations. These equations are defined by Equation (1), (2) and (3).

Wave equation for the velocity potential ψ can be expressed by next equation.

$$\Delta\psi - \frac{\partial^2\psi}{c^2\partial t^2} = \frac{\beta}{\rho C_p} S \qquad (1)$$

Where grad ψ is the velocity vector of the wave motion, c is the speed of sound, β is the thermal expansion coefficient, ρ is the density, C_p is the specific heat capacity at constant pressure and S is the heat generated by absorption of an electromagnetic wave per unit volume and time. This equation is valid under the assumptions that heat conduction and viscous damping can be neglected. Under short pulsed irradiation the heat source term S can be expressed as $S(r,t) = W(r)\delta(t)$, using the volumetric energy density W.

With $p = -\rho\frac{\partial\psi}{\partial t}$, the wave equation for the acoustic pressure p can be expressed by next equation.

$$p(r,t) = \frac{\partial}{\partial t}\left[\frac{\iint p_{0(r')}ds}{4\pi c^2 t_{|r-r'|=ct}}\right] \qquad (2)$$

$$\text{With } p_0(r') = \frac{\beta c^2}{C_p} W(r')$$

The integration is performed over the surface of a sphere with surface element ds and radius ct around the detection point r.

In the following we will use a Cartesian coordinate system and assume that a line detector of infinite length is oriented parallel to the z -axis. It receives signals given by next Equation (3).

$$q(x,y,t)=\int_{-\infty}^{+\infty} p(x,y,z,t)dz \quad (3)$$

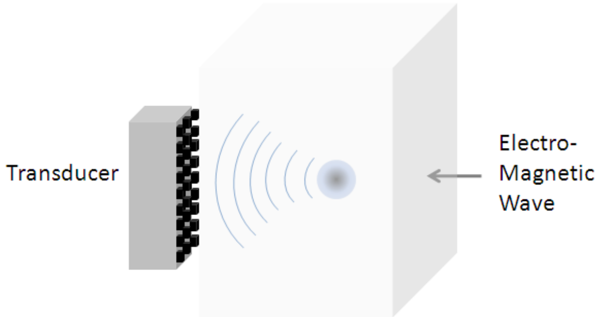

Figure 9: The method of optoacoustic signal detection

4.2 Evaluation System

Client configuration performed is as follows. (Refer to Fig. 4)

The client consists of a camera input device, a data-acquisition board, a monitor, and a transducer for scanning the object. The flat-panel-display device is used for monitoring a voxel image.

Server configuration is as follows.

The server has two 4-core Xeon processors and a GPU. The specifications of the video card using the GPU (nVIDIA Quadro FX4800) are as follows.

- Chipset:Quadro FX4800
- Stream Processors: 192
- Memory Bandwidth: 76.8GByte/sec

The video card's processing chip (GPU) has a parallel streaming architecture. The GPU has 192 streaming processors. If the GPU is used in a server, the speed of calculations becomes 100 times faster than a single-core processor with optimal parallelization. We used two 19-inch rack-mount cases with 36 units. The size of a server was downsized considerably by using a GPU. However, servers are still too large to fit in the operation room.

4.3 Experiment & Results

We evaluated the process of reconstructing a volumetric image. We show the material of a target object in Fig. 10. The target object is a black colored sphere shaped object in the intralipid with the coagulant. The black colored sphere is india ink as the absorber. First, we irradiate the electromagnetic wave to the target object. We receive the optoacoustic waves from the target object. Then we reconstructed an image of the black colored sphere shaped object in intralipid with the coagulant.

The system configuration for the evaluation is shown in Fig. 11. The transducer is connected to the proposed portable device. The electromagnetic wave is irradiated from the right side of a target object. And a transducer is arranged to the left side of a target object. The transducer detects optoacoustic signals. The signals are transmitted to A/D converters on the data-acquisition board, while the operator holds the transducer. The converted digital data are transmitted to a processing server via a LAN or a WLAN when a "Transmit Data" command is recognized. After the processing server completes the reconstruction of the volumetric image from the data, the volumetric image is transmitted from the processing server to the data-acquisition board via a LAN or a WLAN. When a "Display Image" command is recognized, the display i/f outputs the volumetric image to a system monitor.

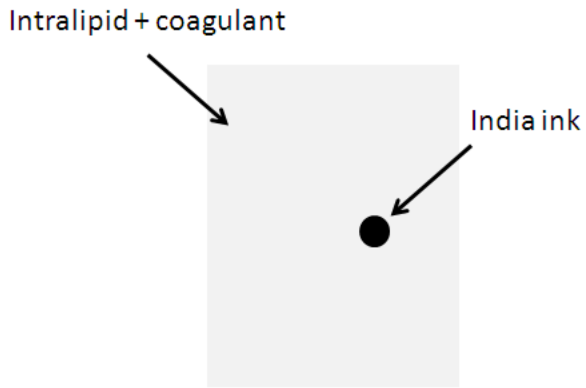

Figure 10: Material of the target object

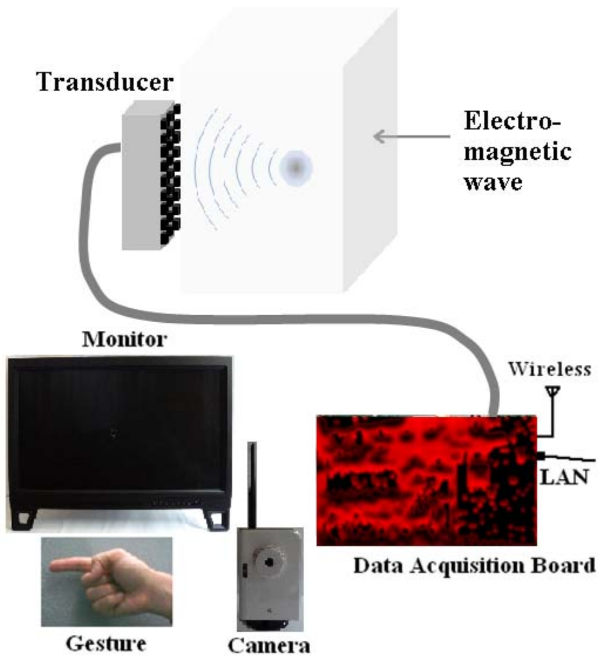

Figure 11: The system configuration for the evaluation

We performed image processing to reconstruct a volumetric pixel image. The reconstructed 3D image is shown in Fig. 12; it was obtained using the reconstruction algorithm mentioned above. In this experiment, it took approximately to reconstruct a volumetric image using the two 4-core Xeon processors and the GPU in the processing server.

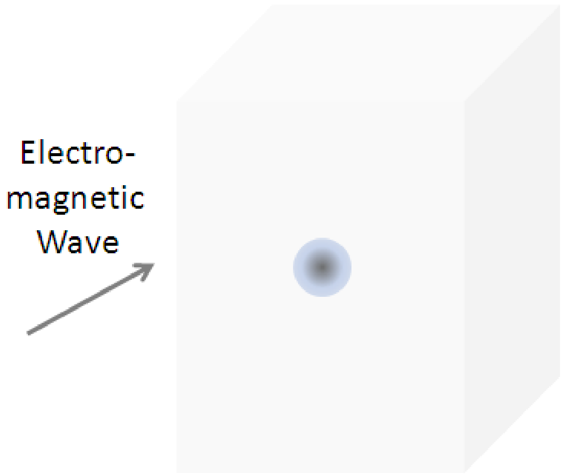

Figure 12: Reconstructed 3D Image

4.4 Summary of the Evaluation

The summary of the evaluation is as follows.

(1) The client prototype is not small enough to be treated as a portable device. Our future target is an iPad-size device that includes an embedded camera. The transducer will have a data acquisition function and a WLAN function.

(2) The gesture recognition system sometimes failed to classify gestures correctly. The rate of misrecognition was approximately 42%.

(3) It took 234 mS to process an optoacustic image using the wired network system. And, it took 303 mS to process an optoacoustic image by the wireless network system. The processing time consists of the data acquisition time, image reconstruction time, and communication time. It took approximately 60 mS to reconstruct a volumetric image using the GPU in the processing server. Other modalities are taking 5 minutes to 30 minutes for taking imaging. These systems are workable for screening diagnosis. For more many applications available, hereafter, we are trying to speed up the reconstruction time. The processing speed of the processing server is good. The portable device has a 1 Gbps Ethernet port. However, the average speed of communication is lower than the speed given in the specifications. It took approximately 74 mS to communicate between the client and the server. The transfer rate was approximately 122 Mbps.

For wireless communication, the portable device has an 802.11n wireless port. However, the average speed of this communication medium is lower than the specified speed. It took approximately 143 mS to communicate between the client and the server. The transfer rate was approximately 65 Mbps.

We have summarized these processing times in table 2.

Table 2: Time required for optoacoustic image processing

	Wired	Wireless
Amount time	234 mS	303 mS
Data acquisition time	100 μS	100 μS
Reconstruction image time	60 mS	60 mS
Communication time	74 mS	143 mS

5 CONCLUSION

In this study, we developed a portable device based on gesture recognition as a functional prototype. The communication between the server and the client is controlled by a gesture. We conducted an experiment using the portable device. The device was operated through gestures. We demonstrated that near natural communication could be achieved with the device by conveying information through gestures. People around the portable device were not disturbed by the noise of handheld devices. In addition, one hand of the operator remained free and could be used for other purposes. Furthermore, we conducted the experiment using a GPU. The server was downsized as a result of using the GPU, and its calculation speed was faster than that of conventional processors such as CPUs. We optimized the gesture recognition time, data transfer time, and calculation time. The proposed system used a Client/Server architecture. Therefore, servers did not disturb the people in the operation room, and people near a client did not feel overwhelmed.

In the future, we will design a smaller and thinner portable device. The communication and image-reconstruction speeds of the system achieved in this experiment will be improved. In addition, we will include many more cameras for a more accurate control of the portable device. We optimized a gesture recognition time, data transfer time and calculation time.

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