

## An Interactive Walkthrough System with Omni-Directional Camera

Chao Liu<sup>†</sup>, Katsuhiro Arai<sup>††</sup>, Susumu Shibusawa<sup>††</sup>  
and Tatsuhiro Yonekura<sup>††</sup>

Most virtual walkthrough systems use prepared images to create the virtual environment and it is hard for the walkthrough system to be in real time. In this research, we create an interactive walkthrough system with omni-directional camera. This walkthrough system consists omni-directional camera, server PC and client PC. The server PC sends to the clients panoramas that is transformed from omni-directional images. The clients construct virtual environments with panoramas and other prepared files.

### 全方位カメラを用いたインタラクティブ ウォークスルーシステム

劉超<sup>†</sup> 荒井勝大<sup>††</sup> 渋沢進<sup>††</sup> 米倉達広<sup>††</sup>

これまでのウォークスルーシステムの構築手法では、多量の画像を事前に用意しなければならず、リアルタイム性を実現することが容易でない。本研究では、全方位カメラを用いてリアルタイムに映像を配信するインタラクティブウォークスルーシステムを作成する。本システムは、全方位カメラ、サーバ、クライアント PC から成り立っている。サーバはウォークスルーシステム構成用のパノラマ画像を作ってクライアントに送る。クライアントはサーバから送られてきたパノラマ画像、及び事前にダウンロードした紹介用の画像と音声に基づいて、ウォークスルー環境を生成する。このシステムでは、全方位画像をパノラマ画像に変換する改良した地図展開手法を用いている。

<sup>†</sup> Graduate school of Engineering, Ibaraki University

<sup>††</sup> Colledge of Engineering, Ibaraki University

## 1. Introduction

As the advent of communication network and multimedia processing technologies, everybody can send or receive plenty of data easily. Systems that provide the video delivering service are becoming more popular. In the videos of Websites, walkthrough videos are often used to introduce a street or hotel. These videos are mainly taken by a photographer who holds the camera walk in the street or hotel.

Since these walkthrough videos are recorded previously, the video viewers can only follow the recorder's route. To solve this problem, some researchers use prepared images to construct virtual walkthrough systems<sup>4), 5)</sup> for interactive virtual walkthrough. The virtual walkthrough system allows users to enjoy the walkthrough and also decide their walkthrough direction. Most virtual walkthrough systems use prepared images to create the virtual environment. Preparing all the images is time consuming, and it is hard for the walkthrough systems to be real time.

On the other hand, the functions of omni-directional cameras are improved a lot recently. Omni-directional camera is a camera with a 360-degree field of view and often used for sightseeing, monitoring security and teleconference system<sup>1), 2)</sup>. People can set the omni-directional camera in the park or home to delivery the videos to multi-users<sup>7), 9)</sup>.

In this research, we constructed an interactive walkthrough system with omni-directional camera. We utilize omni-directional directional camera to gather omni-directional videos in real time and use capturing software to capture the images. Then, we use improved map projection method on the omni-directional images and get the panorama. With the image we constructed a virtual walkthrough system. Users can use keyboard to control their walk direction of walkthrough with this system.

In the second section we introduce the related works and background. In the third section we introduce the improved map projection method we used in this system to change omni-directional images to panoramas. The forth section describes the design of walkthrough system. The fifth section presents the system installation and sixth section presents the results and evaluation. The seventh section concludes this research.

## 2. Related Works and Background

Walkthrough videos which usually taken by walking people with cameras perform well in introducing streets or hotels for Internet Web users. Some methods use to achieve the walkthrough function of virtual environment with 3D models and Image based environment.

### 2.1 Virtual Environment with 3D Models

One method to provide walkthrough functions to the Web users is to construct a virtual

environment<sup>8)</sup> with 3D models of geometry and material properties. In Japan, for example, a group of researchers is under study on constructing the Shirakawa-go virtual heritage<sup>6)</sup>. The project examined the procedures and techniques for digitization of external views and cultural aspects of Shirakawa-go by using VR technology.

## 2.2 Image Based Environment

The Creation of large-scale environments is one of the most important applications in computer vision and computer graphics. Conventionally, such environments are created using 3D models of geometry and material properties. However, conventional modeling techniques are generally very time consuming and still fall short of recreating the detailed geometry and subtle lighting effects found in most real-world scenes. As a substitution for conventional modeling techniques, recent advances in image-based rendering have exhibited great potential for photo-realistic image synthesis.

## 2.3 Omni-Directional Camera

Omni-directional camera is a camera with a 360-degree field of view. Fig. 1 shows an omni-directional camera. Fig.2 shows a image taken by omni-directional camera.



Fig.1 An omni-directional camera.



Fig.2 An image taken by omni-directional camera.

## 3. Map Projection Method

Map projection is any methods to represent the surface of a sphere or other shape on a plane which is used for creating maps. The surfaces created by map projections are distorted in some fashion.

Omni-directional images are represented as Fig.3. We set the center of the omni-directional image  $(x_0, y_0)$ , the radius  $r$ , and the angle  $\theta$  for the coordinate  $(x, y)$ . We can get the following relations below between the omni-directional image and the panorama image:

$$x = x_0 + r \cos \theta \quad (1)$$

$$y = y_0 + r \sin \theta \quad (2)$$

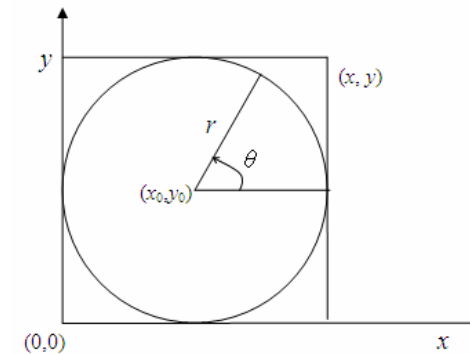


Fig.3 Map projection method.

Using this method, we can transform the omni-directional image of Fig.2 to Fig.4.

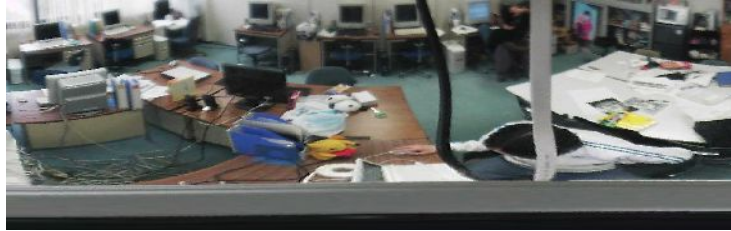


Fig.4 Panorama image projected by map projection method.

In the map projection method introduced above, we transform the omni-directional image into the panorama without any distortion correction. Fig.5 shows the distortion of the omni-directional images during map projection process and we consider a distortion correction method to keep the height/width ratio of the objects in the image, we define the following variables to describe this transformation in Table 1.

Table 1 Variables to describe this transformation.

Variable	Function of the variable
$K$	Parts of the omni-directional image, we take sector $K$ as analysis object
$\theta$	The angle of sector $K$
$r_1$	The radius of empty sector $m$
$m$	The empty sector that contains no visual information in sector $K$
$a$	The height of the map projection panorama
$F(i)$	The area of the sectors of the panorama
$F(K)$	The area of the sector $K$
$f(K2)$	The area of the rectangle $K2$
$A$	The sample object in omni-directional image in Fig.5
$F'(i)$	The area of the parts of the omni-directional image ( $1 < i \leq 5$ )
$f'(i)$	The area of the parts of the panoramas $K2$ ( $1 < i \leq 5$ )
$r_2, r_3, r_4$	The radii of the parts of sector $K$

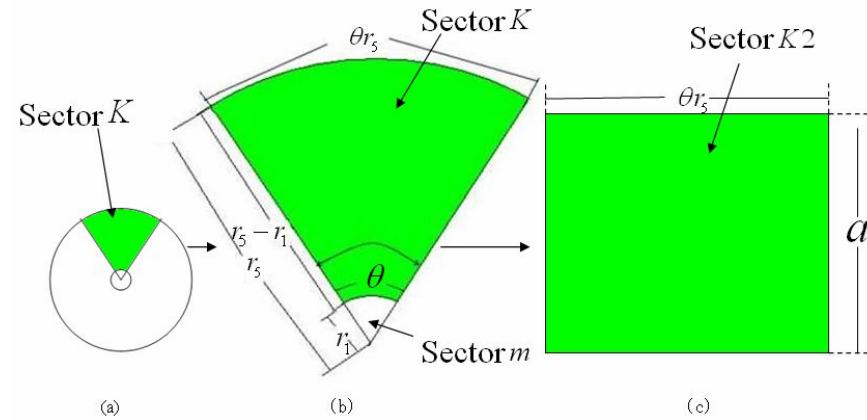


Fig.5 Distortion happens during map projection process.

Before the map projection image process, the area of sector  $K$  is:

$$F(K) = \frac{\theta r_5^2 - \theta r_1^2}{2} \quad (5)$$

After the map projection image process, the area of the rectangle  $K2$  is as follows:

$$f(K2) = \theta r_5 a \quad (6)$$

The height of sector  $K2$  in Fig.5(c) equals the radius of sector  $K$ :

$$a = r_5 - r_1 \quad (7)$$

So the area of image (c) is as follows:

$$f(K2) = \theta r_5 (r_5 - r_1) \quad (8)$$

The height/ width ratio is also controlled by the omni-directional camera, which is nearly the same with one directional camera images. The height/width ratio is changed after the image process. The Fig.6 shows for an object “ $A$ ” in the original omni-directional image which is changed after the map projection method:

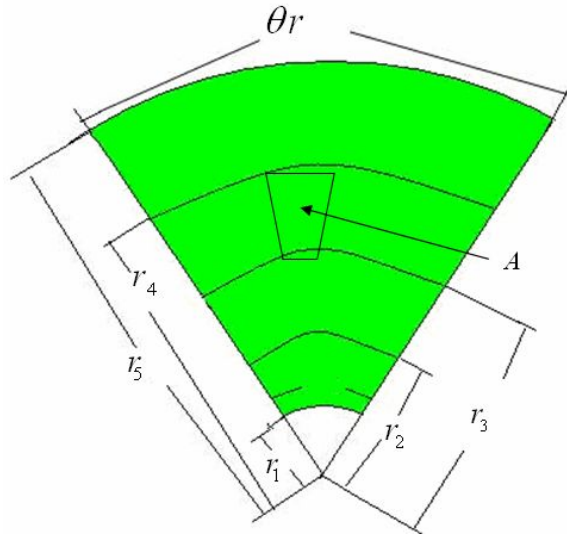


Fig.6 Height/width ratio is changed to object A.

We assume the area of object  $A$  is  $F'(4)$ . After the map projection process, the area is changed to be  $f'(4)$ , and  $f'(4)$  satisfies the following Equation:

$$F'(4) = \frac{(\theta r_4^2 - \theta r_3^2) / 2}{\theta r_5 (r_4 - r_3)} f'(4) \quad (9)$$

For keeping the ratio of the objects in the image, we divide the original image into some parts as Fig.7.

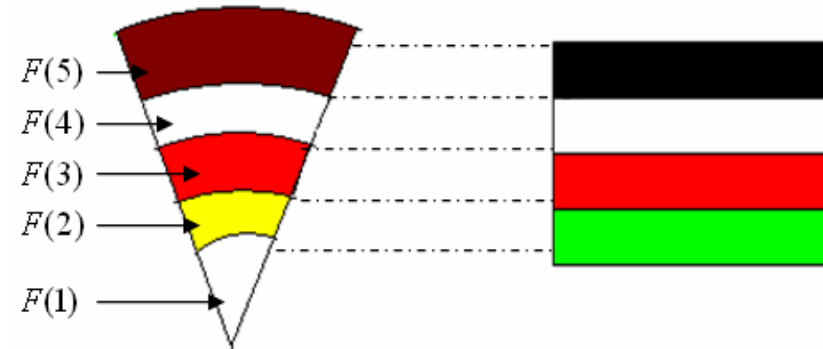


Fig.7 Distortion happens during map projection method.

We pull the omni-directional image into rectangle in the map projection process. During this process,  $F(5)$  is not pulled too much, but  $F(2)$  is distorted very much. The height of the area  $F(2)$  is not changed through map projection procedure, but the length are pulled much longer as Fig.7 shows. To keep height/ width ratio of objects, the following equation shows a distortion correction method.

$$H_i = \frac{2r_5}{r_4 + r_3} h_i \quad (1 < i \leq 5) \quad (10)$$

In this equation,  $h_i$  is the height of map projection panorama parts, and  $H_i$  is the height of improved map projection panorama parts. If we divide the panoramas into  $N$  parts, the height/width ratio distortion correction is represented as following equation.

$$H_i = \frac{2r_N}{r_i + r_{i-1}} h_i \quad (1 < i \leq N) \quad (11)$$

#### 4. Design of Walkthrough System

Conventional modeling techniques are generally very time consuming and still fall short of recreating the detailed geometry and subtle lighting effects found in most real-world scenes. As a substitution for conventional modeling techniques, recent advances in image-based rendering have exhibited great a potential for photo-realistic image synthesis<sup>3)</sup>. Some

researchers use lots of prepared images to construct virtual environment. For reducing the time on preparing images, we construct a walkthrough system using real-time images taken by omni-directional camera. In this system, the virtual environment is constructed with omni-directional panoramas sent by server in real-time for interactive walkthrough, introduction audios and introduction images. The files for the functions are as Table 2.

Table 2 File types in walkthrough system.

Image files	Images processed when user walk forward/back or turn left/right
Audio files	Audios prepared in advance
Introduction files	Images files to introduce some spots or objects

#### 4.1 Image Processing for Interactive Walk

In this system, we construct a walkthrough system for sightseeing based on images taken by the omni-directional camera in real time. Firstly, we set omni-directional cameras in the place for walkthrough. Then the users can use computer to connect the server and use the walkthrough service. User can use direction keys on the keyboard to change their move direction.

In the server PC, omni-directional video capture software and map projection processing program are installed. The virtual walkthrough environment is installed in the client PC. Users can download the images and audios from the server and walkthrough in virtual environment. The steps are as follows:

1. Users send their commands to the server and download the audio files and image files for introduction.
2. Client PC connects the server and downloads the panoramas in real time.
3. Client PC construct a virtual walkthrough environment with audio files, image files for introduction and panoramas, In the walkthrough system users use keyboard to achieve the walkthrough activity, they can go forward/back or turn left/right.

#### 4.2 Audio files

During the interactive walking, when user walks to some area, they can hear the introduction audio files which are recorded previously. The introduction audios can lead the user to some spots by introducing the location of the spots to the users. When users are near enough to a certain spot, introduction audios also can help the users to know more about the objects.

The virtual audios are voices which are recorded previously, and the client can download the audios and when the users' walking meets some conditions, the sounds are connected with some objects.

### 5. System Installation

The walkthrough environment program is installed on Clients. The server and client environments are as Table 3.

Table 3 Server and client environments.

OS	Windows Vista	OS	Windows XP
CPU	Intel Core 2 Quad CPU Q9550 @ 2.6GHZ 2.7GHZ	CPU	Intel Core 2 Duo CPU E6550 @ 2.3GHZ 2.3GHZ
Memory	4GB	Memory	1GB

The softwares we used to process images are Visual C++ and OpenCV. On the server, capture software takes the  $1632 \times 1216$  pixels omni-directional images every 0.2 second. By VC++ and OpenCV program, the omni-directional images are diminished to  $544 \times 404$  pixels. Then, the improved projection program changes the  $544 \times 404$  pixels to  $800 \times 190$  pixels panoramas. The total image processing time is less then 0.2 second.

Fig.8 shows the construction of interactive walkthrough system. In this system, the client can download the panorama images and prepare introduction audios and images to construct the virtual walkthrough environment.

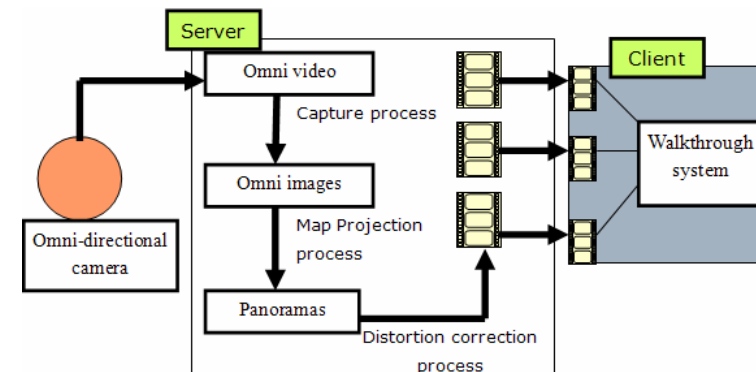


Fig.8 Construction of the interactive walkthrough system.

We implemented the interactive walkthrough system as following steps:

1. We prepare the audio and image files: recording environment audios and introduction

audios on server. When the client starts to connect with server, these prepared audio files are sent from server to clients.

2. When the downloading procedure is over, server takes images with omni-directional cameras, and use projection method to transform the omni-directional image to panorama.
3. The panoramas are sent to client immediately since it was transformed.
4. With the panorama and prepared audio files, clients construct a virtual environment and let user execute walkthrough function.

## 6. Results and Evaluation

We conducted and evaluated the improved map projection image processing and the interactive walkthrough experiments. Fig.9 is one of omni-directional image sample we used for improved map projection image processing. Using usual map projection method, the image is transformed from Fig.9 to Fig.10.



Fig.9 Sample of omni-directional image.



Fig.10 Sample of map projection panorama.

Then, we conducted the distortion correction method on the map projection panorama.

In the distortion correction step, the process we implemented is as follows:

1. We divide the original map panorama into several parts depending on the parts' distance

from the origin of the original omni-directional image.

2. We use distortion correction algorithm to reduce the distortion.
3. We combine the parts of map projection panoramas that processed with distortion correction method. Fig.11 shows the result of improved map projection panorama.

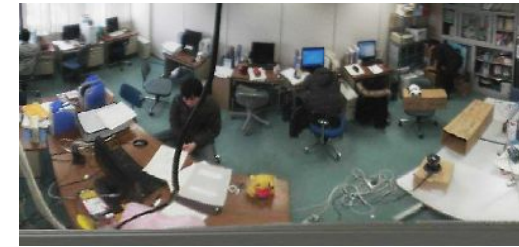


Fig.11 Sample of improved map projection panorama.

We compared the quality of the panoramas got from improved projection method and map projection method. We draw out the objects in panoramas and compared them with the objects in one directional photos. We find the distortion of improved projection and one directional image is less than 26% according to the height/width ratio. Compared to samples from map projection panorama, the distortion of samples from improved projection panorama is from 2% to 57% less than distortion of samples form map projection panorama according to the height/width ratio.

The interactive walkthrough function is achieved in the system with one omni-directional camera. We test the move forward/back/left/right commands. Fig.12 and Fig.13 show that the client displays a new image when receive user' command: move right.



Fig.12 The client is displaying this image before the move right command.



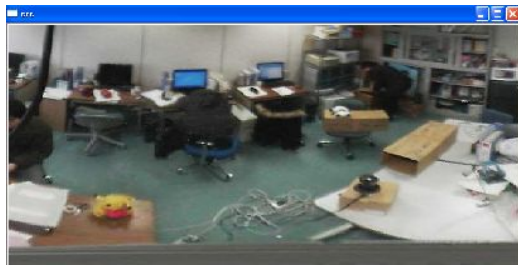


Fig.13 The client is displaying this image after the move right command.

When people go to some certain place in the virtual environment, the system will display the introduction voice and tell the user can use keyboard to see introduction images. Fig.14 shows when the user is near enough to an omni-directional camera, the introduction audio will ask user whether he wants to see more. If the user agrees by pushing the space key on keyboard, the system will show prepared image and play specific introduction audios.

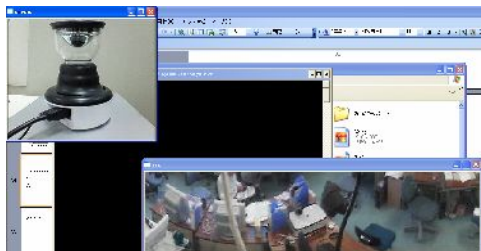
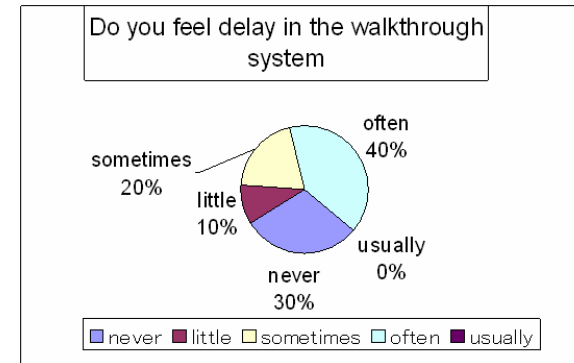
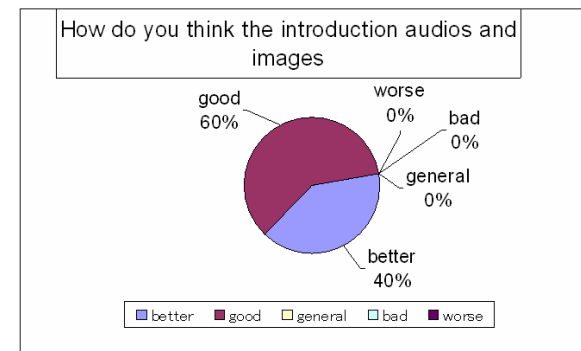


Fig.14 The introduction image is displayed as users' requirements.

We made an investigation questionnaire to ask ten people to evaluate the functions of this walkthrough system. Fig.15 shows the results of questionnaire answers.



(a) The evaluation of the delay.



(b) The evaluation of the introduction audios and images.

Fig.15 Results of questionnaire answers.

According to the questionnaire answers, users are satisfied with the integrated audios and images in the walkthrough system. Most of users often or sometimes felt the delay.

## 7. Conclusion and Future Work

Using the improved map projection panoramas and other prepared files we constructed an interactive walkthrough video delivering system in real time. This walkthrough system consists of omni-directional camera, server PC and client PC. On the server, capture software takes the 1632×1216 pixels omni-directional images every 0.2 second. After the image processes, the panoramas are sent to clients to construct the walkthrough system. The server PC transmits panoramas that are used to construct the virtual walkthrough system to clients. On the clients, the walkthrough process program construct a virtual environment with panoramas and other prepared files for introducing the objects in the environment. When users walk to some certain places where have introduction objects are set, they can view the prepared introduction images by following the introduction audios.

According to the questionnaire answers, the delay of videos displaying on the client is obvious. Our next work is to use better omni-directional camera to raise the omni-image capturing speed, to reduce the image saving time. It is also necessary to reduce the improved map projection speed and add more functions in the walkthrough system.

## References

- [1] Ishikawa, T., Yamazawa, K., Ikeda, S., and Yokoya N.: Telepresence System Using Web Browsers and Omnidirectional Video Streams, *IEICE Transactions on Information and Systems*, D-II, Vol.J88, No.8, pp.1750-1753 (2005).
- [2] Habe, H., Yamazawa, K., Nonura, T., and Matsuyama, T.: Compression of Omni-directional Video with Polyhedral Mapping, *IPSJ Technical Report, CVIM*, pp.59-66 (2003).
- [3] Lee D., and Ki Jung, S.: Capture Configuration for Image-Based Street Walkthroughs, *Second International Conference on Cyberworlds CW'03*, pp.151 (2003).
- [4] Takeshi, U., Tomohiro, Y., Masayuki, T., and Toshiaki, F.: Walk-through View for FTV with Circular Camera Setup, *IEICE Technical Report, Image Engineering*, pp.57-61 (2009).
- [5] Ripper K'os, J. , Barbosa, A. S. , Krykhtine, C., da Silva, E. M., and Paraizo, R. C.,: The City That Doesn't Exist: MultiMedia reconstruction of Latin American cities, *IEEE MultiMedia*, Vol.7, No.2, pp.56-60 (2000).
- [6] Hirayu, H., Ojika, T., and Kijima, R.: Constructing the Historic Villages of Shirakawa-Go In Virtual Reality, *IEEE MultiMedia*, Vol.7, No.2, pp.61-64 (2000).
- [7] Sato, Y., Maita, Y., Hashimoto, K., and Shibata, Y.: Face Image Tracking System for Surveillance Using an Omni-directional Camera, *IPSJ Technical report, MUC*, Vol.2007, No.58, pp.13-18 (2007).
- [8] Takahashi, T., Kawasaki, H., Ikeuchi, K., and Sakauchi, M.: Arbitrary View Position and Direction Rendering for Large-Scale Scenes, *IEEE Computer Society Conference on Computer Vision and Pattern*

*Recognition*, pp 296-303 (2000).

[9] Morita, S., Yamazawa, K., Terazawa, M., and Yokoya, N.: Networked Remote Surveillance System Using Omnidirectional Image Sensors, *IEICE Transactions on Information and Systems*, D-II, Vol.J88, No.5, pp.864-875 (2005).