

# Adaptive Multi-Camera Shooting System Based on Dynamic Workflow in a Compact Studio

Norihiro NISHIO, Yuki DEGUCHI, Takahiro SUGIYAMA, and Yoichi TAKEBAYASHI

**Abstract**—We developed a multi-camera control system that a (one) cameraman can operate several cameras at a compact studio. we analyzed a workflow of a cameraman of some program shootings with two cameras and clarified their heavy tasks. The system based on a dynamic workflow which adapts a program progressing and recommends of cameraman. we perform the automation of multi-camera controls by modeling of studio environment and perform automatic camera adjustment for suitable angle of view with face detection. Our experiment at a real program shooting showed that one cameraman can carry out the task of shooting sufficiently.

**Keywords**—camera work, compact studio, dynamic workflow, shooting support.

## I. INTRODUCTION

RECENT years have seen the digital video internet broadcasting of information in enterprises, schools, museums, and so on, through the spread of Internet video streaming services and video cameras drop in price. In this paper, we focus on a studio for the above organizations (not pro-studio). We construct a compact studio operable in small number of staffs, and we research on it to support staffs for producing video programs in our studio.

In the compact studio, a cameraman operates several cameras. In addition, because of program shooting proceeds real-time, cameraman does not have enough time to decide camera angle to the next scene and check proceeding of program shooting.

We analyzed workflow of staffs shooting a program by comparison with a traditional TV program studio and the our studio. In this analysis, we defined workload, degrees of concentrations and skills, then organized guidelines to support staffs in the compact studio[1].

We develop a supporting system in the compact studio based on guidelines.

There are many approaches to develop shooting support system by analysis of cameraman's behavior[2], [3], [4], [5], [6], [7]. Tsuda develops automatic program shooting system by robot cameras with connect up to sensors[6]. Onishi proposes a computer-controlled camera work that shoots object scenes to model the professional cameraman's work and selects[7].

With these approaches, we develop a system to support staffs shooting program in a studio.

For this reason, we propose a adaptive multi-camera shooting support system based on dynamic workflow of studio staffs. This system can reduce workloads to operate several cameras, and cameraman concentrates program shooting.

N.NISHIO, Y.DEGUCHI, T.SUGIYAMA, Y.TAKEBAYASHI are with Shizuoka Univeristy. Jyohoku 3-5-1, Naka-ku, Hamamatsu-shi, Shizuokaken, JAPAN e-mail: westtail@sugilab.net.

## II. PRODUCING VIDEO PROGRAM IN A COMPACT STUDIO

First of all, to clarify a problem of a cameraman's task support, we explain our compact studio and a cameraman's workflow.

### A. A compact studio operable in small number of staff

Our compact studio is assumed to shoot a program for internet streaming. This studio is devised to reduce shooting cost. The areas of the studio are all direction 5m. The equipments to use at the studio are as Fig1.

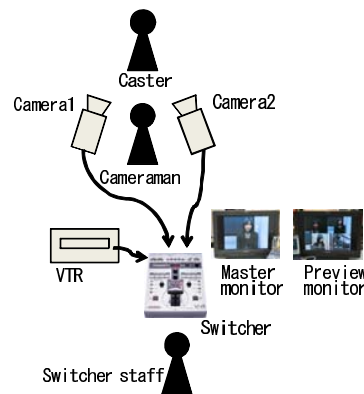


Fig. 1. Facilities of a compact studio

Table I shows the comparison of the number of staffs and roles about traditional TV program shooting studio and our compact studio. In our compact studio, one staff covers several tasks because there are few staffs. For example, in a cameraman's task, one cameraman covers one camera at a traditional TV shooting studio, but at our compact studio, one cameraman covers several cameras. One switcher staff operates VTR and covers Director's task. These tasks usually are covered by specialty staffs. In the next, we notice cameraman's task, and we analyze cameraman's role and workflow.

### B. Workflow of cameraman of program shooting.

As for the role of the cameraman in the program shooting at a studio, cameraman decides suitable angle to shoot program situation, and operate a camera. Fig.2 shows a workflow when cameraman operates a camera. Task from ① to ⑧ are necessary for the change of the angle of one time. These tasks also need operation skills of the camera and know-how about the angle. Then, we explain analysis of a detailed workflow and a problem which we find it.

TABLE I  
COMPARISON WITH A TRADITIONAL STUDIO AND A COMPACT STUDIO

	Traditional studio (Seven people in the assumption)	Compact studio (Two people in the current situation)
Cameraman1(CM1)	Operate camera1	Operate two cameras
Cameraman2(CM2)	Operate camera2	
Switcher staff(SW)	Operate switcher	Carried out another tasks by switcher
VTR representative(VTR)	Operate VTR or PC etc	
Director(D)	Observation and command in the whole thing	
Timekeeper(TK)	Observation all the time in the program	
Assistant director(AD)	Give information to the caster	

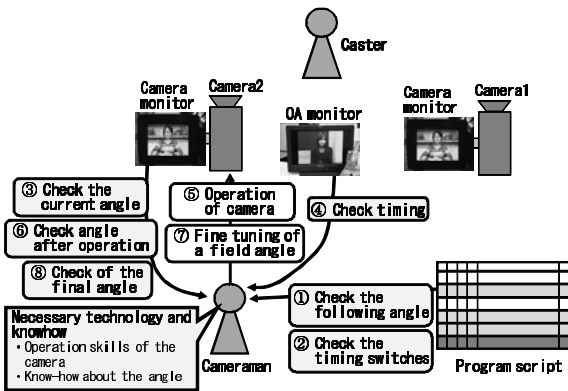


Fig. 2. Workflow of cameraman of program shooting

III. ANALYZE A WORKFLOW OF PROGRAM SHOOTING

We analyzed the staff’s workflow in a traditional TV shooting studio and our compact studio, we also quantified the workload, degrees of concentrations, and skills, then organized guidelines of task support in a program shooting at our compact studio[1]. Fig.3 shows change of the amount of the camera operations at the traditional TV program shooting studio and our compact studio. A horizontal axis shows a number of scene, vertical axis shows how many tasks every scene has. We explain problems of one cameraman operating several cameras at our compact studio based on this analyze of workflow.

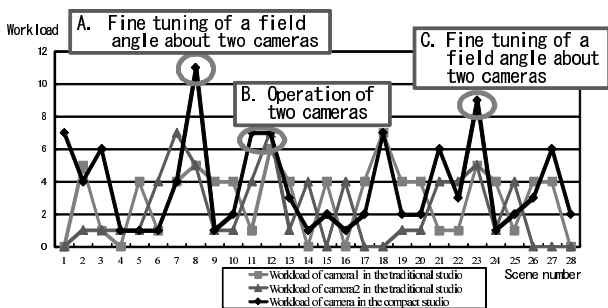


Fig. 3. Change of the amount of the camera operations

A. A problem of several cameras operation

Fig.3 shows cameraman’s workloads at the compact studio which is twice as much as traditional TV program shooting cameraman’s. There are two causes in this. One, it takes time for the operation of the camera. When cameraman operates a camera to a target angle, he operates a camera head of the tripod and a zoom button. Because these tasks must finish in the limited time, it is burden when cameraman operates several cameras.

Two, cameraman must decide next angle about several cameras. Cameraman decides the next angle by an image which switcher staff’s choice and a situation of the program. by several cameras operation, however, the workload of this task is high with doing several cameras operation mentioned first.

B. Adjustment camera to suitable angle

The inside of the Fig.3 A,C is task to tweak the angle of two cameras to the suitable angle shows by Fig.2 ⑦. This task needs operation technique of camera to tweak the suitable angle. In the camera operation, cameraman tweaks the angle suitable, so as not to the angle gives artificial feelings and confuses to audience.

Concretely, we show examples of suitable angles and unsuitable angles at Fig.4. In Fig.4(a), the example of unsuitable angles show that the top of head is too vacant in the angle of view frame, zoom balance is bad, a desk is greatly came in, the space at the point of the eye line is small to show (b). Show the point which it must pay attention to in the camera angle the following.

- Take a headroom a little
- Adjust camera parameter of zoom not to shoot unnecessary article.
- Take a space enough of the direction of caster’s eye line

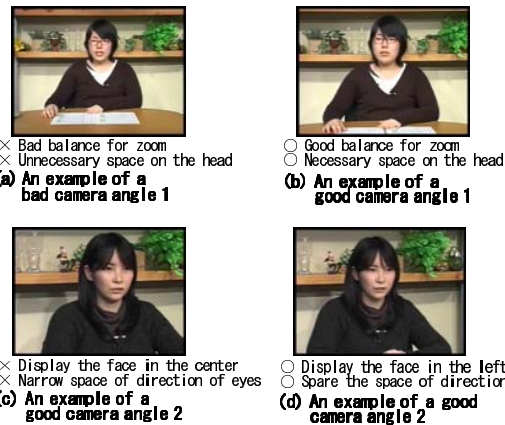


Fig. 4. Some example of suitable camera angle and unsuitable camera angle

IV. THE APPROACH OF STAFF SUPPORT

Fig.5 shows a new work flow by our multi-camera shooting support system which is based on the analysis of the work flow.

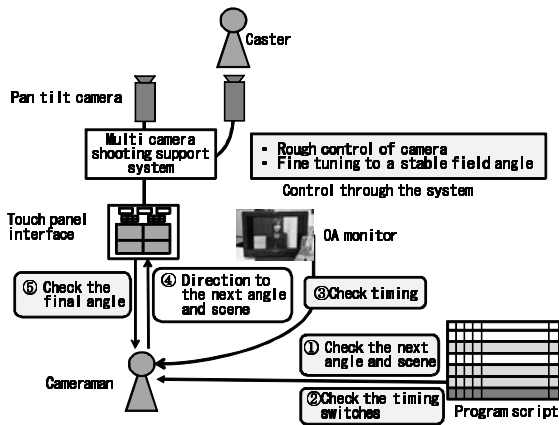


Fig. 5. The workflow cameraman shooting with our system

The proposal system controls camera angle semiautomatically by directing to the next angle or scene to the touch panel interface. As a result, the task of ⑤, ⑦ about the camera operation of the Fig.2 is made semiautomatic, and the simplify it for the task to direct to the next angle or the next scene of the Fig.5 ④. Making camera operation semiautomatic can reduce the check work to accompany a camera operation like ③, ⑥ of Fig.2. We express a point of problem when we build proposal system.

#### A. High operability interface

We design for a simple interface which can integrate of the information which is necessary for the program shooting and can be done with simple thinking until it is operated from a situation judgement. If cameraman uses this interface, he can operate camera only few judgements and few operates.

#### B. Operation of Several cameras

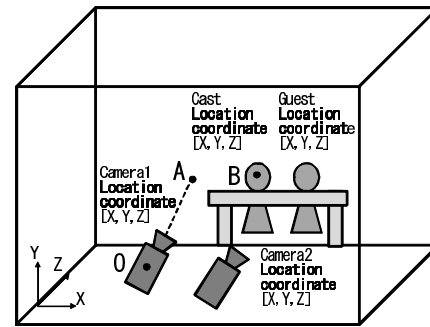
To operate several camera easily, it can change camera angle only one action corresponded to program progress. In our proposal technique, we describe the combination of the camera angle which is proper for the program style and every scene. A cameraman directs to a program scene during the shooting, and the system controls a camera to the proper camera angle.

#### C. Adjustment suitable camera angle

To tweak suitable camera angle in our system, with tweaking stable camera angle, we digitize knowledges about professional 's workflow, the system controls a camera by image processing. By this, we automate the task of the tweak stable camera angle.

### V. MULTI-CAMERA SHOOTING SUPPORT SYSTEM

Our system controls a camera to the angle of the purpose by the two steps. The first step, this system controls a camera roughly by calculating a degree of control camera angle from the three-dimensional coordinate of the studio environment. The second step, by the face detection, the system tweaks a

Fig. 6. Three-dimensional coordinate space  
Three-dimensional coordinate space

camera to the stable angle which is based on the description of the amount of characteristics. Explain to the following, the order.

#### A. Define of studio environment

To control a pan tilt camera, we defined casters, a table, other small articles and cameras as the fixed position. We showed a studio environment in the three-dimensional coordinate space  $(x, y, z)$ , and described the position coordinate and the height each casters, articles, equipments were described(Fig.6). As a result, the degree of control camera angle of the camera can be calculated from three points of "the position coordinate of the camera, the present center coordinate which a camera shoots and the coordinate of the subject of the purpose". Because fine control by the face detection is done by the camera operation of the next step, a person's coordinate shows approximate position of the face, and the coordinate of the article shows central position. Show the position coordinate of the camera by the center coordinate of the rotation axis.

#### B. Camera control by studio model

When we think about the relative coordinate which a camera is in the center. The center coordinate that a angle which a camera shoots at present is A. The coordinate of the subject of the purpose is B. The degree of control camera which moves the angle of the camera from the point A to the point B is able to calculate as follows.

Calculate a degree of control camera of the PAN direction  $\theta_p$  with the next formula.

$$\theta_p = \arctan \frac{\vec{Axz} \times \vec{Bxz}}{\vec{Axz} \cdot \vec{Bxz}} \quad (-\pi/2 < \theta \leq \pi/2) \quad (1)$$

In this time,  $(\vec{Axz} \cdot \vec{Bxz})$  shows a scalar product of vectors  $(\vec{Axz}, \vec{Bxz})$  projected each point A and B on XY dimension.  $(\vec{Axz} \times \vec{Bxz})$  shows a vector product of vectors  $(\vec{Axz}, \vec{Bxz})$ .

In addition to calculating a degree of control camera of the TILT direction with the next formula.

$$\theta_t = \arctan \frac{\vec{Ayz} \times \vec{Byz}}{\vec{Ayz} \cdot \vec{Byz}} \quad (-\pi/2 < \theta \leq \pi/2) \quad (2)$$

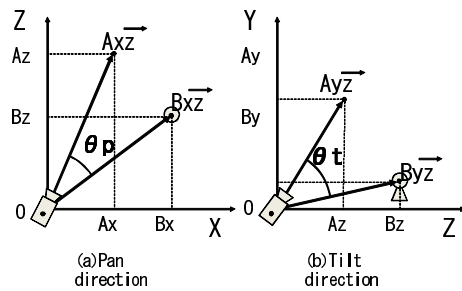


Fig. 7. A image of operating camera

In this time,  $(\vec{A}_{yz} \cdot \vec{B}_{yz})$  shows a scalar product of vectors  $(\vec{A}_{yz}, \vec{B}_{yz})$ .  $(\vec{A}_{yz} \times \vec{B}_{yz})$  shows a vector product of vectors  $(\vec{A}_{yz}, \vec{B}_{yz})$ .

Moreover as a size of the subject, when objects are articles, specify width  $\delta L$ , and when objects are figure, define  $\delta L$  as width 60cm of the side in the figure. The system controls the zoom value of the camera by specifying a distance with the subject and the size to shoot it.

Furthermore, a distance with the camera and the subject are shown with  $(|\vec{B}|)$ , the system calculates the angle of view  $\theta_z$  of the camera by using the next formula from the distance  $(|\vec{B}|)$  and the width  $\delta L$  of the subject.

$$\theta_z = 2 \arctan((\delta L/2)/|\vec{B}|)(\text{rad.}) \quad (3)$$

Besides, the system shows the zoom value of the camera with (1-999), the horizontal angle of view of camera to 1:about zoom  $34.7^\circ$  and 999: about  $2.23^\circ$ . These values were found which were based on the cameras "Panasonic AW-E650 and AW-E350" used by this research.

$$Z = -30.74\theta_z \times 180/\pi + 1067.54 \quad (4)$$

### C. Adjust a camera angle suitable

After the system shoots a figure who is an object by the first-step rough camera control, the system tweaks the angle by using face detection. Fig.8 shows a example of the camera angle of view which the camera shoots a figure.

Based on the method of thinking in the video grammar[8] and the experience of our program production, we defined three kinds of angles which show Fig.8 often used by information program, talk program and so on.

- WS(Waist shot):Shoot object upper the waist.
- BS(Bust shot):Shoot object upper the bust.
- CU(Closed-up):Shoot object upper the shoulder.

Due to the position relations of the camera and the subject, in consideration of the case that it is shot from a oblique, we decided to specify either three position "A right oblique direction, A face direction, A left oblique direction". As a result, the camera angle which shoots one person was divided into nine kinds of angles. By the way, when it shoots several people, it says strictly as for there are several angles to shoot people. But there are not so various expressions as a camera angle which shoots one person. Camera angle is also decided



Fig. 8. Camera angle

and it depends on the position shoots of the subject and so on. In this research, we decided to use only one camera angle when the several people and articles are shot.

In an adjustment of the angle of the camera, it detects a face by using OpenCV[9] technology, and gets a value of barycentric coordinates and face area of the face which is the amount of face characteristics of camera angle made a target from camera view.

## VI. EVALUATION EXPERIMENT

As an evaluation experiment of the proposed system, we made comparative experiments of the operation interface in the camera angle adjustment and the camera operation in the shooting mimic program. We express contents of experiments and results to the following.

### A. Evaluation experiment of operation interface

#### [Experiment Outline]

In the experiment, to verify the efficiency of a camera angle adjustment function to our system, examinees adjust camera angle with three kinds of interfaces. (1)When cameraman operates camera directly. (2)When cameraman operates camera with joystick which is an existent interface. (3)When cameraman operates camera with our system. Examinees operates camera to adjust present camera angle to target camera angle with each interface.

- A number of camera : 1 or 2
- Caster : 1 person
- A number of camera angle: 16
- Examinees : 10

Examinees adjust camera angle with each interface in the following method.

#### (1)Operate camera directory

Examinees use an usual camera, and operate a camera directory.

#### (2)Operate camera with joystick

Examinees use a pan tilt camera and joystick interface, operate a camera with memory button which records a camera position and to tweak angle with joystick by remote control in the interface.

#### (3)Operate camera with our system

Examinees use our system, operate a camera to adjust camera angle with angle operation button "WS", "BS", "CU".

In the experiment, we timed operation until examinees finish adjustment to target angle. Table II shows a combination of angle which we direct examinees to adjustment. And the

TABLE II  
COMBINATION OF CAMERA ANGLE

Number of times	Camera angle 1	Camera angle 2	Camera angle 3
1	Cam1 WS → BS		
1	Cam1 BS → CU		
1	Cam1 CU → BS		
1	Cam1 BS → WS		
1	Cam1 WS → CU		
1	Cam1 CU → WS		
2	Cam1 WS → BS	Cam2 BS → CU	
2	Cam1 BS → CU	Cam2 CU → WS	
2	Cam1 CU → WS	Cam2 WS → CU	
2	Cam1 WS → CU	Cam2 CU → BS	
2	Cam1 CU → BS	Cam2 BS → WS	
2	Cam1 BS → WS	Cam2 WS → BS	
3	Cam1 WS → BS	Cam2 BS → CU	Cam1 BS → CU
3	Cam1 CU → BS	Cam2 CU → BS	Cam1 BS → WS
3	Cam2 BS → WS	Cam1 WS → CU	Cam2 WS → CU
3	Cam2 CU → WS	Cam1 CU → WS	Cam2 WS → BS

TABLE IV  
QUALIFICATION

	Cam 1	Cam 2
OP	GuestBS	2shot
Interview	Guest BS	Caster WS
ED	2shot	CasterBS

object of shooting moved right or left a little it also, changed attitude after examinees finished operation of one combination. For this reason, cameraman must tweak camera angle every combination of angle.

In this experiment, we timed operation of change angle, and evaluated subjectivity adjusted angle by the valuator who learned contents production by professional. How to evaluate is to choose either ① suitable, ② little unsuitable, ③ unsuitable as adjusted angle.

TABLE III  
EVALUATION OF CAMERA ANGLE

	Results		
	①Stability	②Few instability	③Instability
(1)Operate camera directory	270	29	1
(2)Joystick operation	280	15	5
(3)Our system operation	272	15	13

[Experimental result]

Fig.9 shows the result of the time which switching camera angle. The time tends longer as cameras increase. Our system was the least increment operation time.

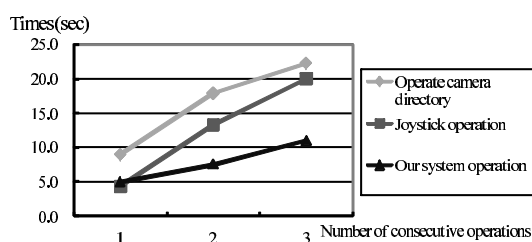


Fig. 9. Average of the time switching camera angle

Table III shows the results of the evaluation of all adjusted angle. The number of angles which got the evaluation of “1. Suitable” was about the same in three kinds of interfaces. Our system got 13 evaluations of “3. Unsuitable”. This is two kinds of reasons. First, the system stopped operating camera on the way because of face characteristics extraction did not go well. Second, the head of the object was cut off drastically from the frame.

B. Experiment of program shooting

In this experiment, we explain the evaluation experiment that the validity of our system is in the program shooting of the actual on-site. This experiment takes up a interview program which cameraman has to decide the camera angle during program shooting.

[Experiment Outline]

The outline of the interview program targeted in this experiment is as the following.

- The length of the program : 10min
- The number of casters: 2
- Title of the program : “About study abroad”

In the experiment, the examinees shoot in the turn as showing below. The examinees of this experiment separate from four people two set.

- Shoot two people one set, and each cameraman operates one camera directory.
- Shoot one person, and operates two cameras directory.
- Shoot one person, and operates two cameras with our system.

[Qualification]

This mimic program which is shot in this experiment is composed of three scenes as the follow.

Opening(OP): The scene program is beginning, a greeting and guest introduction.

Interview: The scene the guest talk about a question.

Ending(ED): The scene program ends by greeting.

Each cameraman shoots the angle which shows table IV in the each scene.

When Cameraman 1 judges the message of the guest’s remark is good, he adjusts a guest to the angle “CU”, and Cameraman 2 adjusts a cast to the angle “BS”. After experiment, we questionnaire examinees, and collect opinions of camera operation, the advantage and the defect of our system by interview investigation.

[Experimental result]

We show the opinions by interview investigation.

Opinion of two people one set, and each cameraman operates one camera directory.

About cameraman operates two camera to adjust angle during program shooting, we got a opinion that “It is difficult to operate two camera at the same time”. Compared with the shooting which two people one set operate each camera, we got a opinion as follows that cameraman felt burden when one person operates two cameras.

- It got confused because it increased notability task during operating camera.

- It increased the judgement task about checking program proceeding task and memorable task.
- It can't notice the on-air image because it increased of the time to camera operation.

#### **Result of experiment that program shooting with our system**

- It never wavers in judgement and operates of camera angle.
- It decreases of the time to operate a camera because of the camera operation with one button by the system.
- It is good to check the two cameras' image without moving.
- It becomes easy because cameraman can operate two cameras by scene button at the same time.

#### **The problem when cameraman used the system**

- There was a case that the system sometimes couldn't adjust angle until the next scene of the program because the system operated the camera slowly.
- There was a case that cameraman pushed the button twice because the system stopped camera operation halfway.

#### **The consideration of comparative experiments of the operation interface**

As comparative experiments of the operation interface, the operation time was short comparison with the time that cameraman operates several cameras directory and cameraman operates a camera with joystick interface. Joystick interface has memory button that operates a camera to the position where it was decided in advance. But cameraman must adjust a suitable camera angle when caster changed position and direction of face in the program shooting. In this point, our system reduces the necessary time for the camera operation.

#### **The consideration of program shooting experiment that one people operates two camera.**

When a person operates two cameras, it is not only the amount of camera operation increases in twice but also a working burden and a mental burden increase because cameraman always notices another camera angle. As this reason, cameraman can't operate two cameras separately at once, and it becomes difficult to expect a timing of operating camera and a transition of the next scene. In addition, it is unrealistic for a general user that cameraman operates two cameras directory from the point that cameraman can't adjust camera angle enough.

It increased to not only operating burden twice but also increased to a working burden and a mental burden.

#### **The consideration of program shooting with our system.**

The system changed the camera operation only push button. By this, cameraman can use more time to check around situation compared that one people operates two cameras directory.

#### **The problem of program shooting with our system.**

As a problem for our system, there is a point about the adjustment speed of camera angle. First, our system adjusts a suitable camera angle to in about three seconds. But in the program shooting, cameraman sometimes adjusts camera angle instantly by sudden judgement. In this experiment, we bring these cases that the caster switches talk theme earlier than

expectations and the transition of the next scene is earlier. This problem needs the improvement of the camera control speed, and a future subject.

Second, there is a point about the system sometimes can't control cameras. It is a cause that the system couldn't do face detection well, and the system stopped operating cameras halfway because the caster tilt head and nod continued. By the face detect with OpenCV, the system can only detect to the face normally at the side to about thirty degrees, and can't detect the face when the caster is nodding and tilting head. Because casters were shot facing each other in this experiment, it increased that a camera shoots the caster's side view. For this reason, the system stopped operating camera halfway.

## VII. CONCLUSION

In this paper, we proposed an adaptive multi-camera shoot support system to reduce cameraman's task in a compact studio operable in small number. Cameraman operates several cameras only push button which is assigned a camera angle or a program scene. The system controls several cameras by calculating amount of degrees with a three dimensional coordinate of the studio environment and tweaks camera angles by face detect to the suitable angle for audiences agreeably. In evaluation experiment of camera operation interface and program shooting, we showed that cameraman can shooting a program by the system without increasing workload.

## REFERENCES

- [1] N. NISHIO, Y. TAKEBAYASHI, T. SUGIYAMA. *A comparative analysis of workflows for staff works in a new compact studio for internet video programs and a conventional studio for TV programs*, IEICE Tech. Rep., vol. 108, no. 343(CS), 344(IE), CS2008-53, IE2008-117, pp. 81-86, 2008. (In Japanese)
- [2] M. KUMANO, K. UEHARA, Y. ARIKI. *Online Training-Oriented Video Shooting Navigation System Based On Real-Time Camerawork Evaluation*, CME2006 (International Conference on Multimedia and Expo), CD-ROM, pp.1281-1284, 2006.
- [3] Y. ARIKI, S. KUBOTA, M. KUMANO. *Automatic Production System of Soccer Sports Video by Digital Camera Work Based on Situation Recognition*, Eight IEEE International Symposium on Multimedia (ISM), second IEEE international workshop on Multimedia Information Processing and Retrieval (MIPR2006), pp.851-858, San Diego, 2006.
- [4] S. SHIBA, A. INOUE, J. HIRAISHI, H. TAKAKU, H. SHIGENO, K. OKADA, *Score-Based Camerawork Planning for Orchestra Shooting* IPSJ SIG Notes, Vol.18, pp.65-70, 2003. (In Japanese)
- [5] D. KATO, K. ABE, A. ISHIKAWA, M. YAMADA, T. SUZUKI, S. KUWASHIMA, *Detecting method of subjects' 3D positions and experimental advanced camera control system*, Proc. SPIE Vol. 3018, p. 65-75, Color Imaging: Device-Independent Color, Color Hard Copy, and Graphic Arts II, Giordano B. Beretta; Reiner Eschbach; Eds, 2000.
- [6] M. OKUDA, T. TSUDA, K. MUTOU, H. YANAGISAWA, S. INOUE, *Method of shot determination in a robot camera cooperative shooting system*, Proceedings of IS&T/SPIE 20th Annual Symposium on Electronic Imaging (EI2008), 6820-25, 2008.
- [7] M. ONISHI, K. FUKUNAGA, *Shooting the Lecture Scene Using Computer-controlled Cameras Based on Situation Understanding and Evaluation of Video Images*, Proc. 17th International Conference on Pattern Recognition, vol.1, pp.781-784, 2004.
- [8] Roy Thompson *.Grammar of the Shot*, Focal Press, 1998.
- [9] *OpenCV-1.0 Reference Manual*, <http://www.cs.unc.edu/Research/stc/FAQs/OpenCV/OpenCVReferenceManual.pdf>.