Annotation view management for wearable projection

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ABSTRACT

Under fieldwork conditions in real world, a wearable projector is applied as an instruction tool for presenting annotation. However, this method has difficulties in projecting annotations clearly in case of that annotation is indicating to unsuitable projection area such as non-flat, jagged and mirror-liked surface. This paper proposes a method of selecting projection areas based on different circumstance to overcome the difficulties of unclear annotations. First this paper focuses on the case when the annotation is overlapping the worker's arms or hands. In this case, we propose a projection method of avoiding the worker's arms. Secondly this paper focuses on the case of non suitable area for projection around the worker. In this second case, we propose another method in which the annotation is projected onto the worker's arm. Experiments are conducted to evaluate the proposed methods in two situations; case of existing suitable projection surface in front of the worker and no suitable surface to be projected around the worker. The result shows that the visibility of annotation was improved with the method of selecting projection area based on worker's arm position.

Index Terms: H.5.2 [Information System]: Information interface and presentation—Interaction style;

1 INTRODUCTION

The applications and interfaces of a wearable projector have been studied a lot[11][6]. These studies support the method of projecting an AR annotation into such as wall, floor, desk or other objects around a worker. Concepts of interface and interaction on these studies are focused on touching, pointing and gesturing toward projected surfaces. Also, a user conducts a physical field work such as cutting and assembling based on the projected information. Some studies of a wearable projector assume that a user is able to gazes the projected annotation. However, the difficulty of projecting annotation clearly is underestimated. However, we assume that the user with a wearable projector feels view-ability burden because the projected annotation is often overlapping user's arms or hands when they interact with real objects. The problem is that the projection device does not project information without distortion because of the occlusion by worker's hands or unsuitable projection surface. Our research aims to solve this problem by considering the position of the worker's hands.

Concretely, we use a wearable projector which can project to wide area, and a wide angle camera which measures position and posture of worker's hands and arms while he is working. This research proposes "Avoiding of worker's hand" as the technique of an annotation view management for wearable projecting. This method is used to position the projection on a suitable surface when the annotation is overlapping the worker's hand. Also, in the case that there is no suitable surface to be projected around worker, we propose "projecting on worker's arm" as an additional function of wearable projector. This method is used to position the projecting on worker's arm in these cases. Then the experiments were conducted to evaluate these proposal methods in each situation.

2 RELATED WORK

Augmented Reality, which overlays information of virtual objects onto the real world, is spread to researches field widely. Especially, to provide photometric and geometric consistency, a lot of researchers use Head Mounted Displays(HMD). Tenmoku shows the guide system which overlaps the annotation to real world [8]. However, HMD imposes heavy burden on wearer in terms of weight, sweat and feeling of wear. Therefore, some researchers use a projection device to build in AR environment [3][5]. Of them, Kurata aims to assist a real field work with using teleoperated laser pointer as a primitive device for remote collaboration [2]. PALM-bit [10] is a mobile AR interface which projects annotations onto palm of the hand and assumes the other hand to be a pointing device. Tajimi [7] shows a method of projecting information onto the ground depending on user's circumstance by a hip-mounted projector. Sixthsense [5] proposes the comfortable GUI and gesture operation of a wearable projector for daily life support. Harrison C. shows a wearable projector as a device which projects to arm of an annotation input from skin [1]. Those researches unveil that these projection devices can provide enough AR environment for various applications without physical burdens. However, these researches of a projector did not consider the limitation of projection area in working space. We assume that the suitable surface for projection is limited when using a wearable projector because the worker's arm often occludes the projected image due to the short distance between worker's body and projection area. Therefore, in this research, we focus on the selection of the projection surface.

3 ANNOTATION VIEW MANAGEMENT METHOD WITH WEARABLE PROJECTOR

Some researches show that they conduct a variety of work-support using a projector installed in body. However, there is no commercial product projector which has a capability of projecting annotations to wide-area in close-up range. Commercial product projectors cannot select the suitable projection area within the range of the hands while working due to narrowness of range of the light of projector. To realize the wide projection area with small and normal angle projector, a device which can turn its projection lights in wide direction is necessary. Therefore, we need to develop a device which can move the projector body to turn the projection lights to wider direction than normal projectors. However, moving the projector in itself make a worker feel fatigue. Pinhanez realizes selecting projection surface by using the projector with pan/tilt mirror [4]. As the size and weight of pan/tilt mirror are small and light, a worker feels less physical burden. Therefore, we adopt the method that can turn its projection lights in an arbitrary direction

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with pan/tilt mirror. This method allows to use wide area as a projection surface comparing to normal projector by controlling mirror. The proposed method requires a device which has the capability of allowing a projector to select the projection area widely. For above reasons, we developed a composite device which can control pan/tilt mirror to turn the projection light as shown in Figure 1.

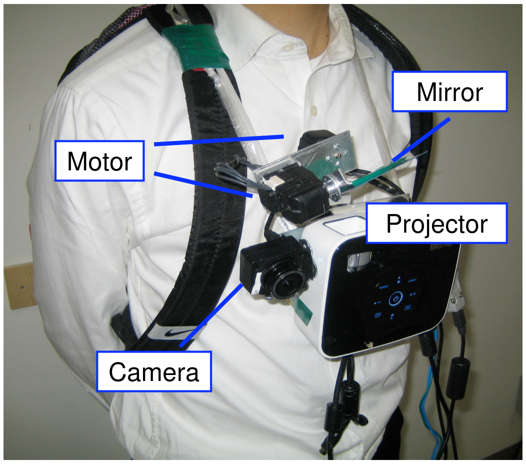

Figure 1: Appearance of system

The device consists of a mobile projector, a wide field of view camera, a mirror to reflect projection light and two motors to pan/tilt the mirror. the mobile projector is a JoybeeGP1(Qisda Co., Ltd). Motors are DYNAMIXEL DX-117(Besttechnology Co., Ltd). The camera is a Firefly MV(Point Grey Inc.) with a fisheye lens. The resolution of projector is 800x600 and brightness is 100 lumen.

4 Experiment

4.1 In case of existing suitable surface

When a worker, who uses a wearable projector to present work support information, faces the front area of him, the front area of the worker tend to be selected as a projection area because these area are easy to watch. However, the projection area and worker's arms can get overlapped while the worker is conducting some tasks, even if the projected area which is not overlapped worker's arm is selected at beginning of the task. In this case, we assume that the work efficiency would decrease and the time of work would take longer. In such situation, we hypothesize that the worker can keep watching the projected annotation easily and clearly by projecting annotation by the avoiding worker's arms. Then, based on the hypothesis, we conducted experiments to examine the effects ”avoiding of worker's hand” method when the worker's arm overlaps with projection area.

4.1.1 Configuration

In the experimental space, a board with three wooden boards of 130 cm height was fixed straight on the wall as shown in Figure 2. The distance between each wooden board was 20 cm. Each wooden board had four holes to install four nuts. The left wooden board and the right one were bilaterally symmetric and both were 15 cm width and 10 cm height. The center wooden board was rectangular and it was 15 cm width and 7 cm height. The following task was conducted in this configuration. The images were presented as an annotation by the projector. The images indicate the point where a subject tightens the screw. The projected image was changed every four seconds. Also the projected images were four patterns and each image pattern indicated only one hole to tighten. Those images

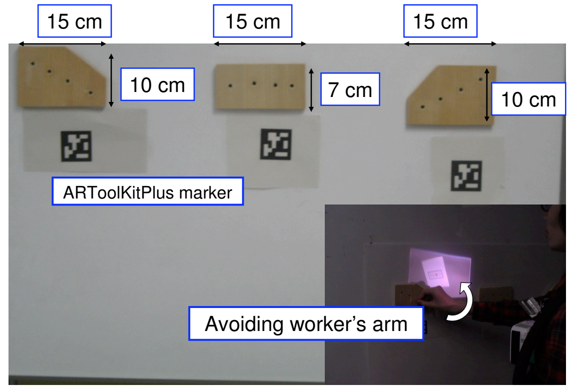

Figure 2: Configuration of experiment

were projected iteratively in certain order. Subjects watched the annotation and tightened the screw to a hole indicated by annotation. Subjects started the task when the first image was projected, and finished the task when they tightened the fourth screw. Tightening four screws to wooden boards was defined as one task. Five tasks were conducted in two conditions; one was ”Avoiding of worker's hand” and the other was ”simple overlaid view” as shown in Figure 3. Subjects stood in front of wall, and they could move to the place

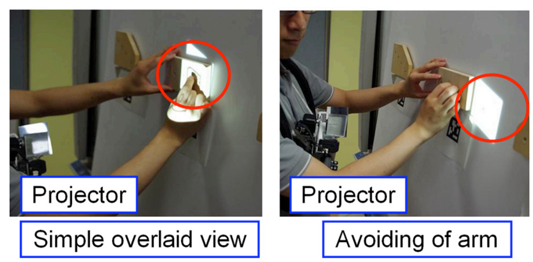

Figure 3: Scene of experiment

where they could perform the jobs easily. Then they were told to allow to make sure the image indicating next point while tightening current point. When subjects worked at left wooden board, the image was projected on a place between left and center wooden board. When subjects worked at right or center wooden board, the image was projected to a place between center and right wooden board. The projected annotation was a picture on which the shape of the indicated wooden board was drew and the indicated hole to be tightened was shown in red. In ”Avoiding of worker's hand” condition, projected annotation was moved to suitable projection area which was not occluded by arm when the subject's arm overlapped the annotation. In ”simple overlaid view” condition, even if the projection area was overlapped by the subject's arm, it continued to the project the same place. We used ARToolKitPlus markers [9] to measure the relative position and posture of developed wearable projector between the three markers. Also, the system has environmental models such as the exact distance among three wooden boards and three markers. The system can calculate relative position and posture between the wearable projector and the surface where the selected area to project the images. Therefore, the system can project images to desired surface without distortion. The experiment was conducted with nine subjects (gender: nine male; age: 21to27; dominant hands of all subjects are right). The order of instruction conditions was different for each subject to prevent the order effect. In this experiment, the time from the voice announcing the start of a task to the subject's voice announcing the end was recorded as the task completion time. Subjects answered following questionnaires on a scale of 1 to 7(Table 1).

Table 1: Contents of Questionnaire

Q1	which method was easier for you to read out an annotation when you were working on left wooden board?
Q2	which method was easier for you to read out an annotation when you were working on center wooden board?
Q3	which method was easier for you to read out an annotation when you were working on right wooden board?
Q4	which method was easier for you to read out an annotation in the entire work?
Q5	which method did interrupt your task?
Q6	which method did interrupt watching annotation?
Q7	which condition did you feel troublesome?
Q8	which condition did you feel easy to work?

4.1.2 Results

Figure 4 shows task completion time in each experimental condition. The result shows that the task completion time of "arm avoiding" was significantly shorter compared to "simple overlaid view"(Wilcoxon signed rank test :p<0.05). The result shows that there "arm avoiding" was significantly evaluated as better in Q1, Q2, Q4, Q5, Q6, Q7, Q8(t-test: p<0.05).

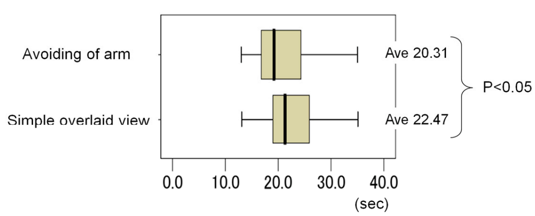

Figure 4: Work completion time

4.2 In case of no suitable surface

The results of the previous experiment suggest that the "avoiding of worker's hand" is efficient in case of existing suitable surface in front of the worker. In this section we conducted another experiment in case of no suitable surface for projection around the worker, where a projector cannot present any information. We assume that such situations happen sometimes in catwalk or out-door constructions. Then, we examine whether our developed device can project effectively for this case. As shown in Figure 5, we propose the projection method of selecting worker's arm as a projection surface. As comparison, we set another condition that workers wear the PDA on their arm so as to watch instruction information. We study the work-ability between the "projecting on arm" method and "PDA" condition.

4.2.1 Configuration and result

As shown in Figure 6, four wooden boards were hanged up on 140cm and 110cm from ground by a vinyl tape. The distance between the upper wooden boards was 50cm and the distance between the lower boards was 20cm. Those wooden boards were colored respectively. The upper left wooden board was colored yellow, the upper right one was colored blue, the lower right one was colored red. The lower left one was not colored especially, and was color of the wood.

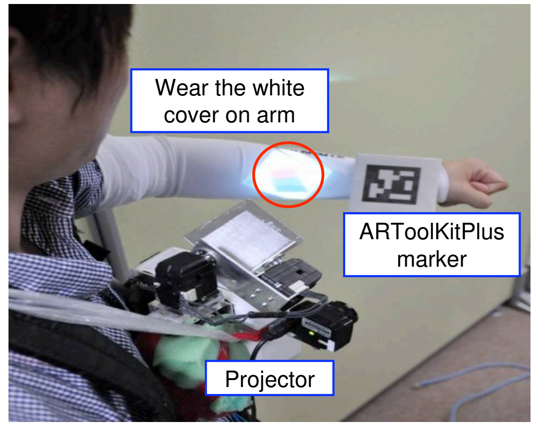

Figure 5: "Projecting on arm" condition

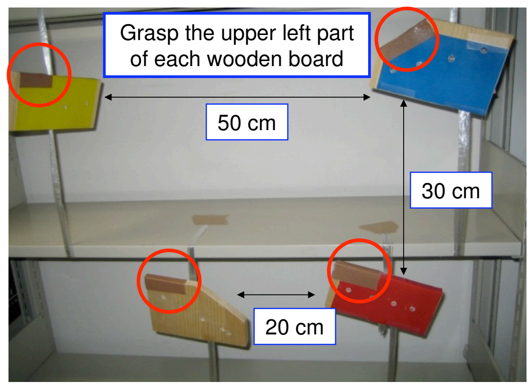

Figure 6: Configuration of experiment2

Each wooden board had four nuts attached and subjects tightened the screws to the point which was shown by "projecting on arm" or "PDA condition". The wooden boards used in this experiment were same shapes in configuration 4.1.1. There was a total of 16 holes where subjects tighten screws. Additionally subjects had to grasp the upper left of the wooden board when they tightened the screws. We set these configurations to observe situations of "using both hands" and "working with various angle of arm". The following task was conducted in this environment. The projector projected an image indicating the tightening point. Projected image was changed every four seconds. The subjects watched the annotation and tighten the screw directed by annotation. Five images were projected. Those five images were projected iteratively in certain order. Subjects watched annotation and tightened the screw into indicated point just like in configuration 4.1.1. In this experiment, 5 screws were tightened in one task. Subjects started when the first image was projected, and finished when they tightened the fifth screw. Five tasks were conducted in following two conditions. The projecting images were designed of the shape of each wooden board and the indicated hole was exaggerated for different color from the other holes in the image. Additionally, the designed wooden boards were colored the same color of the indicated wooden board. In first "projecting on arm" condition, we measured the position and orientation of the subject's arm by a bracelet with ARToolKitPlus marker [9]. In "projecting on arm" condition, subjects wore the white cover on their projected arm to facilitate visualization of the annotation. In the PDA condition as shown Figure 7, subjects chose the position and posture where they wore the PDA. The PDA was attached

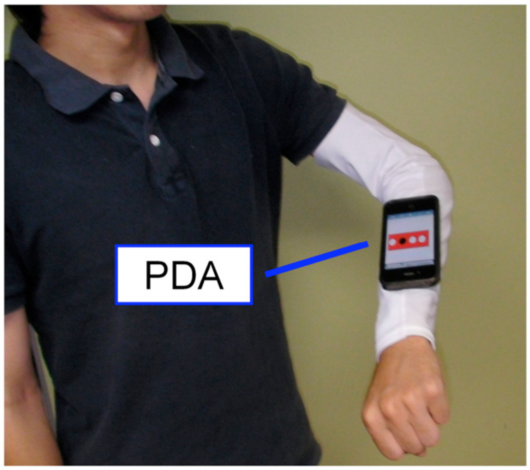

Figure 7: "PDA" condition

to subject's left forearm. The projected image was shown on the PDA display in the same images and time interval, and then subjects tightened the screws directed by the presented image on the PDA.

The experiment was conducted with seven subjects (gender: all males; age: 22 to 25). After the experiment, subjects answered questionnaires on a scale of 1 to 7 about visibility, Interruption of task, Work-ability and Subjective work time. Note that, we did not measure work completion time in this experiment because the difference of work completion time was little in the small pilot study with same configuration. Therefore, we did not evaluate a work completion time, and evaluated two condition only by questionnaire.

Figure 8 shows the result of the questionnaire. As a result, we found no significant difference between "projecting on arm" and "PDA" conditions (t-test: $p<0.05$).

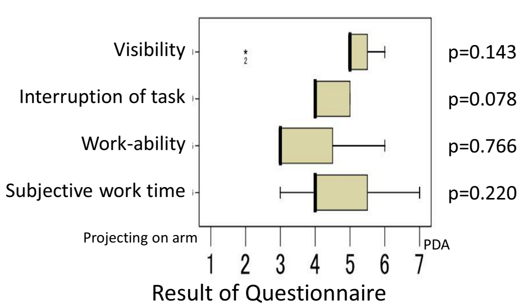

Figure 8: Result of questionnaire

5 Conclusion

As a result, completion time of "avoiding of hand" is shorter than "simple overlaid view". In "simple overlaid view" condition, the worker cannot watch projected annotation clearly because the worker's hand overlaps it. That make the work time longer. On the other hand, in "avoiding of hand" condition, workers can read out annotation easily. The main reason why no significant difference is found in Q3 of questionnaire is that right-handed subject's arms did not overlap the projection area because the projector projected to left when the subject was facing the right wooden board. That shows that selecting projection area is an important factor in case of projecting annotation with wearable projector. When a worker watches annotation while working, overlapping his/her hands and projection area may influence on the working efficiency because they must gaze at the working area.

As a result of experiment 4.2, there is no significant difference between "projecting on arm" and "PDA" condition. Therefore we can say that our proposed method "projecting on arm" is as effective as the "PDA" condition. When the worker's arm with the display of PDA rotates, worker cannot watch the display .On the other hand, in the method of projecting on arm, presentation surface is not fixed. Even if the arm rotates, the worker can watch a projection. Moreover, in the case where arm is hidden because of the shielding, they cannot watch the display of PDA wearing on their arm. In such case, prototype wearable projector can change the projection surface aside from arms. And it can project where the worker can watch it depending on the circumstances.

Future works are constructing a system changing projection surface automatically and evaluating which surface is suitable as projection surface. In addition, according to the positional relation of head and arms, worker sometimes cannot watch annotation even if they are not overlapped. Therefore we propose the method of considering embodiment of worker.

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