

# Shadow Awareness: Bodily Expression Supporting System with Use of Artificial Shadow

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**Abstract.** As a supporting means for self-creating bodily expression, shadow media system was developed with which shadow is artificially deformed into diverse forms and such deformed shadow can be displayed on a screen without separating it from the own body. With the system, it was found that the awareness was established inside the body via deformed shadows; therefore it can support an improvised creation of the images. Furthermore, by the subject-object inseparable interaction through shadows, co-creation of images with others was encouraged. Accordingly, it was indicated that this media system is promising and effective to support co-creative expression and shows its potential applicability as a creative archive technology to connect to past people.

**Keywords:** Bodily Expression, image, awareness, co-creation, shadow media.

## 1 Communicability and Bodily Expression

For expanding the communicability of each individual, the following two things are considered essential; (I) you should respect and accept other people's expression as an equivalent value as yours, and its irradiation should be taken inside yourself, and (II) "bodily sensitivity" with which a new awareness on your and other's existence will be created by the reflection of the expression. When the equivalence of expression is secured, diverse expression with personality can be extracted from each individual by the so-called "function of open body" which are supported by bodily sensitivity; so that the "Ba" of encounter might be created [1-4]. At the same time, in the co-creative expression [5], a new image will be co-created with the other person while sensing reflection of your own expression pre se, by the "function of open body". With this manner, the impromptu and self-consistent expression can make advance in simultaneous and complementary manner without any interruptions.

Based on what has been described above, in the present study aiming on expanding the communicability, it should be pointed out that expressing self should sense the reflection of own expression, and this supports creation of new image. For approaching this aim, we turned our attention to be ontologically inseparable between body

and shadow. This study will also investigate possible method with which, a clear awareness can occur or body itself can be expanded by visualizing the reflected expression which was normally sensed inside yourself as an expression by your own shadow. Moreover, this study will examine possible methods for a shadow expression for perpetually spinning expression by continuous image creation. Furthermore, “creative archive expression method of “Ba” will be investigated. This will allow current people to encounter past people beyond time and space by re-displaying other person’s past expression recorded with use of shadows. The last purpose was aimed to acquire design guidelines for media technology which can support the communicability and co-creative expression. There are none previous works on technologies using shadow as an embodied media expect our works [6] and [7].

## 2 Ontological Inseparability of Shadow

### 2.1 Structure of System

In this study, as discussed in more detail below, bodily expression was intended to be extracted by the free deformation of own shadow. For achieving this task, the system for creating artificial your own shadow is necessitated. Fig.1 shows the system structure as well as creation process. In the developed system, the thermal vision camera for obtaining human image is installed at the Backspace as a virtual light source. With this virtual light source, shadow artificially produced by PC is then displayed from participant’s standing position. With this system, thermal distribution image of human obtained from the thermal vision camera is sent to PC. The areas of floor surface and

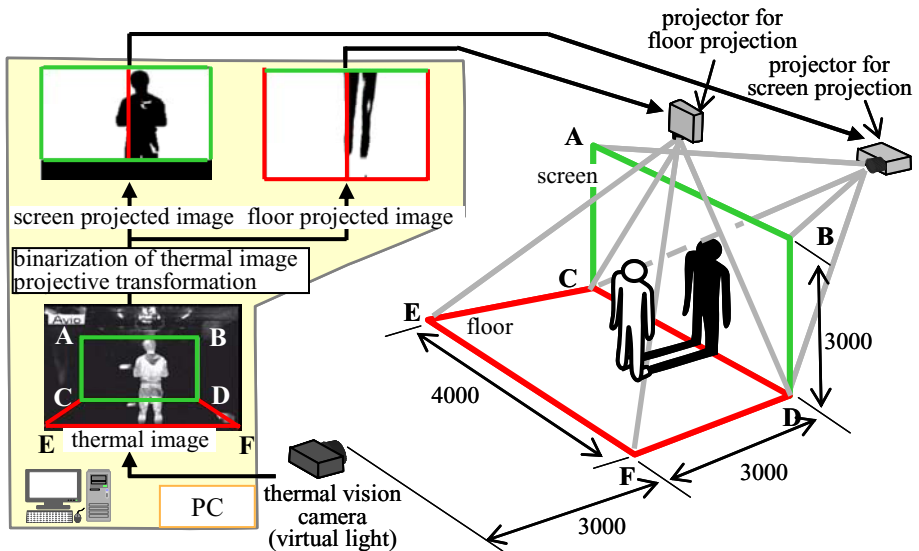


Fig. 1. System configuration

screen in thermal distribution image area are designate as two rectangular shapes, and floor projected image as well as screen projected image were produced. Moreover, by binarization of these thermal images, these images were converted to shadow images and further performed with projective transformation to map these images in the projection space. OpenCV was utilized to paste and display images load into PC and for image processing of shadows. Lastly, these two shadow images are projected by a projector for screen surface projection which is installed at the Back surface of the screen and a projector for floor projection which is installed at the ceiling. By the structure mentioned above, shadow created by PC can be projected coordinately from participant's standing position. Moreover, it was verified that artificially created shadow can be projected in 15[fps]. The following experiments were conducted using this system.

2.2 Body, Moved by Shadow

Firstly, authors had performed the following experiments on simple walking movements in order to investigate the ontological relationship between body and its shadow. Subjects are 10 males (age range: 22 - 30 years old). Subject was asked to be moved parallel with the screen. Furthermore, he was asked to walk Back and forth along 3.6 m distance with his preferable walking speed. During their walking, as seen in Fig.2, each subject's shadow (whose speed was proportional to the subject's walking speed) was inclined toward to his walking direction, and inclination angles of subject's body as well as his shadow were measured and recorded. For experiments, red LEDs were installed at subject's chest and waist. These movements were photographed by CCD camera and image-processed to calculate the exact angle of the body with reference to the vertical direction. Moreover, as seen in Fig.3(b), a similar experiment was conducted under a different situation when, instead of a shadow extending from his standing position, a whole shadow of the subject (which is called as "silhouette") was projected on the screen.

As a result, the experiment using an ordinal shadow (which is called as "self-shadow") which was displayed from his standing position without being separated from the subject indicated that the subject's body had a stronger tendency to make inclination as if the subject were unconsciously pulling by the shadow whose inclined angle was manipulated according to the walking speed, in comparison to the

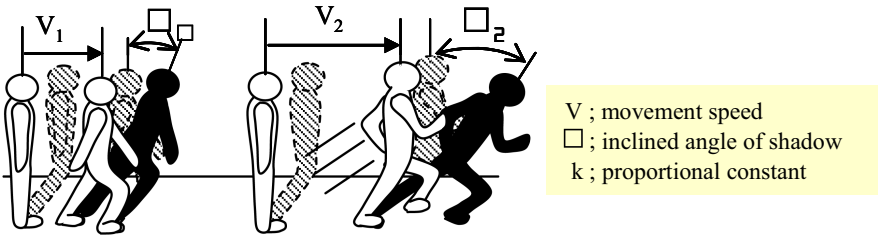


Fig. 2. Inclined shadow, corresponding to body movement speed

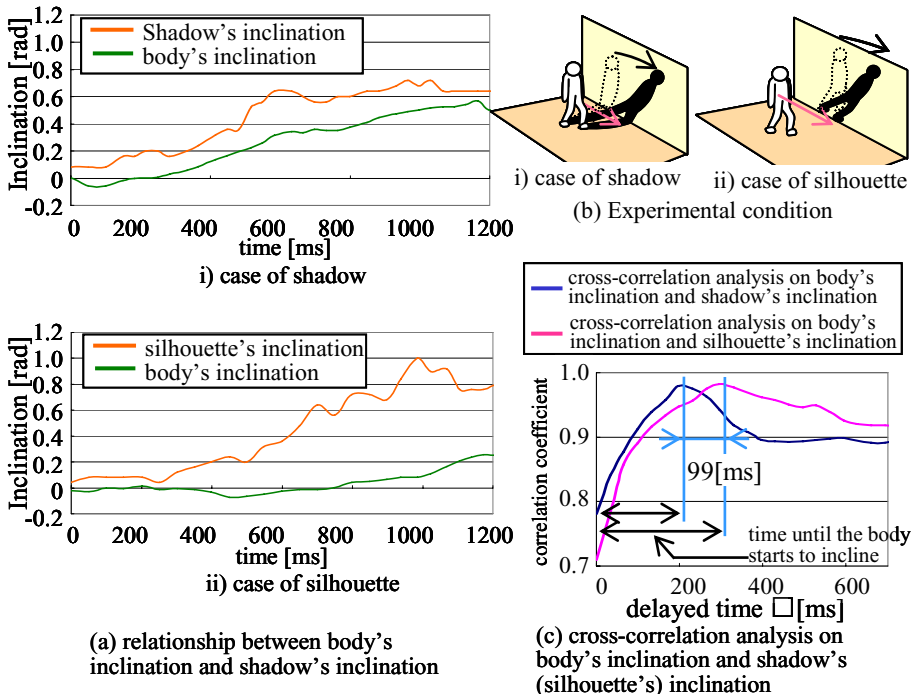


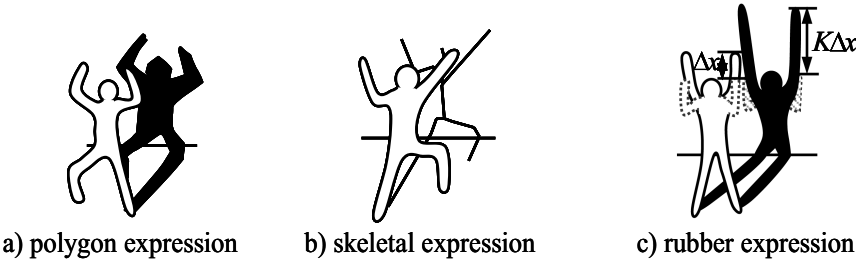
Fig. 3. Experimental Results

silhouette tests. One typical example of results is shown in Fig.3. More interested, it was found that the time when body started to make inclination using the self-shadow was 100ms earlier than that using the silhouette. This characteristic difference suggests that there are two types of functions – function for unconscious reaction and conscious (cognitive) reaction –, and former type of function precede appearance of latter type of function. This implies the characteristic of the self-shadow, which is originated from ontologically inseparable relationship between body and shadow, and a similar phenomenon should not be realized with a body image on mirror (or mirror image) which is ontologically separated from own body. In other words, human can unconsciously position his existence in actual field by his own shadow.

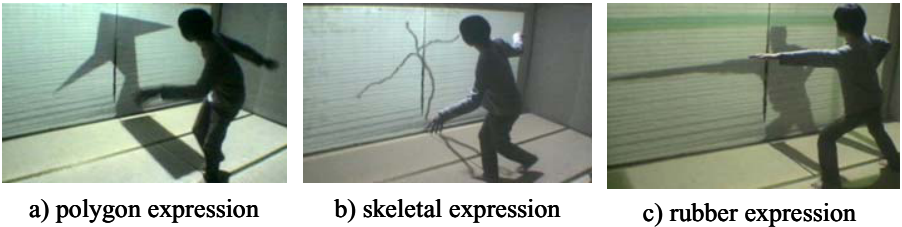
### 2.3 Metamorphosis of Body Sensation by Deforming Self-shadow

If we employ ontologically inseparable relationship between body and shadow as described above, it is expected that bodily expression can be extracted in correspondence to the deformed mode by artificially deforming your own shadow. As seen in Fig.4, we have developed several software for generating polygonized shadow (polygon expression), showing shadow with lines (skeleton expression), or extending the shadow of one part of the body in accordance to its body part's moving speed (rubber expression), which were installed in the above system. Several image examples of shadow are demonstrated in Fig.5. These systems were experienced by general

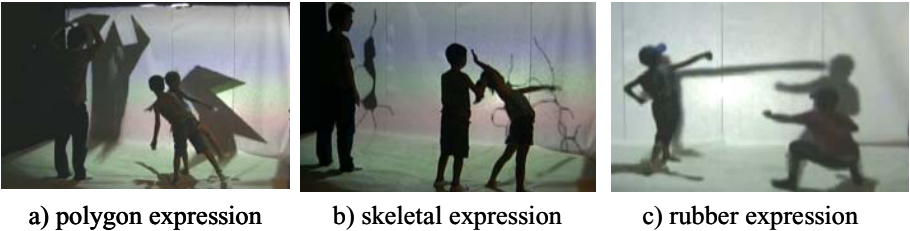
participants (at national museum of emerging science and innovation; 2008.7.25-30) and we obtained various bodily expressions which were extracted from shadow's shape as well as movement, as seen in Fig.6. For example, for the case of the polygon expression, bodily movement per se appeared to be rather linear and angle was emphasized by bending their joints. Furthermore, a certain portions of body such as head or arm of your shadow is extending toward the upper or horizontal direction, so that this makes a sense of expansion of your own real body. As a result, jumping up and down or pushing arms outward was frequently observed. Moreover, it was also found that when a shadow of the subject on wheelchair became larger than the real size while swinging his arm upwardly, the bodily action of wheelchair subject appeared to synchronize with other participant unconsciously and "Ba" with an equivalent feeling seems to be created between two individuals.



**Fig. 4.** Various expressions of shadow



**Fig. 5.** Example of shadow expression



**Fig. 6.** Creation of bodily expression by various shadow expressions

### 3 Self-creation of Expression by Shadow Image

The previous results can be understood by the thought that the feeling in gap generated between your own body and unexperienced shadow might create the bodily awareness, and it is furthermore hypothesized that the body kept its expression in order to accept such feeling in gap. If our assumption is correct, it can be expected that each subject can open their bodies by respective expression through their shadows and they can create “*Ba*” of encounter, being accompanied with mutual bodily awareness. However, since such gap is defined by designers’ preference for this case, the restriction caused from the system is strong and the thus image has a tendency to be fixed. As a result, a reflection of expression (with which body sensation as well as existence sensation could be jeopardized) might be unidirectional. In order to solve this problem, it seems to be crucial for participants involved in the system to self-create the gap per se. In other words, a development of novel expression software with self-referentiality is urgently required. By the self-creating shadow image using such software, gap between your body and shadow can be eliminated, and a new gap can be generated at the same time. In fact, this software can create an expression by the circulation between body and shadow.

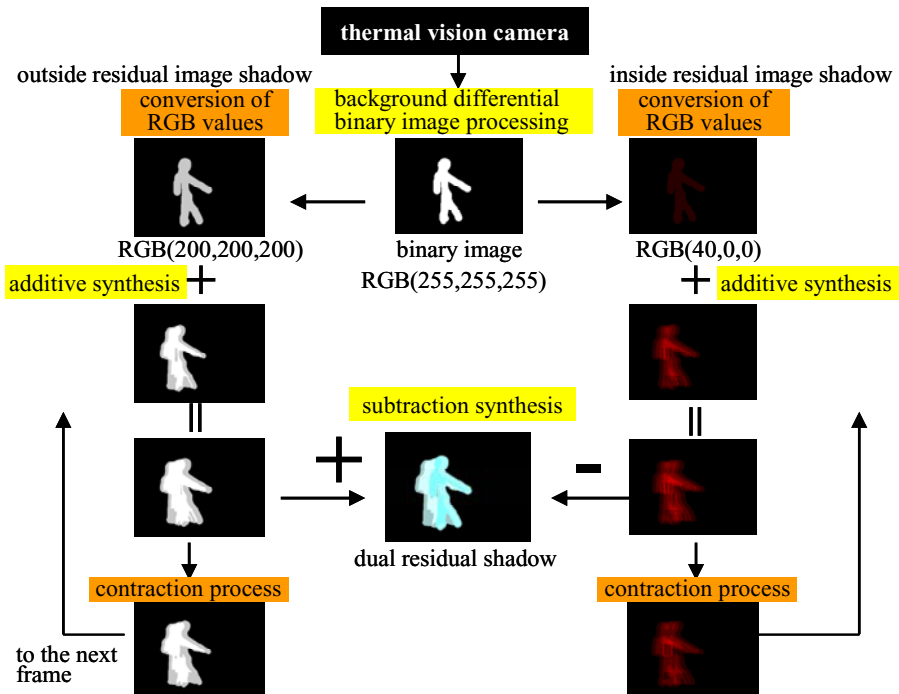
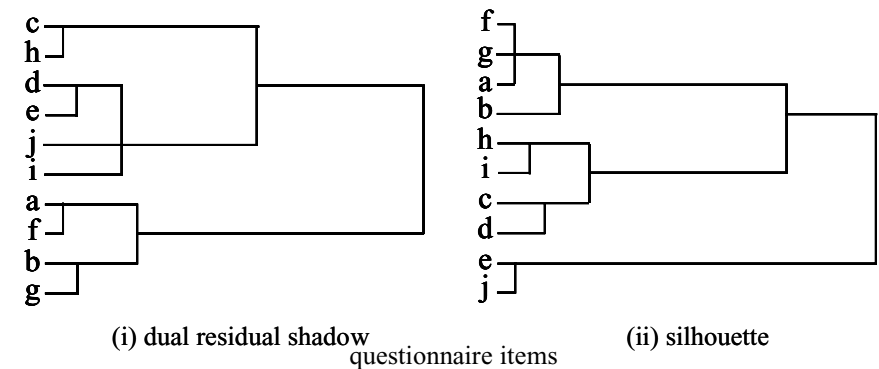


Fig. 7. Generation algorithm for dual residual shadow



Fig. 8. Bodily expression using dual residual shadow



a	I felt that body was unified with shadow as far as the timing is concerned. At that time, body was felt to become to be coincided with shadow.	f	I felt that body was unified with shadow in space. At that time, body was felt to become to be coincided with shadow.
b	I felt that body was unified with shadow as far as the timing is concerned. At that time, shadow was felt to become to be coincided with body.	g	I felt that body was unified with shadow in space. At that time, shadow was felt to become to be coincided with body.
c	Body was felt to be shifted from the shadow as far as the timing is concerned. At that time, body was felt to create a shift.	h	Body was felt to be shifted from the shadow in space. At that time, body was felt to create a shift.
d	Body was felt to be shifted from the shadow as far as the timing is concerned. At that time, shadow was felt to create a shift.	i	Body was felt to be shifted from the shadow as far as the timing is concerned. At that time, shadow was felt to create a shift.
e	I felt that body and shadow were separated in time.	j	I felt that body and shadow were separated in space.

Fig. 9. Results of hierarchical cluster analysis

Based on the previously described Background, dual expression software for shadow with use of residual image has been developed by R. Okiyama of our laboratory. As seen in Fig.7, residual image can be generated by contraction-processing present images made with additive synthesis. For this process, two types of shadow images with great differences in shadow's color (RBG value) were prepared. Then this software performed the above processing to respective image, and, at the final stage, the dual residual shadow was generated by subtraction synthesis of these two residual image shadows. Here two cases are demonstrated; I) outside residual image

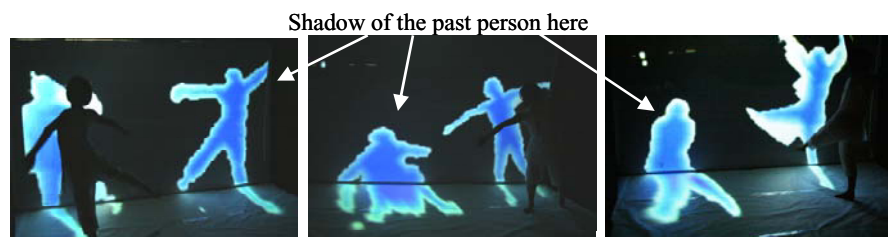
shadow (with large RGB value), showing a sharp reaction to variations on bodily movements, and (II) inside residual image shadow (with small RGB value), showing a slow reaction to the m. Since each residual image possesses different contrast, experiment subject can feel a boundary appeared at inside and outside residual image shadows and the boundary defined at outside residual image shadow and system space as a temporal and spatial gap. As a result, this makes the subject feel to have competing bodily expansion and contraction. The feature of bodily expression using the present software is demonstrated in Fig.8. Among many comments, the followings are typical; “I felt as if I wanted to continue to move.” “There was a sense of relief as well as a sense of unity.” “Time sensation has been varied.” “Changes and movements of mind can be sensed.” Hence, it was noticed that diverse expression can be spun along with creating images.

Furthermore, we conducted a questionnaire survey with regard to temporal and spatial gap between shadow and body. Obtained results were subjected to the hierarchical cluster analysis by Ward method, as seen in Fig.9. In Fig.9, for comparison purpose, results on the silhouette tests are also shown. Several points should be noticed. By the dual residual shadow, two situations - a situation where body and shadow are unified in time-and-space and inseparable, and another situation where body and shadow have a gap or are separated - form two large clusters which divides all items in two. Namely, in the case of the dual residual shadow, it can be speculated that relationship between body and shadow circulate among inseparable and separable situations, and this circulation make it possible to create new expression constantly. Moreover, results on the dual residual shadow show that a pair of time and space forms nearest cluster in the items about unity, so that it can be also suggested that, when subjects feel body and shadow unified, time and space can not be separated inside the subject mind. On the other hand, when subject feel time and space separated, the subject can sense the separation of the time and space which are taking place inside the subject’s mind, and feel that shadow create such a gap. From these results, in the case of the dual residual shadow, expression can step by step advance by dual situations - inseparable feeling of time and space in the case of unification between shadow and body, separable feeling of time and space in the case of separation between shadow and body-. This furthermore indicates that the “*Ba*” (space) can be varied by subject’s expression, and new expression can be created at the “*Ba*” (space) if such a thing is felt as a gap. Moreover, space and time which construct the expression can be self-created by complementary and circulating manner by the unifying the body and shadow and gap via the double shadow, just like the similar situation where time providing the Base for the expression can advance by time-difference in ever-changing expression.

#### 4 Creative Archive of “*Ba*” with Use of Shadow

The present authors have previously developed “Communication System of “*Ba*” (WSCS)” which employs the shadow as your own agent and we have reported that, by reproducing past actual field by the shadow, we can position our existence together with the past people’s shadow in past actual field [6]. However, since it is principally impossible for us to have an interaction with people’s shadow, we could not





**Fig. 10.** An example of archive in case of dual residual shadow usage

accomplish a creation of context of “*Ba*” by playing with past people. Hence, in order to overcome this problem, the present authors examined the creative archive expression of “*Ba*” which can integrate the bodily expression of past people and current people in subject-object inseparable manner. As a result, it is hypothesized that current people can position past people in the same stage (“*Ba*”) by not making the direct interaction between past and current people’s shadow, but creating an another shadow image enveloping partner’s shadow through the mutual bodily expression. This requires that shadow has different dual function. One is subject-object inseparable function. The other is subject-object separable function. Then, we tried to apply the previous dual residual shadow. A part of results is presented in Fig.10. In this figure, current people dance with past people’s shadow by re-displaying the recorded past people’s shadow. Among many comments, the followings are typical; “Although I was firstly very confused, later on, breath of shadow and “*Maai*” entered into me and started to feel “we are unified.” “Although I only moved very awkwardly by forcing to adjust to the other people, later on I felt that I can dance more freely unconsciously and I found some joyful moment when I noticed that we danced in prefect harmony.”

When respective shadows of past and current people are expressed with dual residual shadow, participants feel that the outside residual image precedes the inside residual image. As a result, it can be considered that a unique expression - with which the current people behaves as if he anticipates the movement of the past people - was extracted from the present people. In other words, the outside residual image has a subject-object inseparable function. Through this function, the expression of the current people can be unified with that of the past people in complementary and simultaneous manner, so that the current people can be apparently related to the past people and position himself in their mutual common “*Ba*”. Namely, the present authors consider that, by an occurrence of an apparent co-creative expression with the past people, the current people can continue to self-create his expression while the current people is grasping past people’s mind and past people’s context of expression to some extent.

## 5 Toward Supporting the Image Creation for Bodily Expression

The dual residual shadow is characterized by utilizing the differences between outside and inside residual image processing, and creating the temporal and spatial gap at

their boundary by bodily movements; therefore, body being inseparable from its shadow is felt as if the outside shadow appears to advance in time (or anticipate the future) than the inside shadow. In other words, changes in inside shadow is sensed and recognized as a mental gap which changes by sensing the reflection of self expression, and on the other hand, the outside shadow's changes are sensed as an existence gap of self bodily expression. The expression can be constantly created in such a way that such explicit double gap is integrated as an original function for connecting outside and inside of the body. The fact that majority of experiment subjects had comments on projecting his mind to shadow might suggest that reflection of expression is circulated between shadow and yourself by encountering the shadow, and "*Ba*" where you might had a conversation with the shadow is created. By the single display of the residual shadow or dual shadow having previously fixed boundary between inside and outside shadow, we have received comments "There was some sort of restriction." "I did get any positive imagination." These comments suggest us that it appears to be important for boundary of "*Ba*" to renew autonomously by the bodily expression, in order to set free the time-and-space restriction for expression and support constantly the image creation. Moreover, the interaction of the bodily expression via the duality of shadow like the dual residual shadow can promote the co-creation of images and can be effective for supporting the co-creative expression. Furthermore, it was indicated that dual residual shadow shows its potential applicability as a creative archive technology to connect to past people.

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## References

1. Shimizu, H.: The Thoughts of "*Ba*": Creative Stage of Life (in Japanese). University of Tokyo Press (2003)
2. Shimizu, H., Kume, T., Miwa, Y., Miyake, Y.: *Ba* and co-creation (in Japanese). NTT Publishing (2000)
3. Miwa, Y., Nishi, H.: Communicability support for "*Ba*" of encounter - a trial on functional relationship and existence relationship with bodily expression. In: Proceedings of Human Interface symposium, pp. 889–892 (2008) (in Japanese)
4. Nishi, H., Noguchi, H., Yoshikawa, K., Hattori, M.: How can we apply three-dimensional computer graphics to creative physical expression? In: Proceedings of Human Interface symposium, pp. 137–140 (2008) (in Japanese)
5. Miwa, Y., Itai, S., watanabe, T., Nishi, Y.: Communicability and co-creative expression. In: Proceedings of SI 2008 (2008) (in Japanese)
6. Miwa, Y., Itai, S., Sakurai, D., Hasegawa, S.: Shadow arts-communication -System supporting communicability for encounter among remote groups. In: Smith, M.J., Salvendy, G. (eds.) HCII 2007. LNCS, vol. 4558, pp. 84–94. Springer, Heidelberg (2007)
7. Miwa, Y., Ishibiki, C.: Shadow Communication: System for embodied interaction with remote partners. In: Proceedings of CSCW 2004, pp. 467–476 (2004)