A Camera-based Tangible Controller for Cellular Phones

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ABSTRACT
This paper proposes a novel easy-to-use camera-based tangible controller for cellular phone applications. It realizes continuous analog input by tracking a marker at the top end of a controller device attached to the embedded camera. In contrast to the conventional keypad which enables limited operability to four discrete directions, the proposed controller brings not only an unconstrained continuous input to arbitrary directions but also continuous input for depth and for a rotation angle. In order to evaluate operability, we conducted a user experiment of time trial for path tracing, and the results showed that the subjects completed the task with the proposed controller in 27.9% less than with the conventional keypad input.

Categories and Subject Descriptors
H.5.2. User Interfaces, H.1.2. User/Machine Systems, I.3.6. Interaction Techniques, I.4.8. Tracking

General Terms
Design, Experimentation, Human Factors.

Keywords
Cellular phones, human machine interface, camera-based controller, tangible device, video analysis.

1. INTRODUCTION
In accordance with increasing applications and functions of cellular phones, users' keypad operation is also increasing and becoming more complicated. The controller plays an important role in usability of a cellular phone. Recently, some new interfaces emerged for cellular phones to bring simpler and more natural operability. For example, the touch-screen is gaining popularity due to its intuitive and intelligible operability [1]. However, the touch screen is not appropriate for the applications which require continuous control with eyes on the screen, because a part of the screen is occluded by the fingers.

We propose a camera-based tangible controller with a simple controller device. Instead of installing an expensive controller, we put a simple device made of transparent and flexible material on the embedded camera which is now commonly equipped on a cellular phone. The embedded camera is mostly equipped on the opposite side of the screen. The users control the pointer by a single finger in a natural grasp style like an analog joystick without hiding the screen. We evaluated the interfaces using a Sony W54S phone. The simulation results showed that the proposed controller improves the usability for cellular phones.

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2. RELATED WORK
Gesture recognition based on video analysis is now attracting attention as new controllers [2-4]. Gallo, et al. [2] proposed a pointing controller based on finger tracking using image gradients in a color space relevant to human skin. Kato, et al. [3] proposed a camera-based controller which recognizes a user's gesture based on certain camera motion parameters. However, recognition accuracy is influenced by background and lighting conditions. Hachet, et al. [4] proposed a 3-DOF controller that tracks a target object that the user holds behind the screen. A relative position can be estimated by analyzing the specific color pattern on the target. However, it is not considered so easy-to-use in the practical use since it requires holding the device and the target with both hands.

3. PROPOSED TANGIBLE CONTROLLER
The tangible device consists of a marker, a spring and a magnetic ring which are simple, common and inexpensive materials (Fig. 1(a)). We set up the red and blue rectangle as a marker at the top end of the device (Fig. 1(b)). Next, the spring is made of transparent and flexible material. Transparency is required for allowing light to reach the camera to capture the marker image. Flexibility is required for haptic feedback. Finally, the magnetic ring enables the device to be equipped on the metal ring which is pasted up on the surroundings of the camera lens (Fig. 2(a)).

The users are able to move the marker in any directions including the depth by a single finger operation. The proposed algorithm

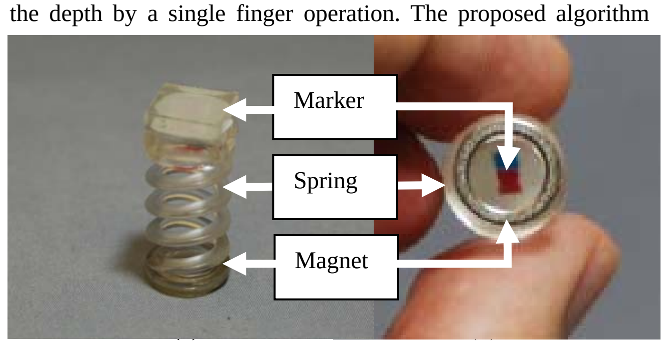
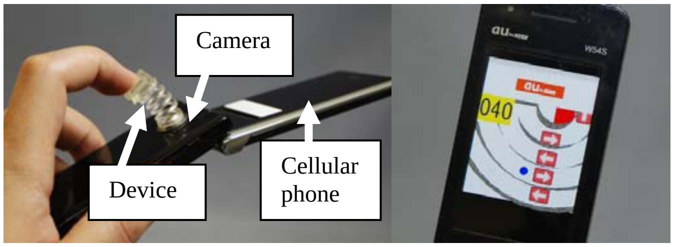
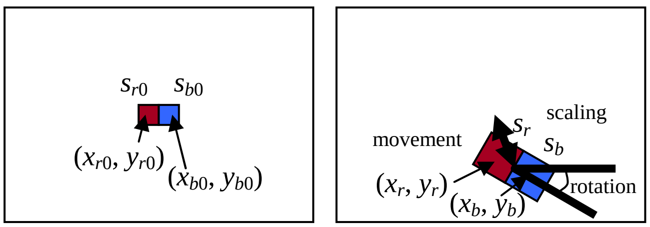


Figure 1. An example of tangible device.



(a) Device on cellular phone **(b) test application**

Figure 2. Evaluation process.



(a) Initial image **(b) Input image**

Figure 3. Change of center and size of marker.

analyzes the image which the embedded camera captures, and detects the position and size of the marker as shown in Fig. 3. First, the proposed algorithm binarizes the red and blue channel of the input image, respectively. Then, the blob analysis is performed on binarized channels to find the center (x_t, y_t) and size s_t of the largest blob in time t. The blob features of each input image are compared with those of the initial image. The motion is estimated by the displacement of the average center of the initial image and the input image (Eq. (1)).

$$((x_{bt}+x_{rt}-x_{b0}-x_{r0})/2,\ (y_{bt}+y_{rt}-y_{b0}-y_{r0})/2) \quad (1)$$

Here, (x_{r0},y_{r0}), (x_{b0}, y_{b0}), (x_{rt}, y_{rt}) and (x_{bt}, y_{bt}) are the center of the red and blue in the initial image and those in the input image, respectively. The rotation angle is estimated by Eq. (2).

$$\arccos(\langle \mathbf{v}_0, \mathbf{v}_t \rangle / (|\mathbf{v}_0||\mathbf{v}_t|)) \quad (2)$$

Here, $\mathbf{v}_t$ is the vector $(x_{bt}-x_{rt}, y_{bt}-y_{rt})$. The operator < > and | | are inner product and norm, respectively. The scaling for the depth direction is estimated by the geometric average of sizes of the markers (Eq. (3)).

$$\mathrm{sqrt}(s_{rt}s_{bt}/(s_{r0}s_{b0})) \quad (3)$$

Here, s_{r0}, s_{b0} s_{rt} and s_{bt} are the size of the red and blue in the initial image and those in the input image, respectively.

4. SIMULATION RESULTS

The image processing algorithm was implemented on the Qualcomm BREW platform on a cellular phone. We used a Sony W54S for development and testing. In order to evaluate the usability, we designed a path-tracing application on the cellular phone. A user can control a pointer on a large map interactively in real time. We compared the keypad and the proposed controller by average time to trace the winding path (Fig. 2(b)).

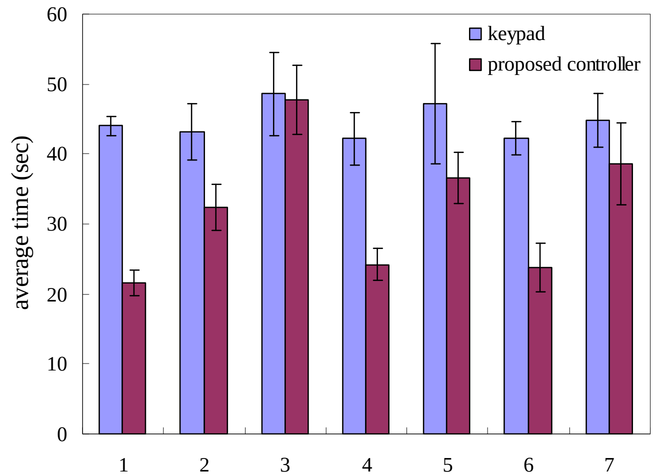


Figure 4. Task completion times.

We had each controller operated by 7 subjects (two men in their 20's, four men in their 30's, one man in his 40's). We measured the time required to move the pointer through the path for five times. The results of the comparison are shown in Fig. 4. The average time was shortened to 32.1 seconds with the proposed controller, while the keypad took 44.6 seconds. We performed an analysis of variance (ANOVA). There were significant effect (F_0=144.2>$F_{(1,56)}$(1E-16)) The advantage of the proposed controller is the precise control which enables fine adjustment of direction.

5. CONCLUSIONS

This paper proposes a novel camera-based tangible controller for cellular phone applications. The proposed method exploits the camera with a simple controller device on it, and realizes natural operability with a single finger. The main advantage of the proposed method is high ease of use in continuous operation without occluding the display. This controller allows the users to operate a cellular phone like an analog joystick which is suitable for mobile gaming. The experimental results of the path-tracing task showed that the proposed method reduced the time required to pass through 27.9% less than the conventional keypad.

6. REFERENCES

[1] Nichols, S.J.V. 2007. New interfaces at the touch of a fingertip, Computer, vol.40, no.8, 12-15. DOI=10.1109/MC.2007.286.

[2] Gallo, O., Arteaga, S. M., and Davis, J. E., 2008, A camera-based pointing interface for mobile devices, ICIP, 1420-1423. DOI=10.1109/ICIP.2008.4712031.

[3] Kato, H., Yoneyama, A., and Takishima, Y., 2006. An intuitive interface based on camera parameters for portable devices. ACM SIGGRAPH Research posters, 142. DOI=10.1145/1178622.1179787.

[4] Hachet, M., Pouderoux, J., and Guitton, P. 2005. A camera-based interface for interaction with mobile handheld computers. In Proceedings of I3D-ACM SIGGRAPH, 65-71. DOI= 10.1145/1053427.1053438.