Image Defocus Analysis for Finger Detection on A Virtual Keyboard

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1.The target of our research

The target of our research is the virtual keyboard of a smart watch.
The touching area of the smart watch is very small.

We can overcome this problem by using the virtual keyboard. Because the virtual plane is large.

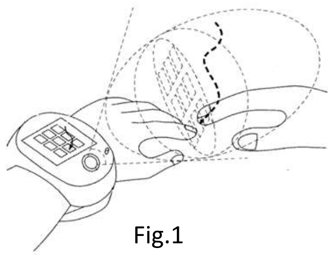

Fig.1

2. The architecture of the virtual keyboard

Our virtual keyboard used 2 cameras and a half mirror. A half of light from the finger goes direct through the half mirror and it is caught by camera A. Another half light from the finger is reflected by the half mirror and it is caught by camera B.
The focal distance of the camera A and camera B are different with each other a little bit. When the finger is positioned at the middle point of these focal length, the blur becomes almost same. Then we can know if the finger is at the middle point of the focal length.

If the virtual keyboard is set at the middle point virtually, we can touch the virtual keyboard.

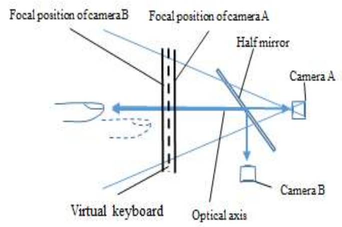

Fig.2

3. Detecting blur information

We detect blur information by using DCT coefficients.
The key area on the captured image is divided 8 * 8 pixels blocks (called dct block). Each dct block is transformed by DCT. DCT coefficient is summed. The sum data of one camera is compared with sum data of another camera.
When the sum becomes almost same, it is considered that the finger touches the virtual key.

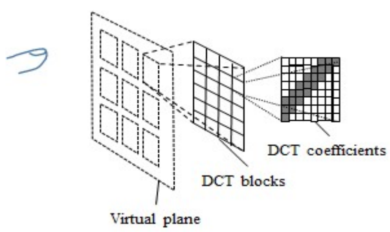

Fig.3

4. The depth resolution

The depth resolution of the camera is the minimum distance by which we can distinguish the finger is in focus or out of focus when the finger approaching the camera.
When the finger is out of focus, blur circle σ becomes large (Fig.4). If σ becomes larger than the resolution of the image plane(CCD), we can recognize if the finger is out of focus or not.
The length d1 and the length d2 is near position and far position where we can distinguish if the finger is out of focus or not when the camera is focused at d'.
We can calculate d1 and d2 by eq.1 and eq.2 when the radius of the lens is D and focal length of the lens is f.
The minimum blur circle we can distinguish is the resolution of the camera (CCD resolution).

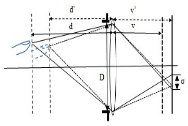

Fig.4

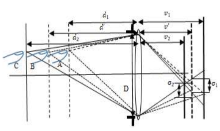

Fig.5

$$d_1 = \frac{d' f (D+\sigma_1)}{d'\sigma_1 + Df} \quad \text{eq.1}$$

$$d_2 = \frac{d' f (\sigma_2 - D)}{d'\sigma_2 - Df} \quad \text{eq.2}$$

5. Experiment

Table 1 is the specification for the camera. The original pixel size of the CMOS is 2592 * 1944. After taking the image from the camera, we shrink the image to 320 * 240 for reducing calculation time. Then the resolution of the image is estimated as 0.017813 mm per pixel.
The minimum blur circle we can distinguish is the resolution of the camera (CCD resolution). The table 2 shows d1 and d2 when σ is 0.017813 (our camera).
We use raspberry-pie computer and OPENCV library compute the DCT coefficient.

camera	CMOS size	5.7mm × 4.3mm
	pixel size	320 × 240 (2592 × 1944)
	ρ	0.017813 (0.002199)
lens	D	10
	f	16
cpu	raspberrypie	ARM 1.4Ghz

Table 1

d'	200	250	300
d 1	195.9924	243.6637	290.8214
d 2	204.1902	256.6991	309.8129

(σ = 0.017813)

Table 2

When the finger approaching the the camera, the DCT sum changes. The focal length of the 2 camera is different each other, then the peak is different. In fig.6 The cross point means where the blur is same. We can know if the finger is at this position or not by checking the DCT sum.
Fig. 7 shows that the virtual keyboard is touched

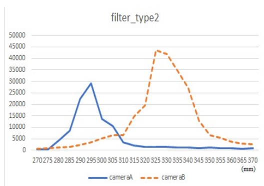

Fig. 6

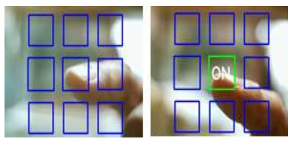

Fig. 7