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VISUAL GESTURE BASED AUGMENTED VIRTUAL KEYBOARD SYSTEM

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This paper presents a novel enhancement in design of virtual keyboards for consumers of tablets and standard computing devices. Hand video is captured for virtual keyboard functionality. Hand video is augmented with a background keyboard and displayed on lower part of screen to provide feedback to user for seamless interaction with virtual keyboard. Hands are detected in video sequence. Finger joints trajectory based keystroke detection and recognition fused with augmented keys spatial information reveals the key pressed. Real time system is developed by integrating USB camera with tablet computer. Reliable results are experienced while a low cost system is achieved in comparison to existing virtual keyboard systems.

Keywords : Virtual keyboard, Trajectory estimation, Fingertip detection, Hand gesture recognition.

1. Introduction

Keyboards are input devices for text entry in computing devices. Technology advancements produces computing devices in different form factors such as tablets, smart phones etc. Reduction in size made it difficult to fit standard keyboards in these designs. Number of alternatives designs of keyboards is then proposed to fit these computing devices. Additionally, new forms of keyboards are also designed such as on-screen keyboard and virtual keyboards.

On-screen keyboards appeared both in tablets and smart phones. On-screen keyboards relied upon advancements in touch screens with increased sensitivity to human fingers. However, research studies showed that text input through on-screen keyboards are 1.8 to 2.8 times slower than standard QWERTY keyboards.

A virtual keyboard is defined as a touch typing device that does not have a physical manifestation of the sensing areas. A number of designs for virtual keyboards have been proposed in literature. These virtual keyboards rely upon either sensor or machine vision based technologies to detect key stroke recognition.

Examples in sensor based virtual keyboardsare Finger Joint Wearable Keypad [1], Chording Glove [2], FingerRing [3], VType [4], Samsung Scurry [5] and Senseboard [6] proved to be much intrusive. Similarly examples in vision based virtual keyboards are Visual Panel [7], VKPC [8] and VKB [9]. In addition to these devices, researchers have been developing computer vision algorithms for detection and recognition of hand movements for key classification [10-13].

Gesture recognition based methods have also been investigated to develop human computer interaction solutions such as [14]. Other applications include sign language recognition [15], human machine interfacing using hand gestures [16], camera mouse control [17], controlling the secondary tasks in automotive [18], robotic control [19].

Augmented reality adds information to the views of real-world environments or physical objects. Generally, computer graphics and sounds in some cases are added directly or indirectly to these views. Augmentation is performed in real time. Current advancements in augmented reality technology made it possible to interact information about surrounding environments or physical objects. Augmented reality has successful applications in entertainment, gaming, education, architecture etc.

2. Visual Gesture Based Augmented Virtual Keyboard System

This paper presents a novel enhancement in design of virtual keyboard using gesture recognition and augmented reality technology as shown in Figure 1

The proposed design shows hand with keyboard augmented in background as shown in Figure 2.

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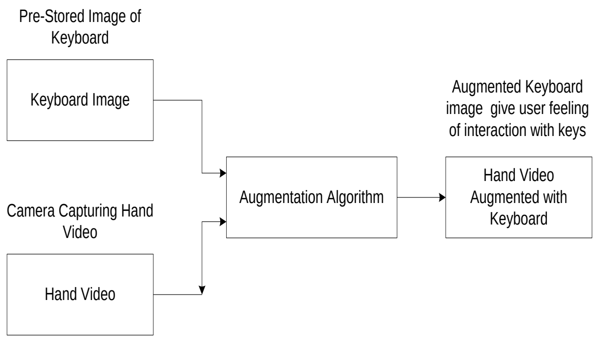

Figure 1. Augmented virtual keyboard system design.

Figure 2. Hand with keyboard augmented in background.

Virtual keyboards used projectors or sensors to provide keyboard user interface. This involved hardware and relatively higher cost due to projector or sensor. Tablets provided on-screen keyboards where user can type. The novel concept introduced in this paper adjusts keyboard according to hand position and user can type anywhere on plane surface or even in air. Augmentation algorithm registers hand and augments keyboard for typing of user.

Video camera captures the hand movements for pressing keys. Augmented reality displays the keyboard on lower part of screen and presents keys to the user for typing. A gesture recognition algorithm analyzes the interaction of hand with augmented keys to reveal the key pressed; which is then communicated to host application as output of typing procedure. Considering the number of keys on any on-screen virtual keyboard of tablets, output of proposed system is defined as

$$K = \{k_1, k_2, k_3, \ldots, k_j, \ldots, k_L\}$$

Where k_j represent keys on the keyboard. These k_j include keys such as $k_1 = 'A'$, $k_2 = 'B'$ etc. and some control keys. $j = 1, 2, \ldots, L$ represents total number of keys and L = 36.

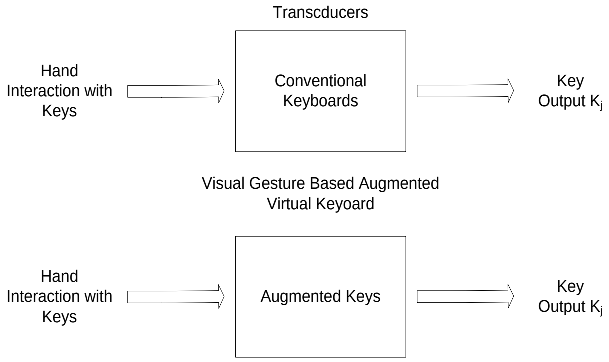

Figure 3. Traditional keyboard vs. visual gesture based augmented virtual keyboard.

Both traditional and visual gesture based augmented virtual keyboard output in K_j as shown in Figure 3.

Figure 4 shows the architecture of the visual gesture based augmented virtual keyboard. Proposed system augments the hands video at on-screen keyboard of mobile devices. Finger joints trajectories are estimated and incorporated with augmented keys on the screen. A keystroke detection event is recorded through finger triggering and real-time fusion of trajectory data with screen coordinates results in the recognition of keystroke generated.

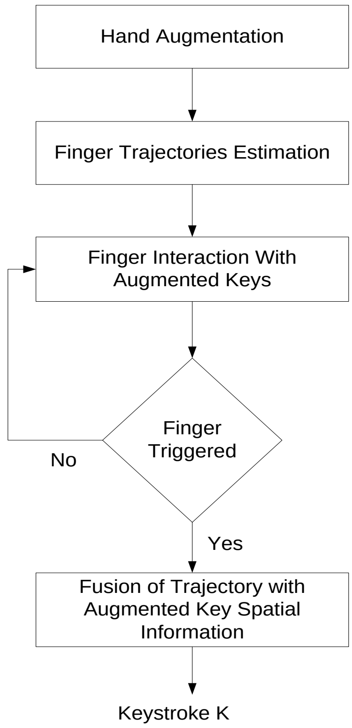

Figure 4. Visual gesture based augmented virtual keyboard.

3. Architecture of Visual Gesture Based Augmented Virtual Keyboard

Algorithmic architecture of proposed system is shown in Figure 5. Video is captured of the hands interacting with augmented keys on a flat surface or in air. After video capturing, frame extraction is performed.

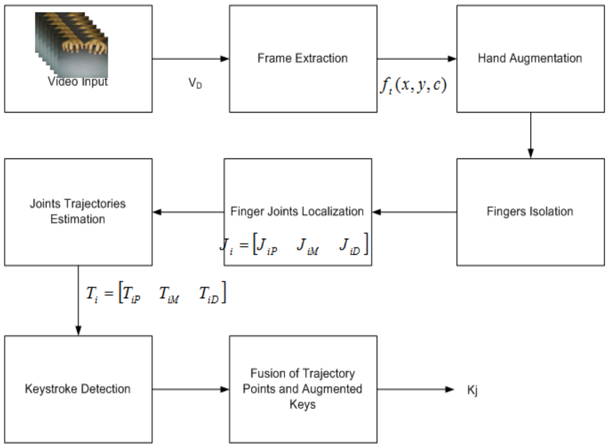

Figure 5. Algorithmic architecture.

3.1 Hand Augmentation

Augmentation is process that requires control points. Position of hand acts as control point for augmenting the keyboard. Therefore, hand detection is performed. To detect hands in real-time, skin color detection based approach using Bayes SPM [20] is employed. Biggest skin color blob is considered as hand region detected in the video, which is then extracted through morphological operations and connected component analysis. Figure 6 shows the hand detection results.

Once the hands are detected, system augments keyboard to give user look and feel of keyboard. Position of hand changes keyboard position. Augmented keys spatial information at end are then fused with extracted keystroke from trajectory points to classify the pressed key.

(a) (b)

Figure 6. Hands detection results.

3.2. Finger Isolation and Finger Joints Localization

Finger isolation and respective joints localization is mandatory to estimate the finger joints trajectories. Hands kinematic model as shown in Figure 7 is considered to model fingers and finger joints according to their position which results in ten fingers/operator as $O = \{O_1, O_2, O_3 \ldots\ldots\ldots O_{10}\}$ and set of joints for respective fingers as

$$D = \begin{bmatrix} J_{11} & J_{12} & J_{13} \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ J_{51} & J_{52} & \Phi \\ J_{61} & J_{62} & \Phi \\ J_{71} & J_{72} & J_{73} \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ J_{O1} & J_{O2} & J_{O3} \end{bmatrix}$$

Where O = 10

Finger isolation and joints localization is achieved through connected components analysis, contour tracking and morphological features mentioned in [21].

3.3. Joints Trajectories Estimation

Joints detection phase returns the objects to be tracked in the subsequent frames. Localized kernel tracking based on probabilistic densities of joints regions [21, 22] is implemented for trajectories estimation of finger joints which results in trajectory dataset both in horizontal and vertical directions as shown in Figure 8.

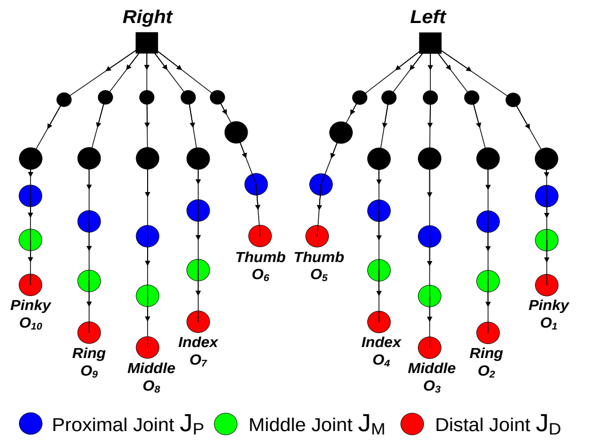

Figure 7. Fingers and Joints modeling for augmented virtual keyboard.

$$T_X = \begin{bmatrix} X_{11} & X_{12} & X_{13} \\ . & . & . \\ . & . & . \\ X_{51} & X_{52} & \Phi \\ X_{61} & X_{62} & \Phi \\ X_{71} & X_{72} & X_{73} \\ . & . & . \\ . & . & . \\ X_{O1} & X_{O2} & X_{O3} \end{bmatrix} \quad T_Y = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} \\ . & . & . \\ . & . & . \\ Y_{51} & Y_{52} & \Phi \\ Y_{61} & Y_{62} & \Phi \\ Y_{71} & Y_{72} & Y_{73} \\ . & . & . \\ . & . & . \\ Y_{O1} & Y_{O2} & Y_{O3} \end{bmatrix}$$

Where O = 10

Figure 8. Horizontal and vertical trajectories for index finger of right hand.

3.4. Keystroke Detection

For keystroke detection, finger joint trajectories are interpreted in the form of feature vectors $v^1\ v^2\ v^3$ and probability of each finger using respective feature vectors are trained and tested over a Bayesian network [21] to detect the occurrence of any keystroke.

Probability for each finger can be calculated as

$$P\left(O^t \mid v^1, v^2, v^3\right) = \frac{P\left(O^t, v^1, v^2, v^3\right)}{P\left(v^1, v^2, v^3\right)}$$

For $t = 1,2,3,...,10$. Only one finger exhibit maximum probability of keystroke detection and hence is the finger making keystroke.

3.5. Fusion

Fusion is last step in declaring the key output. Here the trajectory points of finger having highest probability, extracted in previous step, are correlated with spatial pixel coordinates of augmented keys. For a key to be pressed, it is necessary for trajectory points of keystroke event to occur in spatial pixel coordinates of augmented keys.

4. Application Interface

Visual gesture based augmented virtual keyboard system operates on any computing device in standard environment.

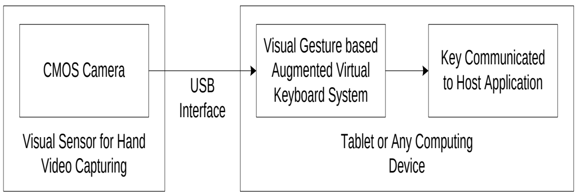

Figure 9. Application interface.

5. Experimentation Results

Proposed system showed reliable results in a laboratory setup where approach has been tested over a standard computing device. Real-time system is tested on 20 test users typing in air or on a flat surface. System performance is evaluated in terms keystroke detection by each finger and keystroke recognition for each key. Figure 10 describes the keystroke detection accuracy for each finger accumulating overall accuracy upto 92 %. Table 1 portrays the % keystroke recognition results for each key. Table 1 clearly indicates that keys on upper and bottom row of the augmented keyboard have less accuracy as compared to keys on middle row. System feedback reveals an increase in typing 1.6 times more number of characters on a mobile device as compared to on-screen keyboard.

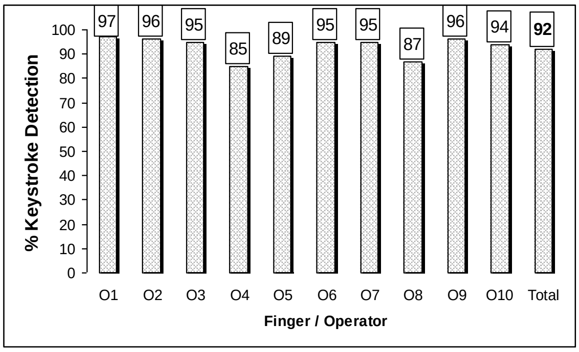

Figure 10. % Keystroke detection results.

6. Conclusion

The proposed system presented a novel concept in virtual keyboard design. The proposed system is suitable for attachment of all types of consumer devices those require text input. The size and number of keys can be varied according to the requirements of attached consumer device.

Camera and gesture recognition provided the functionality of virtual keyboard and augmentation technology provided look and feel of on-screen keyboard. The system is low cost when compared with projector or sensor based virtual keyboards. The system is flexible in placement of keyboard when compared with on-screen board. On-screen keyboards are fixed on screen. The utility of proposed keyboard is possible on a surface or in air where the hand movement is field of view of camera.

In future, proposed system can be improved with respect to flexibility, user friendliness and robustness. Accuracy of the system can be further increased by adopting layered spatio-temporal sequential approach for keystroke detection and recognition. Research work is still in progress for more optimization of the time and processing complexity of the system.

Table 1. Keystroke recognition results.

Key	Test Data	Correct Data	Error	% Keystroke Recognition Result
Q'	34	31	3	91.18
W'	31	29	2	93.55
E'	38	36	2	94.74
R'	33	29	4	87.88
T'	27	23	4	85.19
Y'	29	27	2	93.1
U'	34	31	3	91.18
I'	41	39	2	95.12
O'	39	38	1	97.44
P'	26	22	4	84.62
A'	44	43	1	97.73
S'	35	34	1	97.14
D'	31	30	1	96.77
F'	34	33	1	97.06
G'	28	28	0	100
H'	29	27	2	93.1
J'	30	28	2	93.33
K'	22	21	1	95.45
L'	25	23	2	92
Z'	27	24	3	88.89
X'	19	17	2	89.47
C'	29	26	3	89.66
V'	26	24	2	92.31
B'	22	19	3	86.36
N'	29	24	5	82.76
M'	28	26	2	92.86
Space	49	42	7	85.71
BkSpace	14	14	0	100
,	8	8	0	100
.	23	20	3	86.96
Enter	15	13	2	86.67
Total	899	829	70	92.21

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