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# Comment on: “Extended Hough transform for linear feature detection”

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Cha et al. [1] recently proposed an efficient extended Hough transform (EHT) method for line detection. The most distinctive advantage of their EHT method is the ability to detect any line segment with desired length. In their proposed EHT method, first the input gray image with size $h \times w$ is transferred into the edge map by using the edge detector, e.g. the Sobel operator. For each edge pixel, the voting process is performed in two 3-D Hough spaces, each Hough space is consisted of a set of 2-D Hough planes [2], to detect line segments. In the EHT method, each 2-D Hough plane is used to collect the evidence of the line segments which is passing through a specific column of the input image. Considering the first column of the edge map, the edge pixel is selected one by one in a top-down manner. For each selected edge pixel with location $(x, y)$, $0 \leqslant x \leqslant w-1$ and $0 \leqslant y \leqslant h-1$, a slope-intercept equation $\beta = -\alpha x + y$ is created, and then the voting process is performed in the first Hough plane of the first Hough space for $-1 < \alpha \leqslant 1$ corresponding to the angle range $(-45°, 45°]$; after rotating $x$ and $y$ axes by 90°, i.e. mapping the edge pixels with location $(x, y)$ into the one with location $(-y, x)$, the voting process is performed in the first Hough plane of the second Hough space. Note that each edge pixel in the first column of the edge map must perform two voting processes for the first and second Hough spaces. By the same arguments, for the second column of the edge map, the above two voting processes are applied to the second Hough plane of the first Hough space and the second Hough space, and so on. After finishing the voting processes for the last column of the edge map, we sum up the number of votes of each pair of $\alpha$ and $\beta$ through all Hough planes of each Hough space. For each pair of $\alpha$ and $\beta$, if the number of total votes is lager than the specific threshold, it can be claimed that the input image has a line segment with the parameters $\alpha$ and $\beta$ and its starting point and ending point can be determined by checking the number of votes of each Hough planes. Besides detecting each line segment with desired length, Cha et al.'s method also can determine the starting point and ending point of each detected line segment.

Although the effectiveness of the EHT method has been demonstrated by experiments, this comment wants to show that after classifying all edge pixels into two types according to the orientations of edge pixels, the execution time required in the voting process of the EHT method can be reduced efficiently. Let $H_1[\ ][\ ][\ ]$ and $H_2[\ ][\ ][\ ]$ denote the first 3-D Hough space with size $w \times C_\alpha \times C_{\beta_1}$ and the second 3-D Hough space with size $h \times C_\alpha \times C_{\beta_2}$, respectively. $H_1[i][\ ][\ ]$ and $H_2[j][\ ][\ ]$, $0 \leqslant i \leqslant w-1$ and $0 \leqslant j \leqslant h-1$, denote the $i$-th and the $j$-th 2-D Hough planes of $H_1[\ ][\ ][\ ]$ and $H_2[\ ][\ ][\ ]$, respectively. Further, let $E$ denote one edge pixel with location $(E.x, E.y)$. The voting process of the EHT method is shown as follows.

Procedure VOTING

1. $\Delta\alpha \leftarrow \dfrac{2}{C_\alpha}$ /*Calculate each quantized step for $\alpha$*/
2. $\Delta\beta_1 \leftarrow \dfrac{h+2w}{C_{\beta_1}}$ /*Calculate each quantized step for $\beta$ in $H_1$*/
3. $\Delta\beta_2 \leftarrow \dfrac{w+2h}{C_{\beta_2}}$ /*Calculate each quantized step for $\beta$ in $H_2$*/
4. **for** $i \leftarrow 0$ to $w-1$ **do**
5.   **for** each edge pixel $E$ in the $i$-th column of the image **do**
6.     **for** $k \leftarrow 0$ to $C_\alpha - 1$ **do**
   /*Voting process for the first Hough space*/
7. $\alpha \leftarrow -1 + \Delta\alpha \times k$
8. $\beta \leftarrow E.y - \alpha \times E.x$
9. $\ell \leftarrow \dfrac{\beta + w}{\Delta\beta_1}$
10. $H_1[E.x][\ell][k] \leftarrow H_1[E.x][\ell][k] + 1$
   /*Voting process for the second Hough space*/
11. $\alpha \leftarrow 1 - \Delta\alpha \times k$
12. $\beta \leftarrow E.x + \alpha \times E.y$
13. $\ell \leftarrow \dfrac{\beta + h}{\Delta\beta_2}$
14. $H_2[E.y][\ell][k] \leftarrow H_2[E.y][\ell][k] + 1$

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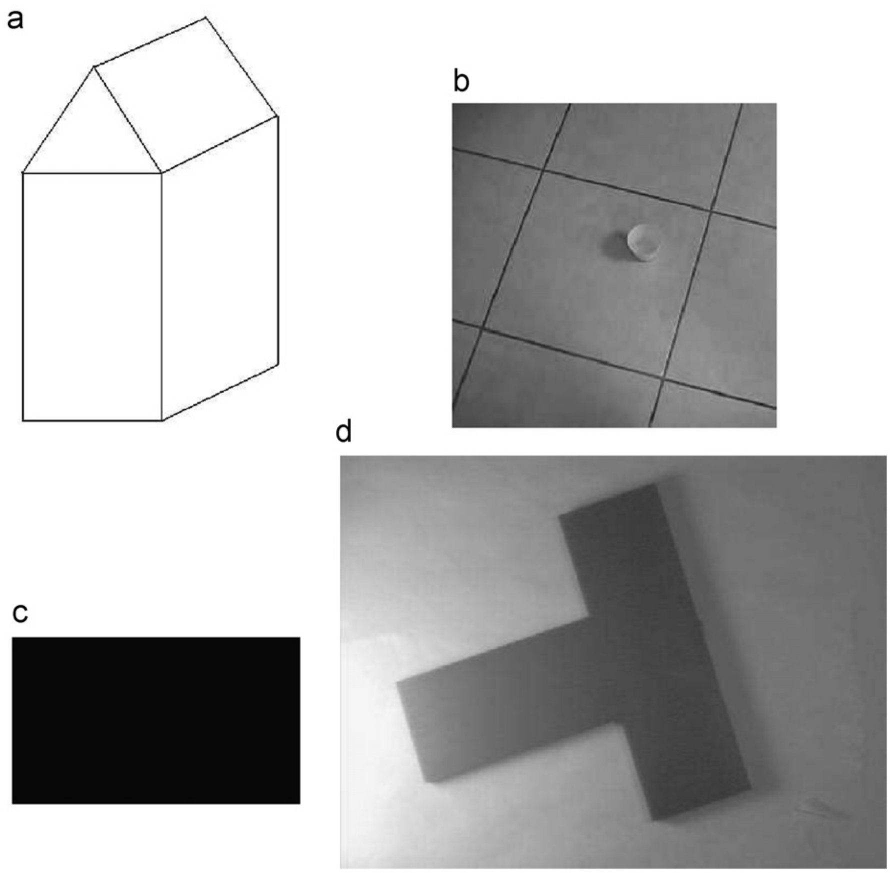

**Fig. 1.** Four testing images.

From lines 6 to 14 in the above procedure, each edge pixel takes $T_{EHT} = (6T_a + 2T_s + 4T_m + 4T_d) \times C_\alpha$ time for voting in the first Hough space and second Hough space where $T_a$, $T_s$, $T_m$, and $T_d$ denote the time required to perform one addition, one subtraction, one multiplication and one division, respectively.

Let $E.o$ denote the orientation of the edge pixel $E$ and it can be calculated by $E.o = \arctan(E.gy/E.gx)$ where the gradients $E.gx$ and $E.gy$ are obtained by using the horizontal mask and the vertical mask in the Sobel edge detector, respectively. By considering the orientations of the concerned edge pixels, we classify these edge pixels into two types: the first type contains the edge pixels whose orientations are in the angle range $(-45^\circ, 45^\circ]$ and each edge pixel's voting process occurs in the first Hough space; the second type contains the edge pixels whose orientations are in the angle range $(45^\circ, 135^\circ]$ and each edge pixel's voting process occurs in the second Hough space. Following this strategy, our proposed improved voting process, the procedure FAST_VOTING, is shown as follows.

Procedure FAST_VOTING

1. $\Delta\alpha \leftarrow \dfrac{2}{C_\alpha}$
2. $\Delta\beta_1 \leftarrow \dfrac{h + 2w}{C_\beta}$
3. $\Delta\beta_2 \leftarrow \dfrac{w + 2h}{C_\beta}$
4. **for** $i \leftarrow 0$ to $w - 1$ **do**
5.     **for** each edge pixel $E$ in the $i$-th column of the image **do**
6.         $E.o \leftarrow \arctan\left(\dfrac{E.gy}{E.gx}\right)$ /*Calculate the orientation of $E$*/
7.         **if** $E.o > -45^\circ$ and $E.o \leqslant 45^\circ$ /*Classify $E$ into two types*/
8.             **for** $k \leftarrow 0$ to $C_\alpha - 1$ **do**
9.                 $\alpha \leftarrow -1 + \Delta\alpha \times k$
10.                 $\beta \leftarrow E.y - \alpha \times E.x$
11.                 $\ell \leftarrow \dfrac{\beta + w}{\Delta\beta_1}$
12.                 $H_1[E.x][\ell][k] \leftarrow H_1[E.x][\ell][k] + 1$
13.         **else**
14.             **for** $k \leftarrow 0$ to $C_\alpha - 1$ **do**
15.                 $\alpha \leftarrow 1 - \Delta\alpha \times k$
16.                 $\beta \leftarrow E.x + \alpha \times E.y$
17.                 $\ell \leftarrow \dfrac{\beta + h}{\Delta\beta_2}$
18.                 $H_2[E.y][\ell][k] \leftarrow H_2[E.y][\ell][k] + 1$

From lines 6 to 18 in our proposed improved voting process, each edge pixel takes $T_{ours} = (3T_a + T_s + 2T_m + 2T_d) \times C_\alpha + 2T_c + T_d + T_{at} = \frac{1}{2}T_{EHT} + 2T_c + T_d + T_{at}$ time for voting in the first Hough space or the second Hough space where $T_c$ and $T_{at}$ denote the time required to perform one comparison and one arctangent operation, respectively. The voting-time improvement ratio of our proposed improved voting process over that in the EHT method is calculated by $I_V = (T_{EHT} - T_{ours})/T_{EHT} = \frac{1}{2} - (2T_c + T_d + T_{at})/T_{EHT}$. Since $C_\alpha$ is usually selected to be larger than 100, $T_{EHT}$ is much larger than $2T_c + T_d + T_{at}$. Thus, $(2T_c + T_d + T_{at})/T_{EHT}$ is infinitesimal and can be ignored in the calculation of $I_V$. Consequentially, the value of $I_V$ is approximated to 50%. By plugging our proposed improved voting process into the EHT, our improved EHT method can speed up the previous EHT method for detecting line segments. The average theoretical execution–time improvement ratio of our proposed improved EHT method over the EHT method is defined by $I_R = R \times I_V$, where $R$

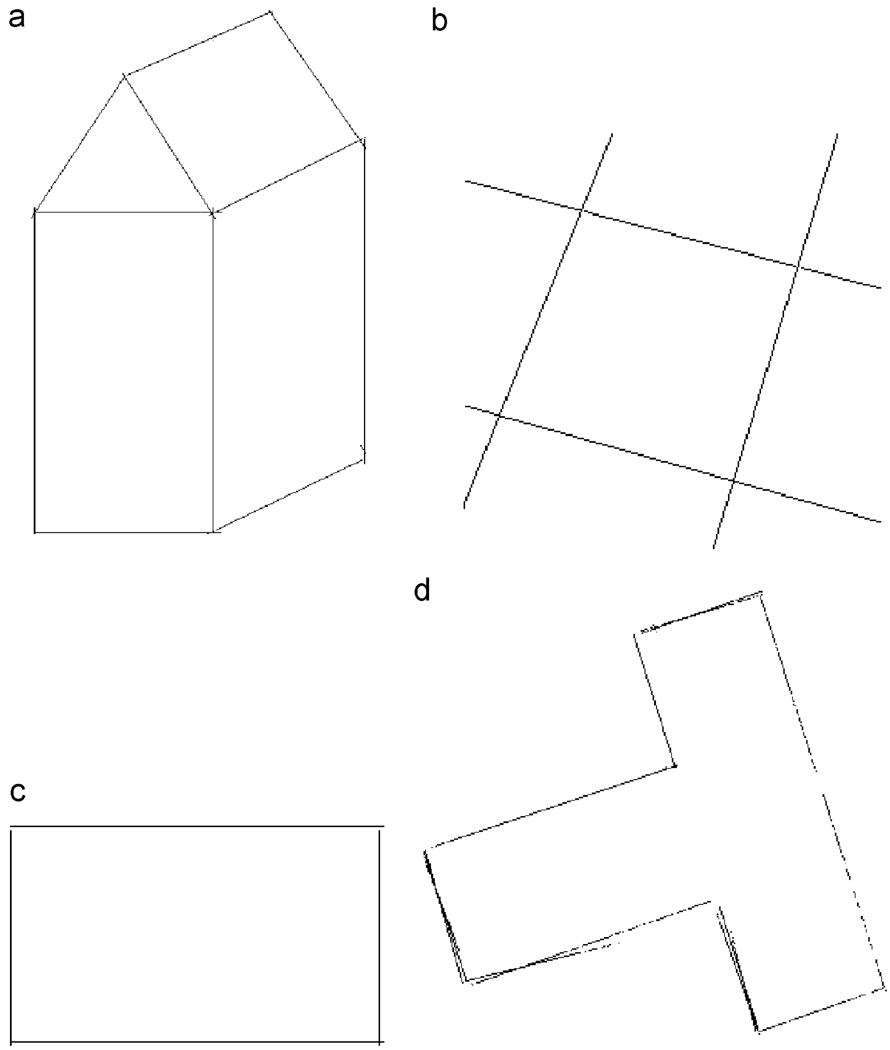


**Fig. 2.** Resultant detected lines for Fig. 1.

denotes the ratio of the voting time over the total execution time required in the EHT method. Based on four testing images as shown in Fig. 1 and the IBM compatible AMD Athlon 64 X2 4800+ microprocessor with 2.4 GHz, the average value of $R$ is 28% and the average theoretical execution–time improvement ratio $I_R$ can be obtained by $I_R = R \times I_V = 28\% \times 50\% = 14\%$. Experimental results indicate that the average practical execution–time improvement ratio is 16% and it is very close to the average theoretical execution–time improvement ratio. Finally, for Fig. 1, both the EHT method and our improved EHT method have the same detected lines as shown in Fig. 2.

## References

[1] J. Cha, R.H. Cofer, S.P. Kozaitis, Extended Hough transform for linear feature detection, Pattern Recognition 39 (6) (2006) 1034–1043.
[2] R.O. Duda, P.E. Hart, Use of the Hough transformation to detect lines and curves in pictures, Commun. ACM 15 (1) (1972) 11–15.