Study of Human Face Image Edge Detection based on DM642

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Abstract—Edge detection of human face is one of the important bases in human face detection and recognition. This article firstly summarizes the basic methods of edge detection and the basis of Sobel operator and Canny operator, then, from a practical perspective, puts forward a novel method that is based on the integration of improved Sobel operator and Canny operator, moreover its results are thinned lastly via the method of Improved OPTA. All of that above is implemented on TMS320 DM642EVM, using design Reference Framework 5 with high expansibility to design Application Program implemented by C and assembler mixed language, and afterward doing optimization according to the characteristics of DSP chip for the real-time purpose. The results testify that this approach is not only good at eliminating noise, but also can detect the edge quickly and completely, so it has well practical significance. All of that is a foregoing preparation for the achievement of the system of human face detection in application.

Keywords—edge detection; human face image; operator; DM642

I. INTRODUCTION

The edges and lineament of human face are important features. In the system of human face detection and recognition, edge detection is extremely vital foundation, whose capability of suppressing noise and precision have always been a scabrous problem, especially in the application system requiring the real-time and practicality.

With the sharp increase of producibility requirement of video image processing and the rapid development of DSP technology, high-performance DSP embedded chip is advent constantly and gradually used in the system of video processing widely. Therefore, this article, based on the DSP chip TMS320 DM642 from a practical perspective, makes an attempt at improving the method of human face image edge detection: preprocess the face image firstly, and then detect edges through the improved Sobel operator and Canny operator, whose results had been integration and lastly thinned according to the method of Improved OPTA. All of that is implemented and optimized on TMS320DM642EVM. This real-time program can not only filter out noise effectively, but have a good integrity for detecting image edges.

II. METHODS OF IMAGE EDGE DETECTION

Edges of image is the aggregation of all pixels that grayscale is discontinuous or rapidly change in image, which concentrates most information of image. Image edges detection is the crucial step in image analysis fields, such as image segmentation, feature extraction and identification etc, and has a vital position in engineering applications. At present, there are several main classification of edges detection methods as following:

1. Traditional edges detection methods. This method determines which image pixels is the edges by calculating of its first-order or second-order differential. Thus, a good derivation operator is the focus of study. The common detection operators are Sobel, Robert, Kirsch, LOG, Canny etc.

2. Surface fitting. This method, which can effectively weaken the noise, use some neighbor pixels surrounding the to-be-detected point, fit out a surface and calculate its gradient of the point[1], thereby to detect the edges.

3. The edges detection based on Wavelet Transforms. Wavelet transform has good time-frequency partial characteristics, and the advantage of making partial features prominent as well as the capability of multi-resolution analysis[2]. Accordingly, it is suitable for edges detection.

4. The edges detection based on Grayscale Mathematical Morphology. This method is based on two computing--Grayscale erosion and Grayscale diation. The algorithm is simple, its Struct Element is flexible, and has a nonlinear characteristics. All of that is good for detecting edges, as well as more effectively eliminating noise, and also retain details information, but it has poor adaptive algorithm[3]

III. IMPROVED METHOD OF DETECTION

A. Image preprocessing

Firstly, the Average Filters and the Median Filters are used to suppress noise. In Average Filters,average of neighbor pixels is to replace the original value of each pixel. The core idea of Median Filters is that all pixels of template is sorted according to gray value, and choose the middle value to replace the central pixel. This will effectively eliminate Isolated Noise, Additive White Gaussian Noise, Impulse Noise and Scanning Noise[4]. After filtering, the
edges will be weaken, so do Histogram Enhance to make the edges and details clearer, improving the image quality.

B. Operator improved

(1) Improved Sobel operator

Traditional Sobel operator uses each pixel of image to do convolution with two templates, shown in Fig. 1, maximum of results to be the output value of corresponding pixel. Those two templates are respectively used to detect vertical and horizontal edges.

\[
\begin{pmatrix}
-1 & -2 & -1 \\
0 & 0 & 0 \\
1 & 2 & 1 \\
\end{pmatrix}
\quad\begin{pmatrix}
-1 & 0 & 1 \\
-2 & 0 & 2 \\
-1 & 0 & 1 \\
\end{pmatrix}
\]

Fig. 1. Templates of Sobel operator

Sobel operator, as a representative classical operator, has good positioning and high speed, but its detecting edges is not completely connected. Therefore, six templates is increased to improve effects\[5\]:

\[
\begin{pmatrix}
-2 & -1 & 0 \\
0 & 0 & 0 \\
1 & 2 & 1 \\
\end{pmatrix}
\quad\begin{pmatrix}
-1 & 0 & 1 \\
0 & 1 & 2 \\
-1 & 0 & 1 \\
\end{pmatrix}
\quad\begin{pmatrix}
2 & 1 & 0 \\
0 & -1 & -2 \\
1 & 0 & -1 \\
\end{pmatrix}
\quad\begin{pmatrix}
-2 & -1 & 0 \\
0 & -1 & -2 \\
2 & 1 & 0 \\
\end{pmatrix}
\]

Fig. 2. Templates of improved Sobel operator

(2) Implementation of Canny operator

The basic ideas of Canny operator is using Gaussian function smoothes image firstly, then determines edges by calculating the maximum of first-order differential. Algorithm steps are as follows\[6\]:

1. Gaussian filter is used for filtering and smoothing image;
2. Differential operator is used to calculate gradient intensity and direction of each pixel;
3. Do “non-maxima suppression” to Gradient Strength: comparing gradient value of a pixel with that of its two adjacent pixels in gradient direction. Turn the value of local non-maximum pixel to zero, which is not the edge;
4. Set Double-threshold Th1 = 0.4Th2 through statistics of Histogram. The value of pixels set to 0, whose Gradient value is lower than Th2. Thus, we can get image1 of edges with the rest pixels. The pixels whose Gradient value is higher than Th2 is certainly the edges, marked image2, which has more information than image1. Do supplementary connection for image1 on the basis of image2;
5. Connect edges of the two images. (a) Beginning with a nonzero pixel in image1 marked X, we track the edges to the last pixel, marked Z. (b) If there are nonzero pixels Y’ in area of eight adjacent pixels of Z’ in image2, which is in the same place of Z in image1, we add Y’ into image1, marked Y. Repeat the front step (a) setting out from Y’, until it can’t continue not only in image1 but in image2. (c) When we finish finding out the whole edges including X, we make the mark that it have been already handled, and then return to step (a) to track the next contour. Repeat those steps until we can’t discover new edges.
6. Operator integration and image refinement

In order to obtain much completely edges, the binarization results of Canny operator and improved Sobel operator have been directly integrated. Anyone is 1, then, the result corresponding to the pixel point is 1, otherwise is 0. Then the Improved OPTA algorithm is used to thin to get the final single pixel edge image.

Thinning which can make the edges becoming a single pixel width line, greatly reducing the redundant information. Currently there are two thinning algorithms are used frequently\[7\]: Quick thinning algorithm and Improved OPTA thinning algorithm. Improved OPTA thinning algorithm is serial algorithm, whose principle is that after constructing a deleting template and a retaining template, Binary image and template will be compared with each other to decide whether the value of original edge pixel 1 should be resetted. This paper, according to the features of edge of human face, constructs eight direction deleting templates\[8\] and six retaining templates. Just as shown in Fig. 3 and Fig. 4 (× standing for 0 or 1).

\[
\begin{pmatrix}
0 & 0 & 0 \\
| & | & | \\
0 & x & 0 \\
\end{pmatrix}
\quad\begin{pmatrix}
0 & 0 & x \\
| & | & | \\
1 & 1 & 1 \\
\end{pmatrix}
\quad\begin{pmatrix}
0 & 0 & 0 \\
| & | & | \\
0 & 0 & 0 \\
\end{pmatrix}
\]

(a) (b) (c) (d)

\[
\begin{pmatrix}
1 & 0 & 0 \\
| & | & | \\
0 & 0 & 0 \\
\end{pmatrix}
\quad\begin{pmatrix}
1 & 1 & 0 \\
| & | & | \\
0 & 1 & 1 \\
\end{pmatrix}
\quad\begin{pmatrix}
1 & 1 & 0 \\
| & | & | \\
1 & 0 & 0 \\
\end{pmatrix}
\]

(e) (f) (g) (h)

Fig. 3. Deleting templates of Improved OPTA operator

\[
\begin{pmatrix}
0 & 0 & 0 \\
| & | & | \\
0 & 0 & 0 \\
\end{pmatrix}
\quad\begin{pmatrix}
0 & 1 & 0 \\
| & | & | \\
0 & 0 & 0 \\
\end{pmatrix}
\quad\begin{pmatrix}
0 & 1 & 0 \\
| & | & | \\
0 & 0 & 0 \\
\end{pmatrix}
\]

(a) (b) (c)

\[
\begin{pmatrix}
0 & 0 & x \\
| & | & | \\
1 & 1 & x \\
\end{pmatrix}
\quad\begin{pmatrix}
0 & 0 & x \\
| & | & | \\
1 & 1 & x \\
\end{pmatrix}
\]

(d) (e) (f)

Fig. 4. Restraining templates of Improved OPTA operator

The chart of improved scheme of edge detection shown in Fig. 5.
C. Algorithm’s Implementation and Optimization on TMSC320DM642

TMSC320DM642 is a kind of high-performance DSP chip directing to the field of multimedia processing, whose main frequency is 720MHz. Its processing performance can reach 5760MIPS and can handle 5.76 billion instruction per second. It has three vital components: CPU kernel, peripheral devices and registers. It mainly contains three configurable video ports, and 64 general-purpose registers which is 32-bit Word Length, and eight parallel computing units, and a 64-bit Enhanced-Memory-Interface (EMIF), and EDMA which has sixty-four independent channels, and general I/O ports, and so on. The DSP chip, using Harvard structure whose storage of program and data are separated, has special hard multiplier, and uses Very Long Instruction Word structure (VLIWs) in architecture and the quasi-RISC instruction set[9]. It has several pipelining between data storage and acquisition, execution and distribution of instruction. Moreover, various arrangements of instruction do its best not to destroy the execution of pipelining. Both of that above result in its high-performance. The DM642's capability of high-speed processing in digital signal and its abundant peripheral ports and devices have such irreplaceable advantage that it is a good platform for constituting the system of communication and processing images and videos. The chart of system of digital image processing built on DM642 is shown in Fig. 6.

(1) Algorithm Achievement on DM642

The high expansibility RF-5 (Reference Framework 5) of design reference structure is used to design Application Program, mainly including three task threads: input tasks, disposal tasks and output tasks. Before going into DSP/BIOS scheduling process, the program firstly does DM642 initialization, including initialization of BIOS, CSL, Cache setting and so on; after that, do initialization of RF-5 modules: using CHAN init, ICC init and SCOM init respectively initializes channel module, ICC and SCOM modules, which is used for communication of internal unit and information transmission. Three tasks threads accomplish efficient mutual messaging communication through the SCOM module of RF-5. RF-5 is the launch of TI’s DSP software development and that is a new version of RF reference frame, based on DSP/BIOS, primarily to achieve three functions, memory management, threading model and channel packages. Simply changes these three elements complement for different applications, rather than designing the entire application from scratch, thus greatly simplifying the development of difficulty and shortening development time. All shows that RF-5 is very suitable for program that contains a large number of algorithms, and requires multi-threading and multi-channel applications such as image processing, multimedia applications and other systems more complex applications.

The entire program is implemented by C and assembler mixed language. C language has been proved to be good in readability and efficient in programming development, mainly for the achievement of algorithms of image processing and system's control, while assembler language is used to accomplish system’s initialization and some optimization. The calculation of Canny operator’s gradient intensity and direction have been achieved by templates. Improved Sobel operator and some of other image processing are achieved by modifying source code in img64x.lib, such as IMG_Sobel etc. That is specially provided to do image processing by TI for DSP chip DM642, in which there are lots of functions, such as filtering, analysis, wavelet transform and so on. All of those functions, which has already been optimized and can be invoked by C/C++ language, has sufficient pipelining and high efficiency. For reducing access time, uniform $4 \times 4$ template, shown in Fig.7, is used to do thinning. The P1-P9 in its corner of top left is the deleting template.

\[
\begin{array}{cccc}
P1 & P2 & P3 & P10 \\
P4 & P5 & P6 & P11 \\
P7 & P8 & P9 & P12 \\
P13 & P14 & P15 & P16 \\
\end{array}
\]

Figure 7. Improved OPTA unified template

(2) Algorithms optimizing on TMSC320DM642

Optimization is one of greatly important step during development of application procedures in application of DSP chip. Before that, you need to analyze the performance of codes through debug (Debug) tools and analysis (Profiler) tools of CCS, and then prescribe the right medicine to optimize the code after identifying which codes are lower efficiency. Program optimization mainly contains two aspects: C language optimization and linear assembler optimization. Main measures are as follows:

1. Effective using of pipelining.
Select -o2 or -o3 and –mt option of compiler, can make arrange software pipelining as far as possible in accordance with program, accordingly, make full use of software pipelining to enhance operating efficiency[10]. Furthermore, the option –mv6400 can optimize codes via using added hardware resources and instruction set in the chip DM642 sufficiently.

② Optimization of functions.
Using library functions, DSP.LIB and IMG.64X, which is specially provided to do image processing by TI for DSP chip DM642. All of those functions, which has already been optimized and can be invoked by C/C++ language, has sufficient software flow and high efficiency. Besides, in order to save time of push and pop in calling functions, the functions, small or seldom invoked, should be directly written into upper function so that it will take the advantages of DM642 adequately and optimize program. In addition, using specialized Inline Function of C64x compiler can reduce the length of codes to a certain extent and certainly improve the efficiency of program.

③ Memorizer optimization.
Reduce the relativity of memorizer via adding keyword ‘const’ or ‘restrict’ if necessary to show its irrelevance so that compiler can carry it out parallel; put the program called repeatedly and the data used frequently into the inner-chip memorizer, and use EDMA or QDMA to transfer dates, so that it can overcome the contradiction between high-speed CPU and SDRAM out of chip sufficiently, and improve the performance of system efficiently through full use of the powerful processing ability of DM642[10].

④ The choice of Calculations.
According to DM642 computing characteristics to do some calculation transformation. The algorithm of the division operation is converted to multiplication, addition and subtraction to play the advantages of DSP. It should also be possible using logical shift operation to replace multiplication and division can reduce the memory operation, shorten the operation time and improve the efficiency of the compiler.

⑤ The handling of data types.
The use of data package processing technology, its method is to use width length memory access short word length can reduce the memory access cycle; DM642 16-bit multiplier has the most efficient utilized in the short-type data types, whenever possible, using short-type data for fixed-point multiplication. Cycle counting using int or unsigned int, to avoid unnecessary sign extension instructions.

⑥ Find out the inefficient part by profile clock tool, programming it by linear assembly language, and then optimize through assembly optimization.

IV. ANALYSIS OF EXPERIMENTAL RESULTS
This experiment is carried out with face image database of Yale University on ICETEK-DM642-PCI EVM of Beijing REALTIME Technology Company. The results of edge detection as shown in Fig. 8 to Fig. 12. From these images, we can see that the improved Sobel operator and Canny operator make up mutually with part of edges that the other one can’t detect well. The improved process detects the edges being better integrality and continuity after integration. In order to test its effect in realistic environment, we apply the method to the face image that is located and segmented in system of Face Detection shown in Fig.13, whose original video image is captured via camera in realistic environment shown in Fig.14, and whose result of Edge Detection is shown in Fig.15. It is proved to be considered both real-time processing and fair degree of edge’s integrality and accuracy.
V. CONCLUSION

Edge Detection of human face, as one of the foundations in field of information processing of human face, plays an import role in subsequent face detection and recognition. The integrity and real-time of detection have made some improvement in this paper, however, in real-time image processing system, how to achieve the ingenious combination between traditional measures and morphology etc, how to detect edges of human face exactly and real-time in the realistic environment containing such as noise, uneven illumination and its variation and so on, which needs continuous exploration in the application field. All of that above will be the focused direction in nowadays and the future.

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