Filtering Algorithms for Image Processing in Embedded Real-time Systems

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Abstract
The algorithms used in image processing modes differ from each other both at home and abroad. This paper firstly provides a brief analysis of filtering algorithms for image processing in embedded real-time systems, combined with a comparison of their denoising methods. It then puts forward a kind of Kalman filtering algorithm for effective detection. By adopting the methods mainly including literature research, comparative analysis and statistics, this research makes a comparison between this and FAST, SURF and Harris algorithms. Finally, it turns out that all these algorithms are similar in detecting and processing image noise, although the proposed motion filtering algorithm based on Kalman has more obvious advantages and outstanding performance in image restoration, registration, edge detection and compression, and thus has strong feasibility.

Key words: Embedded Real Time Systems; Image Processing; Filtering Algorithms; Kalman

1. INTRODUCTION
Images as one of the most direct and effective information carriers are an important means to effectively pick up and exchange information in the background of highly developed civilization of a modern society. According to authoritative research in scientific fields, more than 75% of human perception of the outside world is basically obtained through vision. Along with the development of science and technology and the growing popularity of digital image correlation equipment, there is an increasingly high demand for both imaging systems and their technical standards and norms in the current production practice of all walks of life. People usually use some real-time systems and process predictable image information to achieve the required clarity of image information. Images as a carrier of information are preferable to be used as one of the most objects for studies on characteristics, but in image processing, especially in that in embedded real-time systems, they are most likely to be submissive to some noise caused by various disturbance factors in such a relatively complicated process of formation, transmission and receiving. Some of the most critical detailed features to be presented by the real-time image processing system (Ding, Qin and Dong, 2015) are likely to be inundated in such noise. In this case, whether in image observation, feature information extraction or the subsequent image analyzing step, the handler will be confronted with great difficulty. To get rid of such difficulty, this paper conducts research on filtering algorithm of image processing based on embedded real-time systems.
Being real-time is the biggest advantage of embedded real-time systems in image data collection and parameter information processing. However, because the systems themselves have numerous weaknesses such as low operation speed, limited storage resource, and small data throughput, miscellaneous difficulties and problems are often confronted within image processing. At present, a frontier investigation on particle filter algorithm based on target tracking has also made great progress in the field of computer science, and has been popularized in many fields of computer application. The main outcome of the research is the confirmation of the target position according to some salient features of the image, such as color, texture, shape, etc., and has gained wide application in the fields of transportation, medical career and security surveillance. Its main disadvantages are that the calculation mode and process are too complicated and that the range involved also has great limitation.
This paper firstly explores the main problems and contradictions existing in both Classic Image Filtering Algorithm and Bilateral filtering algorithm commonly used at present. Then it proposes a kind of Motion Filtering Algorithm based on Kalman. The so called Bilateral Filter is a nonlinear filtering application technology that can both do video and image denoising and further retain details of image edge at the same time. Classical Image Filtering Algorithm, which mainly uses the neighborhood averaging method and median filtering algorithm to achieve calculation, has also won very wide application with its faster image processing, but it has many drawbacks and side effects compared with the former (Bilateral Filtering Algorithm). One of the most prominent problems in its performance is the generation of fuzzy edge paste and submerged details in the filtering process. Although Bilateral filter algorithm is entirely new, it has been proved to have a low calculating and processing speed in practice. This is a significant deficit detected by far, which exists with its own space domain filter.
Motion Filtering Algorithm based on Kalman proposed in this paper relies on advanced electronic image stabilization technology, including the related technology of video processing, computer vision and image shooting. This technology can improve the whole effect, stability and clarity of camera on moving vehicle in operation. Currently, the technology is widely used in the development of the national military field while it has also made progress in the preliminary research in some fields of the civil industry. Kalman filtering algorithm can effectively separate normal scanning motion and basic information of jittering in complex shooting background. This paper focuses on the simple effectiveness test on PC for the algorithm (He, Ma and Liu, 2012) and finally provides an analysis of the new algorithm through experiment operation and result statistics.

2. PROBLEMS AND SHORTCOMINGS OF EMBEDDED REAL-TIME IMAGE PROCESSING SYSTEMS

Embedded systems are different from traditional PC in general use. Compared with other system model, their related hardware resources have few highlights and their basic performance is relatively weak. The problems are among low basic frequency, (extremely) less memory resources, and too simple internal processor architecture system.

2.1. Low Basic Frequency

In practical application, the basic frequency of a PC (Personal Computer) is relatively high. In current industries both at home and abroad, it is usually multi core architectures that enable PCs to reach more than 20G in terms of standard basic frequency. As in the field of embedded systems there are few research outcomes and less development of basic frequency technology of processors. Correspondingly, this has resulted in low basic frequency in the field generally. At present, the basic frequency of commonly used embedded microprocessors mainly lies between 10 kHz and 100 MHz, which is only equivalent to that of 80486CPU launched in the early 90s of last century. Likely, the later high speed components, for example, ADSP, high-speed FPGA, etc., their frequency also is only about 200MHz. However, Intel released Pentium4 with 1.13G frequency in 2000, twice as high as them. In terms of the above-mentioned situation, low frequency severely constrains the development of embedded system in image processing and the key technology lies in improving CPU basic frequency. Currently, in terms of the image processing speed of microprocessors, there is a technology gap of up to ten years between the machines used in the embedded field and ubiquitous PCs.

2.2. Less Memory Resource

As mentioned above, the standard memory of a PC is usually 2G and their hard-disk space is generally more than 320G in China. However, in the embedded field, especially when it comes to real-time image processing, the capacity of memory can only take K as its basic unit, generally lying between 10K and 50K. For those microprocessors with memory more than 100K, there is less selectivity. In the whole system, program memory capacity can take M as the basic unit at most. For most types of existing program memory, their capacity is less than 512M. So not only in the performance and technology of microprocessors but also in memory resource of micro controllers in the embedded field, there is a gap of standard memory as large as a thousand times between machines used in the embedded field and current domestic general PCs.

2.3. Simple Processor Architecture (Zhang, 2015)

The processor in a PC on the market is generally matched with a coprocessor, the function of which is to assist the main processor in data processing, including videos, images etc. The PC system has a multi-core architecture processor of which the data throughput capacity is fairly great. However, as regards the domain of embedded system mentioned in this paper, only few series of micro microprocessor can be taken as coprocessors to match them. Fortunately, since 2010, embedded microprocessors of multi-core structure have been gradually developed.

In general, the main problems existing in the current embedded real-time image processing system really reflects its lack of technology, including the shortage of micro controller resource, low speed of image data processing, weak data throughput capacity, etc. Therefore, in view of the above series of problems this paper focuses on the filtering algorithm based on embedded real-time systems and proposes a new effective computer processing algorithm.

3. EFFECTIVENESS DETECTION BASED ON MOTION FILTERING ALGORITHM

3.1. A Comparative Analyses

Classic Image Filtering Algorithm (The neighborhood average method) mainly takes the average of corresponding component values between neighboring pixels the center pixel for calculation. In the system, the component value of each image point to be processed can be directly input and set as f(J,K). After the point has been set as the center, the following step is to be in accordance with normal procedures, taking the point set
consisting of N x N window pixels, which in the program is expressed with $A$: $N = 3, 5, 7$. The last step is to obtain the formula corresponding to pixel $f(j, k)$ by the neighborhood average method as follows:

$$F(j, k) = \left( \frac{1}{N^2} \right) \sum_{(x, y) \in A} f(x, y) \quad (1)$$

Where in $f(j, k)$ designates each component value of the image.

![Figure 1: Four-point neighborhood](image)

As shown in Figure 1, when it comes to smooth processing with neighborhood average, neighborhood selection usually contains two kinds of calculation methods, which take the unit distance as the radius or the $\sqrt{2}$ times of the unit distance as the radius times respectively.

1. The calculating method taking the unit distance as the radius, called four-point neighborhood:

$$A4 = \{(j, k - 1), (j + 1, k), (j, k + 1), (j - 1, k)\}$$

2. The calculating method taking the $\sqrt{2}$ times of the unit distance as the radius, called eight-point neighborhood:

$$A8 = \{(j - 1, k - 1), (j - 1, k), (j - 1, k + 1), (j, k - 1), (j, k + 1), (j + 1, k - 1), (j + 1, k), (j + 1, k + 1)\}$$

The biggest defect of the algorithm lies in the fact that it just simply does statistical calculation of pixels by using filtering algorithm. During the calculating process, the average value is calculated with respect to the component value of adjacent points, followed by a further replacement of the original pixel value by the measured average value. It does not fully take into account the relation between the center pixel and its surrounding points. Therefore, the image finally brought out is often blurred and as the fuzzy degree of image is proportional to the radius of the neighborhood, the bigger the selected or set radius is, the higher the degree of fuzziness is. At the same time, the image is also associated with mottled parts of different degree, especially in the image edges (Bao, Fan and Rao, 2011).

Motion Filtering Algorithm based on Kalman proposed by this paper mainly employs EIS (Electronic Image Stabilization Technology), which uses an electronic measurement model combined with digital computer image processing technology and the latest electronic devices and its internal structure specially covers electronic, computer and digital image processing technology. The link of motion filtering locates in the central and key position in the whole process of system running and processing. As it has significant effectiveness, it can enhance the texture in image processing to the maximum if applied in modern embedded real-time image processing.

The system setting mainly includes three subsystem modules: (1) motion estimation module; (2) motion filter module; and (3) motion compensation module. This paper focuses on motion filter module, which is both the intermediate and key link of the three modules. Its main function is to reprocess the global motion vector of image obtained by motion estimation.

### 3.2. A Theoretical Analysis of Motion Filter

Different from the above-mentioned particle filtering and bilateral filtering algorithms, Motion Filtering Algorithm based on Kalman in embedded real-time image processing system has its basic working principle dependent on the camera as it can distinguish two types of motion. The application of this technology into embedded real-time image processing can help to remove undesirable jitter of the captured motion image to the maximal extent and make images smooth and complete in system output as far as possible.

The commonly used calculating method of motion filter is as follows:

Iterative filtering calculating:
\[ y(n) = \frac{y(n-1)(2M+1) - x(n-M-1) + x(n+M)}{2M+1} \quad (2) \]

In the above formula, \( x(n) \) mainly represents the original sequence while \( y(n) \) is a corresponding sequence after moving average filtering. The width of the filter in the system is designated by \((2M+1)\).

Hence, the transfer function can be further introduced to calculate mean iterative filtering:

\[ H(z) = \frac{Zm}{2M+1} - \left(1 - \frac{Z}{2m + 1}\right) \quad (3) \]

By the change of video frequency in the system it is obtained the corresponding function expression:

\[ |H(\omega)| = \frac{1}{2M+1} - \frac{\cos(\omega M) - \cos(\omega + M + 1)}{|1 - \cos(\omega)|} \quad (4) \]

Calculated by the above formula, the frequency response based on the system and the width between filtering processor \( M \) has both positive and negative correlation. Here the frequency response is selected respectively with \( M \) value of 3/20/100.

Kalman filter was put forward by R. E. Kalman in early 60s of last century and is a desired signal filtering algorithm estimated by evolution reasoning, via testing experiments in terms of data in observation in correlation with extracted signals (Cao, 2010).

This algorithm has less application in China’s domestic industries except in military and aerospace research for calculating and processing data such as videos and images captured by cameras. Due to its great advantages such as downsizing calculation and flexible performance, it is applicable to data processing including videos and images. The operators generally divide the operating process into three basic implementation steps in practice, namely filter initialization, state estimation and status update. The state equation is:

\[ X(k) = Ax(k-1) + w(k-1) \quad (5) \]

The observation equation is:

\[ Z(k) = Hx(k) + v(k) \quad (6) \]

wherein, \( X \) represents the state of the system, \( Z \) the observation state, \( W \) the noise of the system, \( V \) the observation noise, \( A \) the state transition matrix and \( H \) the observation matrix correspondingly.

The algorithm is substantially similar to FAST, SURF and Harris algorithms in detecting and handling image noise, but its advantages and highlights are more prominent. In embedded real-time image processing system, with the decrease of SNR (Saponara et al., 2007) (Signal to Noise Ratio, in both video playback and image displaying) and the increase of fuzzy degree on after another, all the methods based on grayscale will gradually fail to work, algorithms including FAST, SURF and Harris, although bound to a certain false detection rate, have better robust performance against Gauss Noise and Salt and Pepper Noise. Below is a comparative analysis of Kalman Motion Filtering Algorithm and FAST, SURF and Harris Algorithms in terms of related ability to eliminate possible Gauss Noise and Salt and Pepper noise in images.

| Table 1. A comparison of time-consuming effect of feature points detection (ms) |
|------------------|-------|---------|---------------|----------|
| Algorithms      | Types | Original Image | Gauss noise | Salt and Pepper Noise | Box Blur |
| FAST            | 38    | 73       | 40           | 33        |
| SURF            | 385   | 454      | 421          | 338       |
| Harris          | 236   | 188      | 213          | 186       |
| Kalman          | 410   | 397      | 401          | 390       |

Two conclusions can be drawn from Table 1: (1) FAST/SURF/Harris/Kalman Algorithm is sensitive to image noise; (2) Kalman Filtering Algorithm has a strong ability to resist image noise.

| Table 2. A comparative analysis of amount of extracted features in embedded real-time image processing system |
|------------------|---------|---------|---------------|----------|
| Feature Name     | Original Image | Gauss noise | Salt and Pepper Noise | Box Blur |
| FAST             | 2378    | 2962    | 2822          | 1364     |
| SURF             | 500     | 500     | 500           | 500      |
| Harris           | 830     | 817     | 851           | 1024     |
| Kalman           | 2165    | 6493    | 6476          | 414      |

From Table 2, it is obvious that Motion Filtering Algorithm based on Kalman has an absolute advantage over the other three algorithms in both operation speed and performance matching (Ramsay et al., 2006), and that
the number of extracted image features is never the less more than the three. On this basis, the characteristics of
the previous image can be fully described after further processing.

It is noteworthy that this algorithm is very suitable for integrating the filtering algorithm in the Adaptive
Weighted Median mode into itself, which can further detect the noise contained in the image processing and
make corresponding repair. For example:

\[ S_{i,j} = \{ f(i + k, j + r) \mid k, r = -1, 0, 1 \} \] (7)

Suppose the selected window is 3X3, then the gray value of \((i,j)\) is \(f(i,j)\). Based on this, the average value of
all pixels in the window can be further calculated by:

\[ \text{Average}(S_{i,j}) = \frac{1}{9} \sum_{k=-1}^{1} \sum_{r=-1}^{1} [f(i + k, j + r)] \] (8)

4. CONCLUSIONS

Compared with FAST, SURF and Harris algorithms, the one proposed in this paper, namely motion
filtering algorithm based on Kalman has been found almost similar to them in detecting and processing image
noise. But its advantages are even more prominent than the traditional image processing algorithms. No matter
in image restoration and registration or in image edge detection and compression, it always features strong
feasibility. Through this topic design and research, the common knowledge of the embedded system has been
further solidified. In view of the difficulties encountered in the course of the study, through access to relevant
literature data a real understanding has come into being of the key role the highly efficient and reliable system
software plays in the real-time image processing system.

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