ADAPTIVE INTERPOLATION CONSIDERING WITH SUBJECTIVE PICTURE QUALITY

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ABSTRACT

Recently, we have many kinds of picture format and display, and resizing (scaling) of picture becomes important. In this processing, quality of picture depends on re-sizing method. For this, some methods to improve the PSNR have been proposed. However, subjective picture quality is more important. Especially, degradation caused by re-sizing, such as jaggy (aliasing) and ringing, should be reduced. To solve them, we have proposed the method using directional adaptive interpolation. To improve the performance of this method, we consider the shape analysis this time. In the proposed method, directional adaptive processing is applied for pure edge only. In the texture area and flat area, 8 tap re-sampling filter is used. As the results of processing, the reductions of jaggy and incorrect interpolated pixels are recognized. The subjective picture quality of proposed method is significantly better than 8-tap re-sampling which gives good PSNR.

Keywords: Re-sizing, Interpolation, Direction Adaptive, Super Resolution, Picture Scalar

1. INTRODUCTION

In digital broadcast, we have many kind of picture format. In addition, the numbers of pixel are various in display panel. Therefore, conversion of picture formats is necessary. In the conversion, re-sizing (picture scaling) that convert number of pixel in a frame is required, not only de-interlacing and frame rate conversion. Scaling is realized by re-sampling processing, converted picture quality depends on its method.[1]-[4]

On the other hand, some methods to improve the subjective picture quality have been proposed. They improve the actual resolution and sharpness. However, these processing are not suitable for resizing in a display. For this, we have proposed the method that is combined directional adaptive interpolation and adaptive re-sampling filter. Directional adaptive processing can reduce alias, and adaptive filter can reduce ringing in a picture. However, we could see some degradation in texture because of incorrect interpolation. [5]

To solve this problem, we consider the area estimation for the adaptive interpolation. We choose pure edge area to avoid incorrect estimation of direction at texture area. To realize this, shape analysis using directional operator is used instead of simple edge detection. At first, an operator estimates the flat area and the non-flat area. In non-flat area, shape analysis estimates the direction of each pixel. As results of the direction relation, we separate the edge area and the texture area. We use 8-tap filter for the flat area and the texture area, because, ringing and alias are not visible in such area. Directional adaptive interpolation with wide search range is applied for edge area.

To evaluate picture quality of resizing, we use progressive scanning SDTV pictures. The down-sized pictures are re-sized to the two times size picture which is the same as original.

As the results of processing, the reductions of jaggy and incorrect interpolated pixels are recognized. The subjective picture quality of proposed method is significantly better than 8-tap re-sampling which gives good PSNR.

2. HIGH QALITY RESIZING

2.1 Requirements of Resizing

Resizing (picture scaling) is a basic technology in picture processing. It is very useful for a graphic for a display at PC. On the other hand, picture format is diversified with digitization of broadcast, for example, form QVGA (320x240) to full HDTV (1920x1080). Picture scaling is one of most important processing of video signal.

In this technology, quality of resized picture is most important. Also, processing time and/or complexity should be considered. About the picture quality, objective measurement such as PSNR is usually used to evaluate a processing. However, subjective picture quality is more important. Most of picture degradations caused by a scaling are sharpness, ringing and jaggy (aliasing). This time, we discuss a processing which can reduce these degradations.

2.2 Technology of Resizing

2.2.1 Basic Methods

Most basic picture resizing is the bi-linear interpolation. However, it causes less sharpness picture and not used recently. The bi-cubic method is popular processing currently in PC graphics. However, it has room to improvement.

In a professional video system, such as a format converter, high order re-sampling method is used. In a consumer video system, number of tap in a filter is reduced, because of processing cost. Fig. 1 shows PSNR of the two times up-scaled picture by re-sampling. In this, two taps means the bi-linear, and four taps is similar to the bi-cubic. You can see that high order re-sampling gives better PSNR than bi-cubic.

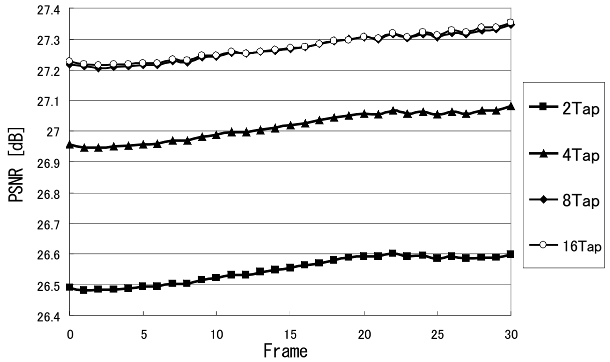


Fig.1 PSNR of Scaled Picture by Re-sampling

2.2.2 Advanced Methods

Improvements of scaling (resizing) method in a picture have been studied. In these methods, adaptive interpolation technologies were improved from the bi-linear or the bi-cubic method. And, performances were improved on PSNR, because they were improved based on square error.

As shown in Fig.1, a high order re-sampling gives better PSNR. By this reason, PSNR should be compared to higher order re-sampling rather than bi-cubic. However, high order re-sampling causes ringing at edges in a picture. This is subjective degradation of picture quality. Also, jaggy should be reduced.

Some methods use a directional adaptive processing. They are useful to reduce jaggy. However, reduction of jaggy is not enough because of a limitation of direction.

2.2.3 Super Resolution

On the other hand, use of a motion compensated inter-picture interpolation has been studied to improve a spatial resolution. They are called "super resolution". This method is very effective for a picture that include alias, for example, it is a RGB picture before de-mosaicing at a mono-CCD camera. However, these methods are not useful for an ideal motion picture that does not have alias.

2.3 Over View of Proposal

We have considered how to improve a subjective picture quality. Ringing and jaggy should be reduced. Sharpness is improved by higher order re-sampling simply.

To realize this, we apply a directional adaptive interpolation with wide range for edges. For other area, higher order re-sampling is used. This architecture is also good to reduce ringing. Ringing is caused by a high order re-sampling at edges.

In this method, area estimation is very important. A directional adaptive interpolation with wide range causes incorrect interpolation at a texture area. Therefore, texture should be rejected in edge area.

Fig.2 shows the general structure of proposed scalar. In this, shape analysis with directional operator is used. Area is decided on a pixel based with spatial smoothing.

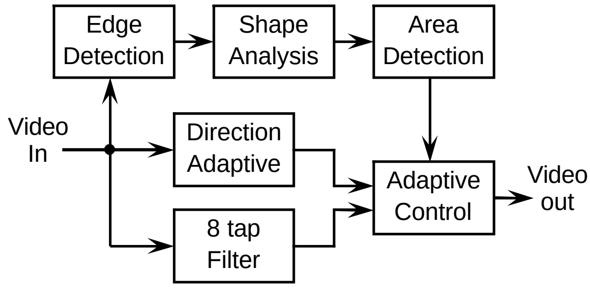


Fig.2 General Structure of Proposed Interpolation

2.3.1 Area Detection

At first, edge detection is processed for the shape analysis. We use Robinson operators instead of usual Sobel filter. Results of this operation show four directions for each pixel. Shape is analyzed by relations of the direction by Robinson operators. Smoothing and area control is

2.3.2 Direction Estimation

In proposed method, direction estimation for each pixel is required to apply a directional adaptive interpolation. In this case, usual direction analysis, such as Robinson operator, is not usable because of range of direction. We should take wide range direction to achieve reduction of jaggy. However, direction estimation for this is not easy to avoid incorrect direction. Therefore, we take two steps analysis method to realize both wide range and problem of incorrect direction.

2.3.3 Adaptive Interpolation

We use only two kind of interpolation. One is a directional adaptive interpolation. Number of filter tap of this method is only two, it is linear interpolation. Another interpolation is higher order re-sampling. We use 8 taps filter this time. Directional adaptive interpolation is applied for a pure edge. For the other area, 8-taps filter is used.

3. Spatial Direction Adaptive Interpolation

3.1 Area Estimation

Structure of the area estimation is shown in Fig.3. The detail of proposed method is described below.

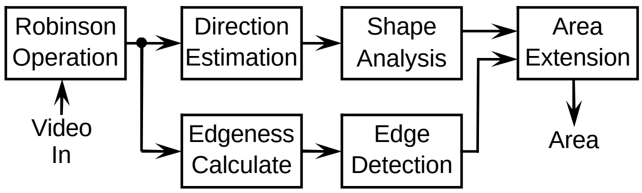


Fig.3 Structure of Area Estimation

3.1.1 Edge Detection

The edge detection for shape analysis has two kind of purpose. One is an estimation of the edge-ness, and, another is the direction analysis. We use Robinson operators in Fig. 4. There are four directions, vertical, 45degree, horizontal and 135 degree. An operator which gives largest value is a direction of a pixel.

Edge-ness is given by root-mean- square calculation of horizontal and vertical component. About the first stage edge detection, an edge pixel is given by exceeding the constant value in edge-ness.

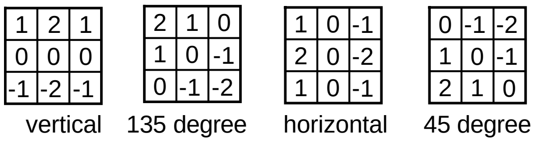


Fig. 4 Robinson Operators

3.1.2 Shape Analysis

The shape of edge is analyzed by relations of the direction. The direction of the pixel in the position of direction is checked. If one of them has the same direction, it is an edge pixel. Fig. 5 shows an example of this. Hatched pixel is an edge pixel.

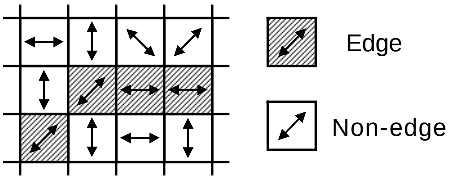


Fig. 5 Shape Analysis

3.1.3 Area Determination

Edge is determined by results of shape analysis and edge-ness. A pixel which fulfilled the conditions of both shape and edge-ness is determined as the edge area. To determine the edge area, edge pixel is extended by maximum operation by 5x5 pixels like Fig.6. All of other pixels are determined as the non-edge area. Extension is required because of 8 tap filter response for non-edge area.

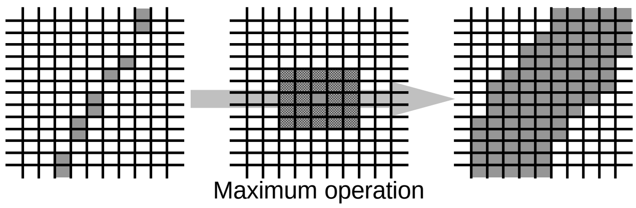


Fig. 6 Area Extension

3.2 Direction Estimation

Direction estimation and the interpolation are processed at horizontal and at vertical separately. Structure of adaptive interpolation is shown in Fig. 7. The reasons of separation are that an actual re-sizing requires different ratio and separate processing is more useful for wide range search.

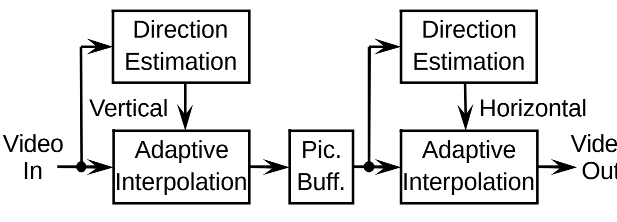


Fig.7 Structure Direction Estimation and Interpolation

The processing is explained in vertical re-sizing below. Basic directional vector searching is performed by Fig.8. If both upper and lower are moved, correct vector cannot be estimated. Therefore, one side is fixed to search a vector. This process is shown in Fig. 9.

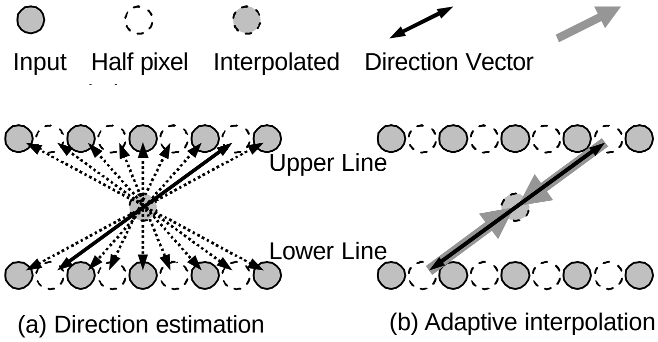


Fig.8 Estimation and Interpolation using Spatial Direction

3.2.1 Vector searching

In case which vector searching with fixing one side, matching operation is given by.

$$SAD_l(x,y,ddx)=\sum_{m=-M}^{M}\sum_{n=-N}^{N}\left|P(x+m+ddx,y+n+1)-P(x+m,y+n-1)\right| \quad (1)$$

$$SAD_u(x,y,ddx)=\sum_{m=-M}^{M}\sum_{n=-N}^{N}\left|P(x+m,y+n+1)-P(x+m+ddx,y+n-1)\right| \quad (2)$$

where,

m is horizontal position of matching block

N and *M* are block size

Therefore, temporary vector for pixel of upper / lower line is determined.

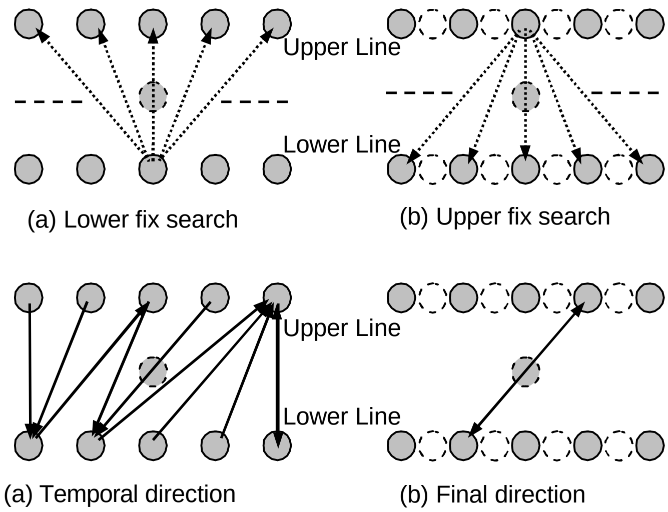


Fig. 9 Proposed Estimation of Spatial Direction

3.2.2 Vector temporary determination

We choose the vector which is through the target position temporarily. If temporal vector is far from target position, because incorrect interpolation will happen, interpolation is switched to vertical interpolation.

3.2.3 Final vector determination

To avoid unnecessary slant interpolation in non edge position, vertical directional (*ddx*=0) is taken preferentially in final vector. If *ddx* is not reasonable, interpolation is not appropriate. Therefore, vector is corrected by re-searching.

3.3 Adaptive Interpolation

We use two kinds of interpolation for the re-sizing as follow. The fixed 8-taps interpolated pixel P_8 is given by

$$P_8(x,y) = \{-P(x,y-7)+3P(x,y-5)-5P(x,y-3)+19P(x,y-1) +19P(x,y+1)-5P(x,y+3)+3P(x,y+5)-P(x,y+7)\}/32 \quad (3)$$

The directional adaptive interpolated pixel P_d is given by

$$P_d(x,y) = \{P(x-dxx,y-1)-P(x+dxx,y+1)\}/2 \quad (4)$$

The final interpolated pixel P_i is given by

$$P_i(x,y) = kP_8(x,y)-(1-k)P_d(x,y) \quad (5)$$

The adaptive control signal k (0-1) is from smoothed estimated area. The value k takes 0 for the edge area, 1.0 for the non-edge area.

4. EXAMINATION

4.1 Evaluation

4.1.1 Evaluation System and Tested Pictures

To evaluate picture quality of up-scaling, a target picture is needed. In this case, the target picture is progressive scanning SDTV (720 x 480) picture. Half down-sized picture is made from the target picture by using 7tap 2D-LPF. The evaluation system is shown in Fig. 10.

We use ITE standard pictures to evaluate performance. There are “Walk through the Square”, “Soccer” and “Yacht Harbor”.

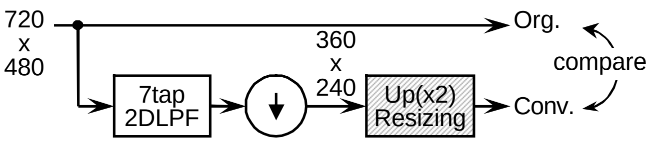


Fig. 10 Evaluation System for Resizing

4.1.2 Evaluated resizing methods

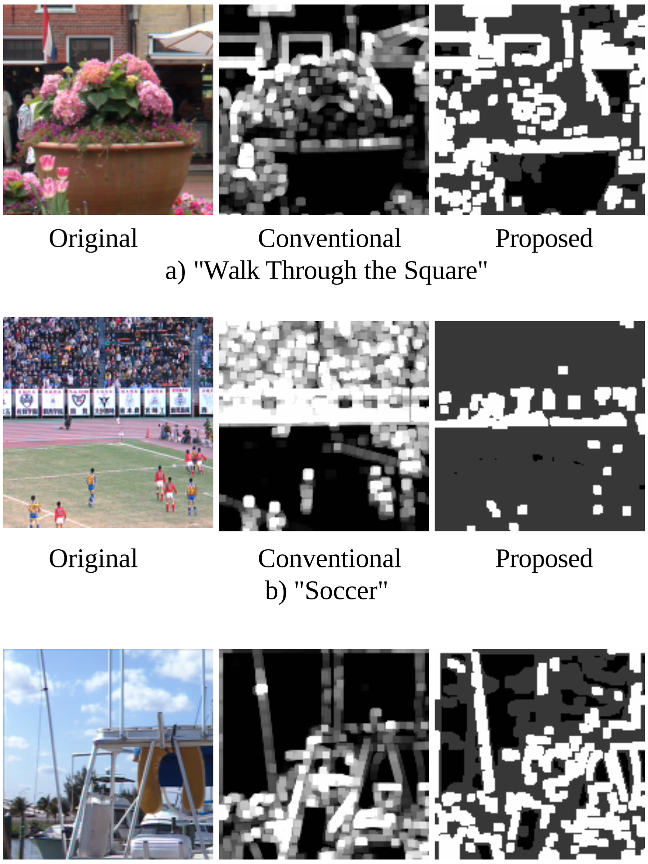
Three methods of up-resizing are evaluated. There are the 8-taps, conventional method which was proposed by us and proposal this time. We used simple Sobel filter for edge detection in the conventional.

About the processing parameters in the proposal, the threshold of edge-ness is 20. The search range of direction is 5 pixel. About the matching block size, M=7 and N=2. Advanced methods are applied for Y signal only. C signal is bi-linear interpolation.

4.2 Evaluation Results

4.2.1 Detected Area

At first, results of area estimations are shown in Fig. 9. In the comparison with the conventional method, only pure edge is estimated by proposal.



Original Conventional Proposed
a) "Walk Through the Square"

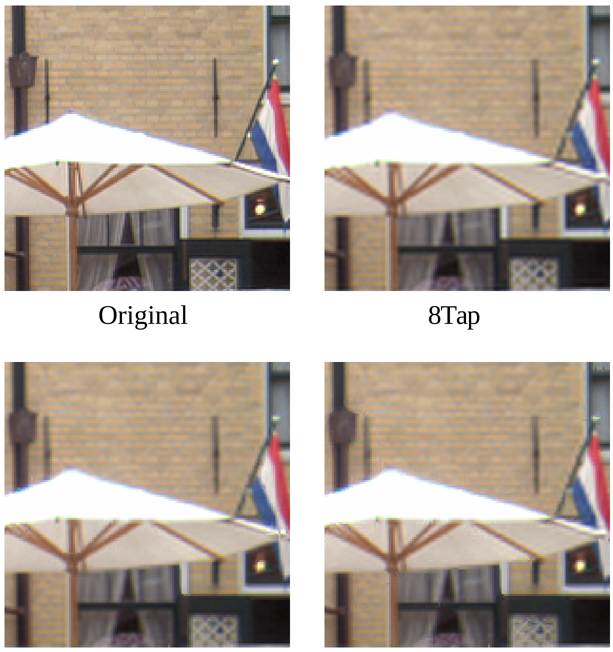
Original Conventional Proposed
b) "Soccer"

Original Conventional Proposed
c) "Yacht Harbor"

Fig.11 Results of Area Estimation

4.2.2 Re-sized Picture

Original picture and three kinds of re-sized pictures are shown in Fig.12-14. In the comparison with the conventional method, degradation caused by incorrect direction is suppressed. Also, Jaggy and ringing are reduced significantly. Sharpness of the non-edge area, such as flat or texture area, are kept by high order re-sampling.



Original 8Tap

Conventional Proposal

Fig. 12 Scaled Pictures of "Walk Through the Square"

Fig. 13 Scaled Pictures of "Soccer"

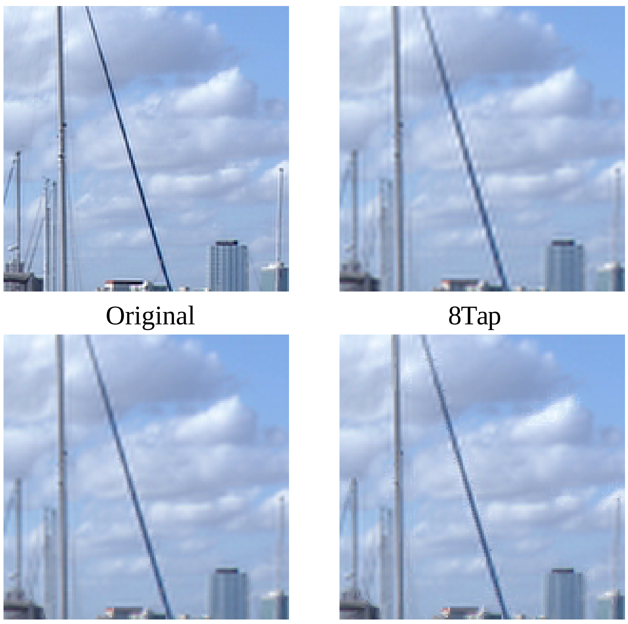


Fig. 14 Scaled Pictures of "Yacht Harbor"

5. CONCLUSION

Adaptive interpolation method considering with subjective picture quality was studied. We discussed the shape analysis this time mainly.

In the proposed method, directional adaptive processing is applied for the pure edge only. In the texture area and flat area, 8-taps re-sampling filter is used. The shape analysis to reject the texture area from the edge area is used. The directional adaptive interpolation with wide search range is applied for edge area and the 8-taps re-sampling filter is used for non-edge area.

As the results of examination, degradation caused by incorrect direction is suppressed in the proposed method. Also, Jaggy and ringing are reduced significantly. Sharpness of the non-edge area, such as flat or texture area, are kept by using the 8-taps re-sampling.

However, directional adaptive processing is used in high edge only. For the next work, application of the directional adaptive processing for the non-edge area should be discussed.

6. REFERENCES

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