Real-time resolution conversion of document image with hierarchical coding

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Abstract

1 Introduction

It has been getting popular for enterprises to have document management systems which provide users with an easy and flexible way to access the stored documents through Local Area Networks.

For this kind of system, it is very important to accomplish the quick response to users who demand the output document image on a great variety of output devices including CRTs, Liquid-Crystal Displays as well as printers, each of which is expected to accept the resolution desired by users.

To cover this variety of output devices, JBIG image coding method is proposed for the next generation FAX machines. JBIG utilizes the hierarchical image data structure by repeating 1:2 resolution conversion on the source image, and employs predictive encoding. It has higher compression rate than JPEG reversible mode, when applied to up to 6 bit gray-scale images. It realizes the selective resolution to match the output devices, and soft-copy with progressive build-up capability.

However, electronic filing systems currently available do not use hierarchical encoding like JBIG but images for displays are stored separately or generated on demand from the original, i.e. images for printers.

It should be also noted that JBIG creates only $1/2^n$ th resolution of the source image, so that it is necessary to complement these resolutions to crate the images in the resolution required by user.

With multi resolution data format, it should be easier to achieve the quicker response and better image quality simultaneously.

In this research, real-time resolution conversion algorithms are developed to get images in the arbitrary resolutions from a bi-level multi resolution document image obtained by the JBIG PRES resolution reduction method.

2 Resolution conversion algorithms

In this research, two classes of resolution conversion algorithms are proposed: "Cropping and complement methods in the spatial domain" and "Bandwidth limitation methods in the translation domain".

2.1 Cropping and complement methods in the spatial domain

5 algorithms are proposed and examined as members of this group.

1. Simple sampling method

   which uses a pixel value sampled from the base image as a pixel value in the converted image.

2. Weighted averaging method

   which uses weighted averaged value of a pixel selected by the simple sampling method and its 8 neighboring pixels.

3. Area ratio method

   which uses weighted average value of base image pixels that is covered by the pixel in the converted image, in proportional to the ratio of the covering area.

4. Nearest neighbor sampling method

   which uses a value of base image pixel which has the biggest area ratio.

5. Nearest neighbor weighted averaging method

   which uses weighted average of the pixels represented by the most neighboring sampling and its 8 neighboring pixels.

2.2 A bandwidth limitation method in the translation domain

- Bandwidth limitation in the frequency domain

  in which input progression $x(n)$ is divided into N-point blocks, and N-point DCT is applied. Then the lower band M points are taken out of resulting N points, and M-point IDCT is applied. This brings out an N to M resolution reduction.

3 Evaluation of proposed algorithms

Each algorithms are implemented and evaluated in conversion speed, S/N ratio, and subjective evaluation of image quality.

3.1 Evaluation of the conversion speed

A set of 200 dpi and 100 dpi images from the ITU-T standard image set with hierarchical encoding are used for base images. Programs for resolution conversion from base image to 56, 62, 68, 75, 81, 87, 93, 112, 124, 136, 150, 162, 174, 186(dpi) images are developed and time required for the resolution conversion are measured.

As a result, conversion time increases in the following order: simple sampling < weighted averaging < area ratio < nearest neighbor sampling < nearest neighbor weighted averaging < bandwidth limitation. Simple sampling method completes conversion under 1 second at any resolution tested. The area ratio needs a maximum time of 7.32 seconds. And with method by bandwidth limitation in the frequency domain reaches a maximum time of 393.4 seconds.

As the result of these measurement, it is considered that any cropping and complement methods in the spatial domain can be used as the real-time conversion algorithm if carefully implemented.

3.2 Measurement of S/N ratio

As it is quite difficult to make subjective evaluations in many resolutions, S/N ratio is measured as the preliminary evaluation, and a relationship between variation of resolution and transition of image quality is examined. Measurement is done at images of 50 dpi to 400 dpi. Images obtained by bandwidth limitation in the frequency domain is used as the reference images.

As the result, it appears that lower the resolution of base image, lower the S/N ratio is, and lower the resolution of converted image, lower the S/N ratio becomes.

3.3 Subjective evaluation of image quality

Based on the result of S/N ratio evaluation, subjective evaluation of image quality is made for each methods with 50 dpi to 200 dpi resolution. Evaluation is made along with the ITU-R BT.500 recommendation, which is based on the Double-Stimulus Continuous Quality Scale method(DSCQS). 42 set of images are used per person. The evaluation was made using the scanned images as the reference, and evaluation image which is made by each conversion method are evaluated in the point of readability. 18 person are participated in the evaluation.

As the result, method by area ratio got the highest score, followed by bandwidth limitation method in frequency domain > nearest neighbor weighted averaging > weighted averaging > nearest neighbor sampling > simple sampling.

In a range of resolution evaluated, it is considered that method by area ratio can get the most highest quality.

As the result of evaluations above, It is considered that method by area ratio has the most highest utility value.

4 Conclusions

4.1 Achievements of this research

Six resolution reduction algorithms are proposed, and the conversion time required for each resolutions are measured.

S/N ratio was measured for each resolution.

Subjective evaluation of image quality was measured, and it is shown that a good quality image can be obtained by the area ratio method and bandwidth limitation in the frequency domain.

As the result of these evaluation, among the algorithms proposed in this research, the area ratio algorithm is considered to be the most useful one.

Because of the differences in the characteristics of the proposed algorithms, dynamic selection of the algorithms should be required in the real applications.

4.2 Future works

Improved implementation and application to the real work are left as future works.

Dynamic selection algorithm of conversion algorithms must be developed.

Evaluation of image quality where the base image is gray-scale must be performed.

Furthermore, application and evaluation with non-CRT display devices is also a future work.