ON THE EFFICIENCY OF THE DIFFERENTIAL PULSE CODE MODULATION IN IMAGE CODING AND COMPRESSION AND AN IMPLEMENTATION ON A DIGITAL SIGNAL PROCESSOR BASED SYSTEM

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Abstract

This paper describes tools for the theoretical and experimental study of several DPCM methods in image acquisition and compression, with applications in Intelligent Visual Sensor development. The paper also presents conclusions about DSP based implementations of the described algorithms.

1.Introduction

DPCM ([1][2]) is a general method of compression useful in various fields of the signal processing technology. Even today, when other tools offer a larger compression ratio , simplicity of the DPCM is a major advantage that results in a cheap implementation and in a higher compression speed.

The basis of DPCM compression is cuantisation and coding of the difference between the predicted sample and the real sample .The predicted sample is often a linear combination of the preceding samples.In most applications the prediction is limited at the closest preceding samples of the predicted pixel.

Shortly, the algorithm can be described in the following formula:

$$e(i,j)=a1*e(i-1,j)+a2*e(i,j-1)+a3*e(i-1,j-1)+ r(i,j) \qquad (1)$$

where e(i,j)- is the image sample for the i,j co-ordinates

a1,a2,a3- coefficients of the prediction
r(i,j)- the residual error

The residual error has a lower entropy than the original image and can be thus represented with fewer bits.

Choosing the coefficients is often the main problem of the algorithm, and can be done for error minimisation and /or to obtain a higher compression ratio.

An other problem in the algorithm evaluation is to establish measures of fidelity. A widely used measure of reconstructed image fidelity, used also in this paper, for an NxN image size is the average mean-square error defined as:

$$N_{ms}^2 = \frac{\sum_{i=0}^{N}\sum_{j=0}^{N} E(e(i,j) - e^*(i,j))^2}{NxN} \qquad (2)$$

Experimentally, the average mean square error is estimated by the average sample mean-square error in the given image:

$$N_{ms}^2 \cong \frac{\sum_{i=0}^{N-1}\sum_{j=0}^{N-1} (e(i,j) - e^*(i,j))^2}{NxN} \qquad (3)$$

2. Short presentation of the software environment designated for algorithm evaluation and of the DSP based system

The software environment ,called DPCM, developed for this application offers the following facilities:

-loading of the original image from the file or from the acquisition board
-modification of the coefficients used for prediction
-modification of the level of cuantisation (compression factor)
-execution of the compression algorithm
-saving the result on disk or in video board
-computing of compression factor
-decompression of the file and reconstruction of the "original " image
-visualisation of the original file or the reconstructed file
-measurements of the difference between the original and the reconstructed image done by one of the formulae presented in par.1

The DSP coprocessor system [3] is a PC hosted system, based on a fixed point DSP , designed to facilitate application development of vision systems in industrial environment.

Basically , the system is composed from support board equipped with **TMS320C25 DSP , 64 Kwords of program/data memory** and the SV-101 acquisition module ,which can digitise a

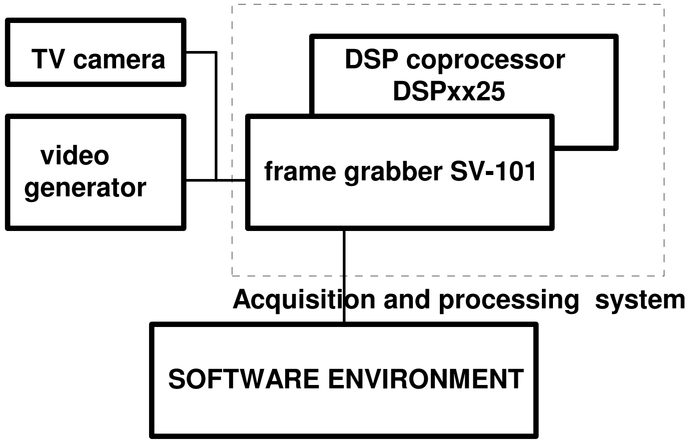


Fig.1.Structure of the development system

monochrome image with **512x512 points** resolution , **8 bits** , in real time.The structure of the system is presented in fig.1.

The software environment assembles an application from a library of elementary functions as described , loads this application in DSP support board memory and controls the program execution.The facilities of the DSP system described are similar to those of the system described in [5].

For the implementation on the DSP system, he offers the possibility for evaluation of the processing speed and complexity of the program.

3.Experimental results

This section presents several results of the experiments, obtained both with DPCM program and DSP development system.

The results are obtained for different sets of prediction coefficients, different thresholds of cuantisation level. The error levels of the difference between the original and the reconstructed image are also exposed.

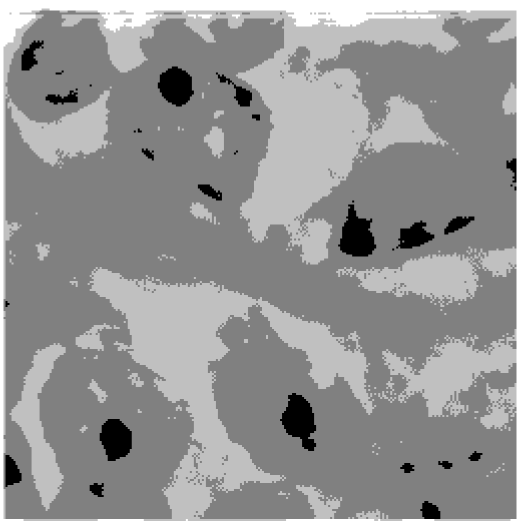
The first image "CELLS" is compressed with a set of prediction coefficients a1=0.75,a2=0.75,a3=-0.5.(as indicated in [1]).The output difference was limited at -8...+7 (4 bits for the residue).The right image is the reconstructed image.For this image the mean residual error is <1LSB computed with absolute value, and 6.4 LSB computed with formula (3)- effective value.

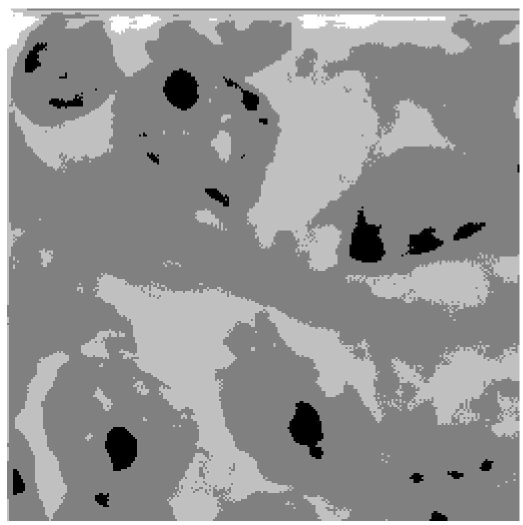
The second image ,"RADU" ,is compressed with the same set of coefficients , but limiting the output residue at -4.....+3 (3 bits).With those values the mean residual error is 2LSB for the absolute value and 8.6LSB in effective value.

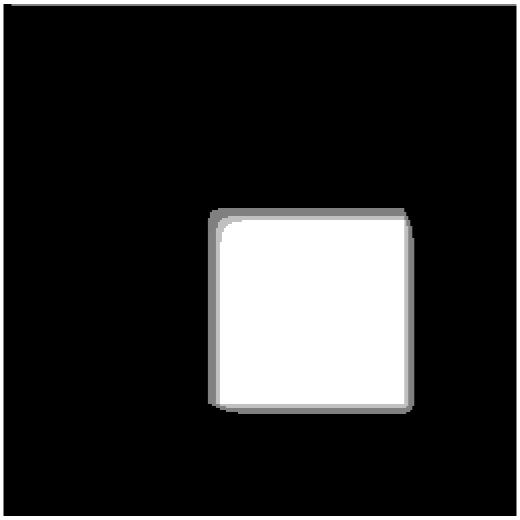
The third set of images illustrates the limits of DPCM compression method in a case of "synthetic" image ("RECTANG").First image was compressed with the same set of coefficients (a1=0.75,a2=0.75,a3=-0.5 , 4 bit residue),and we can observe the "softening" of edges in the reconstructed image. The second image illustrates the catastrophic effect of a bad choice of prediction coefficients combined with a limitation of the residue (a1=1,a2=1,a3=-1 ,4 bit residue).

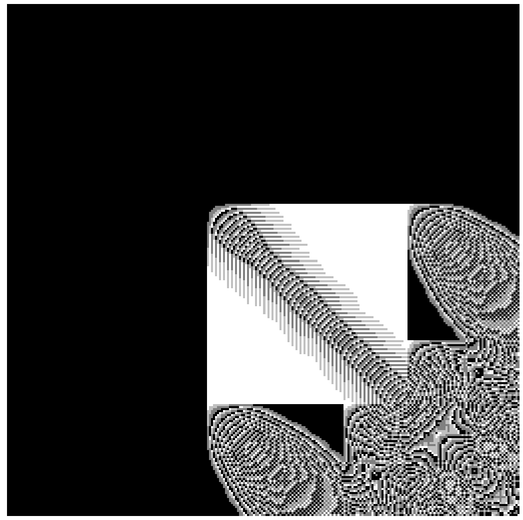
The method exposed offers a compression factor relatively low (2 to 5 depending on the limitations of the residue) , but this algorithm can be combined with other tools (Huffman encoding for example) to achieve a higher compression ratio.

The DPCM program ,written in PASCAL ,compresses an 256x256 pixel image, in aprox.2s (in 386DX/40MHz PC and memory to memory compression). For the DSP implementation an estimation is done in less than 1.5ms pe pixel , which means <100ms for a 256x256 pixel image.Compared cu PC CPU's computing speed , the increase in speed is at least 20.This increase in speed can be greater in a applied system,if we consider the limitations of the PC architecture in I/O high speed transfers.For data archiving applications the performance obtained can be considered satisfactory.









4. Conclusion

DPCM techniques ,despite of the continuos expanding of transform based methods [6] , is a reliable method for data compression. Its advantage consists mainly in simplicity and results in high speed implementations. The advantage of DPCM is more visible in applications which requires lossless compression. The compression factor obtained is moderate(1.5.....5) but can be extended combining DPCM with other methods.Therefore, many producers of LSI ASIC's [4] offer such DPCM implementations.

Based on this set of DPCM tools , we have developed an image storage and transmission system.

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