7

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PROBLEMS AND PROSPECTS IN DIGITAL TRANSMISSION OF COLOR T.V. SIGNALS

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ABSTRACT

A state of the art review of coding of color TV ignals for digital transmission is presented. The po- ential, prospects and problems in this rapidly emerging ield are outlined. Concepts, techniques, ideas and ethods for achieving data compression are discussed. imulation studies, carried out by various researchers, hich are constrained by the conflicting requirements f high subjective quality and low bit rates are re- iewed. Codecs that are already on the market and are n development stage are described. Problems such as leveloping international standards for digital trans- ission of color images are discussed. Further re- earch topics and potential growth for the codes are utlined.

INTRODUCTION

Digital processing of images both for storage and transmission has become a practical reality [1-12,16,18, 19,37,38-45,50-53,64-66]. This has been stimulated by the developments in digital and logic circuitry, high density (such as the VLSI) storage, reduced size and cost, increased speed and the flexibility available in the digital domain. Also conversion between the three broadcast standards (NTSC, PAL and SECAM) is much simpler. As such transmission links, both satellite and terrestrial, are using the digital format for image transmission. International standards for digital transmission and storage of images for different applications are being formulated [20,21]. Some standards have already been set up. There is already a proliferation of hardware on the market and more and more are being developed. Application areas include broadast TV, teleconference [12,16,23,24,37-41,43,56,65,66], satellite imagery, reconnaissance, weather photos, multispectral imagery, graphics, facsimile, high resolution data etc. In most cases the human viewer is the ultimate receiver (and also analyzer), while in some cases machine interpretation is used. Thus, varied classes of pictures are utilized for observation (entertainment or business transaction), classification, identification, recognition, filtering and enhancement. Problems and hence the research areas are not insurmountable. Research and development is directed mainly at simplifying the complexity of processing (and hence the hardware) while maintaining an acceptable level of picture quality (i.e. minimizing the degradation). The object of this paper is to review the state-of-the-art in digital processing of images, such as broadcast TV signal, teleconference and picturephone, both monochrome and color, and to highlight research areas that need to be probed further.

Digital transmission of images necessitates increased bandwidth [1] (and also the cost) compared to that of the original analog signal. Most processors, therefore, concentrate on developing and implementing algorithms that result in reduced bandwidth (bandwidth compression) otherwise called bit rate reduction, while keeping the image impairments to a minimum. The redundancy reduction techniques can be broadly classified as psychovisual (perceptual) and statistical [2,4,8,11,19, 55]. The former is used very little as the human visual system requires further understanding. In contrast, the latter is extensively exploited and the utilization of the algorithms and adaptive features [5,14-17] is in general limited only by the cost constraints of the hardware. Rapid developments in the memory and logic technologies have made it possible to implement several sophisticated algorithms in real time. Further improvements in these areas will lead to a reduction in size and cost of the processing hardware.

In general the data compression methods are based on spatial and transform techniques. Combination of these two, called the hybrid process [2,4,8,11,55] has also been adopted. Spatial procedure involves prediction of the present pel (picture element) based on previous pel or combination of previous pels, whereas the transform technique [19] involves mapping the data in the spatial (and also temporal) domain into another domain (most common example is the Fourier transformation i.e. mapping into the frequency domain) where processing is much easier. Combination of the transform-predictive methods called the hybrid coding is obviously a compromise in terms of performance, capability and costs. These processes inherently involve various stages such as quantizer, source and channel encoders, multiplexers etc. These stages can be fixed or adaptive.

Adapative features inherently increase the complexity and the costs, but they can result in better rendition of the reconstructed images. More recently coding based on motion estimation has been developed [23-29, 31-36,47,55]. Motion compensated coding (predictive, transform or hybrid) has been shown to yield additional bit rate reduction at the same picture quality or improved quality at the same bit rate. Another flexibility offered in motion prediction is interpolative coding. The codecs suggested here are to be supplemented with preprocessors such as spatio-temporal filters [63], low pass filters, analog-to-digital (ADC) converters etc., and post processors such as DAC etc., not to mention the codes needed for various sync sinnals (i.e. frame, line, field etc.) [66].

Digital processing as described here is applicable to both monochrome and color images. For the latter, however, additional options are processing in composite or component forms [58-60]. Simulations have been carried out and hardware has been developed based on

The opinions and comments that are presented in this paper are those of the author alone. This paper is by no means exhaustive and omission, if any, is purely unintentional. This omission, if any, reflects the incomplete knowledge of the author in this field.

both forms of color images. It is however, noteworthy to mention at this point that the Television Transmission Joint Committee (CMTT) of the CCITT/CCIR has formulated the standards for broadcast studio (in plant) processing of color images [20,21]. These are processing the images in component form with 4:2:2 and 4:4:4 options. Priority is given to the former which implies that the sampling frequencies are 13.5 MHz and 6.75 MHz for the luminance Y and for the two color difference signals B-Y and R-Y. Details as to sampling structure etc, can be found elsewhere [20,21]. Standards for digital transmission of images for network broadcasting and teleconferencing are being developed. This however, has not hampered the development of hardware (codecs) for either of the applications. Development of these codecs has been limited to USA, Canada, Western Europe and Japan. It is possible that similar development may be in the offing in Russia and other noncommunist countries but no specific information is available.

PROBLEMS IN DIGITAL TRANSMISSION

Because of the three different color television systems in the world (NTSC, PAL and SECAM) conversion from one standard (525-line scan, 60 Hz and 625-line scan, 50 Hz) to another poses some problems. This can be minimized if the entire systems becomes digital i.e. from the front end of the camera to the receiver. Another related but transitory problem is developing the standards for digital transmission of TV signals for various applications. Hopefully these standards can be set fairly soon, so that codecs meeting such standards can be designed and built. Another problem is concerned with the emerging high density TV (HDTV) [22]. As large screens are being used in public areas, it is essential to go into high resolution (1100-1500 line scan compared to the existing 625 line scan) TV signals. Because of the large bandwidth (27-30 MHz) required for the HDTV analog signal, digital transmission of this signal requires proportionately increased bandwidth. Sophisticated data compression techniques, perhaps with large memories, are required to reduce the bandwidth to economical levels, not to mention the problem of crowding the spectrum.

Decorrelation in the temporal domain has so far been limited to adjacent fields/frames. This requires single field/frame storage (2-3 MB/frame) as a minimum. Motion prediction also requires such a storage. If the full benefits of transform coding of a sequence of frames are to be exploited, then several frames need to be stored. Such a large high speed memory, say about 50 MB, leads to increased costs, size and power. Evolution of 256 KB RAM can partly alleviate this problem. Although a number of motion compensation techniques have been developed, to the author's knowledge, only one codec utilizing motion prediction has been built and is in the process of being placed in the market [24]. Some of the motion prediction algorithms are based on large number of iterations (computations) [29]. Increased logic speeds are necessary to implement these algorithms in real time. Another research area is the design and development of spatio-temporal filters [63] which can lead to reduced frame rate for picturephone application. Another aspect that needs further attention is the Sub-Nyquist sampling [57] with appropriate filters to remove the aliased frequencies. Extension of the C-Matrix transform (CMT) beyond N = 16 i.e., for N = 32,64,128 etc., which can perform almost as good as the discrete cosine transform (DCT) is another challenging task [61].

Hardware, State-of-the-Art

To digitally transmit network quality color TV signals several codecs* have been developed. These are:

	Transmission Rate (MBPS)
HO-DPCM 45B	44
NETEC - 22H	22
NTT	32
DCC(M/A-COM Inc.)	45
OKI Elec. Industry Co.	32
KDD	32
COMSAT (CODIT)	42.9

Several codecs (listed below) for teleconferencing* have been developed.

	Transmission Rate (MBPS)
NETEC - 6/3	6/3
NETEC - X1	1.5
VTS 1.5	1.5
GEC - McMichael (VTC)	2/1.5
NTT (TRIDEC 1.5)	1.5
NETEC 1.5†	1.5
NASA/ARC	12-24
OKI Elec. Industry Co.	2.2
COMSAT (DICE)	Variable Bit Area
NTT (TRIDEC)	6.3
Nippon Hoso Kyokai	16

Also codecs for transmitting images from remotely piloted vechicle (RPV) have been developed. Some of these are:

	Data Rate
RCA	3.6 - 921.6 KBPS [48,50-53]
Harris Corp	Not available

Research is underway for very low bit rate tansmission [62]. This is directed at developing the codecs for teleconference and picturephone services with bit rates approaching 64 KBPS (basic voice channel) or at least, low integer multiple of 64 KBPS. At these low bit rates, some impairments may have to be tolerated. The object here is to achieve low transmission costs at the expense of the image fidelity. However, the basic information in the image needs to be preserved.

CONCLUSIONS

While inherently there are some problems in integrating the different TV standards and also different digital transmission hierarchies, much progress has been achieved in designing and developing the hardware for the digital codecs. Teleconferencing application appears to be much more rapid in view of the vast market that lies ahead. Once the standards for the network quality for color TV are formulated, codecs for such application will be utilized to a greater extent than at present. Nevertheless, codecs for broadcast TV have already been designed and built. Predictive, transform and hybrid coding has been adapted for achieving the data compression. More recently motion compensation has come under the scrutiny of several researchers. With this tool additional bit rate reduction can be achieved. Another focus of research is

†Motion compensated coding.

*Some of this data is collected from the brochures distributed at the technical exhibits.