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Multidimensional Image Compression

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Abstract— The analysis of microscopic and macroscopic objects in the real world needs processing of multiple parameter data. The value of each parameter in the three dimensional space varies from point to point. Hence compression of such images poses multiple challenges. In this paper an attempt is made to provide a framework for compressing image data of such objects.

***Index Terms*—Image compression, 3D images, Medical images, Colour Images**

INTRODUCTION

Image compression has come a long way. Once information is converted to digital data, compression of the data is required for various purposes. Transform techniques offer high level of compression. However image processing software based on various tools has a component of royalty fee reflected in the high cost associated with the product. Hence simple time domain techniques are always attractive. The RLE technique is a good example that proved its worth in the 80s, when the Fax machines appeared in the market. Large volume data associated with medical imaging, satellite imaging and reservoir modeling pose a real challenge for storage and processing. A medical sample of a cube of 50μm can be associated with a huge data contributed by super pixels [1].

DIFFERENTIAL ENCODING

In any given image correlation of pixel values does exist between a given pixel and an adjacent pixel. The periodic variation of pixel values is another important factor. Time domain compression methods exploit the former, while the frequency domain compression techniques thrive on the latter The best transform domain based software products are expensive. In India we need to look at simpler and less expensive software products, so that we are able to do more at a lower cost servicing applications, research and ultimately the customers.

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PROBLEM STATEMENT

The advancements in scientific and industrial research have put a huge pressure on image processing requirements. The development and use of portable devices is increasing. Research workers in India are increasingly using mobile phones as research tools. While the mobile phone serves as a low cost tool for signal and data pick up, the real problem lies in cost effective data processing. In the discipline of precision agriculture the use of mobile phone as a research tool has been reported [2].

The problem can be divided into two parts. The first one relates to the multidimensional nature of the data. The second relates to the need to simplify processing paying sufficient attention to the cost aspect.

Most images we encounter in scientific, medical and industrial research are associated with geometry of the object. Time domain image compression can be effectively done based on the geometry of the object [3] [4].The multiple parameter associated with a single pixel and the geometry of the object pose a real challenge and the current methods may be inefficient for such problems. It is also easy to note that the multiple parameters also will be highly correlated in most regions of the object and the variation of the parameters occurs in the boundary of two regions where feature variation is identified. Typical examples include blight in tomatoes, tumor in cells etc. In a single parameter scenario, application of differential encoding results in long chain of zeroes in the coded bit stream. Conventional 2D image can be processed in a similar manner and can arrive at null and sparse matrix coded image blocks.

If we are looking at multiple parameters coupled with three dimensional images and considering the dimension of time, then we have to consider in general an n-dimensional vector in hyperspace for *each pixel.* We can keep time aside for later consideration.

In general, when each pixel is associated with multi-parameter values, then a vector $\mathbf{P_n}$ in n-dimensional hyperspace represents the values of the parameter associated with the pixel. Consider a six parameter situation of a three dimensional objects. Suppose the parameter values are identical within a sphere of radius 10 μm. We further assume that 10,000 pixels are in this sphere. Then all the 10,000 vectors are identical in the hyperspace. So, taking the pixel at the center of the sphere as the reference and replacing each vector by the difference between itself and the reference vector, all vectors except the reference vector has zero value. We can express this situation as

$$\mathbf{P_{nd}}(x,y,z) \neq \mathbf{0} \text{ when } x=0, y=0 \text{ and } z=0. \quad (1)$$

For other values $\mathbf{P_{nd}}$ is zero, where $\mathbf{P_{nd}}$ is the differential vector in hyperspace. When the parameter variation is slow, then the vector components show fewer variations in the hyperspace for a given volume in the physical space. When the variation is mixed, i.e. some parameters show small variations; while the others show higher variations then they are reflected by the vector components of the differential vector $\mathbf{P_{nd}}$. One can argue that the application of DCT and Wavelet transforms in each dimension of the hyperspace enables compression. However, as mentioned earlier, smaller and portable devices cannot be used for this purpose.

Implementation Issues

We will take specific examples and address the implementation issues. In India healthcare is the vital sector that needs rapid progress in a short time span. Most medical instruments and portable diagnostic kits do have digital outputs and are battery operated. Hence in remote areas, the data will be available in digital form near the patient in public health centers. In certain other areas with no availability of public health centers, mobile medical units can be deployed. Such mobile units also have medical equipment with digital outputs. However image processing software based on expensive software tool boxes may not be available either in the public health center or in the mobile unit. Portable appliances such as mobile phones can be made available in any location. Because of the complex issue of base station availability, we can provide portable low cost information storage and processing devices to the medical personnel working in such inaccessible areas. Hence with suitable software the multi-parameter medical diagnostic data can be preprocessed and compressed with *differential vector encoding* on site. This data can be transmitted to the nearest hospital, when the medical attendant reaches the nearest location where mobile or landline data transmission connectivity is available.

A second approach is to look at this from the point of view of medical equipment industry. One can think of portable low cost devices for preprocessing medical data along the lines mentioned above. Once again by loading the software based on time domain compression, the equipment cost may be reduced considerable. In this context we can look at the example of GPS receiver. In the early days of GPS development, the cost of a GPS receiver was 2, 50,000 dollars. Subsequently it was reduced to less than 3 dollars.

Till now we have not looked at the dimension of time, For certain applications in various fields we need to look at the dimension of time. For example growth process needs time series data. Similarly propagation of infection also needs time series data. Some processes occur relatively on sorter time duration. When we look at the multi-parameter data at different time instants we can define a *motion vector* in an n dimensional hyperspace. In such a situation we need to store only the vector differential, much similar to the well-known motion vector in TV image processing.

The next important factor is the colour. It can be natural or artificial as employed in remote sensing. In certain application areas colour plays a key role.in the field of agriculture. For example fruits and vegetables are classified and even graded according to the colour. The internal defects associated with the colour points to a small abnormal region *inside the* fruit or vegetable. In such a case, with special sensors a huge volume of data is acquired and processed. if the defect is an insect as found in the kernel of mango fruit, then the time series growth data is shared by scientists from different disciplines. In this interesting situation we have to collect time series data of two processes, mango growth and insect growth. This leads us to *two hyperspectral vector spaces*. Two growth processes are inter-related. In such a scenario, we have to doubt the efficacy of the transform oriented compression technique. Of course it does not mean that time domain compression will do the job.

Food processing is another interesting field where different scenarios emerge. It is a vast area and we will restrict ourselves to a small set of examples. Any food process that involves bacterial function needs special attention. Once agin we have look at two entities dynamically, the bacteria and the food. If we take the example of wine, then traditional methods dictate burying the wine underground for decades. Capturing data and processing data associated with such a process is a real challenge. Next we will consider cooked products. Potato chip making is a good example. Here we look at the raw material, potato and the chip making process. The moisture content in the potato is the most important factor that determines the quality of the chip. During the frying process the data generated can be huge and once again we are looking at the time series data. During the frying process some chips end up as objects with double curvature. Here the data becomes more, but can be tackled easily through differential encoding [4]

Remotely sensed data processing is another valid example. During the last decade, hyperspectral data classification has occupied the center stage. However, most images of this type are two dimensional. Data related to land and sea used by customers outdoors such as people in the field of fisheries need to be compatible with low cost portable devices.

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CO-ORDINATE SYSTEMS

It is very important to select a suitable co-ordinate system for a given problem and application. By considering the symmetry we can select a suitable co-ordinate system. For example if we analyzing the 3D image data of radish, we can select the cylindrical co-ordinate system. Considering geometry leads to simplification of compression process. For example by considering the radish as a series of circular discs and applying differential encoding for each parameter yields good compression by simple mathematical operations. Each sample of radish in a lot deviates from a cylinder. The solution for this problem can be found in reference [4].

Multiple co-ordinate systems may have to be employed for the same object. Consider an object with cubic symmetry, suppose one of the parameters is time varying electric or magnetic field. Then for field computation and storage of field strength values, we may have to use cylindrical or spherical polar co-ordinate system. Hence in such a situation we need to isolate the parameter data and process the parameter values separately.

For a given physical material of the object under study one or more parameters can be *anisotropic*. Hence such values have to be expressed as tensor. However this is not a serious problem. For a tensor we need three values of the parameter for three directions.

COMPUTATIONAL ASPECTS

The computational load of an appliance or subsystem os a very important parameter. With the increasing usage of mobile phones, portable devices are expected to more in the future. Differential encoding and its variants coupled with run length encoding come in handy for current and future applications of image processing software. Since such encoding techniques need less memory and code, we can increase the capability of such devices to handle floating point operations with higher precision. Secondly application of differential encoding reduces the data volume; its efficacy can be increased by other techniques. For example, we can define null zones and sparse zones in the hyperspace to drastically reduce data volume of the image data.

If the number of users of such appliances is large custom devices can be built with most coding built with Nano instructions and implemented in a mixed signal chip. For high end systems we can think of software that automatically selects time or frequency domain compression.

VI CONCLUDING REMARKS

Present day technology offers multiple choices for data processing. For a given project, program or initiative constraints impose cost limits. Technology of earlier days can be reinvented to combat digital divide and empower the masses. Image processing will continue to play a leading role in the development of communities across the globe.

The framework presented in this paper can be extended vertically and horizontally to develop hardware and software for sophisticated image processing.

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