Non-Linear Adaptive Temporal Compression of Satellite Images

Boshir Ahmed, Md. Al Mamun, Md. Mortuza Ali

***Abstract*— Frequently collected multitemporal multispectral images mostly present strong temporal redundancies that can be exploited for data compression in temporal domain considering the fact that the user already has a previous reference image. While the spatial and spectral prediction model is applied, the compression considering temporal correlation needs to be explored. In this paper a gradient-based temporal prediction approach has been proposed where the image of a scene is predicted from the previously taken image of the same scene. The geometrically co-registered reference image and the recent image are used for sequential prediction in order to minimize the model residual. The model parameters are optimized automatically to achieve minimum residual entropy for lossless compression. Experimental results demonstrate the effectiveness of proposed method, especially when the new data are not highly correlated to the previous data due to the real changes experienced between the two data collection dates.**

***Index Terms*— Temporal, Gradient, Compression. MED.**

I. Introduction

The transmission of remote sensed images across communication paths is becoming a very expensive process because of the recent advances towards the satellite technologies that enable to generate of terabytes of data every day. Image compression is an effective solution for reducing the number of bits in transmission. Various compression techniques have been developed; including predictive coding, transform coding and vector quantization. However, most techniques perform data compression within a data set exploiting either spatial or spectral redundancy or both. Homogeneous ground features show similar reflectivity values within the same band that, ultimately, cause the pixels to have similar intensity values to their neighbours. Therefore, there are high spatial correlations in each image. Spectral correlation is another main source of redundancy. Image data generated by multispectral or hyperspectral sensors contain a high degree of correlation among the spectral bands. A sensor often overlaps slightly in capturing the spectral responses from the neighbouring bands [1]. The similar response from a pixel at the neighbouring spectrum causes high spectral redundancy.

The satellite images are often compressed by lossless methods to preserve their full quality using prediction based approaches. In CALIC based lossless approaches, spectral predictor is employed together with the context modeling, where one or more of the previous band's spectral redundancy is removed [2][3][4]. Temporal redundancy has gained considerable attention in the field of video image compression. A high compression ratio has been accomplished by removing the temporal redundancies among successive video frames. Compression in temporal domain is important to explore, given that data are collected frequently in the future. Considering the case of sequential image data transmission [5] where images will be available every month, week or perhaps day, a better way to transmit a current image data set is to predict that from the previous image set which are avaiable at both transmission and receiver ends. A gradient-based temporal prediction approach has been proposed where the image of a scene is predicted from the previously taken image of the same scene. The geometrically co-registered reference image and the recent image are used for sequential prediction in order to minimize the model residual.

II. METHODOLOGY

Gradient-based prediction approaches show high adaptive ability compared with other prediction approaches. The median edge detection (MED) prediction of images, in which the horizontal and vertical edges can be identified according to some given condition when applied to the neighbourhood pixels for spatial de-correlation, predicts the current pixel by assigning its values to the pixels which are not part of the edges [6]. If there is no edge, the predicted pixel is on the plane defined by the three neighbouring pixels. The conditions for detecting the edges are given below.

$x(i-1, j-1)$	$x(i-1, j)$	$x(i-1, j+1)$
$x(i, j-1)$	$x(i, j)$	

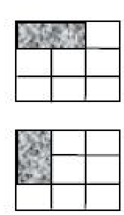

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Fig 1: MED predictions by edge detection.

1. $if\left[x(i-1,j-1)\geq \max\{x(i,j-1),x(i-1,j)\}\right]$

   then predicted $x(i,j)=\min\{x(i,j-1),x(i-1,j)\}$
2. $if\left[x(i-1,j-1)\leq \min\{x(i,j-1),x(i-1,j)\}\right]$

   then predicted $x(i,j)=\max\{x(i,j-1),x(i-1,j)\}$
3. *otherwise,predicted*

   $x(i,j)=x(i,j-1)+x(i-1,j)-x(i-1,j-1)$

This idea has been extended to spectral or band-to-band prediction [2][3][4] and considered for temporal prediction in this paper. If there is any edge detected at the current location in the reference previous image, it is highly likely to also occur in the current image. Considering the local neighbourhood from the previous image and the current image in Fig 2, the gradient-adjusted temporal predictor can be given by the following conditions.

$x(i-1,j-1)$	$x(i-1,j)$	$x(i-1,j+1)$
$x(i,j-1)$	$x(i,j)$	

(a)

$y(i-1,j-1)$	$y(i-1,j)$	$y(i-1,j+1)$
$y(i,j-1)$	$y(i,j)$	

(b)

Fig 2: Pixels' neighbourhoods in (a) previous reference image, (b) current image.

1. $if\left[\left||x(i,j)-x(i-1,j)|-|x(i,j)-x(i,j-1)|\right|>T\right]$

   then predicted $y(i,j)=y(i,j-1)+\alpha\{x(i,j)-x(i,j-1)\}$
2. *else* $if\left[\left||x(i,j)-x(i-1,j)|-|x(i,j)-x(i,j-1)|\right|<-T\right]$

   then predicted $y(i,j)=y(i-1,j)+\alpha\{x(i,j)-x(i-1,j)\}$
3. otherwise predicted

$$y(i,j)=\frac{y(i-1,j)+\alpha\{x(i,j)-x(i-1,j)\}+y(i,j-1)+\alpha\{x(i,j)-x(i,j-1)\}}{2}$$

where T is a threshold and α is selected globally by running single linear regression between the two images. The first condition identifies the sharp horizontal edge and the second the sharp vertical edge in the previous image.

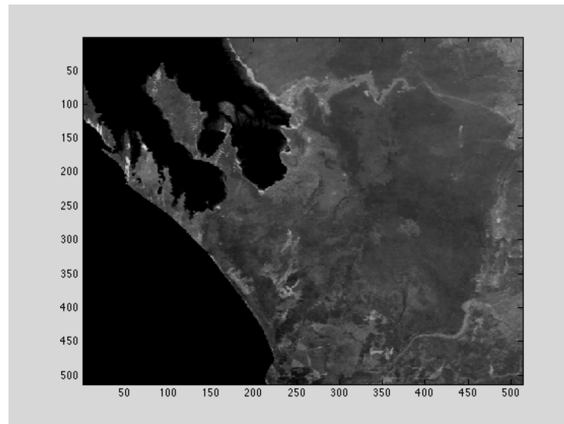
In this way, data reduction for distribution is achieved through a process of temporal redundancy removal or de-correlation. The proposed model is used to achieve the lowest possible entropy of the data, which is then ready to be coded or transmitted. The reduced number of bits (on average) which a compression scheme can achieve is limited to the Shannon Entropy, *E*, of the residuals, *d*.

$$E(d)=-\sum_{i=1}^{n*B}P(d(i))\log(P(d(i)))$$

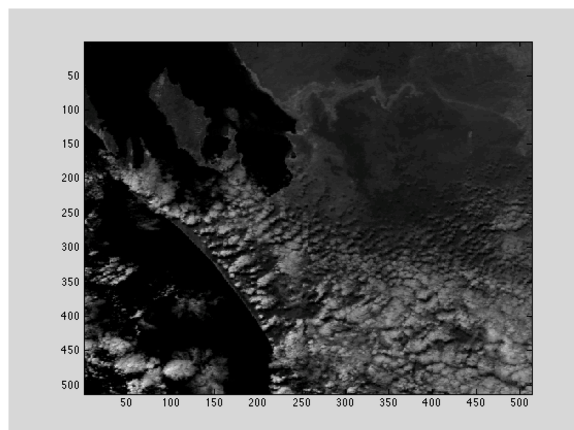
where *P(d(i))* is the probability of *d(i)*.

III. MODIS IMAGE

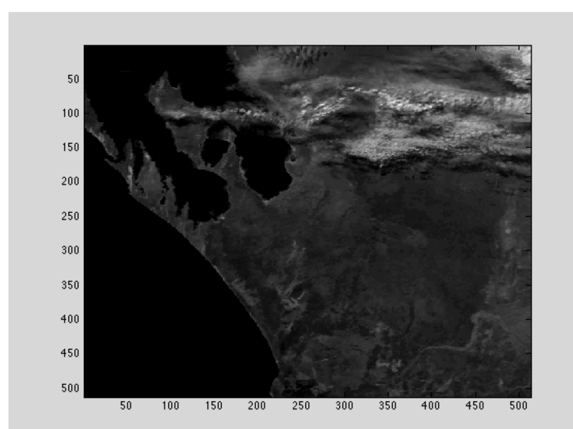
The images used for the experiments are MODIS (or Moderate Resolution Imaging Spectroradiometer) images of part of the Australia. The three images are each taken one-week apart. Each image is 512×512 pixels in size and already co-registered with each other. MODIS data improves the understanding of global dynamics and processes occurring on the land, in the oceans, and in the lower atmosphere. MODIS is playing a vital role in the development of validated, global, interactive Earth system models able to predict global change accurately enough to assist policy makers in making sound decisions concerning the protection of our environment[1].



(a)



(b)



(c)

[1] http://modis.gsfc.nasa.gov/

Fig 3: MODIS images of part of Australia each taken one week apart. (Courtasy: Geoscience Australia)

IV. EXPERIMENTAL RESULTS

The proposed method has been used to predict one image from another of Figure 3 where one was taken as reference and the other was taken as recent. Table 1 indicates the original entropy of the images and Table 2 is the same of the difference images. However, Table 3 is residual entropy of the prediction method. The residual can be transmitted to reproduce the recent image from the reference image. It can be easily seen that the prediction approach gain the entropy of the transmitted data much less compare to the originals.

Table 1. Entropy of the original images

Images	Entropy
3(a)	9.4978
3(b)	11.4322
3(c)	10.4348

Table 2. Entropy of the difference images

Images	Entropy of Difference
3(a)-3(b)	10.8703
3(b)-3(c)	11.8443
3(c)-3(a)	9.8443

Table 3. Residual entropy of proposed method

Images	Residual Entropy (Proposed Method)
3(b) from 3(a)	9.8229
3(c) from 3(b)	8.8940
3(a) from 3(c)	7.9770

V. CONCLUSION

The key issue in temporal prediction is to model the relationship between the two images of the same scene taken some time apart by selecting a suitable regression function. Due to system noise and sometimes, the real changes experienced in the imaged sites, the correlation between the two date's data is low and the associated scatter plots are widely spread. This will lead to high residuals if a non-adaptive model is used. By adopting the propose model instead the overall prediction residual is reduced.

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Boshir Ahmed is a Capital city Dhaka native and received his BSc degree from Dhaka University of Engineering & Technology in 2001 and his MSc Engineering degree from Rajshahi University of Engineering & Technology in 2011 and continues his PhD degree. He had a PhD fellowship scholarship from Prime Minister, Peoples Republic of Bangladesh in 2012-13 and joined the department of Computer Science & Engineering Rajshahi University of Engineering & Technology in June 2001. He has more than 30 publications (Books, journals and Conference Paper). His research interests are digital image processing, remote sensing, digital signal processing, computer networks and microprocessor embedded system design etc. He is CISCO certified instructor in the same Department of this University. He served as the head of this Department from 6th May, 2011 to 25th May 2013 and also Legal Main Contact (LMC), CISCO Systems, RUET Local Academy, Bangladesh from 7th May, 2011 to 6th May 2012.

Awards and Achievements

• A Project on Temporal Analysis of Satellite images for Seasonal Changes in Bangladesh to Improve Crop Production financed by UGC through RUET, June, 2013.

• Prime Minister Scholarship in PhD Fellow, July, 2012.

• University Scholarship by the Vice-Chancellor, RUET for MSc Engineering (2010-2011).

• Technical Scholarship by the Government of Bangladesh for BSc Engineering (1997-2001)

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Dr. Md. Al Mamun have 8 long years of teaching experience in the various fields of computer science and engineering. Graduated from Rajshahi University of Engineering & Technology, Bangladesh. In 2009, he got teaching assistantship in the University of New South Wales, Australia. This was the opportunity, which he got when he was doing his PhD in the same university. He was responsible for lecturing various computer science courses like Object oriented programming (Java), Computer Graphics (Game Simulation-Alice) etc in UNSW@ADFA, Australia.