Astronomical Data Analysis Software and Systems IX
ASP Conference Series, Vol. 216, 2000
N. Manset, C. Veillet, and D. Crabtree, eds.

The Communication of Images from New Generation Astronomical Telescopes

P. McNerney

Astrophysics Research Institute, Liverpool John Moores University, Birkenhead, Merseyside CH41 1LD, UK

Abstract. New Generation Astronomical Telescopes (NGAT), a class of telescopes designed to be operated remotely and robotically, require efficient methods for communicating images over heterogeneous and low-bandwidth data networks such as the Internet. NGATs enable the allocation of time on a telescope to a diverse range of users having differing requirements. To satisfy these needs, research into novel ways of compressing astronomical images has been undertaken. Methods researched thus far involve the classification of astronomical images based on object parameterisation, progressive image transmission, and evaluation of existing image compression schemes. The methods being developed target the needs of users that include astronomers, schools and colleges, and Public Understanding of Science and Technology (PUST) displays.

1. Introduction

The Astrophysics Research Institute (ARI) and the Electronic Design And Manufacturing (EDAM) Centre of Liverpool John Moores University (JMU), in collaboration with dB Research Limited have set out to design leading-edge hardware and software for the purpose of acquiring, communicating and processing astronomical images from the New Generation Astronomical Telescope (NGAT).

The aim is to develop the means, in software, to efficiently communicate, process and display images generated by the telescope for a diverse audience that includes professional astronomers, schools and colleges, and the general public visiting a planetarium. The members of this audience have different needs and expectations of the images acquired by the telescope. The communication system must take into account and cater for these.

2. New Generation Astronomical Telescope

The New Generation Astronomical Telescope (NGAT) is to be a fully automated robotic telescope. The Liverpool Telescope (LT) will be the first NGAT and will be the demonstration unit for the technology being developed. The LT is to be sited on a mountain top at La Palma in the Canary Isles and controlled from the ARI. The NGAT will be controlled and operated via the Internet, enabling remote operation by researchers and astronomers, and promoting the Public Understanding of Science and Technology (PUST). Schools, colleges and planetariums will be given time on the telescope, during which they will be able to remotely position and capture images from it. Images will be acquired using a 2048x2048 pixel 16-bit CCD. To preserve the large dynamic range of the CCD, the read-out has to take place at a relatively low data rate of 100-150kB/second or less. At these rates, it would take 55-80 seconds to completely read out the contents of the CCD. For public displays this is unaceptably long, and a lower SNR may have to be tolerated.

3. Data Links to La Palma

An investigation of communications links (Thoma & Long 1997) was undertaken throughout 1998 to ascertain the necessary level of compression required in both average and worst case conditions. The investigation utilised **ftp** to perform unattended retrieval of three test files, once per hour, from ing.iac.es on La Palma to a JANET Starlink node at JMU in the UK.

Table 1. **ftp** transfer rate ranges for each quarter of 1998

		Transfer Rate (kB/sec)			
Filename	File size (bytes)	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
rnd1500	1568	3 - 4	4 - 5	5 - 6	4 - 6
rnd15k	15488	10 - 15	12 - 18	14 - 20	12 - 18
rnd150k	153458	15 - 28	14 - 26	25 - 56	38 - 81

4. Overview of Existing Image Compression Methods

An appraisal of existing lossy compression schemes was done to determine how they perform at high compression ratios (>80:1). Figure 1 compares the effects of block-DCT and fractal compression with compression based on wavelets (Rioul & Vetterli 1991). Blocking artefacts are very noticeable for the DCT encoded image and the fractal encoded image. It was found that wavelet-based compression schemes produce visibly better images at high compression ratios.

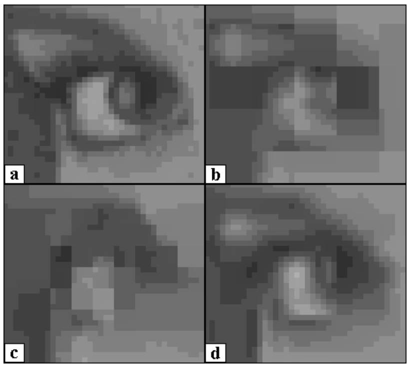

Figure 1. Comparison of existing image compression schemes.

Table 2. File sizes & compression ratios for lossy encoding schemes

Compression type	File size (bytes)	Compression Ratio
(a) None	64000	1:1
(b) block DCT	4170	15.3:1
(c) fractal	735	87.0:1
(d) wavelet transform	785	81.5:1

5. Considerations of Image Content and User Requirements

Photometric accuracy needs to be preserved only for images of stellar fields and extended sources. Therefore, different compression schemes can be applied for images of planets, etc., where visible structure is important rather than intensity profiles.

Table 3. Classification of astronomical images

Type	Image content	Scientific	Characteristics	Compression type
0	Stellar fields, Galaxies, etc.	Photometry	Largely empty sky	Novel
1	Local planets/ surfaces, solar	Structure	Little or no sky	Transform-based encoders

Image classification can be achieved by analysing the profile and features of the image histogram. Stellar fields and galaxies are classified as type 0; planets and surfaces are classified as type 1. The classifications are determined by analysing the histogram with respect to a parabola and gradients of vectors that are a function of histogram bins intersecting the parabola.

Table 4. User requirements for astronomical images

User	Requirement	Comments
Professional Astronomer	High photometric accuracy and retention of low SNR features	Access to fast Internet connections
School/ College student	Decompressed images that retain sufficient photometric accuracy to enable useful science	Slow connections to the Internet via modems (slow)
General Public	Images that look good, i.e. high perceived quality of the decompressed image to the observer	ISDN or modem connections to the Internet (slow)

6. Description of New Compression Methods

Methods typically used by software developed to highly compress astronomical images, e.g. Hcompress (White 1992), have been based on wavelet transforms. These perform well at retaining photometric accuracy, but suffer from the introduction of visible artefacts in the sky background, and error in the detected position of sources. This is illustrated by (b) and (c) of Figure 2, square-rooted images of a stellar field. Figure 2 (d) is the result of applying a new method based on thresholding and run-length encoding that aims to model the sky background so that only pixels above a threshold, calculated from the image median, need to be transmitted. The LT requirement is for compressed images to be $\leq$30 kB. By applying a suitable loss-less encoding method (Nelson 1996) after thresholded RLE, a 1024x1024 16 bits/pixel FITS image of a stellar field can be compressed to $\sim$25kB. An extension of this method allows progressive transmission of the image by decomposing it into layers.

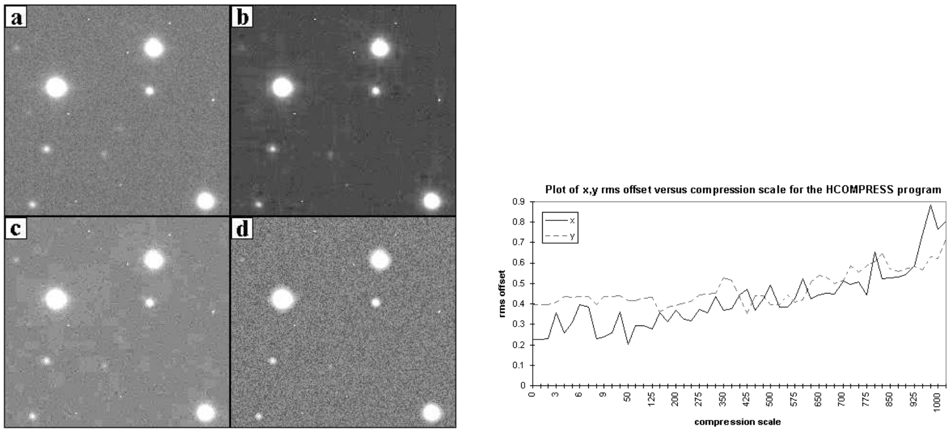

Figure 2. Comparison of astronomical image compression schemes.

Table 5. Comparison of astronomical image compression schemes

Image	Size (bytes)	Compression Scale	Compression Factor (x:1)	Fraction of original (%)
(a) Original	2102400	-	1	100
(b) Fitspress (DWT)	63360	1	33.2	3.0
(c) Hcompress (H-transform)	64943	275	32.4	3.1
(d) Thresholded RLE	42788	-	49.1	2.0
+ BWT coding	25188		83.4	1.2

Acknowledgments. I thank my supervisors; Dr Iain Steele and Dr David Harvey of JMU, and Prof Bill Mullarkey of dB Research Ltd, for their guidance.

References

Nelson, R. 1996, Dr. Dobb's Journal, September, 46

Rioul, O. & Vetterli, M. 1991, IEEE Signal Processing Magazine, October, 14

Thoma, G. R. & Long, L. R. 1997, IEEE Multimedia, April-June, 36

White, R. L. 1992, Proc. of the NASA Space and Earth Sciences Data Compression Workshop, ed. James C. Tilton, March