COMPRESSION AND DISTRIBUTION OF SNB SOFTCOPY ORTHOPHOTOMAP DATABASE

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ABSTRACT

Service New Brunswick (SNB), a crown corporation operated by the province of New Brunswick, Canada, is at a very advanced stage of constructing a huge orthophotomap database which contains digital color orthophotos covering the coastal zone area of the province at a scale of 1:10,000. Furthermore, SNB's next step is to extend its efforts to cover the whole province. The size of each orthophoto is 130 MB and the whole database is expected to be approximately 270 GB. SNB is considering distribution of these image files via CD and on-line using its web server allowing its clients to request and download any desired orthophoto(s) through the internet. Image compression is being considered in the interest of more efficient data storage and faster file transfer.

While the market is still immature in many respects, many image compression software packages now exist in the market. Those software packages perform the compression/decompression operations using a variety of lossless and/or lossy algorithms. In mid-1998, SNB assigned researchers from the department of Geodesy & Geomatics Engineering at the University of New Brunswick (UNB) the tasks of selecting up to five commercial image compression software packages, developing the procedure and acceptance criteria to test those software packages, and choosing the most appropriate product based on these criteria. Extensive background research was conducted in order to acquire the overall view of image compression products in the market necessary to select and test up to five compression/decompression software packages. This paper presents the results of the extensive investigation that had taken place towards answering the question "*which one best meets SNB's requirements at this time?*".

1. INTRODUCTION

Advancements in softcopy photogrammetry and in mainstream GIS software to accommodate digital images as a raster backdrop have led to a great demand for digital orthophoto images. Recently, many agencies and organizations have began constructing on-line digital image libraries as a means of exchanging and distributing their products.

Service New Brunswick (SNB) is now committed to the production of a softcopy orthophoto map database that covers at least the coastal portion of the province. Each SNB softcopy orthophoto map database file will be approximately 130 MB in size. Since the whole database will contain 1875 orthophoto files, approximately 270 GB of data must be efficiently stored, manipulated and distributed. Significant advanced planning will be required to address packaging, storage and handling issues.

It was believed from the outset that different users of the orthophoto base would employ the products in any of three different ways:

(1) Simply as an "image backdrop" to vector topographic mapping, property mapping and resource inventory data stored and accessed using GIS or WWW-based software;

(2) As a base for interpreting and "on-screen" digitizing vector information for the purposes of updating or augmenting other theme data stored in a GIS; or

(3) As a base upon which more advanced image analysis and processing operations made be made for advanced resource inventory applications. The compressed image products were intended to satisfy the needs of most users in the first two categories only. Original uncompressed imagery (available on CD) would be suggested for those users involved in more advanced operations covered in Category 3.

In order to ensure efficient, fast, and cost-effective manipulation, these image files must be stored in a compressed format and decompressed when needed. Image data compression is concerned with minimizing the image size based on reducing the number of bits required to store the image pixels by eliminating the redundancy and correlation within the image pixels (Novak and Shahin, 1996).

At the time this research was conducted, mid-1998 to mid-1999, there were several techniques and software products on the market which deal with digital image compression/decompression. Those techniques are mainly based on two compression schemes, namely *lossless* and *lossy* compression. Lossless techniques produce compressed images by reducing the information content of each pixel, but using processes which still yield decompressed images identical to the original ones ([Baxes, 1994]; [Novak and Shahin, 1996] . Lossless compression can only achieve relatively low compression ratios (<5:1) (i.e., an image of size 150 MB will be compressed and stored as a 30 MB image). Lossy techniques deal with reconstructing an approximate version of the original image by throwing some information away during compression. Lossy compression algorithms offer the potential of very high compression ratios (50~100:1 or more), but preserve an arbitrary level of image quality.

In order to determine which technique and associated software is suitable for compressing digital color orthophotos, SNB required further information concerning: (1) the respective strengths and weaknesses of alternative approaches to digital orthophoto compression; (2) appropriate acceptance criteria which might be used in evaluating up to five compression software packages; and (3) the respective capabilities and limitations of these software packages to handle high-volume digital orthophoto base-line production in a timely and efficient manner. The goal of this research was to address these requirements.

2. IMAGE COMPRESSION

Image compression/decompression operations are used to reduce the data content size of a digital image file. In other words, we can say that "image compression is concerned with minimizing the number of bits required to represent an image" ([Novak and Shahin, 1995]; [Lammi and Sarjakoski, 1995])

Image compression reduces the image file size by removing the redundancy from the image data, i.e. extracting essential information from the image, so that it can be reconstructed with a certain degree of accuracy. Image compression/decompression operations are essential for large images archival and/or transmission ([Baxes, 1994]; [Novak and Shahin, 1996]; [Lammi and Sarjakoski, 1992).

2.1 Image Compression Schemes

2.1.1 Lossless image compression

Lossless compression or error-free compression is a technique used when the image applications require the reconstructed image to be numerically identical to the original image. One of these applications is the archival of medical or business documents. In these documents we need every single character to be reconstructed again without any loss of information ([Baxes,1994]; [Gonzalez and Wintz, 1987]).

Error-free compression will give a very low compression ratio in comparison with the lossy compression. Examples of lossless image compression/encoding techniques have been developed include Run-Length Encoding, Huffman Coding, lossless Predictive Coding, lossless Block Coding. An extensive review of these methods can be found in ([Novak and Shahin, 1996]; [Baxes, 1994]; [Gonzalez and, Wintz,1987]; and [Rabbani and Johnes, 1990]).

2.1.2 Lossy image compression

Lossy image compression schemes introduce degradation in the produced image quality. In other words, lossy schemes cannot be used to exactly and precisely reconstruct the original image. Examples of lossy encoding techniques include Truncation Coding, Lossy Block Coding, Transform Coding, Lossy Predictive Coding. An extensive review of these methods can be found in ([Novak and Shahin, 1996]; [Baxes, 1994]; [Gonzalez and Wintz, 1987]).

2.1.3 Standard/Non-Standard image compression schemes

Image compression standards and non-standards has been developed to support the industry needs such as JPEG “Joint Photographic Experts Group”, CCITT Group3 / 4 and Joint Bi-level Image Experts Group (JBIG), and Wavelets. For detailed discussions, please refer to ([Elysium Ltd., 1998]; [Schroeder, 1997]; [Novak and Shahin, 1996]; [Lammi and Sarjakoski, 1995]; [Storer, 1988]; and [Gonzalez, and Wintz., 1987]).

3. FACTORS AFFECTING THE TESTING CRITERIA

In order to set valid testing criteria, the following factors should be considered:

- **Choice of Compression Algorithm**

As mentioned earlier, after an extensive discussion with SNB at an early stage of the project, it was concluded that a ratio of 25:1 or more was desired by the client provided image fidelity could be maintained. As a result, it was agreed that lossless compression algorithms or software-related products would not be considered in our project.

- **Visual Quality**

High quality compressed/decompressed images were required for the following reasons:

1- Digital Orthophotos need to be correctly interpreted. For example, the end users need to define spatial features correctly, i.e., they need to be able to distinguish different vegetation species and landscape features within a coastal zone. As a result, the compressed/decompressed image should maintain a reasonable quality for such purposes.
2- In most of the applications using digital orthophotos, the end users need to correctly point to specific feature or a location to get the spatial positions. In order to do so, they should be able to recognize or distinguish these features clearly i.e. we need to maintain a good visual quality for the end users.

In this project, both objective and subjective criteria were employed in assessing the quality of an image in a certain manner. In the objective fidelity criterion, the effect of image compression/decompression operations on the image quality can be tested using statistical measures. Those measures allow for the expression of the average information lost within the image pixels. The information lost may be expressed in terms of root mean square error, number of unaltered pixels, and signal to noise ratio. On the other hand, the subjective fidelity criterion measures the effect of the compression/decompression operations by human observer. A scale rate can be constructed and the image can be evaluated by different observers based on that scale.

- **Geometric Distortion**

Geometric distortions change the location of image points and, as a result, it degrades the accuracy of any further measurement operations or applications using the reconstructed images. In order to quantitatively determine the geometric distortion caused by the compression/decompression operations, several points were selected and their coordinates compared in the original and reconstructed images. Using RMSE (Root Mean Square Error), the average range of errors occurred in the spatial position could be identified and compared with the accepted tolerance based on SNB specifications.

- **Compression Ratio**

lossless compression provides a low compression ratio which would not be applicable for our project. On the other hand, lossy compression yields higher compression ratios. Compression ratio is a very important factor in our project because of the need to reach high compression ratio without scarifying the image quality. For this project, high compression ratio was an essential requirement for on-line access to files over widely accessible service. The higher the compression ratio, the more information will be lost within the image. So, the main goal was to reach the optimum compression ratio with an acceptable level of geometric and visual quality. This was done by applying different compression ratios for different algorithms and measure the effect of the ratio increasing on the overall image quality. In our project we have applied the following compression ratios: 5:1, 10:1, 15:1, 20:1, 25:1, 30:1, 35:1, 40:1, 45:1, 50:1, 100:1 .

- **File Manipulation Time**

File manipulation time is a very important factor when choosing the compression algorithm or software related product. Compression ratio and the resulting file size have the greatest effect on the file manipulation time. Also, the computational efforts introduced by the algorithm employed have a strong influence on the file manipulation time. For each algorithm or software related products, the time required to compress, restore, and decompress the image file was measured. A comparative study conducted among the different software packages for the same compression ratio and a decision was made concerning the suitable software that yielded the least manipulation time.

- **Price**

Software price was an important factor as well as the other factors. After the testing performed the prices of the selected software packages were compared.

4. TEST DESIGN

Testing criteria was developed for geometric and visual quality testing based on the discussed factors shown in the previous section. Figure (1) illustrates the workflow of the testing process.The following sections summarize the steps that had been taken in each testing step as well as the results.

4.1 Software Packages Selected

The selection of five software packages was based on a survey of products available commercially in mid-1998.
Table(1) describes the selected software packages which were tested within our project. In this project, an Intergraph TD-225 workstation with, 333 MHz processor, 128 MB RAM, 3 GB free space, 1.2GB Virtual memory, and a 19 inch color monitor was used.

4.2 Test Image

A test image was created to test the perfomance of the software packages selected and define any problems that might appear which might lead to exclusion of any software package. The test image employed in the objective testing was actually a composite image containing a number of different scenes and objects. It contains a part of forest area, color charts, logos and vector data superimposed with the image. The image size was 12 MB and it was 2000x2000 pixels.

4.3 Results and Analysis

Since the purpose of the test image was to measure the performance of the software packages from the visual quality perspective, we did not apply any geometric testing at that stage. We used all the previously mentioned software packages in this stage. We compressed the test image using all the packages with the following compression ratios: 5:1, 10:1, 15:1, 20:1, 25:1, 30:1, 35:1, 40:1, 45:1, 50:1 and 100:1.

The results of the testing are illustrated in Figures (2) through (6). According to the results appear in those charts, we can see that:

1- All of the software packages gave almost the same performance in terms of:
   - Mean Absolute Error;
   - Signal to Noise Ratio; and
   - Number of unaltered pixels.

SOFTWARE PACKAGE	WEB SITE	VERSION USED
MrSID	www.lizardtech.com	MrSID PUBLISHER "Full Version" as at Nov, 1998
COMPRESSION ENGINE	www.cengines.com	CE 1.2 "downloaded version" CE 2.0 command line tool "specially-released beta version"
POWER COMPRESSION	www.imagepower.com	Power Compression 1.04 "downloaded version"
AWARE	www.aware.com	Aware "AccuPress for Remote Sensing" "Evaluation Copy"
Lurawave	www.luratech.com	"Lura Wave Studio" & "Lura Wave Command Line Tool 2.0"

Table 1. Selected software packages

(Approximate test time: November 1998 – March 1999)

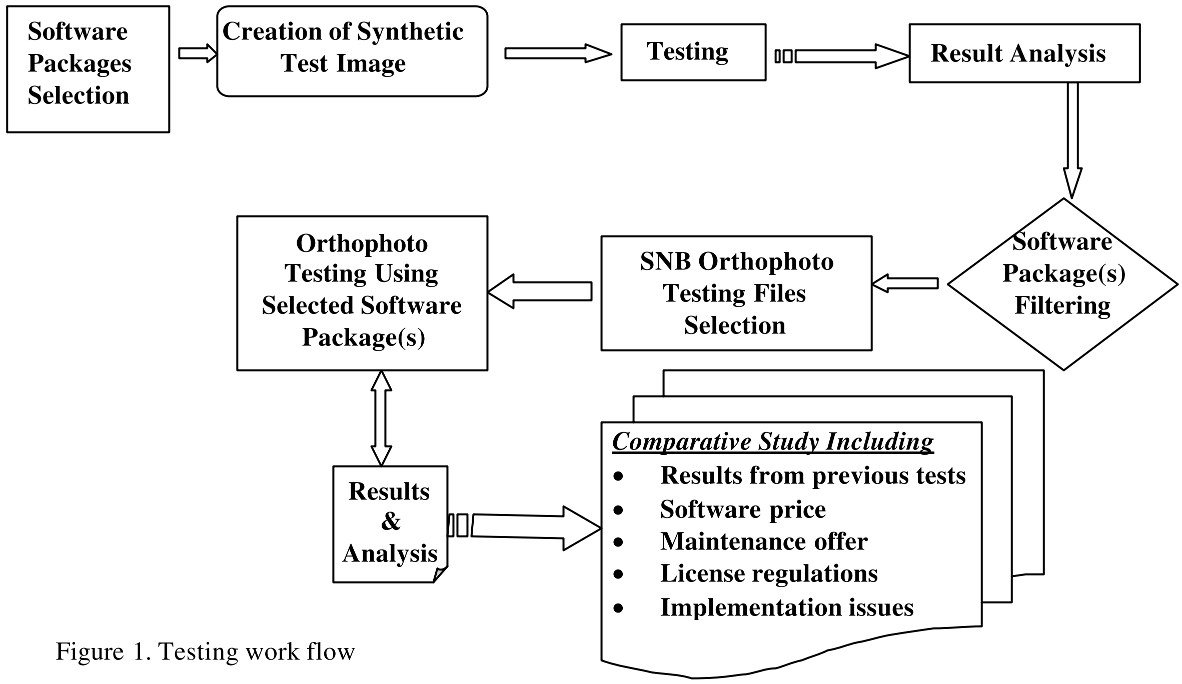

Figure 1. Testing work flow

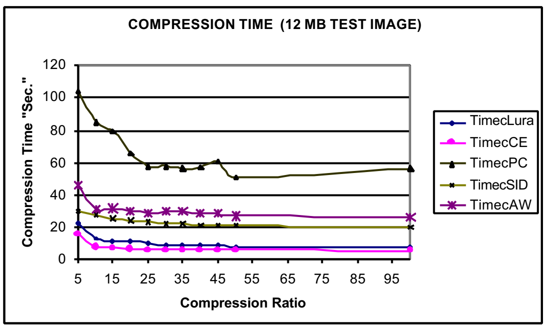

Figure 2. Test image " Compression Time"

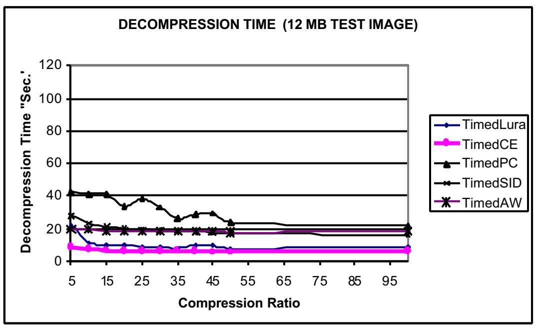

Figure 3. Test image " Decompression Time"

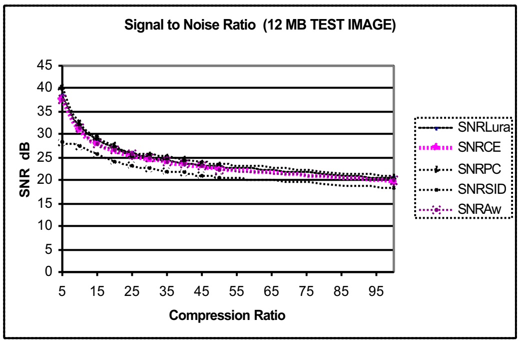

Figure 4. Test image " Signal to Noise Ratio"

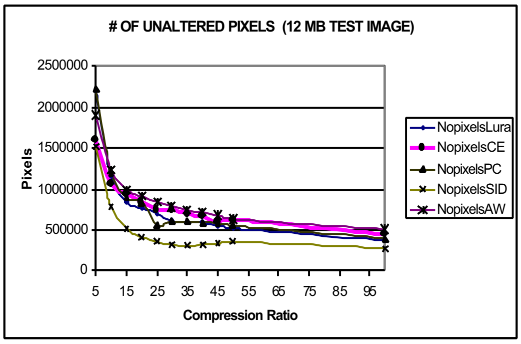

Figure 5. Test image " Numaber of Unaltered Pixels"

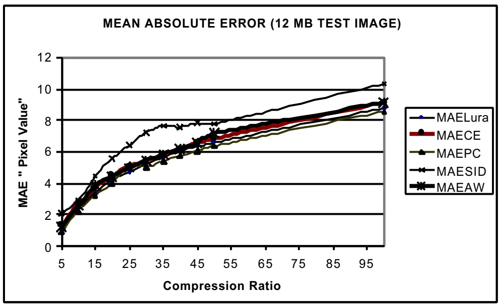

Figure 6. Test image " Mean Absolute Error"

2- In terms of compression/ decompression time, the performance ranking of the software packages was consistent in both operations. Based on the versions of the products available in mid-to-late-1998, Compression Engine 1.2 delivered the best results, compressed the image 50:1 in less than 10 seconds. After Compression Engine came "Lura" , "MrSID", "Aware", and then "Power Compression". The same order had been found in the decompression operation.

3- The objective criteria employed did not adequately reflect the difference between the output image quality delivered from different packages. While there were a noticeable differences in the compressed test image quality using the different software packages, the results from objective testing did not indicate those differences clearly. With this in mind, the team decided to apply the subjective criteria when testing the actual SNB orthophotos.

After an extensive discussion within our team and based on the results obtained from the compression/decomprssion operations, we concluded that:

- Niether the image quality measures nor the compression/decompression time measured gave sufficient indicator that we should exclude any of the software packges.
- If possible, all six of the software packages would be used in the following testing with SNB orthophoto files.

4.4 SNB Orthophoto Files

For the purpose of the project we selected three Orthophoto files which represented different scenes and a variety of terrain. The first image mainly covered forested areas. The second covered urban areas and some water areas. The last image covered forest, urban, and water areas. In each case, the image were in TIFF format with a size of about 130 MB, a 1 meter pixel resolution, and the dimension was 7805x5371 pixels. The testing flow for the orthophotos is shown in Figure (7).

4.5 Software Packages: Operational Problems

When started testing SNB orthophotos, a series of operational problems with the software packages were encountered. These problems can de summarized below:

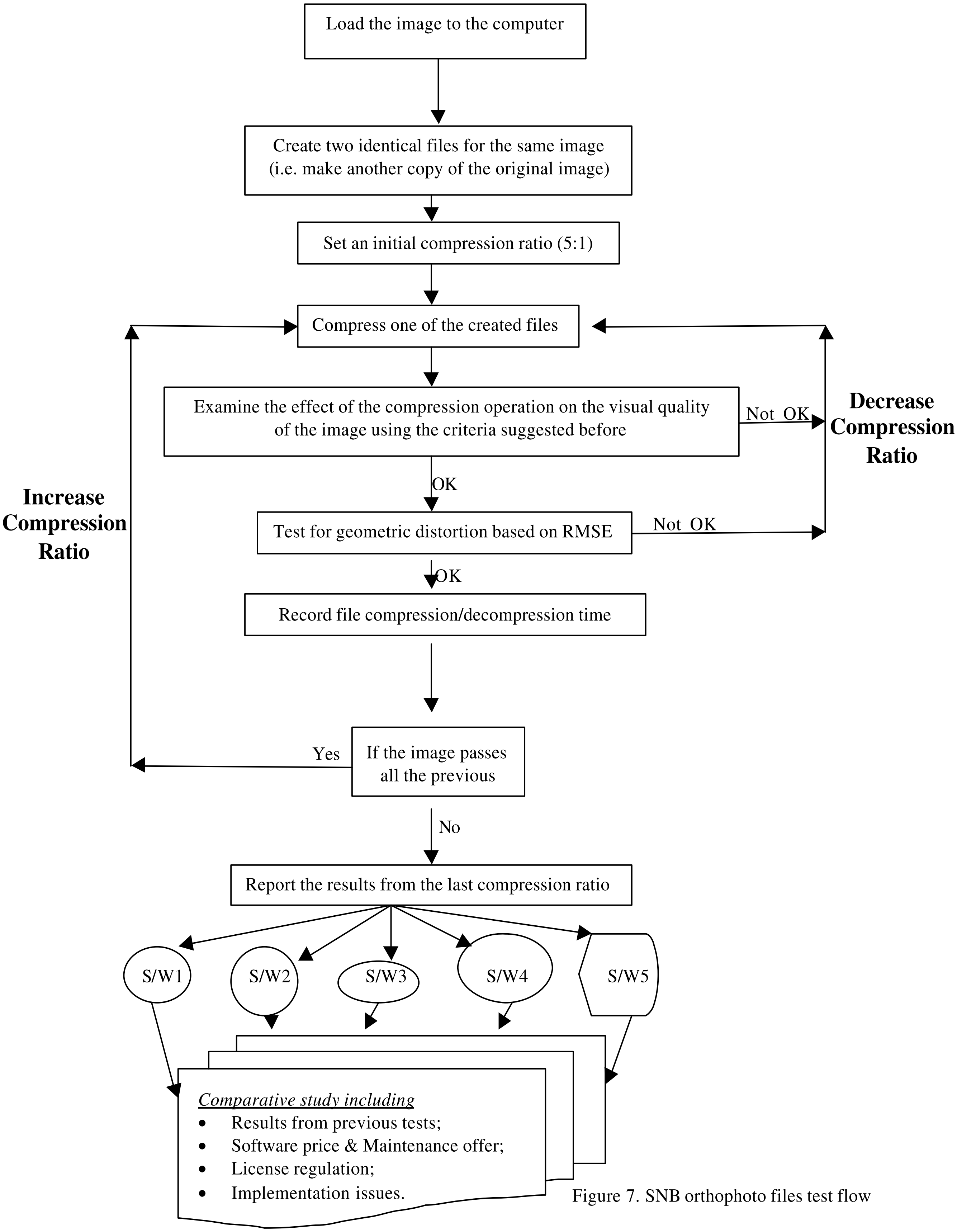

Figure 7. SNB orthophoto files test flow

- Compression Engine 1.2

We started with a download of a standard version of Compression Engine and it took a very long time to just open the 130 MB othophoto file. In March 1999, we contacted the company and they provided us with a new version of the software, Compression Engine 2.0. This version was a command line tool version which " had not yet been fully tested by the company" as they mentioned to us. This version contained 2 main routines, namely "Encoder" and "Decoder". In order to use those routines, the image had to be first transformed from TIFF to internal PPM format. After this conversion we tried the encoder and it gave us a very good results in terms of compression time (65 seconds to compress an orthophoto file to (100:1). When we applied the decoder it gave an error message. The decoder was tried in different workstations running Windows 95/98/NT and the same error message was encountered. As a result, by that time, we could not test SNB orthophoto files using that particular version of Compression Engine.

- Aware

The following problems have been encountered:

- It took 3 hrs to compress the full orthophoto in 100:1.
- It will take more time to compress the image in a smaller ratio, for example 50:1. After discussion with SNB, it was agreed that it would not be practical to use the software due to the very long time required for compression.

- Power Compression

The following problems have been encountered:

- We found it very hard to contact the company either by phone or via e-mail, so we downloaded the version available through the internet and proceeded on our own.
- When we tried to compress the full orthophoto using the wavelet options in the software, it gave an error message in the middle of the process.

By the beginning of February 1999, several e-mail messages had been sent to the company explaining the problems found. The company replied after a further 3 weeks, claiming that:

"The Power Compressor is a demonstration application that we are in the process of upgrading with our new wavelet coders. The original coder used a rather inefficient memory model which could cause unstable operation on small memory machines. The new version of the Power Compressor should be available in the next few months. Also available is a command line application which uses our Power SDK. The Power SDK uses the current memory efficient wavelet coder."

A decision has been made to postpone the testing with this software until a solution was found to the problems encountered.

- LURA

The following problems have been encountered:

- It took almost 1.5 hours to open the full orthophoto using the windows-based versions
- Using the more advanced version " Lura command line tool" It took "17" hours to compress the orthophoto in 100:1.

4.6 MrSID Testing and Evaluation

In testing MrSID, we used different compression ratios, namely 5:1, 10:1, 15:1, 20:1, 25:1, 30:1, 35:1, 40:1, 45:1, 50:1 & 100:1. After compressing the files, the MrSID free viewer was used to open the images in "SID" format. The results were very promising. There was relatively little degradation of image quality between the original image and any of the compressed images. The next step was to geometrically test the effect of image compression/decompression operations in the orthophoto quality.

4.6.1 Visual Quality

In order to test the visual quality subjectively, the research group prepared color plots and an image quality questionnaire. We had the best opportunity to test those images by some experts end users by taking a part of the agenda in the N.B. Geographic Information Management Advisory Committee "GIMAC" which have been held on March 18th 1999. After presenting a brief overview of the work, participants were asked to evaluate the images (in a "blind test") based on the factors presented in the questionnaire and based on their experience in dealing with imagery. Plots were prepared at scales 1:10,000, 1:2,000 and 1:1,000. In each case, images were prepared and plotted at compression ratios of 20:1, 50:1 and 100:1, Figures (8) through (11) show a portion of the resulted compressed urban image. A code was assigned to each image, which was hidden from the reviewer, and the reviewer were asked to select the ratio in each case. The findings of these subjective evaluations were as follows:

1- 100:1 compressed/decompressed images were recognized by some evaluators because slight degradation was apparent in densely detailed features and along edges.
2- Although the reviewers could identify the original image, almost nobody could distinguish the 20:1 compressed image from its 50:1 counterpart.
3- The group concluded that the image compressed to 50:1 ratio using MrSID would be satisfactory for most applications using the image as a backdrop or as the base for subjective photo interpretation usage.

4.6.2 Geometric quality:

In measuring the geometric effect, 10 to 14 control points have been selected for each image. All the original and compressed/decompressed images were georeferenced. The coordinates of the previously selected control points, for each image, have been measured for the original images as well as the compressed/decompressed images with different compression ratios. Figures (12) through (17) show the results of the RMSE for x, y, and planimetric direction as well as the maximum shift in x and y for all these cases.
From the results presented on the charts we can see that:

1- Max. RMSE in either direction is 1.8m;
2- Max. Resultant RMSE is 2.7m;
3- Max shift in both directions is 2m;

The software itself does not introduce any geometric distortion, at least in the images tested. It seems to be that the positional shift introduced is more a function of operator pointing error than any compression/decompression operation. We can conclude that the compression/decompression operation using MrSID can introduce an error of 2 to 3 meters (i.e. 2 to 3 pixels in our case). These results proved satisfactory when discussed with SNB and the GIMAC group.

4.6.3 Compression/Decompression Time

Compression and decompression time for each compression ratio for all the images have been recorded. Figures (16) and (17) show the results. Based on the workstation configurations we used and the SNB orthophotos, the average compression time we expect is 6-9 minutes for a compression ratio up to 50:1 and the decompression time is about 4-6 minutes for a compression ratio up to 50:1. These results were satisfactory for the client.

Figure 8. Portion of the urban image "Original"

Figure 9. Portion of the urban image "20:1"

Figure 10. Portion of the urban image “50:1”

Figure 11. Portion of the urban image “100:1”

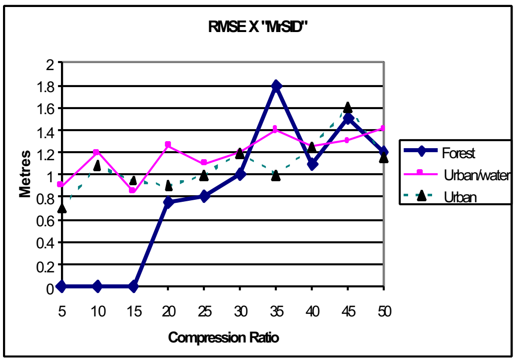

Figure 12. RMSE x “MrSID”

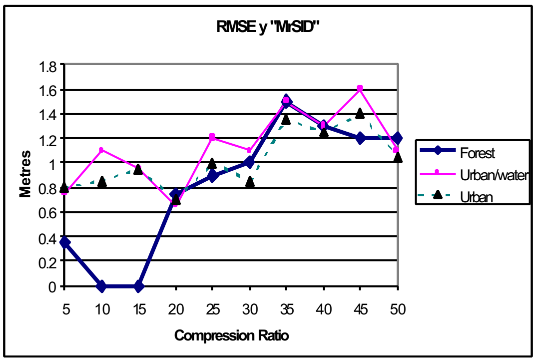

Figure 13. RMSE y “MrSID”

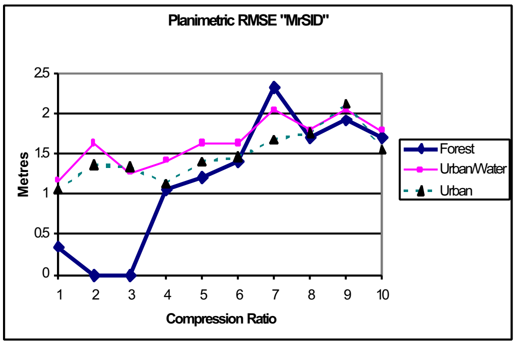

Figure 14. Planimetric RMSE “MrSID”

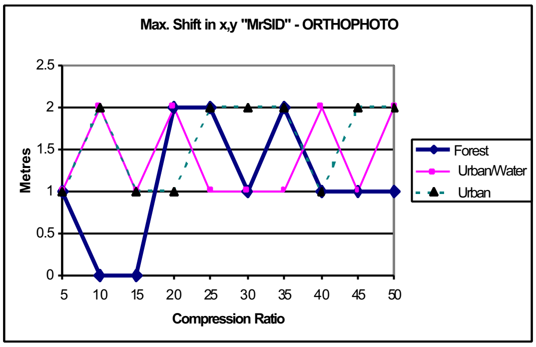

Figure 15. Max. shift in x,y “MrSID”

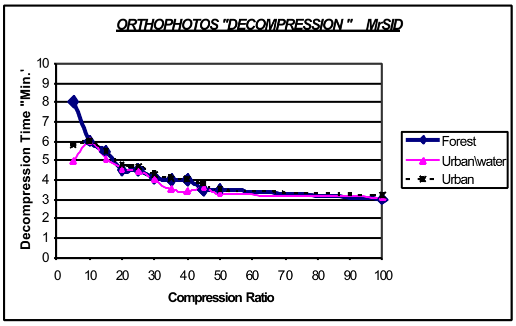

Figure 16. Decompression time “MrSID”

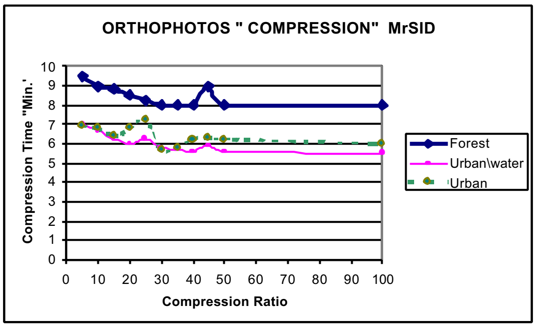

Figure 17. Compression time “MrSID”

5. RECOMMENDED IMPLEMENTATION

Based on the information presented to the research team from Lizardtech company, Lizardtech had two main products, namely "MrSID Publisher" and "MrSID Professional". The two products are almost the same except for the maximum image size that can be handled and also the price. Although the price for MrSID Publisher is 3 times the price of MrSID Professional as well as the maintenance charge per year, we recommended the use of MrSID Publisher because of it can handle image files of any size . We have tested "MrSID Publisher" and we recommend of using that product rather than "MrSID Professional" because of future considerations. SNB might in the near future consider creating an image database for orthophoto imagery at a variety of resolutions covering large areas in province or they might be interested in distributing mosaics of orthophotos which will exceed the 500Mb image size restriction of MrSID Professional. In our opinion, if LizardTech products will be used by SNB, we recommended using "MrSID Publisher" to have a great flexibility in any compression issue in the future.

5.1 Plug-in vs off Line Decompression:

For the purpose of decompressing or viewing SID files, LizardTech. has several tools. These tools allow the user to integrate SID viewer capabilities into their applications which have been used by different GIS vendors such as Beta MicroStation®95 MrSID Viewer, MrSID for MapInfo®Professional 5.0, and MrSID ArcView Extension. Another tool is the stand-alone viewer that can be downloaded free from the company's web page. Using this viewer the user can view SID image, measure distances, decompress a part or the whole image into TIFF format, pan, zoom, etc. If the user wants to publish SID images on-line, another tool called MrSID Image Server allows viewing an image with the smallest resolution view, and allows for a complete control in navigating through larger and smaller zoom levels. For complete details on these products please refer to the company's web page. As recommended by the research team and as shown in Figure (18), SNB can use MrSID To compress their 130 MB orthophotomap files using a compression ratio of 50:1, which proved satisfactory from the image quality perspectives. SNB orthophotomap database will reside in the SNB Server in a compressed format, i.e. in SID format, and the size of each file will be approximately 2.6 MB. Then, the clients will access the database through the internet, browse the database, select the appropriate orthophoto files for their needs and download that file(s) in SID format. After downloading the file(s), the end user(s) will have two main choices. First, they might use the image in SID format by a software package which has MrSid viewing capabilities embedded within it, such as ArcView. Secondly, the user may need to convert the image or part of it into TIFF format to use it within any GIS or Image Processing Package, as shown in Figure (18). For the second case, the user will need to download the "FREE" MrSID Stand Alone Viewer from the LizardTech. Web site and use it directly to handle SID Image. Two Factors should be considered. First, SNB needs a tool to allow people to navigate SID imagery in SNB server across the internet. Second, the users may need a decompressed version of the orthophoto i.e. a TIFF format file. For the first factor, SNB can use MrSID Image Server. For the second factor, MrSID free stand alone viewer will accommodate the user needs.

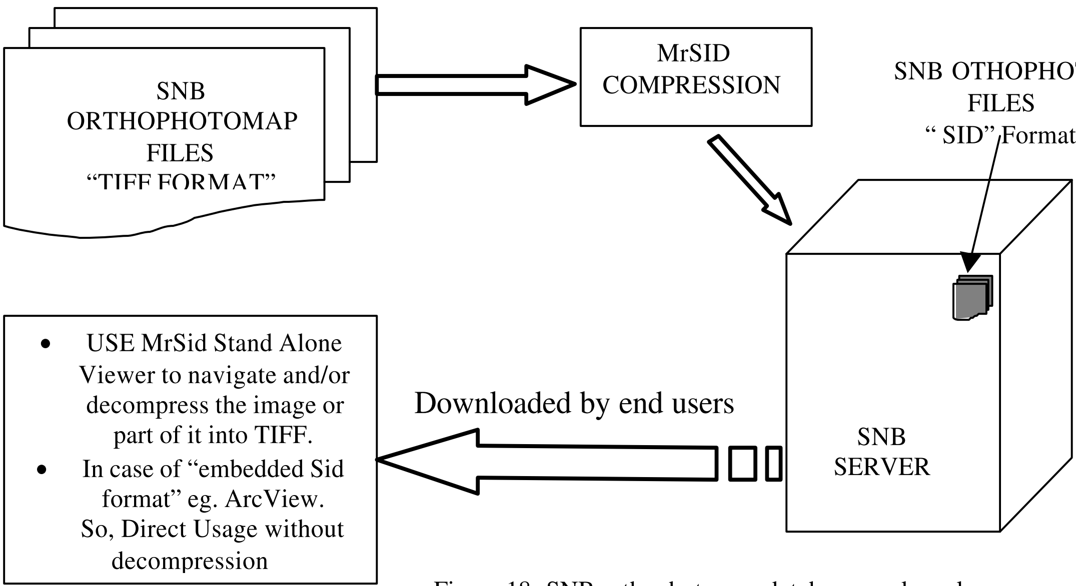

Figure 18. SNB orthophotomap database work cycle

6. CONCLUSIONS & RECOMMENDATIONS

The Image compression era is really still immature. Many software packages dealing with image compression issues exist in the market. All of these software companies are claiming that their software can provide a very high compression ratio with almost no loss/degradation in image quality. In a very recent technical paper published by ERMapper Inc., a well known company in image processing and mapping, a new image compression product, ECW 2.0, was released by them and compared with MrSID (http://www.earthetc.com/). A strong debate is still taking place between vendors and supporters of the two products. This indicates clearly the immaturity of the spatial image compression software market. These software products are all improving with each new release, new products are entering the market all the time, and users are well advised to investigate the performance, reliability, documentation, and ease of use of competing packages before selecting one for internal use.As can be seen from this research, many of these packages are suffering from operational problems when dealing with large image files. The following can be concluded from this research:

1- Several image compression software packages have been tested using a test image of 12MB of size and all of the packages performed well;

2- Three SNB orthophotomap files, 130 MB each, have been selected to be tested using these packages and, except for MrSID, all the other packages failed to handle SNB orthophotomap files and several problems have been reported;

3- Several software vendors indicated the release of new versions that might be useful in handling large image files in the future;

4- MrSID gave a reasonable time in both compressing and decompressing SNB orthophotomap files as shown in the result charts.

Based on the information presented to us from our research, testing results, web site-based investigations, discussions with SNB, GIMAC and great efforts in contacting software vendors we recommend the following:

1- Use *"MrSID Publisher"* for compressing SNB orthophotomap database;

2- Use MrSID Image Server to browse the orthophoto files across the internet;

3- Each user can download MrSID Stand Alone Viewer for decompression purposes;

4- For optimum storage purposes on-line or on CD, SNB should compress the softcopy orthophotomap database using a compression ratio of 50:1;

5- SNB softcopy orthophotomap database User Guide should caution the users that a 2-to-3 meter maximum geometric shift can be expected when employing softcopy orthophotomaps which have been decompressed as outlined earlier.

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