



# Research

Image Compression for  
Storage Transmission of  
Digital Images

1. Report No.  <p style="text-align: center;">MN/RC – 2001-14</p>	2.	3. Recipients Accession No.					
4. Title and Subtitle  <p style="text-align: center;"><b>IMAGE COMPRESSION FOR STORAGE TRANSMISSINO OF DIGITAL IMAGES</b></p>		5. Report Date  <p style="text-align: center;">August 2000</p>	6.				
7. Author(s)  <p>Vladimir Cherkassky, Xuhao He, Jie Shao</p>		8. Performing Organization Report No.					
9. Performing Organization Name and Address  <p>University of Minnesota          Department of Electrical Engineering &amp; Computer Science          200 Union Street, S.E.          Minneapolis, MN 55455</p>		10. Project/Task/Work Unit No.					
12. Sponsoring Organization Name and Address  <p>Minnesota Department of Transportation          395 John Ireland Boulevard Mail Stop 330          St. Paul, Minnesota 55155</p>		11. Contract (C) or Grant (G) No.  <p>c) 74708 wo) 141</p>					
		13. Type of Report and Period Covered  <p style="text-align: center;">Final Report</p>					
14. Sponsoring Agency Code		15. Supplementary Notes					
16. Abstract (Limit: 200 words)  <p>This project researched image compression methods for storage and transmission of digital images at the Minnesota Department of Transportation (Mn/DOT).</p> <p>Researchers compared the performance of several commercial and research methods for image compression based on the "typical" image provided by the Mn/DOT Office of Land Management. They also surveyed some new image compression methods based on wavelet thresholding. The report details the analyses and comparisons and includes recommendations.</p> <p>Researchers choose MrSID, a commercial software package for image compression, as a suitable method for the needs of Mn/DOT's Office of Land Management. MrSID uses a wavelet transform-based algorithm to achieve both the efficient storage and retrieval of large digital images. Its main practical advantages include improved utilization of storage and transmission resources and a multi-resolution browsing capability. MrSID can selectively decompress a portion of an image by zooming at different levels of detail.</p> <p>Researchers implemented a demo website, which can be browsed easily and implements the zooming function. The web site address is <a href="http://rocky.dot.state.mn.us/research">http://rocky.dot.state.mn.us/research</a>.</p>							
17. Document Analysis/Descriptors  <table style="width: 100%; border: none;"> <tr> <td style="width: 50%;">Digital Images</td> <td style="width: 50%;">MrSID</td> </tr> <tr> <td>Digital Compression</td> <td>Wavelet Thresholding</td> </tr> </table>		Digital Images	MrSID	Digital Compression	Wavelet Thresholding	18. Availability Statement  <p>No restrictions. Document available from:          National Technical Information Services,          Springfield, Virginia 22161</p>	
Digital Images	MrSID						
Digital Compression	Wavelet Thresholding						
19. Security Class (this report)  <p>Unclassified</p>	20. Security Class (this page)  <p>Unclassified</p>	21. No. of Pages  <p style="text-align: center;">28</p>	22. Price				

# **Image Compression for Storage and Transmission Of Digitized Images**

## **Final Report**

*Prepared by:*

Vladimir Cherkassky  
Xuhao He  
Jie Shao

**August 2000**

*Published by:*

Minnesota Department of Transportation  
Office of Research Services  
First Floor  
395 John Ireland Boulevard MS 330  
St. Paul, MN 55155

This report represents the results of research conducted by the authors and does not necessarily represent the views or policy of the Minnesota Department of Transportation. This report does not contain a standard or specified technique.

## TABLE OF CONTENTS

Introduction.....	1
Objectives .....	3
Research Methods and Approach .....	5
Analysis and Results .....	7
Evaluation of Image Compression.....	7
Software Development and Implementation.....	9
Image Samples from the Demo Website .....	11
Research on Methods for Incremental Transmission .....	16
Conclusion and Recommendation.....	19
References.....	21

## LIST OF FIGURES

Figure 1.....	12
Figure 2.....	12
Figure 3.....	13
Figure 4.....	14
Figure 5.....	15
Figure 6.....	15

## **Executive Summary**

This project focuses on image compression for storage and transmission of digital images for the Minnesota Department of Transportation (Mn/DOT). We compared performance of several commercial and research methods for image compression using ‘typical’ image provided by the Mn/DOT Office of Land Management; and surveyed some new image compression methods based on wavelet thresholding. Based on our analyses and comparisons, we recommend most suitable methods to the need of Office of Land Management.

Our main practical recommendation is the choice of MrSID, a commercial software package for image compression, as a suitable method for the needs of the Office of Land Management. MrSID utilizes a wavelet transform-based algorithm to achieve both the efficient storage and retrieval of large digital images. Its main practical advantages include improved utilization of storage and transmission resources, and providing a multi-resolution browsing capability. MrSID can selectively decompress a portion of an image by *zooming* at different levels of detail. Such a selective zooming capability is an attractive property for users interested in exploring ‘interesting’ parts of a large aerial map. Hence, we recommend using MrSID as an image compression tool for the Office of Land Management. We have implemented a demo website which can be browsed easily and implements the zooming function. The web site address is

<http://rocky.dot.state.mn.us/research/> .

We have also surveyed recent research methods for image compression based on wavelet thresholding. The main practical advantage of these methods is providing an *incremental transmission* capability, that is currently not available with commercial packages such as MrSID. This capability is necessary for transmitting large image files over low-bandwidth channels when users do not know in advance which parts of a (large) image they actually need, and they determine what is 'interesting' by examining the whole image.

# CHAPTER ONE: INTRODUCTION

The Minnesota Department of Transportation's (Mn/DOT) Office of Land Management provides digital mapping products for maintaining our state's transportation system. Due to current trends towards digitization of the image/map and Web-based delivery of services, there is a growing need for compressing large image files such as aerial photographs and maps. Such compression is needed for efficient storage and retrieval of image data, and for image transmission over low-capacity Internet connections.

We identify two useful properties of a compressing method. One is the *zooming function*, indicating the capability of a method to selectively zoom on a part of an image as specified by a user. [1] The other one is *incremental transmission* capability, referring to a capability to transmit/compress first the more important information about an image. Even though both functions are both very useful for the users of the Office of Land Management, they may not be readily available in existing commercial packages for image compression.

There are many standard techniques for image compression, such as the JPEG standard based on the Discrete Cosine Transform (DCT) linear method. [2][3] In recent years, many researchers have introduced certain nonlinear methods for image compression based on wavelet thresholding. In many cases, these new algorithms have outperformed traditional linear approaches according to both subjective and objective measures. Moreover, wavelet-based methods can be used to achieve incremental compression and



progressive transmission of compressed images, so that a user can control the trade-off between image compression and image quality.

## **CHAPTER TWO: OBJECTIVES**

- 1) Compare performance of several commercial and research methods for image compression using 'typical' images provided by Mn/DOT.
- 2) Survey image compression methods based on wavelet thresholding and discuss the possibility of its performance fitting to the needs of the Office of Land Management.
- 3) Based on comparison results, provide recommendations for selecting the image compression method most suitable to the needs of the Office of Land Management.
- 4) Construct a demo website to illustrate the compression procedure and to guide users of the Office of Land Management who are interested in accessing and browsing large image files.



# **CHAPTER THREE: RESEARCH METHODS AND APPROACH**

- 1) Evaluate different image compression methods and available commercial software.

Comparisons are intended to investigate the trade-off between the compression ratio and the quality of the decompressed images for typical (large) images used by the Office of Land Management.

- 2) Install and configure a test system based on MrSID Image Encoder/Server and Windows NT 4.0 with IIS Server on computer. Encode images of 'tiff' type to 'sid' files, which are special file type for MrSID package. Realize the zooming function by clicking the interested portion in an original image. Publish the images on experimental website.

- 3) Investigate image compression methods that enable incremental transmission. Survey some practical software implementations that can realize incremental transmission. Provide recommendation for the possibility of such methods to be used by the Mn/DOT for image compression and transmission.



# CHAPTER FOUR: ANALYSIS AND RESULTS

## 4.1 EVALUATION OF IMAGE COMPRESSION

### ALGORITHMS

- **Existing Commercial Implementations**

There are two major image compression methods based on DCT (JPEG) and DWT (Discrete Wavelet Transform). We investigated MrSID as a representative commercial software applying DWT for image compression. Based on a thorough evaluation of these two approaches, we found JPEG to be unacceptable for compressing geo-spatial imagery for the following reasons:

- 1) JPEG requires at least twice as much space as MrSID.
- 2) JPEG resolution is extremely uneven; MrSID method is based on a local transform and provides clear, more even resolution.
- 3) Computerized pattern recognition is difficult when using JPEG because there are significant edge artifacts.
- 4) Post processing, such as filtering, results in poor image quality when using JPEG.
- 5) Format conversion, such as transforming from 24-bit color JPEG compressed image to 8-bit color image results in poor image quality..

Our comparisons indicate that DWT based image compression methods have two advantages over DCT/JPEG:

- 1) DWT is a local transform and it does not deteriorate at the image boundaries.  
Uniform resolution and superior quality can be achieved at all parts of an image.

- 2) DWT enables multiresolution compression of an image. As a result of multi-resolution capability, DWT methods provide many important features such as selective decompression and selective multi-resolution browsing which can be achieved by a mouse click in MrSID. These features can be explored by using a standard web browser such as IE and Netscape Communicator.

In addition, commercial software package MrSID provides outstanding capabilities suitable for compressing/ processing large geophysical images, such as:

- 1) Compressing images of large size (MrSID Publisher has no limit on the image size).
- 2) MrSID provides practical compression rates at an acceptable loss of image quality between 15:1 to 20:1 for 8-bit gray scale images and between 30:1 to 40:1 for 24-bit color images.
- 3) Robust batch processing capabilities (i.e., many images can be compressed automatically and continuously in a batch). This feature is important for processing large amount of images.
- 4) Each MrSID image can include up to 9 resolutions (zoom levels) in the same compressed image file. Image at these resolutions can be viewed very quickly and easily over Internet (with the help of MrSID server and plug-ins for www browsers). Clients can download and use this software free of charge. This may be an important factor for attracting Mn/DOT customers to use their system.

- 5) MrSID's ability to selectively decompress a portion of the overall image and also to selectively decompress by zooming the image at different levels of detail is a desirable property for Mn/DOT users.
- 6) Capability to mosaic multiple images into single MrSID image.
- 7) Metadata support which can provide Geo-referencing information.
- 8) Free MrSID image viewers (stand alone viewer, on-line image viewer and plugins for PhotoShop) make MrSID software a popular portable image format.
- 9) Good technology support.

- **Conclusion**

Due to the above discussion above, we recommend MrSID software for image compression needs of Mn/DOT.

## 4.2 SOFTWARE DEVELOPMENT AND IMPLEMENTATION

- The complete system should including three parts:
  - *compression part*: implementing compression of the original '.tiff' files to '.sid' files, which is specific files used in MrSID system and its zooming operation.
  - *publishing part*: implementing web publishing administrator software, used to publish processed images over the Internet, and provide users connection to the server which stores many images.



- *interface part*: simple and convenient interface for users to browse the whole image or selective portion of it by clicking a mouse. There will be three implementations of browsing capability---- with plug-in, no plug-in and Java.
- We have installed the whole MrSID system in the software environment used by Mn/DOT Office of Land Management, comprising the following steps:
1. In order to install MrSID image server, we should first install Windows NT system in a server. The setup and configuration is given below:
    - Windows NT Server 4.0
    - Service Pack 6a
    - Option Pack 4.0
    - The 8G hard disk is segmented into 2-4G drives.
  2. IIS 4.0 has been installed and configured as the WWW server, and it is used as an administrative tool to manage the whole website system.
  3. ActivePerl 5.6 is installed to cooperate with IIS 4.0, which is necessary when we use some interactive web pages to transmit image or other information.
  4. MrSID Image Server for NT version 2.2 is installed to publish .SID image files through Internet. It is necessary for providing browsing function from the web.
  5. MrSID Image Compressor is installed and can be used to compress image files into .SID files that can be published through the server.
- Compression procedure
- Users can compress the TIFF image files in the CDs available from Mn/DOT and add them into a subdirectory under the Image Server installation directory to create a profile

(i.e. a subdirectory containing related image files). The compressed images can realize selective zooming function at several levels. Using this implementation, users can access the server through the Internet and browse the large image files conveniently and quickly. There are three different ways for users to browse the images, including with plug-in (download certain s/w before browsing), no plug-in (directly browse the image) and JAVA. The system operation using representative images can be seen using the following URL: <http://rocky.dot.state.mn.us/research/>

### 4.3 IMAGE SAMPLES FROM THE DEMO WEBSITE

Here we show some examples of zooming function using no plug-in method. The original image is showed below. We can use the mouse to click on certain portions in the image (as specified by a user), such as the rectangular part in Fig. 1. Zooming on that part we obtain an image shown in Fig. 2, which shows more details in the clicked portion of Fig. 1. Continued zooming on the same part of an image would produce different levels of resolution of this part, as shown in Figs. 3 - 6.

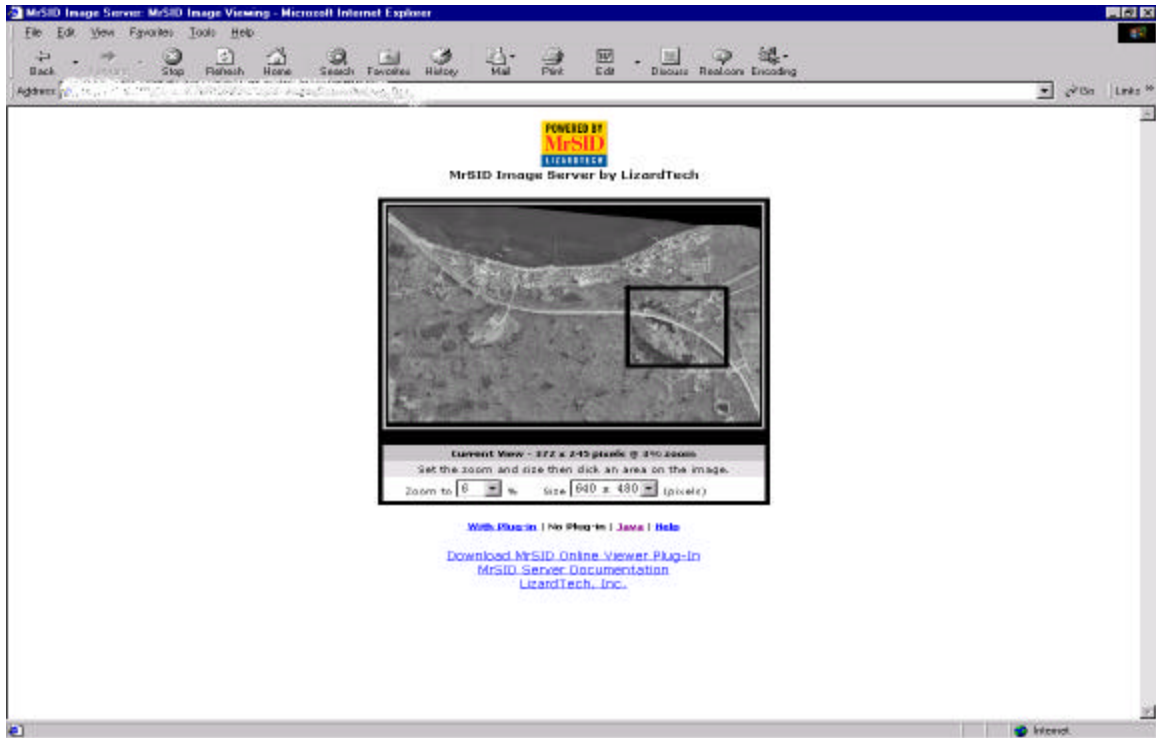


Fig. 1



Fig. 2

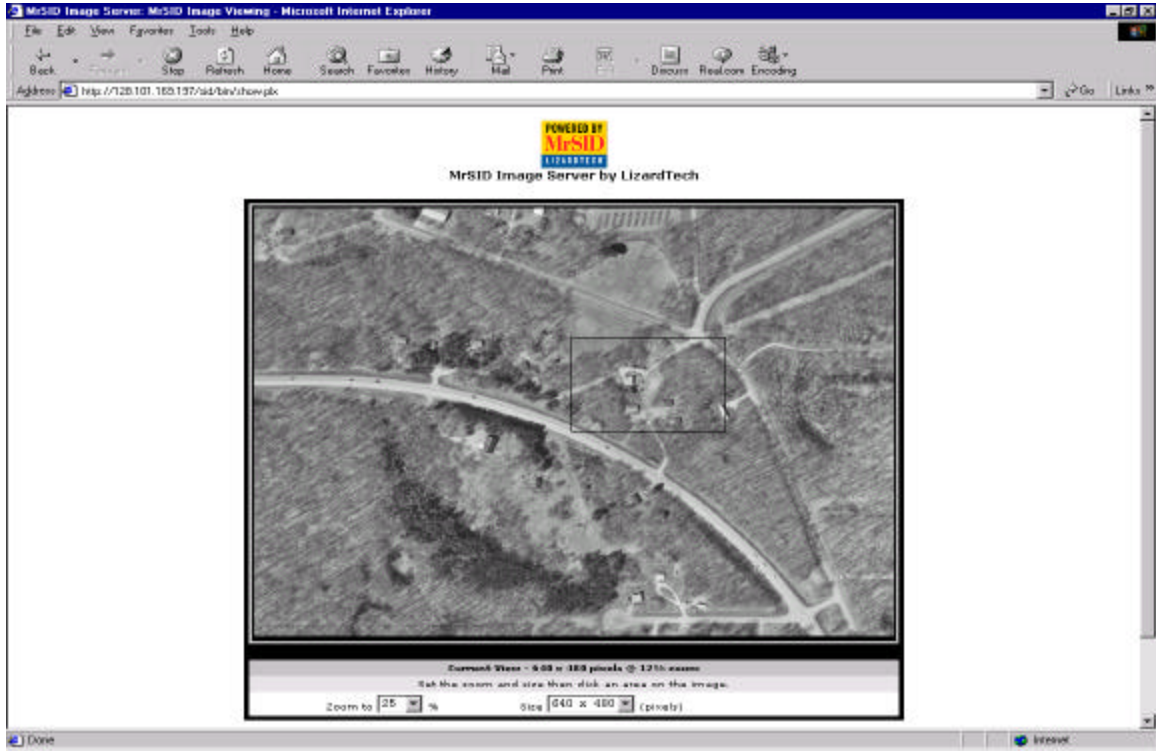


Fig. 3



Fig. 4

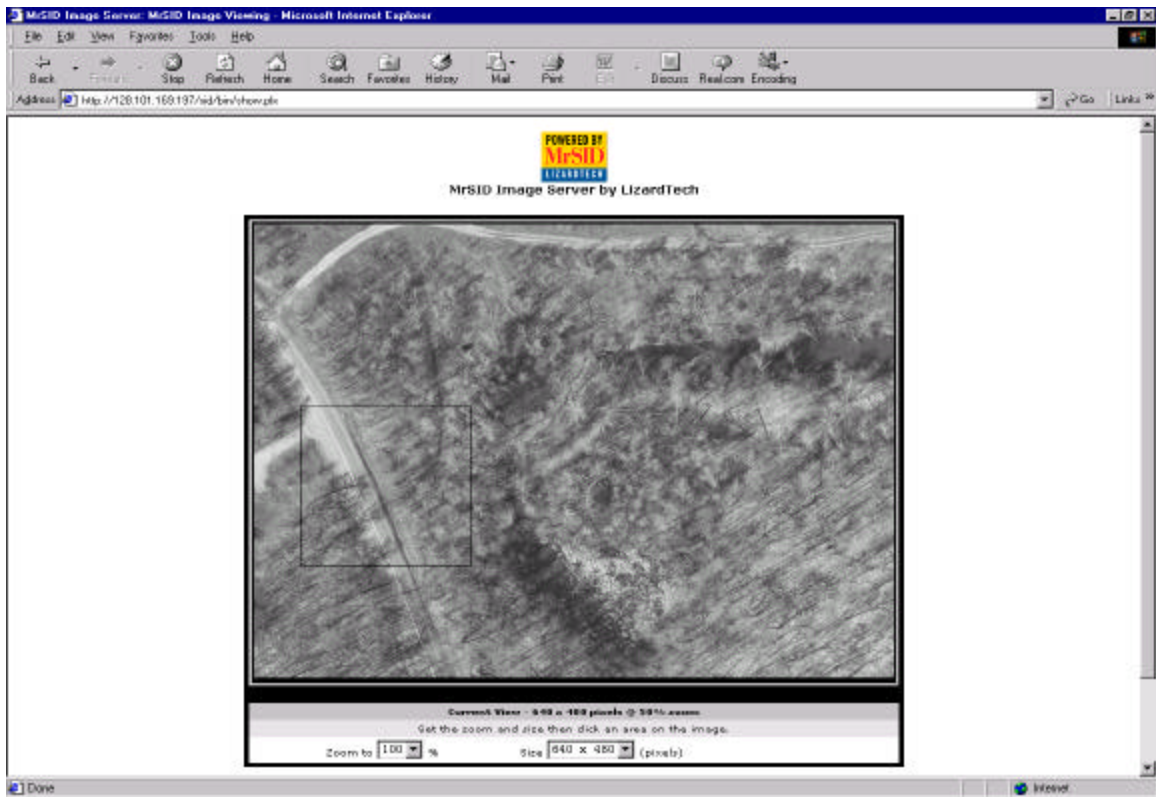
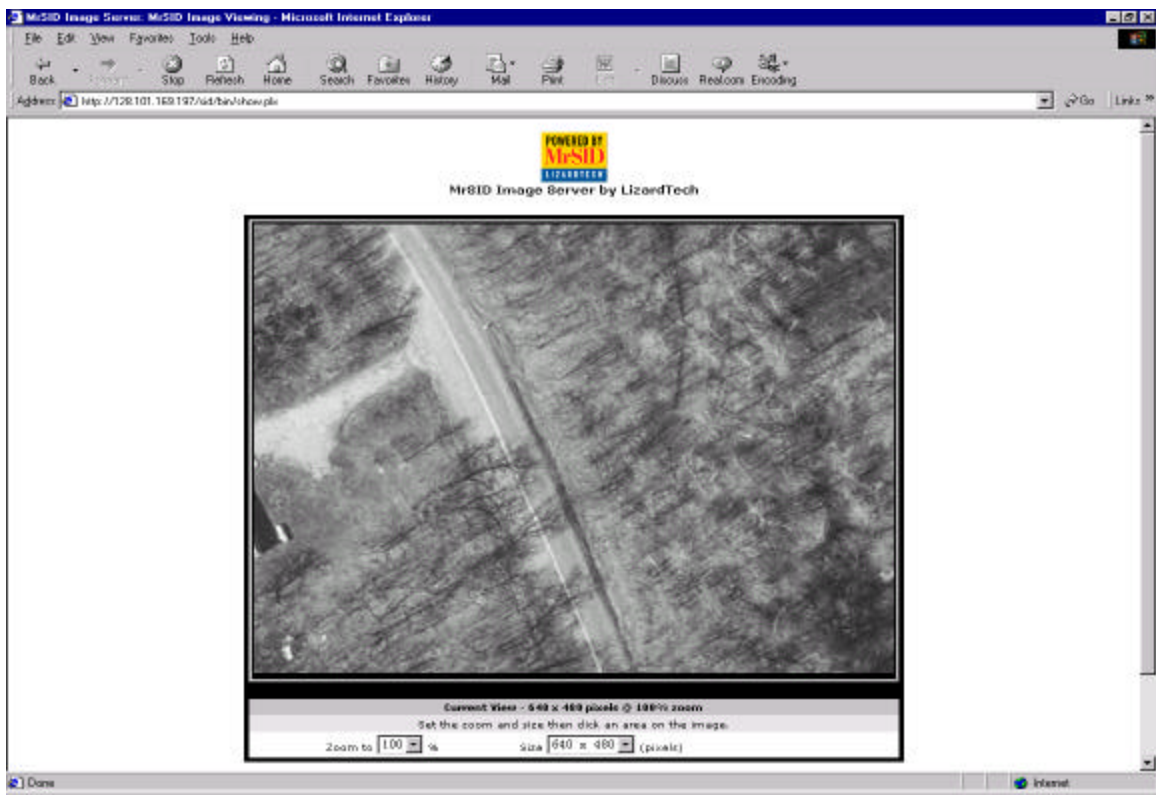


Fig. 5 (ABOVE), Fig. 6 (BELOW)



## 4.4 RESEARCH ON METHODS

### FOR INCREMENTAL TRANSMISSION

Compression methods for incremental transmission enable progressive transmission of the whole image starting with low-resolution, and then gradually increasing the resolution. This capability is important when a user does not know a priori which part(s) of an image are of interest, and such determination needs to be done by visual examination of the whole image. In many practical situations (i.e., large images transmitted over low-speed connections), it is not feasible to transmit the whole image at the high resolution, hence the need for incremental transmission.

Incremental compression is intrinsically more difficult problem than standard compression, because of the additional requirement that low-resolution images need to be interpretable by a human user. This also means that incremental compression methods need to process the whole original image, in order to decide which parts are important for human interpretation. Recent wavelet thresholding methods for image compression enable incremental compression by ordering the wavelet basis functions (of the original image) according to their importance (for human interpretation). [4]

The main idea of wavelet thresholding is to take the wavelet transforms of an image, order the wavelet coefficients according to their ‘importance’, and then discard the ‘insignificant’ coefficients. Each wavelet coefficient corresponds to a wavelet basis function. The denoised signal can be then obtained by taking the inverse wavelet transform with the remaining coefficients.

We performed research on two representative wavelet-based methods suitable for incremental transmission:

- SPIHT(Set Partitioning in Hierarchical Tree), which is a powerful new wavelet-based image compression method. [6][7].
- VC-based wavelet image compression, currently being developed at U. of Minnesota. This compression algorithm is based on wavelet zerotree ordering of the wavelet basis functions. [5].

Even though VC-based image compression can achieve high compression rates and incremental image compression, it is research software, and its implementation lacks many features of the commercial image compression software.





## **CHAPTER FIVE: CONCLUSION AND RECOMMENDATION**

In the first part of this project, we compared several commercial image compression packages using ‘typical’ aerial images provided by the Office of Land management. We recommend MrSID compression package (over DCT/JPEG methods) for the needs of Mn/DOT. MrSID provides excellent compression rates with an acceptable loss of image quality, and it provides multi-resolution zooming capability where a user can selectively view (decompress) parts of an image at different levels of resolution. In order to demonstrate practical applicability of MrSID, we ported MrSID into software environment used by the Office of Land Management, and developed a web site demonstrating the use of MrSID compression software for Mn/DOT users.

In the second part of the project, we performed research on wavelet thresholding methods for image compression that enable incremental transmission of large images over the Web.



## REFERENCES

- [1] D. Donoho and I. Johnstone, Adapting to unknown smoothness via wavelet shrinkage, *JASA*, v.19, pp. 1200-1224, 1995
- [2] A. Chambolle, R. DeVore, N. Lee and B. Lucier, Nonlinear Wavelet Image Processing, *IEE Transactions on Image Processing*, v.7, pp319-335, 1998
- [3] K. Castleman, *Digital Image Processing*, Prentice Hall 1996
- [4] V. Cherkassky and F. Mulier, *Learning from Data*, Wiley, N.Y. 1998
- [5] V. Cherkassky and X. Shao, Model Selection for Wavelet-based Signal Estimation, *Proc. International Joint Conference on Neural Networks*, Anchorage, Alaska, 1998
- [6] Amir Said and William A. Pearlman, A New Fast and Efficient Image Code Based on Set Partitioning in Hierarchical Trees, *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 6, pp. 243-250, June 1996
- [7] Amir Said and William A. Pearlman, An Image Multi-resolution Representation for Lossless and Lossy Image Compression, first submitted July 1994, and published in *IEEE Transactions on Image Processing*, vol. 5, pp. 1303-1310, Sept. 1996