3-DIMENSIONAL TILING TECHNIQUE TO PROCESS HUGE SIZE HIGH RESOLUTION SATELLITE IMAGE SEAMLESSLY AND RAPIDLY

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ABSTRACT: This paper presents the method to provide a fast service for user in image manipulation such as zooming and panning of huge size high resolution satellite image (e.g. Giga bytes per scene). The proposed technique is based on the hierarchical structure that has 3D-Tiling in horizontal and vertical direction to provide the image service more effectively than 2D-Tiling technique in the past does. The essence of the proposed technique is to create tiles that have optimum level of horizontal as well as vertical direction on the basis of current displaying area which changes as user manipulates huge image. So this technique provides seamless service, and will be very powerful and useful for manipulation of images of huge size without data conversion.
KEY WORDS: Image Tiling, 3D Tiling, Image Pyramid, Seamless Display.

1. INTRODUCTION

Recently, the data size of image to handle has increased enormously, as the very high resolution satellite images getting popular. Therefore, it is necessary to reduce response time to user's manipulation request. The display related functions such as zooming and panning are most frequently used for image manipulation. Hence it is important for the image manipulation tools to provide faster service in such functions. In this paper, we suggest so-called 3-Dimensional Tiling technique that works in real-time, which reduces response time in image display in local environment.

There have been many approaches to reduce this response time such as Image Tiling, Image Pyramid and composition of both, which are based on pre-processing of image before manipulation-namely data conversion. The image data converted by one of these pre-processing techniques provides faster response time to the operation of user. However, the pre-processing requires a lot of time and large storage capacity when dealing with very large images as most of very high resolution satellite images are.

The proposed 3D-Tiling technique can be applied directly to the raw image data of large size without data conversion, which is essential for Image Tiling, Image Pyramid technique and time consuming. The 3D-Tiling technique is a *"memory base method,"* which pre-stores the image tiles of optimum level in three dimensional directions in memory. The image tiles required are computed based on the current display area of given depth before further manipulation. In this way, proposed method saves time and disk space required for data conversion that conventional techniques can not avoid. The response time is improved thanks to the tiles of three dimensional directions stored in memory when user requests zoom-in, zoom-out, and panning. Consequently, the proposed technique achieves very fast response time without pre-processing.

Composition of this paper is as follows. Chapter 2 explains the image data used in this paper. The detailed description of proposed 3D-Tiling technique is explained in comparison with conventional pre-processing techniques in Chapter 3. The result of performance evaluation is given in Chapter 4, and finally conclusion and future work are presented in Chapter 5.

2. DATA PREPARATION

Table-1 shows the information on the test images.

Product Level	Level 1A strip
Data size	33. 4 GB
Row size in pixel	1197763
Col size in pixel	15000
Data Type	16bit

Table1. Test Data Information

3. METHODS

3.1 3-DIMENSIONAL TILING

Image Pyramid is the method to generate sub-images with hierarchical resolutions in an image. The lowest level in Image Pyramid is raw image with original resolution, and each hierarchical level is down-sampled image with filtering and a certain ratio. For example, when the image is zoomed out, certain area of image can be displayed as one pixel on the computer screen. At this moment, user can use appropriate image of hierarchical level in the Image Pyramid for display rather than re-filtering the image according to LOD(Level Of Detail). Image Tiling is the technique to divide whole image into the small unit area which is called Tile to achieve fast panning function. As the size of Tiles is getting smaller, efficient search function is necessary for searching Tiles. In case of using Image Pyramid and Image Tiling techniques, data convert should be required. However, as

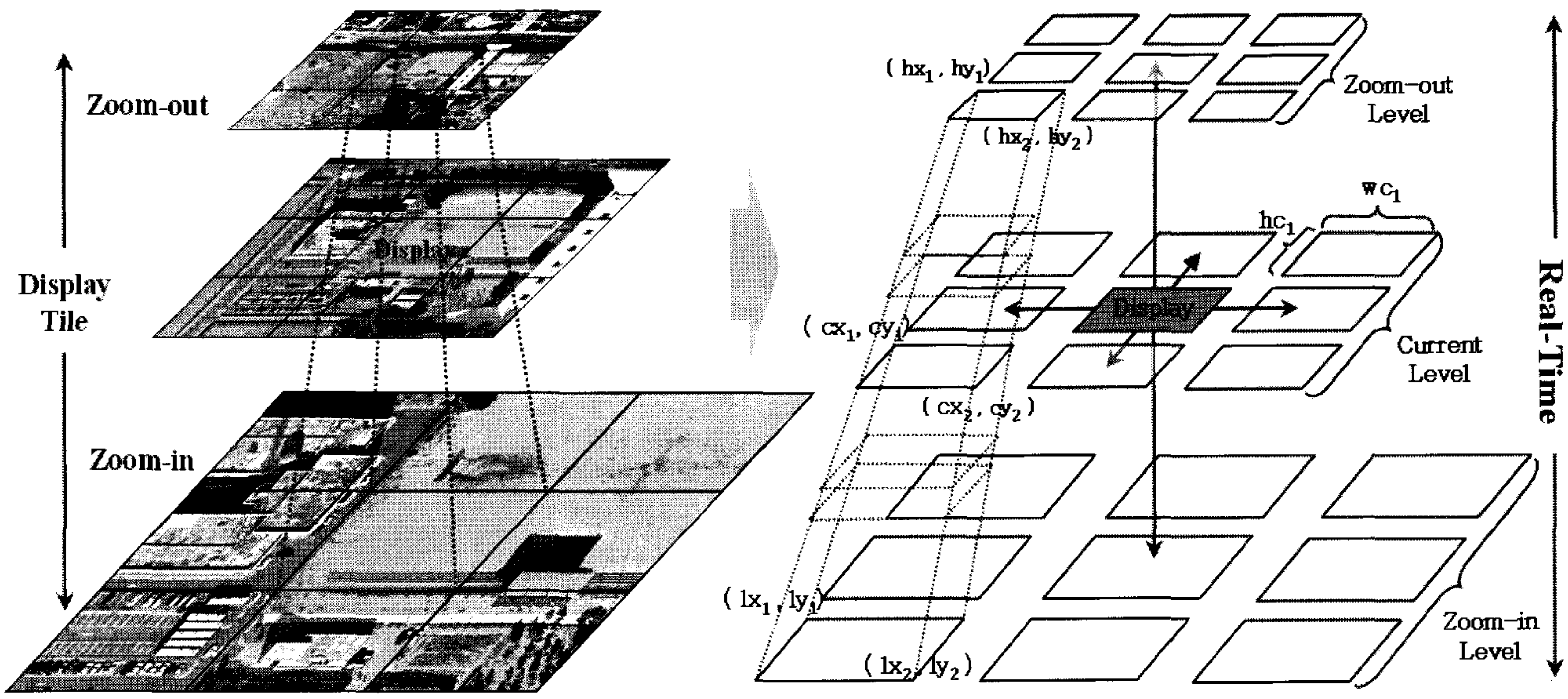

Figure 1. The structure of 3D-Tiles

the size of image data gets very large, it takes very long time and requires large disk space to convert image data.

3D-Tiling is similar with the combination of Image Pyramid and Image Tiling techniques, but has unique characteristics. First of all, 3D-Tiling does not need the pre-processing time, which was necessary to convert data for conventional methods. The 3D-Tiling generates only necessary tiles in real-time with appropriate level. This technique is implemented using Multi-Threading to help sacrificing response time. Secondly, smooth moving of image is possible and a memory share is lower because 3D-Tiling uses not file (hard disk) but memory. Thirdly, efficient search function is not required since only small number of tiles is used. Fourthly, the size of Tiles is determined dynamically by user screen resolution, so more smooth movement is possible. In this manner, 3D-Tiling overcomes shortcomings of Image Pyramid and Image Tiling techniques and achieves near real-time response.

The structure of 3D-Tiling is described in Figure 1. The data structure of 3D-Tiling is divided into three levels, namely, Current Level, Zoom-in Level and Zoom-out Level. Those have similar meaning with level-of-detail in Image Pyramid. The Tile marked by "Display" (Current Level) is displayed on the screen where hc_1 and wc_1 means height and width of the displayed tile. It is very important that "Display" Tile should be generated firstly and provided to user for real-time response, and then the other tiles should be processed by Background Thread. When generating tiles, "Display" Tile is generated first with the highest priority and is provided to user. Then adjacent tiles of same level (left, right, up, down and diagonal direction) and zoomed tiles (Zoom-in and Zoom-out level) are generated based on "Display" Tile. Normally these tiles are generated through the Background Thread to assure real-time operation. These tiles are saved only in memory.

The (cx_1, cy_1) (cx_2, cy_2) are coordinates of Current Level, (hx_1, hy_1) (hx_2, hy_2) are coordinates of Zoom-out Level and (lx_1, ly_1) (lx_2, ly_2) are coordinates of Zoom-in Level in original image. These coordinates can be calculated by Equation 1. The denominator 2 and 4 in Equation 1 are determined by zoom ratio. In this paper, the default zoom ratio is 2.

$$(hx_1,hy_1),(hx_2,hy_2)=\left(cx_1-\frac{wc_1}{2},cy_1-\frac{hc_1}{2}\right),\left(cx_2+\frac{wc_1}{2},cy_2+\frac{hc_1}{2}\right)$$

$$(lx_1,ly_1),(lx_2,ly_2)=\left(cx_2+\frac{wc_1}{4},cy_2+\frac{hc_1}{4}\right),\left(cx_2-\frac{wc_1}{4},cy_2-\frac{hc_1}{4}\right)$$

Equation1. Coordinate calculation

3.2 THE PROCEDURE OF 3D-TILING

The procedure of proposed 3D-Tiling technique is shown in Figure 2. A Thumbnail Tile is generated once during first loading for the display of full view and saved in memory. Then, 3D-Tiles are constructed in foreground and background. A display tile in the current level is generated in foreground. The resolution of display tile can be any number by user's manipulation such as zoom-

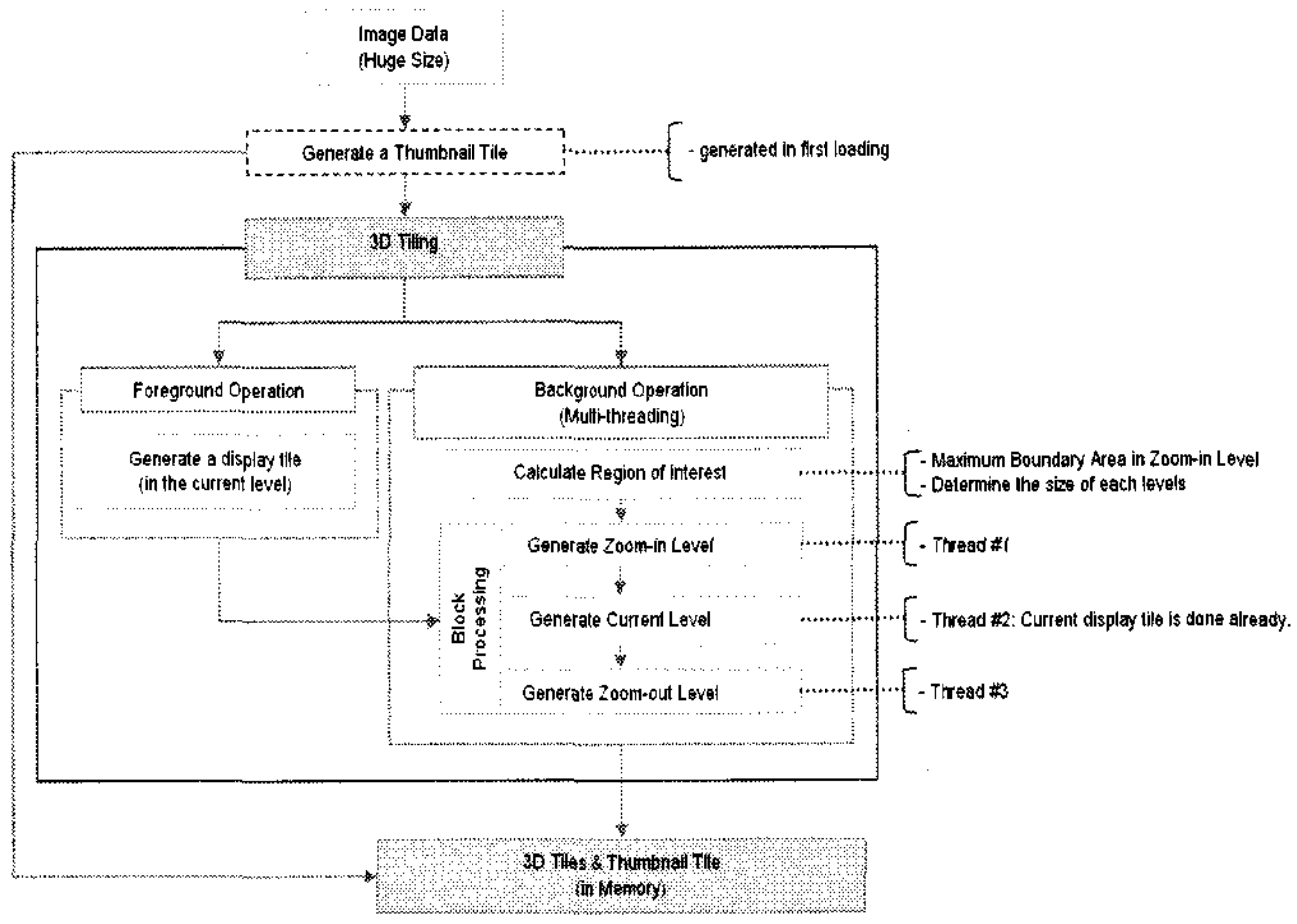

Figure 2. Procedure of 3D-Tiling

in and zoom-rectangle in overview. At the same time the region of interest that means the maximum boundary area in zoom-in level are calculated in the background and created the tile of Zoom-in level first among Figure 1's levels (colored in gray in the figure). And then, another tiles are created which adjoin to center tile of Current level and Zoom-out level using of coordinates computed by Equation-1. Therefore, 3D-Tile images of interest areas are generated immediately in the background. Finally, 3D-Tiles and thumbnail tile images are stored in memory

3.3 THE OPERATION OF 3D-TILING

The context diagram of proposed 3D-Tiling's operation is shown in Figure 3. According to user's image manipulation, *"Tile Manager"* manages each case as follows:

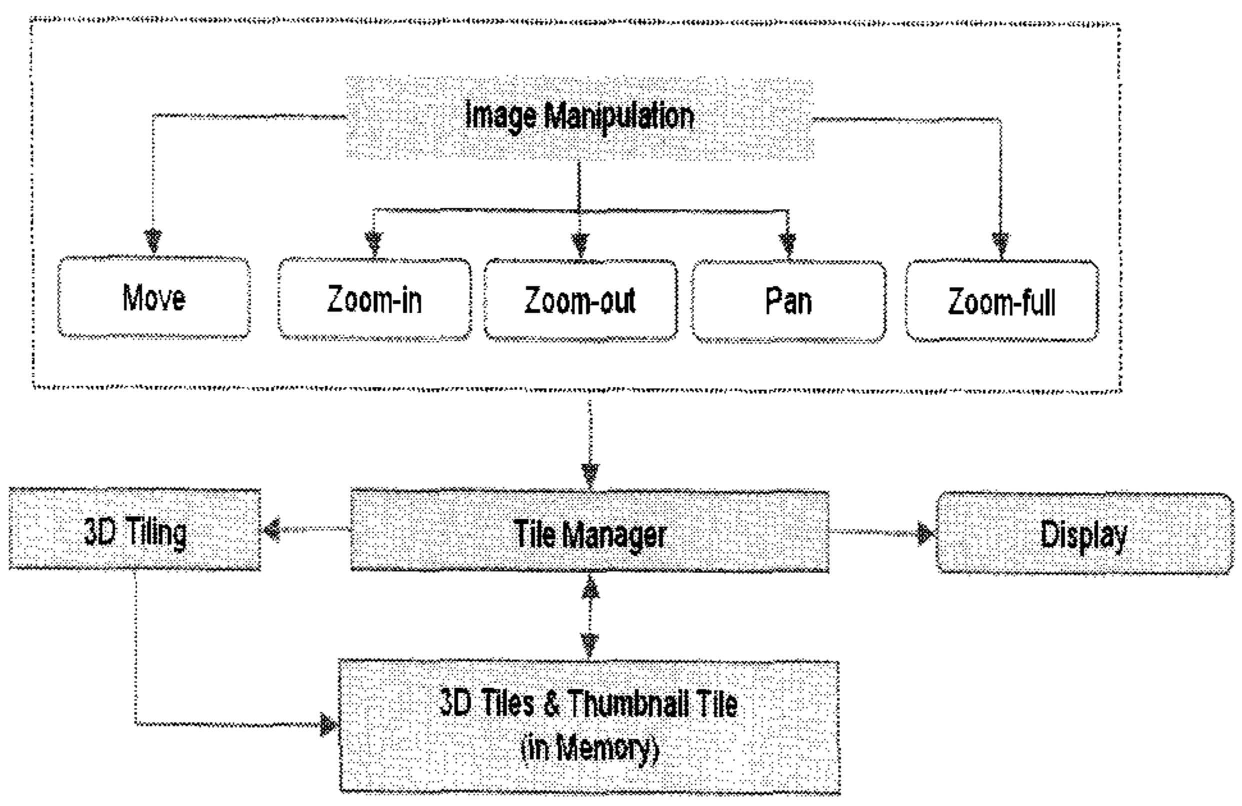

Figure 3. The context diagram of Tile Manager's

Case-1 (Move): Re-operate a 3D-Tiling procedure in Figure 2's. Display 'the current display tile' in memory.

Case-2 (Zoom-in): Display tiles of Zoom-in level stored in memory in case of user does Zoom-in. Then, change level of tiles stored in memory. In this case, Zoom-in level that is stored in memory becomes Current level and Current level becomes Zoom-out level. Finally, create tiles of Zoom-in level and store in memory.

Case-3 (Zoom-out): Display tiles of Zoom-out level stored in memory in case of user does Zoom-out. Then, change level of tiles stored in memory. In this case, Zoom-out level that is stored in memory becomes Current level and Current level becomes Zoom-in level. Finally, create tiles of Zoom-out level and store in memory.

Case-4 (Pan): Display tiles of Current level stored in memory in case that user does Move. Create tile if tile to display is not in memory and then display. In that case, the new tile becomes Figure 1's center tile. Create tiles required in each level for this tile. Then, store in memory. In this case, level of tile has not changed.

Case-5 (Zoom-full): Display the thumbnail tile simply in memory.

4. EXPERIMENTS

4.1 PERFORMANCE EVALUATIONS ENVIRONMENT

In this paper, we have compared proposed 3D-Tiling technique with two commercialized tools: ERDAS and ENVI. For the analysis, the access time of disk is assumed by 30 milliseconds on average. Original image data, i.e. data without any pre-processing, was used in performance test of 3D-Tiling technique. On the average 345 milliseconds were required to create all tiles of three steps level in 3D-Tiling technique. And converted image data was used in performance test of commercialized tool: ERDAS. The test environment of 3D-Tiling technique is given in Table-2.

Local Desk Top PC	
CPU	Intel Core2- 2.4GHz
O/S	MS-Window XP Professional
RAM	1.00GB
Development Tool	MS-Visual C++ 6.0
Disk File System	SATA-II (NTFS)

Table2. Test Environment

4.2 PERFORMANCE EVALUATIONS RESULT

For the performance test, we used newly developed tool using proposed algorithm and commercialized tools (ERDAS and ENVI) for the comparison. And, for the performance test of 3D-Tiling technique, we set up default tile size as 1024×1024 and the range of tile size from 512×512 up to 2048×2048. With given range the size of tile can change dynamically according to the zoom level. This configuration was decided considering the display performance of local user and the maximum memory within 150MByte.

The performance test is conducted in three ways. Firstly, the necessary time for the first loading of image data is measured in comparison *"SIMapViewer"* tool with commercialized tools (ERDAS and ENVI). Secondly, Secondly, we analyzed the performance through the response time measure of various image manipulation. The response time means required time to display. And we compared the average display performance of 3D-Tiling technique with commercialized tool. Thirdly, we applied 3D-Tiling technique to *"SIMapViewer"* with multiple thumbnail viewer for practical use in desktop environments.

Test1. Table-3 shows the necessary time for the first loading of image data between *"SIMapViewer"* tool applied proposed technique and commercialized tools (ERDAS and ENVI). As described in chapter 2, we used image data which size is 33. 4 GB. In case of ERDAS, it took 1 hour 35 minutes to load image data because of the pre-processing of the image (*import*) for the first loading. As ERDAS needs image import procedure at any case and it takes long time to import full pass image, it is difficult to compare the performance of image loading time. And in case of ENVI, it took 2.07 seconds. *"SIMapViewer"* showed the best performance as 0.6 seconds. This result shows that the performance of *"SIMapViewer"* can provide real-time service without import procedure when users want to see whole image of huge size image at once.

Tool	Necessary Time
ERDAS	1 hour 35 minutes (about)
ENVI	2.07 seconds (about)
Developed Tool	0.6 seconds (average)

Table3. Result of data loading time

Test2. We analyzed the performance of the response time of 3D-Tiling technique. Figure 4 shows the result of display response time of 3D-Tiling technique. In the test result, the response of 3D-Tiling technique is very fast (average 30.8 milliseconds) when performed image manipulations. The variations of display response time are low and steady. The maximum variation of response time in Figure 4 is 25 milliseconds on average. The 3D-Tiling technique showed display performance of real time level without time consuming pre-processing. This result confirmed that 3D-Tiling technique is very useful and efficient when displaying the huge size image.

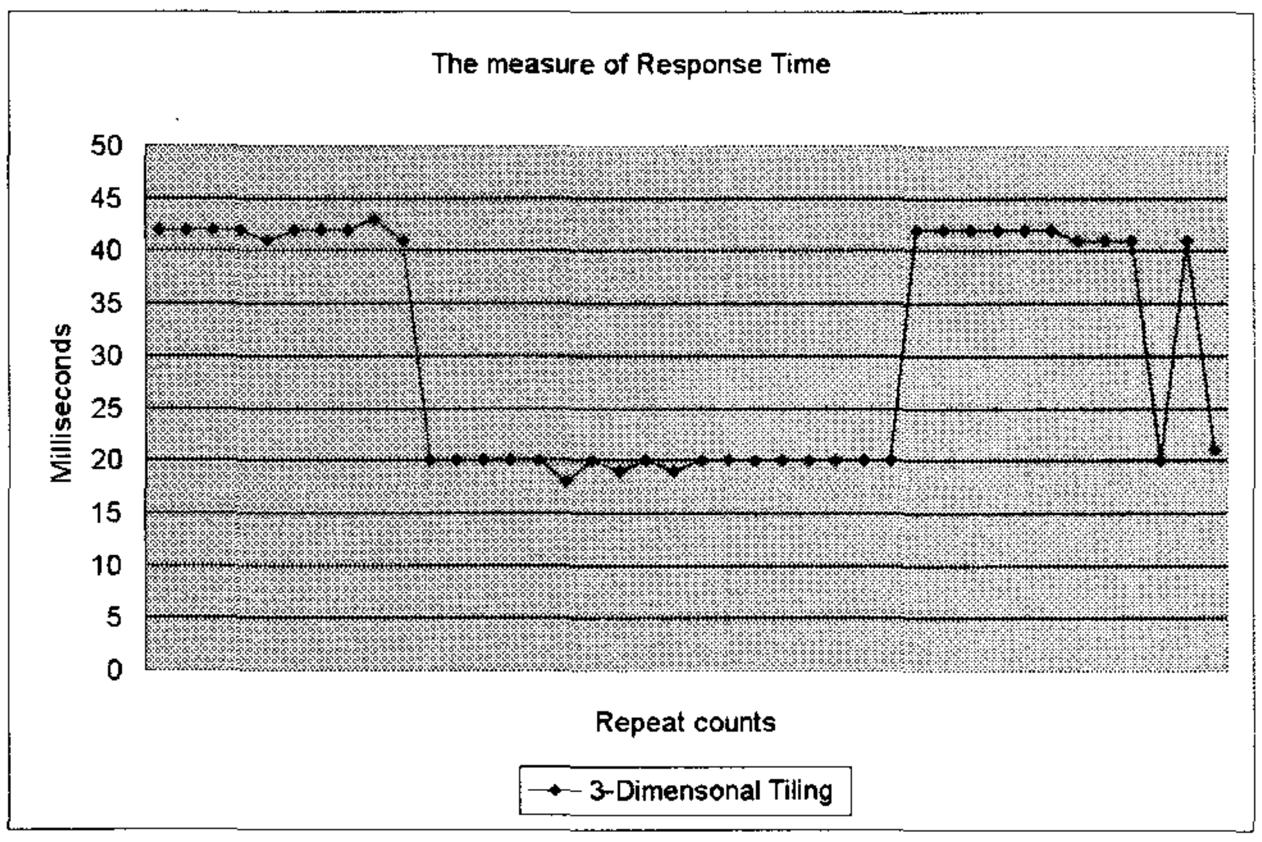

Figure4. Result of performance test

We also measured response time by display manipulation of commercialized tool (ERDAS and ENVI). Average display time is shown in table 4. The result in display time of *"SIMapViewer"* showed better performance about 7 times. Indicating average 0.03 seconds, it is reliable to provide seamless and rapid service when users manipulate the huge size image. For *"SIMapViewer",* we used internal *"time measure function"* to measure necessary time of display. However it was not possible to measure exact time in case of ERDAS and ENVI. Therefore we measured approximate time.

Tool	Average Display Time
ERDAS	0.21 seconds (about)
ENVI	0.17 seconds (about)
Developed Tool	0.03 seconds (average)

Table4. Result of display time

Test3. We applied 3D-Tiling technique to *"SIMapViewer"* which is our own image processing S/W for practical use. Figure 5 shows the UI of our software. The huge size image such as satellite pass image, high resolution aerial image and mosaic image of large area could be generated and provided as Thumbnail. Display performance was also rapid when zooming the image. In case of panning in an enlarged image, the image display showed seamless response without time delay between display. Therefore proposed technique can apply to various fields such as ground receiving system of satellite image in local environment or internet application of web service in network environment because of rapid display capability of the huge size image.

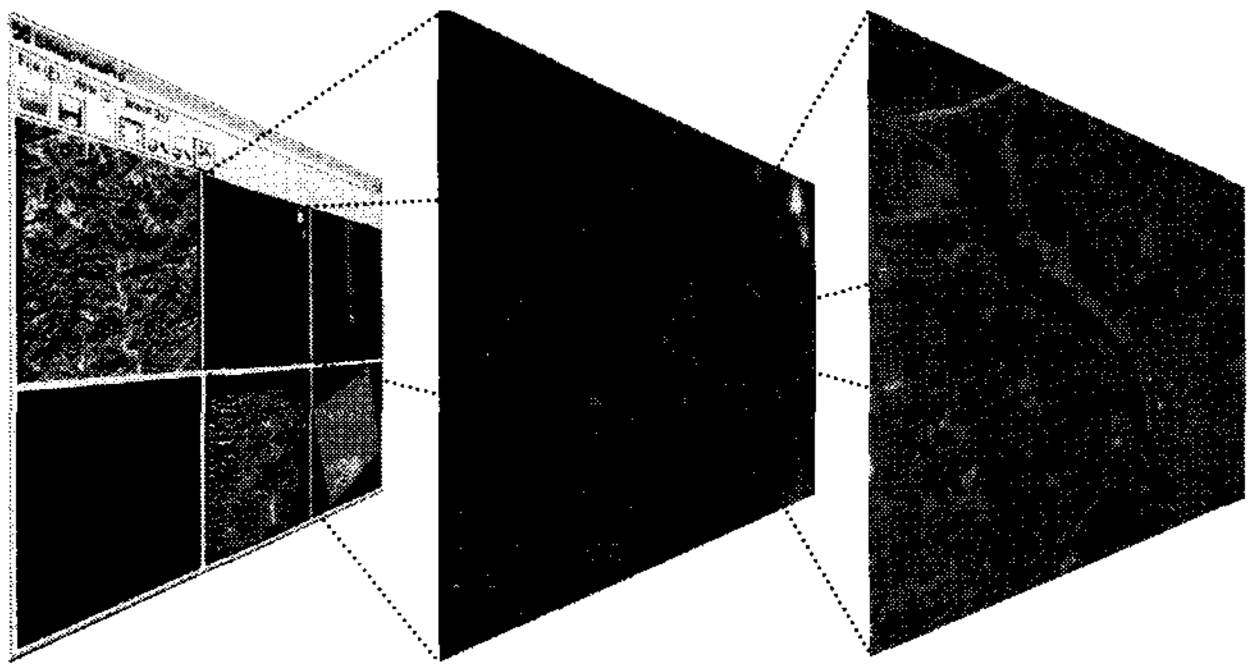

Figure5. An Example of SIMapviewer used 3D-Tiling

5. CONCLUSION

The size of satellite image will increase continuously as the resolution is getting higher. Therefore, the study is required to reduce response time further for user's processing request. This paper proposed 3D-Tiling technique to provide high performance of display, namely real time level, without pre-conversion of image data. The 3D-Tiling technique achieves real-time display performance of very huge image data using improved data structure, architecture and utilization of multi-threading technique. In this way, 3D-Tiling technique can provide more useful and stable service to user and it can make the most of advantage of multi-threading. Through performance evaluation, the efficiency of 3D-Tiling has been shown. For future work, we are interested in developing the algorithm that predicts user's image manipulation pattern, faster re-sampling algorithm, and full utilization of multi-threading.

6. REFERENCES

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