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OPTICAL TOMOGRAPHY: REAL-TIME IMAGE RECONSTRUCTION SYSTEM USING TWO DATA PROCESSING UNITS

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Abstract. An investigation is performed to investigate whether or not using two data processing units can increase image refreshing rate in online mode. The functions of these data processing units are capturing data, reconstructing and displaying the image respectively. The measured results are compared with real-time image refreshing rate using a single processing unit. The graph of percentage improvement versus various resolutions represents the performance of the image reconstruction system using two data processing units.

Keywords: Data processing unit; image refreshing rate

Abstrak. Penyelidikan dilakukan untuk memeriksa jika penggunaan dua unit pemprosesan data boleh meningkatkan kadar penghasilan imej ketika mod masa nyata. Fungsi unit-unit pemprosesan data adalah masing-masing untuk merekod data, membina semula dan memaparkan imej. Perbandingan antara hasil yang direkodkan dan kadar penghasilan imej masa-nyata dilakukan menggunakan unit pemprosesan tunggal. Graf peningkatan peratusan melawan berlainan resolusi menggambarkan prestasi system pembinaan semua imej dengan menggunakan dua unit pemprosesan data.

Kata kunci: Unit pemprosesan data; kadar penghasilan imej

1.0 INTRODUCTION

A basic tomography system is constructed using a combination of a sensing system, a data acquisition system, an image reconstruction system and a display unit. The sensor system is the heart of any tomography system because it decides

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the sensing method for the process vessel, the principle used (acoustic, electromagnetic radiation, light, etc) and the application to certain kinds of flow measurements. A good tomography sensor should be non-invasive and non-intrusive. It should not necessitate rupture of the walls of the pipeline and should not disturb the nature of the process being examined.

Optical tomography involves the use of non-invasive optical sensors to obtain vital information in order to produce images of the dynamic internal characteristics of process system (Sallehuddin et al., 2000). It has the advantage of being conceptually straightforward and relatively inexpensive (Hartley et al., 1995). The optical tomography system uses a number of light emitter-receiver pairs and a wide variety of light sources such as visible light, infrared or laser light. Its working principle involves projecting a beam of light through a medium from one boundary point and detecting the level of light received at another boundary point (Ruzairi, 1996). For the type of projection used in the system, it can be a parallel beam (orthogonal) projection, rectilinear projection, fan beam projection or a mixture of projection types. The corresponding applications are in pneumatic conveyors for food processing industries, plastic product manufacturing and solids waste treatment. The specific measurements of it are flow concentration, flow velocity and mass flow rate determination.

2.0 GENERAL IMAGE RECONSTRUCTION SYSTEM

A general optical flow imaging system is constructed by using optical sensors, signal measurement circuitry, a data acquisition system, and a computer acting as data processing unit and display unit. The system designed for this project is illustrated in Figure 1. It can be noticed that there are two tomography sensors in this project, which are upstream sensor and downstream sensor. Thus, the developed system will display two tomograms using the program written.

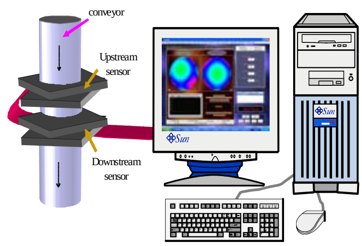


Figure 1 General system configuration

In this project, the process flow timing structure is shown in Figure 2. One frame of the process starts from data capturing, data processing up until the final stage of displaying both upstream and downstream cross-sectional images on screen.

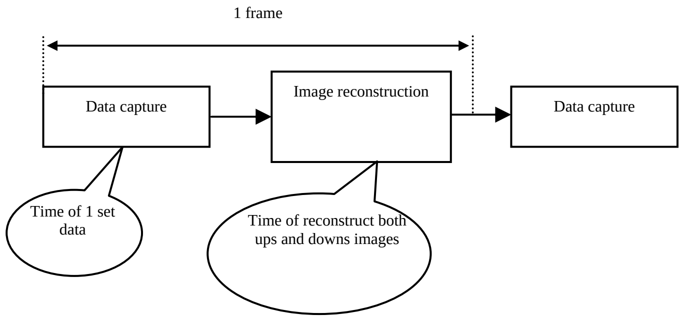


Figure 2 Process flow timing structure using a single processing unit

3.0 DATA DISTRIBUTION SYSTEM

This system uses multiple processing units to replace a single processing unit in Figure 1. Two PCs are used, namely PC1 and main PC. Both PCs communicate with each other through the local area network that has been setup for them. The establishment of 2 PCs network is using WinSock programming function. All relevant steps are shown in the flow diagram of Figure 3. The flow diagram explains the process performed by PC1 and mainPC to set up a connection for data exchange in network using TCP reliable data delivery protocol. Practically, it is very difficult for two computers to run programs at the same time; therefore the program in mainPC starts before PC1. Without user's interruption, program will create UDP and TCP sockets automatically. The TCP socket stays in listen mode whereas UDP socket stays in receive mode. Another socket of UDP will broadcast an argot. The argot used is 'TN' with the purpose of giving opportunities to other PCs to make TCP connection to the broadcaster if a match occurs. It is imperative to allow such establishment when two or more data distribution systems are constructed in the same local area network bto ensure all systems' operation will not crash with one another. Since UDP socket of PC1 is not operating in receive mode during broadcasting of mainPC, PC1 is unable to make TCP connection to mainPC. Conversely, when PC1 broadcasts the argot, UDP socket of mainPC is in receive mode and enabling mainPC to make a TCP connection to PC1. TCP socket of PC1 will accept the connection because it always stays in listen mode.

Finally, 2 PCs system is established and ready for data exchange in measurement process.

The hardware configuration of this network system is shown in Figure 4. All PCs will be linked to a switch via UTP cable. One end of the cable connects to the RJ45 socket on the NIC of PC and the other end connects to the socket provided by a switch. Only the mainPC will connect to display unit (monitor). The PC1 of the system functions to capture data from optical tomography sensors via the DAS card that is plugged into the PC. The mainPC reconstructs the cross-sectional images of upstream sensor and downstream sensor, then displays them via the monitor. The whole process flow timing structure is presented in Figure 5. One frame of process starts with PC1 captures data from sensors, then compiles the data to the corresponding format and sends to mainPC. The process is ends when mainPC successfully receives data, reconstructs and displays both upstream and downstream cross-sectional images via the display unit.

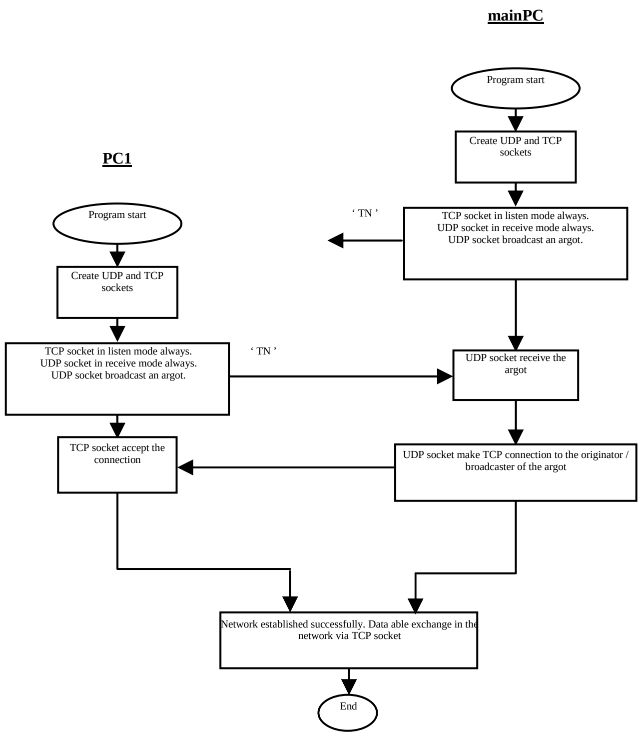


Figure 3 Flow diagram for network establishment in 2PCs data distribution system

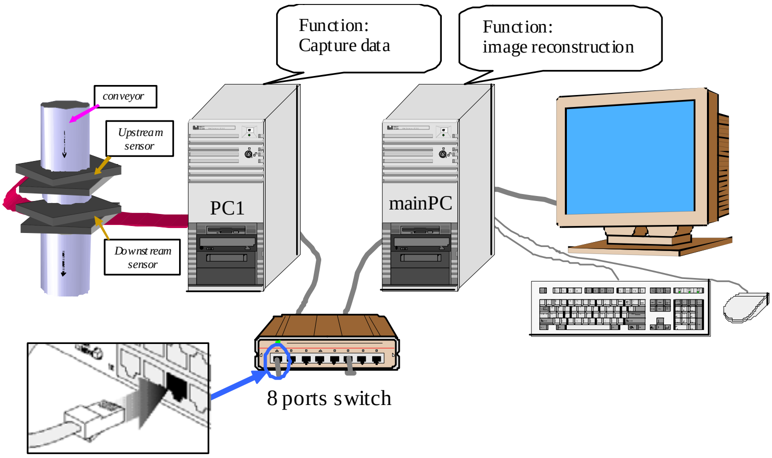


Figure 4 Hardware configuration of data distribution system in image reconstruction system

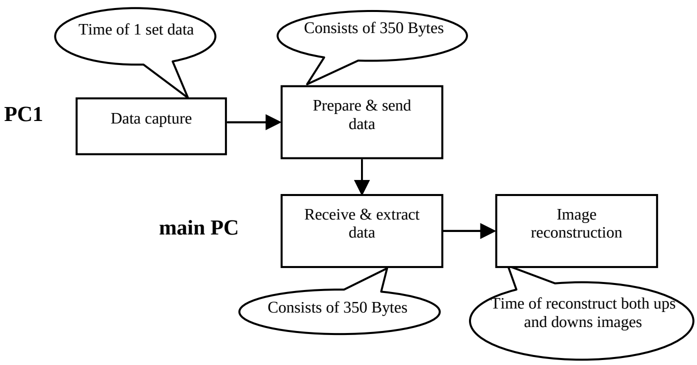


Figure 5 Process flow timing structure using data distribution system

4.0 IMAGE RECONSTRUCTION AND RESOLUTION

The Hybrid image reconstruction algorithm is used to reconstruct the image. This algorithm was proposed by Sallehuddin (Sallehuddin , 2000). The main purpose of it is to improve the accuracy of the image reconstruction using LBP by neglecting the blurry image. The algorithm assumes binary values from the sensor, either zero for no material or one for the presence of material (Sallehuddin , 2000). The sensor value is first measured, if the reading is zero, then any pixels traversed by that sensor's beam are set to zero and omitted from further calculations. The rest of the pixels will be involved in the Linear Back Projection algorithm.

There are 5 types of resolutions to be investigated in this project, they are the 16×16 pixels, 32×32 pixels, 64×64 pixels, 128×128 pixels and 256×256 pixels. The resolution starts at 16x16 pixels because it is the hardware resolution of the optical tomography sensors being used. Figure 6 shows the cross-sectional images reconstructed using different resolutions.

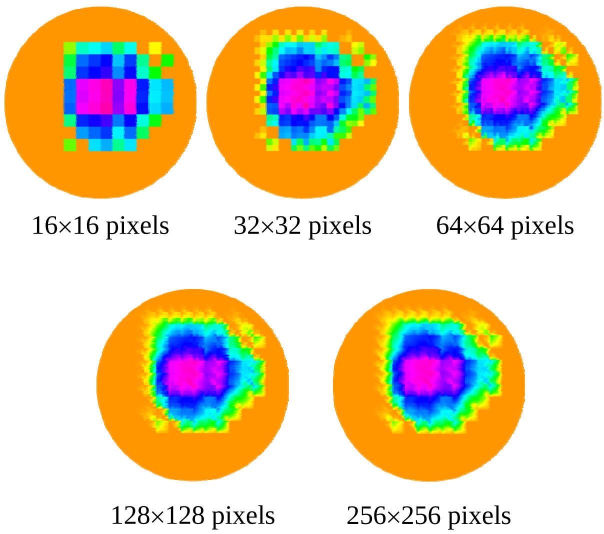


Figure 6 Results obtained from with different image resolutions

5.0 RESULTS USING SINGLE PROCESSING UNIT

The real-time performance of image reconstruction system can be evaluated by measuring the image refreshing rate. This refreshing rate is based on the number of upstream and downstream cross-sectional images displayed per second. The corresponding unit is frames per second (fps). The measurement results using single processing unit (general system) are shown in Figure 7. From the observation, the higher the image resolution, the lower image refreshing rate. This is because longer processing time is needed to compute higher resolution images.

For all image reconstruction systems in this project, the processor's specification is Pentium 4 (2.4GHz) and 512 MB RAM.

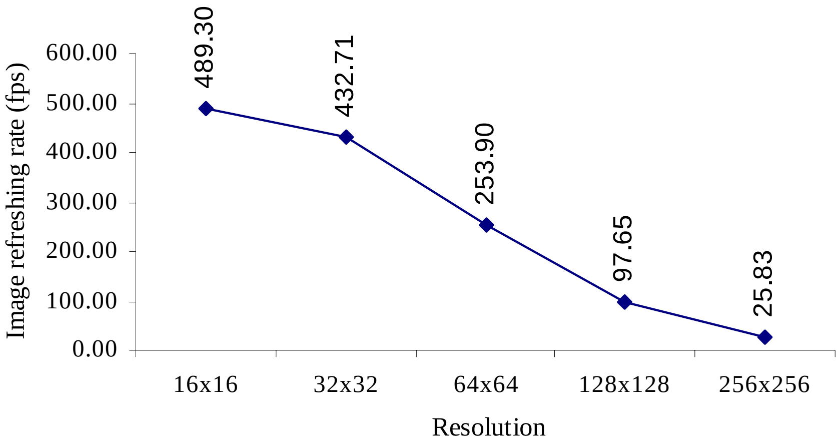


Figure 7 Measured image refreshing rate using single processing unit

6.0 RESULTS OF DATA DISTRIBUTION SYSTEM

The measured image refreshing rates using two processing units are shown in Figure 8. It is noticed when the resolutions used are 16x16 pixels and 32x32 pixels, the image refreshing rate is the same because both have the same processing time per frame. This can be explained by referring to Figure 9. To reconstruct the cross-sectional images using data distribution system, one frame of data processing time can be reduced because PC1 and main PC in the system perform parallel data processing. Therefore, one frame of data processing time can be determined by observing the longest processing time used either in PC1 or main PC. In the cases of 16x16 pixels and 32x32 pixels resolutions, the longest processing time will occur in PC1 and this result in both of them have the same image refreshing rate. From the 64x64 or higher pixels of timing diagram in Figure 9, the processing time per frame is obtained from main PC. Thus, its image refreshing rate drops compared to the previous cases.

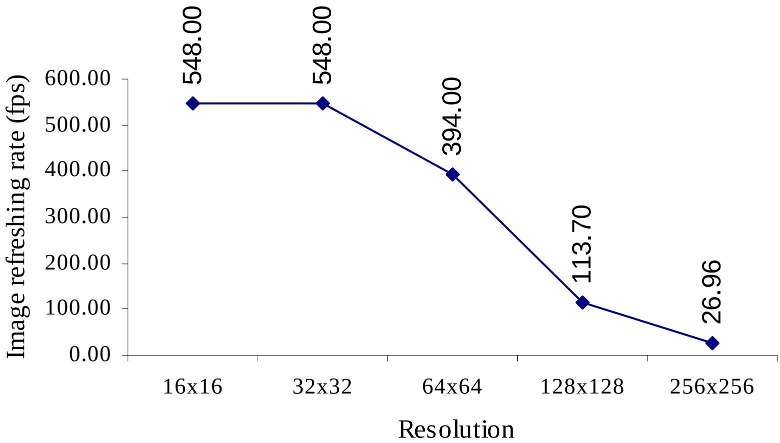
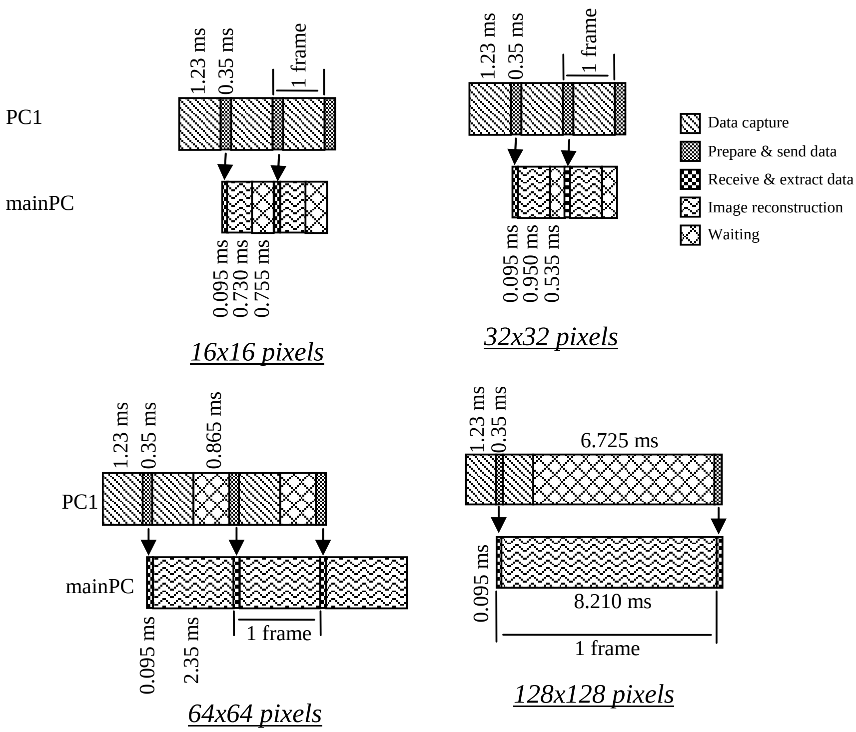


Figure 8 Measured image refreshing rate using data distribution system



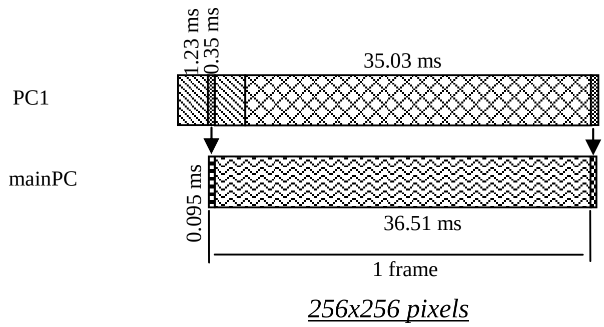


Figure 9 Predicted process times in flow timing diagram of data distribution system

For five distinctive image resolutions, the percentage of utilization for PC1 and mainPC are shown in Table 1. This percentage utilization provides the information of whether the data distribution system can operate in parallel data processing and achieve optimization. It is computed by summing all processing time of the relevant PC and is divided by the total time per frame.

Table 1 The percentage utilization of PCs in data distribution system

Image resolution	**% Utilization**	
	PC1	**mainPC**
16x16	100.00	52.22
32x32	100.00	66.14
64x64	64.62	100.00
128x128	19.02	100.00
256x256	4.32	100.00

Basically, the rule of using data distribution system is based on the data processing time. The data processing time must be much greater than the data transfer time, and this includes data formatting and extracting time. Besides, the %utilization of computers used in the data distribution system is also a crucial element. If the %utilization of a PC in data distribution system is low, the parallel data processing method cannot work successfully because the PC has only a small task to be computed whereas the other PCs have much heavier tasks. The system achieves optimisation when all PCs within data distribution system have the %utilization near to 100%.

7.0 SYSTEM IMPROVEMENT

By referring to the image refreshing rates of image reconstruction system measured by a general system and data distribution system respectively, it can be noticed that the data distribution system is able to improve the performance of the image reconstruction system as presented in Figure 10. The graph shows that the %improvement is incremental at the first three resolutions.

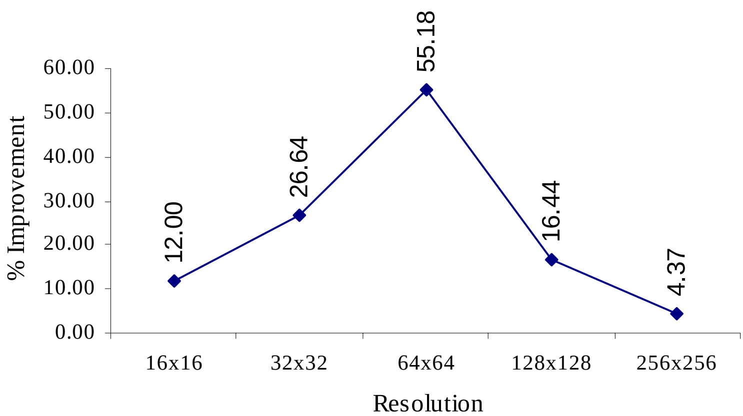


Figure 10 The graph of % improvement of image refreshing rate by using data distribution system

Then, the %improvement decreases dramatically. The peak of %improvement occurs at the resolution of 64x64, which is 55.18%. The %utilization of PC1 and mainPC at this resolution are 64.62% and 100% respectively. The data distribution system performs parallel data processing efficiently in this case. For the resolution of 256x256, PC1 has the lowest utilization because it must wait 35.03 ms to ensure that mainPC has already completed the image reconstruction process before capturing the new data. As a result, the data distribution system is unable to increase % improvement of image refreshing rate at higher resolutions.

8.0 CONCLUSION

This paper presents a method of improving the performance of real-time image reconstruction system especially for those systems that have longer data capturing process (depending on the amount of data readings from tomography sensor). For an offline simulation system, the image refreshing rate can attain 3000 fps. The main consideration for the image refreshing rate is how fast data capture from a sensor can be done. The data distribution system is the best solution for improving any existing system having this kind of problem.

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