Optimization of Data Acquisition System with Parallel Collection for PET

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ABSTRACT

We are under development of a 3D PET scanner with depth of interaction (DOI) capable of high sensitivity and high resolution. In this scanner, a maximum data transfer rate of coincidence pair's event information is 10 Mcps and one event is a 64-bit data format. This maximum data transfer rate corresponds by 10 times a conventional PET scanner. A data acquisition system, which fulfills the specification of this scanner, is considered for parallel collection with banks including several coincidence units. Data transfer rate is improved by optimizing parameters of a message size, and so on.

Keywords: PET, data acquisition, parallel collection, list-mode data.

1. INTRODUCTION

A next generation PET scanner capable of high sensitivity and high resolution is now under design at National Institute of Radiological Sciences (NIRS). Depth of interaction (DOI) information will avoid the degradation of spatial resolution and the DOI PET scanner can strike a balance between high sensitivity and high resolution.[1] This PET scanner is small detector ring diameter and large axial view. A number of coincidence pairs are 10G for structure of four stages in the DOI detector. Therefore, measurement data is collected by a list-mode data format (event by event) as opposed to conventional histogram format. A 64-bit data format[2] is needed for one coincidence event and count rate capability must be more than 10 Mcps (80 MB/s). This value corresponds by 10 times the conventional PET scanner. In this work, list-mode data acquisition is considered for parallel collection with banks including several coincidence units. In this parallel collection system, list-mode data collected by multiple nodes are transferred to a personal computer (PC) through Ethernet for processing of image reconstruction. The data transfer rate with multiple nodes should be improved by optimizing parameters of a message size, and so on.

2. DESCRIPTION OF THE ARCHTECTURE

2.1 Scanner Designs

The next generation PET is a 3D PET scanner for brain studies now under construction. The purpose of this scanner is high spatial resolution kept high sensitivity using the DOI detector. The major aspects of this PET scanner are shown as Table 1.

Table 1. Major aspects of the next generation PET scanner

Crystal material	GSO
Crystal size	$2.9x2.9x7.5mm^2$
Number of crystal	122,880 (384 / ring)
Number of PMT	60 (24 /ring)
Number of ring	80
Number of depth	4
Ring diameter	382 mm
Axial FOV	258 mm
Time window of coincidence	Under 8 ns
Transfer speed of coincidence	10 Mcps
Data acquisition mode	List and histogram

The detector unit consists of 8x8 crystal blocks with four stages of 2x2 GSO arrays coupled to a 52 mm squire PS-PMT having 16x16 multi-anodes.[3] Axial view is 25 cm for promotion of volume imaging and this value corresponds by about two times the conventional brain PET scanner. Therefore, a number of coincidence pairs are 10 G over and the data size becomes fuge.

2.2 Data Acquisition System for PET

Fig. 1 shows example of construction of the data acquisition system using the several parallel PCs. One node with banks including several coincidence units consists of PCs and SCSI-IF protocol. This method can be applied flexibly, when the composition of a detector system changes and the remaining computer resources can be used for calculation of image reconstruction. The coincidence pair events are fed to several data acquisition PCs in parallel through SCSI-IF. These data are stored on PCs concurrent with the data being transferred to a server PC through Ethernet. Network architecture is Gigabit Ethernet for a bandwidth of 80 MB/s. Data acquisition PCs has 32-bit Ethernet board and the server PC has 64-bit Ethernet board for concentrating the coincidence data. The collection data in the server PC are dumped in a RAID HDD by list or histogram mode. Tens of gigabyte of disk storage is needed for list-mode data stored. Since multitask and concurrent processing is needed, these PCs are operated on Linux.

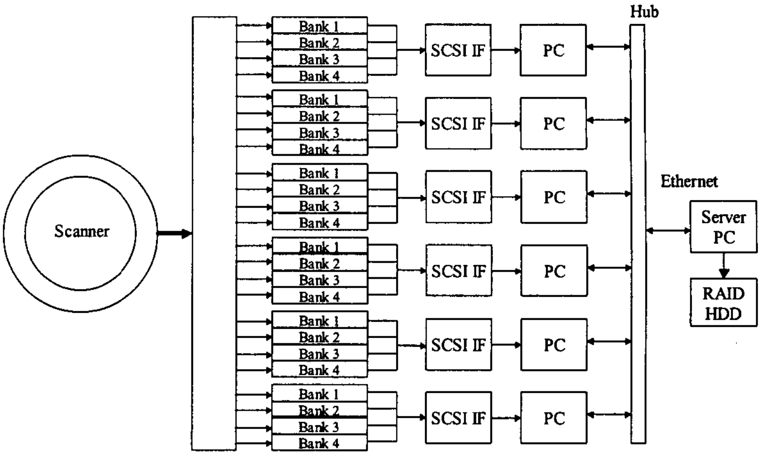

Fig. 1 Example of construction of data acquisition system fo next generation PET

3. SIMULATION STUDIES

Using a simulator, which can imitate list-mode data acquisition with multiple nodes, list-mode data acquisition method were studied to suitable for the next generation PET. Fig. 2 shows as the block diagram of simulator of parallel collection system, which composed of two stand-alone simulators and the server PC. Each stand-alone simulator is composed of data generation PC, data processing circuit, SCSI-IF and data acquisition PC. Data generation PCs generate list-mode data at imitate counting rate configured in advance. This list-mode data provides for Monte Carlo program[4]. Data processing circuits modify the list-mode data format and adjust a timer tag, and so on. The maximum imitate counting rate is 2.5 Mcps per one node, but this value is restricted to the maximum transfer rate of SCSI-IF (ULTRA-SCSI). Data acquisition PCs receive modified list-mode data through SCSI-IF and buffer them for sending to the server PC through Ethernet. The server PC dumps list-mode data in a HDD. Data acquisition PCs and the server PC connect Ethernet through a switching hub. Optionally, stand-alone simulation is acquisition method stored list-mode data in the data acquisition PC without network transfer as shown in Fig. 2. In stand-alone simulation, data transfer of SCSI-IF can be evaluated. Up to now, data acquisition for the PET had been histogramming, but list-mode data acquisition is suitable for the 3D PET more than histogram mode, because a fuge number of address is needed at the 3D PET in histogram mode. Using above simulator, we estimated the data transfer rate by list-mode data against imitate counting rate as shown in Fig. 3. The maximum data transfer rate in the stand-alone simulator was 12.0 MB/s. The maximum data transfer rate to the server PC was 11.0 MB/s with one node and was data loss of 5 % in the absence of network transfer. The

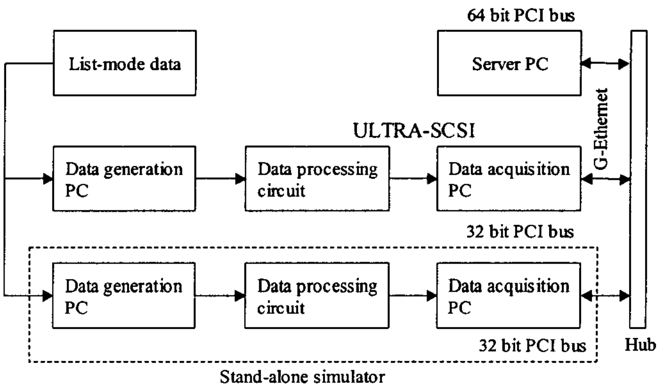

Fig. 2 Block diagram of simulator for parallel collectio system.

maximum data transfer rate with two nodes was 21.8 MB/s and twice about one node. Message size is important factor of such data transfer. Fig. 4 shows the data transfer rate with one and two nodes against message size. (Imitate counting rate was fixed 2.0 Mcps and interval of message size was increased per 256 byte.) A discontinuity is confirmed at several points with either node and appears clearly in high transfer rate.

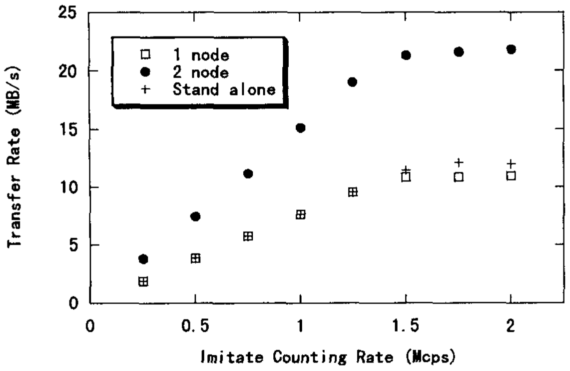

Fig. 3 Transfer rate against imitate counting rate.

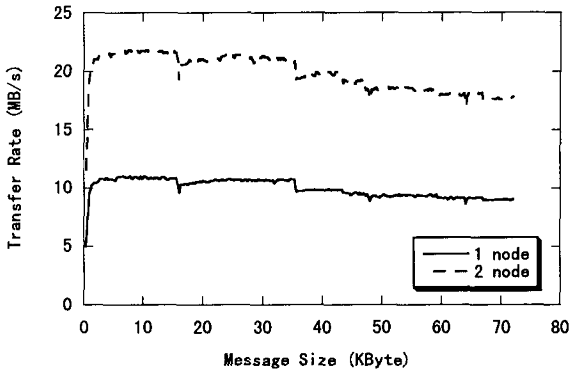

Fig. 4 Transfer rate against message size.

4. DISCCUSION AND CONCLUTION

As the result of simulation studies, the maximum data transfer rate of the stand-alone simulator was 12.0 MB/s, and the maximum data transfer rates at the server PC with one and two nodes were 11.0 and 21.8 MB/s, receptivity. In one node, several percents of data loss was occurred by adding the process of network transfer. Moreover, it is thought that the slight data loss in two nodes is based on the collision by simultaneous transfer. As those data losses are improved, buffer memory is set between data acquisition from SCSI-IF and data transfer process in data acquisition program. A part of list-mode data is stored buffer memory in high-count rate (over 1.5 Mcps), and this data is transferred to the server PC after data acquisition or during low count rate. In list-mode data acquisition, since event information includes timer tag, it is easy that data is rearranged by time line. Distributing list-mode data in high-count rate can avoid data loss by network transfer. In parallel collection, the data transfer rate is implemented by selection of suitable message size. This optimization will be more important in high transfer rate. In this work, evaluation of data transfer with one and two nodes was confirmed. Hence, we will be to estimate the maximum transfer rate and collision by simultaneous transfer and all in structure of actual equipment. Since this scanner is an experimental model for research, data acquisition system is to be advanced towards collecting all data as much as possible.

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