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SYSTEM ARCHITECTURE FOR HIGH SPEED RECONSTRUCTION IN TIME-OF-FLIGHT POSITRON TOMOGRAPHY

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Summary

A new generation of Time Of Flight (TOF) positron tomograph with high resolution and high count rate capabilities is under development in our group.

After a short recall of the data acquisition process and image reconstruction in a TOF PET camera, we present the data acquisition system wich achieves a data transfert rate of 0.8 mega events per second or more if necessary in list mode.

We describe the reconstruction process based on a five stages pipe line architecture using home made processors. The expected performance with this architecture is a time reconstruction of six seconds per image (256x256 pixels) of one million events. This time could be reduce to 4 seconds. We conclude with the future developments of the system.

Time of flight principle and advantages

Usually positron imaging is based on the coincidence detection of the two anninilation photons that are nearly colinearily emitted after the positron-electron annihilation. As the annihilation photons are emitted simultaneously the time difference of the photons arrival at the detectors depends on the difference between the distances separating the event from the detectors (Fig. 1). This method of measurement is called the "time of flight" (TOF) method.

The introduction of the TOF information in the reconstruction process is known to improve the signal to noise ratio of the reconstructed image, to reduce the angular sampling requierement, to greatly reduce the amount of random coincidences and permits a correct transmission measurement [1], [2], [3]. As demonstrated by MULANI and all [4] we can use the TOF information to produce a 3-D imaging using cross sections and improve the total sensitivity.

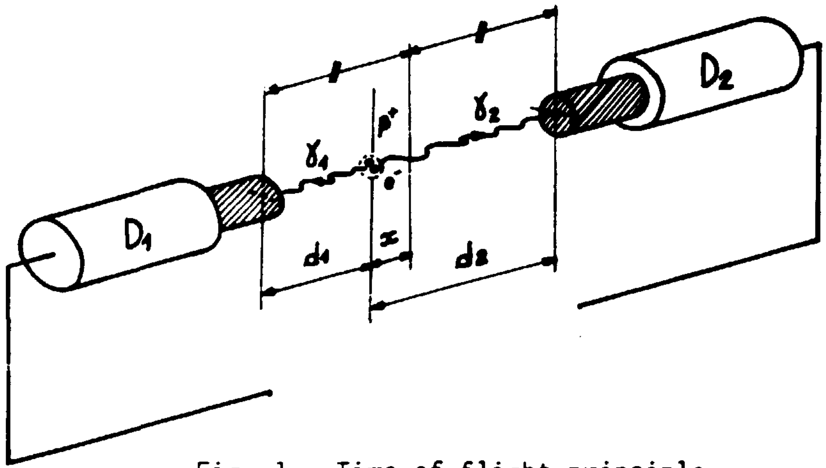

Fig. 1 : Time of flight principle

Data collection process

The high resolution camera with 3-D capabilities uses up to six rings of 324 probes (BaF^2 + PMT) organized in 27 banks of 12 detectors. When a coincidence detection occurs we get the following informations :

SC - identification of coincidence surface (associated rings)

C - identification of the coding system (two associated banks)

PD,PA - identification of the two detectors from the two banks

V - TOF measurement along the coincidence ligne.

As the gantry wobbles it is necessary to get information about the wobble position in order to compute the absolute position. This information just as physiological signal (for gated studies) are packed in one or two words of label data. The label data are mixed with the raw data flow and stored in list mode on a magnetic disk.

Image reconstruction

In this algorithm we use the concept of "histo-projection" which is the set of all the TOF histograms with the same direction (Fig. 2). The raw data are reorganized in a set of histo-projections, then we smooth the TOF information with a gaussian function, and after correction for attenuation sensitivity and random events every histoprojection is rotate according to its angular position and accumulated on the image grid to form what we call the "pre image". This image is filtered using 2 D FFT algorithm to remove the blurring effect of measurements. The discribed algorithm is known as the Confidence Weighting algorithm (C.W.)

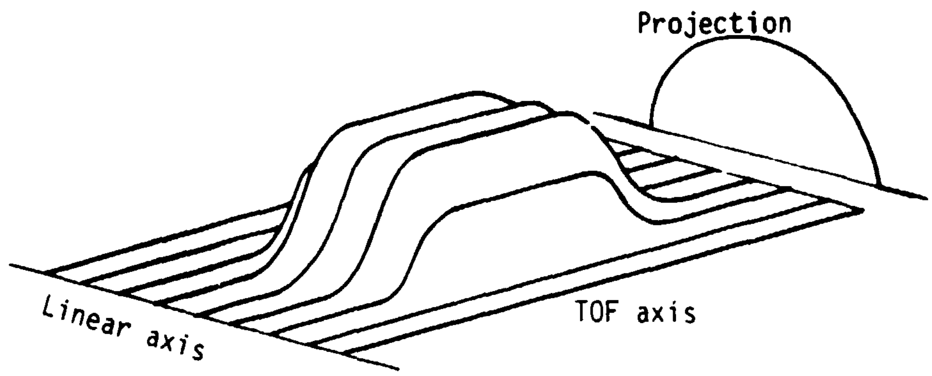

Fig. 2 . histo projection VS. projection

Description of the data acquisition system

As described previously the data acquisition system (DAS) receive information from the coding system and from the mecanical management system. For data compression and to facilitate post reading of the disk the raw data flow is pre processed in real time (TOF calibration, organisation of commonly oriented paths for relative direction and plane).

All the pre processed informations and the label data are stored in the blocks of large high speed MOS memory (2 M bytes 100 ns) called the acquisition memory (AQM) the maximum count rate is in this memory 1.8 Mega events per second for all the slices. Each memory block is then transfered on the 600 Mbytes disk through the disk coupling system module (DCS). With 2 disk modules the acquisition speed in list mode is 800 kilo events/second.

Histogram processor

This special home made processor can compute three kinds of histogram :

1 - Regular histogram : data retrieved from the disk are sorted with respect to direction, track and time of flight class and the histo projections are stored in the histogram memory. The number of direction is reduced from 324 to 54. The duration of this operation is entirely masked because it does not exceed the reading time of the disk.

2 - Non TOF histogram with TOF selection : In order to estimate the sensitivity of each detector pair and the attenuation introduced by the patient we use a ring source of positron emitter. With this design we can eliminate a large amount of random events by TOF windows and calculate projection free of random events.

3 - TOF histogram : we need a special histogram to estimate the calibration of the TOF coding system.

C.W. smoothing and back projection

After correction and angular reduction of histo-projections, the data are smoothed along the TOF axis with a gaussien sphaped function. The histo-projections are then rotated and added into the pre image memory. Assuming an image size of 100 K pixels and a memory cycle of 0.5 μs the time needed for the rotation (bi-linear interpolation) is 50 ms per direction so 2.5 s for 54 angles. The total time for smoothing and rotation is then about 3 s.

Bidimensionnal filtering

This 2 D fillering uses the classical FFT algorithm along row and collums of the image matrix.

The FFT processor used needs 3 ms to perform a 1024 real values FFT and the filtering time is then 3 s for a 100 K pixels image (24 bits).

Expected performances

Each processor is composed of microprogrammable bit-sliced devices organized in 16 or 24 bits architecture, using a one level pine-line structure.

For one million of recorded events a time reconstruction of six seconds per image is expected (256 x 256 pixels) in a 2 levels of pipe-line structure.

Future developments

With a three level pipe line we can reduce the time reconstruction to the time needed to read the data from the disk and obtained a ultra speed reconstruction 3 secondes per image. This will increase the amount of buffer memories, the complexity and the cost of the system.

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