Computational Aspects of Depth-Weighted Maximum Projection

TO THE EDITOR: SPECT has become a routine clinical nuclear medicine tool and requires comprehensive displays obtained in reasonable computing times. Besides the simple but tedious display of all the slices in each plane, specific solutions have been proposed, some of them dedicated to specific organs: three-dimensional surface display (*1*), polar plotting (*2*), and axonometry (*3*). A very impressive shine-through rotating display based on depth-weighted maximum projection (DWMP) recently has been proposed by Wallis and Miller (*4*). In recent issues of the *Journal*, they described application of DWMP to gated blood-pool SPECT (*5*) and elegantly analyzed theoretical basis of volume-rendering by DWMP (*6*). Since we have developed our own DWMP software (*7*), we would like to point out some computational aspects.

1. Computation time can be saved by setting the number (N) of angular views to a multiple of 4, say N = 4n. Thus, only n-1 volume rotations are needed: for a given rotation at α, applying DWMP successively from front to back, from right to left, from back to front, and from left to right gives angular views at α, $\alpha + \pi/2$, $\alpha + \pi$, and $\alpha + 3\pi/2$. But when applied as described, this method requires a very large computer memory:

- Volume rotations must be performed from the original unrotated data rather than from already rotated data in order to avoid propagation of blurring.
- The rotated volume must be saved before each of the 3 first DWMP operations.

So that 3 cubic sets + N final angular views must be stored and available in RAM, which is beyond the capacity of most nuclear medicine computers.

2. Computer memory can be saved when applying the above principle by successively processing single transversal slices for rotation and single columns or rows of DWMP: thus, the required memory is reduced to 1 cubic set (original data) + 1 work frame (current rotated slice) + N result frames.

3. Depth-weighting is necessary, as pointed out by Wallis and Miller (*6*) and by Keyes (*8*), but human visual perception is more concerned with the propagation of light than with the attenuation of gamma rays. Thus, it could be thought that an inverse square function would be a better choice than an exponential function. As a matter of fact, any decreasing function can be used, since the purpose is mainly to avoid apparent rotation reversal. We therefore chose a simple linear model of the form $fi = 1 - i/k$, where i is the depth in pixels (e.g. 0 to 63), fi the weighting factor, and k a user-selected parameter that has a very concrete meaning: all the voxels beyond the kth plane from the eye are masked. In routine applications, k = 63 for 64 × 64 × 64 data has been found to be satisfactory. The weights are linearly decreasing from 1 in the nearest cube side to 0 in the farthest cube side.

Using the fast algorithm described in principles 1 and 2 when writing a DWMP program results in computing times and memory saving consistent with routine daily use of DWMP with probably almost all nuclear medicine computers. For example, our program was written in Forth on a 68020/16MHz based computer (Sophy P, Sopha Medical, Buc, France): 32 views of a 64 × 64 × 64 cubic set are computed in less than 2 min and require only 776 kbytes of memory (= (64 + 1 + 32) frames × 8 kbytes/frame). The question addressed in principle 3 is of minor importance, but a simple user-interaction should not be neglected.

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REPLY: We are basically in agreement with the points made by Gremillet. Regarding his specific comments:

1. Even if the cube is processed as a whole, as in Gremillet's first point, the angular views may be written out to a disk individually as they are created and depth-weighting may be performed at the same time as the maximum is selected, essentially halving RAM requirements from 3 cubic sets + N angular views to 2 cubic sets + 1 angular view.
2. If RAM requirements need to be reduced to the minimum, the method suggested in his second point can be further optimized by loading only a single slice of the original data into RAM at a time, reducing memory requirements even below that suggested by Gremillet; however, this may slow processing due to a need to recompute the rotation for each slice.

The choice of depth-weighting method is arbitrary, but any method takes essentially equal computation time since the weighting factors can be stored in a small array after computing them once.

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