2004 Workshop on the Nuclear Radiology of Breast Cancer
Rome (Italy) October 22-23, 2004

Image Processing Algorithms to Facilitate and Enhance Sentinel Node Detection Using a Hand-Held Gamma Ray Camera in Surgical Breast Cancer Staging

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Abstract

We have developed a miniature scintillation camera to be used in surgical cancer staging. The availability of such a compact hand-held gamma camera may in certain cases improve localization of the sentinel lymph node and reduce the duration of a surgical breast cancer staging procedure. We have investigated image processing algorithms applied to planar images that may improve node detection capabilities for breast cancer staging. We have also studied contrast enhancement methods that may be able to identify nodes that would otherwise be missed. Exposure duration for a given camera position can be adaptively shortened or increased by using an optical flow algorithm to estimate camera motion with respect to the current frame. By determining if the camera is in motion or not, the exposure time may be increased to allow more image counts to accumulate at a given camera position. Adaptive exposure time may improve the ease of use of the hand-held camera, and allow regions of interest to be imaged more effectively. We feel that these image processing techniques can improve the utility of a hand-held gamma ray imager for sentinel lymph node detection during breast cancer staging.

KEYWORDS: Gamma Camera, Image Processing, Optical Flow.

1. Introduction

The practicality of hand-held planar gamma ray imaging during surgical cancer staging may be improved through image processing techniques. Automatic controls of camera parameters allow the surgeon to focus on locating the sentinel node without the burden of adjusting many parameters to get an usable image. Some of the techniques we explored are: Gaussian filtering in the spatial domain and the temporal domain help reduce noise from the very low number of counts that are collected from weak sources in a cold to hot background. Bi-cubic image resizing is used to improve the visualization from the low spatial resolution image data. Non-linear image compression can bring out small weak sources when much brighter intense sources are within the same field of view (FOV). Optical flow is used to set the exposure duration to decrease the number of events that are included in a frame when the camera is moving.

2. Theoretical Background

The Lucas-Kanade optical flow constraint equation assumes that the intensity is constant over motion that involves translation and rotation over small distances [1].

$$(\nabla E)^T \cdot \vec{v} + \frac{\partial E}{\partial T} = \vec{0} \qquad (1)$$

$$\vec{v} = -\left(\nabla E^T \cdot \nabla E\right)^{-1} \cdot (\nabla E)_T \cdot \frac{\partial E}{\partial t} \qquad (2)$$

With this assumption (1), one can solve for the velocity vector (2) for each pixel centered over a small neighborhood, or over the entire camera field (if the entire field is moving).

3. Materials and Methods

A hexagonal parallel hole collimator with 1.3mm hole size and 0.2 mm septa is coupled to a 29x29 pixellated 1.5x1.5x6 mm3 NaI(Tl) scintillation crystal with a flat panel multi-anode Hammatsu H8500 Position Sensitive Photomultiplier (pspmt) and read out using a Symmetric Charge Division pcb Circuit. To simuladte the sentinel node for this work, we used spherical cavities filled with 64 μCi/cc of Tc-99m placed in a plastic disk that was suspended in water. The sphere sizes ranged from 3-8 mm in size, corresponding to approximately a 1-9 μCi total activity range per sphere.

First, the spheres were imaged from 120 seconds and 5 seconds at a depth of 1.6 cm in water. Standard image processing algorithms were individually compared and ranked on their relative improvement to visual quality.

Secondly, the camera was turned upside down and the spheres were moved across the face of the camera in several directions and at different speeds. An optical flow algorithm was run on the frames with a fixed time window of various exposure durations. The velocity of each individual frame was calculated and compared to an acquisition where the spheres were held still. A simple velocity threshold determines if the frame is in motion or not.

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The optical flow is only being used to determine if there is motion in the frame. The entire display algorithm (see Figure 1) uses the optical flow for optimal smoothing in the time domain, while 2-D image processing techniques smooth and compress the intensity data.

4. Results

A. *Image Processing*

Image Resolution can be improved by resizing the image using interpolation to create more pixels (see Figure 2B). Image resizing is itself a filtering process and provides only a very limited amount of noise suppression, especially in images with very low numbers of counts.

Compression of the image intensity using a nonlinear function such as square root can bring out small weak features in images (see Figure 2D). Compression has a high pass filtering effect of amplifying image noise. This can be counteracted by using Gaussian filtering to remove the noise (see Figure 2E).

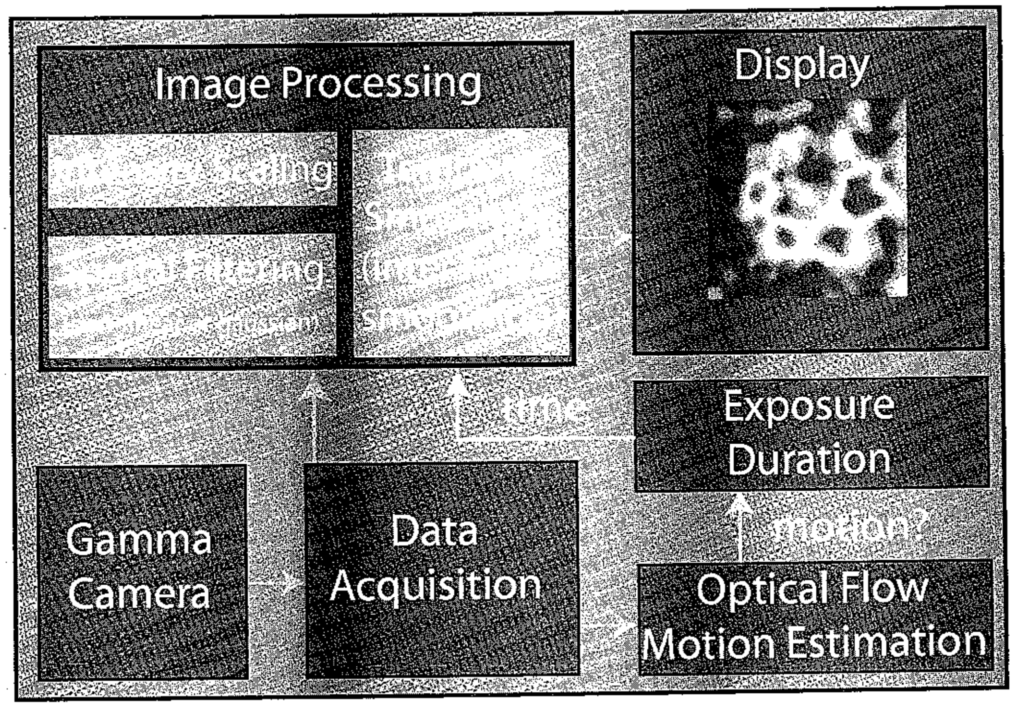

Fig. 1. Block diagram of the display algorithm for the gamma camera. The optical flow velocity is turned into a boolean state, motion or not motion, and used to either increase or decrease the current exposure duration.

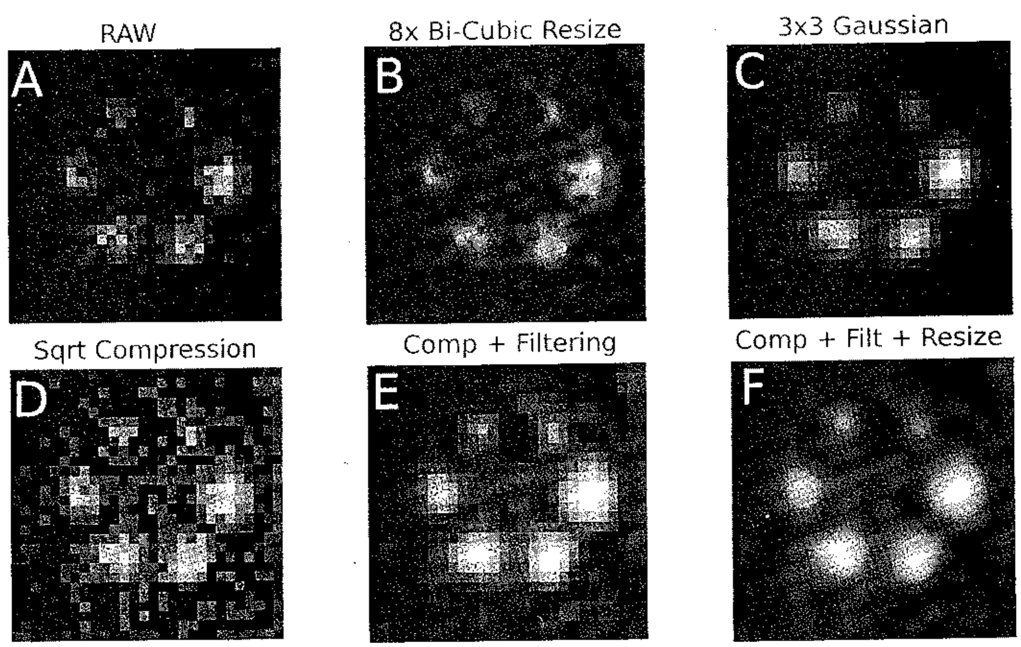

Fig. 2. Comparisons of different image processing techniques. The raw data consists of a 5 second acquisition of the sphere phantom at a depth of 1.6 cm in a water scattering media. Compression and filtering (F) brings out weaker nodes versus large hot objects but at the sacrifice of some resolution.

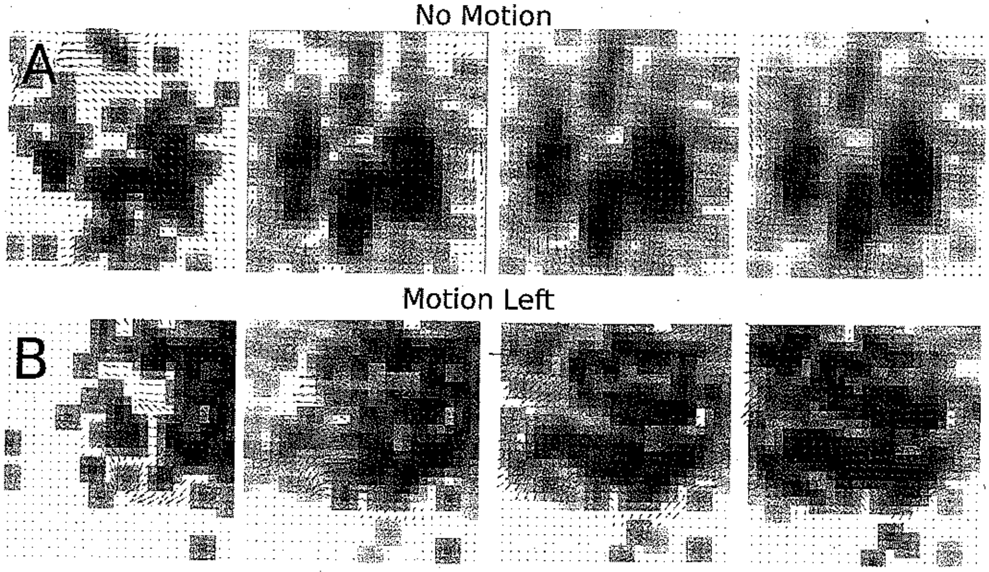

FIG. 3. Motion flow vectors (gray arrows) are superimposed on top of spatial and temporally smoothed frames from two separate sequences. In sequence A, the sphere phantom was held directly over the face of the camera. In sequence B the sphere phantom was moved from left to right. Strongly correlated motion occurs in sequence B because the entire field of view is moving, whereas in sequence A, the flow vectors average to a small magnitude because of the lack of motion.

B. *Optical Flow*

In Figure 3, the optical flow vectors are solved for three short sequences of frames taken with a hand-held gamma camera. If the optical flow vector for the entire frame was robust (determined by the eigenvector magnitudes) and the absolute magnitude of the average velocity for the entire frame is greater than 0.25 pixels/second, then the algorithm will detect motion for that frame (see grey line Figure 4). This will lead to an incremental decrease in the exposure duration for display. If no motion is detected for a sequence of frames, then the exposure duration will increase, allowing more counts to accumulate in a frame (see Figure 1).

5. Conclusions

Non-linear compression and Gaussian filtering can enhance the detectability of small nodes in the presence of injection site activity. There is enough signal for optical flow to detect motion, avoiding the cost of implementing an external motion sensor. Therefore, the detection of motion can be used to adpatively set the exposure duration.

Acknowledgements

This work was supported in part by grant RG-01-0492 from the Whitaker Foundation.

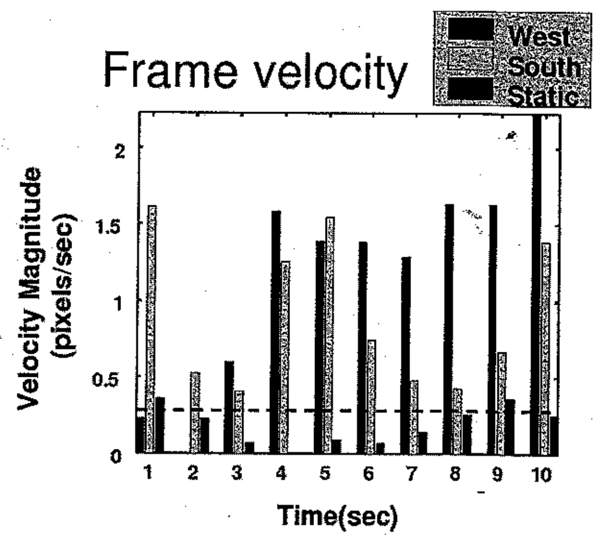

FIG. 4. Average velocity for three different motion sequences. The dotted line is the velocity threshold. If a frame crosses this threshold, the motion is detected for a frame and the exposure duration is decreased. Two of the motion sequences, west and south, cross the velocity threshold over a ten second acquisition, while non-motion is reliably detected in the static sequence. There is some motion in static sequence because the phantoms were hand-held with a small amout of motion.

References

[1] Lucas and Kanade. An iterative image registration technique with an application to stereo vision, proc. DARPA Image Understanding Workshop, 1981: pp. 121-130.