BodyGuard

Automatic Body Contouring with BrightView SPECT Series

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Introduction

Standard use of nuclear medicine gamma cameras requires that the detector be placed very near the patient's body for optimal image quality. Since gamma camera detectors are extremely heavy, they are controlled by robotic manipulators. It is necessary for these manipulators to have information on the location of the patient in order to maintain the desired separation between the detector and the patient's body.

In current nuclear medicine implementations, the robotic manipulators are either guided by an operator to learn the body's location, or fitted with external optical transmitters and receivers to locate any object near the face of the detector. The operator-based methods are reliable, but require an additional step in the image collection process to manually "map" the patient. This mapping adds time to the patient setup, ranging from a few seconds to a few minutes per patient. The optical-based methods are capable of detecting any opaque object that blocks a beam of light transmitted across the face of the detector. The beam transmitter and receiver must extend beyond the face of the detector, and provide a "binary" indication of whether or not there is an object in front of the detector. As such, an object that blocks the beam is detected, and any object that does not block the beam is invisible. This approach is used to "hunt" for the patient by moving the detectors closer and closer until the beam is broken, thereby locating the patient.

In some implementations this information is used immediately by the system to position the detector for imaging. In other implementations this information is used to construct a spatial map of the patient, which is later used in a manner similar to a manually constructed map. This latter implementation has the drawback of requiring a complete robotic "pre-scan" of the patient, which eliminates any time savings from automatic mapping.

For the past eight years, the Philips R&D team has provided an electromagnetic field-based patient detection technology on several diagnostic-imaging systems. This technology has now been extended for use in nuclear medicine. The BodyGuard Automatic Body Contouring system has been incorporated into the Philips BrightView SPECT Series of gamma cameras. In this white paper, we will describe the operation of the technology and discuss its relative advantages over competitive systems.

Objectives and constraints

The purpose of any automatic contouring system is to provide an expedient means of locating the patient so that the detectors can be oriented for best image quality. Typically, this means allowing the detectors to approach as close to the body as possible while maintaining a safe distance to avoid contact. However, the large detectors approaching too close to the body can unnerve some patients. It is therefore necessary for the operator to occasionally choose between a close detector position for best image quality and a farther position for better patient comfort. The optical methods provide only a fixed-distance measurement from the face of the detector, and cannot be adjusted to suit clinical need. The manual map approach gives the operator complete control over the imaging distance, and is therefore worth mimicking in any automatic approach.

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In a clinical environment, it is necessary for the system to prevent snagging patient and operator clothing as well as catheters and IV lines. The apparatus associated with typical optical methods necessarily extends past the face of the detector, thereby creating opportunities for interference between the patient and the system. Again, the manual map approach gives the operator direct control over the robotic path of the system, but cannot account for patients who move after the map is defined. As such the desired approach both eliminates any apparatus that would extend close to the patient and also respects patient movement and the location of any catheter or IV lines.

Every approach to automatic mapping must respect the need to protect image quality. Any material that is placed in between the detector and the patient must be comprised of low-attenuating materials to prevent scatter and lost counts.

Finally, it is imperative that the system be designed to protect the patient from unexpected contact between the detector and the body. It is typical for a contact-sensitive element to be placed across the face of the detectors, which halts robotic motions in the event of contact. The customer of any modern nuclear medicine camera will expect this functionality.

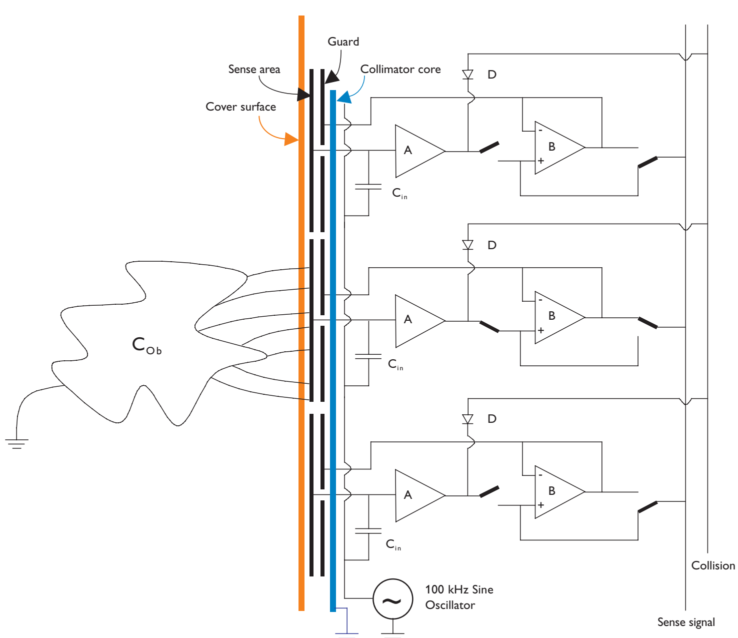

Figure 1: Simplified model of the principle behind the Automatic Body Contouring system

Technique

The BrightView Automatic Body Contouring system makes use of an electric field that is generated by the collimator. The technique makes use of the fact that a grounded object in the vicinity of the cover changes the electric field that it emits. The magnitude of this change is dependent on object size and distance between the object and the cover, and can therefore be used to estimate the distance to the object. This technique is also called capacitive approaching detection because the cover sees the object as a capacitive load, with the capacity changing as the object approaches the detector.

An array of sensors located on the face and sides of the collimator is used to form many measurements of objects near the system. The system electronically scans the array, and samples each independently. At the completion of each scan of the array, the sensor assembly reports a single distance measurement that represents the distance to the nearest part of the object.

In Figure 1 the measuring channel is located at the center. A 100 KHz sine oscillator (5 Vpp) emits an electric field from a sensor element, which propagates through a protecting cover and the air towards "everything" with a different potential. The electric field is "forced" in the direction of the object by feeding the sensor input signal back to the guarding element behind the sensing element via the unity gain amplifier B and to the neighboring guarding elements via the settings of the switches as illustrated in Figure 1. Because of a strong capacitive coupling the neighboring sensor elements are also at the guarding signal level preventing field lines going from the sensing element to neighboring sensors.

Preamplifier A has a very high input impedance, which basically causes the input voltage to this amplifier to be a voltage division between the input capacitance C_{in} and the capacitance of the object in front of the cover, C_{Obj}. The input capacity, C_{in}, is chosen to be approximately equal to the capacitance the sensing element sees with no object in front of the cover. As an object approaches the cover the capacitance of the object increases, which results in a lower input signal at preamplifier A.

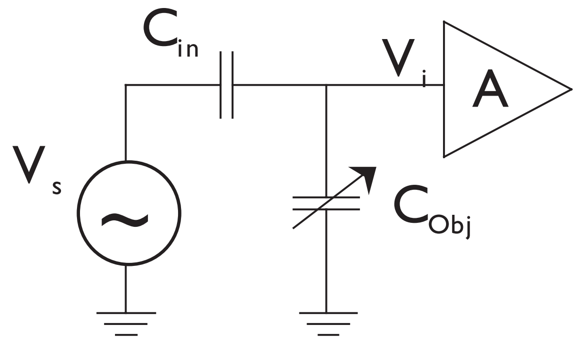

Figure 2: Simplified electrical diagram of the ABC front end.

The system is able to detect a broken wire to both the sense element and to guarding elements. If a wire to a sense element is broken, the voltage division between C_{Obj} and C_{in} will not take place and the input amplifier will see the full 5 Vpp signal. This is above the normal operating range of any object in front of the cover, so the processor that reads this signal can generate a "sense" error message to the host computer. If a wire to a guard element is broken the guard signal will follow the potential of the grounded collimator core behind the guard sensor. This will result in an input signal to the preamplifier A that is below the normal operating range of any object in front of the sensor. This provides a running "self-test" capability that ensures the system is always ready for use.

Also, Figure 1 does not show the high-order high-pass filters, the synchronous detector, or the ADC, and microprocessor containing firmware for computing the distance and compensating for gain and offset errors.

In order to minimize scatter and count loss, the electrodes are comprised of conductive films only microns thick, housed under a robust and cleanable plastic cover. This cover protects the conductive films from physical damage, and also isolates them from moisture and body fluids.

These films also provide a direct means of detecting contact between the plastic cover and external objects. During a collision between the cover and any object, the sense and guard foils are shorted together, acting as a switch. Because the guard is connected to –5 V from a DC perspective it allows current to run through the diode, D, which then generates a collision indication. By connecting this "switch" to the circuitry that drives the electric motors used to articulate the system, an emergency-stop functionality is created.

Reducing setup time

The presence of this unique sensor array simplifies the workflow of a SPECT acquisition dramatically. The operator simply selects the desired start angle and detector orientation, and commands the system to start the study. The robotic manipulators automatically move the detectors to the desired initial azimuth angle, and slowly decrease their radius until the desired detector-to-patient separation is achieved. At the end of each azimuth acquisition, the robotic manipulators move the detectors a small distance away from the patient in order to reorient the detectors for the next azimuth. The distance sensors are then used once again to locate the patient, and decrease the spacing to the desired distance. This is repeated for each azimuth angle. Since the distance measurement is continuous, the operator may choose the desired distance (within the usable range of the sensors, which is 10 cm), and may also increase or decrease it during the course of the study.

Distance sensors are also installed on the leading and trailing edges of the collimators, for use primarily in total body planar applications. In such studies, the collimators are oriented above and below a reclining patient, and move along the patient's body from head to toe (or toe to head). As the detectors move along the patient's body, it is necessary to raise and lower the detector in order to avoid contact with anatomy of varying height, such as breasts, abdomen, and feet. In this application, sensors measure the distance "ahead" of the detector (along the body axis), to allow sufficient time to raise the detector to avoid any tall objects. Once again, the operator workflow is very simple: they select the start and stop distances that indicate the overall scan length, and command the system to begin acquiring. The BrightView system automatically determines the detector relative angle and table start position, decreases the detector radius to the desired distance from the patient, and then begins acquiring.

Even in static acquisition scenarios, where automatically controlled detector orientation is not relevant, these distance sensors are helpful to the operator. Since the sensors can detect objects ahead of the collimator face, they are also used during hand-controller operation. The system will automatically slow down and stop before making contact with an object detected in front of the collimator.

Discussion

The BodyGuard Automatic Body Contouring system available on the BrightView SPECT series of nuclear medicine cameras will simplify workflow and allow operators to focus on their patients, not on the camera.

References

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