Design and Manufacture Detection System for Patient's Unwanted Movements During Radiology and CT Scan

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***Abstract*—**Medical one of the important tools that can help orthopedic doctors for diagnose diseases is imaging scan. Imaging techniques can help physicians in see different parts of the body, including the bones, muscles, tendons, nerves and cartilage. During CT scan, a patient must be in the same position from the start to the end of radiation treatment. Patient movements are usually monitored by the technologists through the closed circuit television (CCTV) during scan. If the patient makes a small movement, it is difficult to be noticed by them. In the present work, a simple patient movement monitoring device is fabricated to monitor the patient movement. It uses an electronic sensing device. It continuously monitors the patient's position while the CT scan is in process. The device has been retrospectively tested on 51 patients whose movement and distance were measured. The results show that 25 patients moved 1 cm to 2.5 cm from their initial position during the CT scan. Hence, the device can potentially be used to control and monitor patient movement during CT scan and Radiography. In addition, an audible alarm situated at the control panel of the control room is provided with this device to alert the technologists. It is an inexpensive, compact device which can be used in any CT scan machine.

***Keywords*—**CT Scan, radiology, X Ray, unwanted movement.

I. INTRODUCTION

IN computed tomography (CT), the term artifact is applied to any systematic discrepancy between the CT numbers in the reconstructed image and the true attenuation coefficients of the object.Respiratory motion during computed tomography (CT) causes artifacts (blurring, streaks, discontinuities, etc.) in thoracic imaging [1], [2].

CT images are inherently more prone to artifacts than conventional radiographs because the image is reconstructed from something on the order of a million independent detector measurements. The reconstruction technique assumes that all these measurements are consistent, so any error of measurement will usually reflect itself as an error in the reconstructed image. The types of artifact that can occur are as follows: (a) streaking, which is generally due to an inconsistency in a single measurement; (b) shading, which is due to a group of channels or views deviating gradually from the true measurement; (c) rings, which are due to errors in an individual detector calibration; and (d) distortion, which is due to helical reconstruction. It is possible to group the origins of these artifacts into four categories: (a) physics-based artifacts, which result from the physical processes involved in the acquisition of CT data; (b) patient-based artifacts, which are caused by such factors as patient movement or the presence of metallic materials in or on the patient; (c) scanner-based artifacts, which result from imperfections in scanner function; and (d) helical and multisection artifacts, which are produced by the image reconstruction process[3], [4].

These artifacts not only degrade the image quality but also may lead to errors in target delineation and subsequently in dose delivery for radiation therapy. For diagnosis, a helical CT is usually acquired during a single held breath with minimal motion artifacts. Treatment planning CT, however, is usually acquired with the patient breathing freely [5]- [7].

Patient motion can be monitored by the radiation technologist through a video camera. However, the human eye is usually not able to quantify such motion and it is not reliable for detecting slow position changes during the whole course of treatment. Infrared (IR) cameras have been used to quantitatively monitor the respiratory motion of a patient, with infrared external markers placed on the patient surface.[8]-[10].

II. MATERIALS AND METHODS

This is a scientific experimental study, in which the detection system of the patient's unwanted motions during radiology and CT scan is created in order to modify the unwanted motions of patients with cancer. The statistical society was all of the patients referring to the emergency department and trauma center of Shohadaye Haftome Tir Hospital in Tehran for two months. In this descriptive study, the samples (51 patients, candidates for scan) are investigated for two months as a non- random survey. Data collection including the type of disease and the amount of unwanted motions by patients are studied and measured and data are entered on the designed forms.

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III. Electrical Circuit

Electrical circuit includes transistor, electric resistance of 1KΩ, resistance of 10KΩ, a light-sensitive diode, and transistor, Op-Amp, LED and a keyboard. Transistors are connected in parallel. The performance of electrical circuit is based on the infrared light passing through the diode. The record button is pressed when the sensor is placed in the desired position and at the intersection of lasers. In this status, the output of infrared diode on which the laser is located is considered as the origin and zero point coordinates is registered in the microcontroller. If the patient moves, IR rays deflect from their axis in such a way that the diode does not have output zero point, while other diodes have output. Since the distance of each diode from the adjacent one is 3mm, by locating the diode with output, the range of patient's movements could be obtained.

Two output tools are employed in this sensor including the alarm and radiation cutoff circuit by CT scan door. The alarm is an auditory device, which is located in the control panel of CT scan room. The separate circuit is a single-phase controller circuit. Using relay, the output of sensor could be directly connected to the micro-switch installed of the CT scan door. Any of the above output equipment could operate during CT scan process.

Fig 1 . The keyboard and receiver circuit microcontroller with light emitting diodes

IV. Result

To measure sensitivity of the equipment, a phantom study was conducted in +Y, -Y, Z and -Z directions. The sensitivity of different situations was evaluated in phantom and the results are shown in Table 4-1. During evaluation, it was observed that the sensors have started working and CT scan was on standby mode.

In this step, the values of 0.6, 1, 1.5, and 1.8cm have been entered into the sensor using the keyboard. In each stage, CT scan table moved in three directions and when it reached the input value, the circuit of circuit controller activated the alarm and CT scan door using the output relay.

Fig 2. The use of CT bed and phantom to test the correct function

TABLE I

Assessments of the sensitivity of the sensor in various positions in the human phantom

Position in Phantom	Input (CM)	Coach direction CM(			
		Y	–Y	Z	-Z
Position 1	0.6	0.6	0.6	0.6	0.6
Position 2	1	1	1	1	1
Position 3	1.5	1.5	1.5	1.5	1.5
Position 4	1.8	1.8	1.8	1.8	1.8

V. Monitoring Movements of the Patient

This sensor was employed to monitor the movements of 51 patients. Among them, 19 patients with accident, 7 patients of chest scan, 4 patients of head and neck scan, 4 patients of lung scan, 4 patients with brain tumors, 9 palliative patients and 4 unconscious patients could be observed. Clearly, it could be observed in Table 2 that among these 51 patients, 25 subjects (9 patients with accident, 3 chest patients, 2 lung patients, 2 patients with brain tumor, 6 palliative patients and 2 unconscious ones) have changed their position during scan, while the rest of the patients have been scanned motionless. Output of the patient's sensory systems was connected to electrical circuit and relay and the scan was prevented through the audio system and stopping CT scan.

TABLE II
THE AMOUNT OF MOVEMENT OF PATIENTS FOR ALL PATIENTS

The type and location of imaging	With movement	The number of positions without moving	All patients	Entered allowance (cm)
Metastatic cancer and palliative	6	3	9	1
Breast scan	3	4	7	1
Head and neck	1	3	4	0.5
Lung Cancer	2	2	4	1
traumatic	9	10	19	0.5
Brain tumor	2	2	4	0.5
Unconscious	2	2	4	1.5

VI. CONCLUSION

Keeping patients motionless is an important parameter during CT scan process. Various tools are available to make patients motionless to perform CT scan in clinical conditions. However, equipment for making motionless are not employed because of unavailability of large thermoplastic sheets for the areas such as the chest, behind the neck and limbs along with the minor effect of thermoplastic sheets on isodose surface. Equipment for fixing the situation is mostly employed for neck, head and brain patients not for patients with injuries in other organs including esophagus, chest, behind the neck and limbs. Equipment to make head and neck motionless is not often used in some hospitals.

During scan process, if the patient changes its initial position, achieving CT scan outcome becomes impossible. Patient's movement occur as a result of uncontrollable unwanted behavior such as coughing, swallowing saliva, exhaling or finding a better position by the patient. It is possible that the patient is not able to stay in a position for a long time. Since patient's movement could potentially lead to severe systematic situational mistakes, monitoring patient's movement during scan process is crucial, especially in long scan processes.

Equipment to monitor patients' unwanted movements has been designed and manufactures successfully and the movements of patients have been analyzed quantitatively using this equipment. It is a small light-weighted electronic device, which is inexpensive and easily applicable. Sensitivity of this device could differ for various parts of the human body. In cooperation with the experts of Siemens Corporation of Germany –Iran representative- this device was connected to the CT scan door switch as a trial. CT scan security system is in such a way that when the door of CT scans is open, the machine alarms for treatment door open error and the radiation stops. When the patient moves more than what determined during scan process, a signal is sent to the CT scan door and shows the door open virtually. Therefore, CT scan is stopped and it could prevent unnecessary radiation on normal tissues of the patient and present radiation in correct position. Another method designed in this device is an audio tool. In this method, when the patient moves out of the permissible area of CT scan, the alarm sounds. Sounding the alarm informs the experts. Using this alarm system, the patient is able to return to his/her initial position after manual disconnection of linear acceleration machine. Since the movement sensitivity of the area under scan is variable in CT scan, the permissible range of unwanted movements of the patient could be determined through the provided input. For instance, in pelvic area where field dimension is 17cm2, permissible movement for unwanted motions of the palliative patient could be up to 1cm. However, it reduces to less than 3mm for head and neck area. The study was conducted on 51 patients. The results verify that this equipment could be employed potentially for movement and motion control of patients during CT scan.

REFERENCES

[1] R. D. Tarver, D. J. Conces, Jr., and J. D. Godwin, "Motion artifacts on CT simulate bronchiectasis," AJR, Am. J. Roentgenol. 151, 1117–1119 _1988_.

[2] M. Arac, A. Y. Oner, H. Celik, S. Akpek, and S. Isik, "Lung at thinsection CT: Influence of multiple-segment reconstruction on image quality," Radiology 229, 195–199 _2003_.

[3] B. NK, Singh B, Namrata S, et al. Development of patient support devices for execution of clinical radiotherapy for cancer patients: A preliminary report. J Med Phys. 2006;31(4):255-261.

[4] Jin JY, Ajlouni M, Ryu S, et al. A technique of quantitatively monitoring both respiratory and nonrespiratory motion in patients using external body markers. Med Phys. 2007;34(7):2875-2881.

[5] S. Shen, J. Duan, J. B. Fiveash, I. A. Brezovich, B. A. Plant, S. A.Spencer, R. A. Popple, P. N. Pareek, and J. A. Bonner, "Validation of target volume and position in respiratory gated CT planning and treatment," Med. Phys. 30, 3196–3205 _2003_.

[6] G. T. Chen, J. H. Kung, and K. P. Beaudette, "Artifacts in computed tomography scanning of moving objects," Semin. Radiat. Oncol. 14, 19–26 _2004_.

[7] I. M. Gagne and D. M. Robinson, "The impact of tumor motion upon CT image integrity and target delineation," Med. Phys. 31, 3378–3392 _2004_.

[8] HD. Kubo,ML Patrick, M Shin-ichi, et al. Breathing–synchronized radiotherapy program at the University of California Davis Cancer Center. Med Phys. 2000;27(2):346-353.

[9] J. Jin,M Ajlouni, Q Chen, et al. A technique of using gated–CT images to determine internal target volume (ITV) for fractionated stereotactic lung radiotyherapy. Radiother Oncol. 2006;78(2):177-184.

[10] G. Mageras , A Pevsner , E Yorke, et al. Measurement of lung tumour motion using respiration-correlated CT. Int J Radiat Oncology Biol Phys. 2004;60(3):933-941.