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MEDICAL PHYSICS

ON-LINE PATIENT POSITION CHECK FOR BREAST IRRADIATION TREATMENTS

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Abstract. Patient's placement in radiotherapy treatment is a critical point of the quality control system and can be correlated with the local control of the tumour and with the side effects of the normal tissue. Each day the therapists positioned the patient on the LINAC couch using immobilization systems. The placement is verify using the radiological images but the patient can move during the treatment session. The scope of this study is to show a patient movement online tracking system based on the video images captured by a video camera placed into treatment room. The system is no-irradiative and no-invasive and is capable to detect and quantify the 3-D patient's movements during the treatment session. Starting from one reference picture taken on the first session, the system can detect the difference of patient's placement from one treatment session to another. The functionality of this tracking system was tested *in vitro* and *in vivo*. The system is used in current activity and the results are based on the 142 patient's placement examinations. Using this system the placements of the patients was improved, the time of placement was reduced and the monitor units administrated for imaging propose was reduced also.

Key words: Radiotherapy, quality control, live movement tracking, video camera.

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1. INTRODUCTION

In the radiotherapy treatment the objective is to deliver the optimal dose at the target volume and at the same time to protect the normal tissue surrounding. This can be achieved using a very good delimitation of target volume and a reproducible set up of patient during the radiation sessions. The fastest technical evolution of the medical equipments used in radiotherapy improves the control of the radiation beam, although the patient's placement continues to be a phase assigned to the radiologists and at the same time exposed to human error.

The external radiation treatment of breast cancer means daily irradiation for a period of between 25 and 33 days. The patient set up on the LINAC couch is made in the manner so that the arms are out of the radiation field. The patient is placed on the breastboard in decubitus dorsal position with the upper and lower arms placed in abduction on the special supports. The upper arm is curved at 180^o and the lower part at 90^o [1, 2].

In the quality assurance program, the placement of the patients is a major point. Conventionally, the placement of the patient on the LINAC couch is based on aligning the patient with the markers tattooed on the skin to the projection of the LASER system. In most of the radiotherapy department, the placement is checked using the imagistic device attached to the LINAC: portal imaging detector and RX tube and its flat panel detector. The images acquire are compared to images planned on the treatment planning system. The set up is estimated by the positions of anatomical structures on both images. Even if the placement of the patient is well done by the radiotherapist team, the patient can move during the treatment and we have no information about that. Additional to this method, today are available some commercial devices like visioRT or ExactTrack, but the disadvantage of using these tools are the irradiation of the patient.

Stating from the necessity of optimal patient's set up on the LINAC couch without using supplementary irradiation of them, we build up a tracking system based on the video images acquisition. The system detects the patient's shift in position during the treatment session and by using a reference image is capable of calculating the difference in position between two sessions [3–5]. Accordingly, by using this life tracking and analysis system we can define a global position's placements for breast cancer treatments, a very useful tool for any radiotherapy department [8–10].

2. MATERIALS AND METHODS

In order to detect the patient's movements during the treatment session and the position differences between two sessions a software is built up based on the analysis of the movie captured by the video camera installed in the treatment room. For that, the web camera QuickCam Pro 9000 produced by Logitech enterprise is used to capture images of interested zone. The choice of this camera was made because of its fitting with software and also for its technical performance: spatial resolution, colours renderings, spatial deformations, chromatic contrast, light adaptation of treatment room condition, zoom and resistance to radiation damages, *etc*. To test all the video characteristic of the camera we use a video pattern composed by 16 grey, red, green and blue (RGV) lines levels, 20 vertical, horizontal and circular spatial resolution and deformation lines and 20 different characters text lines. The placement of the video camera in the treatment room is done so that it can be used for all treatment localization no matter what position the gantry is in and also to compensate for zoom deficiency.

The move captured by the camera is transferred to an ordinary computer *via* the USB cable connection. Because the length between the camera and computer is long, the signal attenuation is compensated by a voltage amplifier .

Accordingly, a proprietary software was built by using Visual Studio 2008 software with command line written in `C` programming language. The software capture the movie generated by the video camera using the graphical card of the computer and split them in to many frames. The camera collects 30 images for each second. Each image is analysed by the software using the graphical algorithm Open CV v.2.0. Finally the movie is recomposed and is displayed on the computer screen. A test is performed in order to determine accurately the time difference between the primary and the recomposed movie.

The spatial tracking system was tested *in vitro* and its entire components were reviewed and match. Using a CIRS breast phantom we placed between the breasts a marker with the same size, shape and colour as ordinary tattoo points. Using the continuous adaptive mean shift function, the system was tested to perform life spatial tracking of the point of interest. To simulate a real treatment, the voluntary movements were applied to the phantom. The system sensibility was tested by using different masks with various shapes, sizes and colours [6, 7].

A group of 12 breast cancer patients were investigated *in vivo* with this detection system. At the same time several objective tests were performed. The first objective was to check the software functionality to create patient's folders and to record the results in the correct place. The second purpose was to inspect the evolution of the spatial tracking function in time. The third objective was to analyze the spatial movements during the same treatment session of the point placed on the patient skin. Fourthly, because the radiotherapy treatment of cancer means irradiation over several sessions, the goal was to study the position placement from one treatment's session to another. By using the images from the first treatment session as a reference, the system can calculate the difference between this one and the actual position. In this way it was possible to indicate radiologist team the optimum patient placement.

Until now, 142 patients with breast cancer have benefited from the support provided by this system. Generally, the patient placement on the LINAC couch is performed by aligning the patient with the markers tattoo on the skin to the projection of the LASER system. Later small set up correction can be done after the acquisition of the anterior-posterior image using megavoltage beam radiation and lateral-lateral image using kilovoltage X-ray or megavoltage beam radiation. Even if the patient's placement is correctly carried out by radiologist, in the traditional way we have no indication if that is staying on place during the treatment. The system is used as an additional placement method to the ordinary practice, offering in real time the information about the patient's position.

3. RESULTS

The use of Open CV library analysis algorithm determined us to use a Logitech Quick Cam Pro 9000 web camera by reason of its technical features and low acquisition price. A video pattern was used to verify the technical parameters of the video camera. The video camera can return accurately only 14/16 of line levels and the tonality of RGV lines is close to reality. Spatial deformation is estimated at 13/20 lines on the vertical and 14/20 lines on the horizontal lines and only 17/20 of the text's characters lines can be read. The automatic light control function, back light control function, electronic light adaptation of light environment treatment conditions were tested and the video camera shows good purpose. The biggest disappointment of this camera is the zoom function. This deficiency was minimized by the placement of the video camera, on the top of the treatment room, on 450 from the gantry axis in order to capture the investigated area for all gantry angles. The transmission between video camera and computer was compensated by using an amplifier signal in order to reduce the 1 V leakage of signal as detected for the 7 m of cable connection.

Using the real condition and different test objects with known shapes, dimension and colours determined from direct measurements that the system can track objects greater than 1 mm. To show this on the picture, the software needs to utilize 10 pixels. This area is spatially tracked on the real time movie using continuous adaptive mean shift function of Open CV algorithm.

One important point of the system is the speed of analysis. Comparing the initial movie with the recomposed one is highlighted that for 1 second of initial movie composed by 30 images, the system returns 29 images in the same time. The time difference (33 ms) between the two movies is not perceptible by human eyes and for that we can say that the software show the results in real time.

Testing of software means also checking the good working of his module: cre-

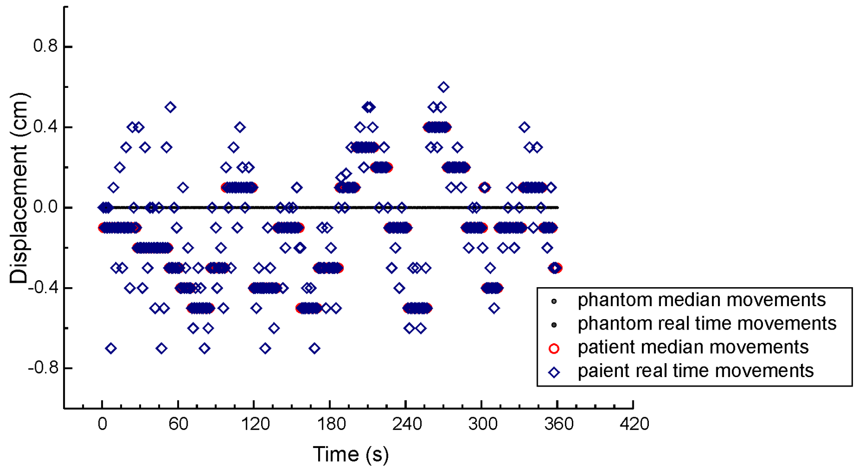

Fig. 1 – Lateral movements of phantom and patient.

ation of patient's folder, correct association of images and graphical results with patient's folder, archiving and unarchiving patient's folder from internal data base. Long time analysis for spatial tracking function was done. Reactivity of the system's small voluntary movement was also tested. *In vitro* testing consists of several tests performed on the phantom. Using the initial movie, the system shows in real time displaying the location of the interested area. Quantification of spatial movements of the area of interest is plotted on 3 graphics, on the X, Y and Z dimension. In Fig. 1 is presented the phantom movements in time. The software creates and updates automatically the graphics each second. The position of the interested point at the second 1, 2, 3, *etc.* is represented with green dots and median value during the time interval between the second 1 and 2, 2 and 3, 3 and 4, *etc.* is represented with black square. The median value was calculated on the 30 recomposed images.By using the image acquired at the first treatment session as reference, the system can analyse in 3-D the placement discrepancies from one treatment session to another, as can be seen in Fig. 2. Using this life tracking and analysis system, one can define the global position placements for breast cancer treatments in the radiotherapy department. Evaluation of this parameter in time can be used in a quality control program [8-10].

In the first phase, our system was tested *in vivo* on the 12 monitor patients with breast cancer. The system tracked and analysed the 3-D movements of the area of interest during the treatment session. In figure 1 is represented by navy diamonds patient position at one second interval while red circles were used to show the median positions between these intervals.

A statistic analyses of the vertical plane movements showed a median value of

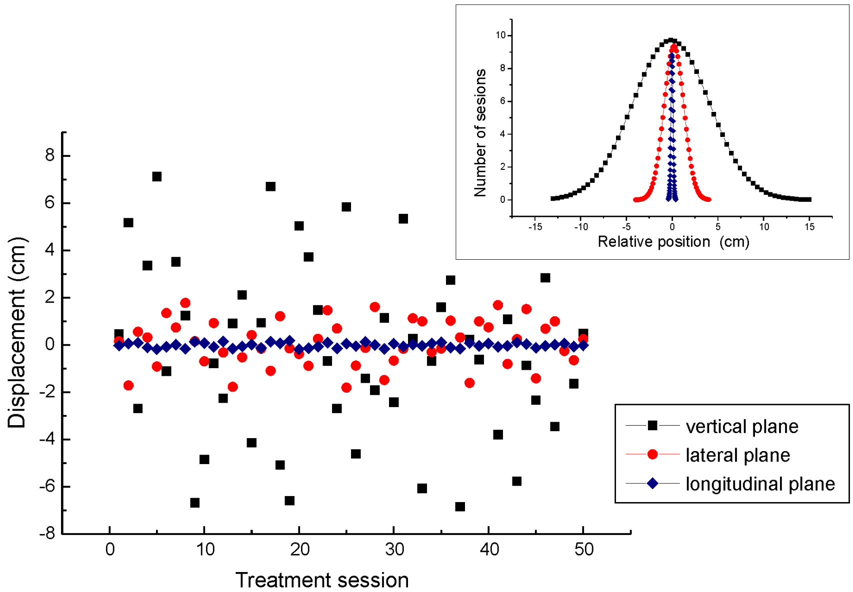

Fig. 2 – Patient movements in all planes during treatment.

-0.102 cm with an average deviation of $\pm$ 3.792 from the reference position (Fig.3). A significant better accuracy we have obtained in the case lateral plane with deviation from the reference position of 0.0702 cm and an average deviation of $\pm$ 0.987 cm while in the case of longitudinal planes the reference position was of 0.013 cm an average deviation of $\pm$ 0.099 cm.

After the all testing phases were successfully passed we have use the support provided by this tracking and analysis system additionally to our current methods LASER and MV/RX positions control, so that, we have used this new system on the LINAC couch to place and check the position of 142 breast cancer patients. It is worth mentioning that, as the movements in the longitudinal plane as observed in the precedent phase was close to 0, we focused in this study on the vertical and lateral planes. To illustrate system performances, in Fig. 4 we have reproduced the median values of the daily placement in vertical and lateral plans.

4. DISCUSSION

Based on the experimental results, we can state that the detection precision of our system is better than the precision archived by the medical team, it depending only on the video camera performances and the algorithm of detection and analysis. The camera lens is one of the weakest points because it is damaged in time by the secondary radiation. To avoid this, the lens should be changed periodically. Testing *in vitro* of the detection system was an opportunity to adjust the essential parameters such as placement of video camera in the LINAC treatment bunker, setting of the camera sensitivity under light environment, detection in real time and spatial following of the markers.

Using this system *in vivo* suppose to monitor the breast cancer patient's treatments. The program follows the zone of interest and makes the analysis for patient placement on the LINAC couch during the treatment session. Using the reference picture tracked during the first treatment session, the program was able to show the difference between daily session's positions and reference one. The results show the biggest amplitude of movements in the vertical plane (transversal plane of the patient), generally due to breath movements during irradiation treatment. Median value of deviation from reference position is -0.102 cm $\pm$ 3.792. Negative value can be explained by the rigid manner of patient's first position placement and the relaxed manner position for the next sessions. With time the patient became familiar with immobilization plane, radiologist's manipulations, LINAC movements and background noises. The median value of movements in the lateral plane (coronal plane of patient) is 0. 0702cm $\pm$ 0.987 deviations from the reference position. This was correlated with patient position on the immobilization plane and with the breast's morphological modification during the association of radiation treatment with chemotherapy. The amplitude's movement in the longitudinal plane (sagittal plane of patient) is negligible $-0.013cm$ $\pm$ 0.099 and was correlated with patient movement during treatment on the immobilization plane.

The solution built out by this system, for instance the real time picture with the difference between initial and actual position of patient, is used additional for general position practice. Using this tool the placement of the breast cancer patients is more precisely: 2.2 time for vertical plane (-0.046 $\pm$ 3.062 with the system *vs.* -0.102 cm $\pm$ 3.062 without system) and 1.7 time in lateral plane (0.041 cm $\pm$ 0.582 with the system *vs.* 0.0702 cm $\pm$ 0.987 without system). No improvement in the longitudinal plane was observed. Another advantage is that the time of the patient's placement is reduced with 1-2 min. for each patient and that has a direct consequence to the treatment of larger number of patients.

5. CONCLUSION

In order to administrate the exact optimal radiotherapy treatment dose it is desirable to have an exact and daily reproducible position of breast cancer patients. Using minimal materials composed by a normal computer and video camera we built a system capable of detecting and monitoring the patient's position during treatment session and also of reporting the difference of positions from one treatment session to another. Using the intuitive graphics of the system can be a real time help support of the radiation therapist team. The analyzed results are recorded as images and graphics in the self data base and can be used to position patients.

Using this method as a real time support in the placement of patients on the LINAC couch, the errors of placement, the patient's movements during session and the time needed to position the patient was reduced. Those have as a direct consequence the possibility to treat more exactly the patients and to treat a larger number of patients. One of the major advantages of this solution of position is no invasive and no irradiative character. In this way the system is not self destructing of its own detection device.

The system can be improved using a direct link with the LINAC in order to stop automatically the irradiation treatment when the movements of patient on the couch are outside of a critical range.

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REFERENCES

1. M.P. Casebow, R.L. Harris, R.J. Jarvis, Radiother. Oncol. **46**, 99-103 (1998).
2. M.F. Spadea, G.Baroni, M. Riboldi, B. Tagaste, C. Garibaldi, R. Orecchia, A. Pedotti, Radiother. Oncol. **79**, 170-178 (2006).
3. D. Verellen, G. Soete, N. Linthout, S. Acker, P. Roover, V. Vinh-Hung, J. Steene, G. Storme, Radiother. Oncol. **67**, 129-141 (2003).
4. Y.S. Kim, S.H. Park, S.D. Ahn, J.E. Lee, E.K. Choi, S. Lee, S.S. Shin, S.M. Yoon, J.H. Kim, Radiother. Oncol. **85**, 424-428 (2007).
5. L.P. Vight, E.N.J.Th. Lin, I. Spitters-Post, A.G. Visser, R.J.W. Lowe, Radiother. Oncol. **90**, 359-366 (2009).
6. L.S. Ploeger, M. Frenay, A. Betgen, J.A. de Bois, K.G.A. Gilhuijs, M. Herk, Radiother. Oncol. **68**, 277-284 (2003).
7. G. Baroni, G. Ferrigno, R. Orecchia, A. Pedoni, Radiother. Oncol. **54**, 21-27 (2000).
8. A.J. Cherpak, J.E. Cygler, S. Andrusyk, J. Pantarotto, R. MacRae, G. Perry, Radiother. Oncol. **102**, 290-296 (2012).
9. G. Vasile, M.Vasile, O.G. Duliu, Rom. Rep. Phys. **64**(3), 728-736 (2012).
10. E. Robu, C. Giovani, Rom. Rep. Phys. **61**(2), 295-300 (2009).