Automated contrast painting for position verification in radiotherapy

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ABSTRACT

Information technology in medicine is constantly changing and has a central role, especially in radiation oncology. The accurate positioning of patients is essential for good treatment, and we use radiographic images to tell us that the patient is positioned correctly. These images display the contours of bones which are then used to compare intended with actual positioning.

Image display software is provided with the linear accelerator. The software is a bitmap paint program which allows the user to manually draw contours for later comparison. This software could be improved by using automated image manipulation algorithms. However, replacing this software is difficult because of cost, copyright, license and certification problems.

In this report, we describe the use of the Java Robot class which is part of the Java platform. The Java Robot does not interfere with the original software, but does allow the user to use automated image processing algorithms which save time and work well. The software development was not difficult and was tailored to individual users' needs.

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1. INTRODUCTION

One of the important parts of treating cancer patients with radiation is making sure that the radiation is delivered precisely to the correct place[1]. The radiation fields used for treatment are planned with the help of a 3D image set like a CT scan. Once the geometry of a particular radiation field is decided, a 2D image of beam's eye view can be generated from the CT scan[2]. This digitally reconstructed radiograph (DRR) can be compared to an image taken in the treatment field position to verify that the beam direction is accurate [Figure 1]. After the patient has been positioned on the treatment couch and the skin markings positioned accurately according to the positioning lasers [Figure 2], and the linear accelerator placed in the treatment position, 2D radiographic images can be taken. Comparing the DRRs from planning (expected position) with the treatment images (actual position) allows the treatment to be verified and adjusted if inaccurate.

Figure 1. Patient position is determined on the CT couch, the patient is treated on the linear accelerator couch. The images from the image on the CT (DRRs) will be compared with the radiographs in the treatment position on the linear accelerator.

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Both images contain visible bony structures as well as markers that indicate where the linear accelerator is aimed. Comparing the contour of the visible bony structures gives a measure of the displacement of the linear accelerator's aim. Patient positioning is very error prone as skin tension and weight loss can make skin markers change their position relative to the bones, Even if the skin marks are accurately positioned [Figure 2], the internal target may be missed. Once the discrepancy between the intended treatment position and the actual position on the bed has been measured, the couch can be moved to bring the actual position into line with the intended position. This ensures that the delivered treatment is accurate.

During a CT scan or a simulation procedure skin markings are applied on a patient.

The patient is positioned on the table and the light system is activated.

The treatment table is shifted so the lines overlap, bringing the patient into the correct position.

Figure 2. Position verification by comparison of skin marks and laser position of the linear accelerator.

The structures on the DRR and treatment image that are relevant for position verification vary from location to location and even from patient to patient. There is however one condition that they must fulfill: they have to be visible in both. In most cases these structures are bones because they don't change shape and they are easily visible.

2. AIM

Because these bony structures were not recognized automatically, they had to be drawn with a painting tool in the verification software. The aim of our project was to automatize identification of these structures. The goal was to produce a tool that would identify and draw bone structures in the image, the main benefit being less time needed to paint the structures manually. The method, which the structures are painted with, resembles most common PC bitmap painting programs. It was necessary to find a solution that would not change the original software which was part of the software package of the linear accelerator.

The image software provided with the linear accelerator does not automatically recognize bony structures, they have to be manually drawn. This deficiency in the supplied software cannot be improved without violating the software patents held by the vendor, necessitating user space manipulation [Figure 3].

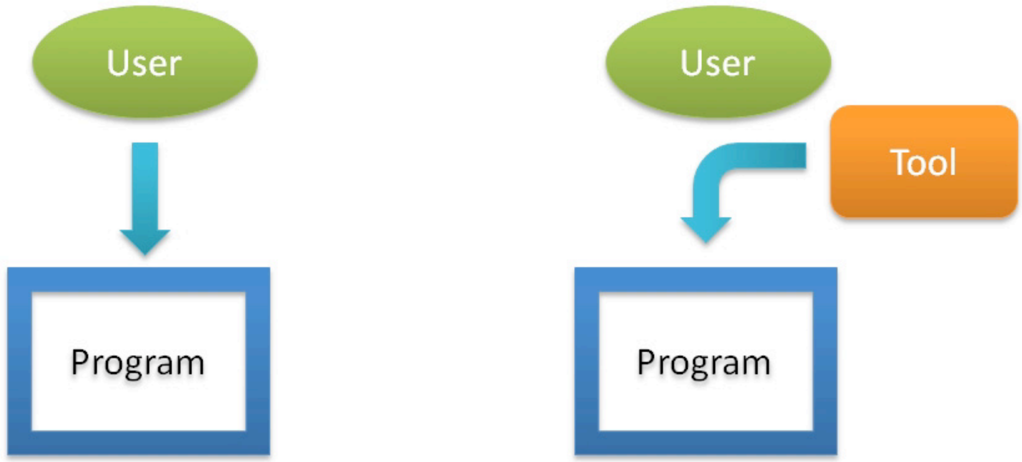


Figure 3. The positioning of the automated contouring tool in 'user space'.

This project aims to produce an automated software tool that can identify bony structures and treatment position indicators faster and more accurately than a human user. The software tool will enhance the functionality without altering the code base of the image software product provided.

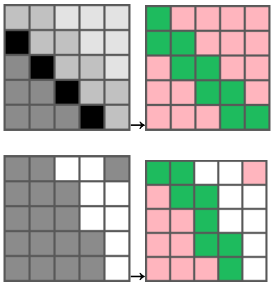
3. METHODS

Our department uses Elekta Synergy® linear accelerators with integrated cone-beam CT and the iView image software (iViewGT® Release 3.4). The Varian Eclipse® planning system produces the DRRs.

The software tool was written using the Java® programming language from Sun Microsystems[3] in the Eclipse IDE (v 3.4.1 Ganymede®, Eclipse Foundation). Java code executes on the Java Virtual Machine (JVM) which is readily available on hospital PCs. The licensing of the image software forced us to work within the user work space to affect the desired changes.

The initial step acquires the images that have been already opened for analysis in IVIEW. The Robot class[4] provides a PrintScreen method allowing a rectangular portion of the displayed screen to be captured to a BufferedImage. The identification of the appropriate screen position was rather simple, because the displayed image in IVIEW always had the same x and y coordinates and Region of Interest (ROI) constant window size. We added a small function with which the ROI could be displayed by an automated mouse movement and changed within the Graphic User Interface (GUI) of our tool.

Once the BufferedImage is captured from the ROI, the image can be manipulated by selected algorithms. An algorithm alters the image by manipulating the pixel matrix according to the values of surrounding pixels [Figure 4]. This results in the automatic identification of high contrast boundaries as happens at bone and graticule borders.

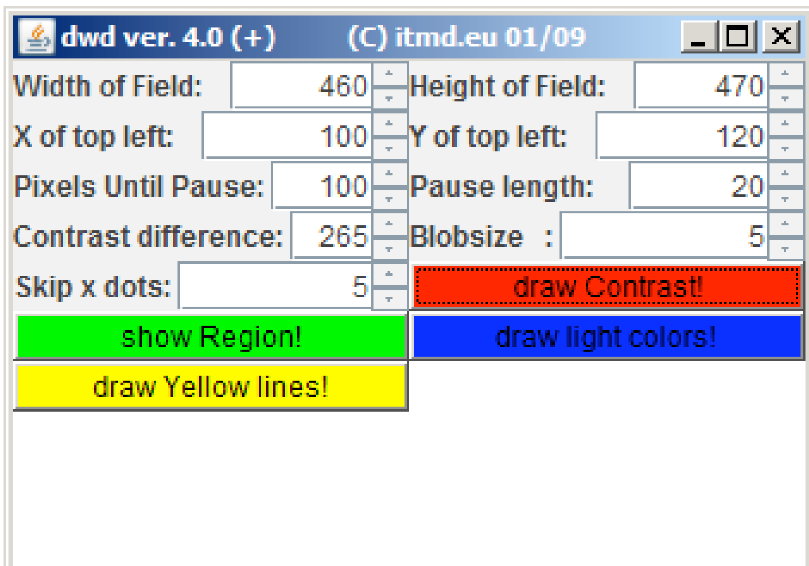


Pixels surrounded by pixels with strongly differing gray scale values are marked as contrast positive. Pixels surrounded by similar gray scale values are negative. The gray scale contrast values are converted to positive (displayed here in green) and negative (displayed here in red).

In the further processing of the image, larger fully positive areas were cleared on the inside, in order to prevent obstruction of the underlying image, to which the structures should be compared to. Very small positive blobs were also reduced, because they did not prove to be helpful in identifying the correct position.

Figure 4. Pixel manipulation by the automated algorithm.

The software tool provides a graphical interface for the parameters that can be varied to give more useful contours [Figure 5]. In some situations skipping every nth pixel while drawing the contours was even faster and did not reduce precision.



Figrure 5. The graphical interface which allows alteration of pre-set parameters.

4. RESULTS

The simple algorithm does not provide elegantly outlined structured such as those produced by humans, but the detected structures provide sufficient information for precise positioning. Occasionally the tool recognized and painted structures which we would have not expected from their visible contrast differences, but these additional and irrelevant structures did not hinder correct position identification [Figure 6, 7, 8].

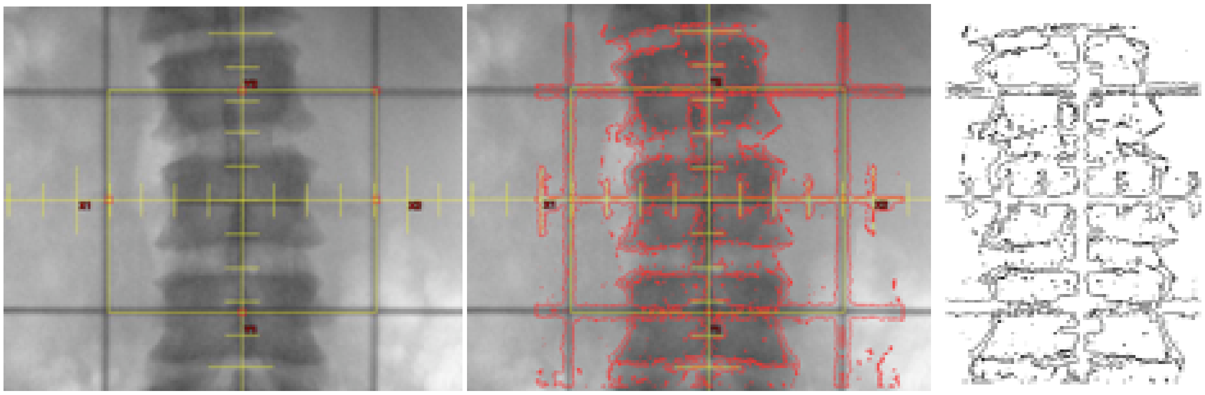


Figure 6. The image on the left is a simulator verification radiograph. The result of automated contrast analysis of this image is shown in the centre. The proposed matching structure is displayed in red over the original image and produced as an outline in the right image.

During software development, an unexpected problem occurred which seemed to be due to the speed at which the tool painted the pixels. This caused the software to crash and the exact cause could not be identified. However when a small delay was added after a specified number of pixels painted the problem was no longer seen. The total amount of drawing for the tool can also be reduced by defining a number of points could be skipped. For example the tool could be set to draw every fourth point. This reduction in points did not cause a significant reduction of visible structure quality.

As the figures demonstrate, once the desired image has been opened in the software, the processing algorithm can provide an enhanced view of the beam's eye view image which is useful for contour matching. In cases where these new structures are not helpful, the human user can draw their own as permitted by the IVIEW software.

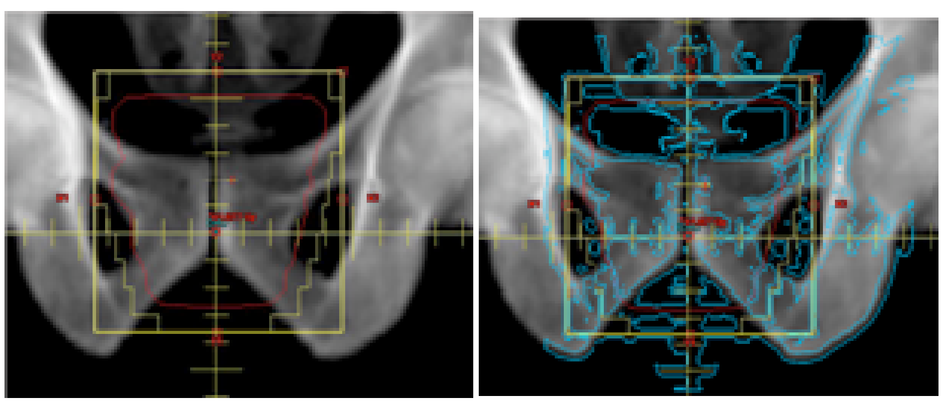


Figure 7. The application has processed the left image (a DRR of the pelvis) to contour structures where the contrast is relatively high. The yellow field markings and the red planned target volume are recognized as well but do not prevent position recognition.

5. DISCUSSION

Radiation oncology is the medical specialty responsible for cancer patients treated with radiation. Radiation therapy is a major treatment modality and is associated with damage to cancerous and surrounding normal tissues. Improving the "Therapeutic Index" by enhancing of the effectiveness of radiation therapy and reducing of its toxicity[5] has been a major goal in radiation oncology since its beginnings in the late 1890s. The proper and exact positioning of the patient is critical to allow the required dose gradients that provide sufficient dosage to the target area but quickly limit the exposure of vulnerable tissues[6].

Correct positioning relies on imaging the patient set up. Visual inspection of the correlation of skin marks and machine axes is easy but inaccurate for deep targets because of the mobility of skin. The use of radiographs to image bones is more accurate as deep targets are attached or at least related to bony structures. The use of fast automated algorithms to detect the contours of bones can help with the accuracy and efficiency of bone matching.

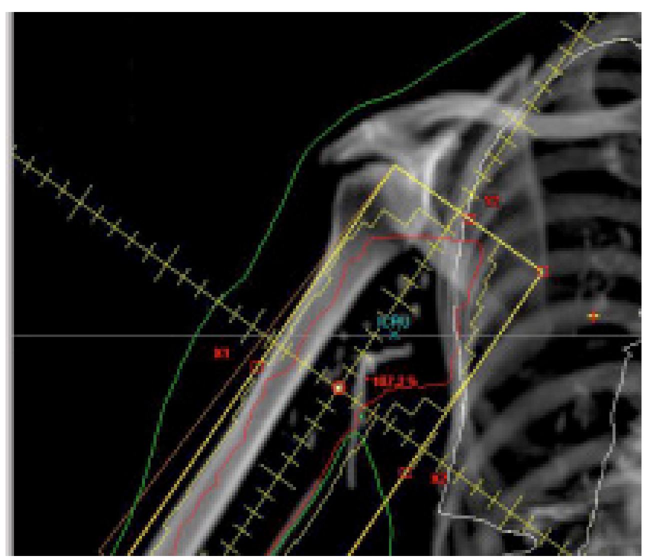
Here we have presented a time-saving tool that can help with the automated recognition of relevant bony structures, while there is still the opportunity to move the treatment fields manually before radiation delivery. The software tool does not undertake any automation of the matching process, which still is under the control and responsibility of the human operator. There is no possibility of inadvertent radiation exposure as the image manipulation and beam activation are undertaken on different consoles/PCs. Manual recognition and drawing of bony contours takes minutes, while the automated contouring takes seconds. Where contour matching uses simple, easy to see bony contours, the automated tool offers little advantage, but where bones are indistinct, the automated tool offers significant advantages.

The tool is based on the freely available Java platform using the Java Robot class which is initiated on user input. This solution enabled us to use the original software supplied with the linear accelerator without alteration. This reduces the need for training, reduces the costs of software development and does not violate license agreements. The tool developed is highly specific, individualized and customizable. It can also be deployed to any other bitmap image software so long as it is running on a computer with the JVM installed. The software is open, visible and accessible for debugging and extension by others.

We have achieved a desirable stability in the software while ensuring sufficient resolution in the images. Software development is not complete and has only been tested on a limited number of cases. More data are needed to evaluate the impact of this tool on the workflow of the department, and its reliability. Later developments could have the algorithm applied automatically to the images. At present, the minimal user input has been judged to be an improvement and acceptable, though not ideal, solution. In common with all software, its acceptance into the clinical workflow is a balance between time saving, effort and the required training for routine use.

We conclude that we have developed an automated algorithm for bone structure recognition aimed to save time in the process of position verification before radiotherapy. Our solution works on the user level with no interference of the underlying original software, thus overcoming associated license and copyright issues. In our early trials, the tool has proved to be time-saving, functional and the development was easily accomplished and individually tailored to users' needs. More tests and trials are still required to assess the reliability and time saving provided by the current tool.

However, it is clear, that the presented approach, namely using small JAVA programs working on provided software in the user workspace can provide exciting possibilities for customization. The ability to extend a vendor's software functionality without cost to the individual department bodes well for medical informatics.



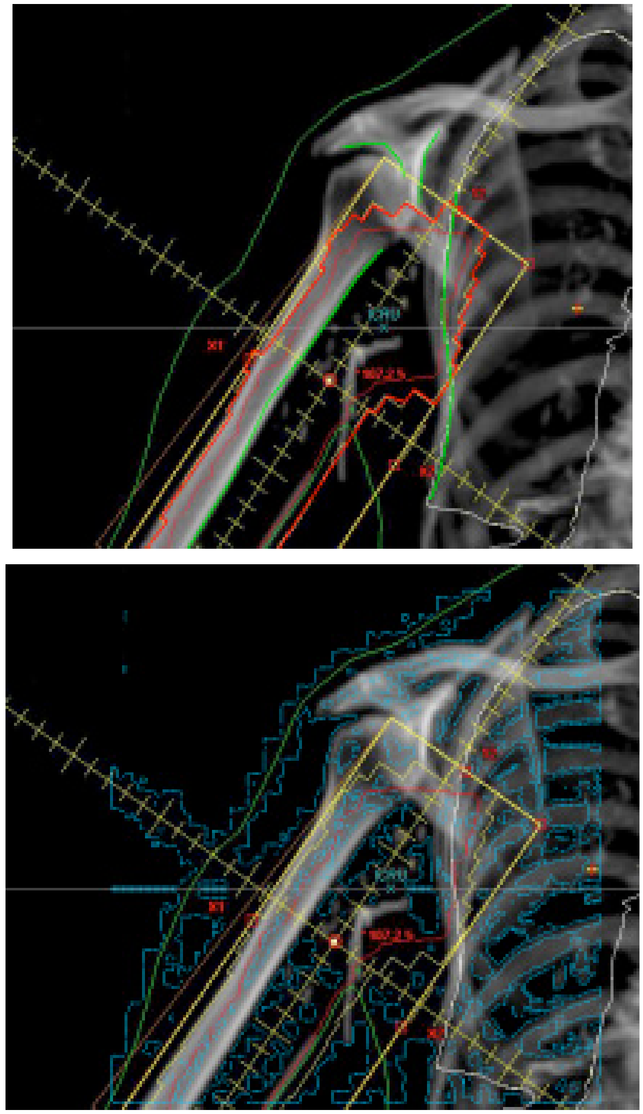


Figure 8. The top image shows a digitally reconstructed radiograph (DRR) from the CT image. The yellow box marks the extent of the radiation field. The central image shows the manual bony contours added in green. The lower image shows the contours painted by the Java application.

REFERENCES

[1] Bakai, A. et al. Positioning accuracy in conformational prostatic irradiation using portal imaging. Strahlentherapie und Onkologie: Organ der Deutschen Röntgengesellschaft...[et al] 178, 84(2002).

[2] Senan, S. et al. Literature-based recommendations for treatment planning and execution in high-dose radiotherapy for lung cancer. Radiotherapy and Oncology 71, 139-146(2004).

[3] Developer Resources for Java Technology. at http://java.sun.com/

[4] Robot (Java 2 Platform SE v1.4.2). at http://java.sun.com/j2se/1.4.2/docs/api/java/awt/Robot.html

[5] Meeks, S.L. et al. Optically guided patient positioning techniques. Seminars in Radiation Oncology 15, 192-201(2005).

[6] Van den Berge, D.L., De Ridder, M. & Storme, G.A. Imaging in radiotherapy. European Journal of Radiology 36, 41-48(2000).