Daily patient set-up control in radiation therapy by coded light projection

*R. Krempien, **S. Daeuber, **H. Hoppe, *M. Treiber, *W. Harms, **J. Raczkowsky,
*J. Brief, *J. Debus, **H. Woern, *M. Wannenmacher

*University of Heidelberg, Department of Clinical Radiology
**University of Karlsruhe (TH), Institute for Process Control and Robotics, Germany

Abstract:
Advances in conformal radiation therapy to control disease via dose escalation are challenged by set-up uncertainties. Recently, techniques have been developed to use surface features to evaluate the patient’s position and correct it where necessary. The aim of this study was to use the patient’s surface as a tool for daily set-up control and monitoring. We use a surface scanner based on the projection of coded light to receive -in a daily routine- a large amount of surface points which enables us to register the CT-based planning data with the patient’s current position. By superimposing current and planned volumes, a volume of congruency was obtained. An error below 1 mm was considered acceptable. In cases where set-up was not satisfactory a map of the surface comparison was evaluated showing the areas of missing alignment. According to this information a manual repositioning was performed. This procedure was repeated until the error was acceptable. No more than 3 repetitions where necessary to obtain an acceptable result. The whole procedure including registration, calculation and visualization took about 20 sec for one repetition. The use of structured light projection in the daily set-up control and monitoring proved to be a noninvasive, easy, quick, inexpensive and reliable solution.

1. Background/Problem
Advances in conformal radiation therapy to control disease via dose escalation are challenged by set-up uncertainties [Killoran]. Recently, techniques have been developed to use surface features to evaluate the patient’s position and correct it where necessary [Milliken, Berry]. The aim of this study was to use the patient’s surface as a tool for daily set-up control and monitoring.

2. Method and Tools Used
We use a surface scanner based on the projection of coded light to receive -in a daily routine- a large amount of surface points which enables us to register the CT-based planning data with the patient’s current position [Hoppe]. The presented system consists of an ordinary video projector, two CCD-cameras and a state-of-the-art PC (800 MHz CPU, 256 Mbytes RAM). The system generates a set of three-dimensional coordinates, i.e. points, which all are located on the surface of the patient. The first step is to project a set of lines varying in width, the so-called coded light. data. The cameras gather the deformation
of the lines on the surface. As their widths correspond approximately to the lattice parameter of the CCD matrix, moiré patterns emerge.

![Fig. 1: Surface reconstruction using coded light projection.](image)

The software is able to analyze the patterns and decode the body’s surface, represented then by a three-dimensional point cloud. The error of a single point is below 1 mm. The density of the point cloud is approx. 4 per mm². After the initial scanning of the patient’s present position, the data must be registered with the planning CT-data. The CT-images are transformed to a distance tomogram. An arbitrary matching algorithm served to minimize the sum over all distances from the CT-surface to the point cloud. The result of this process is the information of the patients present position compared to the CT-based planning data, i.e. a 4x4-transformation matrix describing postponement and rotation. With this information it is possible to iteratively scan and correct the patient’s position to find the optimal set-up according to the predefined planning.

![Fig. 2: Initially the patient is scanned in planing position in the CT. Based on these data a radiation treatment plan is defined. The position of the patient in the planing CT defines the ideal position while the surface of the patient is used as a virtual shell. In the treatment room the surface of the patient is scanned using coded light projection. The point cloud of the patient representing the actual position of the patient is registered with the CT-defined virtual shell using a surface matching. The differences in the set-up of the patients are used to define volumes of incongruency using vector analysis. After calculation of color codes and reprojection onto the patients surface a repositioning of the patient is performed. To ensure a correct positioning this process is repeated until a satisfying alignment of the virtual set-up and the actual set-up of the patient could be achieved.](image)
3. Results

Daily after positioning, a point cloud of an anthropomorphic phantom was acquired using the coded light projector. The CT-rendered body surface in planing position was then registered with the surface data of the phantom. By superimposing current and planned volumes, a volume of congruency was obtained. An error below 1 mm was considered acceptable. In cases where set-up was not satisfactory a map of the surface comparison was evaluated showing the areas of missing alignment. According to this information a manual repositioning was performed. This procedure was repeated until the error was acceptable. No more then 3 repetitions where necessary to obtain an acceptable result. The whole procedure including registration, calculation and visualization took about 20 sec for one repetition.

Fig. 3: Projection of coded light onto the phantom (left). Surface reconstruction of the phantom and registration with the virtual shell obtained through the planing-CT data (right). The dark grey areas resemble surface parts of missing alignment between the virtual CT-shell and the actual patient position.

Fig. 4: Calculation of a volume of incongruency by vector analysis of multiple surface points (left). Projection of the differences as color maps onto the phantoms surface using the video projector. This color maps were used to determine the necessities of changes in the patient set-up.

4. Conclusions

The use of structured light projection in the daily set-up control and monitoring proved to be a noninvasive, easy, quick, inexpensive and reliable solution.

5. References


- Berry JA, Aldrich JE. Surface topography for patient repositioning. Medical Dosimetry 1991;16:71-77
