UT Southwestern Harold C. Simmons Comprehensive Cancer Center Radiation Oncology

CNC-Laser Assisted Automated Electron Cutout Fabrication with 3D print-based Quality Assurance and Computer Vision

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INTRODUCTION

Customized electron cutouts are typically used in the treatment of shallow tumors with electron beams. The cutouts, for any irregular field shape, are fabricated and the cutout factors are measured and subsequently used in the MU (monitor unit) calculations. However, manual fabrication of the cutouts, may potentially involve human error. The error could be found in any of following aspects, size of the cutout, orientation of the cutout, scale of the cutout, and size of the cones. These errors could happen in variety scenarios and it is not easy to verify without proper trace of quality assurance for each fabrication step. Therefore, automating large parts of the electron cutout fabrication process may be highly desirable in order to minimize errors, simplify quality assurance process, improve clinical workflow and maximize patient safety.

AIM

Our method to automate the electron cutout fabrication can improve the workflow in the clinic and patient safety. The method can produce electron blocks from clinical templates with submillimeter accuracy. The automation of the entire process means the user can start the process and walk away without having to be physically present. The aid of computer vision reduces the possibility for errors in block orientation, electron cone size selection, and scaling and fabrication errors that are possible in the common manual block fabrication process.

METHOD

A 3D printed frame was designed to hold the acrylic plate on which the desired electron field was drawn by the physician. The frame has four corner markers, one 5 cm scale, and a pair of orientation notches to match the electron template. The frame markers were used as deformation references to correct the cutout shape to the normal projection direction.

The 5cm scale was used as a verification reference for the scale factor. The plates in the frame could be either scanned with a flatbed scanner, or photographed with a camera. Our software then imported the image, corrected the scale and orientation, and converted it to CNC g-code for the laser cutter to fabricate the foam block.

Fig. 1, demonstrates the key steps in the image analysis process, starting from applying dynamic image processing and thresholding techniques, to pixel masking the shape of the electron tray and block, then finally creating a scaled and projection corrected path for the CNC laser to cut the foam.

The path was then converted to a CNC g-code system to guide the automated foam cutout. The actual g-code required accommodations to the path to reduce the effects of heat build-up on the foam during cutting. Multiple passes were utilized, and additional guide structures were included to help orient the foam block in the electron tray before pouring cerrobend into the mold. Fig. 2, shows the final block template cut by the CNC laser.

In this study, an Uttiny CNC Laser Engraving Machine was used as a foam cutter. It has adjustable output from 500 to 2500mW. The cutting range is 50x40 cm2. The system can operate by loading g-code commands directly as common CNC machines in simplified version. In the g-code, the traveling speed, laser output level, dynamic cutting control can be specified be sides of travel path. The developed g-code generator can easily adapted to other type of CNC machines by adding definition of different cutting tool bits.

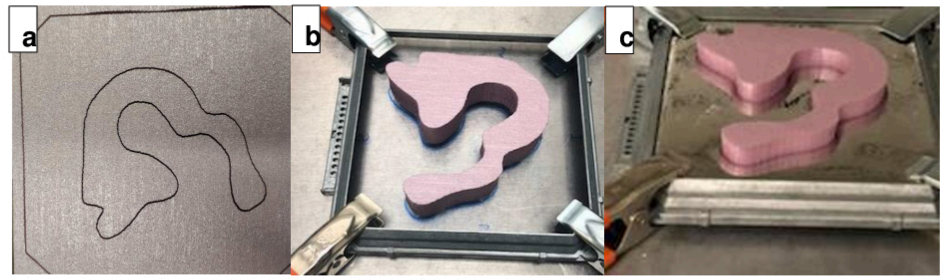

Fig 2: A) Foam block cutout with guide template. B) Cutout placed on top of original block template inside of electron tray. C) Cerrobend poured around block template.

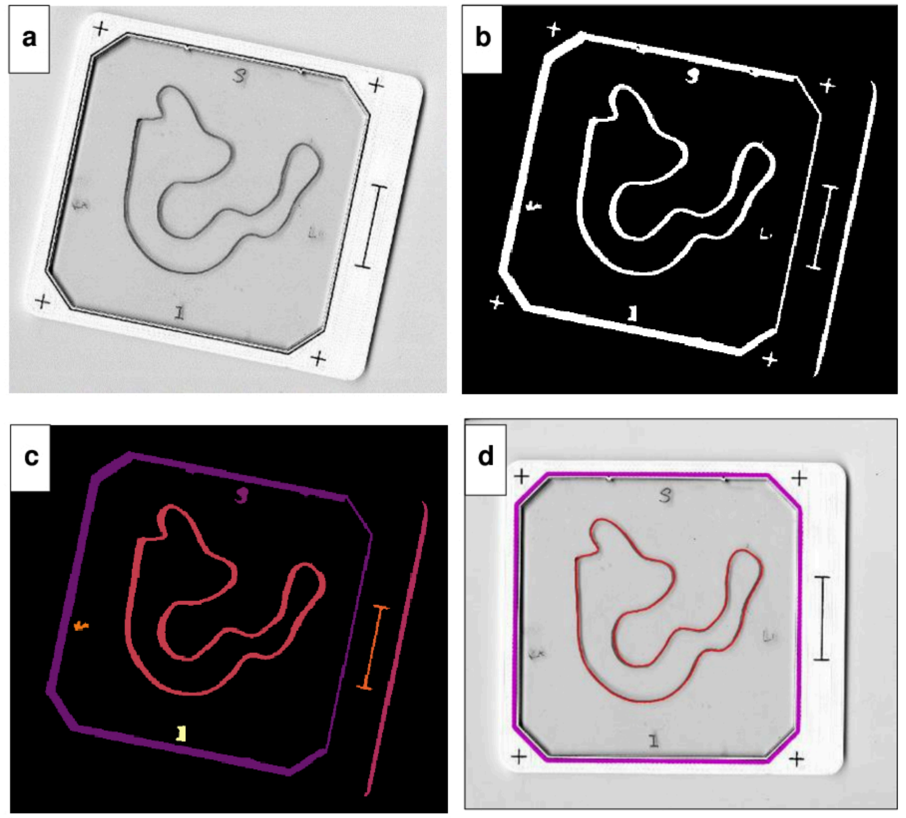

Fig 1: A) Original scan of the electron template converted to gray-scale. B) Contour mask of the regions of interest determined by image processing and dynamic thresholding algorithms. C) Isolated contour shape regions determined from the mask in B. D) Final overlay of detected template edge (magenta) and block outline (red) path contours, including rotation and scaling effects.

RESULTS

The geometric accuracy was verified with predefined shape samples. The scale disagreement was determined to be around 0.25 and 0.5 mm in x and y directions. This asymmetric error came from the rectangular laser lens design. The average material cutting loss was around 0.5 mm which was taken into account when generating the size in g-code.

CONCLUSIONS

Our automated method can produce electron cutouts with high degree of geometric accuracy. We were able to increase the efficacy of the cutout fabrication process and thereby improve the clinical workflow and increasing patient safety.

The proposed new clinical work flow will be

a) Desire cutout shape designs in a clinical setup or from TPS
b) Scan the cutout acrylic plate with 3D printed frame from the clinical setup or export directly from TPS
c) Quality assurance automatically performed including size, orientation, scale and size of the cone.
d) Cutout shape digitalization
e) G-code generation
f) Positive foam cut in the laser cutter
g) Assemble and pour Cerrobend

The steps from c to f could be done remotely and minimizing exposure to foam cutting fume.

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