Making use of virtual dimensions for visualization and contouring

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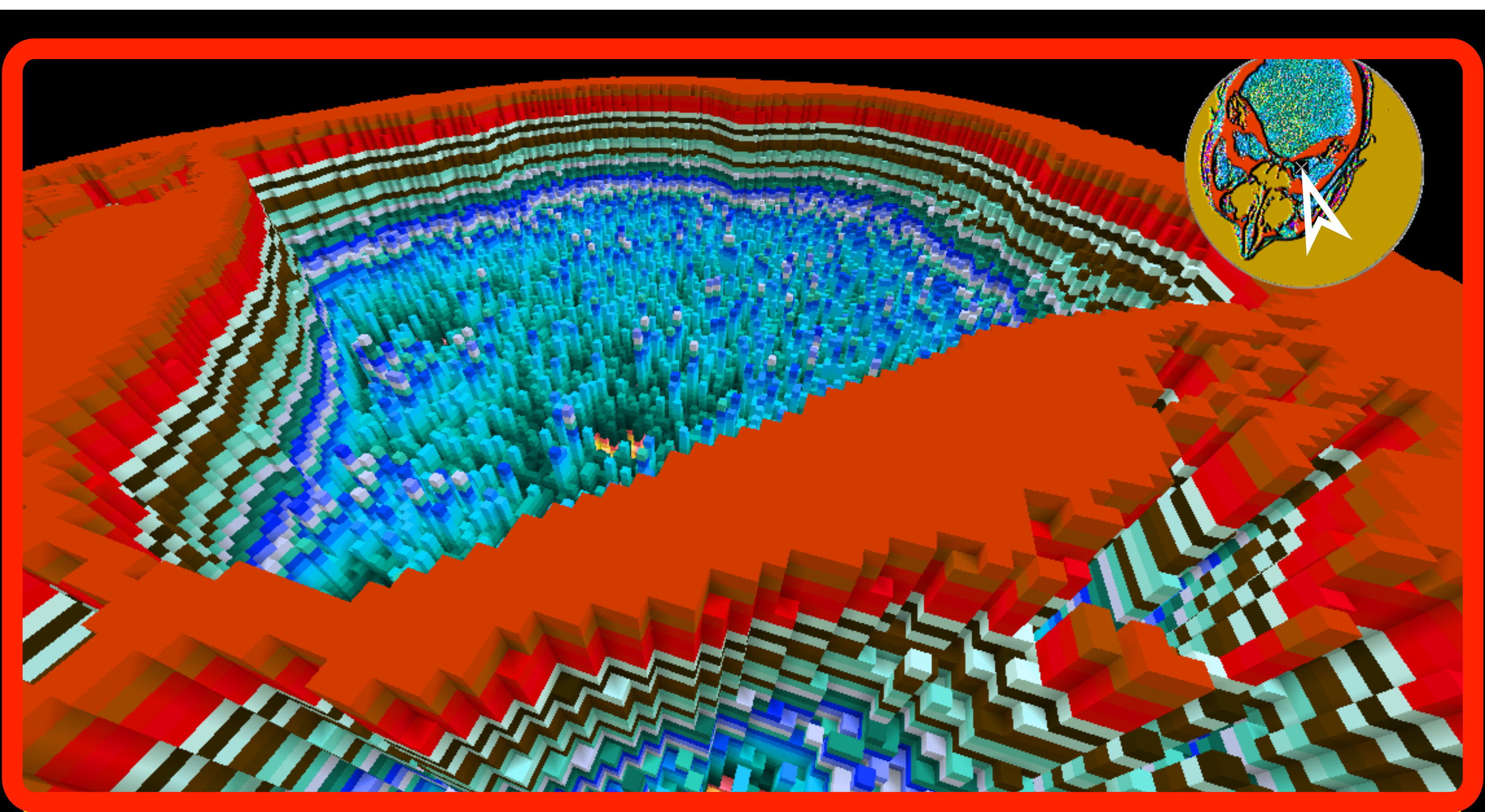
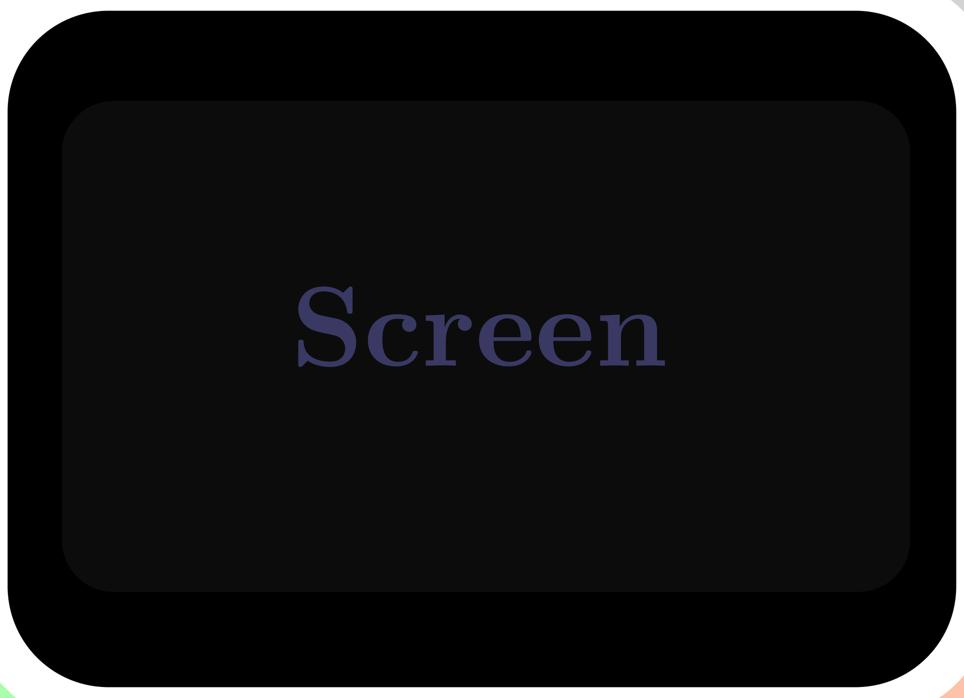


Figure 1: a prototype implementation of the proposed 'volumetric slice mapping' technique.

Introduction

Radiotherapy regions of interest (ROIs) are generated by manually demarcating tissue or object boundaries on planar images. Image modalities commonly used (e.g., magnetic resonance imaging, x-ray imaging, computed tomography) produce single-channel images with bit-depths of 16 bits per pixel or greater, which are generally presented in greyscale. Medical displays and computer monitors offer reduced bit-depths of 8-12 bits per pixel, or 256-4096 shades of grey. Kimpe et. al [1] estimate that human eyes are capable of differentiating only 700-900 shades *in ideal conditions*. **It is therefore not possible to display or differentiate the full range of most medical images. ROI generation is impacted.**

Various techniques have been concocted to address this issue. The most common is windowing, in which a subset range is compressed and specific tissues are exaggerated. Another is colour mapping wherein a subset range is replaced using a colour look-up table. The latter permits a larger range of values to be displayed owing to the high sensitivity of human eyes to colour, but can introduce problems stemming from non-linearity and perceptual differences. Both techniques are commonly used.



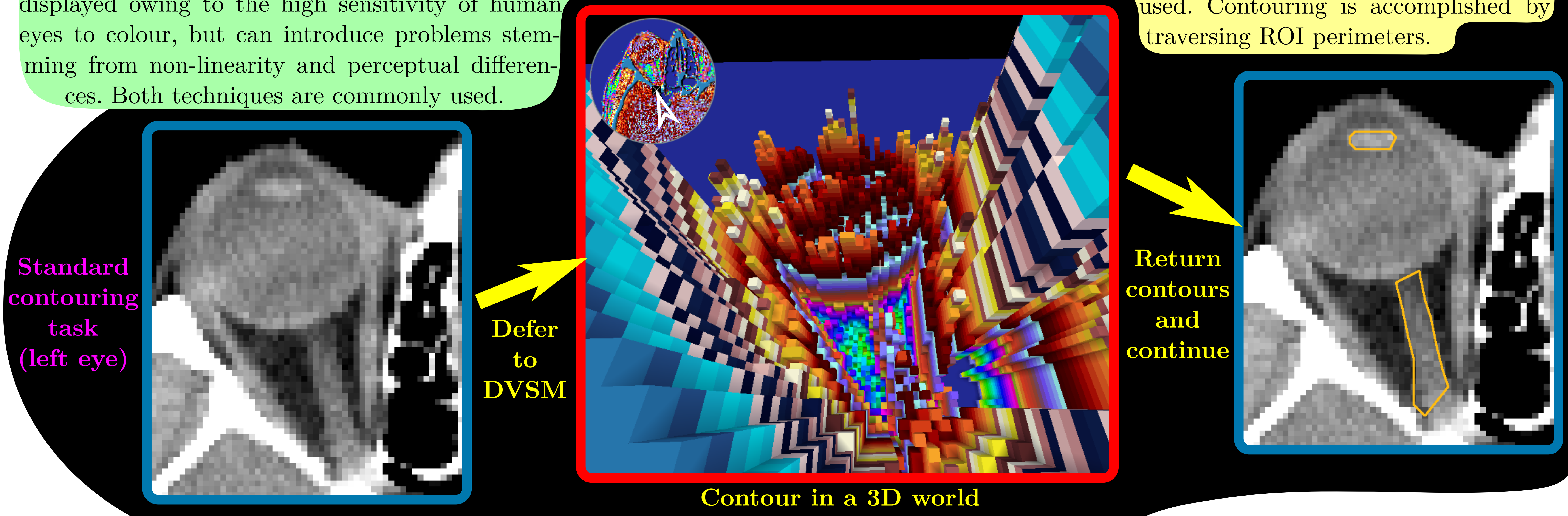


Figure 2: workflow of a DICOM-automaton contouring task (n.b. lens of an eye and part of an optic nerve) being deferred to DVSM. Colour and depth cues are used. Contouring is accomplished by traversing ROI perimeters.

We propose an alternative display technique, **Volumetric Slice Mapping** (**VSM**; figures 1, 2), that: incorporates windowing and colour mapping; exploits inherent human geospatial navigational abilities; naturally permits the addition of other visual cues; and is well-suited to interactive tasks such as radiotherapy contouring. Evaluation of the method was performed by testing reproducibility of a basic contouring task (an eye) using a prototype implementation.

Methods

A prototype viewer was constructed by modifying the free/libre and open source Minetest core [2] and integrated into the DICOMAUTOMATON radiotherapy software suite [3]. We refer to it as **DVSM**. Viability of VSM was evaluated with a blinded reproducibility test. Two individuals contoured 10 eyes each using radiotherapy planning CTs, which were compared to professionally-generated planning ROIs. DVSM can be invoked at any point in a standard contouring session (figure 2), so contouring efforts can be split between VSM and CT demarcation on-the-fly; for evaluation purposes entire ROIs were generated using DVSM. A Sørensen-Dice similarity metric (**SDS**) was used to compare ROIs.

Results

Comparison of DVSM ROIs to planning ROIs resulted in a mean SDS of 0.868 ± 0.005. Comparison between individuals resulted in a mean SDS of 0.889 ± 0.004. The median-mean SDS percent difference was $<1\%$ for both comparisons. SDS >0.995 were attained for larger ROIs, (e.g., whole body). It took approximately $4\times$ longer to contour with DVSM compared with standard CT demarcation.

Discussion & Conclusions

VSM was developed to augment existing methods for displaying images with constrained bit-depths. It exploits innate human geospatial and navigational abilities [4]. DVSM, our prototype viewer, supports windowing, colour mapping, dynamic ranges, and contouring within a virtual 3D environment.

Similarity coefficients for orbits were consistent across all comparisons. Performance on larger structures increased. DVSM contouring took longer than CT demarcation; however, DVSM is designed to augment CT demarcation, not replace it. Optimizations (e.g., coupling with auto-segmentation, additional virtual cues) would ameliorate timing differences and may improve ROI quality [5]. Oblique image slices, time series, and all popular (scalar) imaging modalities are presently supported.

References

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