Partly automated suture trajectory planning using machine learning

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OBJECTIVE

Postoperative wound infections affect approximately 2-5% of all surgical procedures. This study investigates, whether it is possible to design a semiautomated pipeline for trajectory planning of suture techniques (Fig.1.), to make wound treatment faster more consistent, and less dependent on the skill or experience of medical personnel.

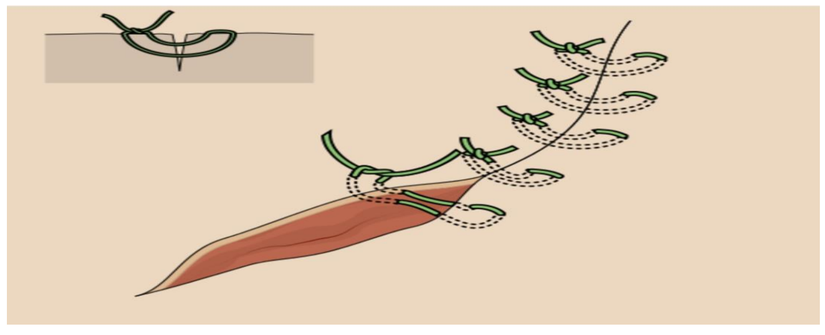


Fig. 1: vertical matrtress suture (Donati Stitch) as one of the suture techniques

METHODS

A U-Net (Fig. 2.) was trained on a public ulcer dataset (831 images) to automatically segment wounds. Subsequently, a suture trajectory planning algorithm was developed that extracts wound contours, determines a closure line using skeletonization and breadth-first search, and calculates puncture points for different suturing techniques (interrupted, continuous, mattress) based on this. As calibration instance, a coin detection was used for pixel-to-millimeter conversion. The system was tested on self-created silicone wound models (Fig. 3.) and implemented in a GUI.

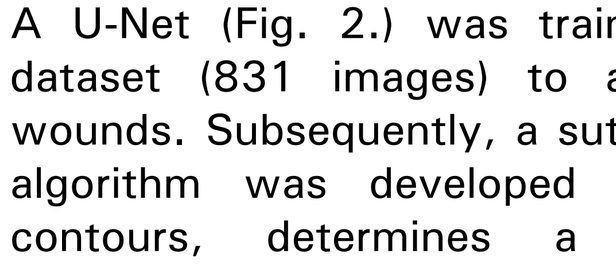
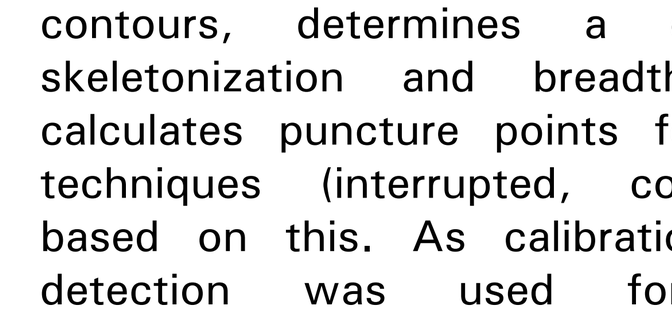


Fig. 2: U-Net [1]



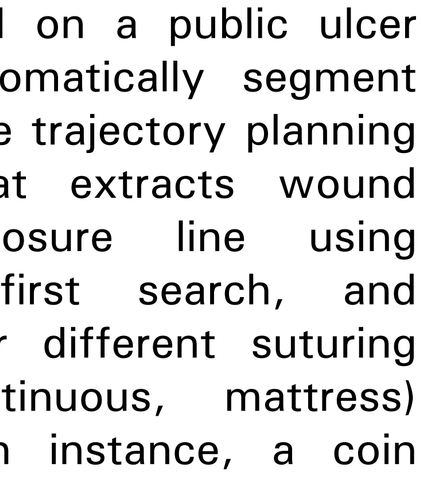


Fig. 3: Woun contour and Closure Line extraction (left) and deployed on original image (right)

RESULTS

The model established good results in segmenting wound areas (Fig. 4.). However, the model failed to generalize to the independently created silicone wound phantoms.

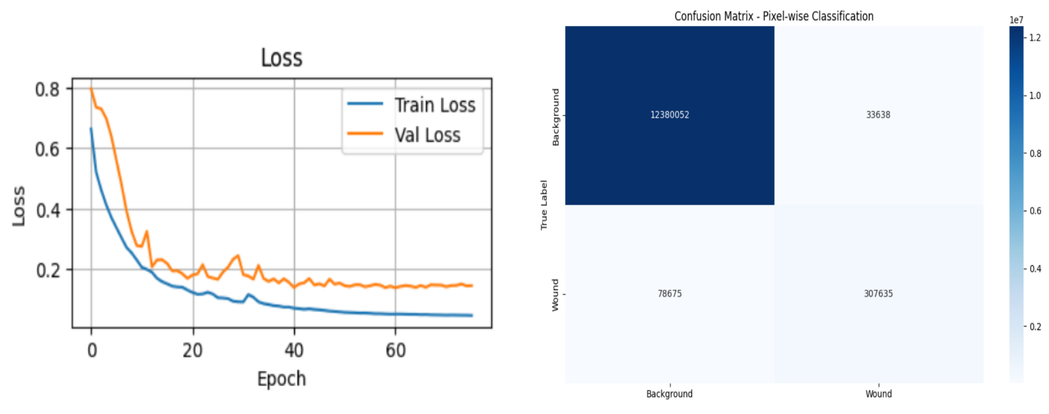
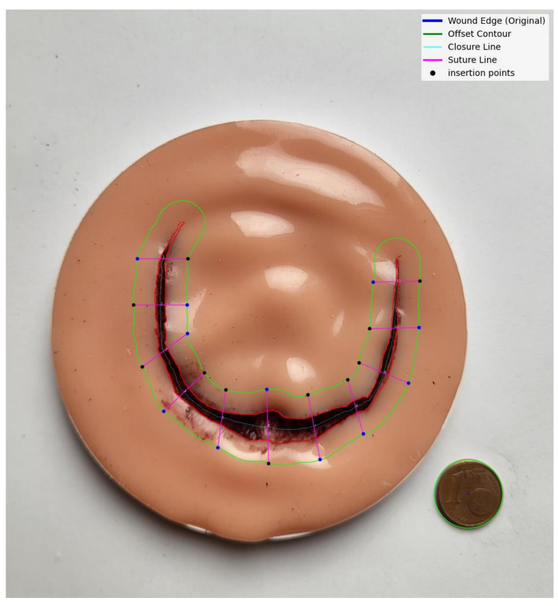


Fig. 4: Model performance (Train loss vs Val loss) & Confusion Matrix for Classification of woundpixels



The system effectively generated appropriate suture patterns for simple interrupted, mattress, and continuous suturing techniques by computing perpendicular intersection points between closure lines and offset contours. The suture points have not been validated by clinical staff.

Fig 5: Simple interrupted Suture applied on silicon wound

CONCLUSION

This approach indicates that generalising suture patterns and applying them to different wound geometries is hard and.
Future studies should incorporate own dataset, improved calibration, perspective correction.

References: [1] Ronneberger et al., "U-Net: Convolutional Networks for Biomedical Image Segmentation", 2015