Instituto Superior de Engenharia
Politécnico de Coimbra

DEPARTMENT OF SYSTEMS AND COMPUTER ENGINEERING

Segmentation of Wounds and Pressure Ulcers

Project Report to fulfill the Master's degree in Informatics Engineering

Specialization in Intelligent Data Analysis

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INSTITUTO POLITÉCNICO DE COIMBRA

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Resumo

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Palavras-chaves: wounds, segmentation, deep learning, neural networks

Abstract

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Keywords: wounds, segmentation, deep learning, neural networks

Dedicatória

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Lista de abreviaturas

IEEE	*Institute of Electrical and Electronics Engineers*
ISEC	Instituto Superior de Engenharia de Coimbra

Lista de siglas e acrónimos

CD	*Compact Disc*
ONU	Organização das Nações Unidas

Lista de símbolos

kN	Quilonewton
ε_{ax}	Extensão axial (%)

1 Introdução

Segmentation of wounds and pressure ulcers is a critical task in the field of medicine and healthcare, as chronic or acute wounds are a major cause of reduced quality of life for patients. When wounds are left untreated, they can cause major complications, leading to amputations or even death. Periodic examination aims to minimize damage and is essential to prevent deterioration. When healthcare professionals assess wounds, it is essential to accurately identify and isolate the wound area on a medical image, being able to separate unhealthy tissue from healthy tissue. This is important for monitoring the progress of healing, determining the extent of the wound and planning appropriate treatments.
However, manual wound segmentation is a time-consuming and error-prone process. Nowadays, wound assessment is typically done visually, using a ruler in which a calculation is made by measuring the height times the width and the result is noted down. Automating this process is highly desirable, as it can save time and reduce the possibility of human error. This is where image wound segmentation comes in.
Some of the challenges in segmenting wounds are represented by their appearance, since they can vary in terms of size, shape, location on the body, age, skin tone and healing time. The quality of the images, taking into account the lighting, the quality of the camera and the environment in which these images are captured, are also factors that make it difficult to accurately segment wounds.
The need to perform this action in real time with reliable results, especially in an emergency situation and in sterile environments adds another layer of challenge, as the segmentation algorithms need to be fast and efficient.

2 State of art

In this chapter, we present a review of articles related to the scope of this academic work, which focuses on wound segmentation using computer vision and deep learning techniques. Over time, techniques for detecting and segmenting wounds and pressure ulcers have made notable advances. Since the assessment of wound images falls to healthcare professionals, the criteria adopted to determine the procedure to be carried out are often subjective and can vary from patient to patient. This variability in the process can result in delays and uncomfortable procedures for the patient, making it a major concern

2.1 Methodology for literature review

Report sources

The following Table 2.1 shows the sources used to collect the state of the art, as well as the number of results and the number of articles selected.

Date	Website	Keywords	Results	Chosen
28-09-2023	Google Scholar	wounds segmentation neural network	12000	3
28-09-2023	DBLP computer science bibliography	wound segmentation	22	0
14-10-2023	Google Scholar	wounds segmentation deep learning	7430	11
14-10-2023	Sciencedirect	wounds segmentation deep learning	992	3
14-10-2023	Scopus	wounds segmentation	0	0

Tabela 2.1: Date of search, website of reports, keywords used, number of results filtered and reports selected.

Search strategy

The search strategy includes terms such as "segmentation", "wounds", "pressure ulcers"and "deep learning". In order to narrow down the results, the search filters were used, as well as the aforementioned criteria.

Inclusion and Exclusion Criteria

- Studies published between 2020 and 2023 will be included.

- Revised articles with more than 10 citations will be considered.
- Studies that do not directly address the relationship between seeding and wounds, studies with small samples and studies not available in English will be excluded.

2.2 Detect-and-segmentation: A deep learning approach to automate wound image

Scebba *et al.* [1] developed a new deep learning approach to automate the segmentation of wound images. Called Detect-and-Segment (DS), this approach consists of three main steps:

- A first deep learning model is used to detect the location of the wound in the image.
- A second model is used to isolate the wound by centering it in the center of the image.
- Finally, a third model is used to segment the wound and identify all the pixels that belong to the wound.

The authors trained the DS approach models on six independent datasets with images of diabetic foot wounds. The dataset includes images with different types of wounds, complex backgrounds and variable lighting.
The DS approach was able to segment the wounds with high accuracy, even in images with complex backgrounds and different types of wounds. The Matthews Correlation Coefficient (MCC), is a performance measure that takes into account both accuracy and sensitivity, was used. The results showed that the DS approach was able to improve the MCC from 0.17 to 0.85 on a test data set.
The article also states that the DS approach can be used to train wound segmentation models with up to 90% less training data, without affecting segmentation performance. In conclusion, the DS approach is considered a promising approach for automating wound image segmentation. The automation of wound segmentation can help clinicians to assess the condition of wounds faster, more accurately, and to make better treatment decisions.

2.3 Fully Automatic Wound Segmentation with Deep Convolutional Neural Networks

Chuanbo Wang *et al.* [2] uses a convolutional neural network (CNN) to learn wound characteristics and to segment wounds from images. In this approach, a large dataset of wounds images is built with segmentation annotations made by wounds experts. This dataset consists of 1109 images of foot ulcers from 889 patients who serve the CNN to be trained. The dataset includes images with different types of wounds, complex backgrounds and different lighting conditions.

In order to unify the size of the images in the dataset, the wound was first located by placing bounding boxes around it using a YOLOv32 model which serves as an object locator and was used for image-labelling. As pre-processing a series of techniques were applied, cropping, zero-padding and data augmentation, in order to increase the training set, the result of these techniques, was a dataset of 5000 images.

The CNN structure proposed for wound segmentation is based on the MobileNetV2 architecture, which is a convolutional neural network that is widely used for computer vision tasks, lightweight, efficient and suitable for mobile applications. For the authors, the choice of this network can benefit professionals, doctors and patients by allowing instant segmentation of the wound and measurement of the wound area immediately after the photo is taken using mobile devices such as smartphones and tablets.

Precision, Recall and Dice were used as evaluation metrics, and other experiments were carried out on other models for comparison purposes. The models used were VGG16, SegNet, U-net and Mask-RCNN.

In the comparison made, the method proved to be effective and mobile in the field of image segmentation, always obtaining the best Dice score.

2.4 Automatic Foot Ulcer Segmentation Using an Ensemble of Convolutional Neural Networks

The article of Amirreza Mahbod *et al.* [3] proposes a method based on two convolutional neural networks, LinkNet and U-Net to segment foot ulcers in medical images. Some of the main steps this method is composed of:

- Data pre-processing: Medical images are pre-processed to remove noise and improve image quality.
- Segmentation: The pre-processed images are segmented using a set of two convolutional neural networks.
- Post-processing: The segmentation results are post-processed to remove false positives and improve segmentation accuracy.

The set of convolutional neural networks used consists of the LinkNet architecture network and the UNet architecture network. According to the authors, LinkNet networks are lightweight and efficient, and UNet networks are accurate and robust.
Three public datasets were used, some of which are made up of more than one type

of wound, from which foot ulcer image data was selected. Augmentation techniques were applied.
The Dice score was used as the main evaluation metric and the results showed that the method used is capable of segmenting ulcers with high accuracy, with a score of 92.07% in the foot ulcer segmentation challenge.
The authors conclude that the proposed method is a promising approach for the automatic segmentation of foot ulcers in medical images, having been ranked first in the recent MICCAI 2021 FUSeg challenge.

2.5 Fully Automated Wound Tissue Segmentation Using Deep Learning on Mobile Devices: Cohort Study

The article [4] presents an approach for the automatic segmentation of wound tissues using deep learning on mobile devices.
The article's authors have developed two methods for segmenting wound tissues:
AutoTrace: This is a deep convolutional encoder-decoder model with attention mechanisms.
AutoTissue: This is a convolutional neural network based on the EfficientNetB0 architecture, with an encoder-decoder focused on segmenting wounds rather than skin.
The authors used a dataset of 465,187 images of wounds to train the convolutional neural network; this dataset is one of the most complete and has been labelled by healthcare professionals. The convolutional neural network was able to learn a model of the wound tissues with high precision, with a hit rate of 0.8644.
The article also states that their proposal identifies four classes of wound tissue: granulation tissue, healing tissue, necrotic tissue and infection.
Accurate identification of wound tissue can be used to improve wound care, making it more effective and efficient.
Automatic segmentation of wound tissues can be a valuable tool for doctors when treating wounds. Accurate identification of wound tissue can be used to improve the effectiveness and efficiency of treatment, which can lead to better outcomes for patients.
For example, identifying necrotic tissue can help doctors remove dead tissue, which can speed up the healing process. Identifying infection can help doctors prescribe the appropriate treatment for the infection. Identifying granulation tissue and scar tissue can help doctors develop an effective treatment plan. Identifying granulation tissue and necrotic tissue can help doctors monitor the progress of healing.
Automatic segmentation of wound tissue is still under development, but has the potential to be a transformative tool for wound care.

2.6 An Automatic Wound Detection System Empowered by Deep Learning

The article *et al.* [4] explore the use of deep learning to automatically detect and classify wounds. The article proposes a technique that uses the YOLO v3 model to detect, locate and classify wounds into four main categories: suture wound, cutting wound, open wound and normal skin. Experimental results show that the proposed technique is more efficient and robust, with an accuracy of 99

The article addresses the importance of early wound detection for the healing process. A wound detection method based on the YOLO v3 model is proposed. It uses a dataset of 400 images which, after a data augmentation process, results in 1550 images. Experimental results show that the proposed method is efficient and robust, achieving an accuracy of 99The article shows a different approach to those used in the state of the art, but it is very contributory to this report.

2.7 Wound Detection by Simple Feedforward Neural Network

The article *et al.* [4] Wound Detection by Simple Feedforward Neural Network

2.8 Conclusion of State of the Art

Report sources

The following Table 2.2 shows the results of articles analyzed in the state of the art. sources used to collect the state of the art, as well as the number of results and the number of articles selected.

Ref.	Objective / Problem	Dataset	Best Architecture	Metrics	Best Results
[1]	Wound image segmentation	SW-DFU/SW-SSD/ Medtec/SIH/FUSC	UNet/DeepLab	MCC/IoU	0.85/0.70
[2]	Wound Segmentation	Own Dataset / Medetec	Mask-RCNN/ MobileNetV2 +CCL	Precision / Recall-Dice	98.40/94.27-94.05
[3]	Foot ulcer segmentation	Medetec/ Chronic Wound /FU-Seg	LinkNet-EffB1	Dice	92.09
[4]	Wound Tissue segmentation and classification	Own dataset	Own model "AutoTrace"and "Auto tissue"	mIOU	0.8644
[5]	Detection and classification	Medetec/ Handsurgery	YOLOv3	Precision / Recall / Accuracy / F1-Score	99%

Tabela 2.2: Columns in Table 2.2 represent the reference, objective or problem that solves, dataset used, the best architecture, what kind of metrics used in segmentation and the best results achieved

3 Commercial solutions

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4 Conclusão

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Anexos

Anexo A - Título do Anexo A

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Anexo B - Título do Anexo B

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