MLSP2018
IEEE International Workshop on
MACHINE LEARNING FOR SIGNAL PROCESSING
September 17-20, 2018 **Aalborg, Denmark**

IMAGINA Research Lab
Imaging, Graphics, and Intelligent Agents

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Chronic Wound Tissue Classification using Convolutional Networks and Color Space Reduction

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Introduction

Chronic Wounds are ulcers presenting a difficult or nearly interrupted cicatrization process that increase the risk of complications to the health of patients, like infections and amputations (73.000 in USA in 2010).
This research proposes a general noninvasive methodology for the segmentation and analysis of chronic wounds images by computing the wound areas affected by necrosis.
It will be a very useful tool for all methods of treatment for chronic wounds, but it was originally devised to be used with Larval Therapy, where disinfected immature forms of flies for cleaning and removing dead tissue in wounds.

Method

- Image Acquisition: The data set with 30 images was obtained from diabetic patients from Hospital Onofre Lopes (Natal, Brazil).
- Segmentation:
  - Otsu;
  - GrabCut;
  - Watershed. ✓
- Color Space Reduction:
  - Use of CIELab color space (perceptually uniform);
  - Quantization of each channel to 6 bits;
  - Maintain the *representative* colors that have at least a pre-defined number of pixels (0.05%);
  - Other colors are mapped to the representative color that is closest to them in the CIELab space.
- Classification:
  - FCN (FCN-8s and FCN-32s);
  - SegNet;
  - U-net. ✓
- Training:
  - We used TensorFlow and Adaptive Moment Estimation (Adam) with MSE;
  - We also used a VGG16 model that was pre-trained on the ImageNet data set.

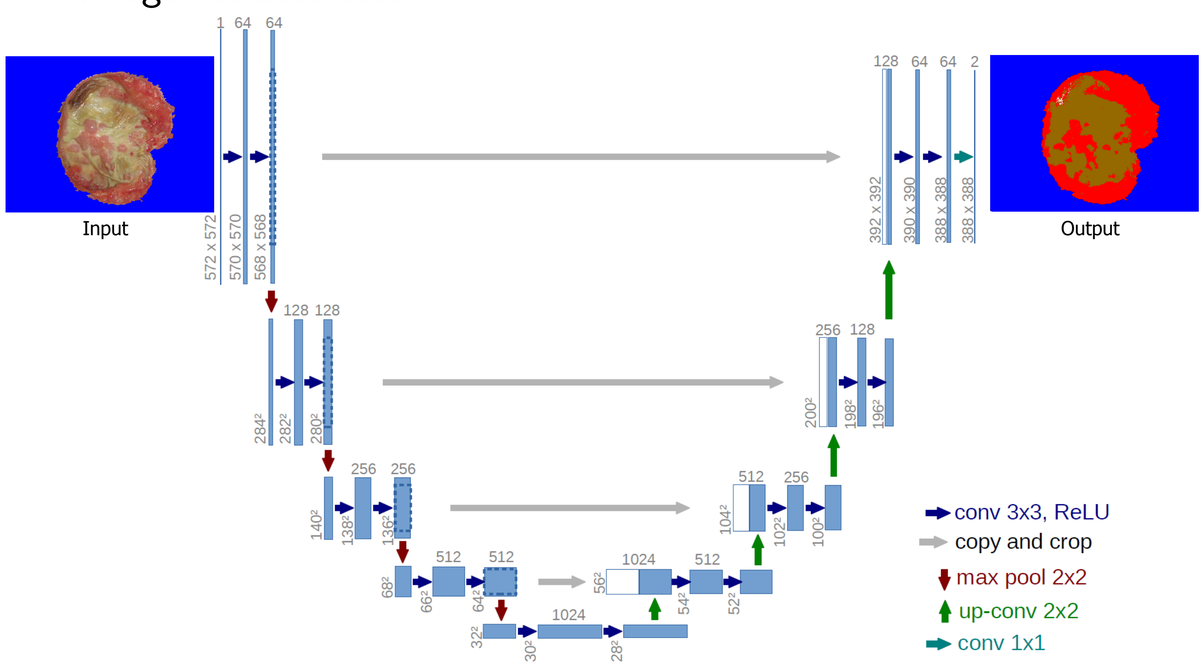

Figure: U-Net architecture.

Experiments

The classification results are computed on the segmented images, i.e., they report on the results of the whole process, that takes about 3s for the Watershed + U-Net combination on a PC equipped with an I5 at 3.4GHz and 8GB of RAM.

Technique	Accuracy	Specificity	Sensitivity	Dice Coefficient
Watershed	0.9892 ± 0.0065	0.9903 ± 0.0085	0.9770 ± 0.0243	0.9526 ± 0.0223
GrabCut	0.9498 ± 0.0303	0.9421 ± 0.0375	0.9908 ± 0.0159	0.8229 ± 0.1018
Otsu	0.4942 ± 0.1614	0.5333 ± 0.1811	0.2139 ± 0.2566	0.1006 ± 0.1428

Table: Segmentation results

Experiment	Accuracy	Specificity	Sensitivy	Dice Coefficient
U-Net	0.9420 ± 0.0451	0.9848 ± 0.0231	0.8681 ± 0.0831	0.9153 ± 0.0651
U-Net_CSR	0.9610 ± 0.0408	0.9876 ± 0.0230	0.9128 ± 0.0740	0.9425 ± 0.0598
SegNet	0.9278 ± 0.0695	0.9684 ± 0.0441	0.8563 ± 0.1121	0.8942 ± 0.1007
SegNet_CSR	0.9234 ± 0.0971	0.9599 ± 0.0625	0.8591 ± 0.1551	0.8879 ± 0.1415
FCN-32s	0.6946 ± 0.1672	0.9443 ± 0.0829	0.4773 ± 0.2095	0.6030 ± 0.2011
FCN-32s_CSR	0.8213 ± 0.1328	0.9403 ± 0.1287	0.6580 ± 0.2182	0.7585 ± 0.1710
FCN-8s	0.2028 ± 0.0469	0.9268 ± 0.0518	0.0761 ± 0.0219	0.1394 ± 0.0384
FCN-8s_CSR	0.3114 ± 0.0669	0.9865 ± 0.0190	0.1438 ± 0.0193	0.1833 ± 0.0354

Table: Classification results for the images with and without color space reduction

Tissue	Accuracy	Specificity	Sensitivy	Dice Coefficient
Granulation	0.9348 ± 0.0681	0.8897 ± 0.1933	0.8370 ± 0.2507	0.8633 ± 0.2304
Granulation_CSR	0.9561 ± 0.0590	0.9176 ± 0.1775	0.9403 ± 0.0601	0.9564 ± 0.0415
Necrotic	0.9669 ± 0.0423	0.9908 ± 0.0218	0.9076 ± 0.0351	0.9510 ± 0.0191
Necrotic_CSR	0.9719 ± 0.0445	0.9873 ± 0.0304	0.9243 ± 0.0535	0.9600 ± 0.0293
Slough	0.8911 ± 0.1505	0.9693 ± 0.0916	0.7066 ± 0.1810	0.8082 ± 0.1327
Slough_CSR	0.9295 ± 0.1074	0.9553 ± 0.1485	0.7525 ± 0.2409	0.8316 ± 0.1773
All	0.9420 ± 0.0451	0.9848 ± 0.0231	0.8681 ± 0.0831	0.9153 ± 0.0651
All_CSR	0.9610 ± 0.0408	0.9876 ± 0.0230	0.9128 ± 0.0740	0.9425 ± 0.0598

Table: Detailed classification results for the U-Net architecture

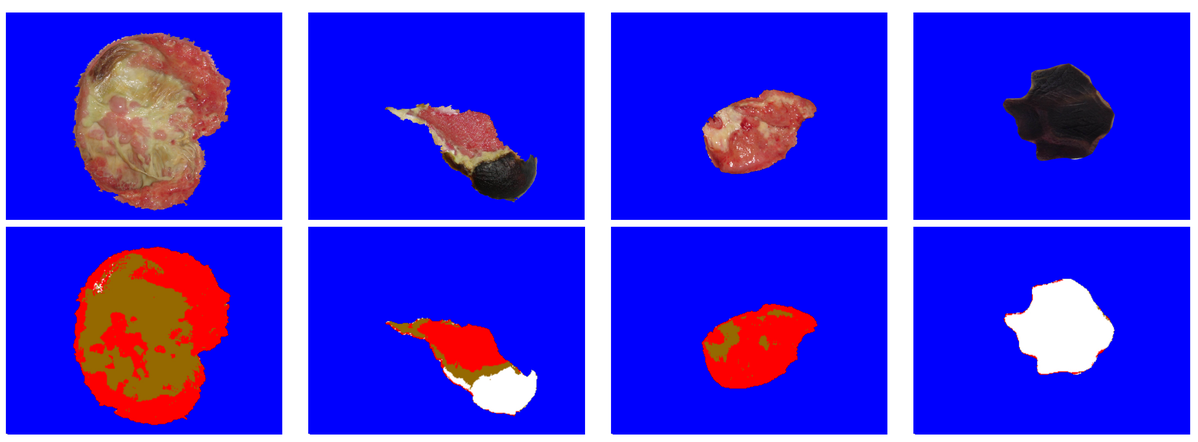

Figure: Results of the Watershed segmentations (top row) and tissue classification using the U-Net architecture (bottom row).

Conclusions

- We proposed a method for segmenting and classifying chronic ulcers into three types of tissues;
- The high values of accuracy, specificity, sensitivity and Dice coefficient obtained in our experiments with images acquired without a strict protocol and with different cameras indicate that this methodology can be applied in a typical work environment of the health care specialists using common cell phones or tablets;
- The tissue classification task obtained values of $\mathbf{0.9610 \pm 0.0408}$ of accuracy, $\mathbf{0.9876 \pm 0.0230}$ of specificity, $\mathbf{0.9128 \pm 0.0740}$ of sensitivity and Dice coefficient equivalent to $\mathbf{0.9425 \pm 0.0598}$ for the chosen methodology;
- As future work, we plan to incorporate 3D reconstruction using a dual camera setting, in order to achieve more accurate area measurements.