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Student Paper

A Two-Phase Learning Approach for the Segmentation of Dermatological Wounds

Wellington Silva, Daniel Jasbick, Rodrigo Wilson, Paulo Azevedo-Marques, **Agma Traina (speaker)**, Lucio Santos, Ana Jorge, Daniel de Oliveira, and Marcos Bedo

Institute of Mathematical and Computer Sciences - University of São Paulo

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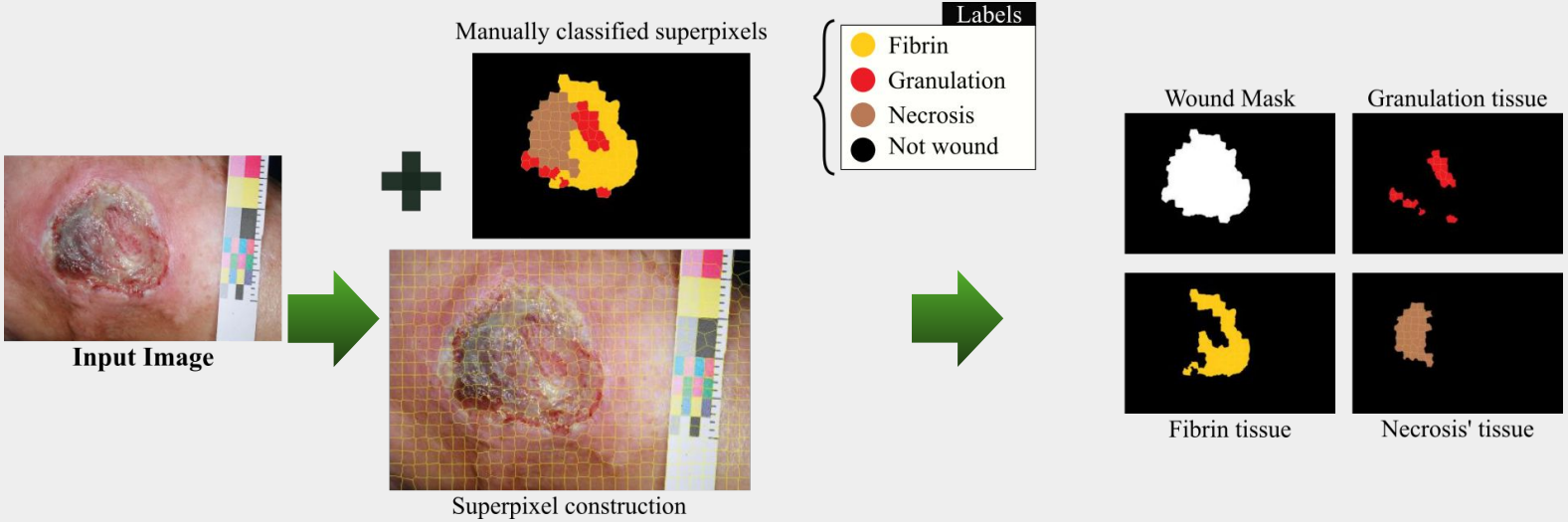
Motivation

- **Photographs of ulcers in lower limb**
  - Support dermatologists' analyses
  - Tissue characterization
  - Non-intrusive process
  - *Non-expensive:* smartphone-based image recording
  - *Non-expensive:* digital photo management

Motivation

- **Current approaches**
  - Wound segmentation as a **classification** problem
  - Tissues of **interest** *vs.* **non-interest**

Building blocks: **superpixels, feature extractor**, **training set,** and **classifier**



Open Issues...

Combination of wound tissues

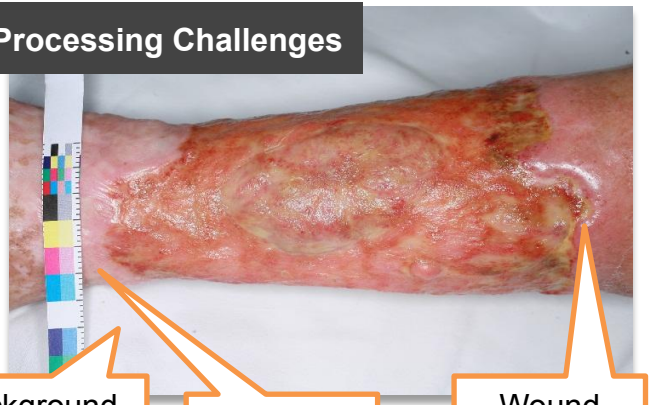
Border and Reepithelization tissues

Goals

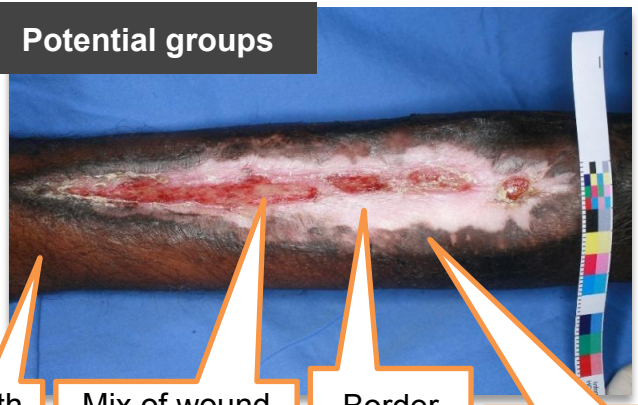
Main Goal:

Designing a divide-and-conquer **cluster approach** for wound analysis

Processing Challenges



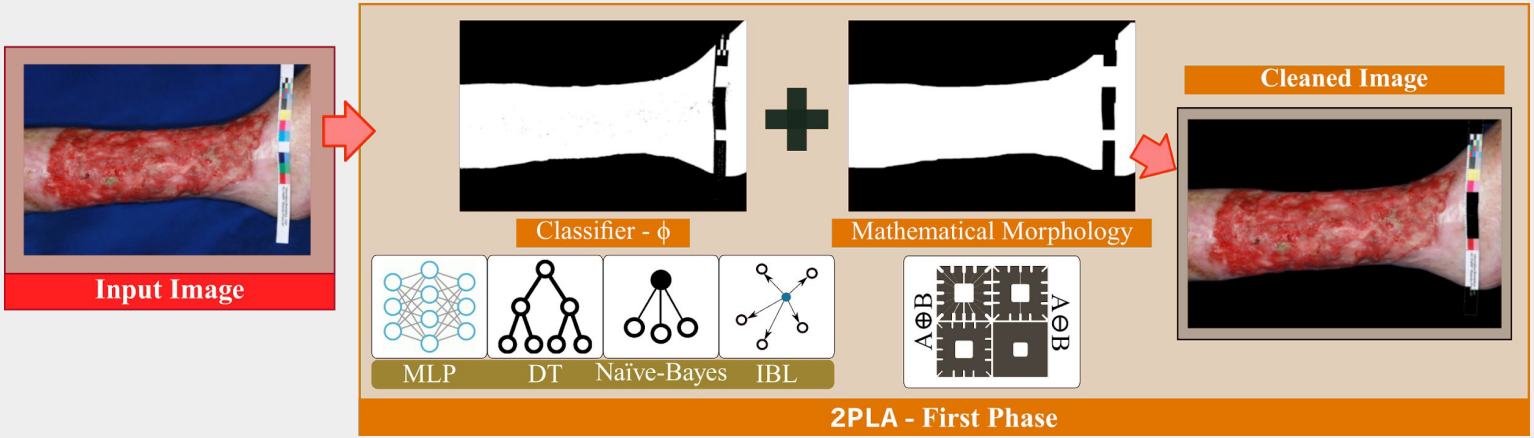
Potential groups



Proposed Method - 2PLA

- Overall idea = two **phases**:
  a. Distinguish **relevant** and **non-relevant** image regions
     i. **Classification-based** task (binary problem)
     ii. **Smooth** noise and misclassifications
  b. Agglomerate remaining tissues by their *similarity*:
     i. **Split** relevant regions into small pieces with well-defined borders
     ii. **Represent** such pieces as points of a multidimensional space
     iii. **Calculate** the distances between the points as a similarity score
     iv. **Aggregate** the similarities according to a clustering criteria
- **Result**:
  a. Object removal
  b. Segmented wound, border and health tissues

Proposed Method - 2PLA



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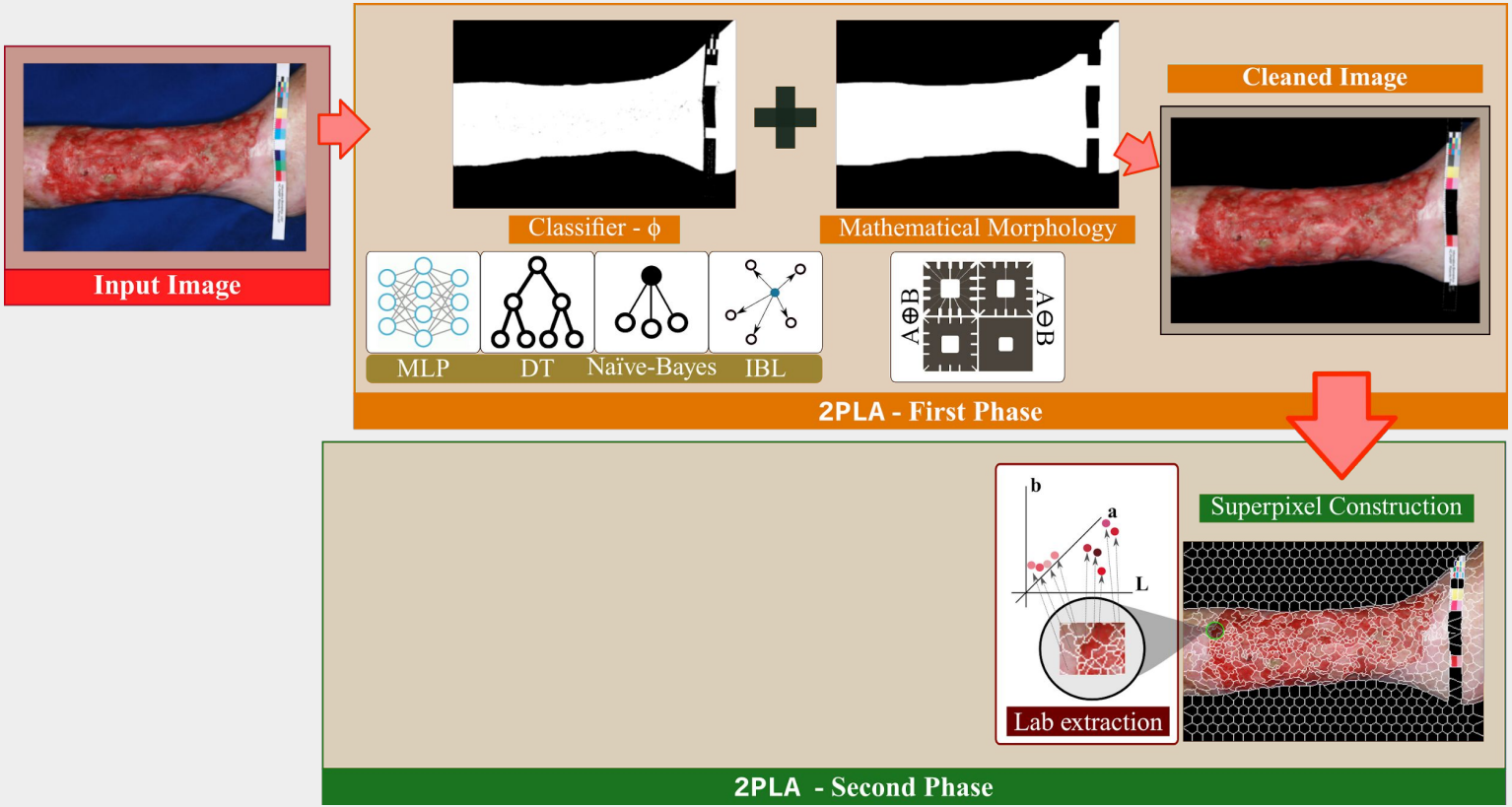

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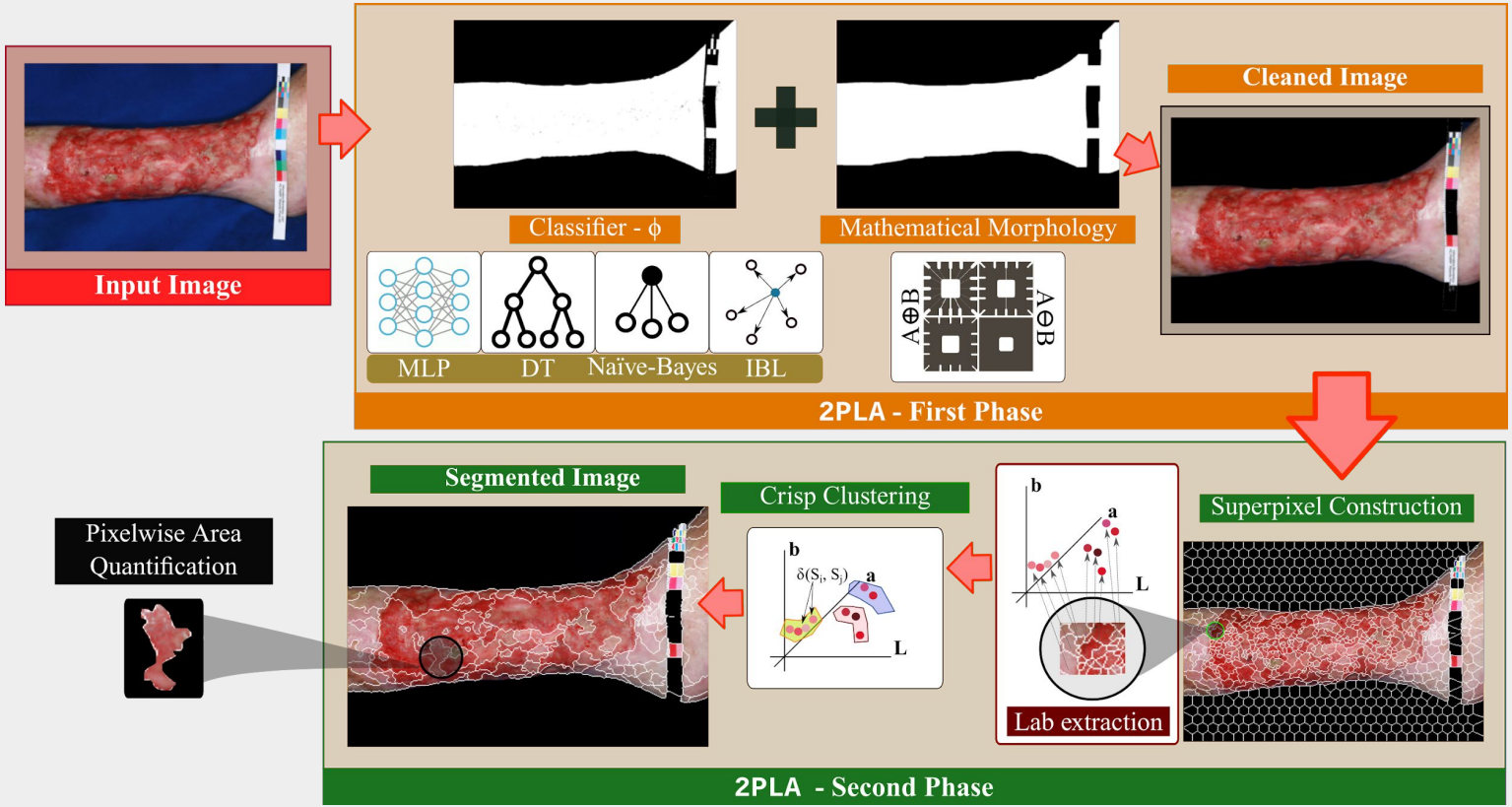
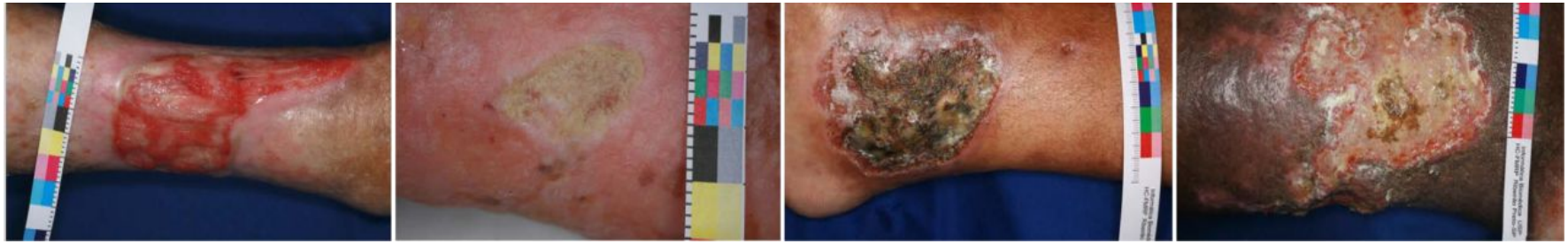


Dataset - ULCER_SET

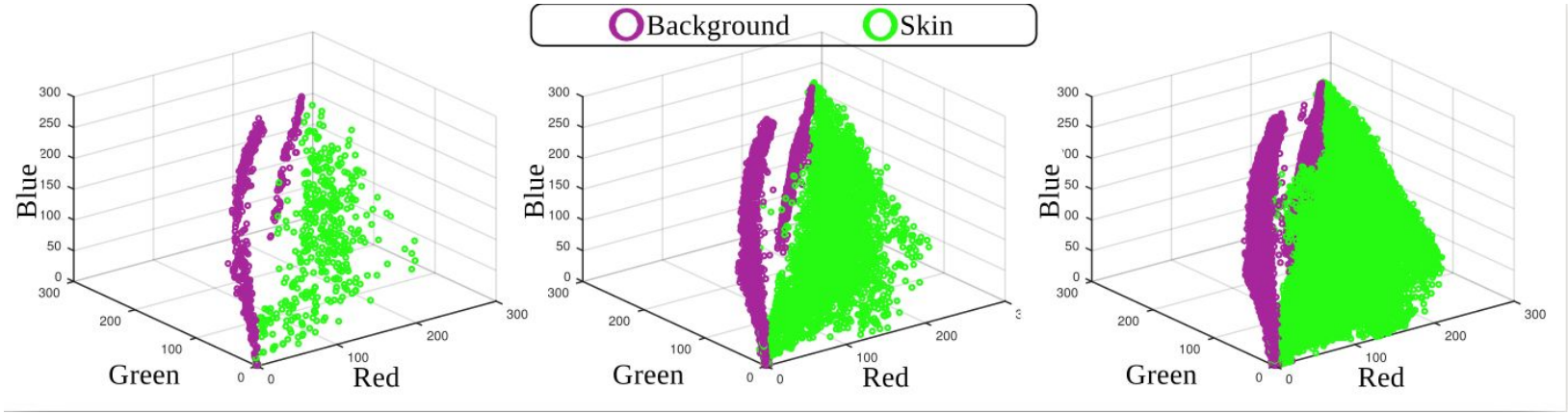
- Curated by Pereira et al. (2013)
  - *Classification of color images of dermatological ulcers. Journal of Biomedicine and Health, 17(1):136–142.*
  - **217 photographies** of venous and arterial ulcers in lower limbs
  - Independent patients with different skin colors, age, and treatments
  - Blue and white cloths were used to emphasize the contrast
  - Photos were taken with the same camera, angle and distance.



2PLA - 1st Phase parameterization

- We asked experts to provide a manual segmentation of **40 representative** ULCER_SET images
- Result:
  - Millions of pixels labeled as either “background” or “skin”
  - Skin pixels form border, granulation, fibrin, and necrosis areas
- Training set:
  - Stratified sampling of labeled pixels in the RGB color space
  - Varying sizes: 1.10^1, 1.10^2, 1.10^3, 1.10^4, and 1.10^5
  - Fed to 10-folds cross-validation routines

2PLA - 1st Phase parameterization



Sampling 1.10.3

Sampling 1.10.4

Sampling 1.10.5

2PLA - 1st Phase parameterization

- Finding the most suitable classifier
  - Training set sizes: 1.10^1, 1.10^2, 1.10^3, 1.10^4, and 1.10^5
  - Average ***Cohen-Kappa Coefficient***

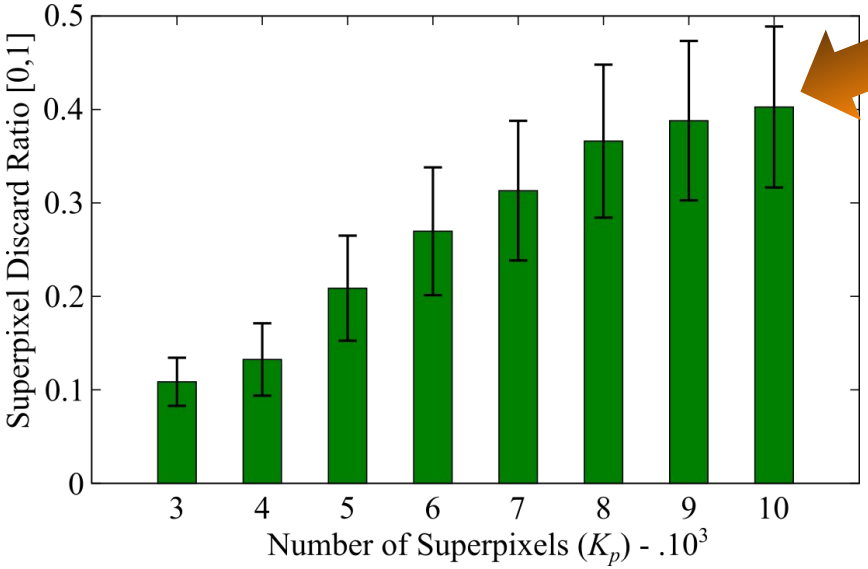
Weighted Mean

	Sample Size						
Classifier	10^1	10^2	10^3	10^4	10^5	μ^*	μ
NB	.156	.710	.793	.797	.805	.804	.652
BN	.038	.423	.639	.722	.743	.739	.513
IbL	.675	.874	**.967**	**.967**	.971	.970	.890
MLP-LM	**.697**	**.895**	.953	**.967**	**.972**	**.971**	**.896**
MLP-RP	.423	.829	.929	.958	.968	.967	.821
DT	.493	.790	.922	**.967**	.970	.969	.828
RF	.350	.854	.947	**.967**	**.972**	**.971**	.818

Simple Mean

Discarding of Superpixels

- **Background removal - 40 images**
  - Mean and deviation for the proportion of discarded regions
  - Discarding ratio grew linearly

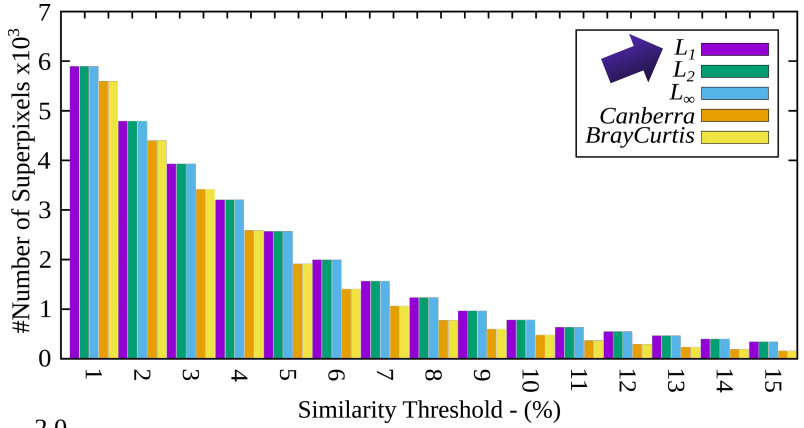


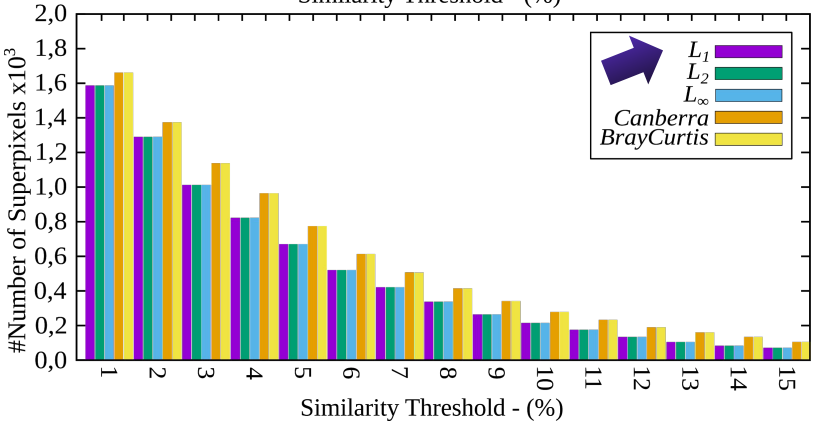
Up to 48% dismissed regions

2PLA - 2nd Phase parameterization

- **Superpixels of ULCER_SET images**
  - Set as 550 to ULCER_SET as pointed out by Chino et al. (2018)
    - *ICARUS: Retrieving Skin Ulcer Images through Bag-of-Signatures. In: CBMS, pp. 82-87*
- **Feature Extractor**
  - Average superpixel value in the LAB color space (3 dimensions)
- **Cluster Method:** DBSCAN
  - Distance functions:
    - L_1, L_2, L_∞, Canberra, and BrayCurtis
  - Similarity threshold ξ:
    - A varying percentage of maximum similarity ranging from 0.5% to 15%

2PLA - 2nd Phase parameterization

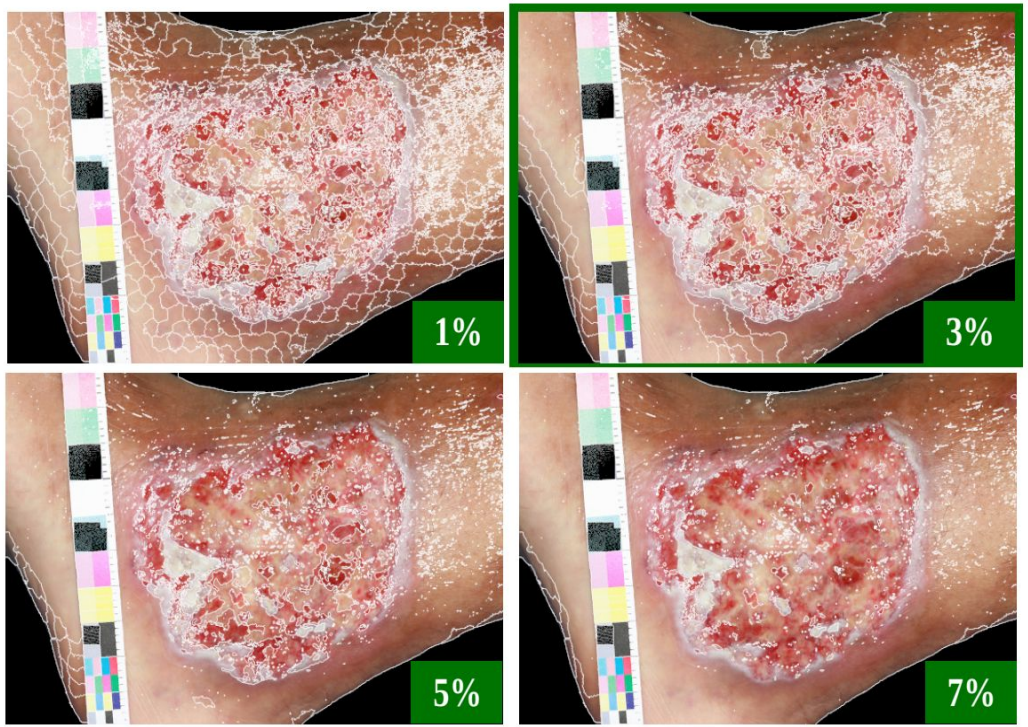




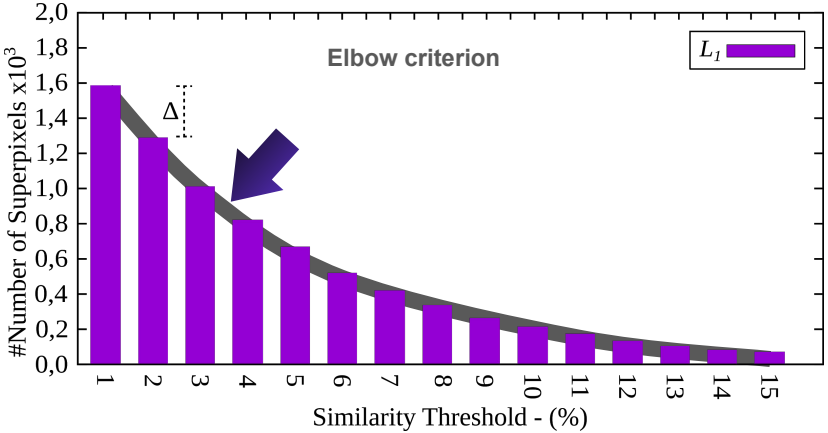
40 images

- Canberra and BrayCurtis presented a greater *variance* regarding the number of clusters
- Functions L_1, L_2, and L_∞ were more *stable*
- On average, **Function L_1** produced fewer clusters

2PLA - 2nd Phase parameterization



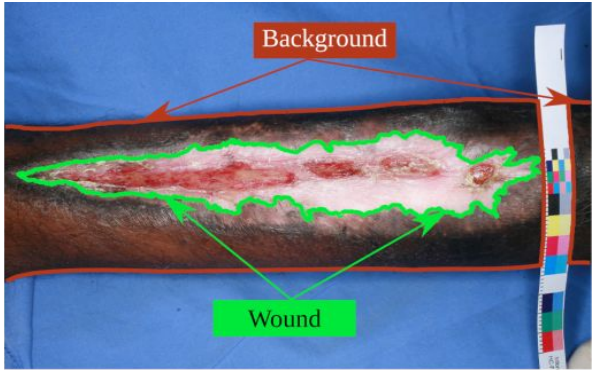
40 images

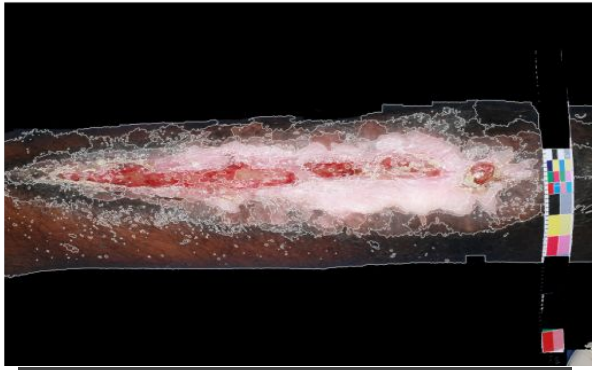


- Cut point determined by the *first of two consecutive bars* whose difference ratio does not exceed a threshold Δ
- Threshold Δ ranging from 5% to 20%
- The most frequent cut was **ξ = 3%**

Empirical findings

- **04 new `ULCER_SET` images manually labeled by experts**
- **`2PLA` Setting**
  - Classifier MLP-LM + 550 Superpixels + Distance function L_1 + Threshold 3%
- **Mean Absolute Error (MAE)**
  - Pixelwise matching of manual *vs.* `2PLA` segmentation





MAE = 0.05, Variance = 0.01

Future Work

- **Expanding dataset**
  - We are working on expanding `ULCER_SET` so that it can be used as a benchmark in the near future
- **Exploring new parameters to `2PLA`**
  - Feature extraction
    - Features learned from autoencoders applied on superpixels
  - Clustering approaches
    - Hierarchical clustering methods
    - Graph-based clustering methods

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Thanks for your attention!

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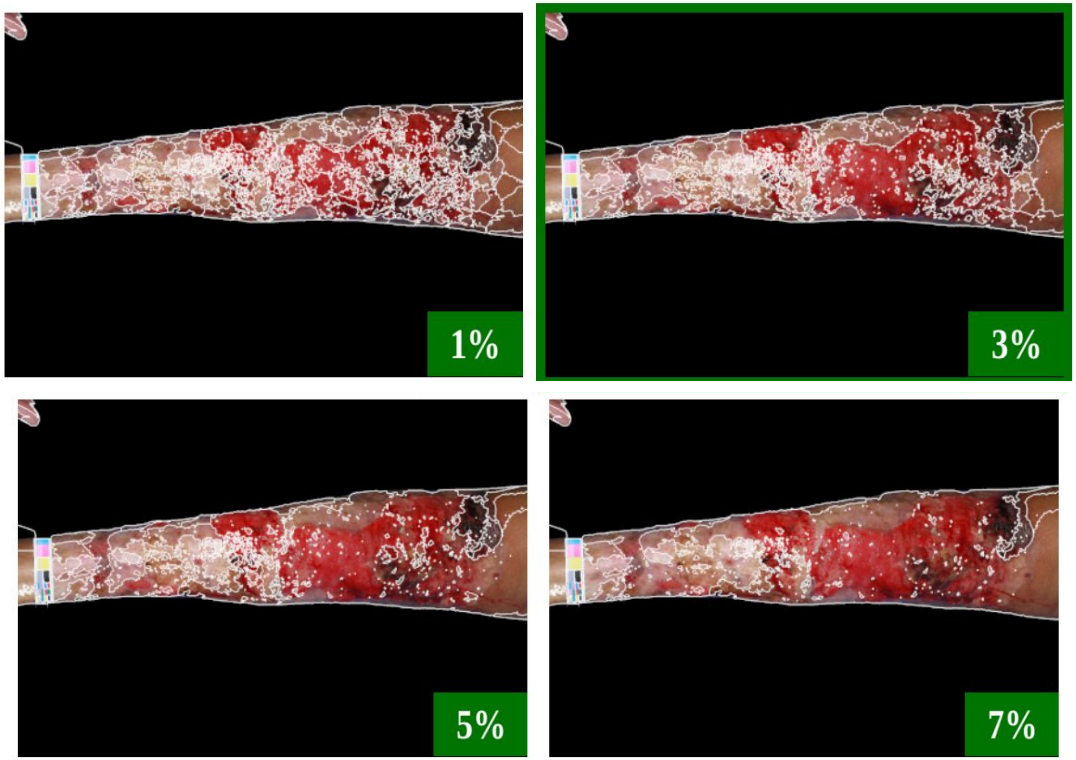
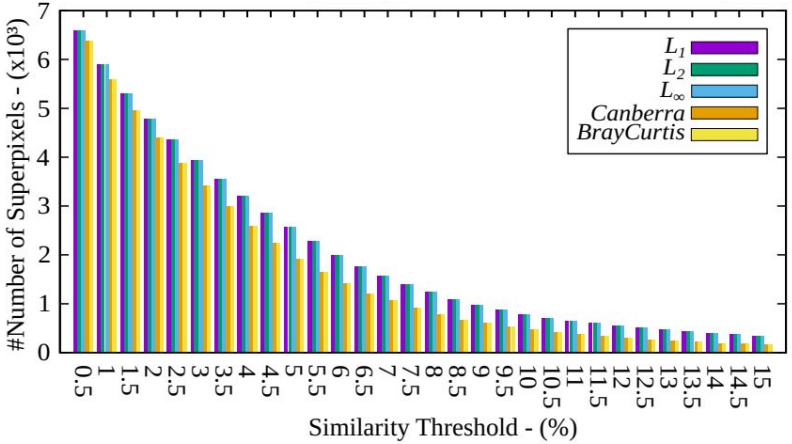
2PLA - DBSCAN parameterization





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Motivation

- **Current approaches**
  - Wound segmentation as a **classification** problem
  - Tissues of **interest** *vs.* **non-interest**

Building blocks:

Input Image

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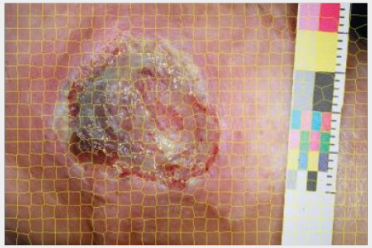

Superpixel construction

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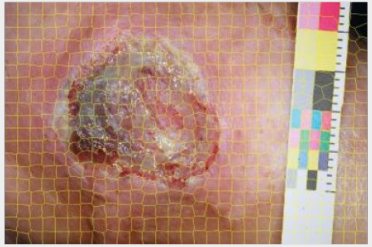
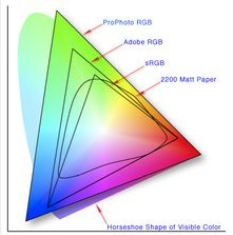
Building blocks: **superpixels, feature extractor**

Input Image



Superpixel construction



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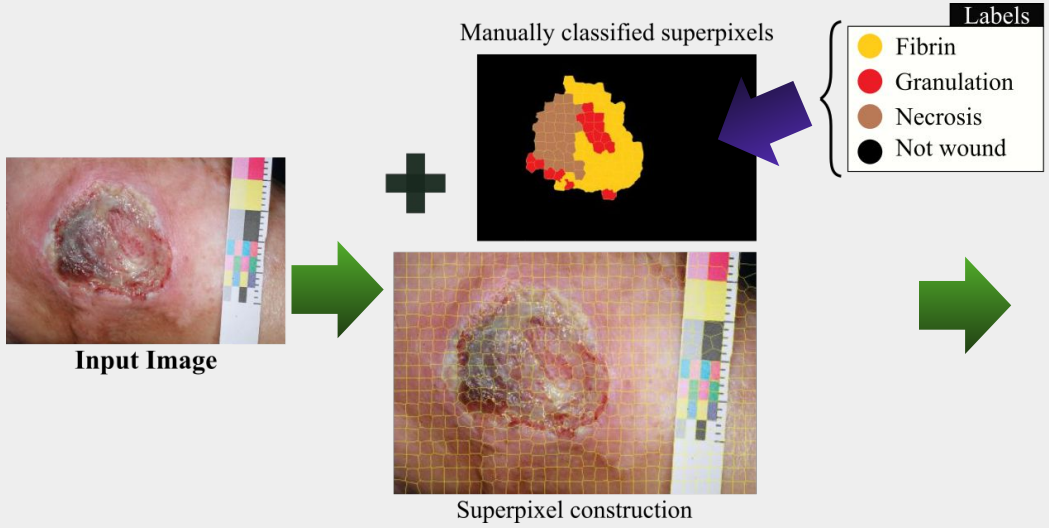

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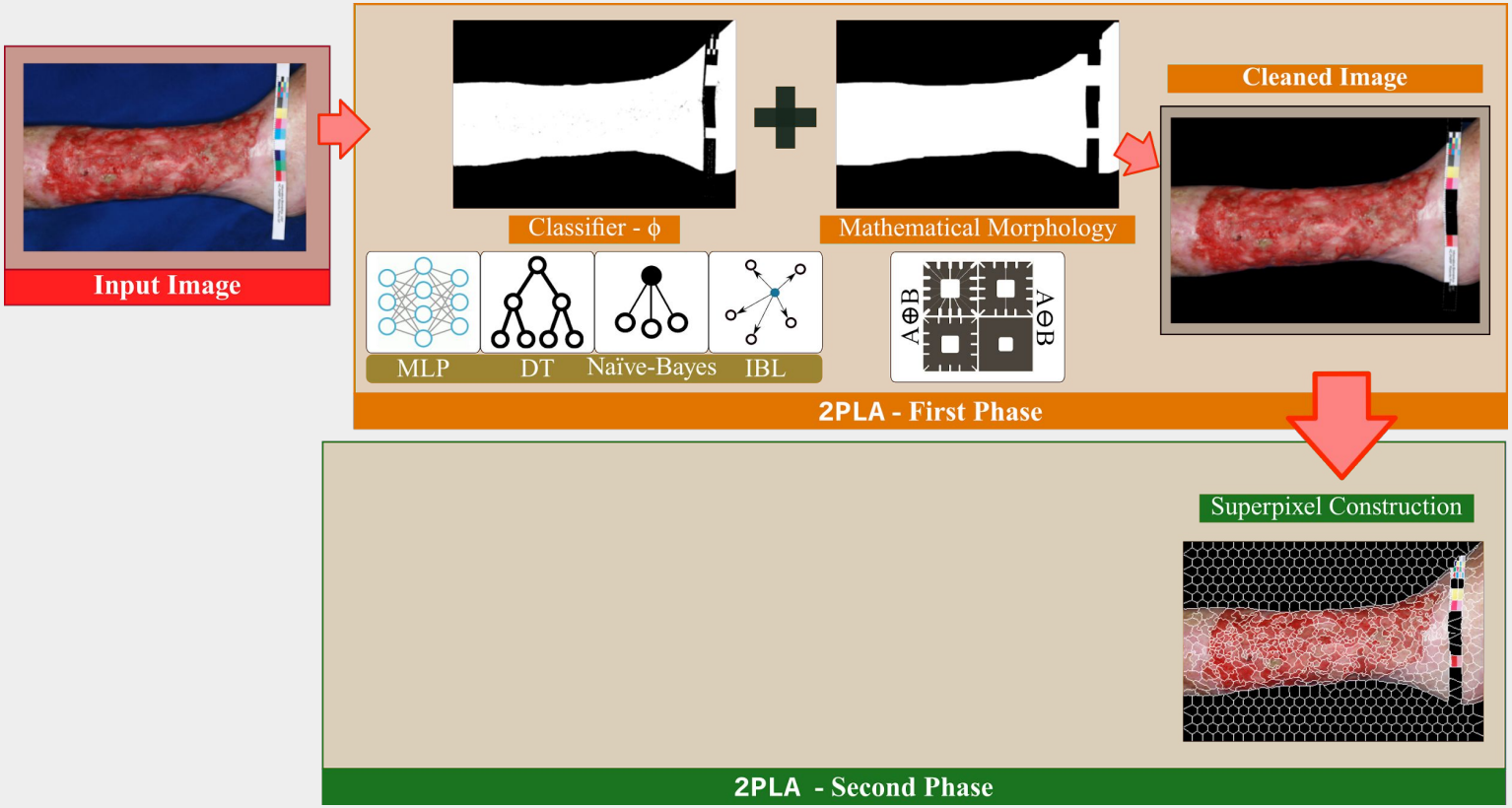

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Questions

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- Empirical Findings
- Future Work

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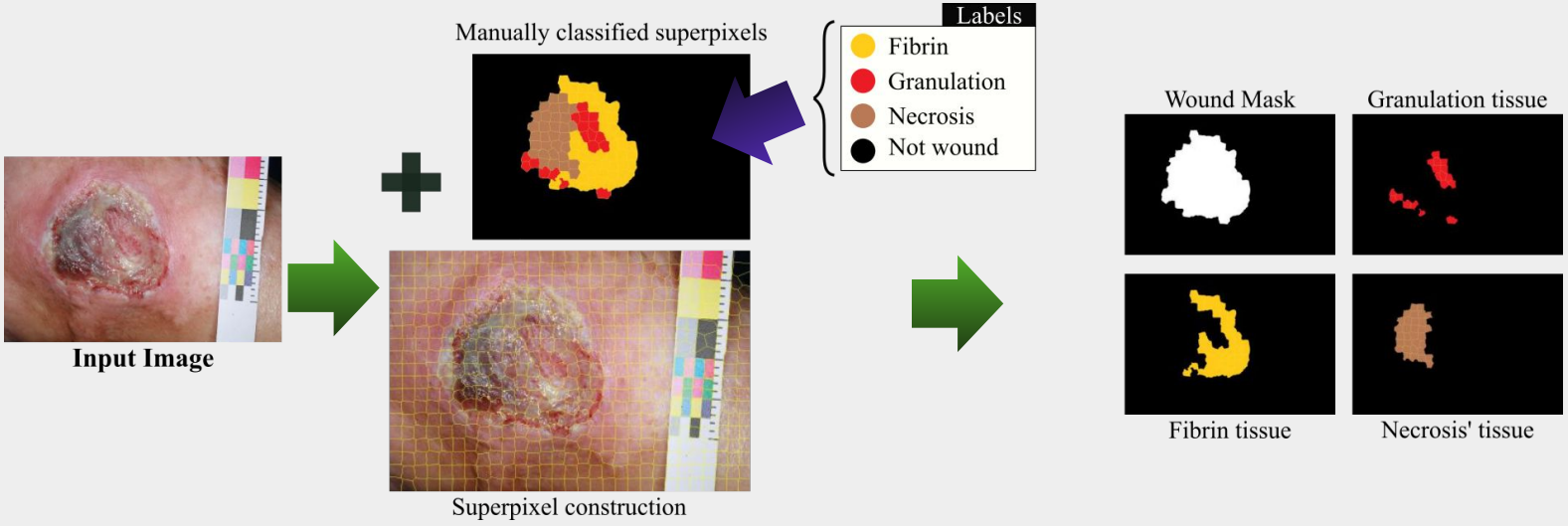

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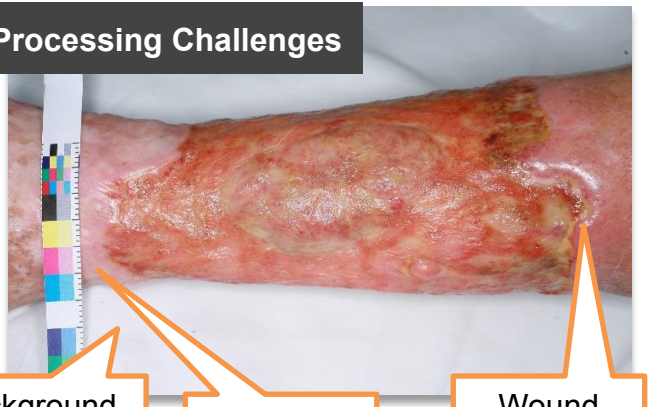
Goals

Main Goal:

Designing a divide-and-conquer **cluster approach** for wound analysis

Processing Challenges



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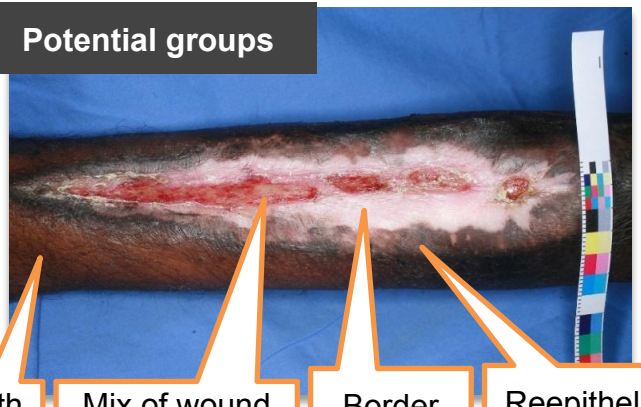

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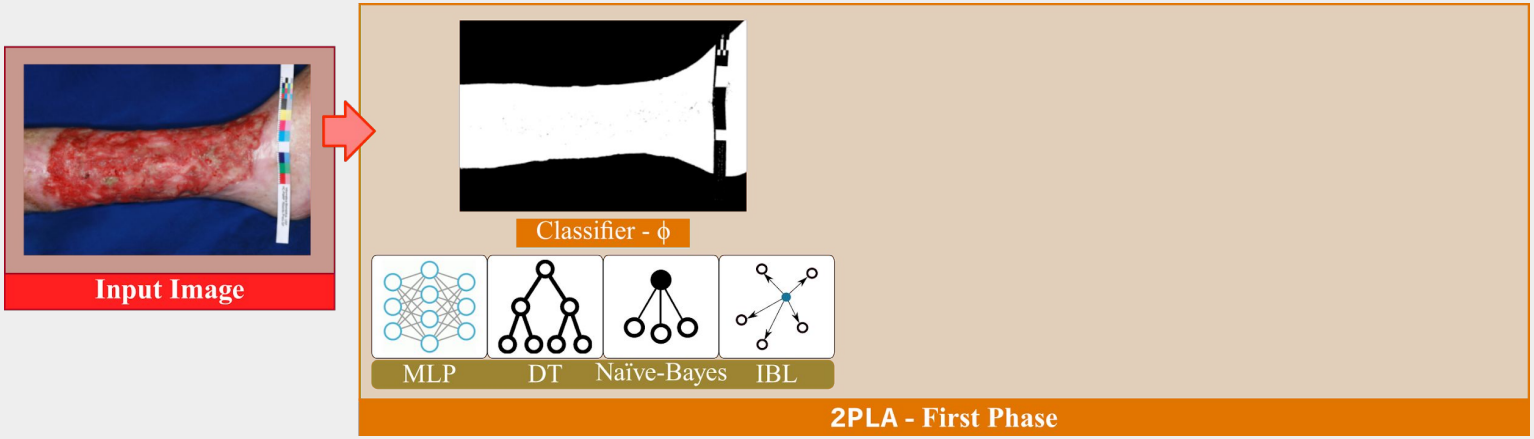
Proposed Method - 2PLA



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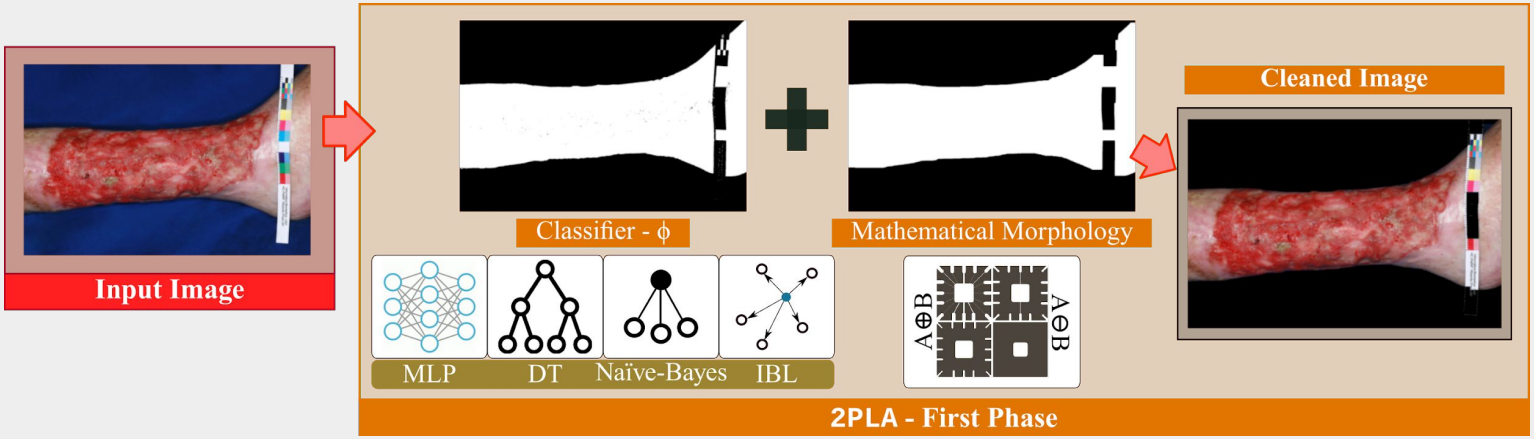

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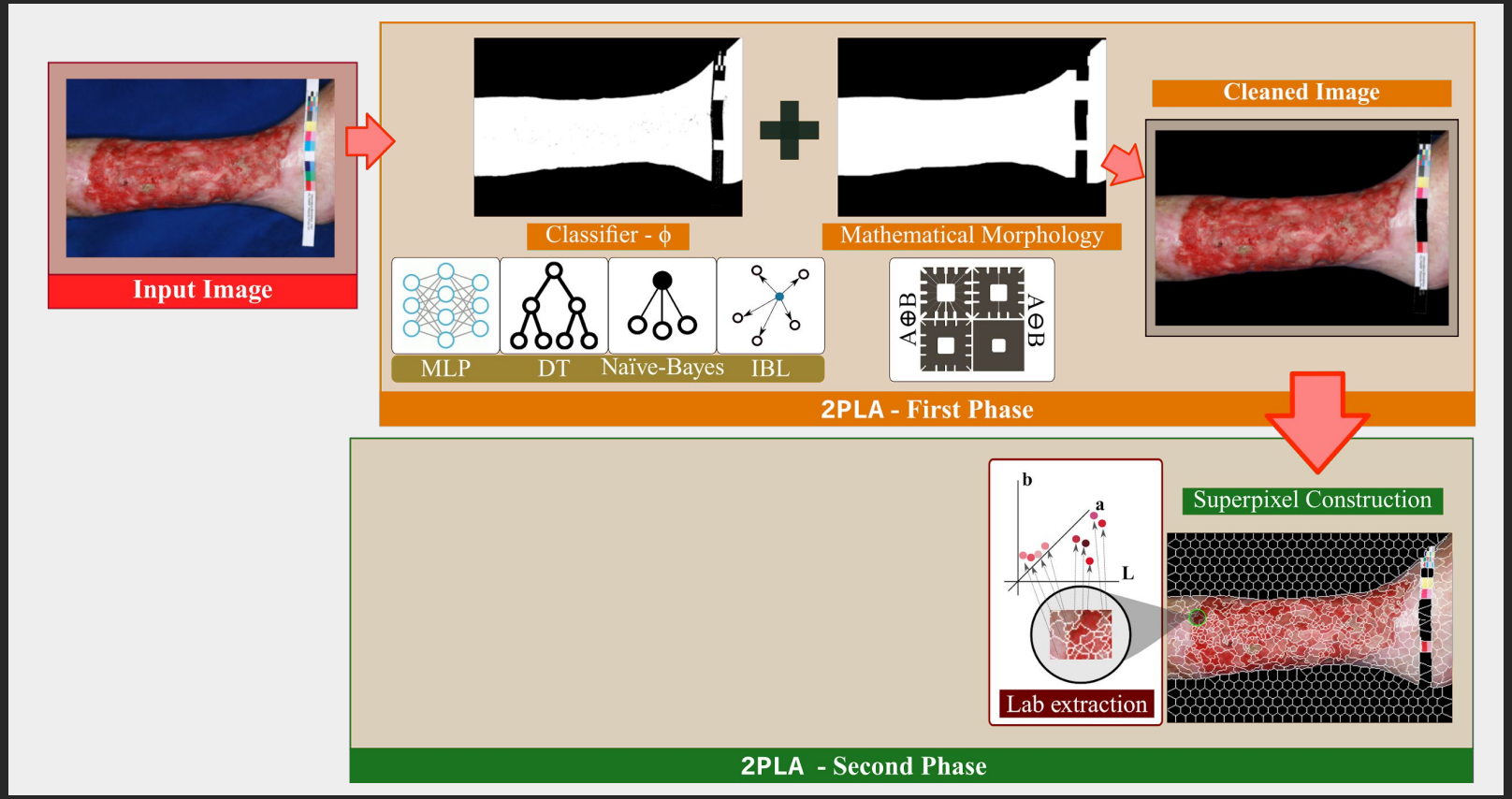

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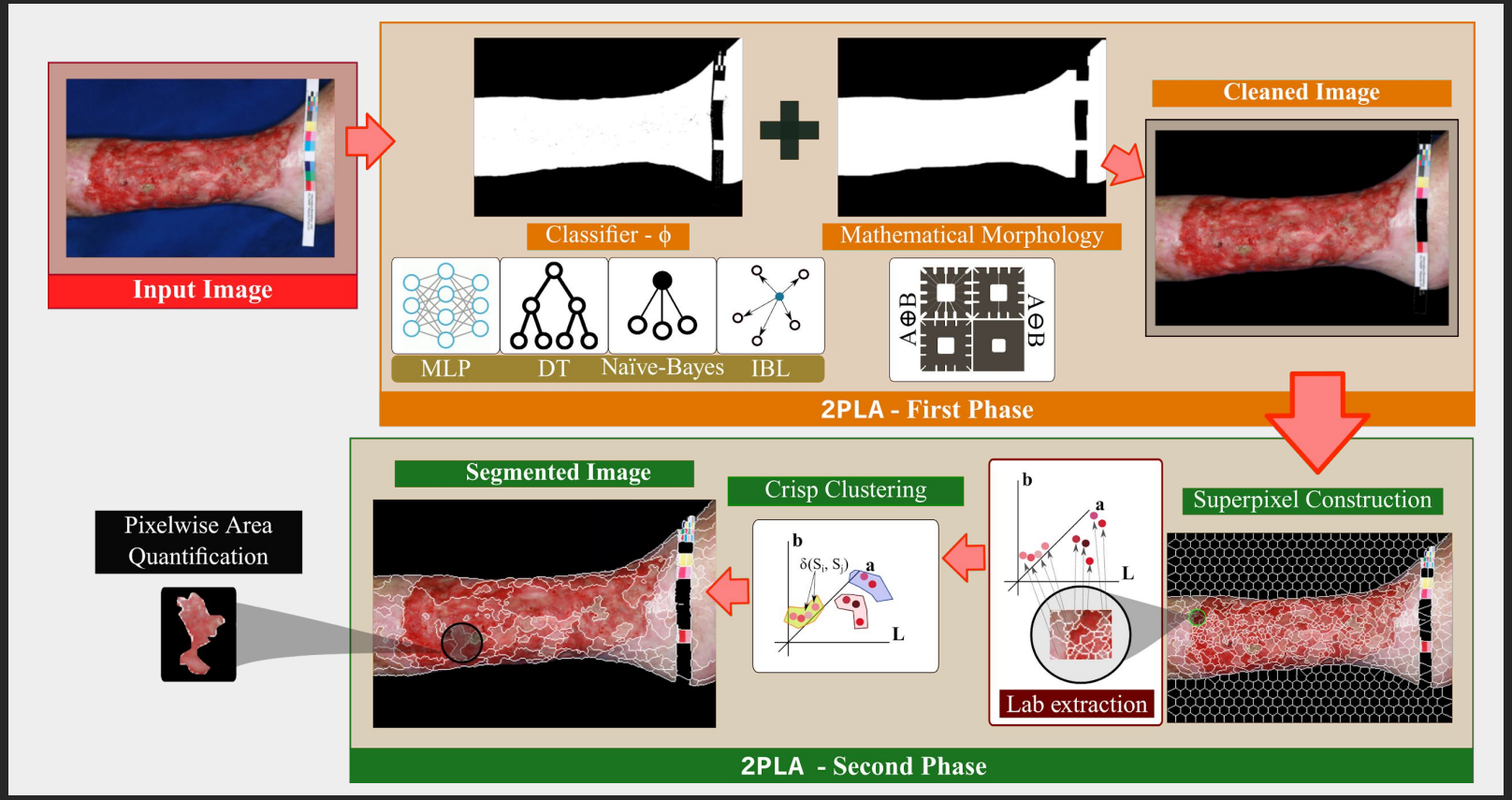

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Dataset - ULCER_SET

- Curated by Pereira et al. (2013)
  - *Classification of color images of dermatological ulcers. Journal of Biomedicine and Health, 17(1):136–142.*
  - **217 photographies** of venous and arterial ulcers in lower limbs
  - Independent patients with different skin colors, age, and treatments
  - Blue and white cloths were used to emphasize the contrast
  - Photos were taken with the same camera, angle and distance.

2PLA - 1st Phase parameterization

- We asked experts to provide a manual segmentation of **40 representative** `ULCER_SET` images
- Result:
  - Millions of pixels labeled as either “background” or “skin”
  - Skin pixels form border, granulation, fibrin, and necrosis areas.
- Training set:
  - Stratified sampling of labeled pixels in the RGB color space
  - Varying sizes: 1.10^1, 1.10^2, 1.10^3, 1.10^4, and 1.10^5
  - Fed to 10-folds cross-validation routines

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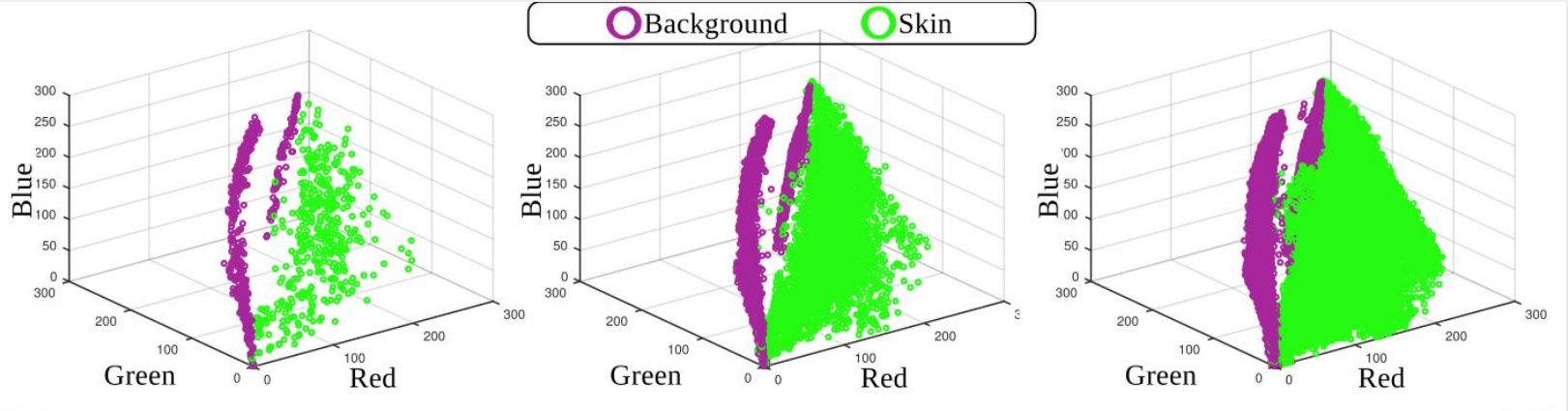

Sampling 1.10.3

Sampling 1.10.4

Sampling 1.10.5

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2PLA - 1st Phase parameterization

- Finding the most suitable classifier
  - Training set sizes: 1.10^1, 1.10^2, 1.10^3, 1.10^4, and 1.10^5
  - Average ***Cohen-Kappa Coefficient***

Weighted Mean

	Sample Size						
Classifier	10^1	10^2	10^3	10^4	10^5	μ^*	μ
NB	.156	.710	.793	.797	.805	.804	.652
BN	.038	.423	.639	.722	.743	.739	.513
IbL	.675	.874	**.967**	**.967**	.971	.970	.890
MLP-LM	**.697**	**.895**	.953	**.967**	**.972**	**.971**	**.896**
MLP-RP	.423	.829	.929	.958	.968	.967	.821
DT	.493	.790	.922	**.967**	.970	.969	.828
RF	.350	.854	.947	**.967**	**.972**	**.971**	.818

Simple Mean

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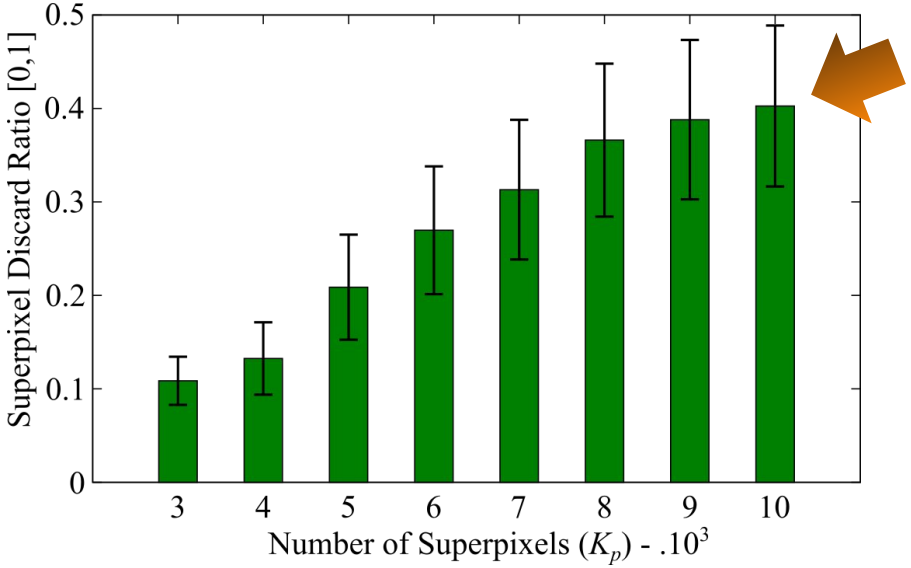
Discarding of Superpixels

- **Background removal - 40 images**
  - Mean and deviation for the proportion of discarded regions
  - Discarding ratio grew linearly



Up to 48% dismissed regions

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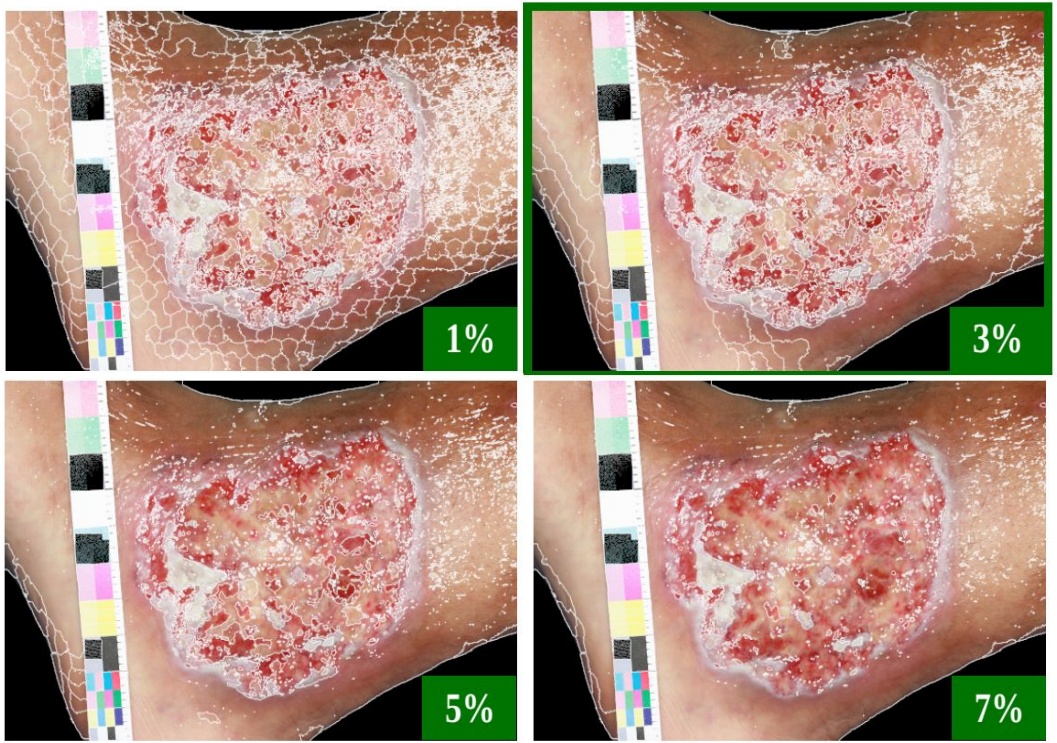
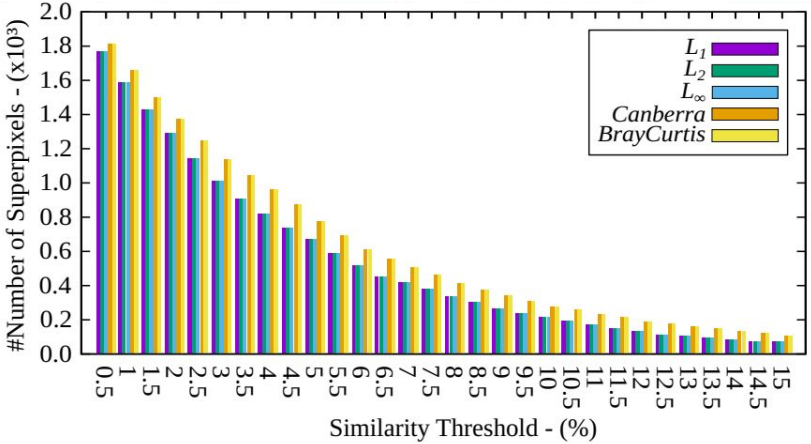
2PLA - 2nd Phase parameterization

- **Superpixels of ULCER_SET images**
  - Set as 550 as pointed out by Chino et al. (2018)
    - *ICARUS: Retrieving Skin Ulcer Images through Bag-of-Signatures. In: CBMS, pp. 82-87*
- **Feature Extractor**
  - Average superpixel value in the LAB color space (3 dimensions)
- **Cluster Method:** DBSCAN
  - Distance functions:
    - L_1, L_2, L_∞, Canberra, and BrayCurtis
  - Similarity threshold ξ:
    - A varying percentage of maximum similarity ranging from 0.5% to 15%

2PLA - DBSCAN parameterization





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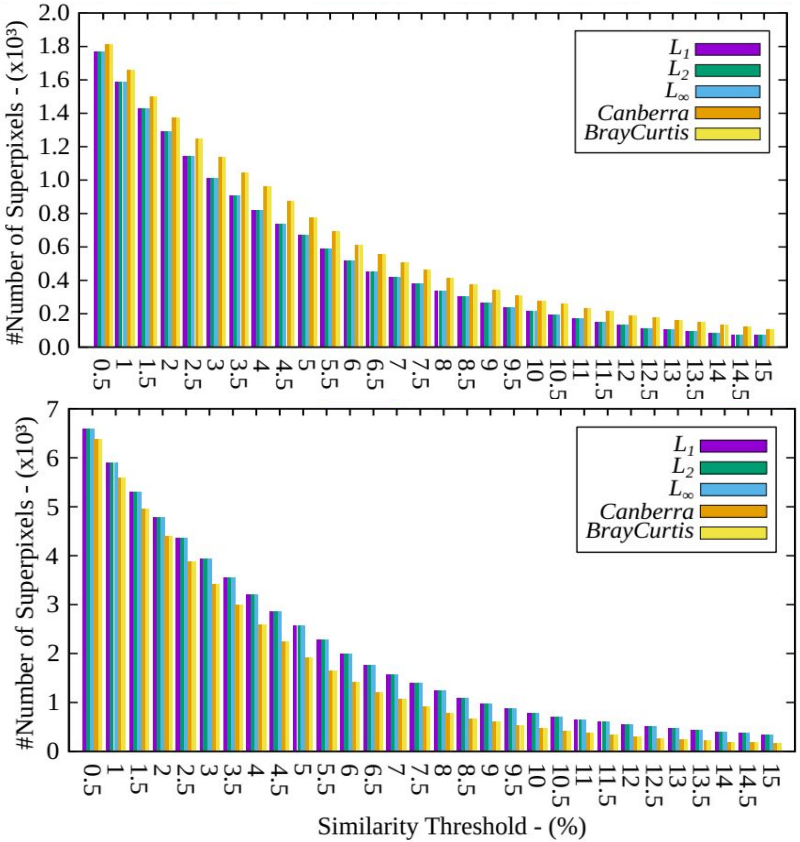
2PLA - 2nd Phase parameterization



40 images

- Canberra and BrayCurtis presented a *wider variance* regarding the number of clusters
- Functions L_1, L_2, and L_∞ were more *stable*
- **Function L_1** generated fewer clusters in comparison to others, on average

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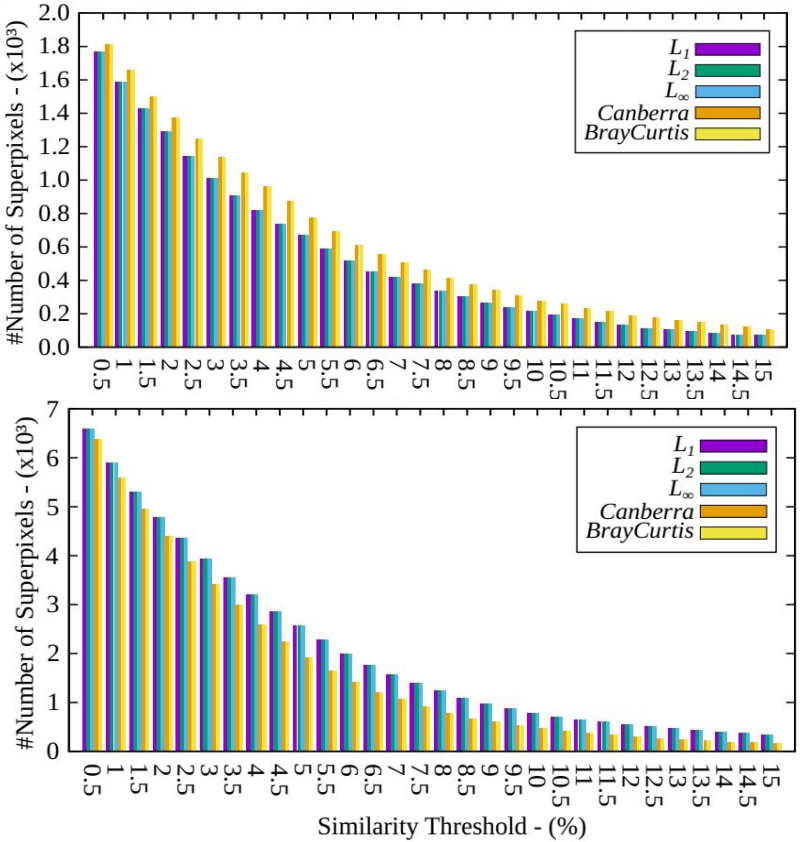

40 images

- Elbow criterion of Scree-Plot
- Cut point determined by the first of two consecutive bars whose difference ratio does not exceed a threshold Δ
- Experiments with Δ ranging from 5% to 20%
- The most frequent cut point was **ξ = 3%**

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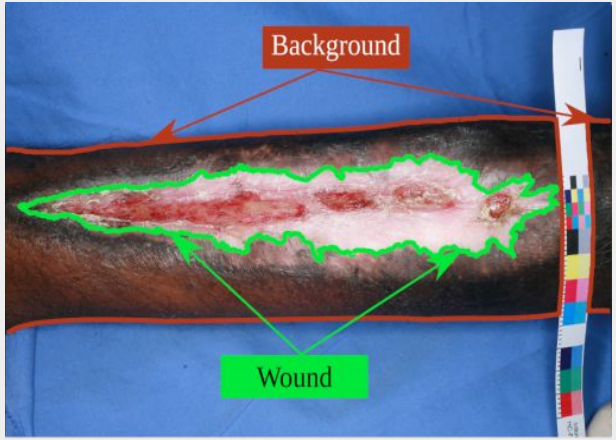
Empirical findings

- **04 new `ULCER_SET` images**
  - Manually labeled by experts
  - Pixelwise matching of manual *vs.* `2PLA` segmentation
- **`2PLA` Setting**
  - Classifier MLP-LM
  - SLIC Superpixels
  - Distance function L_1
  - Similarity threshold 3%
- **Mean Absolute Error (MAE)**
  - Average absolute differences between two labeling tasks

Empirical findings



MAE = 0.05 - Variance = 0.01

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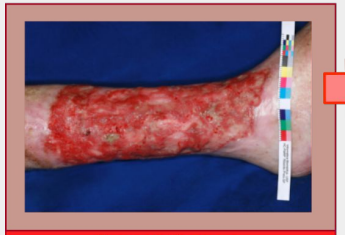
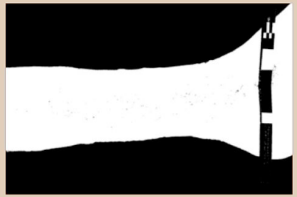
Future Work

- **Expanding dataset**
  - We are working on expanding `ULCER_SET` so that it can be used as a benchmark in the near future
- **Exploring new parameters to `2PLA`**
  - Feature extraction
    - Features learned from autoencoders applied on superpixels
  - Clustering approaches
    - Hierarchical clustering methods
    - Graph-based clustering methods

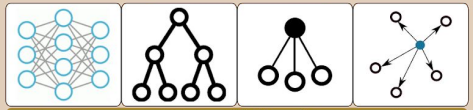
Proposed Method - 2PLA



Input Image



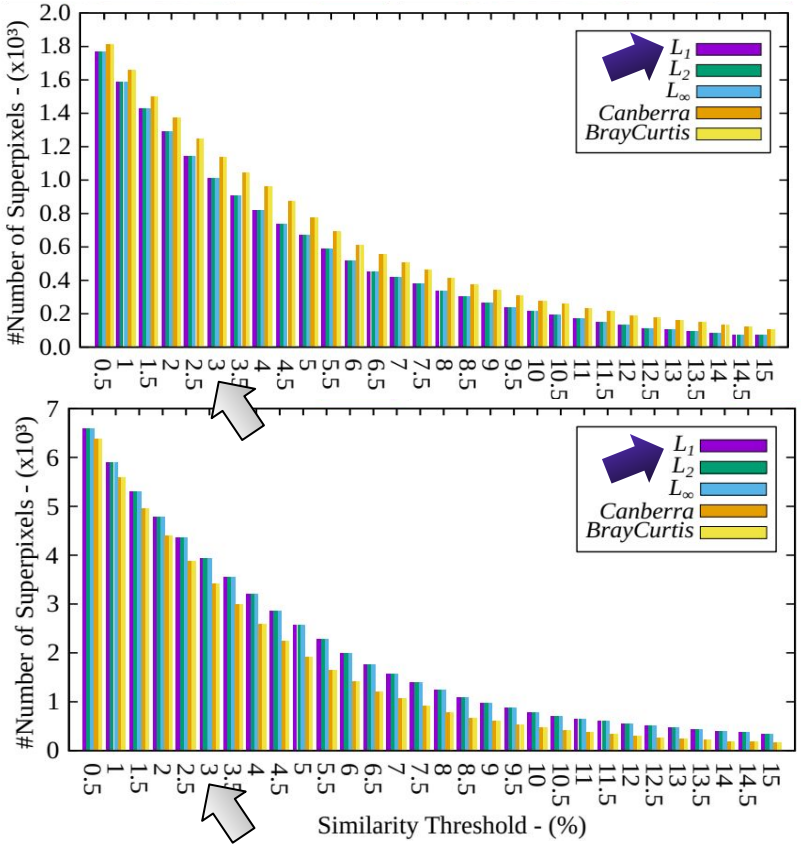
Classifier - ϕ



MLP DT Naïve-Bayes IBL

2PLA - First Phase

2PLA - 2nd Phase parameterization



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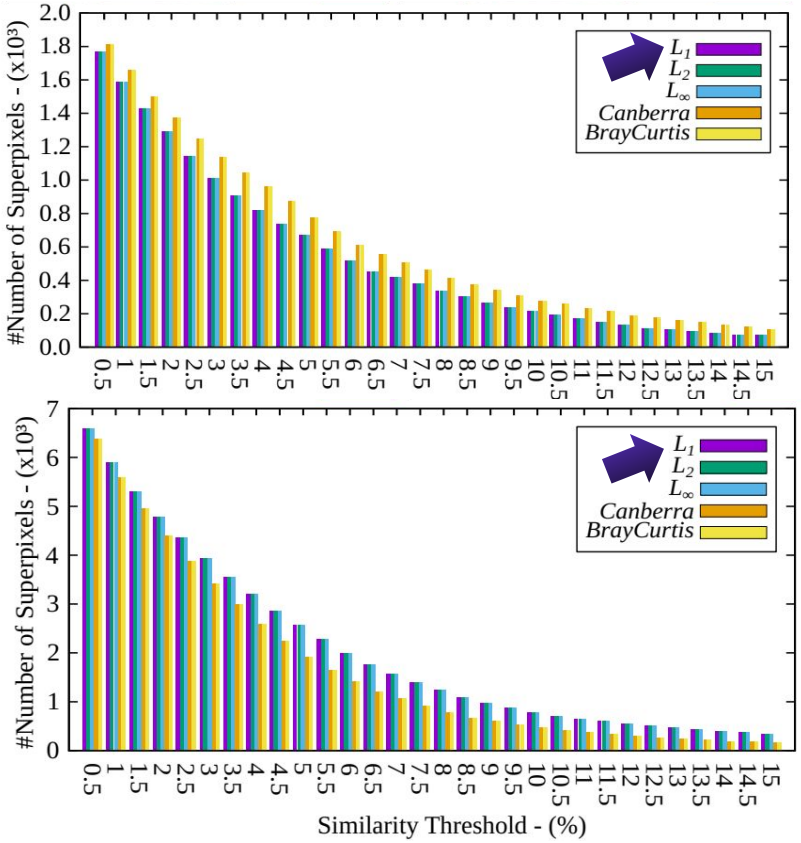

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