

A MOBILE, RELIABLE AND USER-FRIENDLY TECHNOLOGY FOR PROCESSING PLANTAR FOOT INFRARED THERMAL IMAGES APPLIED TO THE EARLY PREVENTION OF FOOT ULCERS.

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CONTEXT

- Diabetes is a rapidly growing worldwide disease which will affect 640 million people in 2040.
- The occurrence of a foot ulcer is often associated with foot hyperthermia.
- **Hyperthermia** is defined as a temperature difference greater than 2.2°C between a foot region and the same region on the contralateral foot.
- **Image modality:** Infrared cameras.

IMAGE SEGMENTATION

Prior shape method

Our method is based on a modified active contour model that includes the prior shape information of the plantar foot curve, as an extra term in the snake energy function of Kass et al.

The total energy of the model is :

$$E_{total} = \int_0^1 (E_{intern}(C) + E_{image}(C) + E_{con}(C) + E_{PS}(C)) ds,$$

E_{intern} is the internal energy term (length and curvature), E_{image} is the image energy given by gradient information, E_{con} is the balloon force to avoid the curve blocking.

The prior shape energy functional E_{PS} assesses and minimizes the normalized difference between the curve curvature C_{SS} and the prior shape curvature C_{SS}^* during the contour evolution.

$$E_{PS} = \gamma |C_{SS}(s) - \zeta C_{SS}^*(s)|^2,$$

γ is a ponderation parameter, ζ is the normalization factor.

Deep Learning SegNet

The encoder network consists of 13 convolutional layers which correspond to the first 13 convolutional layers in the VGG16 network

The encoder depth; which is the number of downsampling (or upsampling) operations, is chosen equal to 5. the networks is trained using the stochastic gradient descent with momentum optimizer (SGDM). The momentum value is chosen equal to 0.9, the initial learning rate equal to 0,0001. The size of the mini-batch is chosen to be 4 images.

SEGMENTATION RESULTS

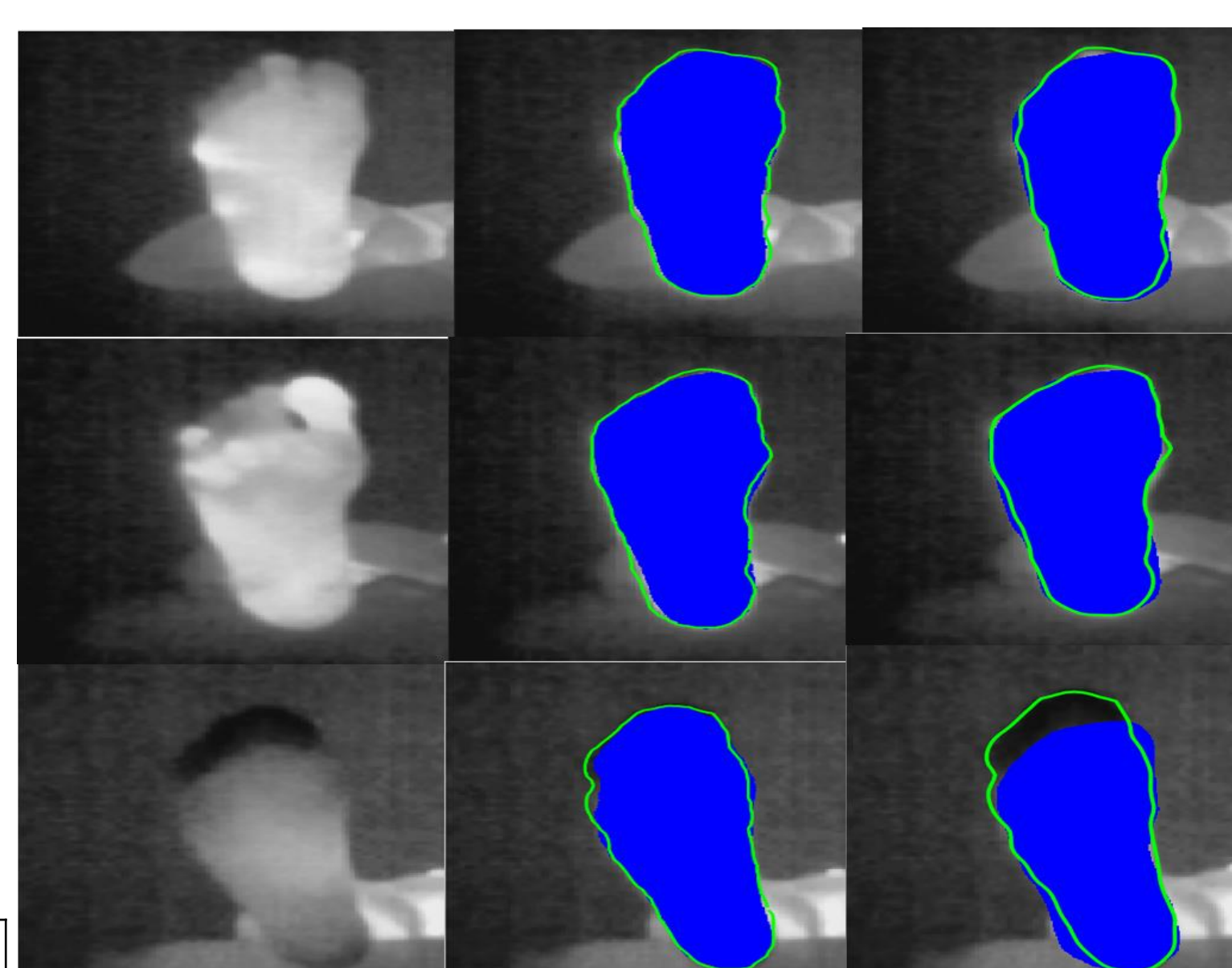
Evaluation metric:

The Dice Similarity Coefficient (DSC).

This score assesses the similarity between the foot region given by the ground truth contour and the regions bounded by the segmentation regions given by the segmentation methods.

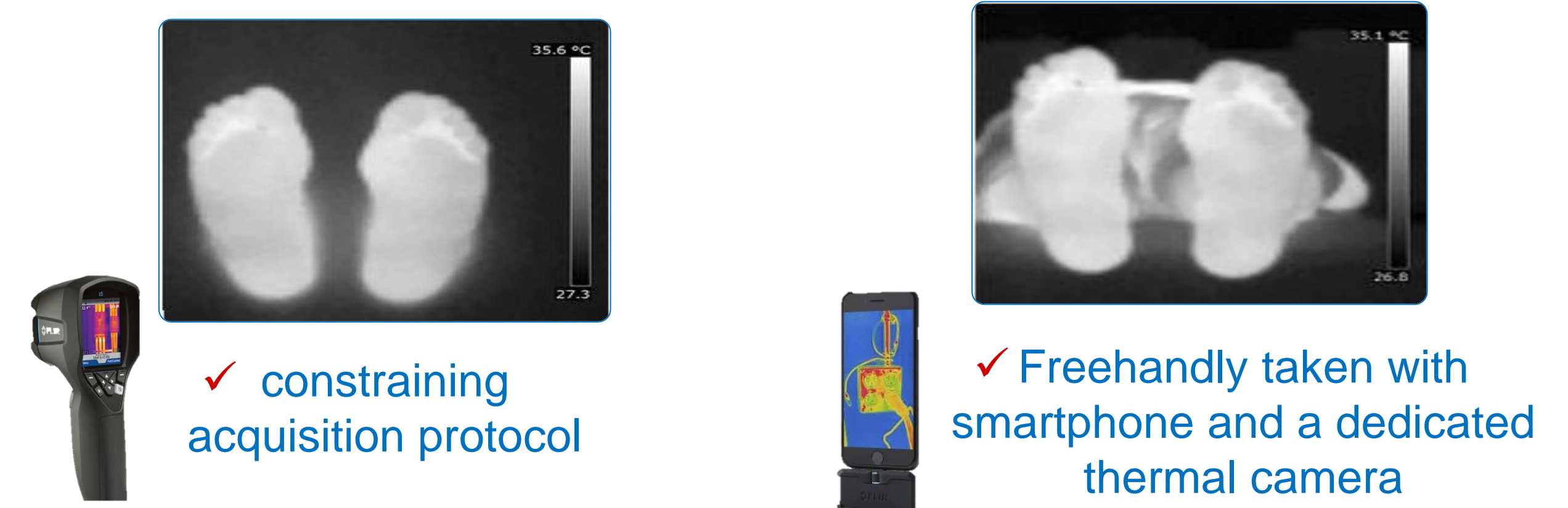
Prior shape method	Deep Learning SegNet
94%	97.26%
±2%	±0.69%

Mean DSC (± standard deviation) of the segmentation methods



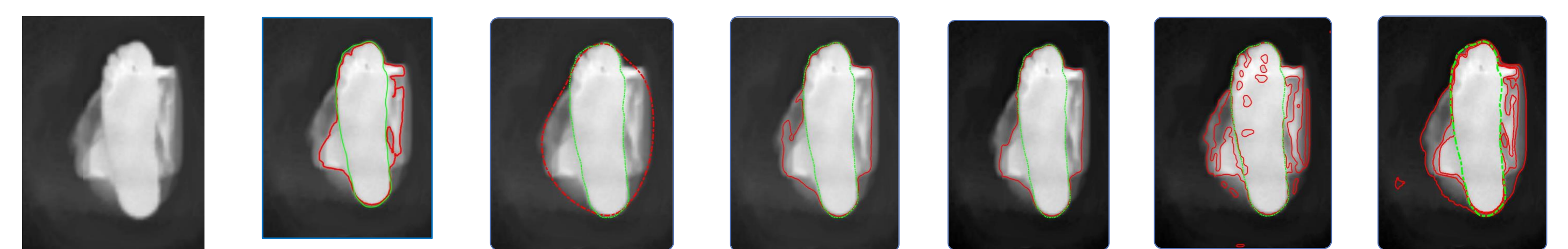
Segmentation of 3 plantar foot thermal images (first column). The second column corresponds to results given by SegNet method. Results given by the prior shape method is in the last column. The blue regions correspond to the segmentation. The green curve is the ground truth contour.

PROBLEMATIC



- Acquired images are noisy and the statistical features of the noise are very close to those of the plantar foot surface.

Automatic segmentation of such images is a powerful challenge. Existing classical methods of blind segmentation methods fail to segment these IR images.



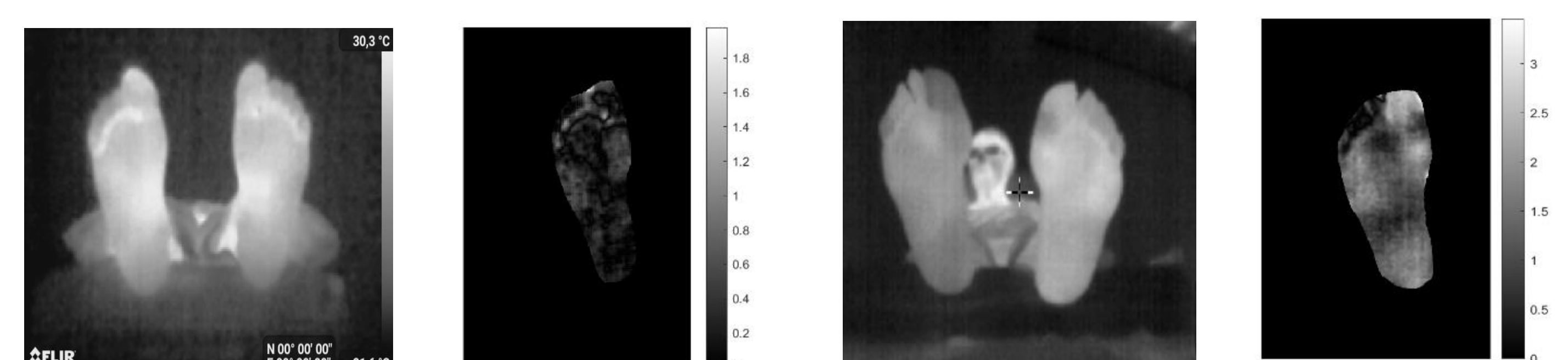
Right foot Region growing Snake Chan-Vese Zhang, 2010 Dong, 2013 Li, 2017
Red curve is the segmentation result and green curve is the ground truth contour

MATERIALS

- The chosen camera is the FlirOne thermal camera that has to be used with a smartphone. This camera has a resolution of 160 x 120 pixels and a spectral range of 8 - 14 μm . FlirOne is sensible enough to detect temperature differences of 0.1°C.
- **25 healthy** (non-diabetic) persons participated in our acquisition campaign. This sample group was composed of 10 women and 15 men with a mean age of 34 from staff members of Orleans University, France
- **146 diabetic foot subjects** (the Diabetic Foot Service of Dos de Mayos hospital of Perou): This sample group is composed of 52 women and 94men with a mean age of 58.
- **36 diabetic foot subjects presenting ulcers** (the Diabetic Foot Service of the Regional Hospital of Orleans): This sample group is composed of 10 women and 26 men with a mean age of 69.

HYPERTHERMIA DETECTION

- We register the two segmented feet images using the iterative closest point (ICP) registration method.
- The point to point absolute temperature difference image $|\Delta T|$ is calculated.
- It is known that $|\Delta T|$ is of about 1°C for healthy subjects.
- The average $|\Delta T|$ is of 0.27°C for the first person (healthy person).
- The $|\Delta T|$ is about 3°C, much higher than the 2.2°C for the patient presenting an ulcer.



healthy person

patient presenting an ulcer

in the big toe.

REFERENCES

- Bougrine, A., Harba, R., Canals, R., Ledee, R., & Jabloun, M. (2017, November). A joint Snake and Atlas-based segmentation of plantar foot thermal images. In Image Processing Theory, Tools and Applications (IPTA), 2017 Seventh International Conference on (pp. 1-6). IEEE.
- Kass, M., & Witkin, A. (1988). Snakes: Active Contour Models. International Journal of Computer Vision.
- BADRINARAYANAN, Vijay, HANDA, Ankur, et CIPOLLA, Roberto. Segnet: A deep convolutional encoder-decoder architecture for robust semantic pixel-wise labelling. *arXiv preprint arXiv:1505.07293*, 2015.