

# Estimation of spinal cord symmetry from MRI data to improve registration algorithms

Nicolas Pinon  
2018-2019

Supervisors : Julien Cohen-Adad (Neuropoly)  
Thomas Rodet (ENS Cachan)

école  
normale  
supérieure  
paris-saclay



## Introduction

Registration is the process that maps an image to another, allowing for better comparison. It is essential in medical imaging, allowing tracking of the same patient, or conduction of longitudinal studies.

To improve this process, we are interested in detecting the rotation of the spinal cord, which can happen for instance when a patient tilt its head in the scanner.

To tackle this problem we decided to use the natural *bilateral symmetry* of the spinal cord.

The main assumption of this project being that the axis of symmetry will give us the rotation of the spine.

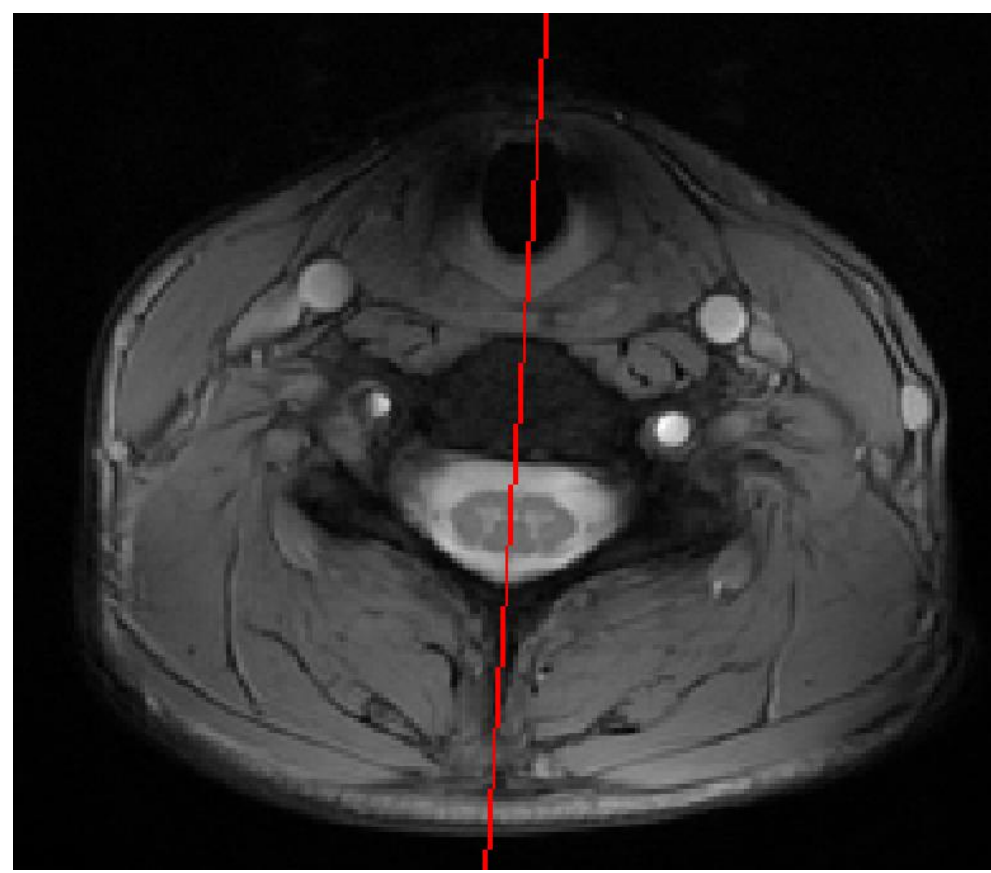


Figure 1 : Transverse MRI of a spinal cord with the detected axis of symmetry superposed in red.

## Evaluation

The rotation detection method that we proposed will be used in a registration process. At this stage of the registration, we have at our disposal the image itself and a segmentation of the spinal cord (see figure 6),

The method that was used before to detect the rotation is a simple PCA [3], meaning we take the two eigenvectors of the segmentation and determine the orientation of the ellipse.

This method has the major drawback that it will not work in cases where the spinal cord is almost round.

We propose 2 ways of evaluating our method VS the PCA method :

i) A *qualitative evaluation* : we visualize a great quantity of MRI with the axis of rotation superposed.

ii) A *quantitative evaluation* : this process is done in 2 steps shown in figure 7. We register a great number of images to a template and we will compute similarity metrics between the registered image segmentation and the atlas segmentation. For instance we can compute the Dice score.

The qualitative and quantitative evaluation are complementary, we can study the link between a visually pleasing or unpleasing symmetry axis and the metric score to validate our evaluation method.

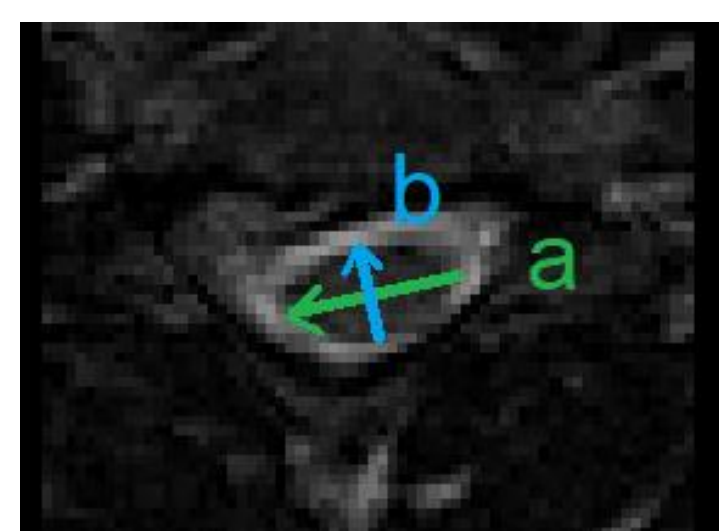


Figure 4 : The two eigenvectors of the spinal cord segmentation.

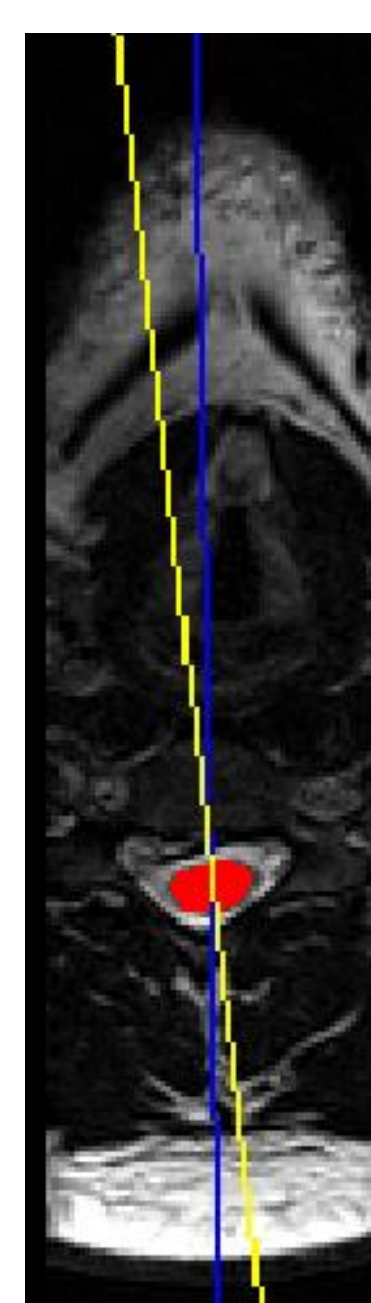
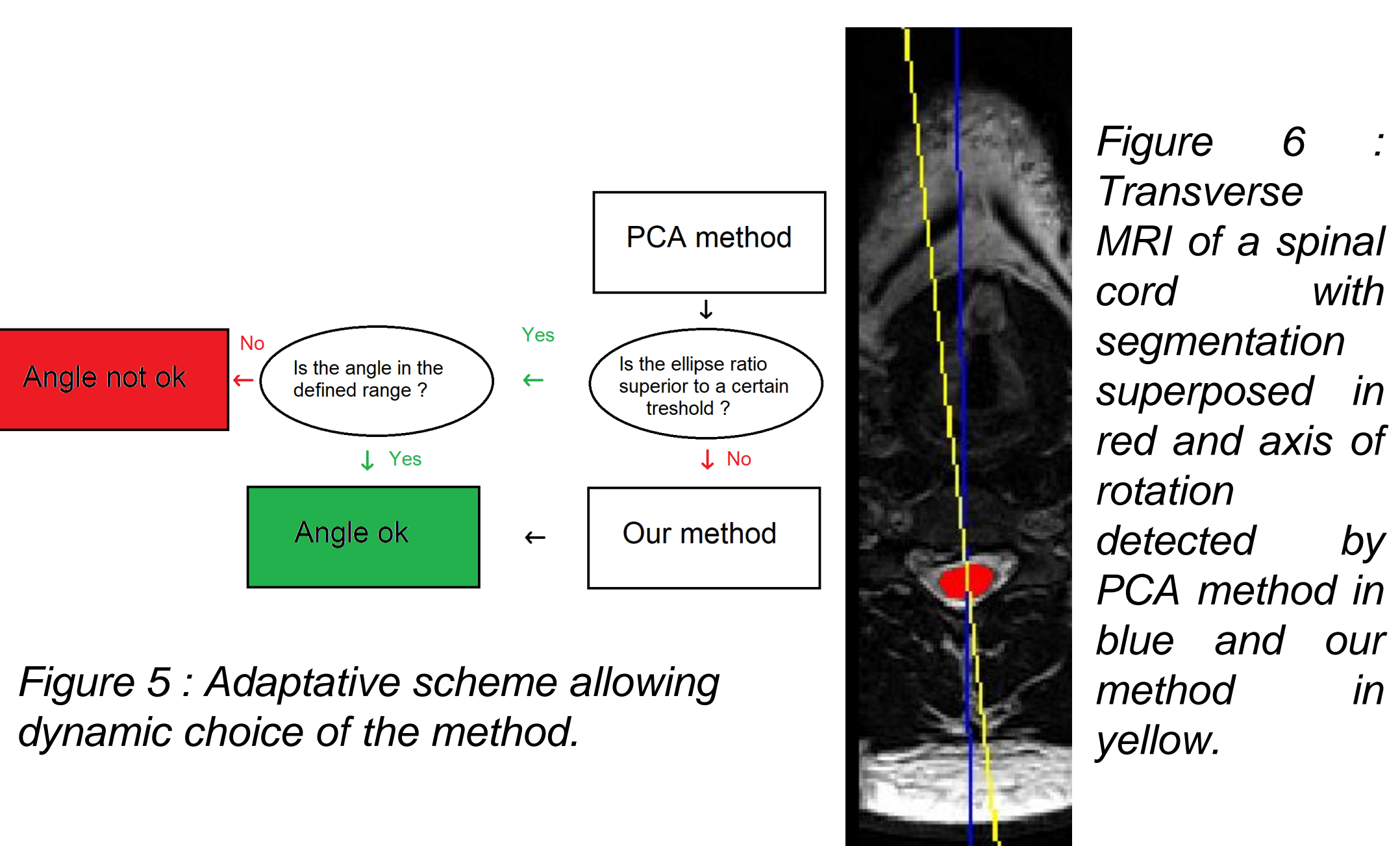


Figure 6 : Transverse MRI of a spinal cord with segmentation superposed in red and axis of rotation detected by PCA method in blue and our method in yellow.

We also noticed after many experiments that neither our method nor the PCA method was better. We then propose an adaptive scheme (figure 5) that chooses between the two methods based on quantitative criteria.

## Conclusion

We have shown that our improvements to the method are conclusive (denoising figure 8) and the detected axis are visually pleasing.

Our method performs better in quasi-circular spinal cord cases, which is what was expected. It will be implemented in the lab main project : SCT [4].

We still suggest trying and improving other symmetry detection algorithms [5][6][7] and trying fine tuning the hyperparameters present in this method. There is still large quantitative evaluation to do to validate our method, the adaptive scheme and the evaluation method.

## Algorithm

### I. Base algorithm

Sun et al. [1] proposed an algorithm based on the gradient of the image. We first compute the  $x$  and  $y$  gradient of the image  $I$  :

$$G_x = \frac{\partial I}{\partial x} \quad G_y = \frac{\partial I}{\partial y}$$

We can then compute the magnitude  $G_M$  and orientation  $G_\theta$  of the gradient :

$$G_M = \sqrt{G_x^2 + G_y^2} \quad G_\theta = \arctan\left(\frac{G_y}{G_x}\right)$$

Sun et al. then noticed that if the image has a bilateral symmetry axis of angle  $\alpha$ , like figure 3, the histogram  $h(\theta)$  of  $G_\theta$  will also have a symmetry axis of angle  $\alpha$ . This condition can be expressed as :

$$h(\alpha - \theta) = h(\alpha + \theta)$$

We can then show that we can find the symmetry axis by searching for the maximum of the circular auto-convolution of  $h(\theta)$  defined as :

$$(h \otimes h)(\theta) = \int_{-\pi}^{\pi} h(\theta - t)h(t)dt$$

This means that the symmetry axis  $\alpha$  will be given by :

$$\alpha = \frac{1}{2} \arg \max_{\theta} (h \otimes h)(\theta)$$

### II. Improvements

The two improvements we propose are based on the same principle : in the original method, when computing the histogram, each pixel vote is counted equally. We propose, as it is the case with many Hough detection techniques [2] to weight the vote of each pixel according to certain criteria.

i) The first criterion will be the proximity to the centerline of the spinal cord. This is justified because the spinal cord is rotated in a *continuous* fashion, tissues near the spinal cord will be strongly rotated and those who are farther away will be less rotated.

ii) The second criterion will be to weight each pixel by its gradient magnitude. This make sens because the pixels that really indicate the orientation of an object are the pixels located on the *edge* of the object.

Figure 2 shows the weighting map associated with the figure 1.

Figure 2 : Weighting map (normalised between 0 and 100) that takes into account for each pixel its proximity to the spinal cord and its gradient magnitude.

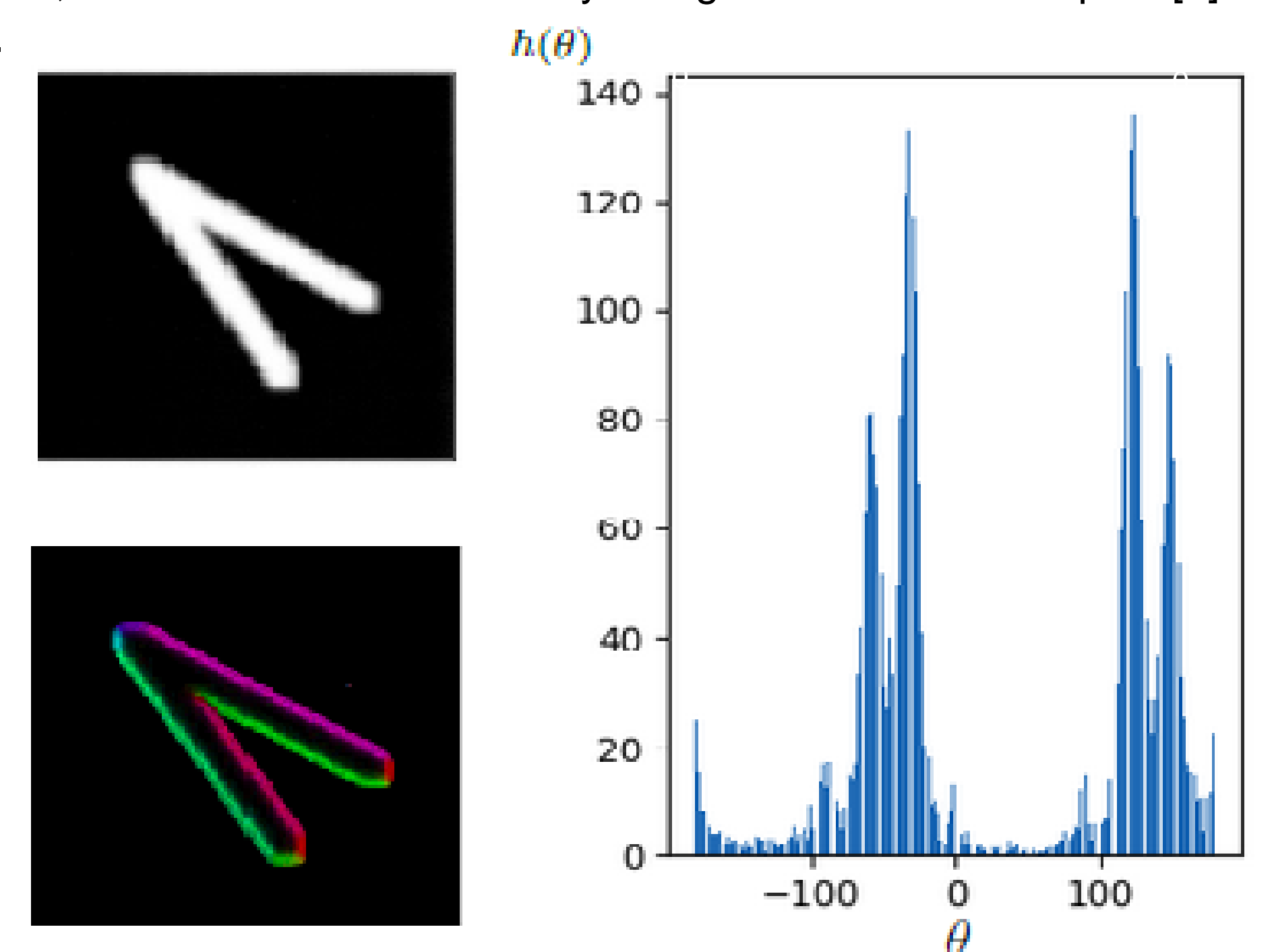
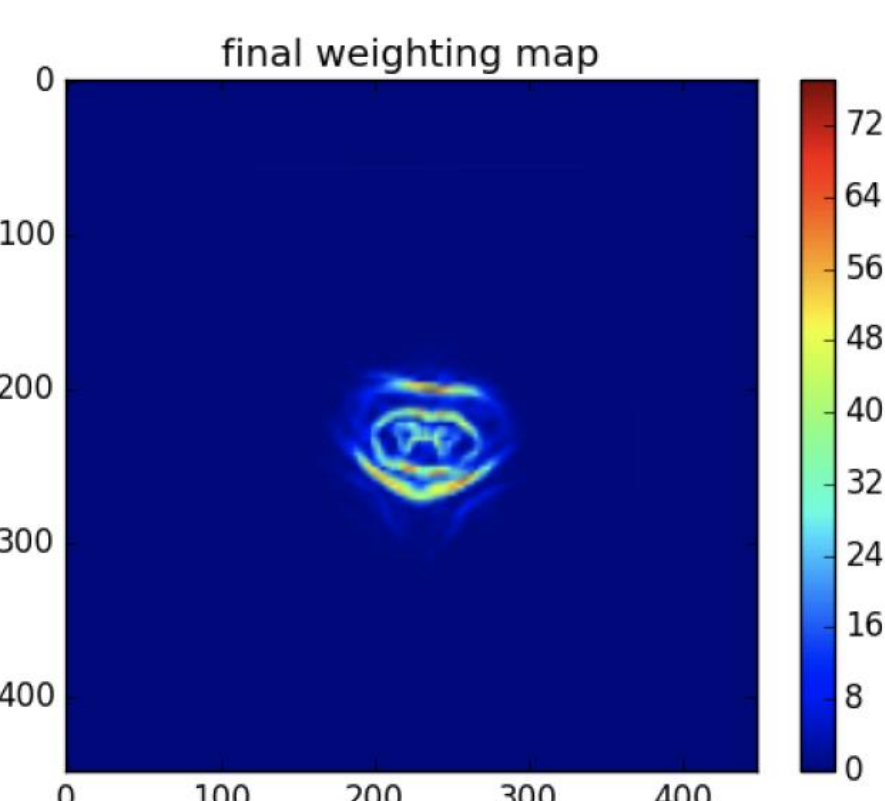


Figure 3 : On the top left a simple image with symmetry axis at angle 45°. On the bottom left its gradient orientation weighted by the gradient magnitude (color indicating angle and brightness indicating magnitude). On the right the gradient orientation histogram, with a clear symmetry axis at angle 45°.

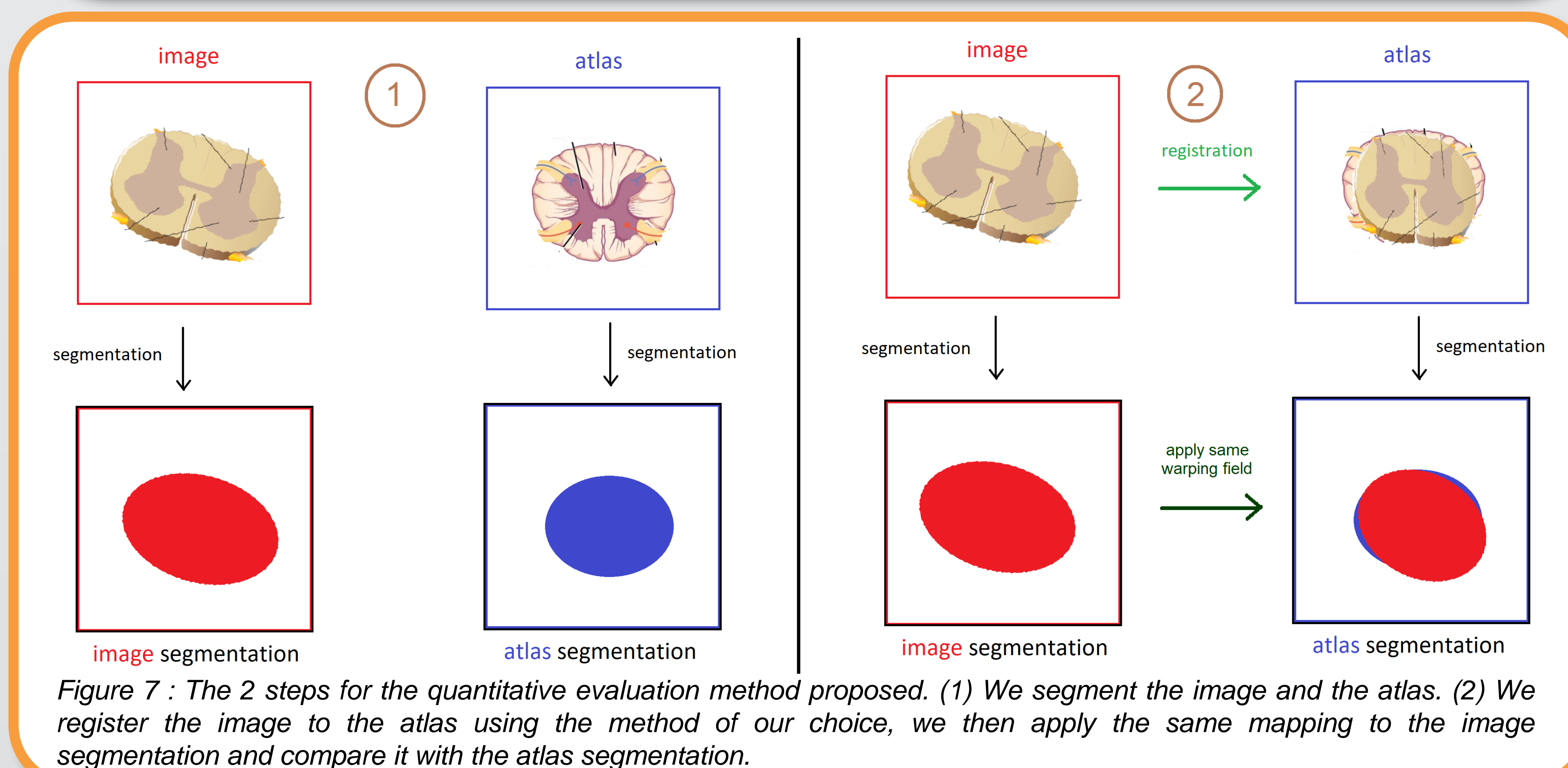


Figure 7 : The 2 steps for the quantitative evaluation method proposed. (1) We segment the image and the atlas. (2) We register the image to the atlas using the method of our choice, we then apply the same mapping to the image segmentation and compare it with the atlas segmentation.

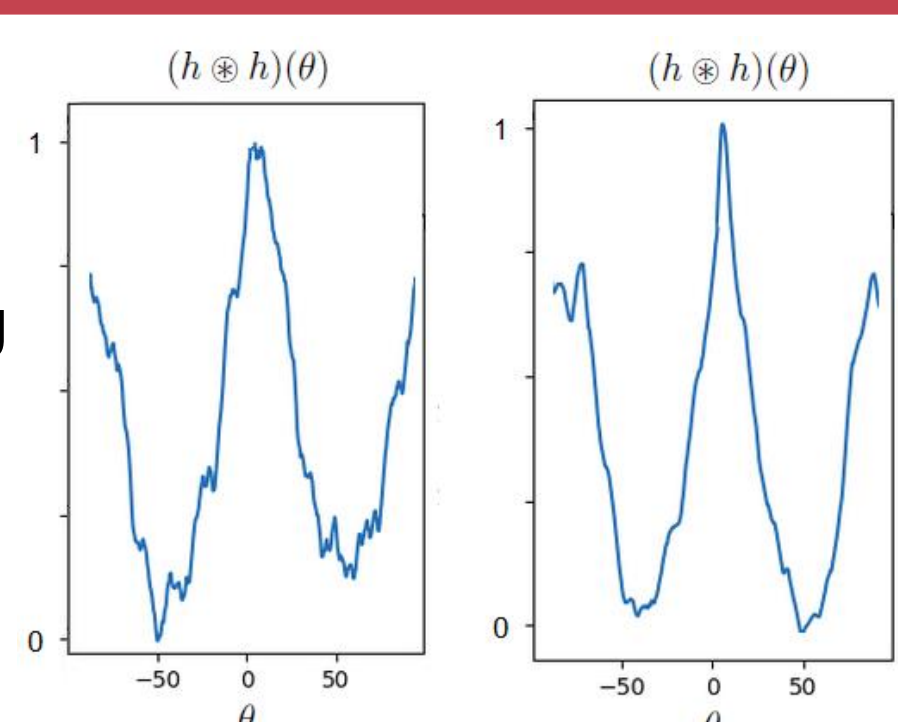


Figure 8 : Circular auto-convolution of  $h(\theta)$  : Sun et al. method VS Sun et al. improved.

## References

- [1] C. Sun and D. Si, Fast Reflectional Symmetry Detection Using Orientation Histograms, *Real-Time Imaging*, vol. 5, no. 1, pp. 63-74, Feb. 1999.
- [2] Leandro A.F. Fernandes et Manuel M. Oliveira, « Real-time line detection through an improved Hough transform voting scheme », *Pattern Recognition*, vol. 41, no 9, 2008, p. 299-314
- [3] Wikipedia : Principle Component Analysis
- [4] B. De Leener et al., SCT: Spinal Cord Toolbox, an open-source software for processing spinal cord MRI data, *NeuroImage*, vol. 145, pp. 24(43, Jan. 2017.
- [5] G. Loy and J.-O. Eklundh, Detecting Symmetry and Symmetric Constellations of Features, *Computer Vision ECCV 2006*, vol. 3952
- [6] H. Akbar, K. Hayat, N. ul Haq, and U. I. Bajwa, Bilateral Symmetry Detection on the Basis of Scale Invariant Feature Transform, *PLoS One*, vol. 9, no. 8, Aug. 2014.
- [7] A. Migalska and J. Lewis, An information theoretic approach to reflectional symmetry detection, in *2015 International Conference on Image and Vision Computing New Zealand (IVCNZ)*, Auckland, New Zealand, 2015, pp. 1-6.