Automatic Estimation of Cephalometric Landmarks for Lateral Skull X-rays using CNN

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Introduction

Automatic detection of landmarks in lateral skull cephalograms is considered as a Computer-Aided Diagnostics (CAD) tool. It helps physicians to detect pathologies such as craniofacial growth, orthodontic diagnosis, and oral-maxillofacial treatment planning.

This study aims to find 19 landmarks out of 300 images (previously labeled by experts, as it is shown in Figure 1), which form the public dataset. The dataset was proposed by the 2014 IEEE International Symposium on Biomedical Imaging (ISBI-2014) [5]. Deep Convolutional Neural Networks (CNN) were used as a direct regression framework for the probabilistic estimation of 19 landmarks. A total of 50% from the dataset was used for training and the other 50% for testing.

The obtained outcomes show up to 1.2 mm of average accuracy per image. The results were calculated between the 19 landmarks proposed by the expert and the estimated points.

Methodology

The CNN framework models (shown in Figure 2) are a supervised algorithm that has as objective a regression function, previously obtained from the experts labeling process and used during the framework's training. During the training, the model learns the patterns around the landmark, estimating the probability of coinciding with the targeted pixel (previously established by the expert). The architecture is formed by two fundamental parts. The first one learns the features, while the second one classifies them into their 19 possible landmark positions. These 19 pairs of coordinates represent the output of the neural network [3, 1].

Results

The resolution of the input images is 1935x2400 pixels, each pixel has a scale of 0.1 mm x 0.1 mm with respect to the real world. The mean radial error (MRE) is used as an evaluation metric [2, 4].

$$MRE = \frac{1}{n}\sum_{i=1}^{n} \left\| \overline{X_{experts}} - X_{CNN} \right\| \quad (1)$$

In equation 1, the constant n represents the number of images used in the test, $\overline{X_{experts}}$ is the average of 19 pairs of landmarks previously proposed by two medical experts and X_{CNN} is the estimation result provided by the CNN. The final outcome is an average of 3 mm error, using 150 test images (50% of the total Dataset).

Conclusion

This study proposes a CNN framework model for the automatic estimation of landmarks using regression. The method predicts the 19 landmarks contained in the cephalometric analysis. Promising outcomes are obtained using this technique. Future work is aimed to improve the performance of the network and test with a private database, providing a large dataset and publishing the results.

Acknowledgements

Mexican Council of Science and Technology (CONACyT) PhD program grant number 455203.

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No.	Anatomical Landmarks
1	sella turcica
2	nasion
3	orbitale
4	porion
5	subspinale
6	supramentale
7	Pogonion
8	menton
9	gnathion
10	gonion
11	lower incisal incision
12	upper incisal incision
13	upper lip
14	lower lip
15	point Pm or MN
16	soft tissue pogonion
a	posterior nasal spine
b	anterior nasal spine
AR	articulate

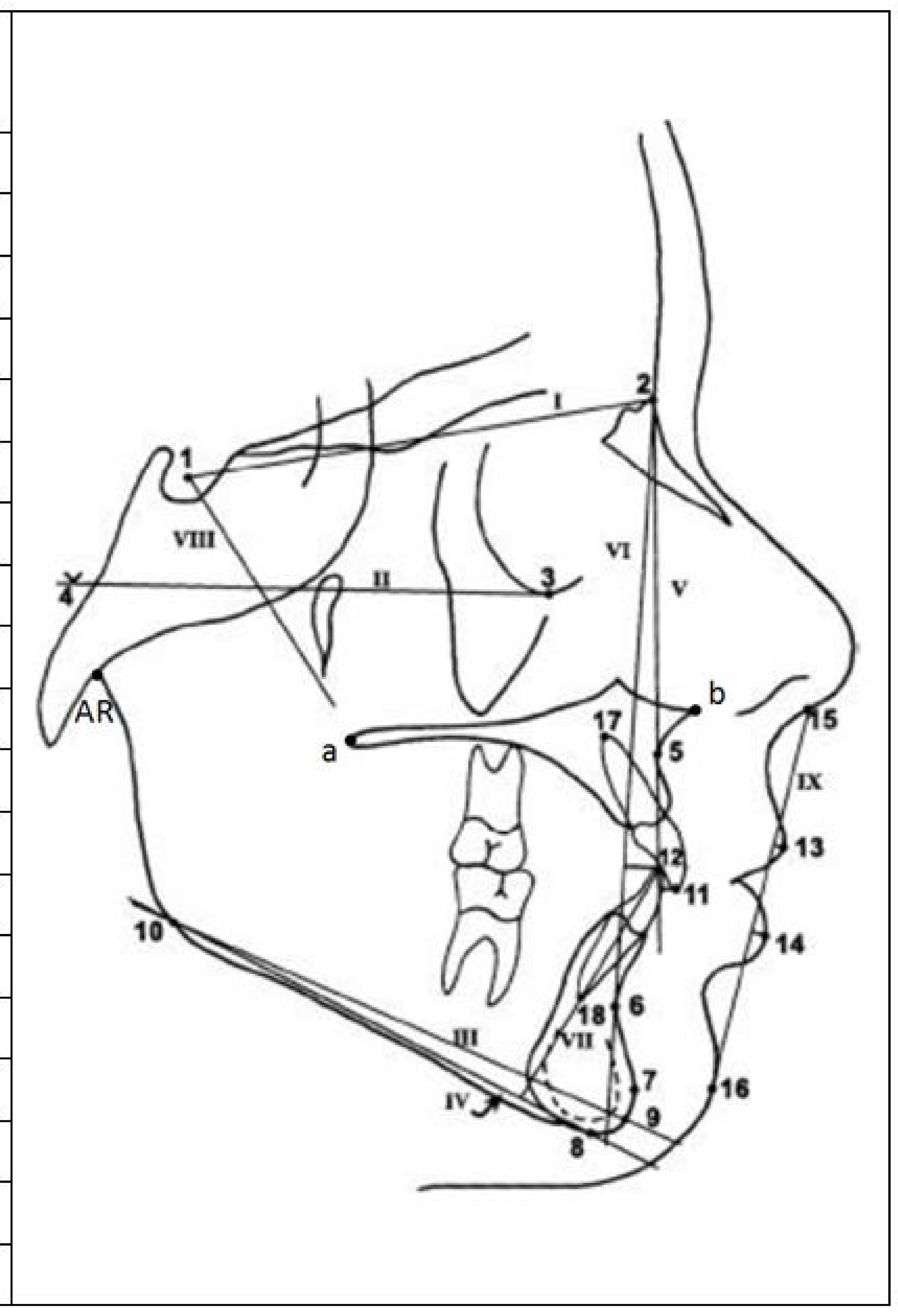

Figure 1: Landmarks for cephalometric analysis.

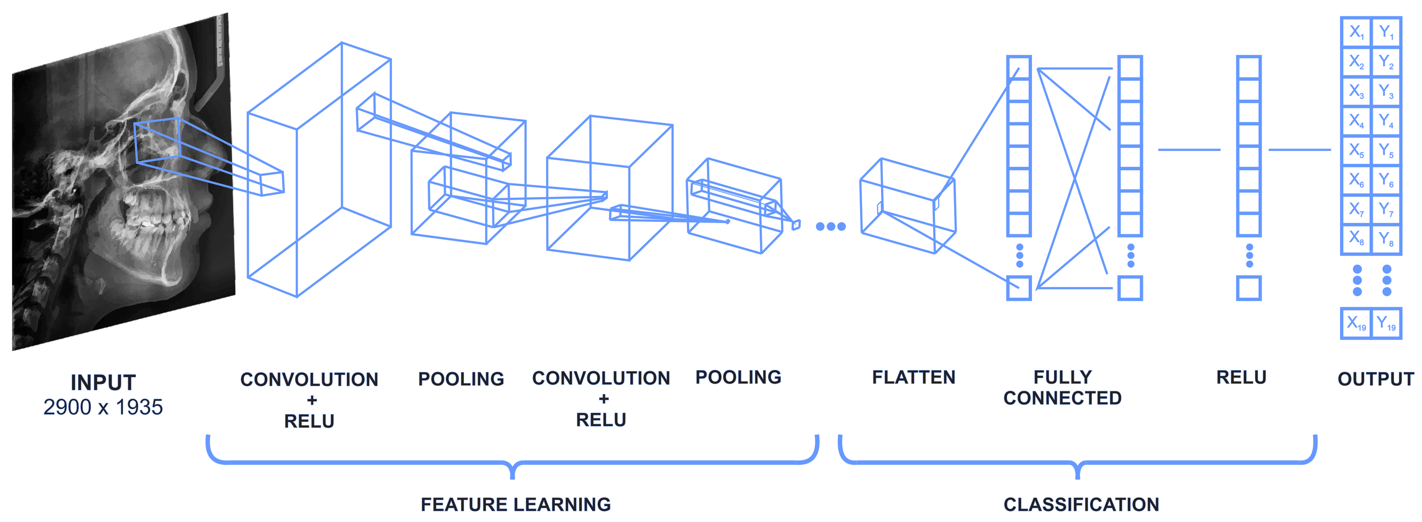

Figure 2: Architecture proposed for estimation of landmarks.

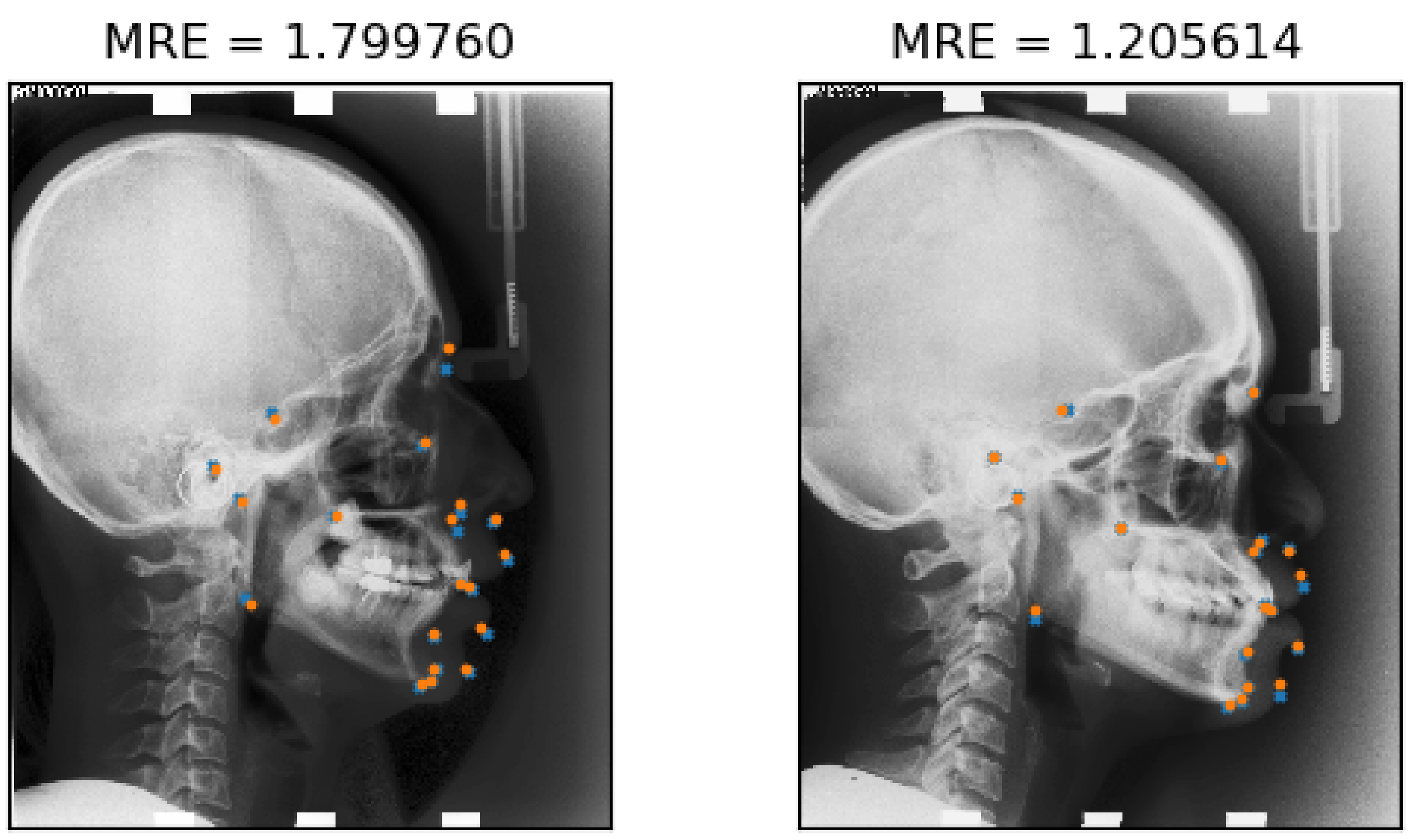

Figure 3: Landmarks predicted by CNN (blue points) vs landmarks proposed by experts (orange points).

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