Fully automated solution for Cervical Vertebral Maturation (CVM) assessment by deep learning approaches

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Introduction

Deep learning approaches have recently used in many studies of CVM (the cervical vertebral maturation) degree classification. Although, some studies showed high precise results, the features that the models learned are difficult to clinically explain. Therefore, it needs to do a lot of effort in improving the model accuracy.

In this study, we developed a fully automated deep learning solution of CVM classification procedure that consistently follow to CVM assessment clinical research.

Aim of the study

This study aimed to establish and evaluate a new AI method for determining classification cervical vertebral maturation (CVM) by analyzing lateral cephalometric radiographs based on clinical research.

Materials and methods

Data annotation

In this study, we used public dataset **IBSI 2015 Challenge - Grand Challenges in Dental X-ray Image Analysis** (*Fig. 1*) for annotating **13 CVM landmark points** on the bodies of C2, C3, C4 cervical vertebrae – *Fig.2* (*). Each image then be annotated to six different maturational stages from CS1 through CS6 (Fig. 3)
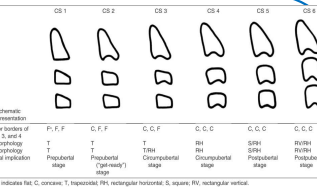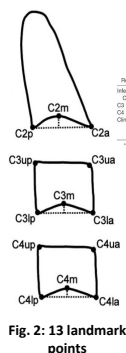

Fig. 1: IBSI2015 dataset

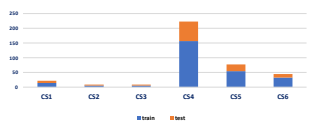

Fig. 2: 13 landmark points

Fig. 3: CVM assessment method

Fig. 4: Distribution of annotated data
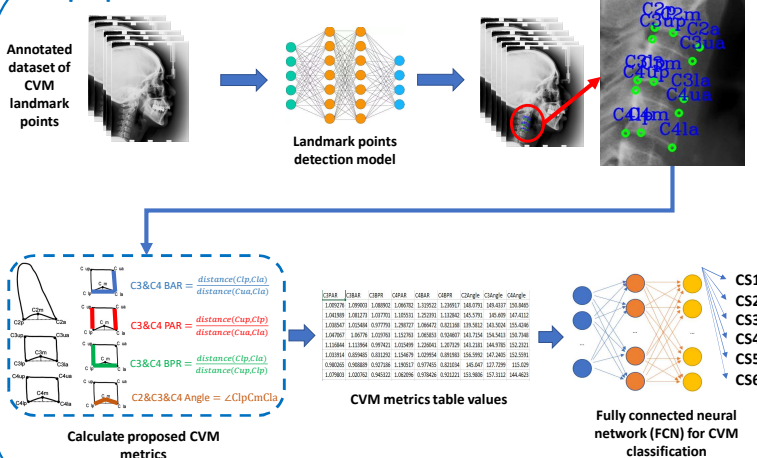
Our proposal solution

Annotated dataset of CVM landmark points → Landmark points detection model → Calculate proposed CVM metrics

$$C3\&C4\ BAR = \frac{distance(Clp,Cla)}{distance(Cua,Cla)}$$

$$C3\&C4\ PAR = \frac{distance(Cup,Clp)}{distance(Cua,Cla)}$$

$$C3\&C4\ BPR = \frac{distance(Clp,Cla)}{distance(Cup,Clp)}$$

$$C2\&C3\&C4\ Angle = \angle ClpCmCla$$

CVM metrics table values → Fully connected neural network (FCN) for CVM classification → CS1 CS2 CS3 CS4 CS5 CS6

Fig. 5: Fully automated solution for CVM assessment

Results

Cephalometric landmark points detection model – Accuracy 99.42%
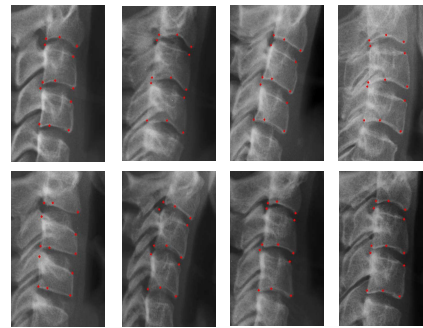

Fig. 6: Output results of Cephalometric landmark detection model
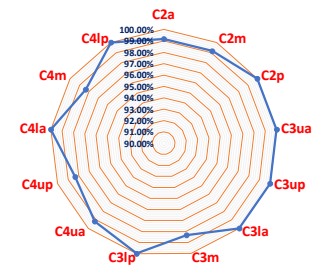
Accuracy of CephaLandmark model by landmark points

Fig. 7: Average accuracy 99.42%

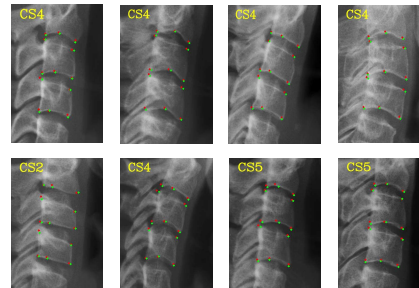### CVM classification model – Accuracy 92.3%

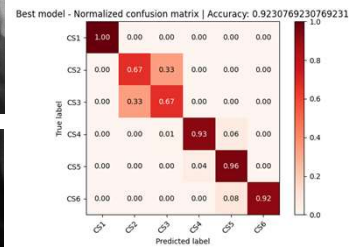Fig. 8: Final results of our proposed solution

Fig. 9: Normalized confusion matrix

Conclusion

- We created a fully automated AI solution with clinical acceptant accuracy.

- Thanks to the CVM classification system-based solution (*), our model can use various clinical features to improve classification accuracy instead of the regular deep learning technique.

Contact information

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(*) McNamara, James A., and Lorenzo Franchi. "The Cervical Vertebral Maturation Method: A User's Guide." The Angle Orthodontist 88, no. 2 (March 1, 2018): 133–43. https://doi.org/10.2319/111517-787.1.