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Predicting skeletal age and beyond - insights from winning the 2017 rsna machine learning competition

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Purpose: Develop a computer algorithm to predict skeletal age from pediatric hand x-rays.

Material & Methods: The competition was split into three phases (dataset sizes provided in each phase from 2 U.S. hospitals are in parentheses): Training (n=12,612), Leaderboard (n=1,425) and Test (n=200). Images, gender, and bone age in months were provided for the training set. We used a 85:15 training:validation split to train our deep convolutional neural network which consisted of an Inception V3 module which took the images at 500 x 500 pixels as input and concatenated it with the gender input (0-female, 1-male). This was followed by two additional 1000-neuron fully-connected layers before the single node linear output (in months). Training was done on a single NVIDIA P40 GPU for 500 epochs using the ADAM optimizer to minimize the mean absolute deviation (MAD). Real-time image augmentation was used with up to 20% horizontal/vertical translation, 30 degrees rotation, and random horizontal flip. At inference, we created 10 random augmentations of the candidate image and fed those to an ensemble of the top 5 trained models. The 50 outputs were averaged and rounded to the nearest integer - representing the final bone-age prediction in months.

Results: Our top 3 models achieved a MAD of 5.99 months on the validation set and our fourth and fifth model achieved a MAD of 6.00 months. Our approach resulted in a MAD of 4.265 months on the test set achieving first place in the 2017 RSNA pediatric bone-age machine learning competition.

Conclusion: Specifically designed multi-input deep neural networks are effective at predicting pediatric bone-age. The algorithm presented here represents the current state-of-the-art for bone-age prediction.

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