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What Machines Can Read: Gender Identification from Hand and Wrist Radiographs in Children

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Introduction

Machine learning extracts meaningful patterns from medical images without use of explicit hand-crafted features. This approach shed light on finding patterns that have been previously beyond human visual perception to detect an early stage disease or discover new insights. Skeletal sexual dimorphism develops mostly in pelvis during puberty. In hand and wrist, prior work has shown higher second-to-fourth digit ratio (2D:4D) and smaller carpal bones in females compared to males. However, no discrete feature has been described in hand and wrist that distinguishes male from female, either in children or adults. To explore the ability of deep learning algorithms to detect subtle differences in medical images that are not recognized by human radiologists, we trained and tested a deep convolutional neural network (CNN) with hand and wrist radiographs of children to predict gender.

Hypothesis

Deep learning algorithms can identify gender from hand and wrist radiographs of children.

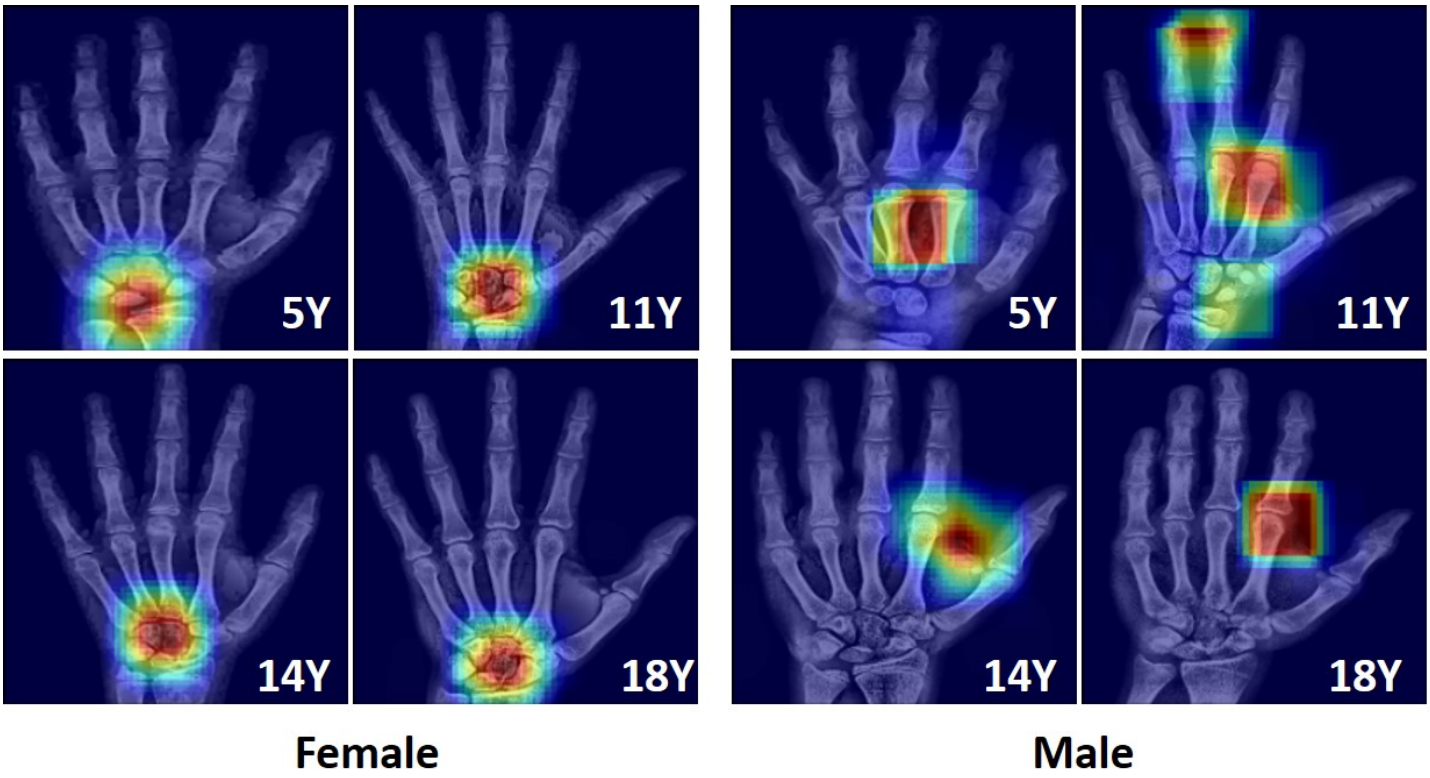
Methods

We compiled a dataset of 8,325 radiographs of hand and wrist from a cohort of pediatric patients, ranging from 5 years to 18 years of age. A total of 6,268 (3,222 females and 3046 males) radiographs were used for training, and 821 images (421 females and 400 males) separate from the training data were randomly selected for validation. Images from the remaining 1,236 cases (635 females and 601 males) were reserved for testing. The images were labeled solely with the gender of the subject, and all other demographic information was not provided. Following a series of preprocessing steps, images were analyzed using a deep CNN. We fine-tuned an ImageNet GoogLeNet on our training dataset by a stochastic gradient descent (SGD) with a minibatch size of 64, a weight decay of 0.005, and a base learning rate of 0.001. The learning rate was decreased by a value of 0.1 by three steps to attain a stable convergence of loss function. The best CNN, selected based on the validation loss, then provided automated prediction of gender, which was compared to the gender in the patient's medical record.

Results

The mean age of the cohort was 11.7 years with standard deviation of 3.74 years (11.5±4.08 in females, 12.0±3.32 in males). Of the 1,236 radiographs tested, the algorithm predicted gender with 91.1% accuracy (89.8% in females and 92.5% in males). Fig. 1 shows representative attention maps for each gender. In females, the focus is mostly on the carpal bones, whereas in males the focus is more dispersed on second or third metacarpal bones or second metacarpophalangeal joint in many cases, and first web space in some cases.

Figure 1



Conclusion
We developed a deep learning algorithm that identifies gender with high accuracy from hand and wrist radiographs in children.

Statement of Impact
This is the first study to demonstrate distinct skeletal sexual dimorphism in hand and wrist, regardless of the method or age of subjects. This finding suggests that deep learning can be used to discover new knowledge that has been beyond the limits of human perception.

Keywords
machine learning, deep learning, skeletal sexual dimorphism