# Prediction of adolescent bone age by hand X-rays

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# Contents

# Introduction

# Introduction

Bone age?

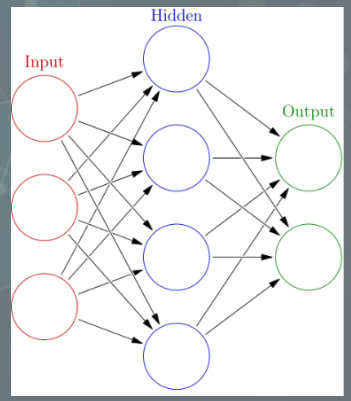
# Introduction

## traditional method

Greulich and Pyle atlas

## Deep learning method

Convolutional neural network



# Idea & Rationale

# Idea & Rationale

**IDEA I**: A few specific pieces of bones are primary factors in determination of bone age prediction.

| Bones | Weights in CHN | | Weights in TW2 | Bones | Weights in CHN | | Weights in TW2 |
|---|---|---|---|---|---|---|---|
| | male | female | | | male | female | |
| radius | 9.52 | 8.39 | 10 | proximal phalanx V | 6.96 | 7.97 | 2.5 |
| ulna | 0 | 0 | 10 | middle phalanx III | 7.69 | 7.89 | 2.5 |
| metacarpal bone I | 1.97 | 4.51 | 3.34 | middle phalanx V | 1.14 | 3.83 | 2.5 |
| | | | | distal phalanx I | 10.2 | 8.61 | 3.33 |
| metacarpal bone III | 7.75 | 7.76 | 2.5 | distal phalanx III | 6.69 | 7.06 | 2.5 |
| metacarpal bone V | 4.53 | 6.61 | 2.5 | distal phalanx V | 1.61 | 3.33 | 2.5 |
| proximal phalanx I | 2.09 | 3.87 | 3.33 | capitatum bone | 14.29 | 10.76 | 7.1 |
| proximal phalanx III | 11.19 | 9.21 | 2.5 | hamate bone | 14.13 | 10.75 | 7.1 |

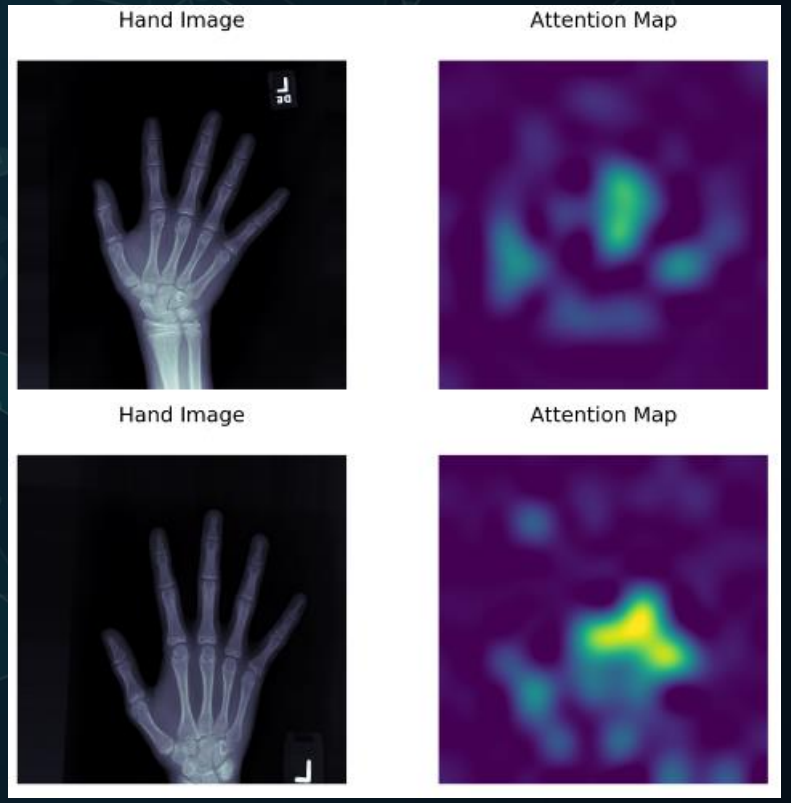
(CHN、TW2: The Standards of Skeletal Maturity of Hand and Wrist.)

# Idea & Rationale

**Attention mechanism:**

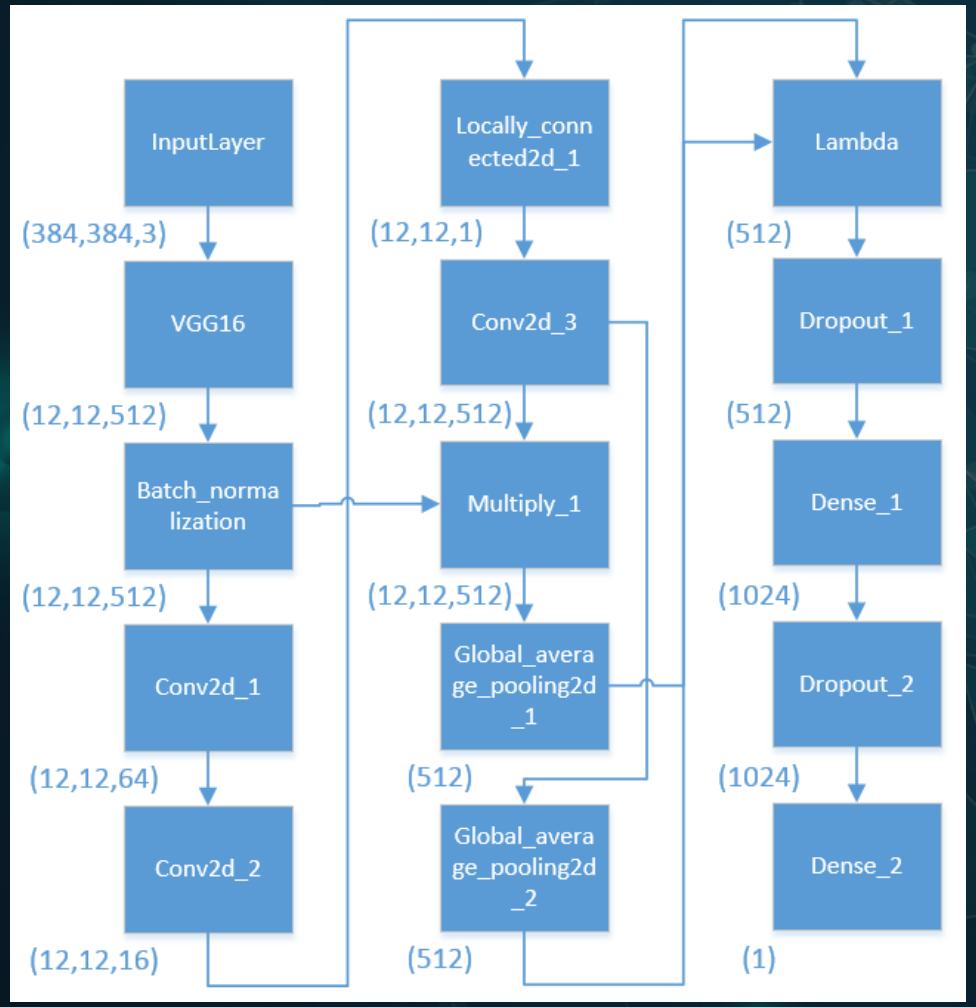
1.To reduce the computational burden of processing high-dimensional input data, and to reduce the data dimension by structuredly selecting a subset of inputs.

2.To make the task processing system focus more on finding useful information related to the current output in the input data, thereby improving the quality of the output.



# Idea & Rationale

## Neural Network Architecture




Input: PNG files(12611 files)

Output:Floating point number

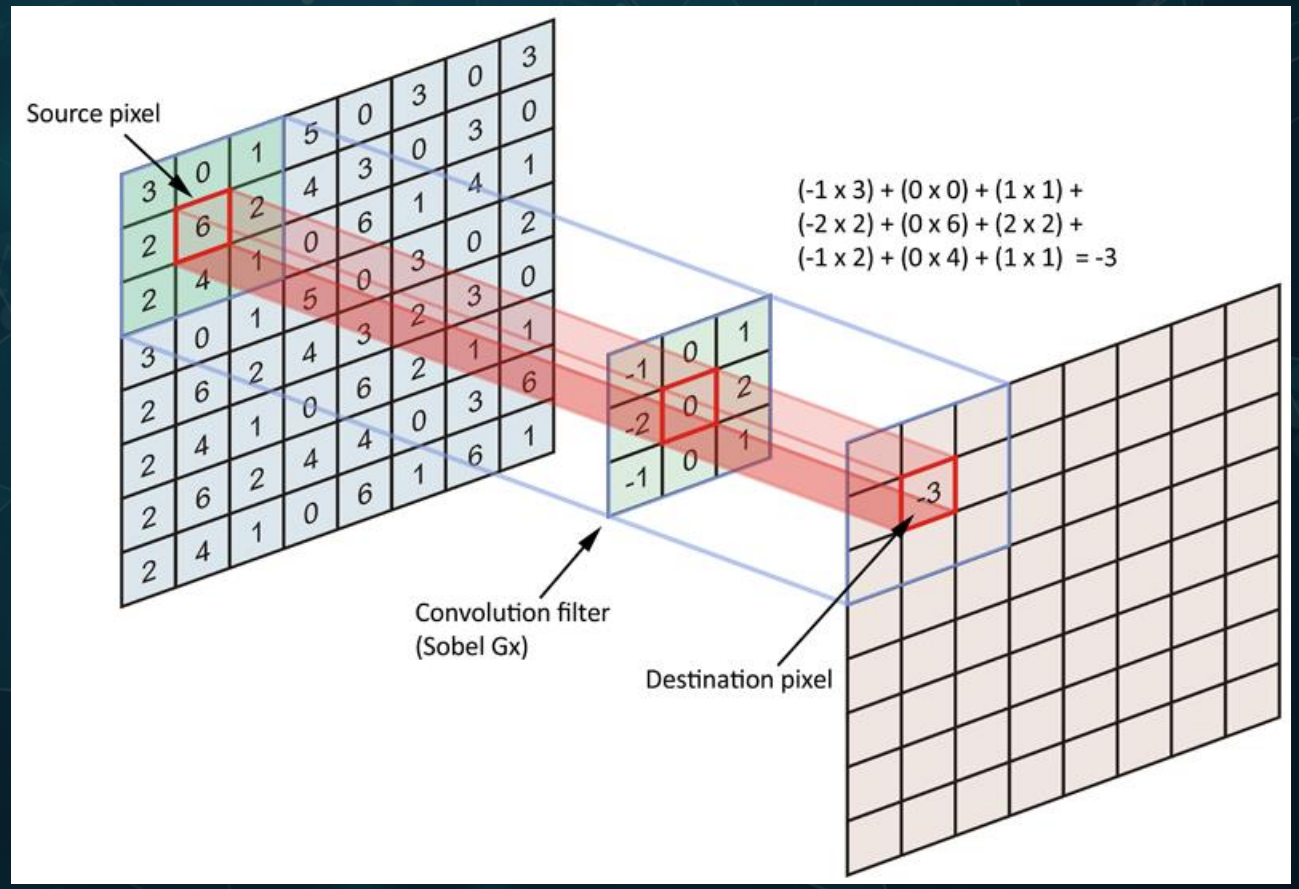
Attention mechanism:Conv2d_1~Conv2d_3

Mean Absolute Deviation:13.6961 months

(VGG16: Pre-training model)

# Idea & Rationale

**IDEAⅡ**: We wonder whether and how the size of convolution kernel will influence the accuracy of the final prediction.



# Idea & Rationale

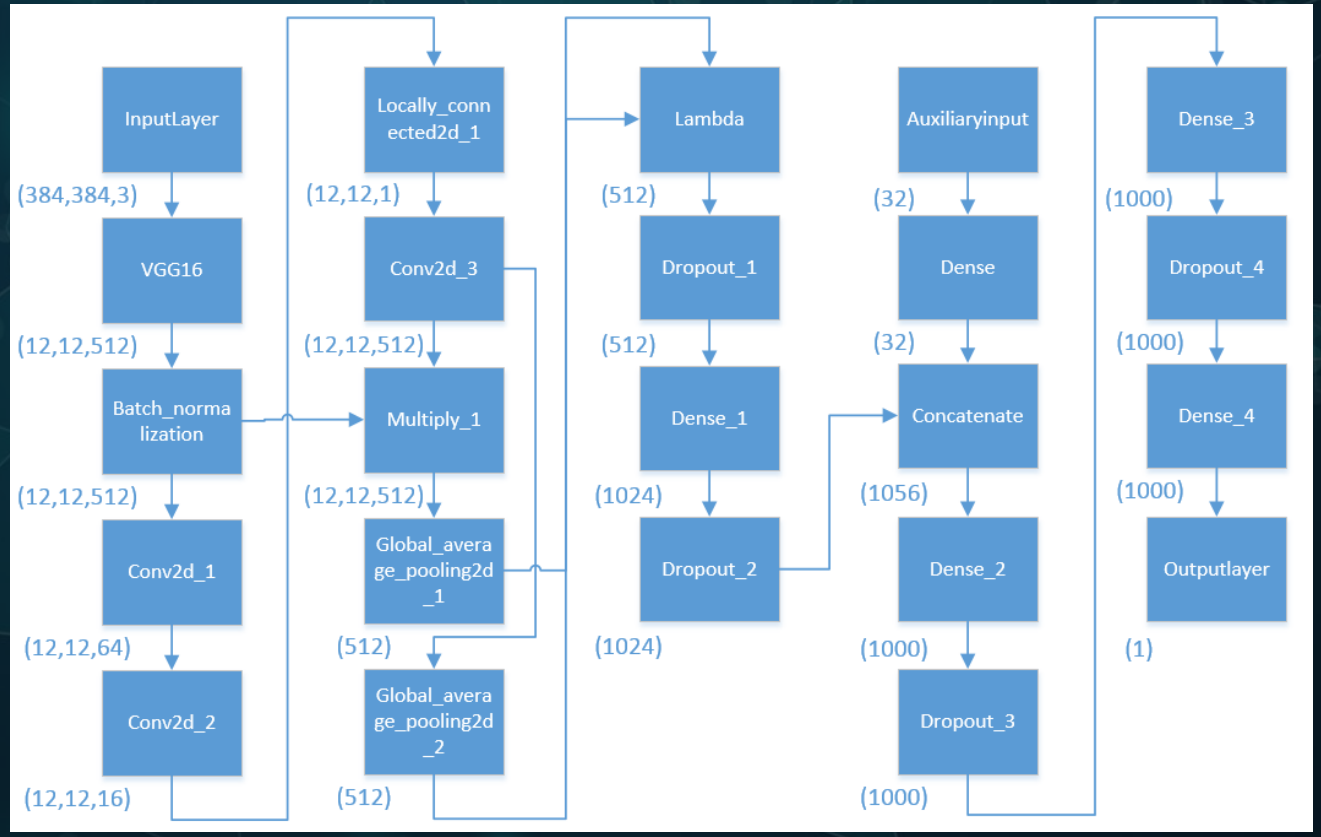
**IDEAⅢ**: Gender might be a potential influencing factor on bone age prediction.

| Features | Female | Male |
| --- | --- | --- |
| Height increase period | Bone age 11-13 years | Bone age 13-15 years |
| Puberty | Bone age 11 years and about 9 months | Bone age 13 years and about 9 months |
| Stop growing in height | Bone age 17.3 years | Bone age 18.4 years |

# Idea & Rationale

1、Training male and female X-rays separately.

2、Adjusting the convolutional neural network structure to introduce Gender as a new feature.



# Experiments & Discussion

# Experiments

Using attention mechanism:

| | val_mae_month |
|---|---|
| **Attention** | **13.6961** |
| No_Attention | 16.8528 |

(Evaluation standard:Mean Absolute Deviation)

Attention mechanism is suitable.

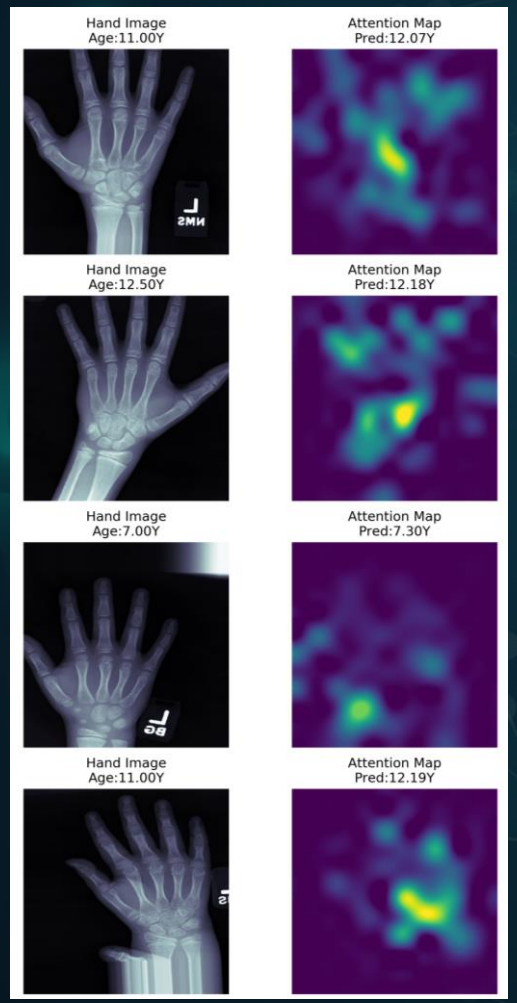
# Experiments

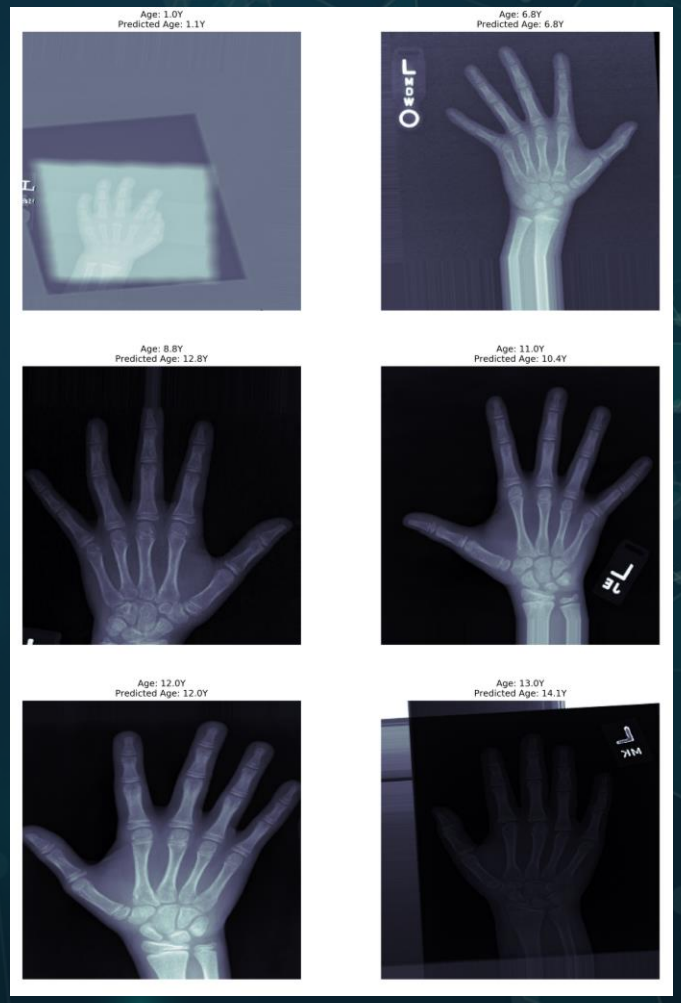
The contents of experiments:

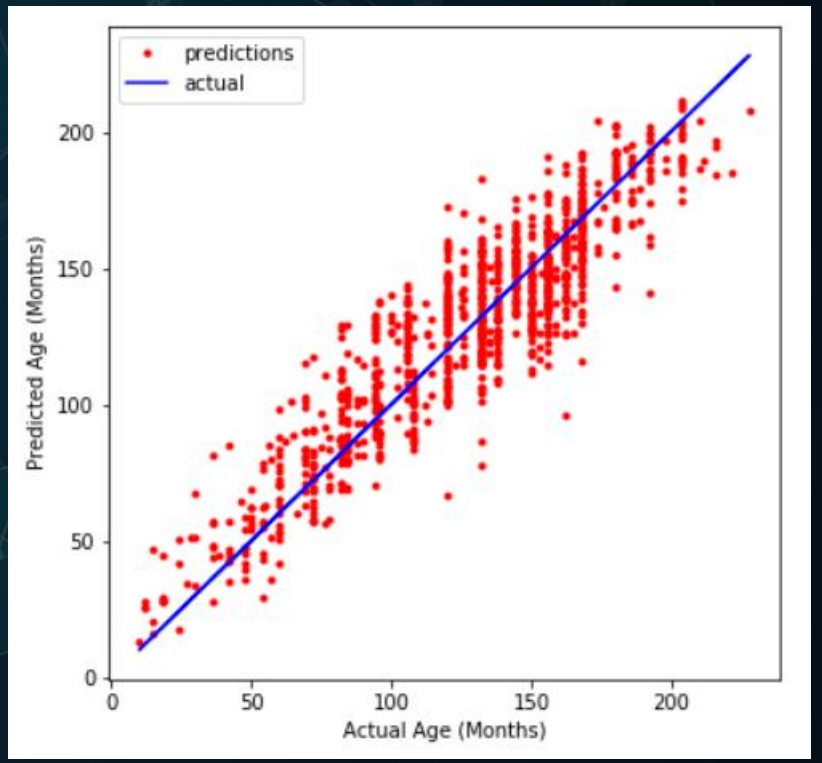
| | |
|---|---|
| Idea Ⅰ: | pre_train=vgg16 |
| | pre_train=vgg19 |
| | pre_train=resnet |
| | pre_train=inception_v3 |
| Idea Ⅱ: | kernel_size=(1,1) |
| | kernel_size=(3, 3) |
| | kernel_size=(5, 5) |
| Idea Ⅲ: | no_balance |
| | male only |
| | female only |

# Experiments

Idea I: Using VGG16 as pre-training model.

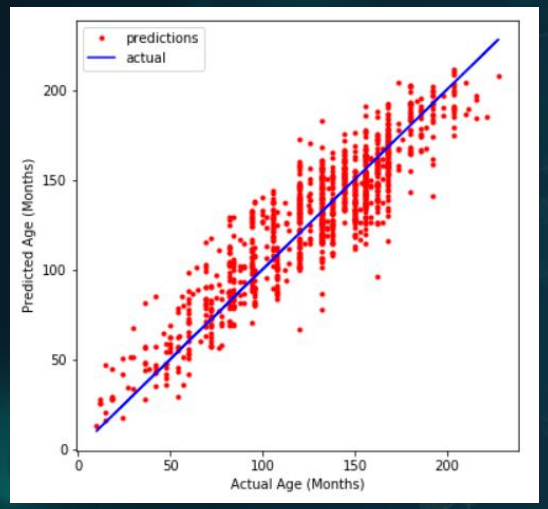


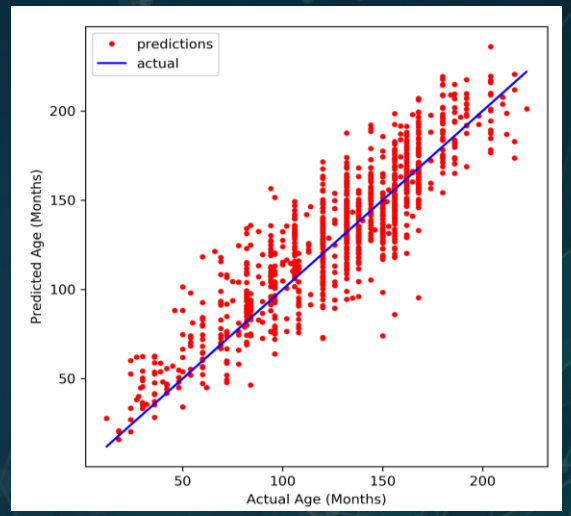



# Experiments

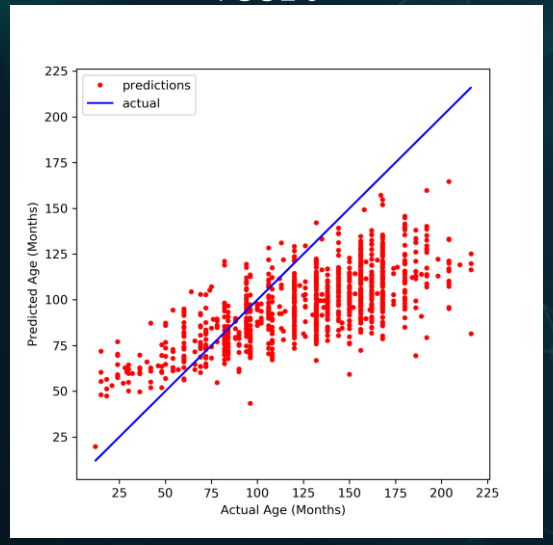
Regressions of 4 different pre-training models.



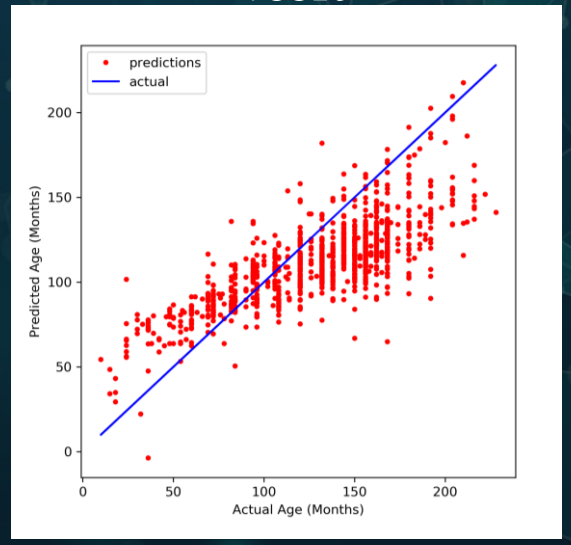

VGG16




VGG19




resnet




inception v3

| pre_train_model | val_mae_month |
|---|---|
| **vgg16** | **13.6961** |
| vgg19 | 15.2857 |
| resnet | 26.9282 |
| inception_v3 | 35.3809 |

# Discussion

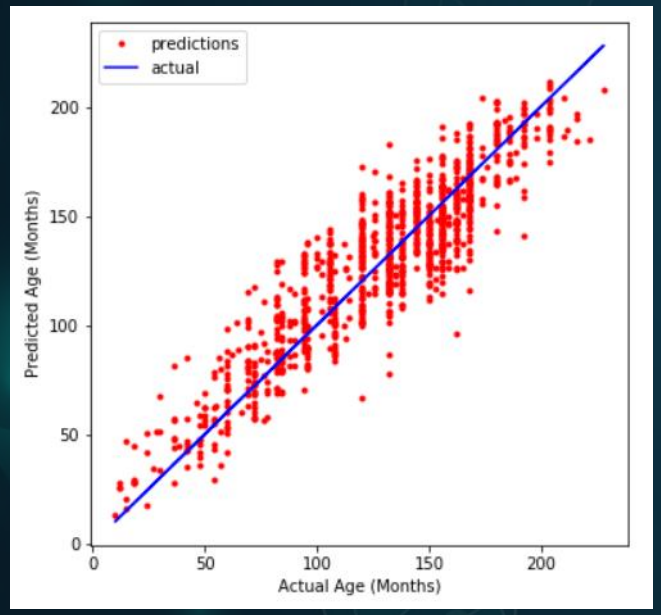
It seems that images pre-trained by VGG16 attain The best performance in bone age prediction.

A possible conjecture is about VGG16's generous parameters and shallow depth.

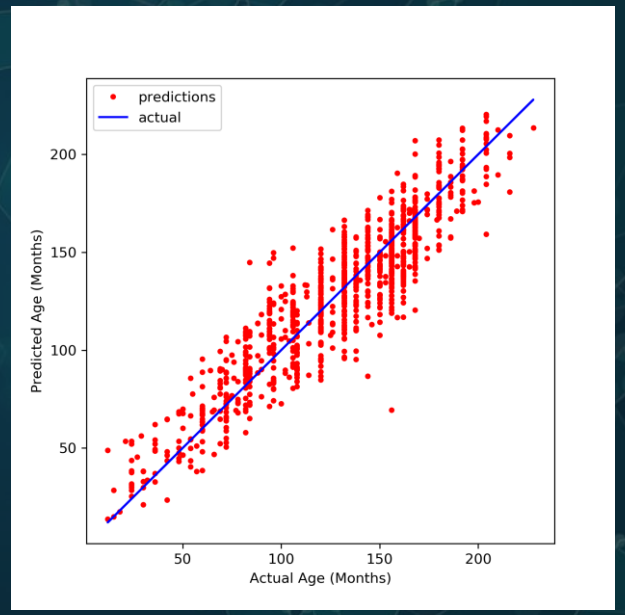
| model | size | accuracy of Top1 | accuracy of Top5 | amount of parameter | depth |
|---|---|---|---|---|---|
| Xception | 88MB | 0.79 | 0.945 | 22,910,480 | 126 |
| **VGG16** | **528MB** | **0.715** | **0.901** | **138,357,544** | **23** |
| VGG19 | 549MB | 0.727 | 0.91 | 143,667,240 | 26 |
| ResNet50 | 99MB | 0.759 | 0.929 | 25,636,712 | 168 |
| InceptionV3 | 92MB | 0.788 | 0.944 | 23,851,786 | 159 |
| InceptionResNetV2 | 215MB | 0.804 | 0.953 | 55,876,736 | 572 |
| MobileNet | 17MB | 0.665 | 0.871 | 4,253,864 | 88 |

# Experiments

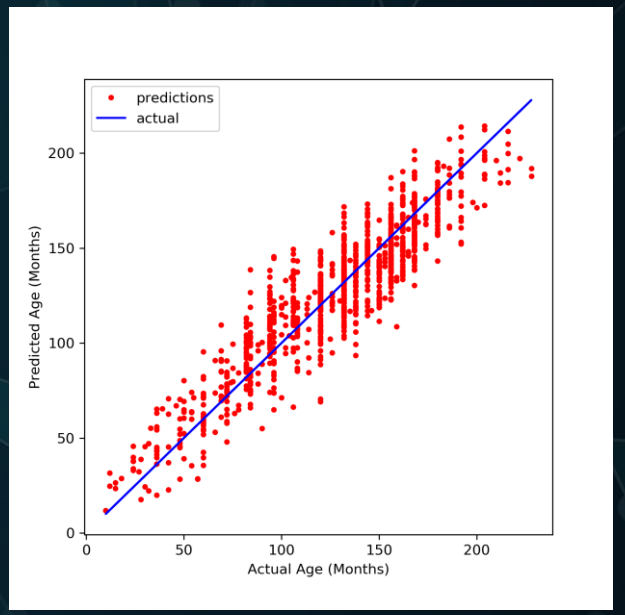
Idea Ⅱ: Replacing the original kernel of 1*1 with one of 3*3 and 5*5.




(1*1)




(3*3)



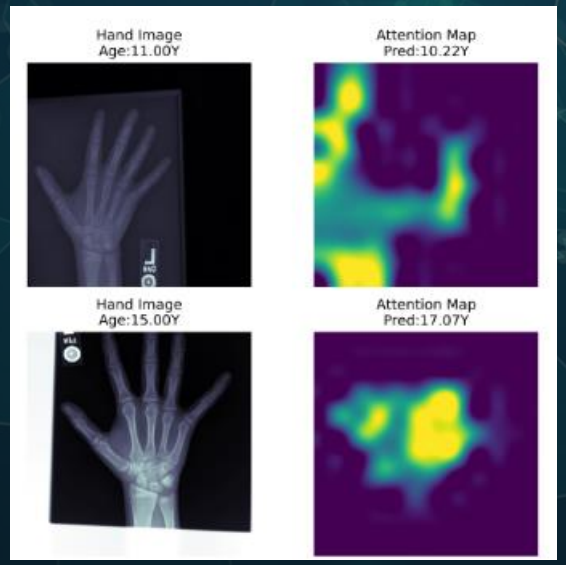

(5*5)

| Kernel_size | (1*1) | **(3*3)** | (5*5) |
|---|---|---|---|
| val_mae_month | 13.6961 | **13.0673** | 12.9808 |

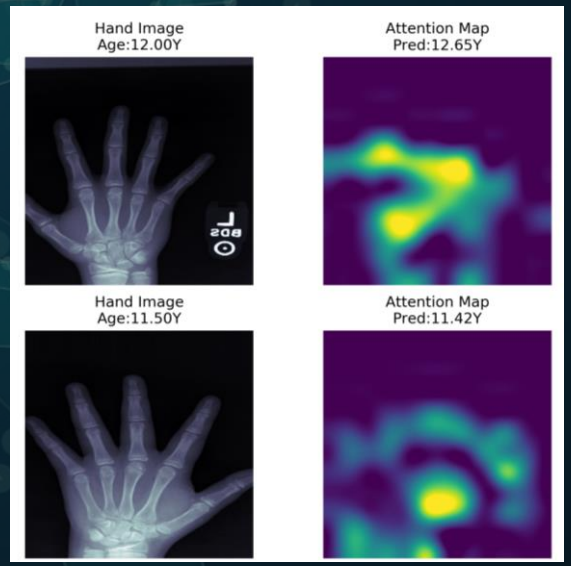
# Discussion

A 5*5 kernel perform the best compared with a 1*1 kernel and 3*3 kernel in Mean Absolute Deviation but it has an no obvious difference compared to 3*3 kernel.

Guess:Overfitting.



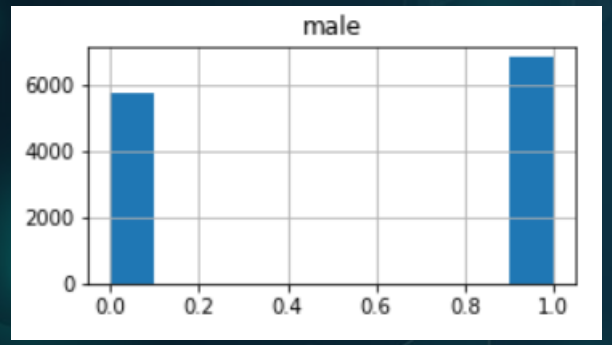

(5*5
)



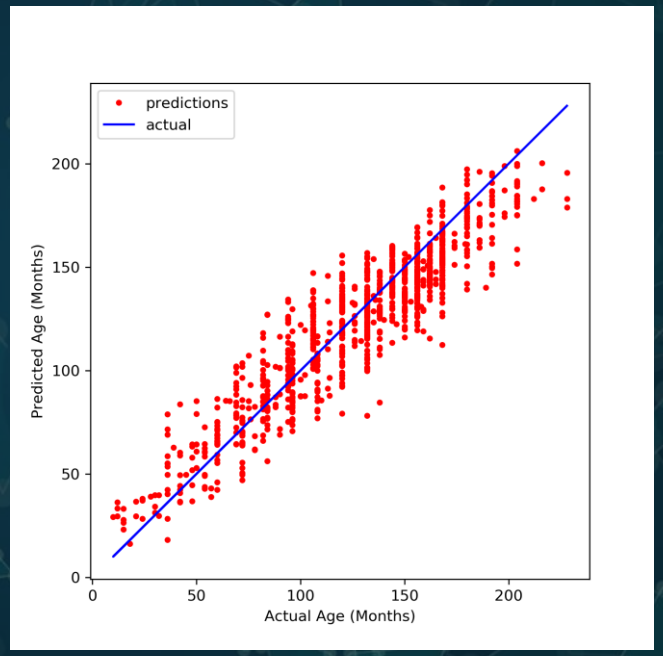

(3*3
)

# Experiments

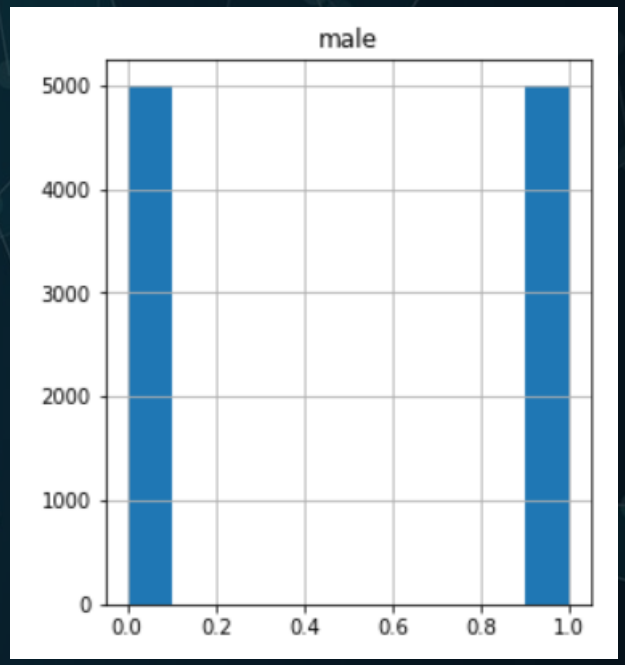
## IdeaⅢ: Using gender as a new feature.




Original data without balance in gender information.




No balance

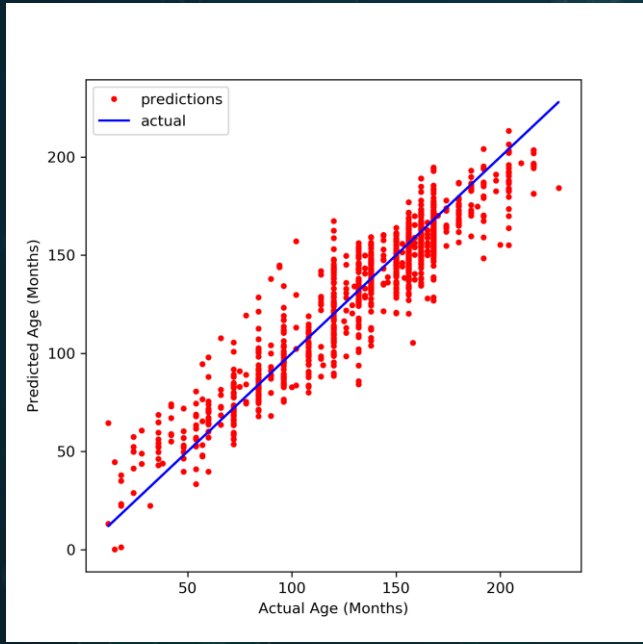



Data with balance in gender and information.

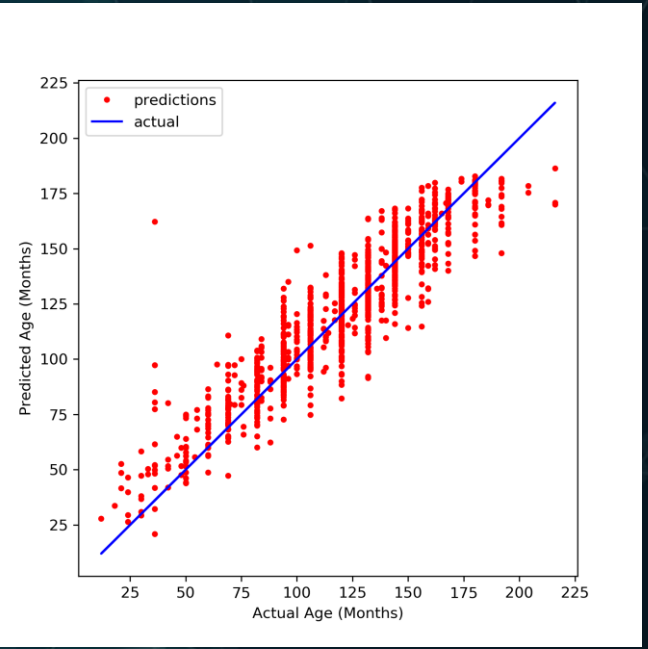
| | Convergence time |
|---|---|
| No_balance | 8:27:58 |
| Balance | 4:09:50 |

# Experiments

Regressions of male-only and female-only.



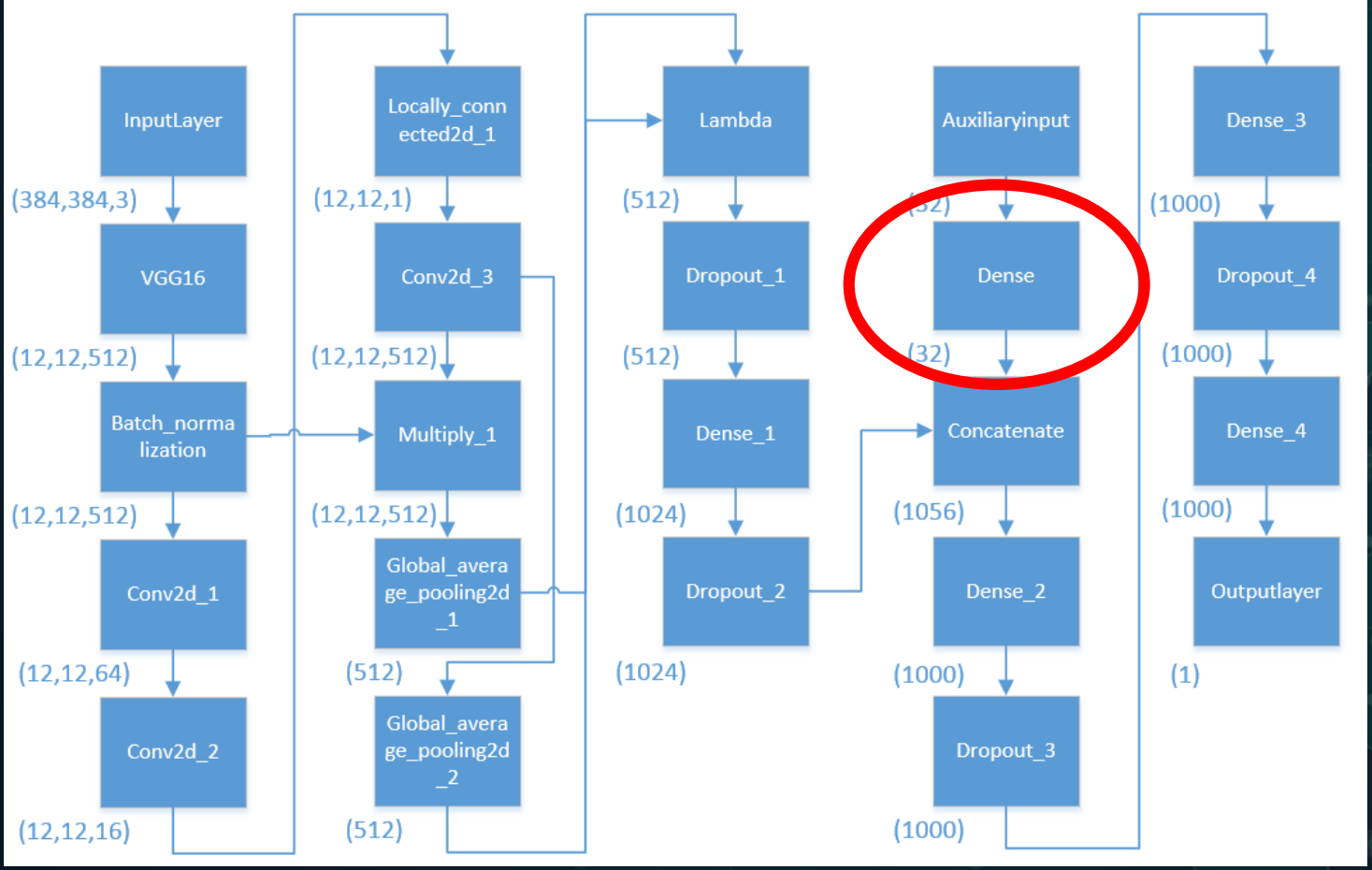

Male-only




Female-only

| Gender information | no_balance | **male only** | **female only** |
|---|---|---|---|
| val_mae_month | 14.1151 | **10.8182** | **10.6902** |

# Experiments




| shape | val_mae_months |
|---|---|
| 16 | 11.2869 |
| 32 | 10.969 |
| **64** | **9.7845** |
| 128 | 10.2238 |
| 256 | 10.8532 |

# Discussion

This experiment indicates that there indeed exists difference between male and female in skeletal development.


Conclusion

# Conclusion

1、Attention mechanism is effective in the task.

2、VGG16 performed best in several pre-training models that had been tried.

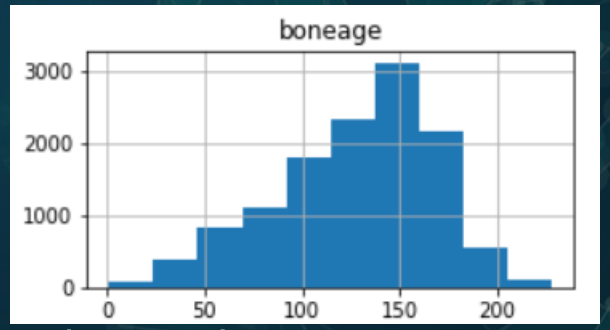
3、There indeed exists difference between male and female in skeletal development.

4、3*3 kernel is suitable for this task.

# Future work

1、Grayscale graph should be processed by one channel.

2、If we have pre-training weights for medical images,the pre-training model may perform better.




3、The uneven distribution of bone age may have potential effect on prediction.

4、The scanned image is noisy and can be converted to original image.


Q & A