Image source: https://radiologykey.com/skeletal-age-2/

Predicting Bone Age Using Deep Learning

Sunna Jo

Bone Age

Interpretation of **skeletal maturity** based on radiographic imaging

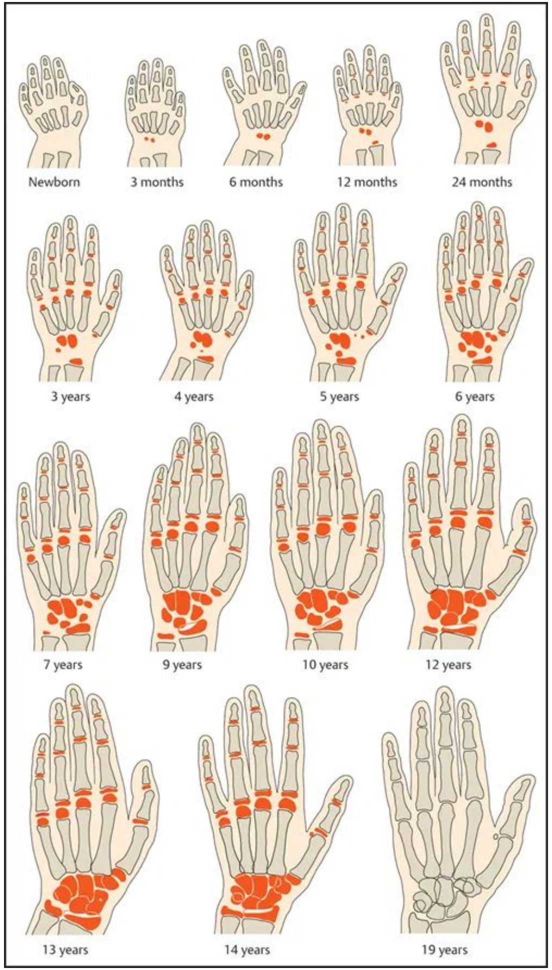


Image source: http://www.rajeun.net/boneage.html

Bone Age: Use Cases

Clinical Uses

Diagnosis of growth disorders

Determining & monitoring treatment

Prognosis

Non-Clinical Uses

Athletics

Forensics

Legal/Policy

Bone Age: Use Cases

Clinical Uses

Diagnosis of growth disorders

Determining & monitoring treatment

Prognosis/adult height

Non-Clinical Uses

Athletics

Forensics

Legal/Policy

Bone Age

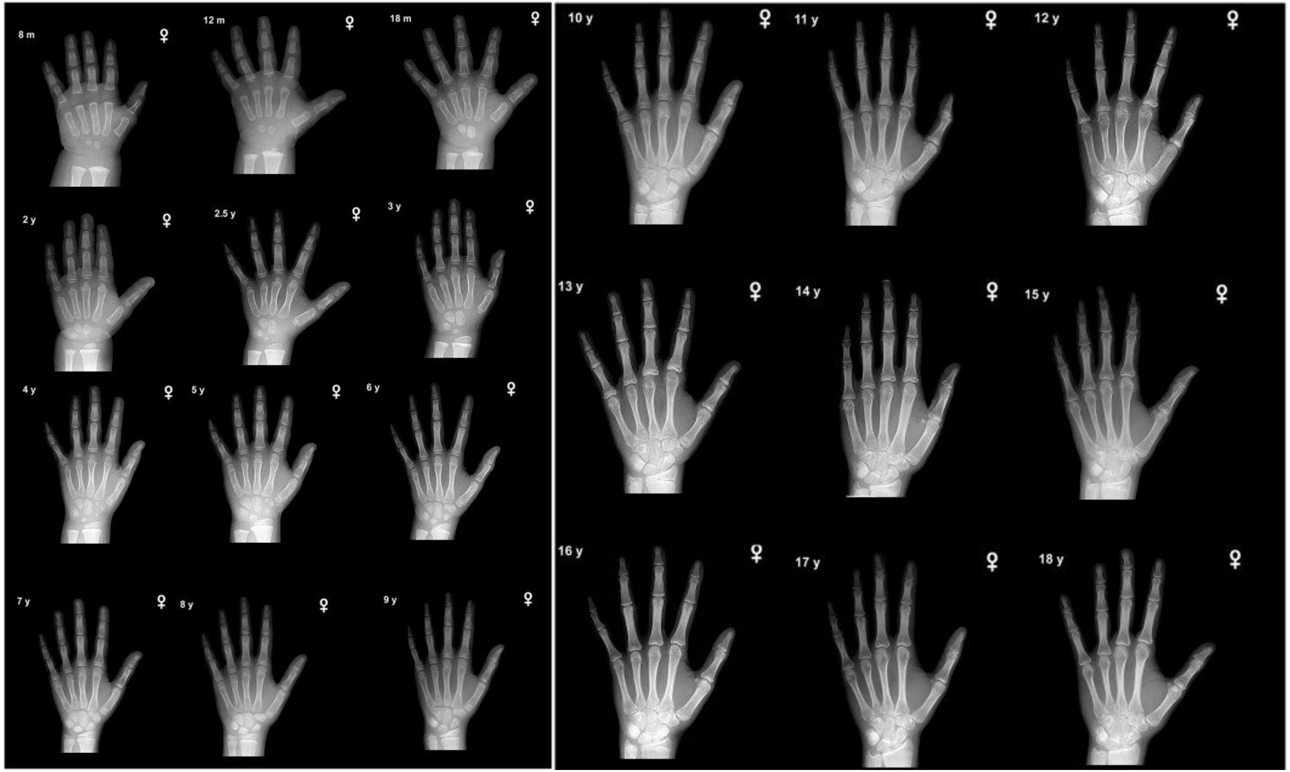
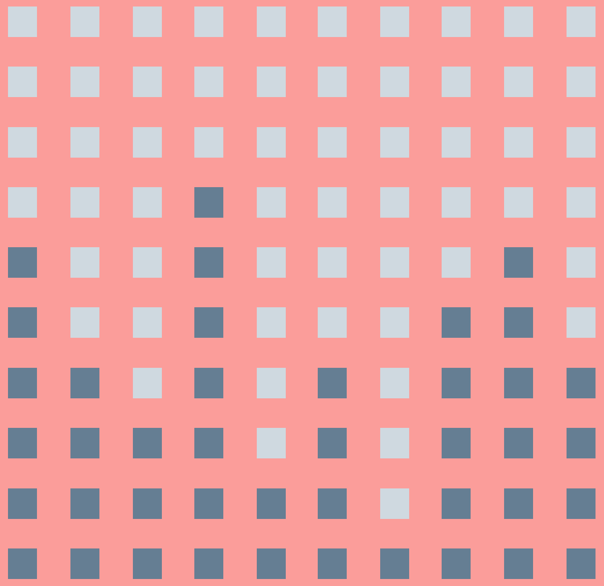


Image source: http://www.rajeun.net/boneage.html

Objective



Determine which factors may be important to consider in using **deep learning** to predict *bone age*

Process

Data

RSNA Pediatric Bone Age Challenge 2017 dataset

14,236 X-rays

1-228 months

54% M, 46% F

Images provided by: Stanford University, University of Colorado, UCLA

Data

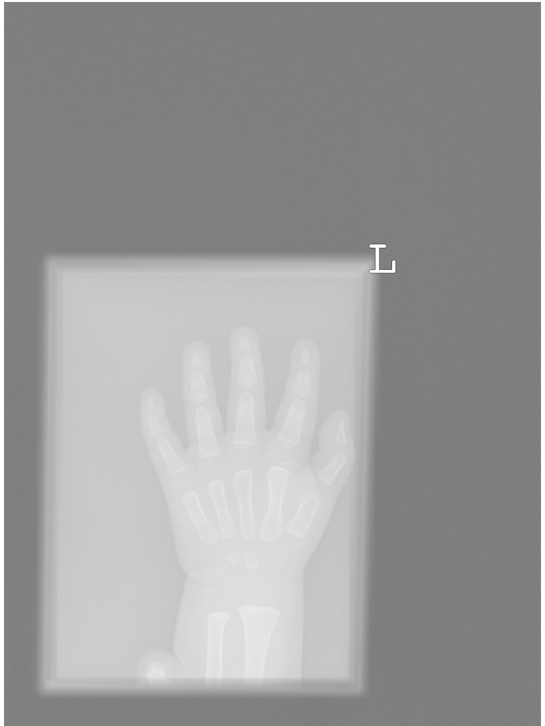
RSNA Pediatric Bone Age Challenge 2017 dataset

14,236 X-rays

1-228 months

54% M, 46% F

Images provided by: Stanford University, University of Colorado, UCLA



Modeling

Data

Augmentation

Enhancement

Resampling

Image source: https://aimi.stanford.edu/news/2017-rsna-bone-age-challenge-test-set-image-dataset-released

Modeling

Data

Augmentation

Enhancement

Resampling

Transfer Learning

Pre-trained CNN: *Xception*

Fine-tuning

Image source: https://aimi.stanford.edu/news/2017-rsna-bone-age-challenge-test-set-image-dataset-released

Modeling

Data

Augmentation

Enhancement

Resampling

Transfer Learning

Pre-trained CNN: *Xception*

Fine-tuning

Sex

Separate models

As feature

Image source: https://aimi.stanford.edu/news/2017-rsna-bone-age-challenge-test-set-image-dataset-released

Modeling

Data

Augmentation

Enhancement

Resampling

Transfer Learning

Pre-trained CNN: *Xception*

Fine-tuning

Sex

Separate models

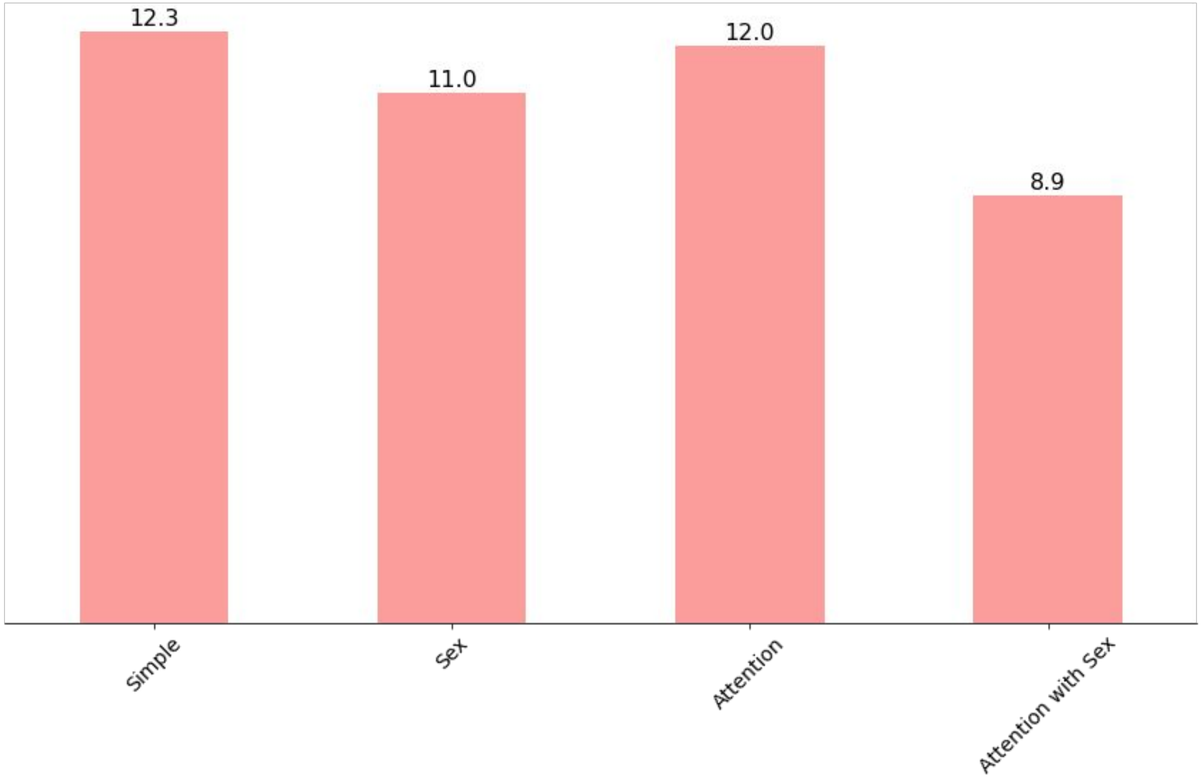
As feature

Attention Mechanism

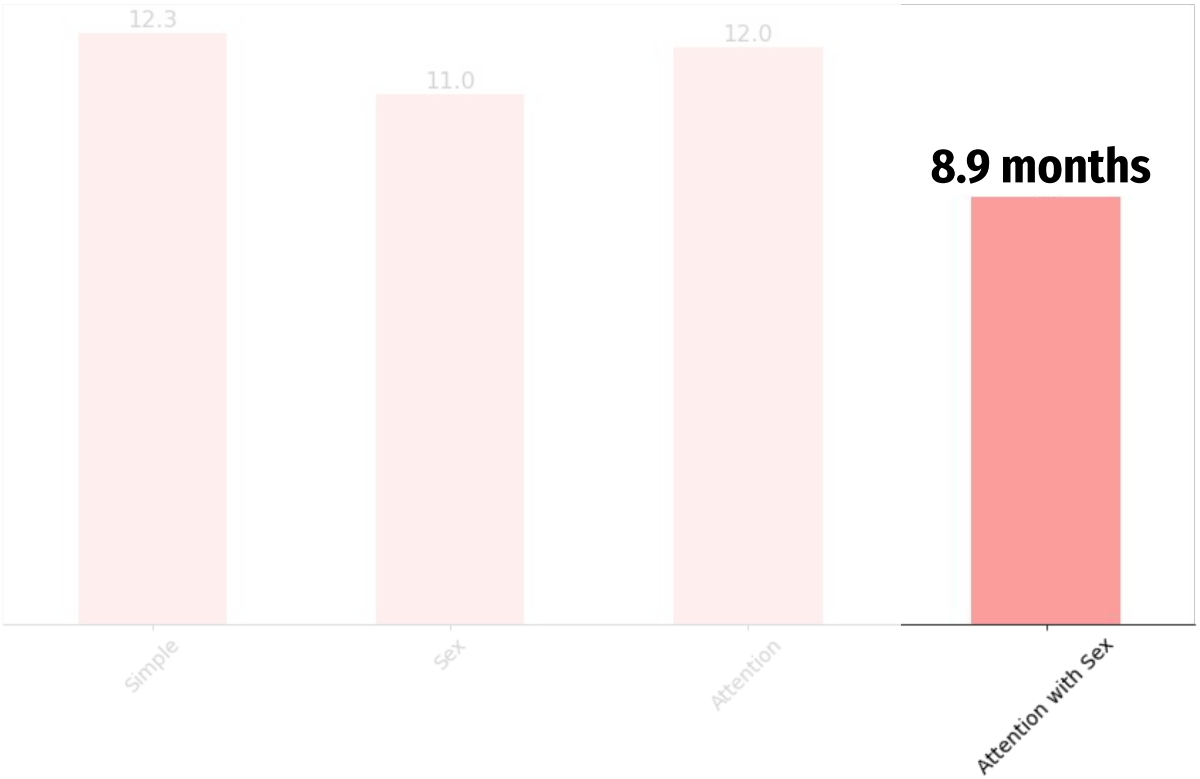
Image source: https://aimi.stanford.edu/news/2017-rsna-bone-age-challenge-test-set-image-dataset-released

Models

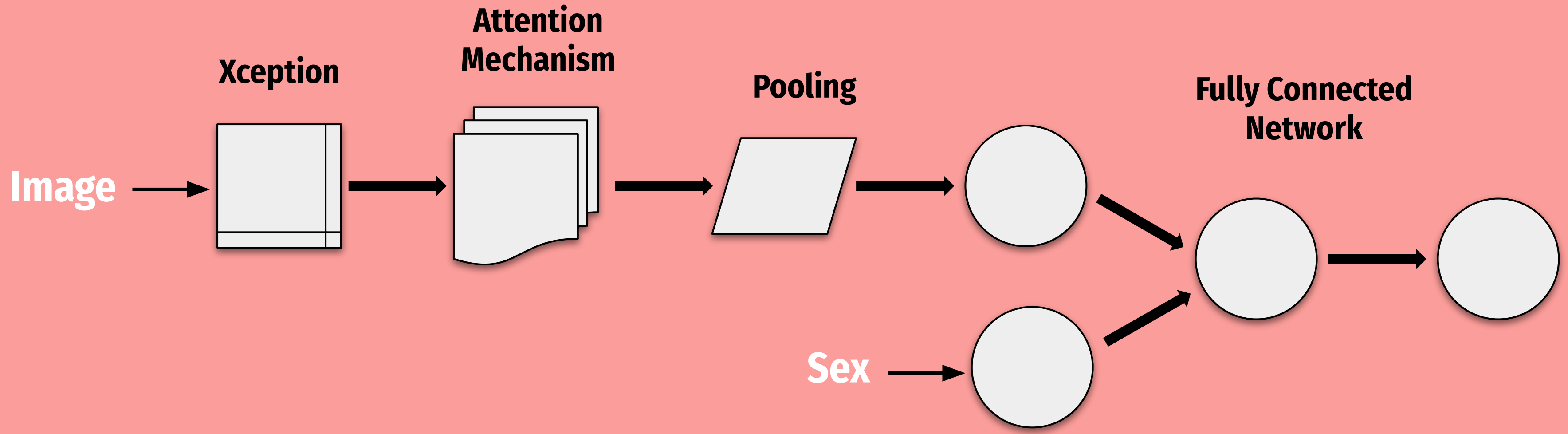
Comparison of Models: MAE (Months)



Best Model


12.3
11.0
12.0
8.9 months
Simple
Sex
Attention
Attention with Sex

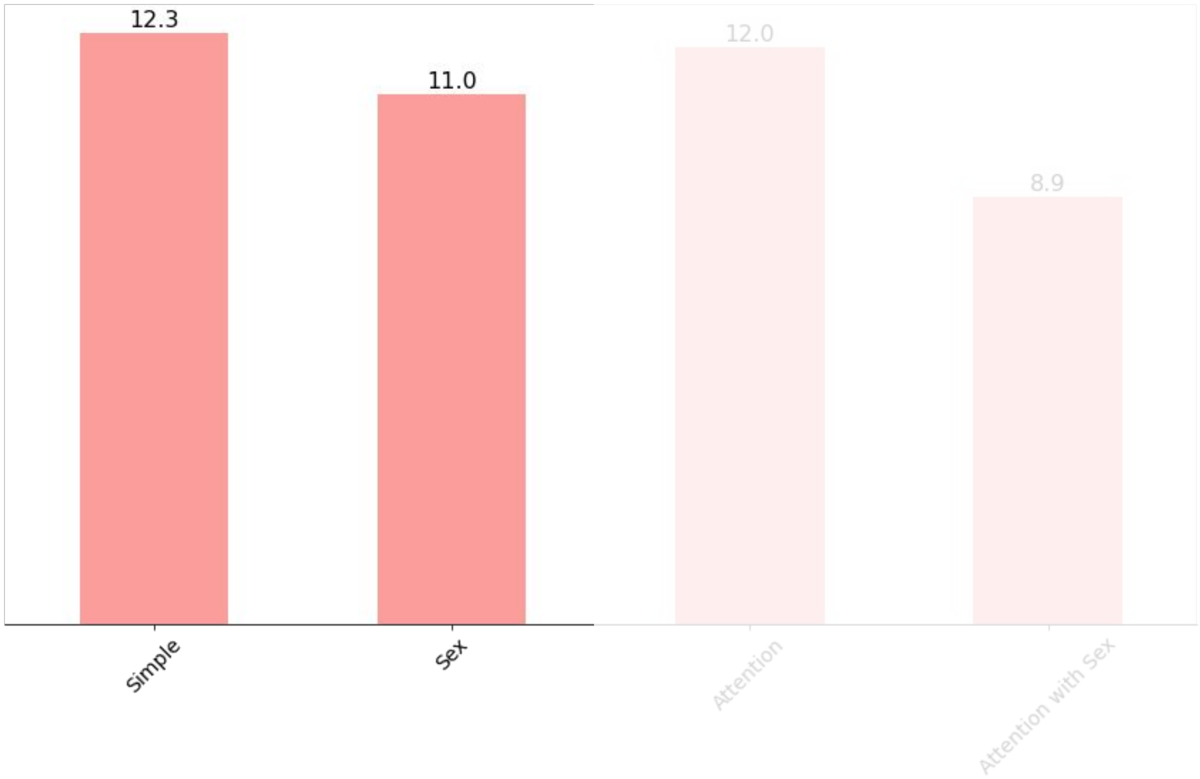
Best Model



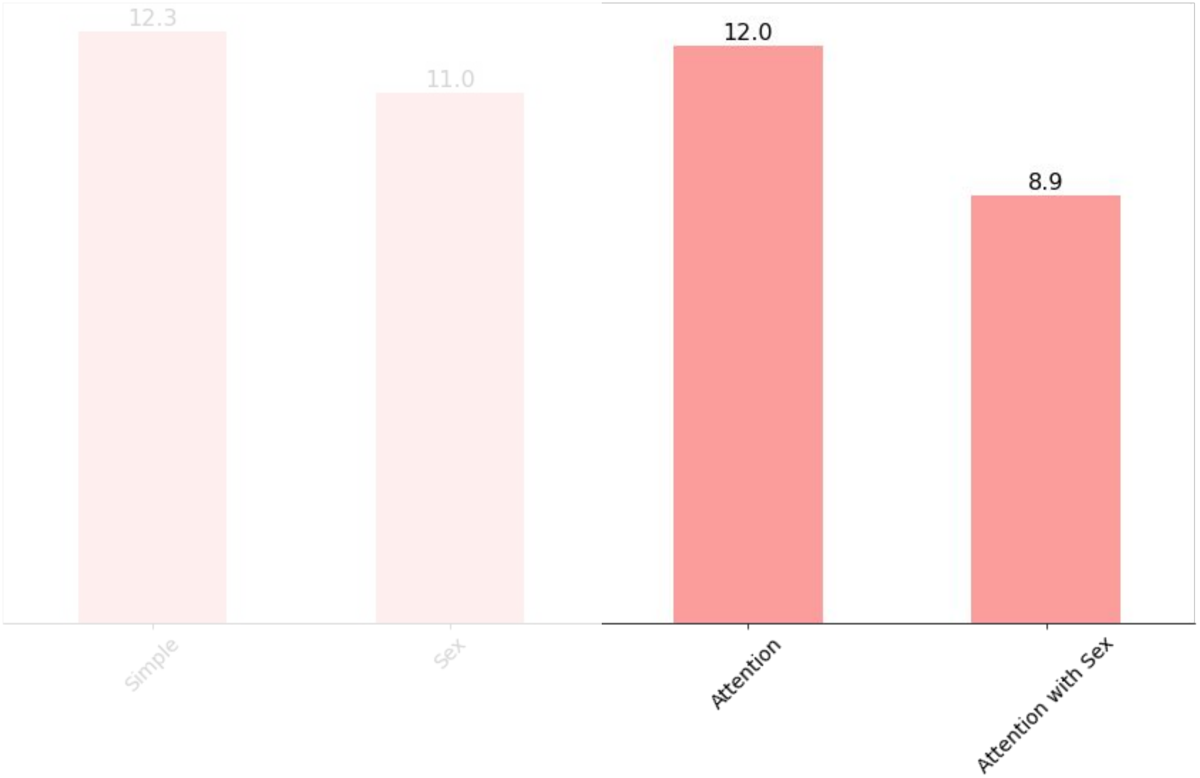
Xception
Attention
Mechanism
Pooling
Fully Connected
Network
Image
Sex

Insights

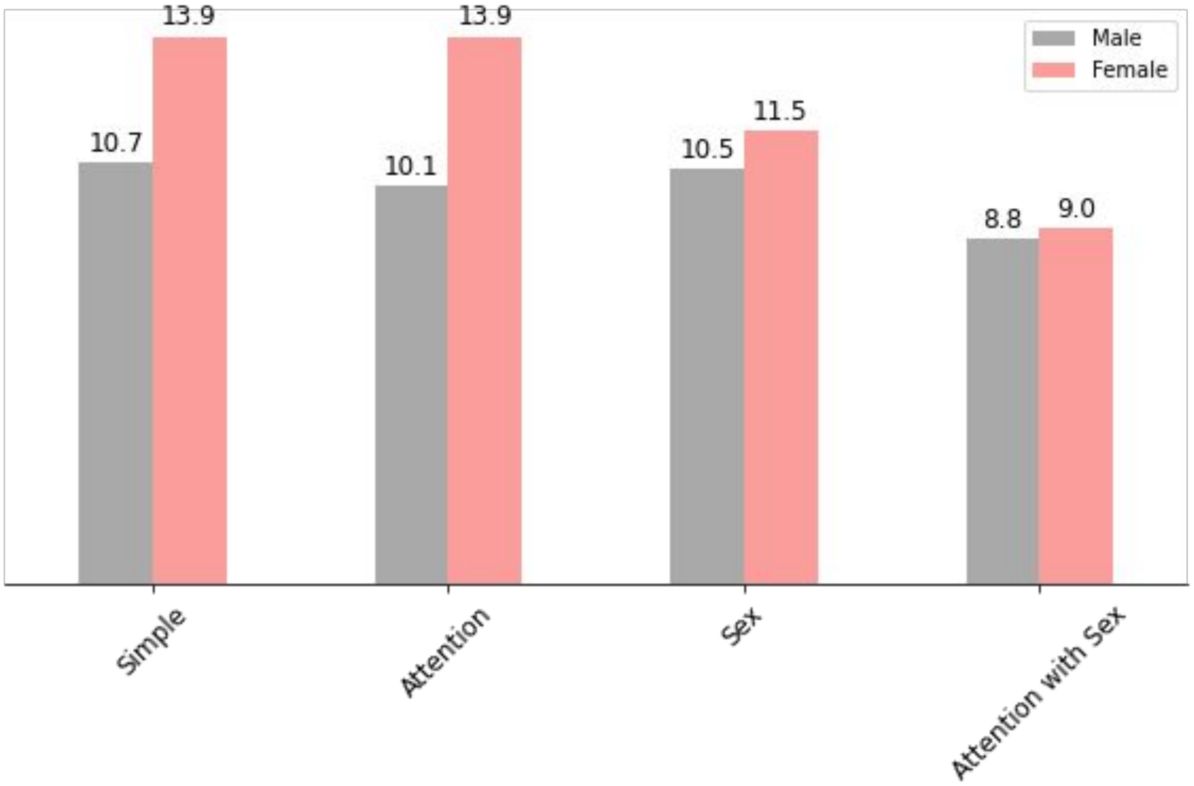
Insight: Sex



Insight: Sex

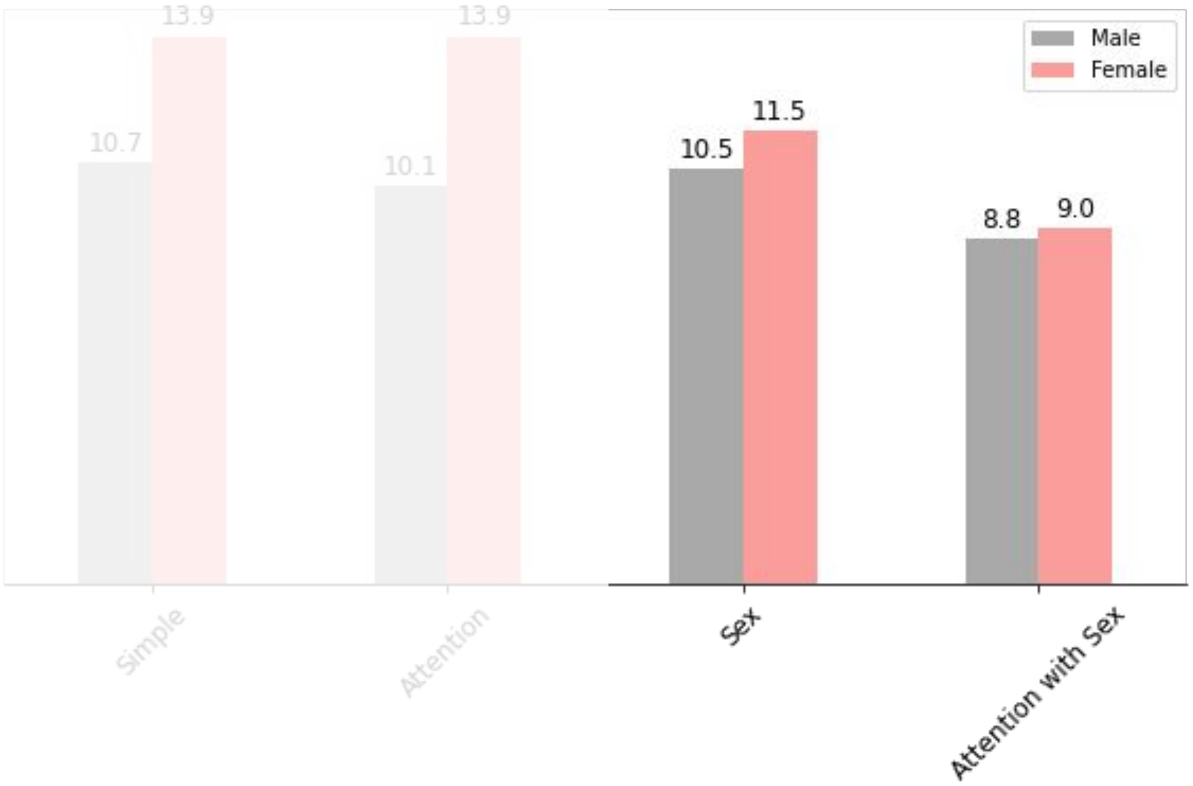


Insight: Sex



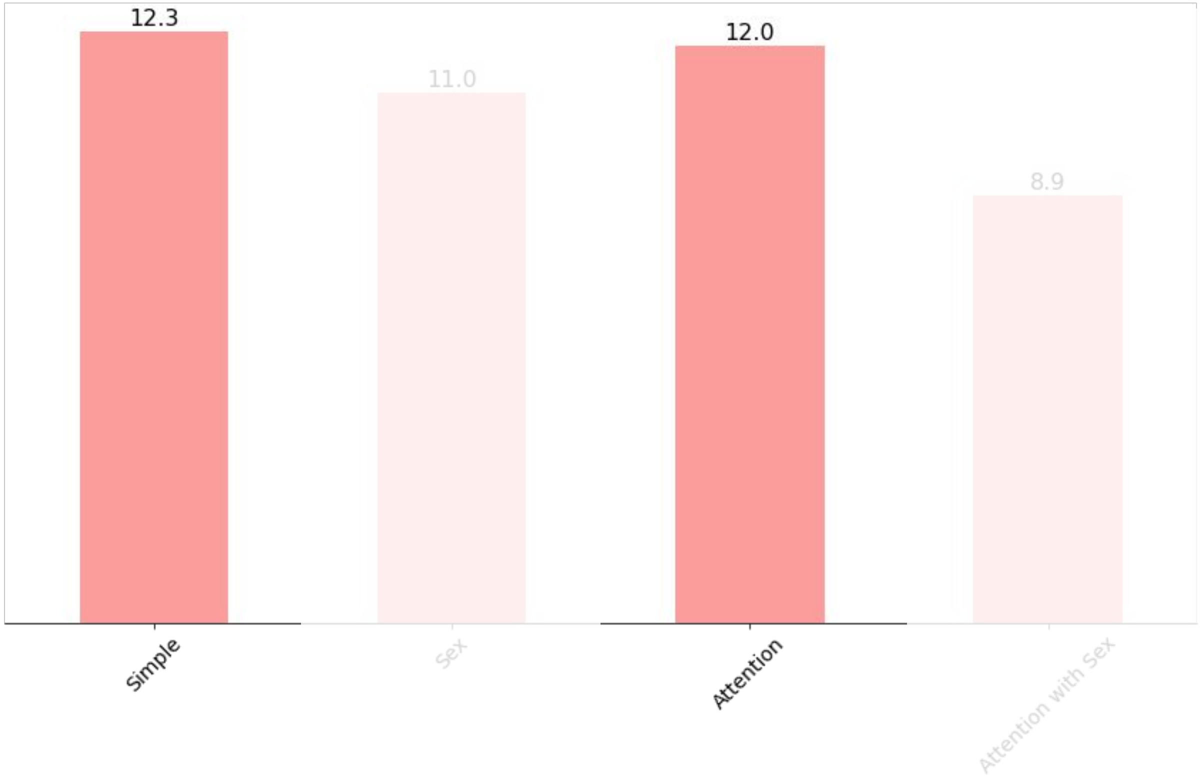
Male
Female
10.7
13.9
10.1
13.9
10.5
11.5
8.8
9.0
Simple
Attention
Sex
Attention with Sex

Insight: Sex

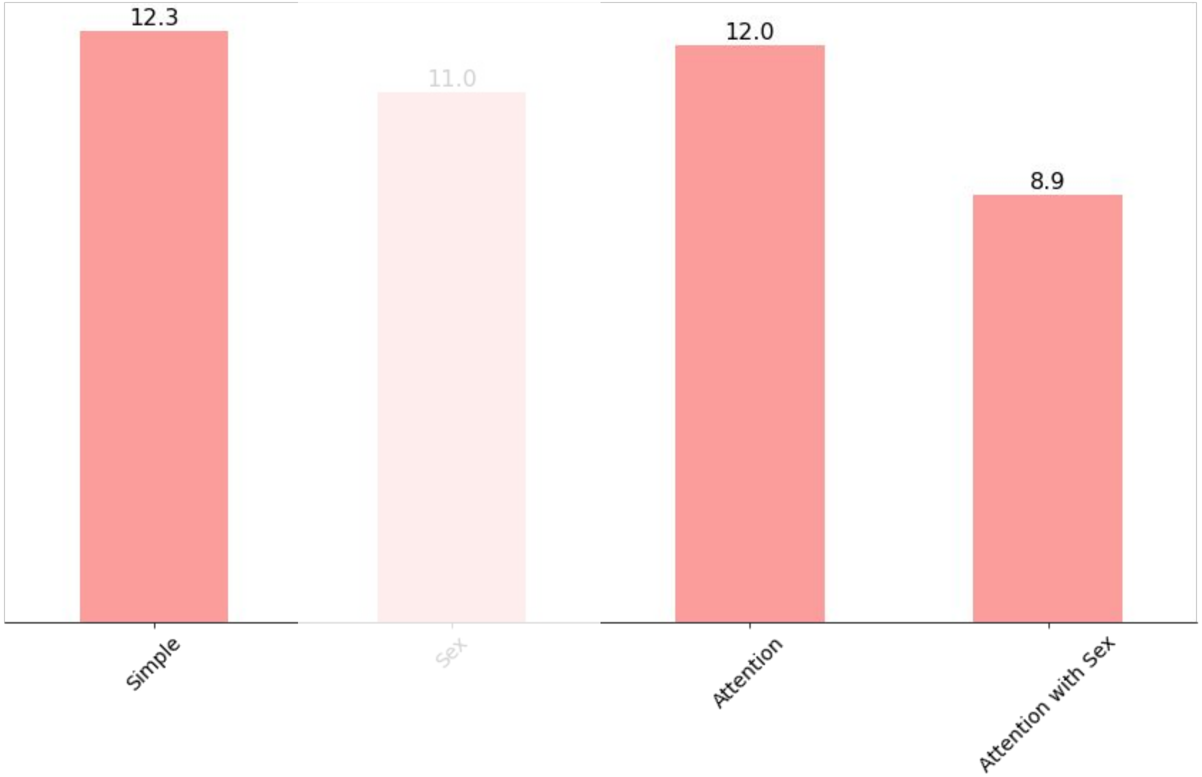


Male
Female
13.9
13.9
10.7
10.1
11.5
10.5
9.0
8.8
Simple
Attention
Sex
Attention with Sex

Insight: Attention

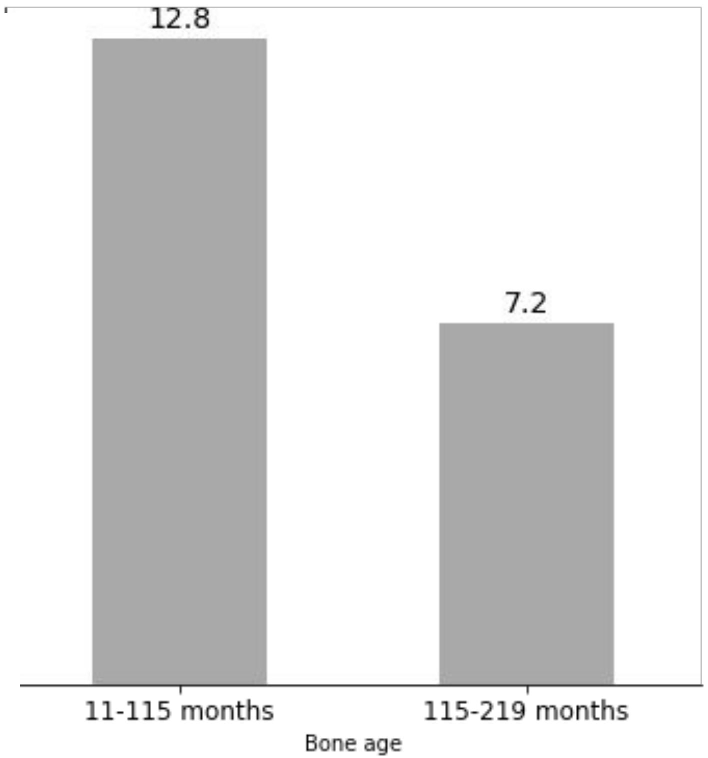


Insight: Attention + Sex



Insight: Age

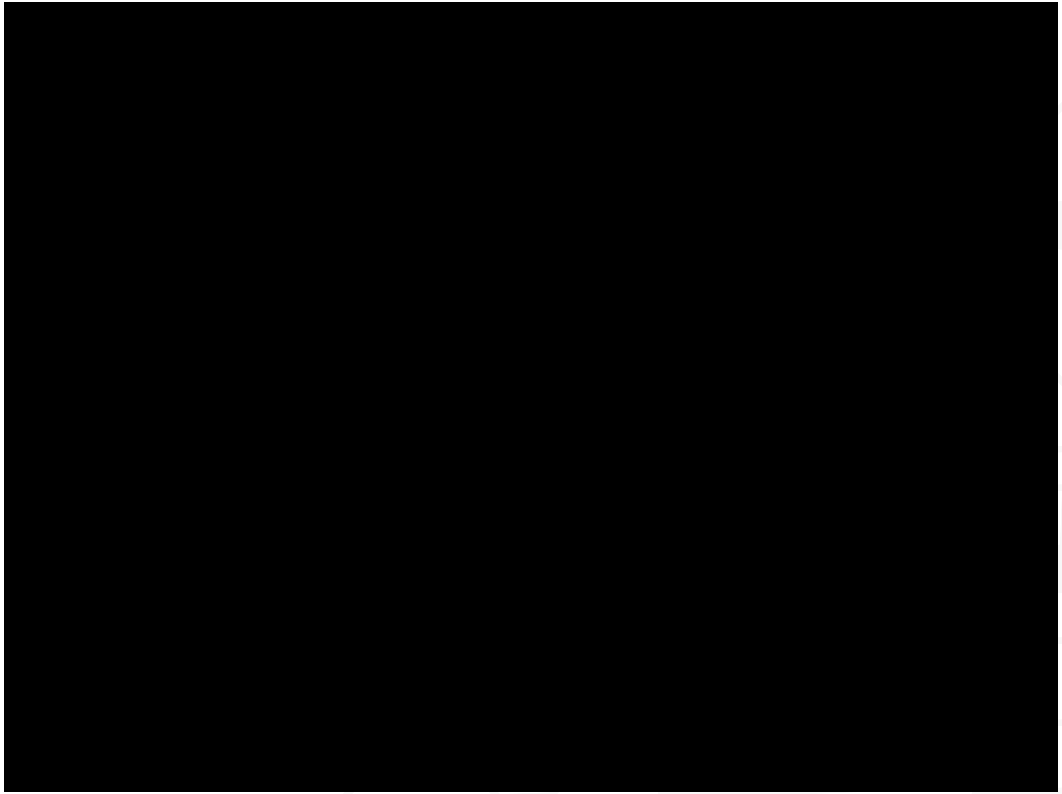
Attention-sex model: MAE (months)



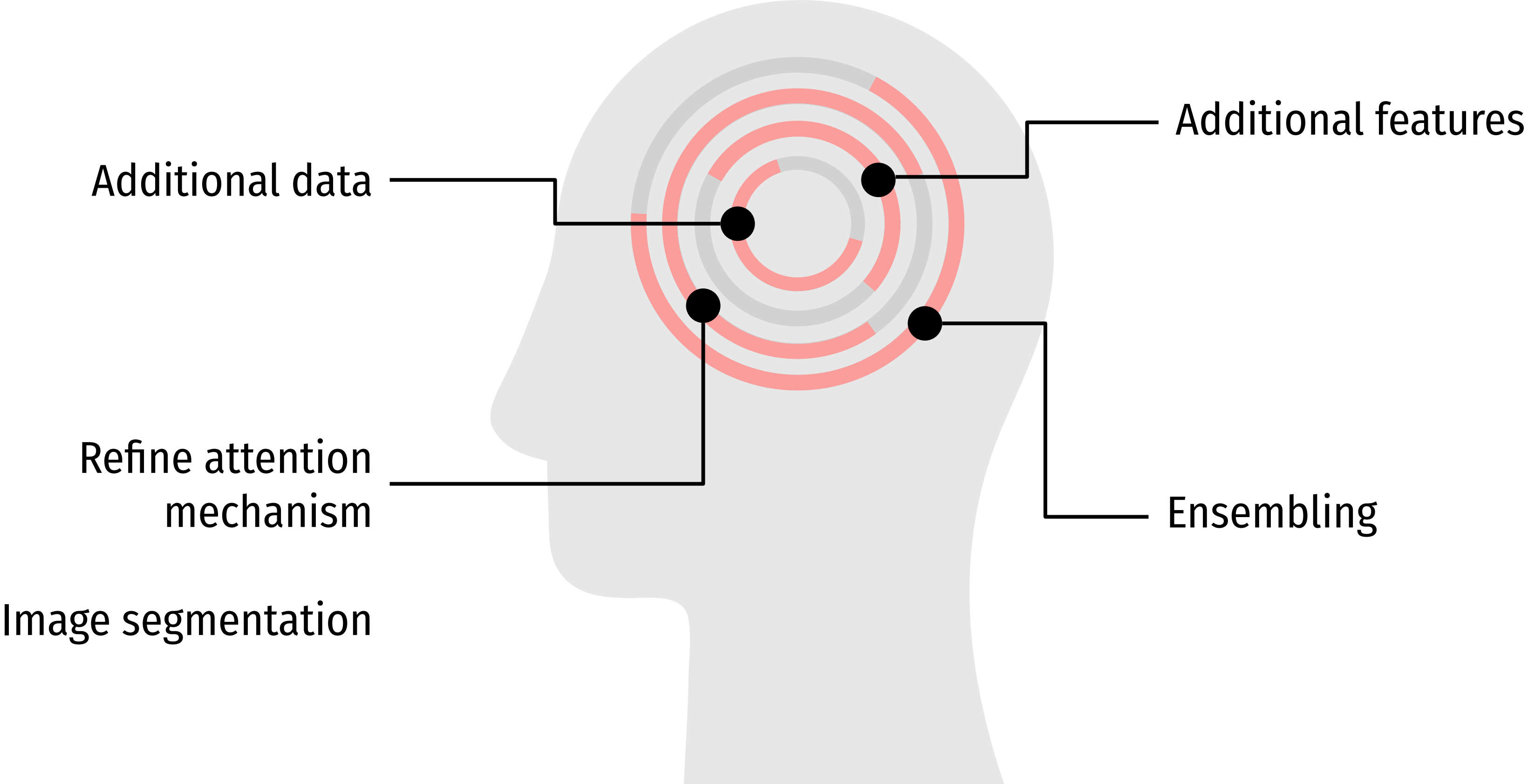
Takeaways

- Consider sex differences, which may be associated with regions of interest
- Pre-identifying regions of interest may improve performance
- Consider age differences

Application



Future Work


Additional data
Additional features
Refine attention mechanism
Ensembling
Image segmentation

References

Data sources:

- https://www.rsna.org/education/ai-resources-and-training/ai-image-challenge/RSNA-Pediatric-Bone-Age-Challenge-2017
- https://stanfordmedicine.app.box.com/s/4r1zwio6z6lrzk7zw3fro7ql5mnoupcv/folder/42459416739
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Model architecture and code adapted from:

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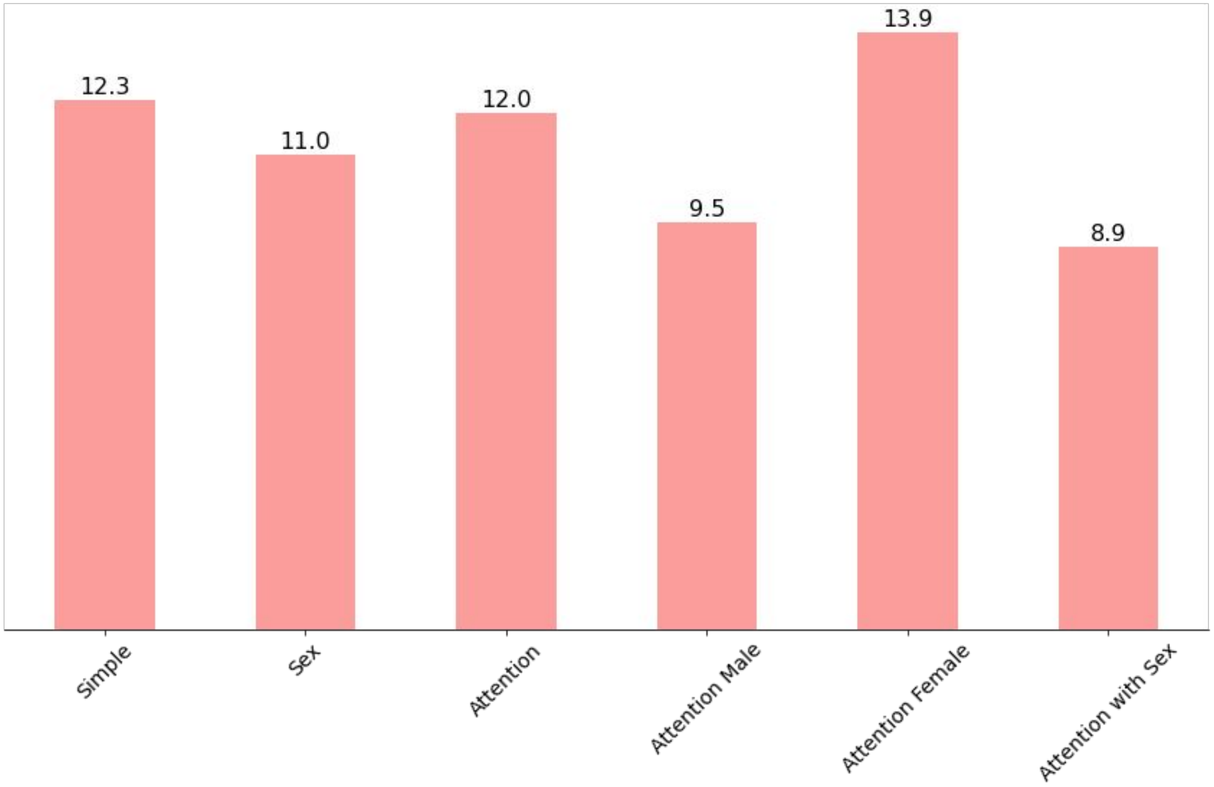
Thank you!

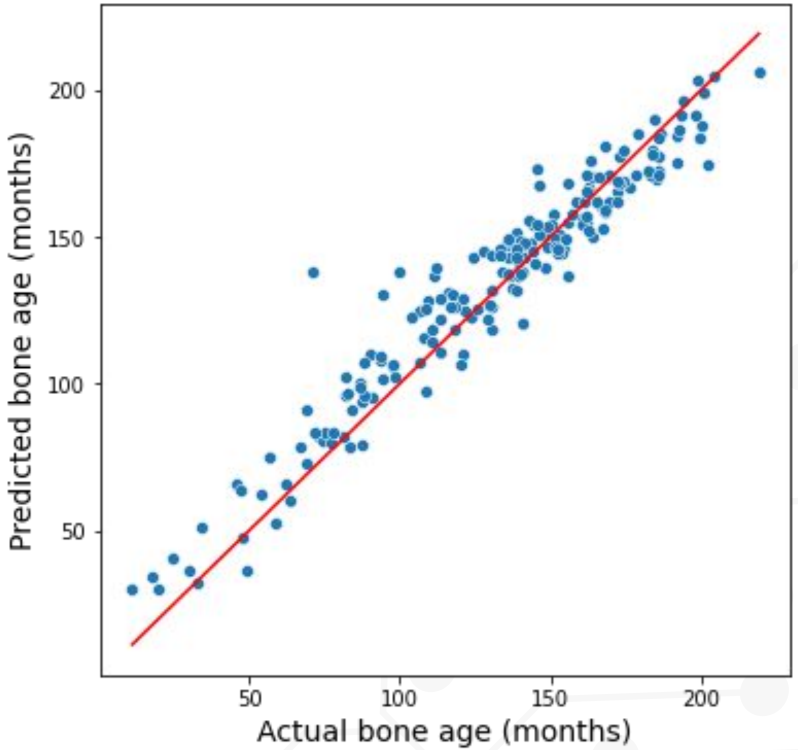
Questions?

Predictions

Appendix: Additional Models - MAE (months)



Appendix: Best Model Predictions



Appendix: Best Model Diagnostics