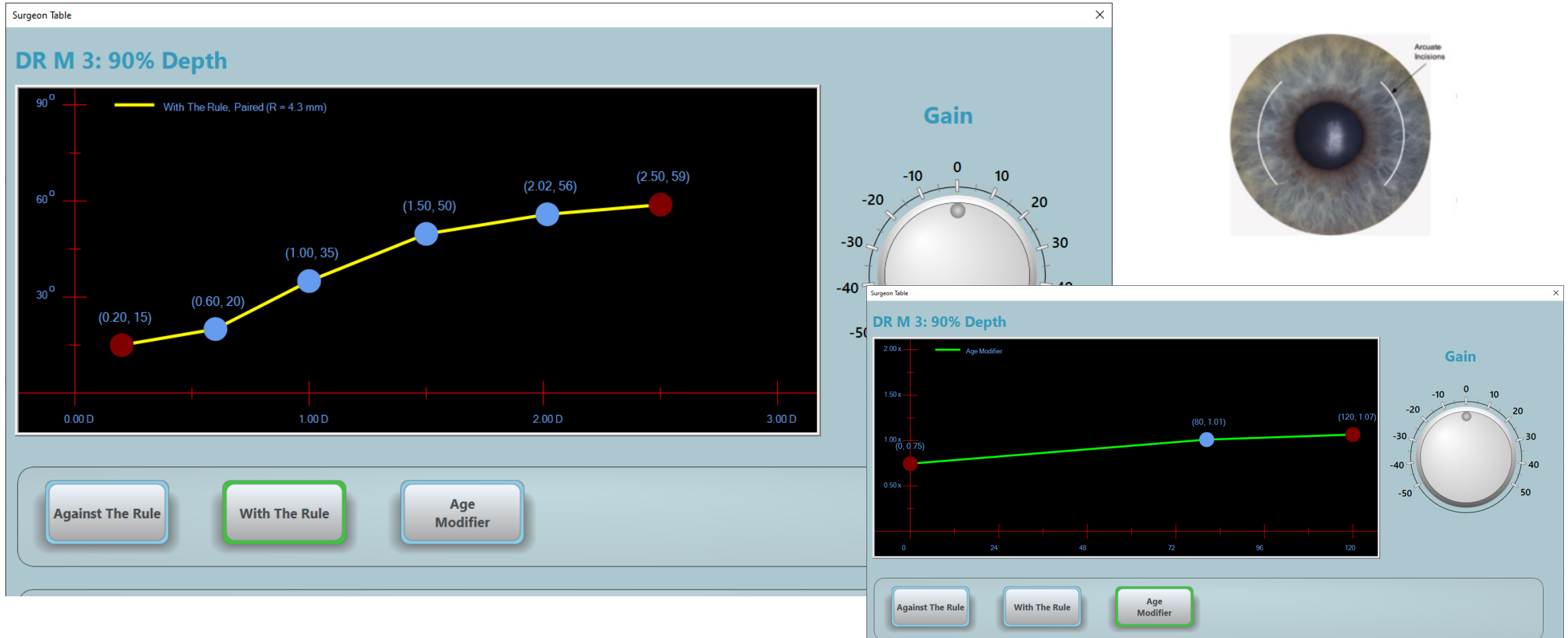


**RETROSPECTIVE ANALYSIS  
OF FEMTOSECOND ARCUATE  
KERATOTOMY (AK) DATA  
TO DEVELOP A PREDICTIVE  
MACHINE LEARNING MODEL**

**JOAQUIN DE ROJAS, MD**

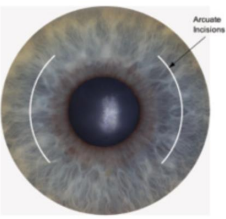
**DENISE VISCO, MD**

# CURRENT METHODOLOGY



# GOAL

## CREATE A BETTER FEMTO AK PLANNING TOOL



- Improve accuracy of astigmatism correction
- Leverage more input data
- Customize for specific surgeon(s)
- Make it easy to use and update

# METHODS

- Patients who underwent FLACS (with the LENSAR)
  - Started with 720 patients from D.V.
  - Added 59 cases from J.D. (to improve prediction at low levels of astig)
  - Excluded certain entries if:
    - Important features missing, typos, BCVA worse than 20/30 (*bad data*)
    - Pre-op biometric astigmatism  $> 2.00$  (*outliers*)
    - Post-op manifest astigmatism  $> 1.00$  (*outliers*)
    - Treated astigmatism  $\geq 1.5$  diopters (*unnecessary data*)
- N = 443 eyes
- Set up which variables ("features") to include to predict arcuate sweep
  - Created models using different algorithms (XGBoost and neural networks in PyTorch)

# HOW DO WE LEARN FROM OUR RESULTS?

Treated Astigmatism =

Pre-op K astigmatism - Post-op MRx cylinder at original steep axis



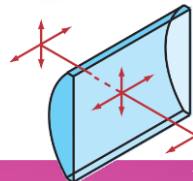
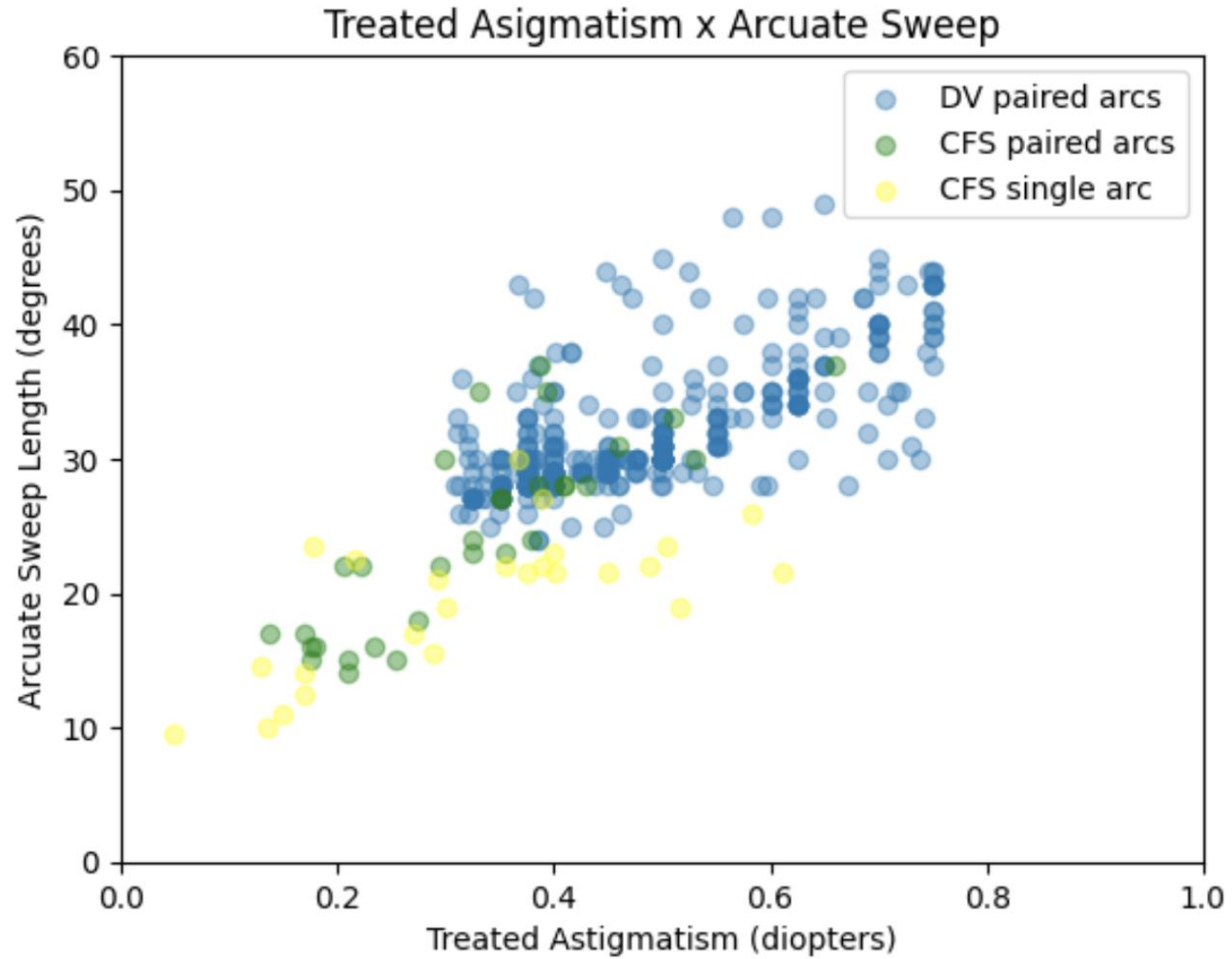
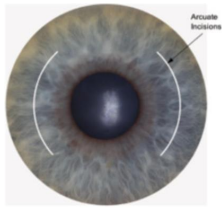
(i.e., the cylinder component)

	A	B	C	D	E	F	G	H	I	J	K	L
1	Age	Sex	Eye	WTW	TCA_Cassini	TK_IOLMaster	Mean K	Treatment Astigmatism	Arcuate Sweep	Steep_Axis	type	Residual Astigmatism
2	56	Female	OD	11.7	1.02	0.548127275	45.3	0.475	33	105	paired	0
3	51	Female	OS	12	0.364378869	0.437095575	46.57	0.32	31	110	paired	0
4	57	Male	OS	12.1	1.209262901		43.61	0.625	41	70	paired	0
5	68	Female	OD	11.8	1.075962361	0.727721795	45.44	0.5	30	105	paired	0
6	67	Male	OD	12.7	1.017630472	0.980071828	45.29	0.5	30	155	paired	0.021706022
7	82	Male	OD	11.8	0.748453892		45.06	0.45	28	167	paired	0
8	72		OS	12.5			44.81	0.41	28	99	paired	0
9	66	Female	OD	12.6	0.85	1.107296096	42.81	0.475	30	43	paired	0
10	69	Female	OD		0.619622313	1.093136606	42.61	0.4	28	2	paired	0
11	69		OD	12.8			42.76	0.3	19	23	single	0
12	69		OS	12.2			42.36	0.17	12.5	11	single	0
13	69	Female	OD	13.1	0.98758841		42.39	0.625	35	10	paired	-0.089917475
14	75		OS	11			48.99	0.435	23.5	2	single	-0.069899113
15	61	Female	OS	12.4	0.628465352		43.63	0.45	31	100	paired	0
16	69		OD	12.6			43.98	0.445	22.5	143	single	0.228386364
17	74		OD	12			42.36	0.235	14.5	143	single	0.106006012
18	50	Male	OD	12.6	0.958584649		43.64	0.5	35	137	paired	0.101127125
19	64	Female	OS	12.3	1.039781472	0.65	45.83	0.5	31	84	paired	0
20	79	Male	OS	12.3	1.229250717	1.419134974	42.21	0.65	35	178	paired	-0.069899113
21	66		OS	12.1			46.23	0.335	21.5	168	single	-0.114193182
22	62	Female	OS	12.3	0.889457836	1.147831871	46.62	0.5	31	95	paired	0
23	68	Female	OS		0.64	1.03	43.85	0.55	33	72	paired	0
24	74	Male	OD	12.1	0.726000984	0.964686239	43.04	0.475	29	7	paired	0
25	64		OD	12			42.32	0.17	14	178	single	0
26	68	Female	OS	12.4	1.5		44.45	0.75	43	88	paired	0
27	76	Female	OD	12.1	1.15	1.37	42.68	0.65	37	89	paired	0
28	57	Female	OD	12.3	0.989396919		45.27	0.5	35	74	paired	0
29	58	Male	OS	11.7	0.53830655	0.623538291	43.19	0.375	30	140	paired	0
30	68		OS	11.7			46.93	0.45	35	103	paired	0.120157712
31	82	Male	OD	12.7	0.638440992	0.890114317	45.16	0.5	30	55	paired	0
32	76		OD	12.1			44.39	0.525	26	166	single	-0.058683945
33	69	Female	OD		0.53	0.387863539	45.7	0.25	26	52	paired	-0.069899113
34	77	Male	OD		0.911046623	1.11	43.47	0.55	32	11	paired	0
35	64	Female	OD	12.2	1.137223017	0.719561395	46.18	0.5	31	73	paired	0.101684161
36	75	Female	OS	11.8	1.157174298		43.21	0.625	34	163	paired	0

$$\text{cylinder\_component} = \text{cylinder} \times \cos [2 \times (\text{arcuate\_axis} - \text{axis})]$$

44	68	Male	OS	11.8	1.203121549	1.362494997	45.97	0.65	35	172	paired	0
45	69	Male	OD	12.1	0.322258277	1.193426274	36.25	0.5	30	177	paired	0
46	69	Female	OS	12.2	1.310717785	1.723413568	42.43	0.625	34	8	paired	0
47	51	Female	OD	12.2	1.134288801	0.336691143	41.64	0.4	32	92	paired	0
48	75	Male	OS	11.9	1.113864523	1.056989594	42.83	0.575	33	155	paired	0
49	66	Female	OS	12.3	0.706258874		44.00	0.375	30	58	paired	0

# DATA



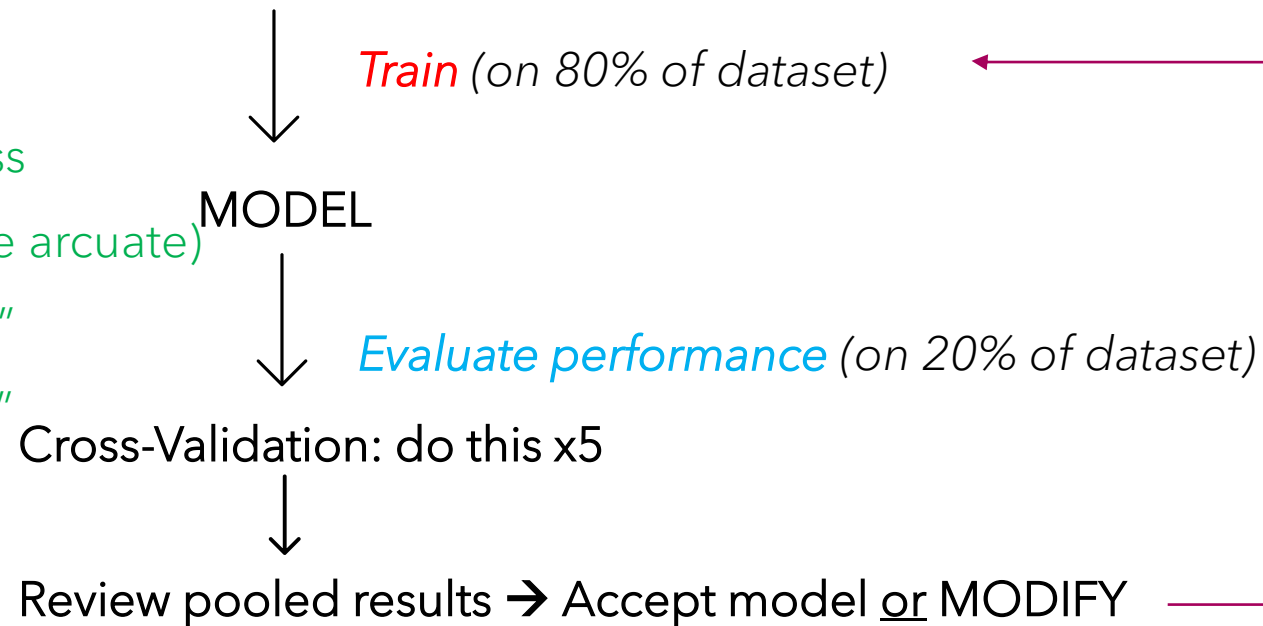
# CREATING A MODEL (TRAINING)

## Designate Features (X):

- Treated Astigmatism
- Steep axis (as  $\text{Cos}(2\theta)$ )
- Age
- White-to-white
- Mean corneal steepness
- Tx type (Paired vs single arcuate)
- Astig from biometer "X"
- Astig from biometer "Y"

## Designate Target (y):

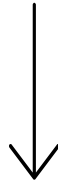
- Arcuate Sweep length



# USING A MODEL (INFERENCE)

Input patient Features (x):

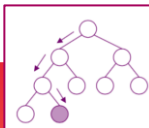
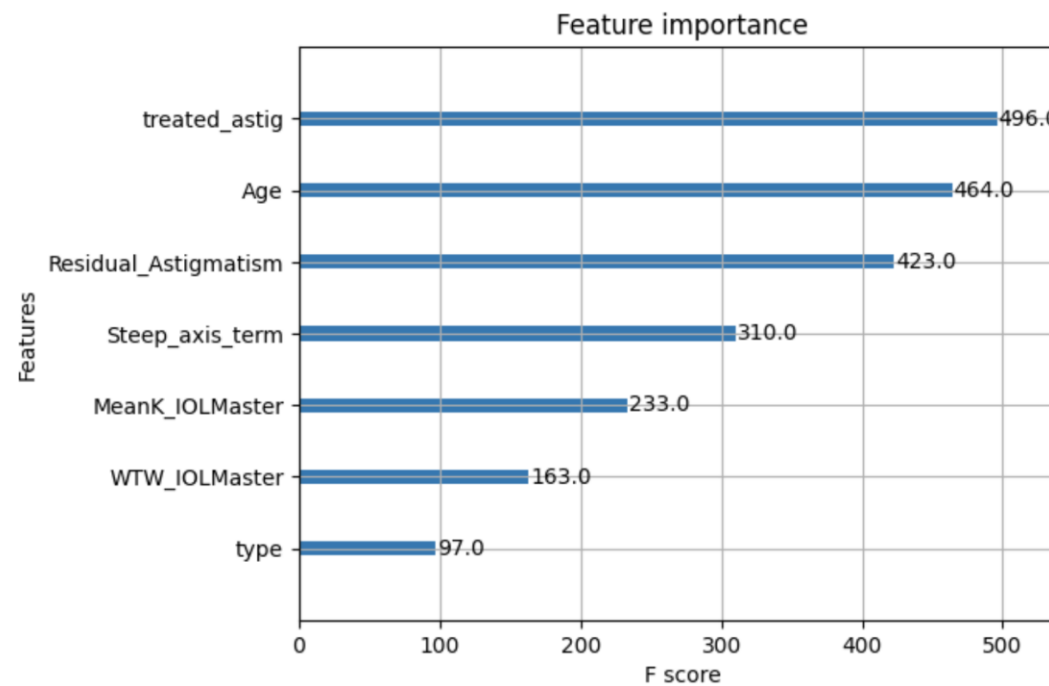
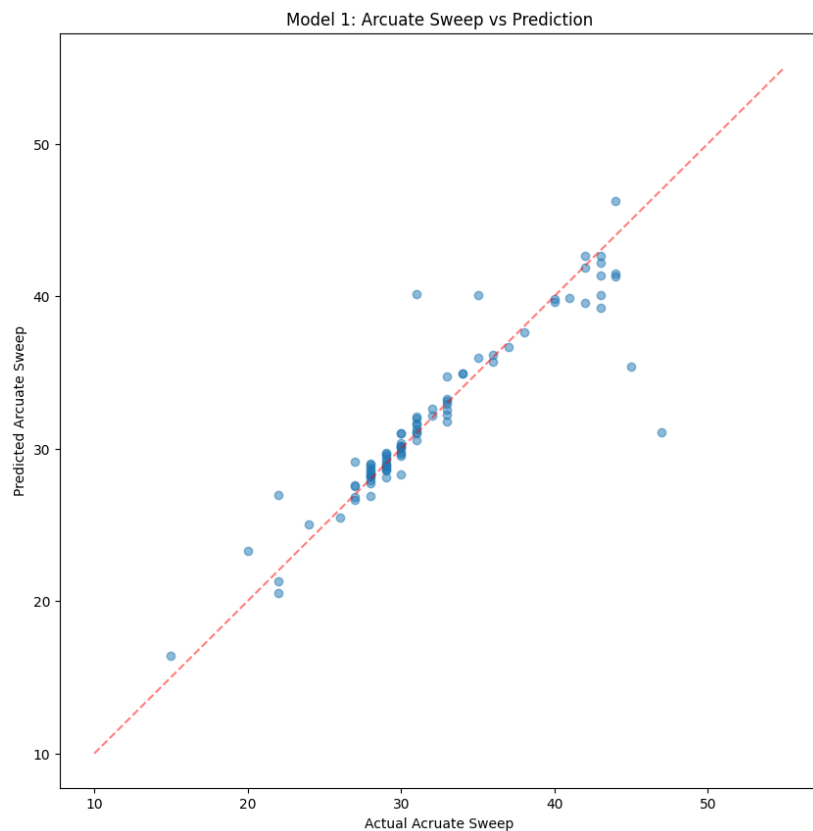
- Treated Astigmatism
- Axis
- Age
- Other features...



Use the Model ("Inference")

Predicted Arcuate sweep length

# MODEL 1 RESULTS (XGBOOST)



\***XGBoost** is a fast, scalable machine learning algorithm that uses gradient boosting to optimize decision trees for high performance and accuracy.

# MODEL 1 PERFORMANCE

Average scores across all folds:

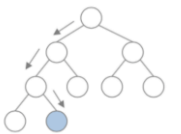
MAE: 1.1714

RMSE: 2.0416

R2: 0.8813

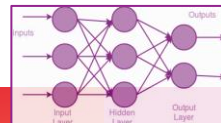
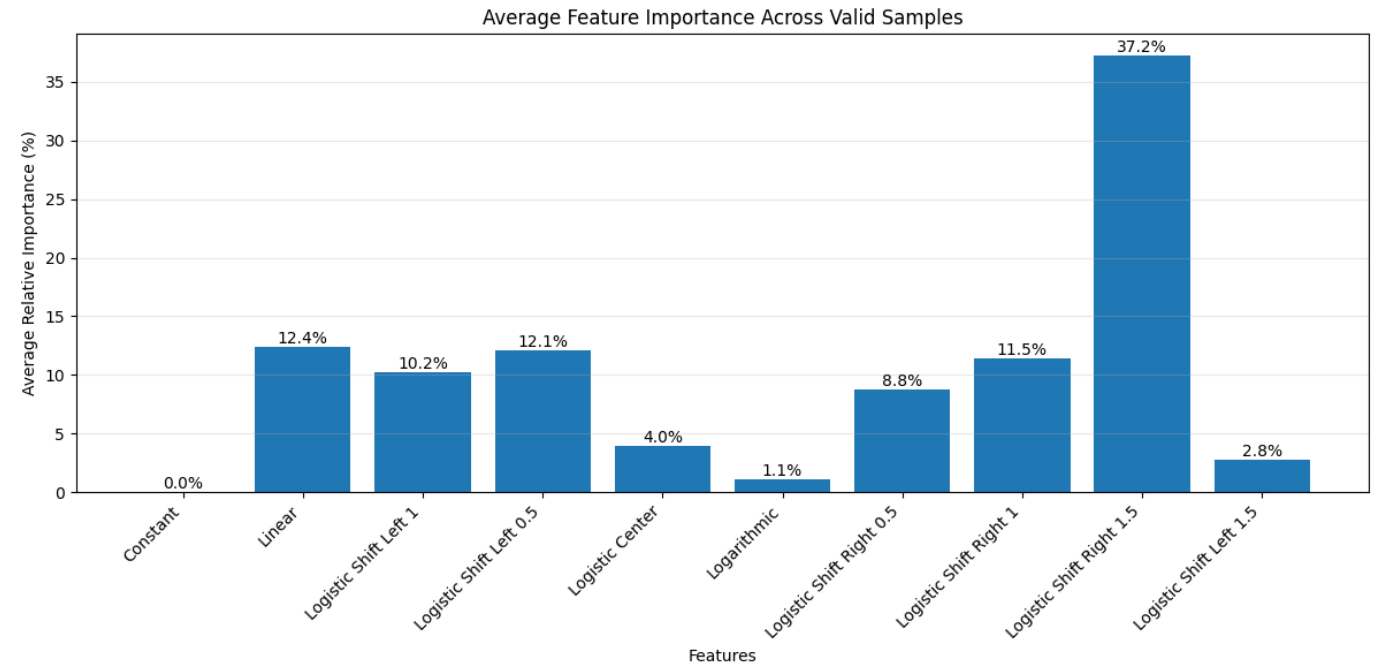
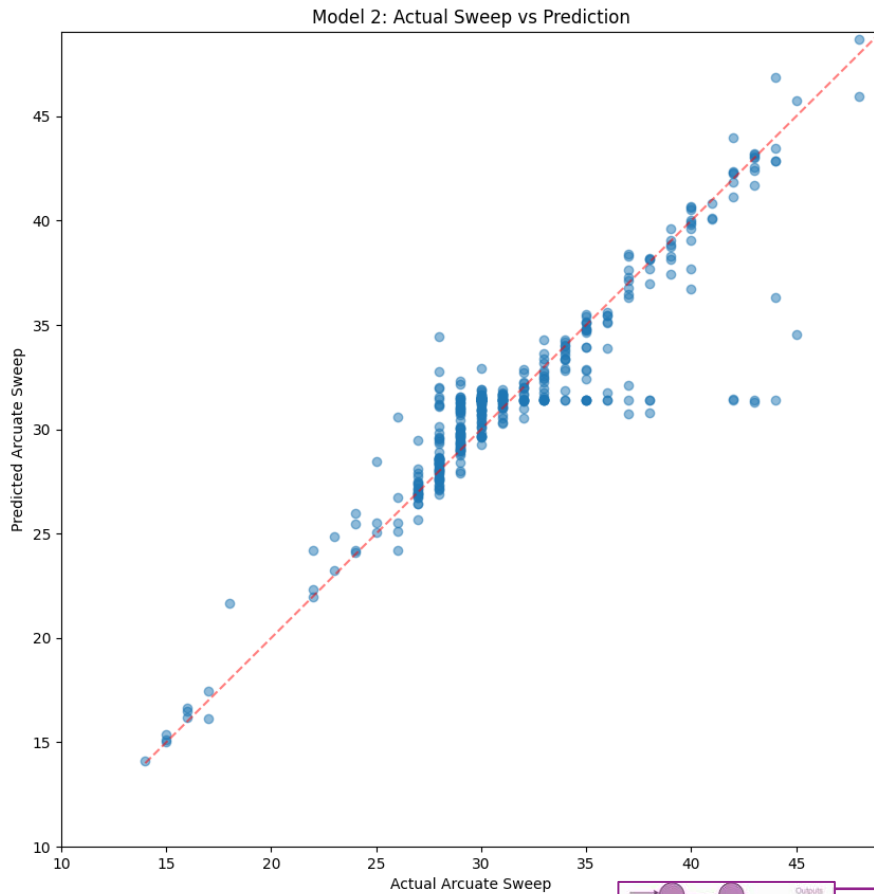
Epochs: 192.0

*Expected margin of error ~2 degrees  
of arcuate sweep length*



\*This model used the XGBoost algorithm

# MODEL 2 RESULTS (MONOTONIC NN)

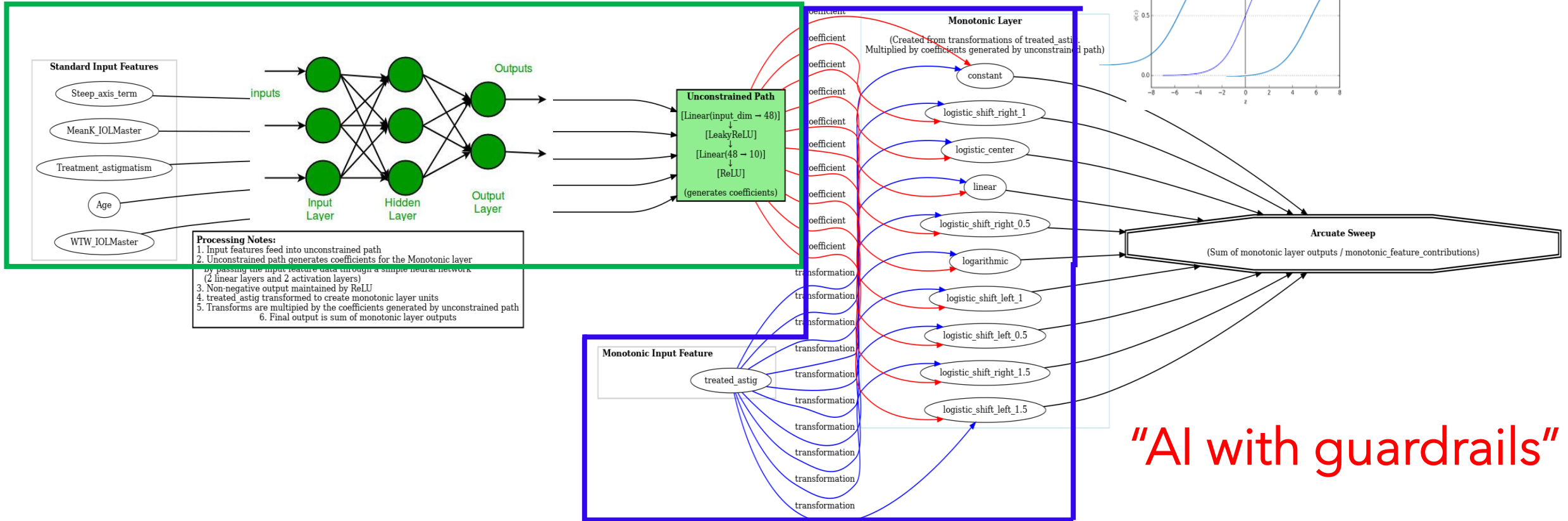


\*A monotonic neural network is a custom deep learning model that enforces consistent input-output relationships, improving interpretability and trust.

# MODEL 2 DETAILS

Unconstrained region:  
NN w/ 2 hidden layers

Constrained region



"AI with guardrails"

# MODEL 2 PERFORMANCE

Average scores across all folds:

MAE: 2.0169

RMSE: 2.9697

$R^2$ : 0.6805

Epochs: 198.6

*Expected margin of error  
~3 degrees of arcuate sweep length*

# MODEL 2 PERFORMANCE

*Used BINARY SEARCH to work backwards and determine accuracy in terms of astigmatism:*

MAE (D): 0.0677 diopters

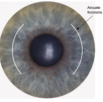
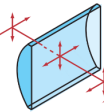
RMSE (D): 0.1156 diopters

Within 0.25D: 92.9%

Within 0.50D: 100.0%

*Expected margin of error <0.15 diopters of treated astigmatism*

# CONCLUSIONS

- Current FLACS AK planners are outdated and limited
- We analyzed retrospective data to build 2 AI-based models that analyzed complex interactions between multiple input features to precisely predict arcuate incision length
- AI Model 1 and AI Model 2 (with constraints) showed strong performance:  
**Error margins within 3° of arcuate sweep**   
**and within 0.15 diopters of treated astigmatism** 
- AI-based models can personalize and improve as more data is introduced

# **A SPECIAL THANKS TO**

Dustin Morley, PhD

Principal Research Scientist at LENSAR



Website:

[www.derojas.info](http://www.derojas.info)

Coding repositories:

[https://github.com/wak1616/AI\\_calc](https://github.com/wak1616/AI_calc)

Email:

[Joaquin.derojas@gmail.com](mailto:Joaquin.derojas@gmail.com)

**THANK YOU!**