Artificial Intelligence in Ophthalmology

Image Courtesy: Saul Gravy/Getty Images

Kishan Gupta, MD, PhD
Ophthalmology Resident
Casey Eye Institute
Oregon Health and Science University

Overview

Brief Introduction to Artificial Intelligence

FDA Approval for Screening Diabetic Retinopathy

Intraocular Lens Calculations with Artificial Intelligence

Future Use with Retinopathy of Prematurity

Summary

What is Artificial Intelligence?

Applying learning to non-sentient entities like machines

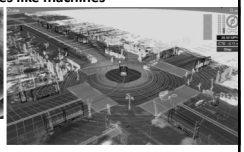


Image Courtesy: Digital Innovation and Transformation, Harvard Business School, 2016.

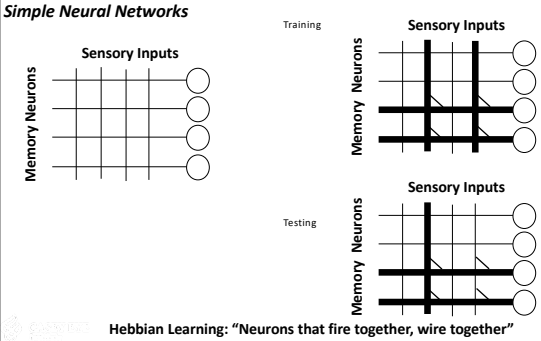
Image Courtesy: Mashable.Com, 2018

Image Courtesy: Amazon.com, 2018

Why is Artificial Intelligence (AKA Machine Learning, Deep Learning) Useful?

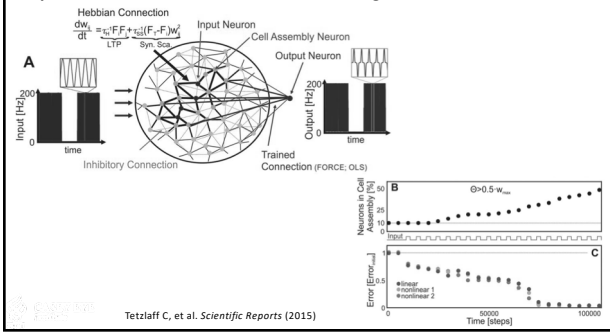
- **<u>Scalability</u> – Eye providers cannot necessarily screen millions at threat for specific diseases. For eyes, pictures are relatively easy to obtain. Interpreting them can be time consuming.**
- **<u>Quantitative</u> – Humans are subjective. Poor interobserver correlation. Algorithms give us quantitative, objective scores.**
- **<u>Efficiency</u> – Tracking disease progression much easier with quicker time to treatment.**

Simple Neural Networks



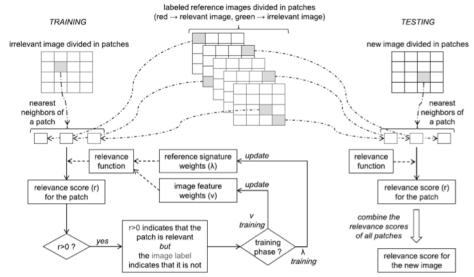
Hebbian Learning: "Neurons that fire together, wire together"

Complex Neural Networks with Hebbian Learning



Tetzlaff C, et al. *Scientific Reports* (2015)

Example of Algorithm for Image Feature Extraction



Quellec G, et al. *Med Imag Anal.* (2012)

Pattern Recognition

Ophthalmology is inherently a pattern recognition heuristic to diagnose disease

Image Courtesy: EyeRounds.org, University of Iowa Carver Medical School

NORMAL or ABNORMAL?

NORMAL

Pattern Recognition (cont'd)

Image Courtesy: EyeRounds.org, University of Iowa Carver Medical School

NORMAL or ABNORMAL?

ABNORMAL

What features are abnormal?

HUMANS ARE EXCELLENT AT PATTERN RECOGNITION!
BUT WE ARE TERRIBLE AT COMMUNICATING SUBJECTIVE FINDINGS

Applying Algorithm to Fundus Photo of Severe Non-Proliferative Diabetic Retinopathy (nPDR)

The Early Treatment Diabetic Retinopathy Study defined Severe nPDR:

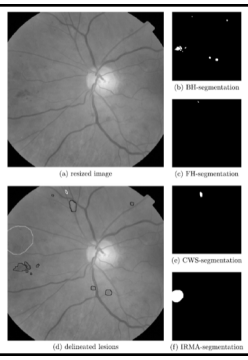
- 4 quadrants of 20 or more Microaneurysms, Dot Blot Hemorrhages, or Intraretinal Hemorrhages

OR

- 2 Quadrants of Venous Beading

OR

- 1 Quadrant of Intraretinal Microascular Abnormality



Quellec G, et al. *Med Imag Anal.* (2012)

IDx-DR – First FDA Approved Deep Learning Algorithm

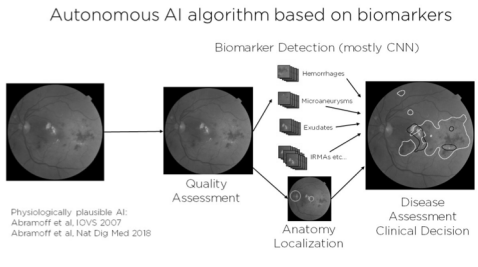


Image Courtesy: IDx-DR, www.eyediagnosis.net

IDx-DR – Intended Screening Guidance

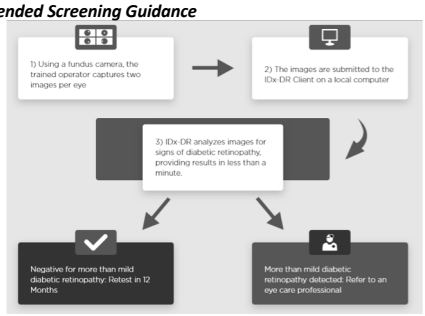


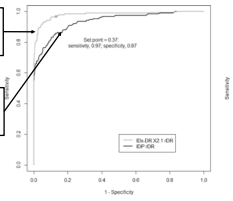
Image Courtesy: IDx-DR, www.eyediagnosis.net

IDx-DR – Validation

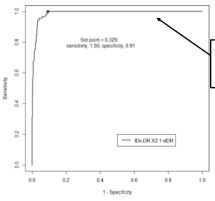
Receiver Operating Characteristic Curve

IDx-DR Area Under Curve: 0.980

IDP (3 Readers) Area Under Curve: 0.937



Referral Diabetic Retinopathy (moderate nPDR or worse)

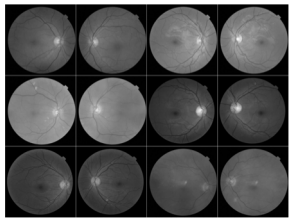


Vision threatening Diabetic Retinopathy (Severe nPDR or worse)

IDx-DR Area Under Curve: 0.989

Abramoff MD, et al. *IVOS* (2016)

IDx-DR – Examples of False Negatives



Right and left eye images of the 6/874 subjects diagnosed as having referrable DR, per the adjudicated consensus of the retinal experts, that were false-negatives for the referral DR output (i.e., were missed by the device). All six subjects had consensus grading of moderate DR without ME.

Abramoff MD, et al. *IVOS* (2016)

Artificial Intelligence in Intraocular Lens Calculations

Image Courtesy: ASCRS/ASOA Symposium 2015

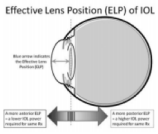


Image Courtesy: ASCRS/ASOA Symposium 2015

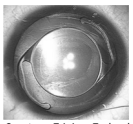


Image Courtesy: Trinium Technology, 2017

Formula Optimization

STANDARD DOGMA

AL.	Formula
<22mm	Hoffer Q
22mm - 26mm	Holladay 1
>26mm	SRK/T

Image Courtesy: ASCRS/ASOA Symposium 2015

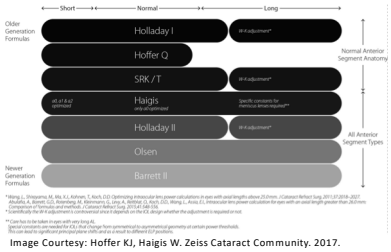
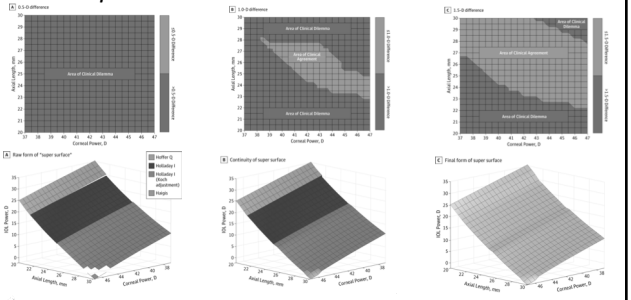


Image Courtesy: Hoffer KJ, Haigis W. Zeiss Cataract Community. 2017.

The Ladas Super Formula



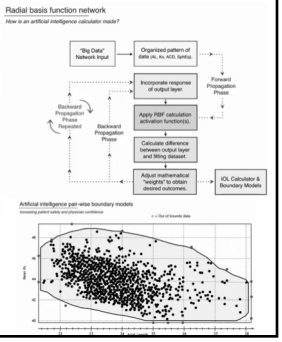
Ladas JG, et al. *JAMA Ophth* (2015)

The Hill-RBF Formula

Version 1.0 was based on 3400 surgeons inputting their data into the database

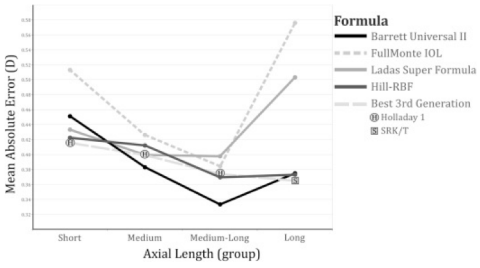
Number of Factors Selected	4	5	6	7	8	9
	PostOpSE	PostOpSE	PostOpSE	PostOpSE	PostOpSE	PostOpSE
	AL	AL	AL	AL	AL	AL
	Kmean	Kmean	Kmean	Kmean	Kmean	Kmean
		ACD	ACD	ACD	ACD	ACD
			PreOp SE	PreOp SE	PreOp SE	PreOp SE
				Age	Age	Age
					CCT	CCT
						WTW
Fitting Dataset ±0.50 D	92.1	97.8%	93.1	94.6	95.13	94.8
Validation Dataset ±0.50 D	82.6	90.2%	89.3	92.2	91.9	92.7
Number of Out-of Bounds Points	9	15	35	57	73	92
Ranking	6	1	5	2	3	4

The process is repeated and the factors that produce the best performing model are identified over time.



Hill WE, Haag-Streit AG EyeWorld Corporate Education Talk at ASCRS 2017.

Inter-Formula Validation

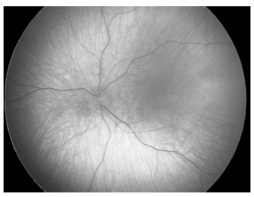


Kane JX, et al. *J. Cataract Refract Surg* (2017)

Retinopathy of Prematurity

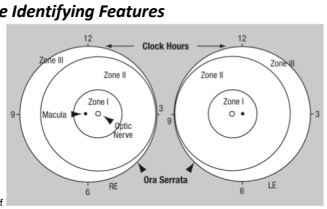
Normal Retinal Development:
Nasal Development by 36 weeks Gestational Age
Temporal Development by 40 Weeks Gestational Age

- Premature infants can have maldevelopment of retina known as Retinopathy of Prematurity
- Screening usually performed in infants with…
  - Birth weight < 1500 g
  - gestational age ≤ 32 weeks
- Timing of initial eye exam based on gestational age at birth



Retinopathy of Prematurity – Disease Identifying Features

- International Classification of Retinopathy of Prematurity (ICROP)
  - Zone
  - Stage
  - Extent
  - Presence of plus disease (vascular dilation and tortuosity)



International Committee for the Classification of Retinopathy of Prematurity. *Arch Ophthalmol* (2005).

WHEN TO TREAT:

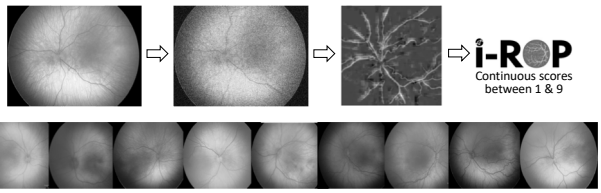
ETROP Classification of ROP

Type 1
Zone I, any stage ROP with plus disease
Zone I, stage 3 ROP without plus disease
Zone II, stage 2 or 3 ROP with plus disease

Early Treatment for Retinopathy of Prematurity Cooperative Group. *Arch Ophthalmol* (2003).

Retinopathy of Prematurity – Deep Learning

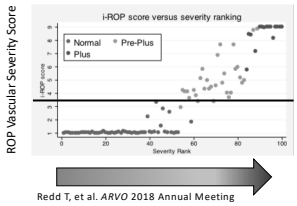
- Automated categorization of data representations



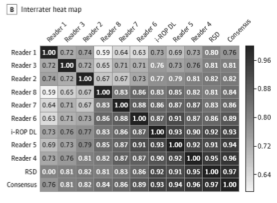
1 → 9

Continuous values between 1 & 9 designed to a categorize a spectrum of disease

Retinopathy of Prematurity – Validation

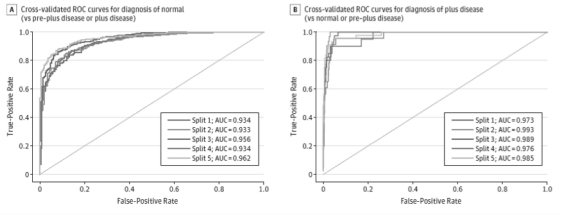


Redd T, et al. *ARVO* 2018 Annual Meeting



Brown JM, et al. *JAMA Ophthal* (2018)

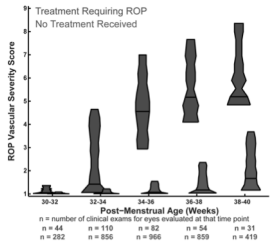
Retinopathy of Prematurity – Validation



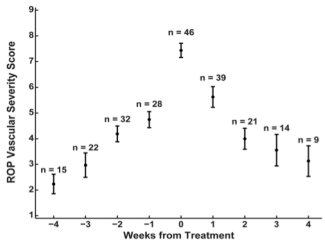
Data were analyzed from 5-fold cross-validation of 5511 retinal images. Mean areas under the ROC curves (AUCs) for the 5 sets were 0.94 for identifying normal images (vs pre-plus disease or plus disease; A) and 0.98 for identifying plus disease images (vs normal or pre-plus disease; B).

Brown JM, et al. *JAMA Ophthal* (2018)

Retinopathy of Prematurity – Tracking Patient Changes with and without Treatment



Taylor S, et al. Under Review.



Gupta K, et al. Under Review.

Summary

- **Artificial intelligence assists in screening conditions with higher throughput than can be accommodated by eye providers.**
- **Diabetic Retinopathy, IOL Calculations, and Retinopathy of Prematurity all lend themselves to Machine Learning's efficiency and reproducibility with quantitative scoring.**
- **Machine learning will likely expand to other Ophthalmic and Non-Ophthalmic domains including Corneal Ectactic Disorders, Ocular tumors, etc.**
- **The purpose of AI is to augment the health care provider…**

Summary

…and not to replace the pr

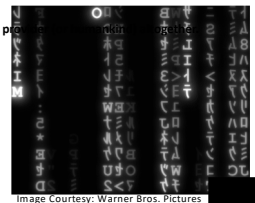


Image Courtesy: Warner Bros. Pictures

OpenAI built a text generator so good, it's considered too dangerous to release

Whittaker Z. TechCrunch. 2018.

Image Courtesy: 20th Century Fox

References

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11. Taylor S, Campbell JP, Gupta K, Brown JM, et al. A quantitative severity scale for retinopathy of prematurity using deep learning: monitoring disease progression. Under review at *JAMA Ophthalmol*.
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