Leading the Future of Health Care Industry with Advanced Analytics, Artificial Intelligence, and Machine Learning

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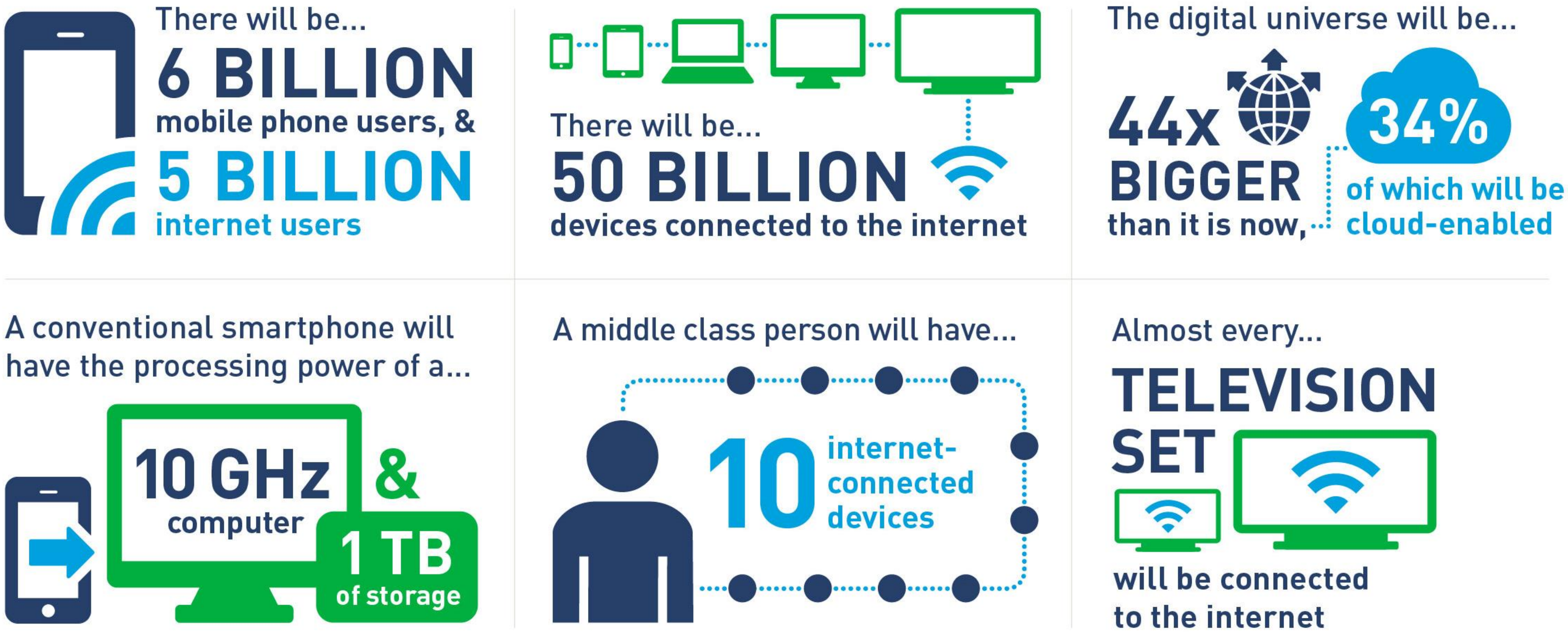
In next 5 years …

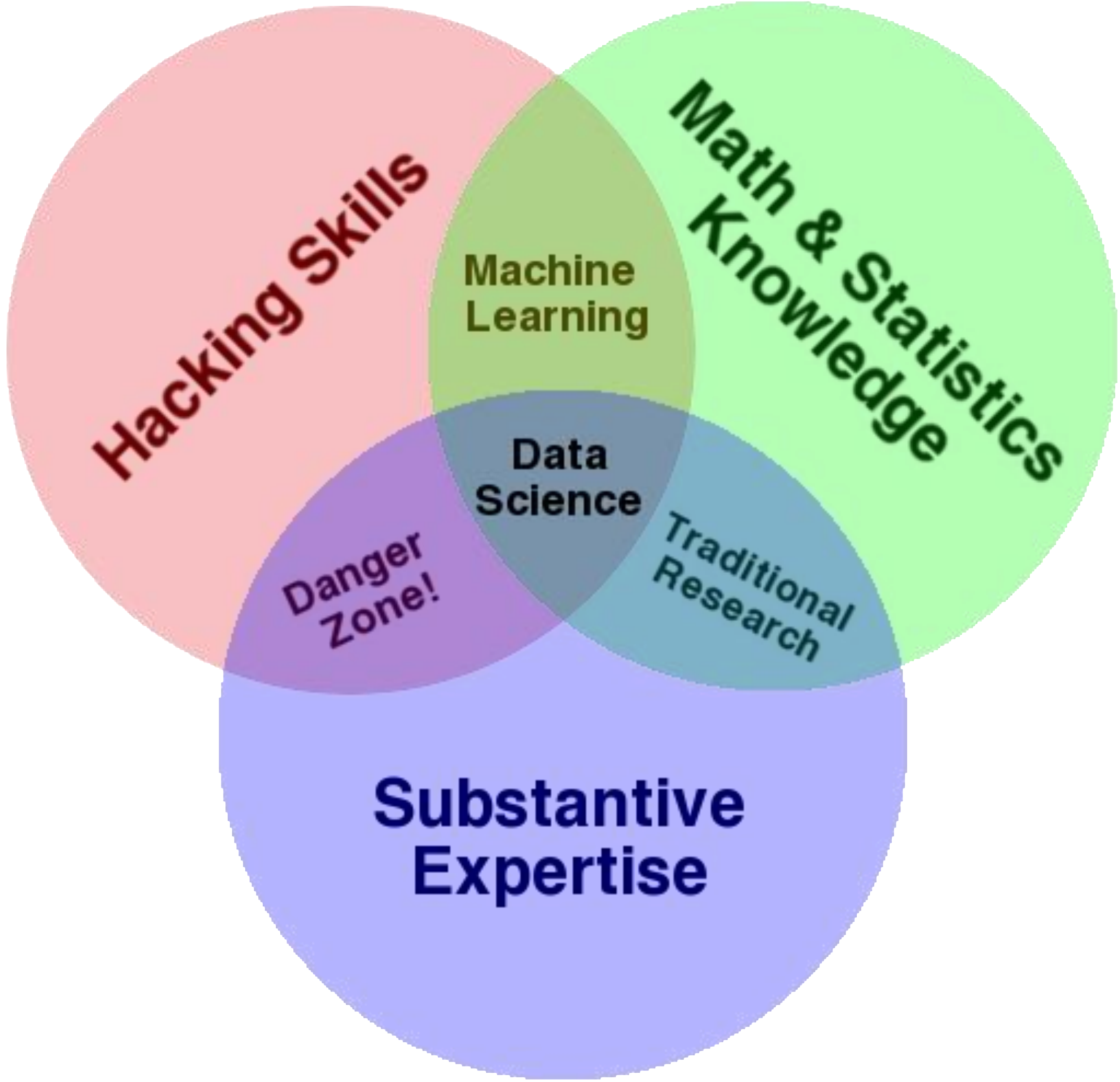


Trends, Challenges and Opportunities

- Technology revolution
- Alternative data sources and volume of the data
- Need for automation
- Beyond pills – digital health and connected care
- Slow adoptions with bottom up innovation vs fast pace environment
- Data access and data quality
- Talent recruiting and development

Potential Data Analytics Pitfalls

- Causality vs association
- Bias and confounding
- Missing data and missing mechanism
- Overfitting
- Multiplicity
- Convergence
- Efficiency – Design and Analytics
- Variance and bias trade off
- …



Different Data Types

Output (outcomes)

Continuous

Binary

Time to event/recurrent events

Longitudinal data

…

Input (covariates)

Continuous

Categorical

Networks

Trees

Unstructured

A Journey at Eli Lilly and Company

Global Statistics

Advanced Analytics

Enterprise AADS – Advanced Analytics and Data Sciences

Digital Health

Contextual Information (Input)

Action (Deep Learning/AI/Statistical Analytics)

Outcome

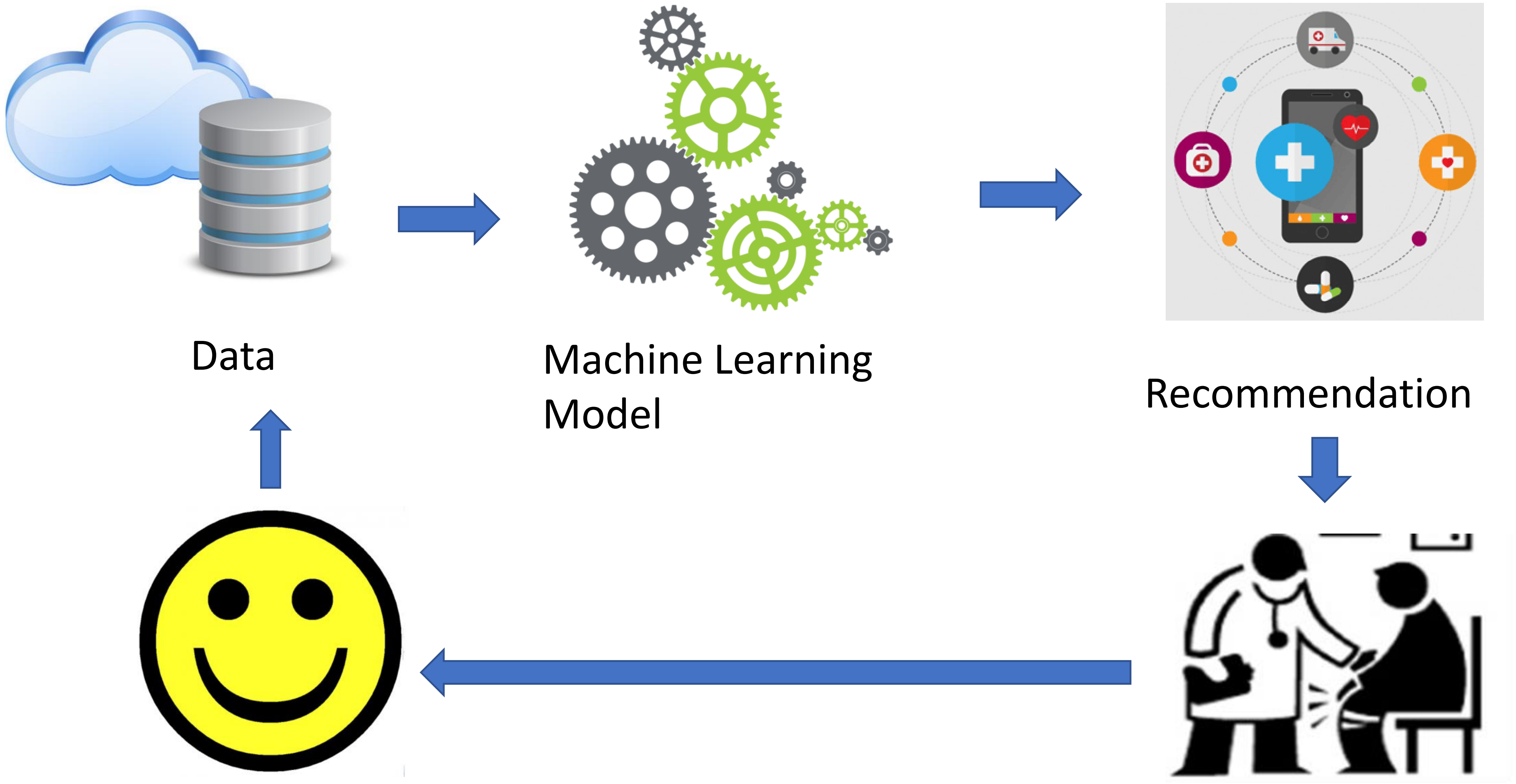
Digital Health Analytics

- Digital Technology: Enables collection of detailed individual information

- Deep learning: Enables generation of *actionable insights*

- Analytics: Work hand-in-hand with technology to identify “replicable” actions to optimize patient outcomes.

Example in Diabetes: What treatment assignment regimen would lead to the best outcome on average?



Individualized Treatment Recommendation (ITR[1,2])

ITR[1,2] is a value function machine-learning algorithm that utilizes **RCT and RWD** to determine optimal treatment selection at the patient level to optimize an outcome

	Outcome	Action	Covariates			
ID	Δ HbA1c	Treatment	Age	Baseline HbA1c	Sex	…
1	−1.5	1	34	8.3	F	…
2	−1.2	2	25	9.2	F	…
3	−2.3	3	29	9.1	M	…
4	−0.9	2	55	7.8	F	…
5	−1.4	3	47	8.7	M	…
⋮	⋮	⋮	⋮	⋮	⋮	⋮

RCT, randomized controlled trials; RWD, real-world data

1. Fu, Haoda, Jin Zhou, and Douglas E. Faries. "Estimating optimal treatment regimes via subgroup identification in randomized control trials and observational studies." Statistics in medicine 35.19 (2016): 3285-3302.

2. Wang, Yuanjia, Haoda Fu, and Donglin Zeng. "Learning Optimal Personalized Treatment Rules in Consideration of Benefit and Risk: with an Application to Treating Type 2 Diabetes Patients with Insulin Therapies." Journal of the American Statistical Association 113.521 (2018): 1-13.

Single Optimization Framework

Value Function

Define,

$$E^{\mathcal{D}}(Y) = \int Y d\mathcal{P}^{\mathcal{D}} = \int Y \frac{d\mathcal{P}^{\mathcal{D}}}{d\mathcal{P}} d\mathcal{P} = E\left[\frac{I\{}{}\right.$$

where we use the fact that,

$$\frac{d\mathcal{P}^{\mathcal{D}}}{d\mathcal{P}} = \frac{p(y|x,a)I\{a = \mathcal{D}(x)\}p(x}{p(y|x,a)p(a|x)p(x)}$$

Our objective is to find $\mathcal{D}(\cdot)$ to maximize the

Value function

$$\mathcal{D}_o \in \operatorname*{argmax}_{\mathcal{D}\in R} E^{\mathcal{D}}(Y) = E\left[\right.$$

where R is a space of possible treatment recommen

ITR.ABC

Original objective function,

$$D_o = \operatorname*{argmin}_{D\in R} n^{-1}\sum_{i=1}^{n} \frac{Y_i}{p(A_i|X_i)} I\{A_i \neq \mathcal{D}(X_i)\}.$$

ITR.ABC objective function,

$$\operatorname*{minimize}_{f\in\mathcal{F}} \frac{1}{n}\sum_{i=1}^{n} \frac{Y_i}{\Pr(A_i|X_i)} \ell\{\langle f(x_i), W_{a_i}\rangle\} + \lambda J(f).$$

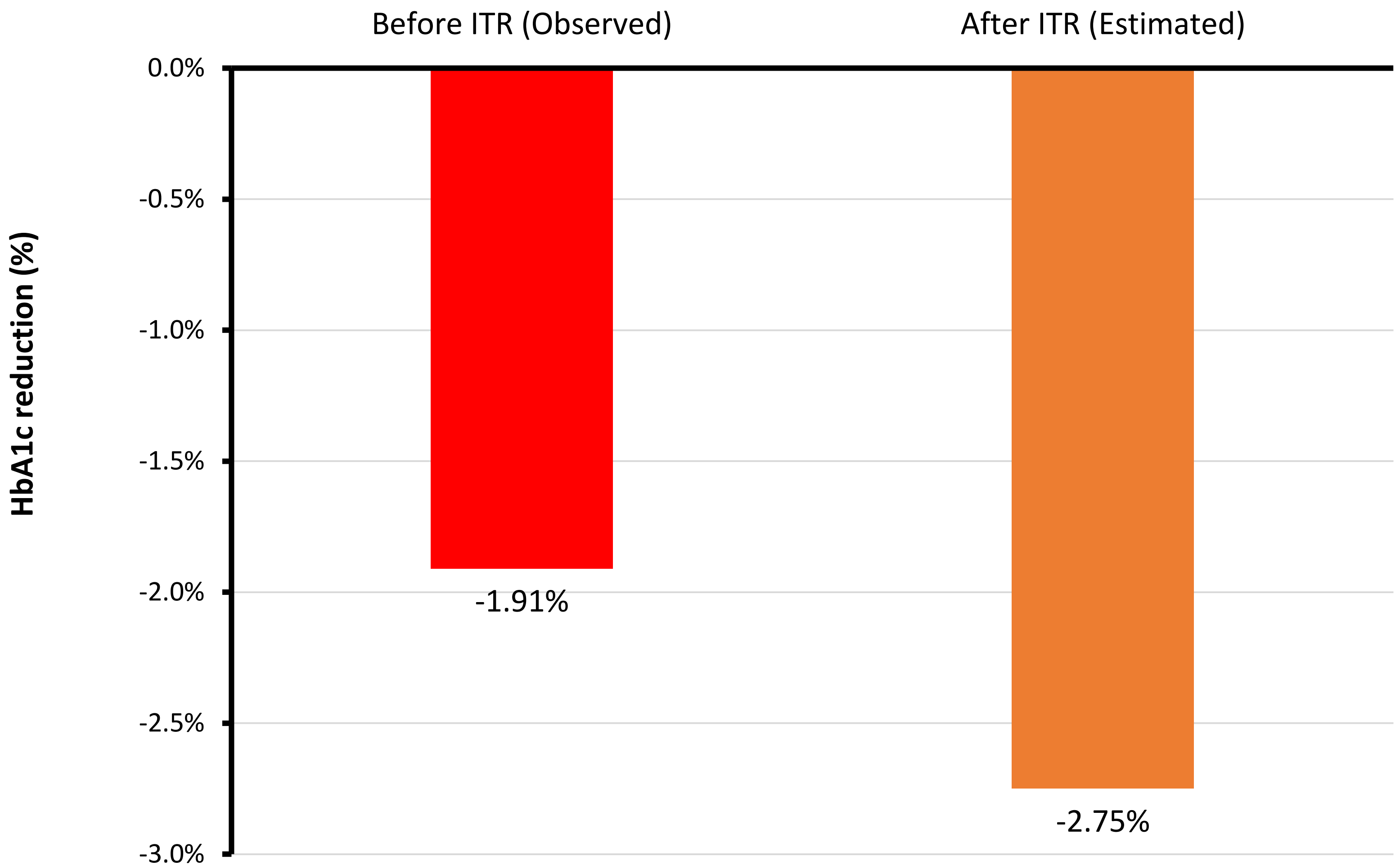
Theorem (Fisher consistency for ITR.ABC)

A classifier $f^*(\cdot)$ is called Fisher's consistence if it satisfies that, $\forall x$,

$$\operatorname*{argmax}_{\forall j}\langle f^*(x), W_j\rangle = \operatorname*{argmax}_{\forall j} E(Y|A = j, x)$$

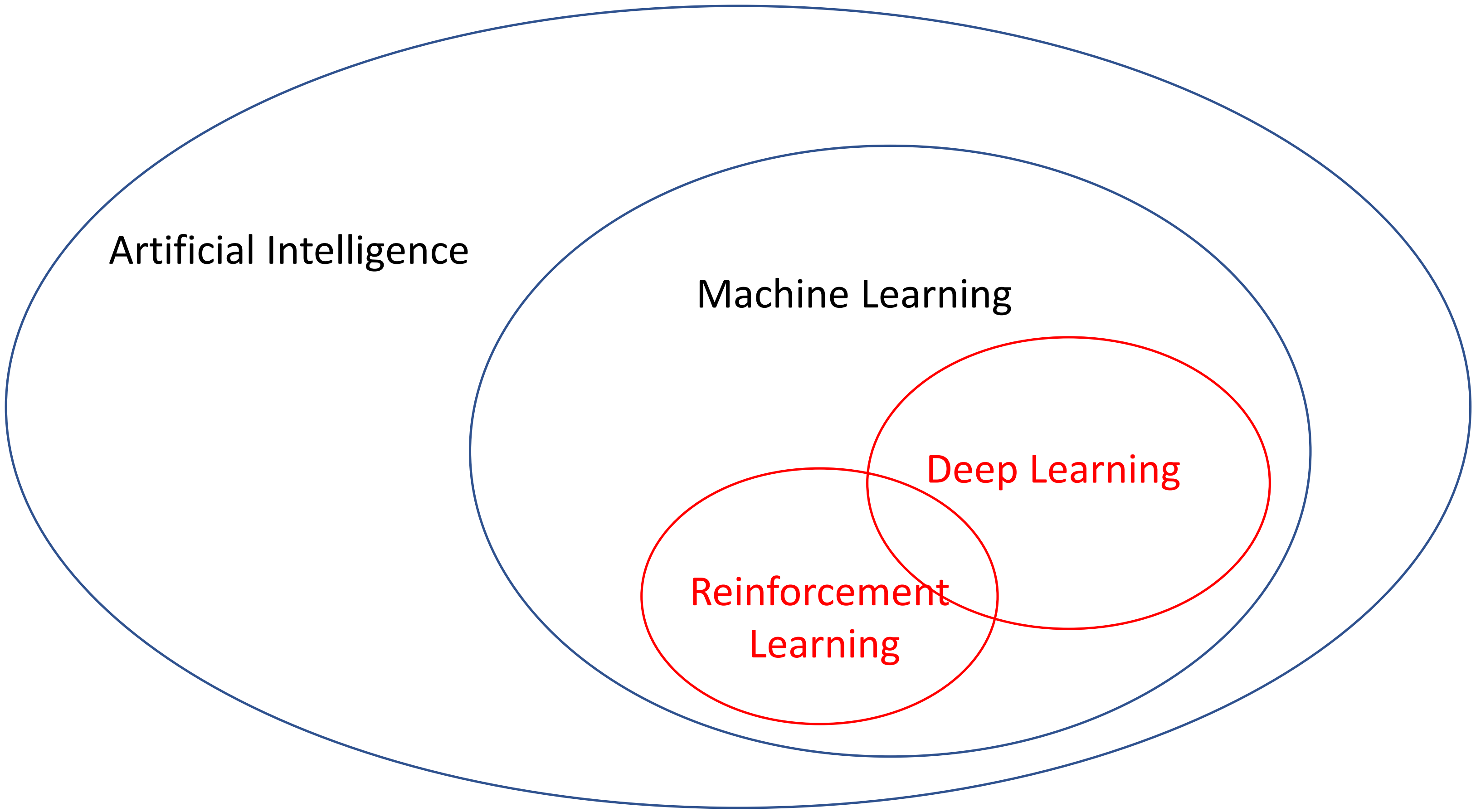
ITR.ABC is Fisher consistency if ℓ is a convex, the derivative ℓ' exists and $\ell'(x) < 0, \forall x$.

HbA1c reduction before and after ITR

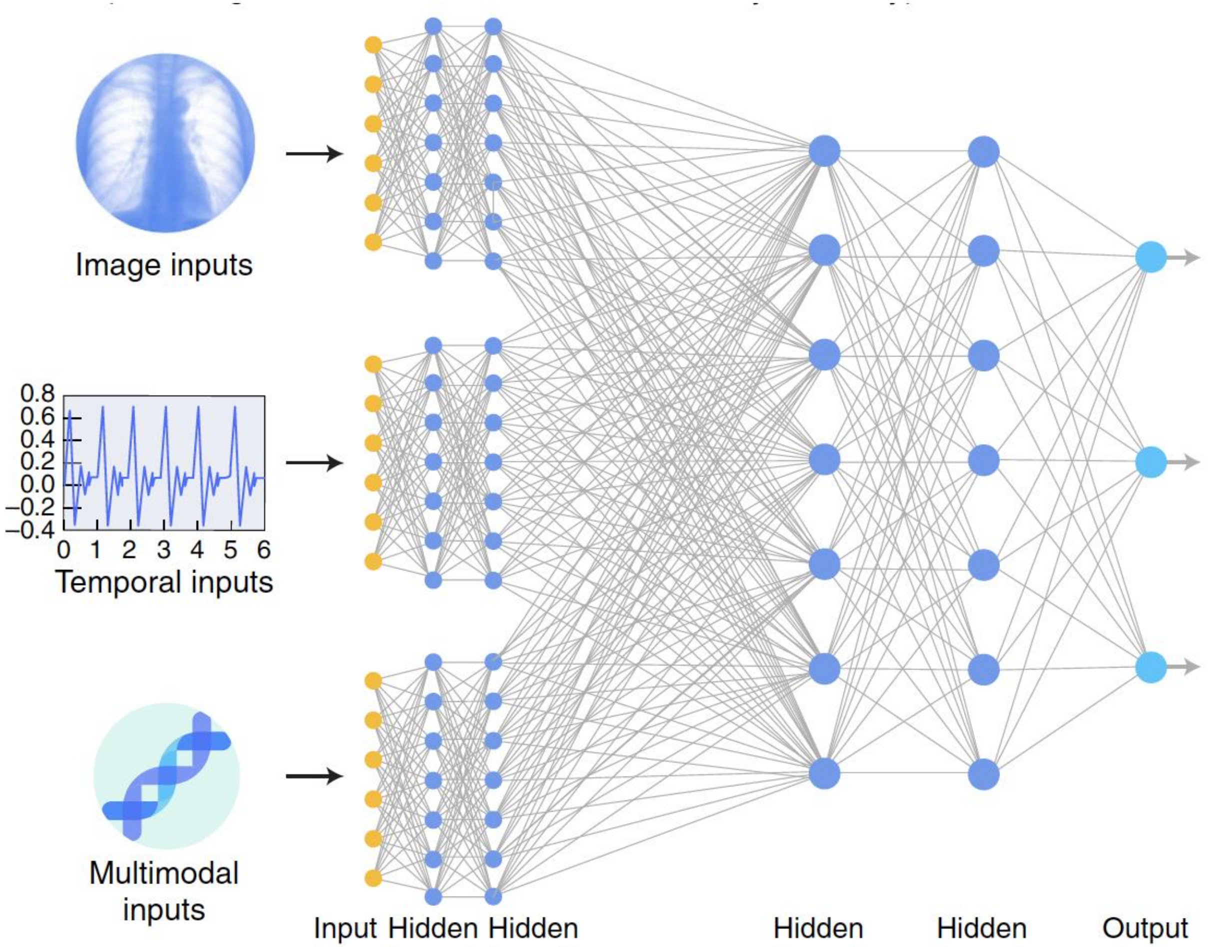


Published in 2016 ADA Conference (American Diabetes Association)

AI – Machine Learning – DL & RL



What's new: using multiple data sources



Medical Image Diagnostic - Diabetes

Research

JAMA | Original Investigation | INNOVATIONS IN HEALTH CARE DELIVERY

Development and Validation of a Deep Learning Algorithm for Detection of Diabetic Retinopathy in Retinal Fundus Photographs

Varun Gulshan, PhD; Lily Peng, MD, PhD; Marc Coram, PhD; Martin C. Stumpe, PhD; Derek Wu, BS; Arunachalam Narayanaswamy, PhD; Subhashini Venugopalan, MS; Kasumi Widner, MS; Tom Madams, MEng; Jorge Cuadros, OD, PhD; Ramasamy Kim, OD, DNB; Rajiv Raman, MS, DNB; Philip C. Nelson, BS; Jessica L. Mega, MD, MPH; Dale R. Webster, PhD

IMPORTANCE Deep learning is a family of computational methods that allow an algorithm to program itself by learning from a large set of examples that demonstrate the desired behavior, removing the need to specify rules explicitly. Application of these methods to medical imaging requires further assessment and validation.

Editorial pages 2366 and 2368

Supplemental content

Medical Image Diagnostic - Oncology

MENU

nature

International journal of science

Letter | Published: 25 January 2017

Dermatologist-level classification of skin cancer with deep neural networks

Andre Esteva, Brett Kuprel, Roberto A. Novoa, Justin Ko, Susan M. Swetter, Helen M. Blau & Sebastian Thrun

Nature **542**, 115–118 (02 February 2017) | Download Citation

A Corrigendum to this article was published on 28 June 2017

Predict CV risk

nature biomedical engineering

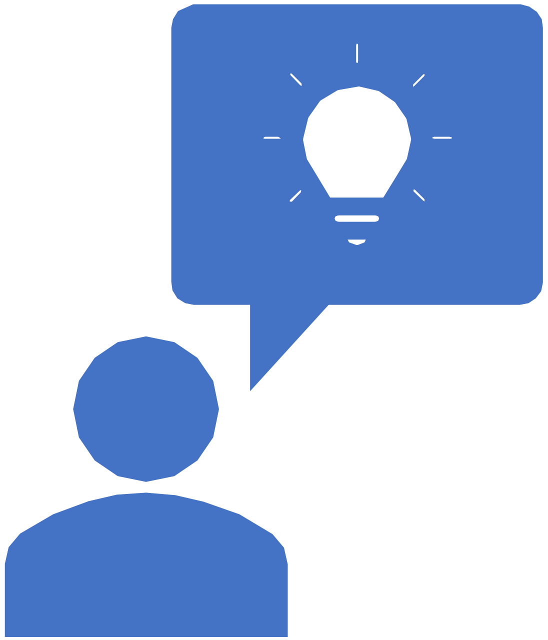
ARTICLES

https://doi.org/10.1038/s41551-018-0195-0

Prediction of cardiovascular risk factors from retinal fundus photographs via deep learning

Ryan Poplin[1,4], Avinash V. Varadarajan[1,4], Katy Blumer[1], Yun Liu[1], Michael V. McConnell[2,3], Greg S. Corrado[1], Lily Peng[1,4*] and Dale R. Webster[1,4]

Summary



- New technology is here and exploding
- Data explosion in health care is a dream come true for Statisticians (of course dream also means there will be nightmares!!!)
- Statisticians have a phenomenal opportunity to collaborate and lead the science forward