AI in Medical Imaging

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How many of you use AI clinically?
What is AI?

“All the impressive achievements of deep learning amount to just curve fitting”

– Judea Pearl
What is AI?

Figure: Linear regression = line fitting

\[ f(x) = w^T x \]
What is AI?

Whatever your problem, the key is to phrase it as ‘curve” fitting.

Optimize loss:

\[ L(y, f(x)) \]

\[ f_1(x) \quad f_2(x) \]

\[ x = (x_1, x_2, x_3) \]

**Figure:** Neural network training \(=\) function fitting
AI in medical imaging: Diagnosis/Risk scoring/anomaly detection/decision support

Deep Multi-modal Latent Representation Learning for Automated Dementia Diagnosis

Tao Zhou, Mingxu Liu, Huaizhao Fu, Ling Shao, and Dingguo Zhang

1 Institute of Artificial Intelligence
2 School of Biomedical Sciences, University of Exeter
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4 Department of Biostatistics, School of Medicine, University of Nebraska Medical Center

Early Prediction of Alzheimer’s Disease Progression Using Variational Autoencoders

Authors: Simama Basu, Konrad Wapnir, Ajar Zandifar, Louis Collins, Adriana Romero, Delina Precup

Conference paper

Unsupervised Anomaly Localization Using Variational Auto-Encoders

Authors: David Zimmerer, Fabio Pardi

Conference paper

First Online: 10 October
AI in medical imaging: Image processing – Registration

Moving 3D Image (m)

Fixed 3D Image (f)

Registration Field (φ)

Spatial Transform

Moved (m ◦ φ)

Source

TopAwaRe_D

TopAwaRe_PD

Target

$I$

$W^{-1}_\psi$

$\Omega_I$

$I_\psi = I \circ W_{\psi}^{-1}$

$I_{\alpha,\psi} = I_\psi \circ W_{\alpha}$

$I_{\alpha,\psi} = I_{\alpha,\psi} \circ W_\psi$

$M = I_{\alpha} \circ W_\phi$

$S$

$\Omega_I$

$\Omega_{I_{\alpha,\psi}}$

$\Omega_{I_{\alpha}}$

$\Omega_S$

$\Omega_S$
Al in medical imaging: Image processing – Segmentation

Figure: Left: Ronneberger et al, 2015. Right: Arnavaz et al, 2020
AI in medical imaging: Image processing – Tractography, microstructural properties

Learn to Track: Deep Learning for Tractography

Philippe Poulin\textsuperscript{1}, Marc-Alexandre Côté\textsuperscript{2}, Jean-Christophe Houde\textsuperscript{2}, Laurent Petit\textsuperscript{4}, Peter F. Neher\textsuperscript{3}, Klaus H. Maier-Hein\textsuperscript{1}, Hugo Larochelle\textsuperscript{3}, and Maxime Descoteaux\textsuperscript{2}

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(a) predicted
(b) ground truth
(c) overlap
(d) overreach
AI in medical imaging: Image synthesis – CT from MR

Deep learning-based MR-to-CT synthesis: The influence of varying gradient echo-based MR images as input channels for CT scans.

Joen Willemsen, Matteo Maspero, Cornells A.T. van den Berg, Harrie Weinans, Max A. Viergever. See all authors.

DOI: doi.org/10.1002/mrm.28008 | Citations: 2
AI in medical imaging: Image processing: Denoising; high quality from low quality; movement removal

Training shortest-path tractography: Automatic learning of spatial priors

Niklas Kasenburg a, b, c, Matthew Liptrot a, b, Nina Linde Reislev c, Silas N. Ørting a, Mads Nielsen a, Ellen Garde c, Aasa Feragen d
The sky is the limit!
The sky is the limit!
Alas – There are still issues..
Uncertainty quantification. Predictions are good, certain predictions are better, knowing how certain is best
Interpretability and transparency

- Neural networks are largely black box

Diagnosing with good accuracy is great, but knowing what caused the diagnosis is even better...

Model communication, visualization, interaction – important, nontrivial open problems
Interpretability and transparency

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Interpretability and transparency

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- Understanding mistakes are yet even better...

![Diagram of a neural network](image)
Interpretability and transparency

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- Understanding mistakes are yet even better...
- Model communication, visualization, interaction – important, nontrivial open problems
Bias and Fairness

The female problem: how male bias in medical trials ruined women’s health

Centuries of female exclusion has meant women’s diseases are often missed, misdiagnosed or remain a total mystery.

Racial bias in a medical algorithm favors white patients over sicker black patients

Scientists discovered racial biases in a widely used medical algorithm that predicts which patients will have complex health needs. (iStock)
Bias and Fairness

Sources of bias in ML algorithms:

- Discrimination embedded in training data
- Imbalanced training data
Bias and Fairness

A computer assisted diagnosis example

- State-of-the-art CNN diagnosing thoracic diseases from X-ray\(^1\)
- Increased % females $\Rightarrow$ improved female test diagnosis
- Increased % females $\Rightarrow$ decreased male test diagnosis
- *Predictor trained only on females performs better on men*

![Figure: Diagnostic accuracy of Pneumothorax for female (left) and male (right) test subjects as a function of % females in training set](image)

\(^1\)Larrazabal et al, PNAS 2020
Bias and Fairness

Sources of bias in ML algorithms;

- Discrimination embedded in training data
- Imbalanced training data
- Different levels of label noise (diagnosis errors) give different training conditions for different groups
- Different feature distributions in different groups (different disease patterns and/or anatomical features) give different training conditions for different groups
Outlook

- Is AI just glorified curve fitting? Yes! But if you have a great curve fitter, everything looks like a curve!
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At this point, AI is all over – in the scanner, in the processing, in the analysis – working quite well!

But there are still pitfalls (and they are very interesting!)
  - Uncertainty modelling/quantification
  - Interpretability/transparency
  - Bias, fairness, ethics – detecting and fixing