Cancer is a Big Deal

Figure 1. Number of deaths due to heart disease and cancer: United States, 1950–2014

Centers for Disease Control and Prevention
Changes in the Leading Cause of Death: Recent Patterns in Heart Disease and Cancer Mortality
Intra-tumor Heterogeneity

Rebecca A Burrell, Nicholas McGranahan, Jiri Bartek, and Charles Swanton

The Causes and Consequences of Genetic Heterogeneity in Cancer Evolution
Nature - 2013
Early Logic and Statistical Pattern Recognition in Medicine

**Reasoning Foundations of Medical Diagnosis**

Symbolic logic, probability, and value theory aid our understanding of how physicians reason.

Robert S. Ledley and Lee B. Lustig

3 July 1959, Volume 130, Number 3566

**The Coding of Roentgen Images for Computer Analysis as Applied to Lung Cancer**

Guylsm S. Lodwick, Theodore E. Keats, and John P. Dorst

AUGUST 1963

This paper will describe a concept of converting the visual images on roentgenograms into numerical sequences that can be manipulated and evaluated by the digital computer. The purpose is to determine the capacity of developing an approach for analyzing as demonstrated and computer methods that can be used to determine the significance of certain radiographic findings in lung cancer.

"a concept of converting the visual images on roentgenograms into numerical sequences...to determine the significance of certain radiographic findings in lung cancer"

Robert S. Ledley and Lee B. Lustig

Reasoning Foundations of Medical Diagnosis

Science - 1959

Guylsm S. Lodwick, Theodore E. Keats, and John P. Dorst

The Coding of Roentgen Images for Computer Analysis as Applied to Lung Cancer

Radiology - 1963
Artificial vs. Human Intelligence

<table>
<thead>
<tr>
<th>Early efforts</th>
<th>Current state</th>
<th>Future outlook</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al with subhuman performance is occasionally used in commercial expert systems with varying degrees of utility</td>
<td>Narrow task-specific AI has started to match and, in some instances, exceed human performance in tasks including conversational speech recognition, driving vehicles, playing Go and classifying skin cancer</td>
<td>General AI exceeds human performance and reasoning in complex tasks, including writing best-selling novels and performing surgery. Human intelligence improves as we learn from AI</td>
</tr>
</tbody>
</table>

Ahmed Hosny, Chintan Parmar, John Quackenbush, Lawrence H Schwartz and Hugo JWL Aerts

Artificial Intelligence in Radiology
Nature Reviews Cancer - 2018
Artificial Intelligence Impact Areas within Oncology Imaging

**a Clinical radiology workflow**
- **Acquisition**
- **Preprocessing**
- **Images**
- **Image-based tasks**
- **Reporting**
- **Integrated diagnostics**

**b Image-based tasks**

**Detection**
Detected potential abnormalities within images on the basis of changes in intensities or the appearance of unusual patterns, with an emphasis on reducing false positives

**Characterization**
- **Segmentation**
  Defining the boundary extent of an abnormality for subsequent diagnosis and treatment planning
- **Diagnosis**
  Evaluating and classifying abnormalities such as benign vs malignant
- **Staging**
  Classifying abnormalities into multiple predefined categories such as the TNM classification of malignant tumours

**Monitoring**
- **Risk**
- **Change analysis**
  Tracking object characteristics across multiple temporal scans for diagnosis as well as evaluating treatment response

*Ahmed Hossy, Chintan Parmar, John Quackenbush, Lawrence H Schwartz and Hugo JWL Aerts*

**Artificial Intelligence in Radiology**
**Nature Reviews Cancer - 2018**
Because statistics are based on large groups of people, they cannot be used to predict exactly what will happen to you. **Everyone is different.** Treatments and how people respond to treatment can differ greatly. Also, it takes years to see the benefit of new treatments and ways of finding cancer. So, the statistics your doctor uses to make a prognosis may not be based on treatments being used today.

Still, your doctor may tell you that you have a good prognosis if statistics suggest that your cancer is likely to respond well to treatment. Or, he may tell you that you have a poor prognosis if the cancer is harder to control. **Whatever your doctor tells you, keep in mind that a prognosis is an educated guess.** Your doctor cannot be certain how it will go for you.
Decoding Tumour Phenotype by Noninvasive Imaging using a Quantitative Radiomics Approach

Nature Communications - 2014
Deep Learning for Automated Quantification of Radiographic Tumor Phenotypes

Under Review
Analytical Setup

**DISCOVERY**
- **TRAINING**
- **VALIDATION**

**RADIOThERAPY**
- HarvardRT $n=293$
- Radboud $n=104$

**SURGERY**
- Moffitt $n=183$
- MUMC $n=88$

**TEST**
- Maastro $n=211$
- M-Spore $n=97$

- end-to-end training
- transfer learning
- fine tuning

Performance was benchmarked against models based on the following features:
- engineered
- clinical
- diameter
- volume

Stability was assessed in the following scenarios:
- test/retest
- variance

Important regions were highlighted using activation mapping:
- activations

Biological basis was defined using genomic associations:
- genomics

Deep Learning for Automated Quantification of Radiographic Tumor Phenotypes
Under Review

Ahmed Hosny, Thibaud Coroller, Patrick Grossmann, Chintan Parmar, Roman Zeleznik, Avnish Kumar, Johan Bussink, Robert J Gillies, Raymond Mak and Hugo JWL Aerts
Benchmarking

> significantly worse than deep learning
* significantly better than random permutation

0.70
p = 1.13e-07

0.66
p = 1.91e-04

0.64
p = 6.18e-04

0.63
p = 2.15e-03

0.71
p = 3.02e-04

0.58

0.58

0.51

0.50

Deep Learning
Clinical
Engineered Features
Volume
Maximum Diameter

Radiotherapy
Surgery

Ahmed Hosny, Thibaud Coroller, Patrick Grossmann, Chintan Parmar, Roman Zeleznik, Avnish Kumar, Johan Busink, Robert J Gillies, Raymond Mak and Hugo JWL Aerts

Deep Learning for Automated Quantification of Radiographic Tumor Phenotypes
Under Review
Activation Mapping

INPUT IMAGE WITH ANNOTATIONS

ACTIVATION HEATMAPS

Ahmed Hosny, Thibaud Coroller, Patrick Grossmann, Chintan Parmar, Roman Zeleznik, Avnish Kumar, Johan Bussink, Robert J Gillies, Raymond Mak and Hugo JWL Aerts

Deep Learning for Automated Quantification of Radiographic Tumor Phenotypes

Under Review
State of the Art

Geert Litjens, Thijs Kooi, Babak Ehteshami Bejnordi, et al.

A Survey on Deep Learning in Medical Image Analysis

Medical Image Analysis - 2017
State of the Art

A Survey on Deep Learning in Medical Image Analysis

Medical Image Analysis - 2017

Open-Source Deep Learning Tools

github.com
Resources to facilitate an informed conversation about AI

Understand the larger context of our efforts

Effectively measure and communicate progress
AI Index Landscape

Artifact Intelligence

Future Health Index

aiindex.org
AI Index Landscape

Artificial Intelligence Index
aiindex.org

Future Health Index
futurehealthindex.com
Audience

- Funding agencies
- The public
- Regulatory agencies
- Researchers
- Journalists

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Medical Artificial Intelligence Index
medicalindex.ai
Findings - Statistics

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Findings - Reproducibility

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Ahmed Hosny, Michael Schwier, Andriy Y Fedorov and Hugo JWL Aerts

Modelhub: Plug & Predict Solutions for Reproducible AI Research
modelhub.ai
Existing Solutions

Yangqing Jia, Evan Shelhamer, Jeff Donahue, et al.
Caffe: Convolutional Architecture for Fast Feature Embedding
arxiv.org/abs/1408.5093
Existing Solutions

Yangqing Jia, Evan Shelhamer, Jeff Donahue, et al.

Caffe: Convolutional Architecture for Fast Feature Embedding
arxiv.org/abs/1408.5093

GitXiv—Collaborative Open Computer Science
gitxiv.com
Components

- scientific
- intuitive
- open-source
- portable
- tool agnostic

Ahmed Hossy, Michael Schwier, Andrii Y Fedorov and Hugo JWL Aerts

Modelhub: Plug & Predict Solutions for Reproducible AI Research
modelhub.ai
How it Works

- **published models**
  - **framework**
    - **backend**
      - modelhub lib and flask python app
    - **contrib_src**
      - contributor pre-/post-processing, sample data and models
    - **frontend**
      - static html, model viewer, jupyter
  - **runtime environment**

- **test drive**
  - for everyone
  - run locally or remotely and quickly explore the model in your browser

- **jupyter notebook**
  - for researchers
  - run modelhub dockers locally and test on your own data

- **API**
  - for developers
  - deploy modelhub dockers and make API calls for model information & predictions

*Ahmed Hossy, Michael Schwier, Andriy Y Fedorov and Hugo JWL Aerts*

**Modelhub: Plug & Predict Solutions for Reproducible AI Research**

modelhub.ai
deep learning models for pathology.
Community Outreach

track progress on benchmarking datasets

track methods for generating and countering adversarial attacks against medical AI systems

understand public attitude towards medical AI applications
Community Outreach

track progress on benchmarking datasets

track methods for generating and countering adversarial attacks against medical AI systems

understand public attitude towards medical AI applications

co-authorship through model contributions

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Medical Artificial Intelligence Index
medicalindex.ai

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modelhub.ai
Thank you!