AI is Disrupting Healthcare.

Getting from algorithm to outcome.

Assoc. Prof. Brent Richards
Gold Coast Hospital and Health Service
Medical Director Critical Care Research
Medical Director of Innovation
Co-founder of IntelliHQ
Trust me -
I’m a doctor.
Robot Passes a Medical Licensing Exam for the First Time Ever

7 Dec 2017 5:00pm, by Kimberley Mok
AI Digital Disruption

4th industrial revolution*

- Machine learning / AI
- Big data analytics
- Internet of things

Desire for improved health outcomes
Increasing health delivery costs
Limited public funds

Healthcare Delivery Transformation

- Role of health care providers
- Augmenting decision-making processes
- Transforming hospital delivery

+ https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/
What is AI?

• Use of computer-based algorithms to perform tasks that would require intelligence if performed by a human
  • Includes predictive analytics, voice recognition, language processing, image recognition, robotics

• And different learning techniques:
  • supervised learning
  • unsupervised learning
  • reinforcement learning
Artificial Intelligence (AI) in everyday use

- In the past, humans would recognise patterns in data, hand design and write the steps (rules) in to a computer programme.
- Now the AI looks for patterns, and from those helps create the rules.
- Yes, you have used AI this week:
  - Google home, Amazon Alexa, Siri
  - Google search, maps, traffic
  - Credit card fraud detection, Superannuation stock market trading
  - Recommendations on Netflix, shopping sites, Facebook advertisements
Building blocks for AI

- DATA
- HARDWARE
- SOFTWARE
- TALENT
Global Outlook

The Future Of A.I.
Forecasted cumulative global artificial intelligence revenue 2016-2025, by use case (U.S. dollars)

- Static image recognition, classification, and tagging: $8,097.9m
- Algorithmic trading strategy and portfolio management: $7,540.6m
- Efficient, scalable processing of patient data: $7,306.4m
- Predictive maintenance: $4,680.3m
- Object identification, detection, classification, tracking: $4,381.6m
- Text query of images: $3,178.5m
- Automated geophysical feature detection: $3,059.5m
- Content distribution on social media: $3,360.6m
- Object detection and classification: avoidance, navigation: $3,169.8m
- Prevention against cybersecurity threats: $2,472.9m

40% CAGR 2017 - 2024

Reasons for adopting AI
Why is your organization interested in AI?

- AI will allow us to develop and sustain a competitive advantage: 84%
- AI will allow us to move into new businesses: 79%
- New organizations using AI will enter our market: 75%
- Incumbent competitors will use AI: 74%
- Process to reduce costs and require us to use AI: 68%
- Suppliers will offer AI-driven products and services to us: 61%
- Customers will ask for AI-driven offerings: 59%

Percentage of respondents who somewhat or strongly agree with each statement

China and North America will see biggest AI gains by 2030

- 26.1% China
- 14.5% North America
- 11.5% Southern Europe
- 10.4% Developed Asia
- 9.9% Northern Europe
- 5.6% Africa, Oceania, & other Asian markets
- 5.4% Latin America

$15.7 trillion potential GDP gain

Where industries will put practical AI to work

- Healthcare: Supporting diagnosis by detecting variations in patient data
- Automotive: Autonomous vehicles for ride-sharing
- Financial services: Fraud detection and anti-money laundering
- Transportation and logistics: Autonomous trucking and delivery
- Technology, media, and telecommunications: Enhanced security
- Retail and consumer: Personalized marketing and advertising
- Manufacturing: Enhanced monitoring and auto-correction of processes
- Energy: Supply chain and production optimization

Theresa May says AI revolution will help NHS prevent thousands of cancer-related deaths by 2033

Medical records, along with information about patients’ habits and genetics, will be cross-referenced with national data to spot those at an early stage of cancer

Gartner expects the AI business market to grow 70% this year

The EU wants to invest 20 billion euros in research by 2020
Driverless Car Journey

Data

- Interventions

- Sensors
  - Blind Spot Detection
  - Rear Collision Warning
  - Park Assistance/Surround View
  - Surround View
  - Park Assist
  - Lane Departure Warning
  - Traffic Sign Recognition
  - Cross Traffic Alert

Actions

- Goals

Outcomes

- Long-Range Radar
- Short/Medium Range Radar
- LiDAR
- Camera
- Ultrasound
- GNSS
Precision Medicine Journey

Data

Actions

Goals

Interventions

Bio-signals

Outcomes
TREWScore

- Targeted Real-time Early Warning Score to predict septic shock
- MIMIC-II database, 13,014 patients (1836 septic)
- Supervised machine learning technique
- AUC 0.83, sensitivity 0.85 at specificity 0.67
- Mean detection 28 hrs before onset of septic shock
- 2/3rds identified before onset of sepsis-related organ dysfunction
Accurate deep learning for EHRs

- Google and Stanford, 216k admissions, 2 hospitals, 4-7 yrs
- Developed a generic data pipeline, with FIHR-coded per patient timeline
- Ensemble of 3 NN architectures – LSTM, TANN, Boosted Time-aware decision stumps
  - Tensorflow for LSTM, TANN, C++ for Boost. Scikit-learn for analysis
  - Google Vizier for automated hyper-parameter tuning, >201k GPU hrs.
- Group mortality 2.3%. Prediction @ 24hrs AUC 0.93
- Actual Re-admissions 12.9%. Prediction AUC 0.75
- Long LoS 23.9%. Prediction @24hrs AUC 0.85

Cardiologist-level arrhythmia detection with CNNs

- Andrew Ng’s Stanford group
- 34 layer CNN to diagnose arrhythmias on 64,000 30sec ECGs
- Model outperformed cardiologists

Note – human performance

https://stanfordmlgroup.github.io/projects/ecg/
Optical Coherence Tomography (OCT)

- OCT is a screening test for over 50 retinal (eye) diseases
- Training set of 997 images, tested on 14,884
- 94.5% accurate, no serious disease missed
- Also identified region on scan
- Equivalent to a retinal specialist

https://www.moorfields.nhs.uk/content/breakthrough-ai-technology-improve-care-patients
So if an AI system looks like this.....

Will AI be trusted?
By patients?
By Clinicians?
Patient acceptability?

Figure 3: Percentage of respondents willing/unwilling to engage with AI and robotics for their healthcare needs (by country)

<table>
<thead>
<tr>
<th>Country</th>
<th>Willing</th>
<th>Unwilling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nigeria</td>
<td>6%</td>
<td>94%</td>
</tr>
<tr>
<td>Turkey</td>
<td>11%</td>
<td>85%</td>
</tr>
<tr>
<td>South Africa</td>
<td>16%</td>
<td>82%</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>24%</td>
<td>66%</td>
</tr>
<tr>
<td>Qatar</td>
<td>24%</td>
<td>65%</td>
</tr>
<tr>
<td>UAE</td>
<td>26%</td>
<td>62%</td>
</tr>
<tr>
<td>Netherlands</td>
<td>39%</td>
<td>55%</td>
</tr>
<tr>
<td>Belgium</td>
<td>43%</td>
<td>51%</td>
</tr>
<tr>
<td>Norway</td>
<td>39%</td>
<td>50%</td>
</tr>
<tr>
<td>Sweden</td>
<td>48%</td>
<td>44%</td>
</tr>
<tr>
<td>Germany</td>
<td>41%</td>
<td>59%</td>
</tr>
<tr>
<td>UK</td>
<td>39%</td>
<td>51%</td>
</tr>
</tbody>
</table>

Source: PwC survey

Perceived advantages of using advanced computers or robots with AI for healthcare

- 34% Healthcare would be easier and quicker for more people to access
- 31% Faster and more accurate diagnoses
- 27% Will make better treatment recommendations
- 27% Like having your own healthcare specialist, available any time and on any device

Perceived disadvantages of using advanced computers or robots with AI for healthcare

- 47% If something unexpected is found, don’t trust robots to make decisions on what to do
- 38% People need the “human touch” when it comes to their healthcare
- 36% Only a human healthcare professional can make the right decisions (e.g. look beyond the data)
- 30% We don’t understand this kind of technology enough to know if it can benefit or be dangerous in healthcare
For Clinicians, trusted AI we will need to:

- Act ethically
- Minimise bias
  - In data and in algorithms
- Research clinical outcomes
- Be accountable and transparent
- Assure development processes
  - Initially and ongoing
- Be secure
- Make AI easy to use
- Be safe
Clinical Ethics

Hippocratic Oath for AI developers

- Reliability
- Safety
- Privacy
- Security
- Transparency
- Accountability

Brad Smith, Microsoft

https://techcrunch.com/2018/03/14/a-hippocratic-oath-for-artificial-intelligence-practitioners/
A crime-predicting algorithm in Florida falsely labeled black people re-offenders at nearly twice the rate of white people. Google Translate converted the gender-neutral Turkish terms for certain professions into "he is a doctor" and "she is a nurse" in English. A Nikon camera asked its Asian user if someone blinked in the photo -- no one did.

Forget Killer Robots—Bias Is the Real AI Danger

John Giannandrea, who leads AI at Google, is worried about intelligent systems learning human prejudices.
- Stability bias
- Harmony bias
- Self-interest bias
- Recognition bias
- Recency bias
- Pattern bias
- Perception bias
- Survivor bias
- Placebo effect
Bias in Clinical medicine

Epidemiology top five

- Regression to the mean
- Immortal time bias
- Lead time bias
- Selection Bias
- Publication Bias

Intervention research bias

- Inadequate literature review
- Inadequate randomisation
- Inadequate blinding
- Poor follow-up
- Competing interests
- Inappropriate analysis

Ben Bray @benthebray

‘Biases’ in EHRs due to processes (know your data)

- Laboratory tests from 669,452 patients
- Predictive accuracy of each test on 3yr survival
- Looked at time of day, day of week, and ordering frequency
- Data about the timing was more accurate in predicting survival than the test result on 118 of 174 tests
- E.g. WBC - 4am –normal = 85% survival, 4pm low results = 93% survival, 4pm high result = 91.4% survival, Sunday, normal result = 87.8% survival

doi: https://doi.org/10.1136/bmj.k1479
Governance

- Software as a Medical Device (SaMD) is a relatively new and diverse area, difficult to both understand and manage.
- Slowly becoming recognised by FDA, TGA however it remains a challenge.
- Requires technical and clinical validation processes
- Will require an assured Quality approach (e.g. ISO 13485) to software management
Continuous review required

- Challenge is assurance around the continuously changing databases, algorithms, and supporting software
- Will require ongoing ‘phase 4’ style review of AI products
- Will need local review bodies
Clinical Validation by Research

- Clinicians will continue to act on evidence
- AI is simply another tool in the clinical armamentarium, and thus should not be treated any differently
- The processes around clinical research are well honed, regarded and accepted
- All research will still be overseen by Clinical Ethics Committees
Translation of AI in to practice has barely started

• Remarkably little work in this area
• Need for algorithm quality assurance (SaMD)
• Need for algorithm explainability
  • (regression, decision forest, cluster analysis, neural ‘net, reinforcement)
• Need for good evidence, free of biases
• Need for user interfaces (UI/UX)
• Need to understand clinician barriers
• Need to understand patient preferences
Technical: Resilient, assured, secure, reproducible environment

- As we become more IT reliant, computer up-time is critical
- This requires increasing duplication of infrastructure
- Many industries have the same requirement, so the capability already exists
- Resilience includes duplicated data centres, and fibre connections
Move to the Cloud

- **Amazon Web Services**
- **HIPAA Compliance**
- **Azure**
- **'Petya' Cyber Attack Worse Than Wannacry Hack That Crippled NHS, Says Expert**
  - The Petya attack wiped out 15,000 laptops at Reckitt Benckiser in just 45 minutes and cost the firm £100m.
  - The WannaCry attack in May 2017 infected 300,000 devices in 150 countries including thousands at the NHS.
  - Equifax admitted the records of almost 700,000 British customers were compromised by a data breach last year.
  - Hackers seized details of 57m Uber users in 2016 and demanded a ransom.
  - Yahoo last year revealed 3bn customer accounts were hacked into in 2013.
Software testing and deployment – unit testing

- Common in the software industry internationally
- Less common in Healthcare in Australia
- Rare in AI anywhere

With strict version control of:
- Database
- Code and Software
- User interface
Cybersecurity

- A continuing challenge, and fast growing industry
- Larger data stores = larger targets
- IoT devices are the new vulnerability
- Hardware supply chain now questioned
- Risks include crashing a system, stealing data, and altering data
- User complacency still a critical issue

Note: a major vulnerability is an old system
Passwords

- Common vulnerability
- Don’t re-use passwords
- Use a password manager
- Use 2 factor where possible
- Use biometrics where possible
Reproducibility

- Remains a challenge in clinical research
- Data research may make this easier, with good tools (e.g. Jupyter, Github)
- Data scientists have a strong culture of version control
- In AI, can use transfer learning to re-test algorithms across different data sets
Privacy

• Inherent to system trust
• Well understood by clinicians and those traditionally involved in the Healthcare industry
• Variously understood by new Healthcare market entrants (which many of the new vendors are)
• Becoming more difficult as information becomes more detailed, making individual re-identification easier

• Legislation to protect against actions from re-identification is needed
The privacy discussion

- De-identification can involve data loss, and this decreased accuracy of predictions
  - e.g. Date of Rx for sepsis outcome
- Risk of re-identification is managed, rarely made null
- Important to consider the context where the data is released, and thus risk.
Explainability

- Crucial for people to use AI
- Required also for accountability
- Need tools to unlock the ‘black box’
- Allows users to assess:
  - Biological rationale
  - Trust in the data points
  - Intervention options
User interface

- Remains generally overlooked in Healthcare
- Tension between ‘safety of same’ and user preferences
- Need for increasing interactive dashboards, voice checklists
- Yet to embrace voice, AR, VR
Safety

• Safety is a key priority for clinical acceptance
• Safe medicine = quality medicine = cost-effective outcomes

• So we need to use AI techniques with a strong safety emphasis
  • Safe deep reinforcement learning (limits set for algorithms)
  • ‘Active machine learning’ – interacts with a human in the loop

• The term ‘Augmented intelligence’ will be more accurate for many clinical scenarios.
AI is here, and becoming part of our daily home and work lives

Human levels of performance have already occurred in some fields

The availability of data in Health will see a rapid growth in use

IT best practice in data science is well understood and available

Clinical best practice will be to understand and AI as a tool

AI will markedly improve patient and system outcomes
ICU – a data science treasure trove, with considerable clinical outcome potential

Data is increasingly valuable
Data is the new Oil, AI is the new Electricity

Find good oil
Drill and retrieve oil
Store oil
Refine oil
Turn to power
Create cars, electricity
Use cars, electricity

Sources of unbiased data
Readable structured data
In useable databases
Create data views
Turn data to knowledge
Turn knowledge to products

Engage users and customers

Domain experts
Engineers
Cloud architects
Database administrators
AI programmers
User interface design
Change management
Precision Medicine Data Platform - $6 million

Data Sources:
- Electronic Medical Records (EMR)
- Bio-Signal Monitors
- GE Healthcare
- Cerner
- PHILIPS
- Amazon Web Services
- KJR
- Intel

Data Science Platform:
- Big Data Store
- Data Compute (map/reduce)
- Toolset:
  - Analytics
  - Visualisation
  - Modelling Tools
  - Systems Integration Tools

Prediction Models:
- Heart Rate Analysis
- Mortality Analysis
- Septic Shock

ETL pipelines:
- iMDsoft
- Bio-Signal Monitors

Tools:
- Python
- Apache Spark
- TensorFlow
- Jupyter Notebook