香港中文大學
The Chinese University of Hong Kong

CUHKBME

AI for Rehabilitation Robotics and Diagnostics

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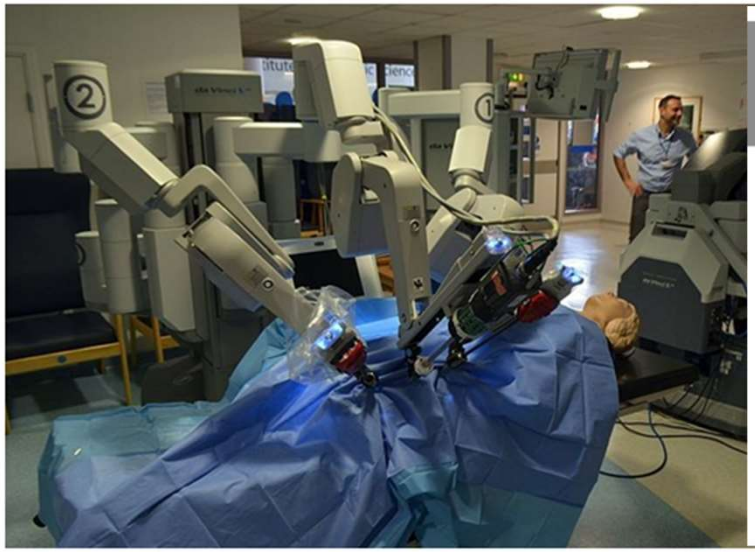
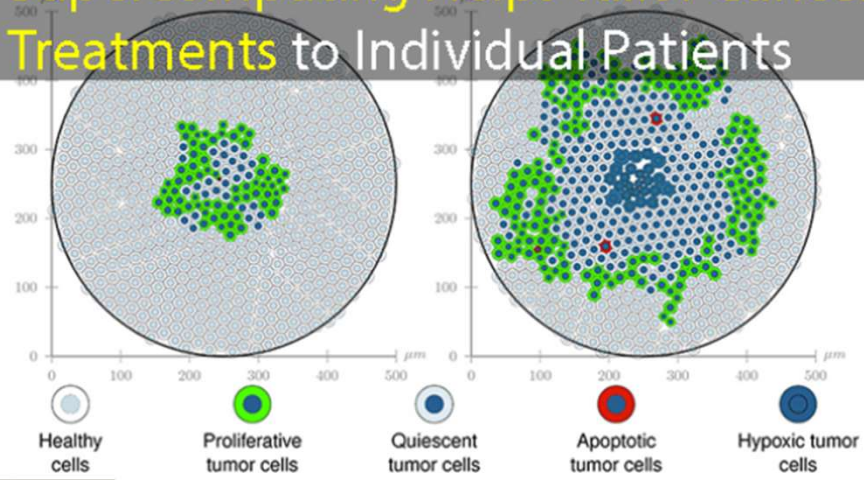
CUHK

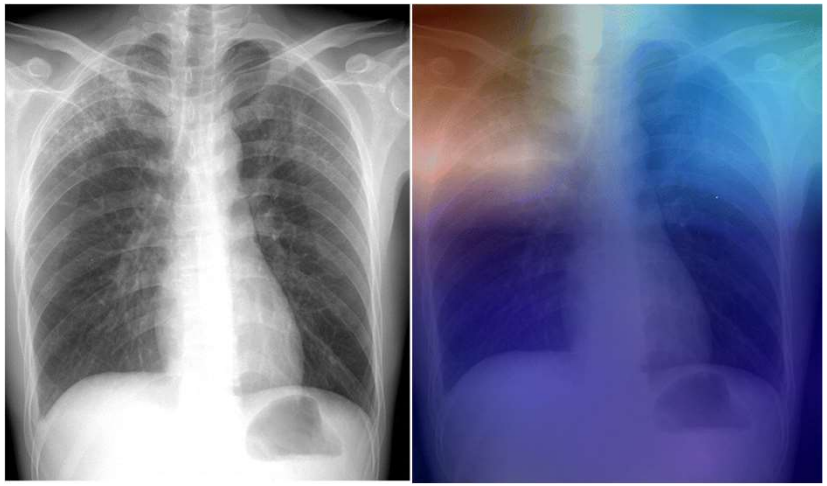


Supercomputing Helps Tailor Cancer Treatments to Individual Patients



Deep Learning at Chest Radiography: Automated Classification of Pulmonary Tuberculosis by Using Convolutional Neural Networks (April 2017 Radiology 284(2):162326)

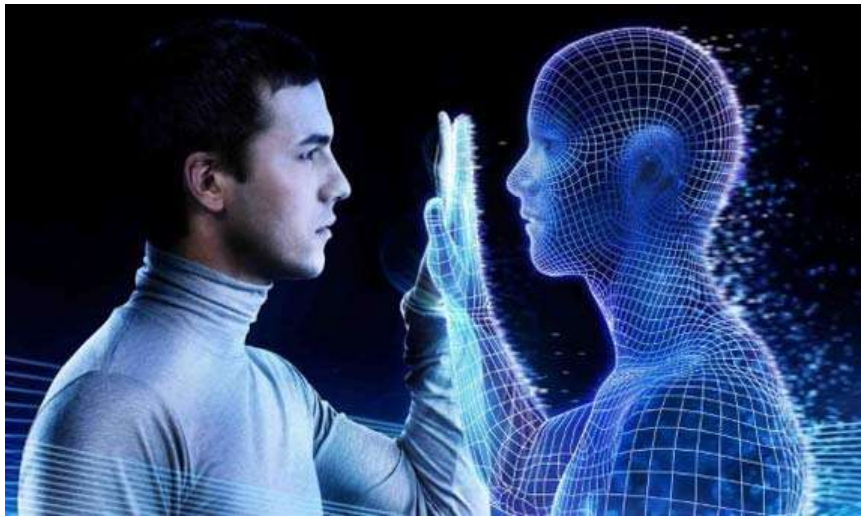
- In the medical field, taking tuberculosis as an example, the accuracy of diagnosis and treatment of senior chief physicians is usually about 70%, while a set of intelligent diagnosis system developed can reach more than 90%. By using Deep learning, the accuracy further improved Deep at chest radiography with an areas under the curve (AUC) of 0.99.



A heat map overlay of one of the strongest activations obtained from the fifth convolutional layer after it was passed through the GoogLeNet-TA classifier. The red and light blue regions in the upper lobes represent areas activated by the deep neural network. The dark purple background represents areas that are not activated. This shows that the network is focusing on parts of the image where the disease is present (both upper lobes).

AI + Human: Better accuracy

- The DCNNs had disagreement in 13 of the 150 test cases, which were blindly reviewed by a cardiothoracic radiologist, who correctly interpreted all 13 cases (100%). This radiologist-augmented approach resulted in a sensitivity of 97.3% and specificity 100%.



Artificial intelligence achieves near-human performance in diagnosing breast cancer (2016)

- Beth Israel Deaconess Medical Center (BIDMC) and Harvard Medical School (HMS) recently developed artificial intelligence (AI) methods aimed at training computers to interpret pathology images
- Automated diagnostic method proved accurate **approximately 92** percent of the time, it is matched the success rate of a human pathologist, whose results were 96 percent accurate.
- **Combined the pathologist's analysis with automated computational diagnostic method**, the result improved to **99.5 percent accuracy**
- **Combining these two methods yielded a major reduction in errors.**

Beth Israel Deaconess Medical Center. "Artificial intelligence achieves near-human performance in diagnosing breast cancer." 20 June 2016.

Artificial intelligence used to identify bacteria quickly and accurately

- Microscope-based artificial intelligence could alleviate shortage of clinical microbiologists
- Automated microscope designed to collect high-resolution image data from microscopic slides.
- The machine intelligence learned how to sort the images into the three categories of bacteria (rod-shaped, round clusters, and round chains or pairs), achieving nearly more than **93 percent accuracy.**

Kenneth P. Smith, Anthony D. Kang, James E. Kirby. **Automated Interpretation of Blood Culture Gram Stains using a Deep Convolutional Neural Network**. *Journal of Clinical Microbiology*, 2017; JCM.01521-17 DOI: 10.1128/JCM.01521-17

Artificial intelligence may aid in Alzheimer's diagnosis

- Researchers in The Netherlands have coupled machine learning methods with a special MRI technique that measures the perfusion, or tissue absorption rate, of blood throughout the brain to detect early forms of dementia, such as mild cognitive impairment (MCI)
- Accuracy 82 percent to 90 percent.

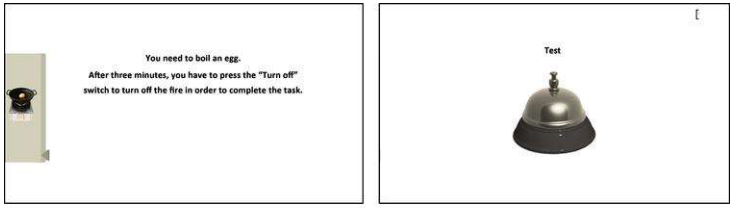
Lyduine E. Collij et al. **Application of Machine Learning to Arterial Spin Labeling in Mild Cognitive Impairment and Alzheimer Disease**. *Radiology*, 2016; 152703 DOI: 10.1148/radiol.2016152703

Computerized Cognitive Screen (CoCoSc): A Self-Administered Computerized Test for Screening for Cognitive Impairment in Community Social Centers

- Adrian Wong, Ching-hang Fong, Vincent Chung-tong Mok, Kam-tat Leung and Raymond Kai-yu Tong*
- **CUHK study** (59 individuals with CI and 101 controls were recruited)
- The CoCoSc is a 15-min computerized cognitive screen covering memory, executive functions, orientation, attention and working memory, and prospective memory administered on a touchscreen computer.
- CoCoSc and MoCA (standard written test) were significantly correlated. CoCoSc area under ROC was **0.78**.

Journal of Alzheimer's Disease, vol. 59, no. 4, pp. 1299-1306, 2017

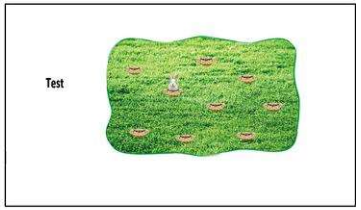
Installed in the Hong Kong Housing Society Elderly Resources Centre



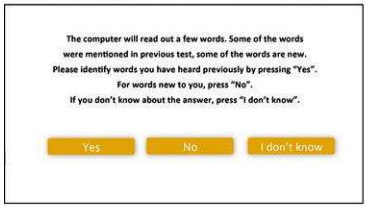
a. Time-based Prospective Memory subtest

b. Conflict Inhibition subtest

c. Orientation subtest



d. Spatial Attention and Working Memory subtest

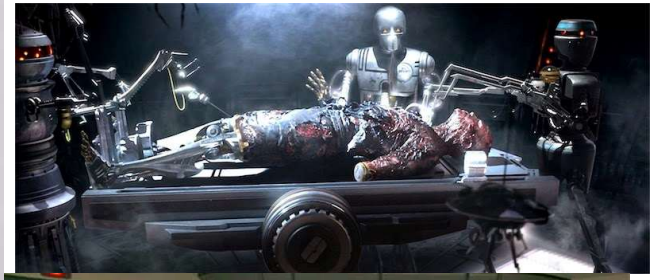


e. Delayed Memory subtest

f. Event-based Prospective Memory subtest

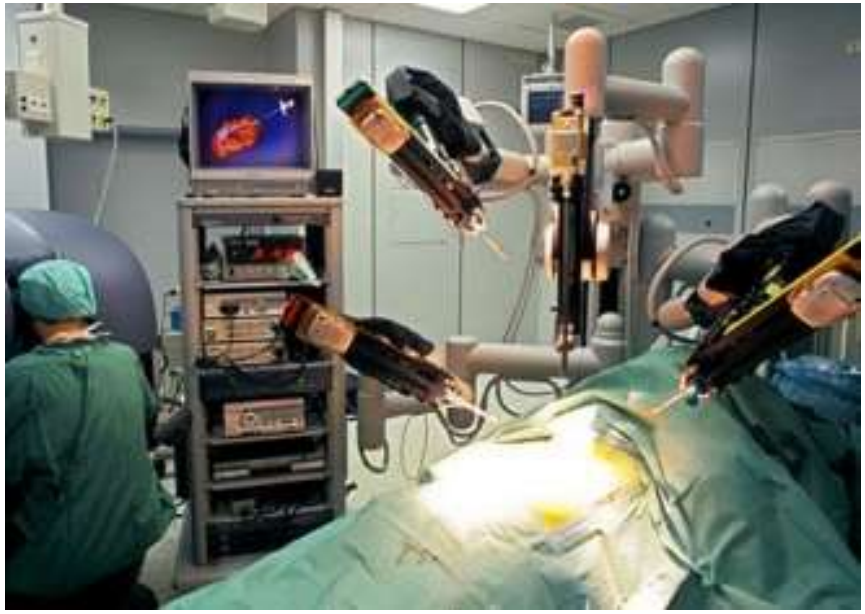
AI + robot

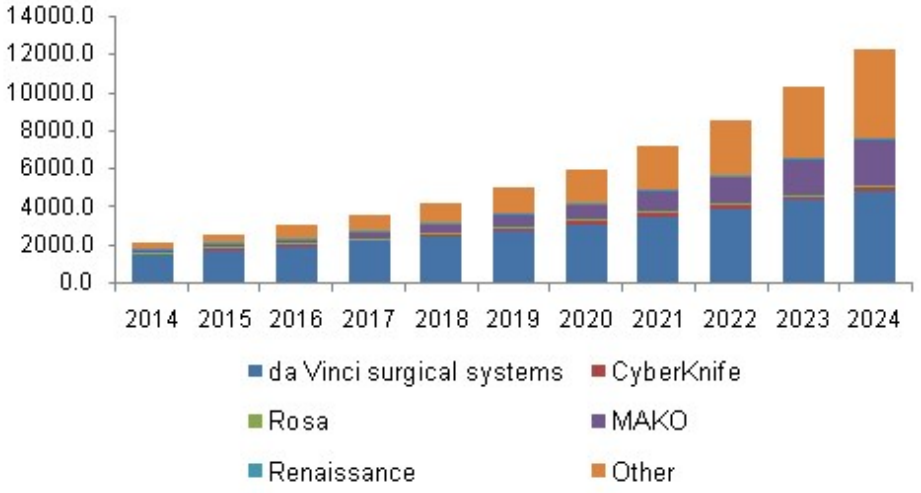
"*Star Wars Episode III: Revenge of the Sith*"(2005)



"*Prometheus*" is called the "*Medical Pod 720i*."

North America surgical robot market share, by product, 2014 - 2024

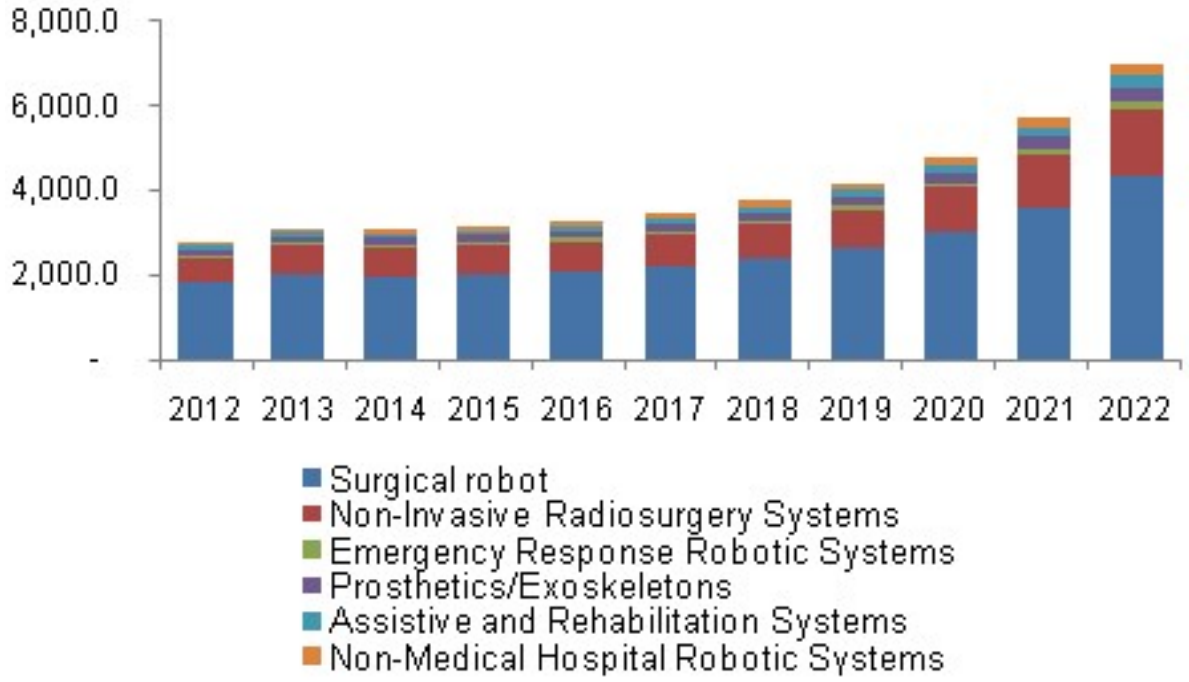




- The global surgical robot market size was valued at USD 4.0 billion in 2015 and is expected to grow at a **CAGR of 20.03%** over the next eight years. The rising incidences of chronic conditions coupled with increasing ageing population and related diseases.
- In 2014, it was reported by the CDC that about 50.0 million people suffer from neurological disorders causing an annual expenditure of over USD 450.0 billion, hence demanding a high volume of surgical intervention.

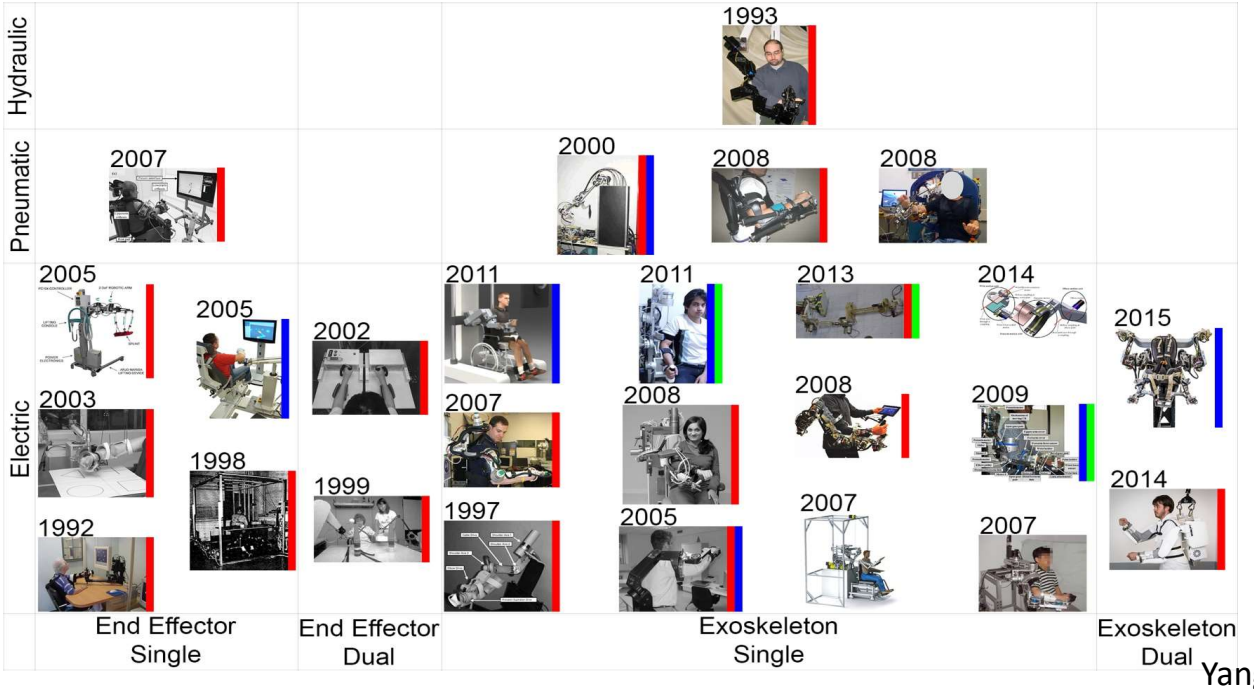
Grand View Research 2016

U.S. medical robotic systems market, by product, 2012 - 2022 (USD Million)



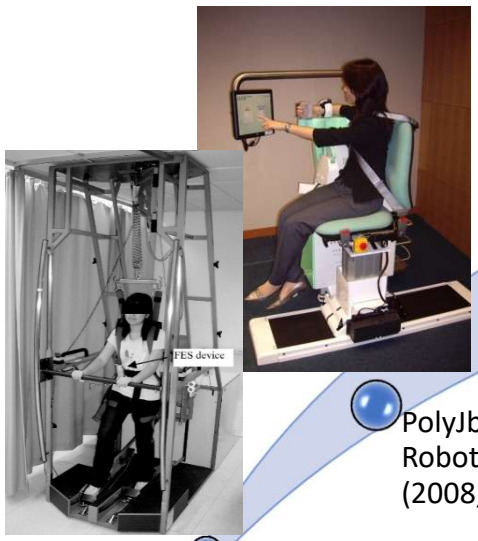
Graphical Summary of Existing Upper Limb Rehabilitation Robots

This healthy market competition is a big reason why the Global Rehabilitation Robotics market is expected to grow at a CAGR of 24.27 percent during the 2014-2019 period.



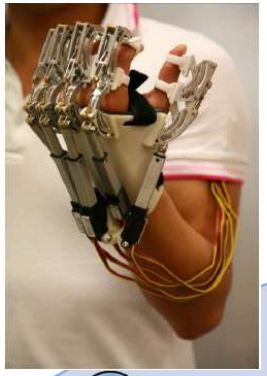
Yang Shen and Jacob Rosen 2018

Trend of Exoskeleton Robotics (Raymond's research interest)

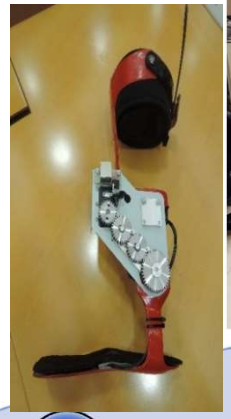


Gait Trainer from Germany (2006-08)

PolyJbot Robot Tower (2008, HK)

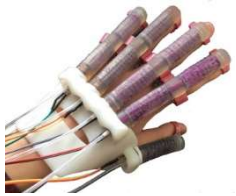


Hand of Hope (2011, HK)



Ankle Robot, Knee Robot (2016, HK)

Soft robot,Shoulder Robot (2017-ongoing)



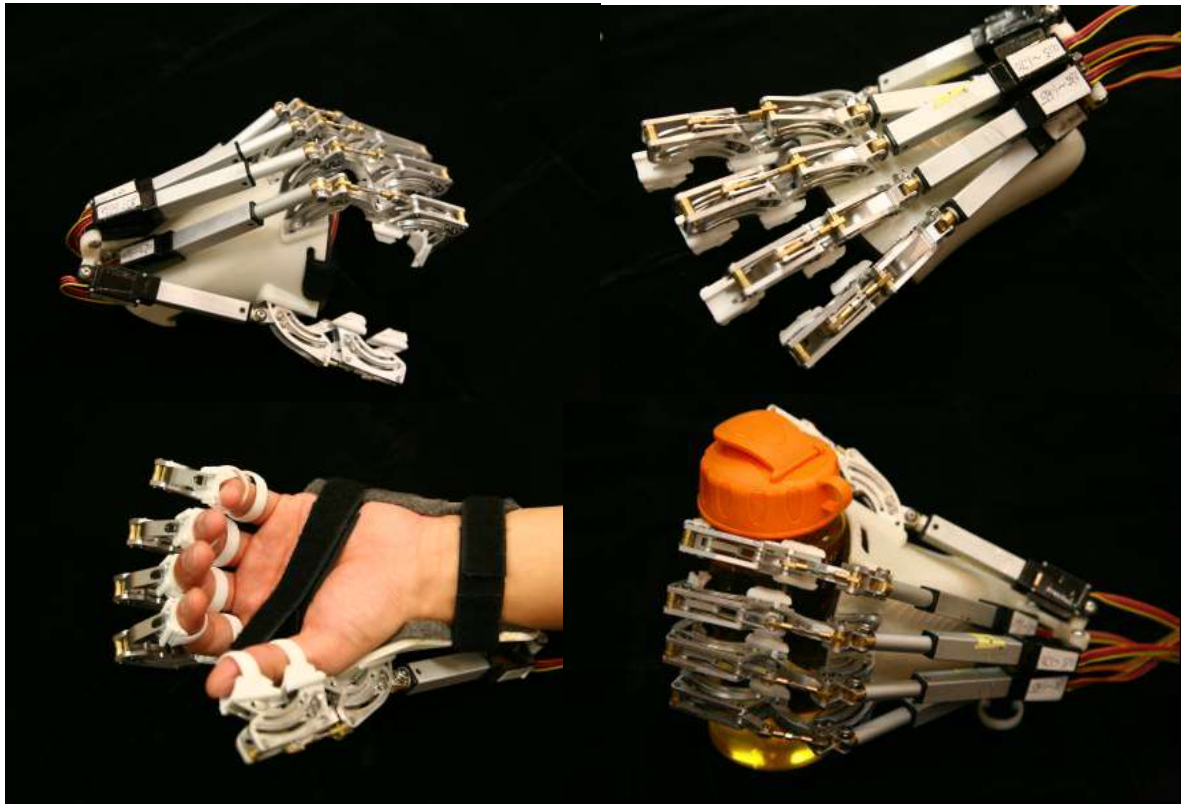
Exsokeleton Robot Hand and Leg

(Raymond Tong, Hong Kong)

- Detect **human intention** to drive the robot for rehabilitation

- Licensed to Rehab-robotic(Top 15 Rehabilitation Robotics Companies in 2014)
- Support Vincent-Medical IPO to be listed in HK Stock Market (2016)

Hand Function Task Training Robot



EA Susanto, **RK Tong** ,et al *Efficacy of robot-assisted fingers training in chronic stroke survivors: a pilot randomized-controlled trial*. J Neuroeng Rehabil. (2015) **[Link]**

Movie clips – Subject with Chronic Stroke

Task without Hand robot

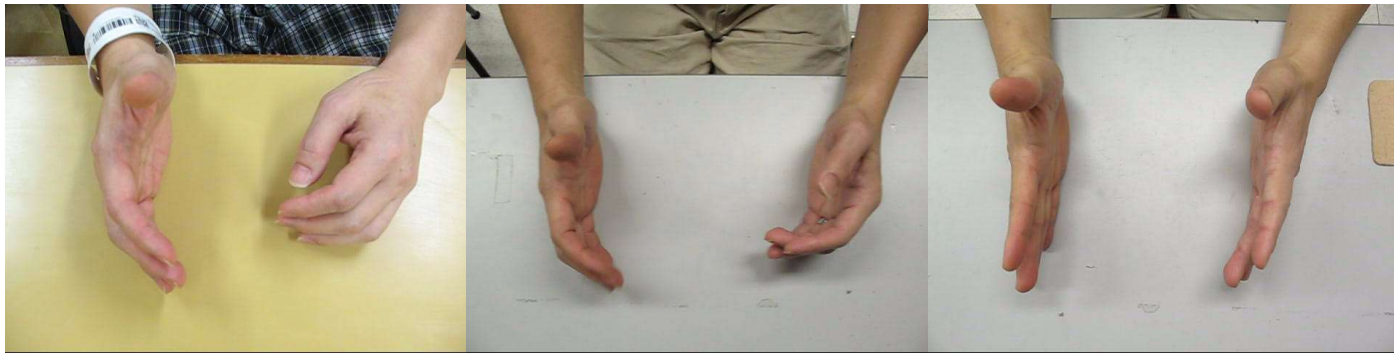
Task with Hand robot

Hu XL, …. **Tong KY**. The effects of post-stroke upper-limb training with an electromyography (EMG)-driven hand robot. *J Electronmyogr Kinesiol* 2013 Oct;23(5):1065-74. [Link]

Lu Z, **Tong K**, Shin H, Li S, Zhou P, Advanced Myoelectric Control for Robotic Hand-Assisted Training: Outcome from a Stroke Patient, *Frontiers in Neurology, 2017, 8*[Link]

Pre- and Post 20-session Training on a Subacute Stroke Suvivor
(Significant Improvement in Hand Opening)

Stroke Type	Affected Side	Gender/Age	Onset Time
Ischemic	Left	M/50	4 weeks

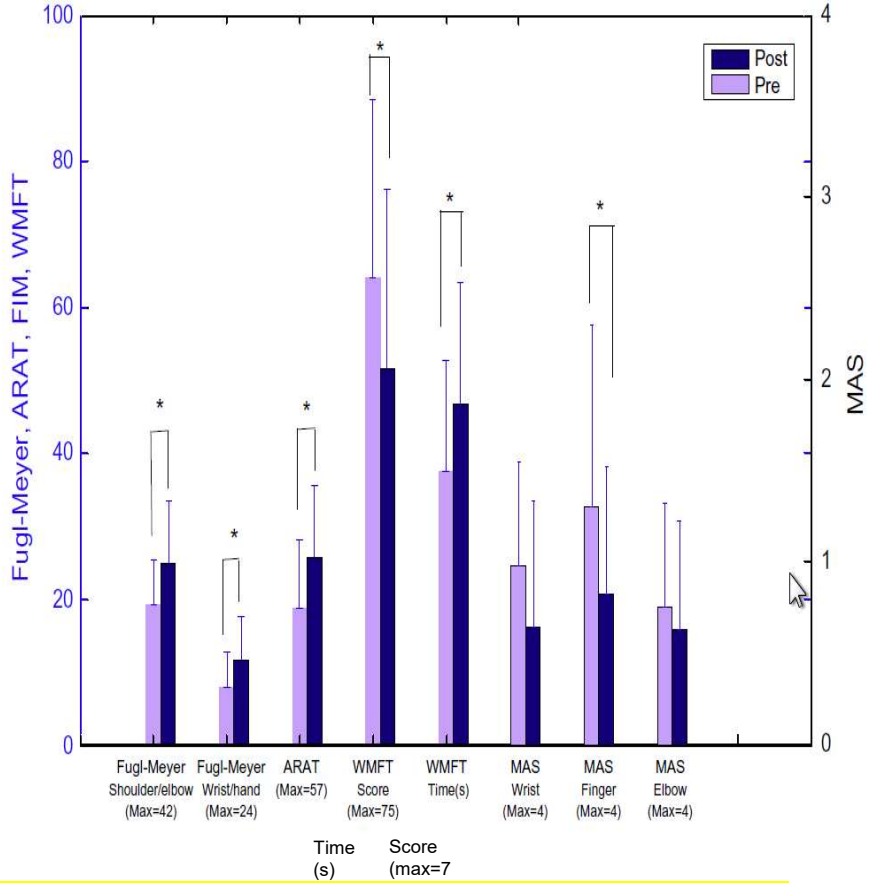


Pre-training, 10-session training, 20-session training

Hong Kong TVB Video 2018 July on our latest Soft Robotics Hand

Clinical Data from Chronic Stroke Subjects before and after 20-session training

It is found that significant motor improvements after the training could be captured by the FMA (shoulder&elbow (S&E), and wrist&hand(W&H), and ARAT. The improvement in ARAT score mainly reflects the motor recovery in hand and finger functions. The increased FMA scores suggest the motor improvement in the whole upper limb after the training. Significant reduction in spasticity of the fingers using MAS.



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EA Susanto, **RK Tong** ,et al *Efficacy of robot-assisted fingers training in chronic stroke survivors: a pilot randomized-controlled trial*. J Neuroeng Rehabil. (2015) **[Link]**

How Hong Kong Smart Robot Leg can facilitate the brain to relearn how to walking again ?

Existing robotic system

Triggered by Joystick or Trunk Movement

Bulky

Heavy (15-20kg) =

Expensive

Smart Exoskeleton Robotic Leg

Patient wears it on his shank/thigh/hip

Effective

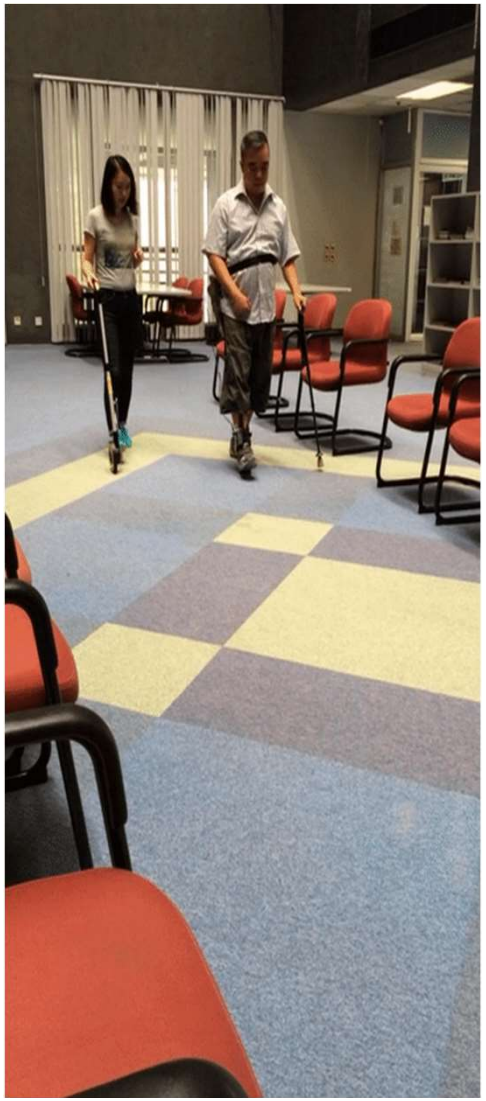
Nature walking

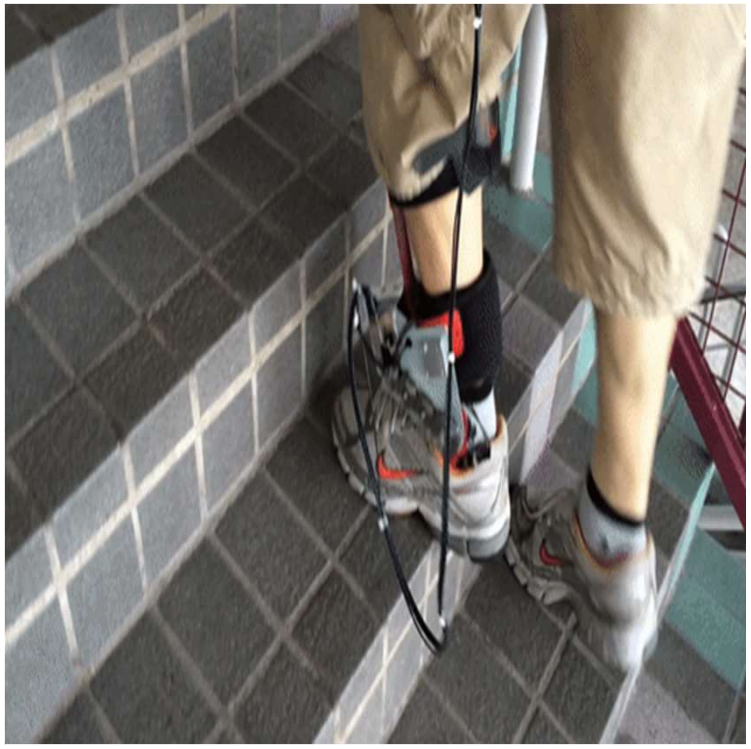
Improve balance

Light weight (500-800g) =

0.5L

It is very unique for rehabilitation purpose :
stroke survivors can use it indoor as well as outdoors for rehabilitation training.





Clinical results : 20 Stroke Patients (20 sessions 1h training)

% of patients with improvement exceeding Clinical Significant Value

Function

Walking speed

Clinical results (20 sessions of training (1 hour with robotic system)

- Ankle robot

10 stroke subjects in ankle robot study

1. 30% of them improved in FAC (Functional Ambulation Category for walking independency).
2. 70% of them improved in FMA-LE (Fugl-meyer Assessment – Lower Extremity).
3. 40% of them improved in MAS (Modified Ashworth Score for Spasicity).
4. 40% of them improved in BBS (Berg balance scale).
5. 80% of them improved in 10 MWT (10 meter walk test).
6. 80% of them improved in 6 MWT (6 min walk test).

- Knee robot

10 stroke subjects in knee robot study

1. 40% of them improved in FAC.
2. 40% of them improved in FMA-LE.
3. 70% of them improved in MAS.
4. 40% of them improved in BBS.
5. 50% of them improved in 10 MWT.
6. 100% of them improved in 6 MWT.

Wearable Technology in Medicine and Health Care (2018), Elsevier edited by Raymond Tong

https://www.elsevier.com/books/wearable-technology-in-medicine-and-health-care/tong/978-0-12-811810-8

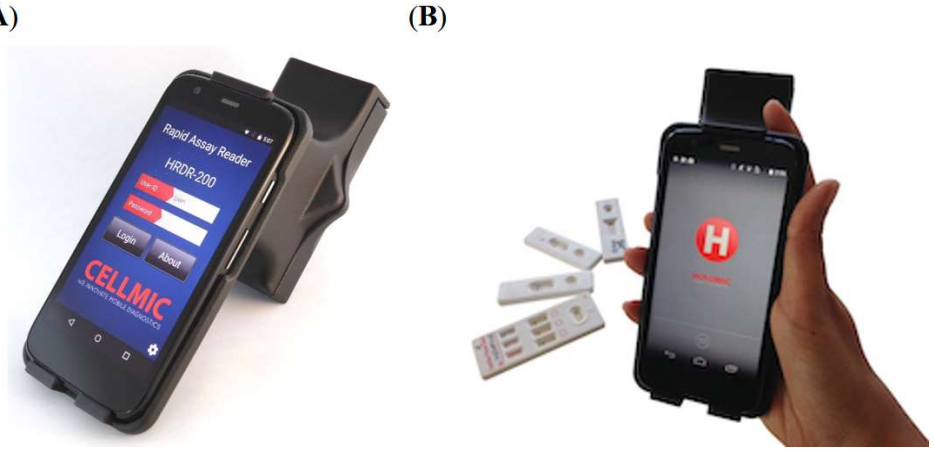
Heart Rate + Blood Pressure + Blood Glucose

Smartphone-based blood glucose meters developed by iHealth Inc.

Heart Rate

Sandeep Kumar Vashist and John H.T. Luong, 2018

BioSensor for Point-of-care, Lab-on-chip



Smartphone based diagnostic readers developed by Cellmic. (A) Holomic Rapid Diagnostic Test Reader (HRDR-200) (B) HRDR-300.

Sandeep Kumar Vashist and John H.T. Luong, 2018

Digital Patient Generated Health Data

- In 2018, it is estimated that **135 million wearable units** will be shipped worldwide – up from 9.7 million units in 2013 (Statista 2016).
- In terms of ownership, **approximately 29% of Americans** have a wearable device, while in the UK research has shown that 3 million wrist-worn wearable units were sold in 2015, up 118% on 2014 (ZDNet 2016; Mintel 2016).
- As wearable devices are frequently accompanied by a dedicated application (app), of equal importance to the wearable industry is the growing number of smartphone users, which is forecasted to reach 2.08 billion worldwide by 2019 (Mintel, 2016). These upward trends are also seen in relation to **mHealth app** market with between 165,000-259,000 apps.
- **BIG DATA and AI for diagnosis and disease prevenetion**

Patrick Slevin & Brian Caulfield (2018)

Patient Engagement

- Enhances the **quality of patient safety**, **reduces healthcare costs** and **improves health outcomes** (Hibbard & Greene 2013; Coulter & Ellins 2007)
- Patients increasingly want to be more involved in the healthcare decision-making process (Auerbach 2001). Healthcare has responded to this need by placing a stronger emphasis on shared decision making (SDM) as mechanism to further engage patients in their healthcare.
- For example, a patient visits their GP after noticing their blood pressure (BP) has been higher than normal for the past two weeks with an alarm triggered by AI system.
- Hospital/Clinic can access the **less clinical visits** they will require, especially with the establishment of eHealth eco-systems that include video-consultations, electronic health records, patient portals and ePrescribing all of which will facilitate the remote alteration of treatment plans.

Patrick Slevin & Brian Caulfield (2018)

Can AI system help lower Health Insurance?

Insurance for healthcare

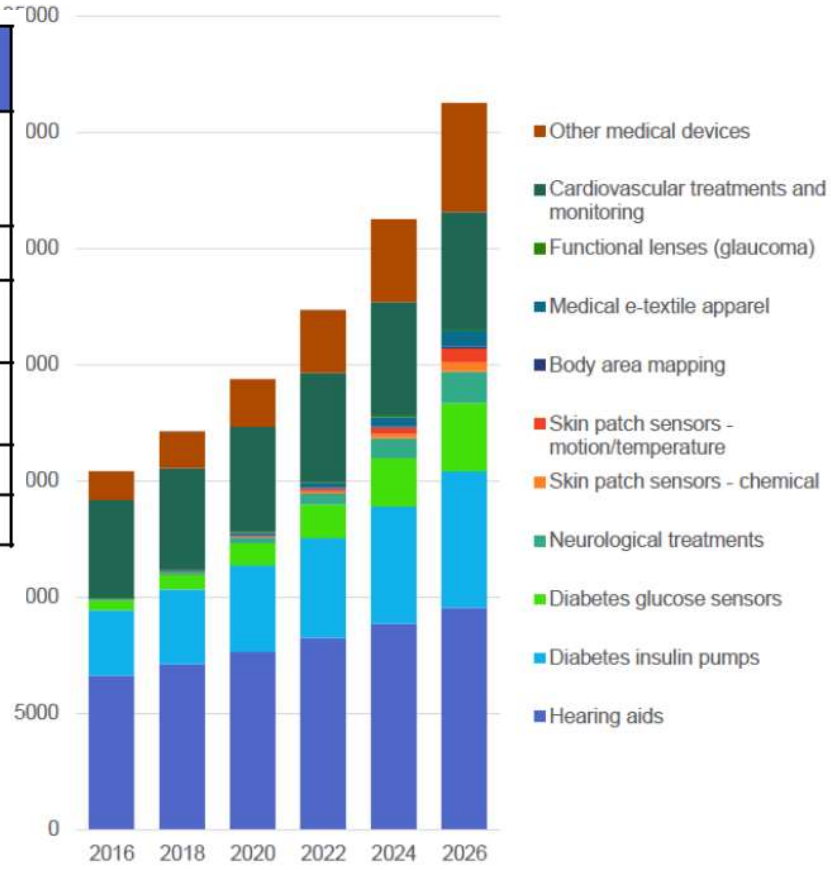
- Insurance models should be of interest to Governments, healthcare systems, consumers and patients particularly in a time when out-of-pocket healthcare expenditure and private health insurance premiums are on the rise (Motaze Nkengafac et al. 2015).
- In 2013 for example, US company Cigna launched a pilot program with four of its US based employer health plan clients (Olson 2015). Employees were provided with a wearable that tracked activity and calories burned amongst other physiological data. The data was then shared with health coaches who worked with the employees to adjust and motivate them to create healthier habits. Employees could earn points based on reaching healthy behaviour targets, the more points they gained the further discounts they received on their premiums (Olson 2015).

THE INTEGRATION OF WEARABLES AND INSURANCE

Kelvyn Young, 12 Jul 2017

Insurance company	Fitness tracker	Rewards
Oscar NY	Misfit (Flash)	$1 credit every time step goal was reached, upto $250 annually in Amazon vouchers
John Hancock	Fitbit	Upto 15% off premiums for hitting targets
Vitality Health	Various	Various reward schemes based on activity
UnitedHealthcare	Fitbit	Offers health management app linking to Fitbits
Aetna	Various	Offered via corporate employer partners
Cigna	Various	Offered via corporate employer partners

Table: Examples of insurers offering incentives based on meeting activity goals with wearable devices **Source:** IDTechEx

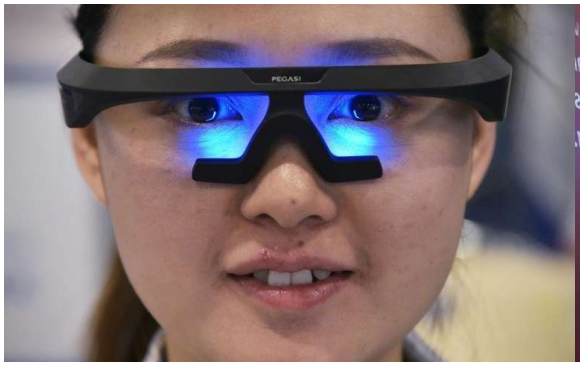


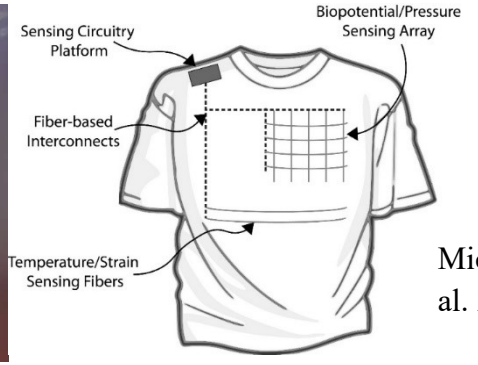

Complex stationary medical monitors
Full range of vital signs
Sophisticated algorithms
Restricted movement
High accuracy
High price
Simple portable medical monitors
Spot monitoring
Single vital sign
Moderate accuracy
Poor motion tolerance
Simple wearable consumer monitors
Limited vital signs
Ergonomic focus
Low accuracy
Limited motion tolerance
Sophisticated, easy to use, wearable, accurate, motion tolerant, secured
Multiple vital signs
Medical grade accuracy
Highly motion tolerant
Relatively low cost
Ergonometric/aesthetic
Data mgnt. ecosystem
Social media connectivity

LAS VEGAS, NV

JANUARY 9- 2, 2018

- The 2018 Consumer Electronics Show, a high-tech showcase this week in Las Vegas, included the latest advances in **digital health, suggesting promising avenues for treatment**, even if many lack full-fledged medical approval.





Michael McKnight, et al. 2018

- Tech firms are looking to cash in on a digital health industry **estimated at about $200 billion annually in areas ranging from app-based diagnoses, to pain management and telemedicine**.
- A growing number of startups focused on the brain—capturing or "hacking" brainwaves with the goal of improving sports performance, enabling relaxation, aiding sleep, and potentially treating pain, anxiety or other ills.
- "**Brain technologies** can help people learn and practise meditation," said Chris Aimone, founder of Interaxon, a Canadian startup which exhibited its Muse headband aimed at using "neurofeedback" to **manage stress and improve athletic performance**.
- Neurofeedback, which teaches self-control of brain functions, has been around for decades, but the arrival of low-cost sensors has made it easier to produce affordable consumer devices.
- Maryland-based startup RightEye announced an eye-tracking assessment in a gaming application to screen for concussions and other brain health problems, with the possibility of early detection indicators for **autism and Parkinson's disease.**

Read more at: https://phys.org/news/2018-01-headbands-sensor-socks-wearable-tech.html#jCp

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