Human-Centric Robotics & Automation for Healthcare

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National Seminar on Productivity in Healthcare 2016
Marina Bay Sands
20-21 October 2016
“One Robot is Robotics”

“Ten Robots is Automation”
Robot Manipulators – Annual Supply

- Estimation for 2015 – 250,000 units
- 70% of robot sales go to China, US, Japan, Korea, Germany
Robot Manipulator – Sales by Industry

Estimated worldwide annual supply of industrial robots at year-end by industries 2012 - 2014

- Automotive industry
- Electrical/electronics*
- Metal**
- Chemical, rubber and plastics
- Food
- Others
- Unspecified

* incl. fabricated metal products, basic metals and machinery industry
** incl. communication, computer and medical precision

Source: World Robotics 2015
Service Robot Sales – By Industry

Service robots for professional use.
Units sales 2014 and 2015, and forecast 2016-2019 (continued)


Source: IFR World Robotics 2016
# Medical Robot Trend

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<thead>
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</thead>
<tbody>
<tr>
<td>Diagnostic systems</td>
<td></td>
<td></td>
<td>800</td>
</tr>
<tr>
<td>Robot assisted surgery or therapy</td>
<td>1,040</td>
<td>978</td>
<td>4,900</td>
</tr>
<tr>
<td>Rehabilitation system</td>
<td></td>
<td></td>
<td>2,100</td>
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<tr>
<td>Other medical robots</td>
<td>252</td>
<td>246</td>
<td></td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1,292</strong></td>
<td><strong>1,224</strong></td>
<td><strong>7,800</strong></td>
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*2015 World Robotics Report

**Da Vinci Surgical Robot**
- 650,000 procedures (2015) globally
- 492 units (2015) vs 3597 (total)
Robotics & Automation in Healthcare

Physicians
- Surgical robot
- Surgical device & tool

Healthcare practitioners/staffs
- Care provider-patient assistant
- Pharmacy automation
- Logistics/Cleaning automation

Patients
- Patient care system
- Assistive robot
- Wearable device
Physician-Oriented Systems

- Complexity of procedures (machine vs. human)
- Precision and consistency of procedures
- Human-machine interface & operation
- System set up and protocols
- Quality of patient outcomes
- Time of recovery
Teleoperated robot-assisted surgical system for minimally invasive procedures. (Credit: Intuitive Surgical, Inc.)

Robotic hair transplant system eliminates scarring and speeds healing time. (Courtesy of Restoration Robotics, Inc.)

Robotic angiography system for 3D mapping of blood vessels during vascular surgery. (Courtesy of Siemens AG)

Robot-guided laser bone-cutting device under development. (Courtesy of AOT AG)
Mechatronic Tracheostomy Tube for Automated Tracheal Suctioning

• Mechanical ventilation required to aid patients with breathing difficulty. Currently, nurses spend millions of person-hours to insert a tracheostomy tube through opening in patient’s neck.
• Novel mechatronic tracheostomy system including development of a long suction catheter, automatic suctioning mechanisms, and relevant control approaches to perform tracheal suctioning automatically.
Magnetically Actuated Ingestible Weight Management Capsule

- Traditional treatment of obesity requires complex insertion tools and flexible endoscope to place and remove balloon inside stomach
- New ingestible weight-loss capsule with magnetically remote-controlled balloon inflation/deflation mechanisms and external magnetic actuator
- Magnetic capsule size significantly reduced compared to current weight-loss capsules existing one and no limitations on power supply.
Surgical Robots & Devices

Projects
• Flexible endoscope robotic system for removal of stomach cancer
• Vision-aided active handhelds instrument for microsurgery
• Micromanipulation system for in-vitro fertilization procedure

Commercialization
• Spin-off: EndoMaster Pte Ltd
Staff Operation-Oriented Systems

- Complexity of tasks vs. cost of tasks
- Cost of automation & throughput
- Hospital environment variation
- Human-machine interface & operation
- Inter-connectivity to medical IT system
- Safety in human crowded situation
- Efficiency & cost reduction of operation
Mobile telepresence robot remotely connects physicians with their patients. (Credit: InTouch Health)

Blood-drawing robot under development. (Courtesy of Veebot LLC)

Autonomous mobile robot travels miles of hospital hallways transporting medications, patient meals, medical supplies, linens and trash. (Courtesy of Aethon Inc.)
Tele-Presence Robotic Avatar

- Intelligent machines for human interaction
- Natural interaction using speech, tone and body gestures
- Robotic avatar (EDGAR)
  - Telecommunication with physical presence
  - Personalise - can represent *a specific facial texture*
- Autonomous interaction robot as Museum Guide, Robotic lecturer
Social Robot for Early Childhood

• Developing interactive content for Pepper in K2 POC study
• Natural & multi-modal interaction using speech, display panel and auxiliary devices
• Outcome study, robot performance evaluation
Robotics & Wearable Sensors: The Future of Tele-medicine
Item-Picking Robot

Intelligent robotic system picking items from shelves to order bin in e-commerce fulfilment centre/pharmacy

- Automatic recognition of shapes, poses of objects in shelves
- Automated grasp planning and picking
- Automated manipulator trajectory generation
- Aim for flexible and high speed operation (5sec/item)
Amazon Picking Challenge
@ICRA 2015 Seattle, USA, 26-28 May
Patient-Oriented Systems

- Values in therapeutic & diagnostic processes
- Affordability of systems and device
- Targeted use cases in home, community centers, hospitals
- Patient compliance
- Human-machine interface & operation
- Inter-connectivity to personal or professional IT systems
- Deployment model for sustainability
Robotic arms provide rehabilitation therapy for patients recovering from stroke and other neurological disorders. (Courtesy of Barrett Technology, Inc.)
H-Man: Planar Robot for Arm Rehabilitation

- H-Man is a compact low cost robot designed for the rehabilitation/training of planar arm movements
- System is homogeneous, lightweight, and intrinsically safe for use
- H-shaped cable-driven differential mechanism
- Provide forces of up to 30 N at end-effector (handle) in any specified direction in a planar workspace to assist or resist motion of user
Light-Weight Exoskeleton (Composite)

- Lightweight
- 3D Printing
- Carbon Fiber
- Self Stabilizing

ACTUATOR CONCEPT

FULLY Predictable Strain Energy

Multi-stable Composite Transmission
Several robots have been created to assist with therapeutic training of wrist with a major goal of restoring motor control.

Proprioceptive impairment may be detrimental to motor recovery, and assessment of proprioceptive dysfunction provides prognostic factor in recovery and long-term functional outcomes after stroke.

This study evaluates feasibility of a wrist robot system to determine proprioceptive discrimination thresholds for different DoFs of the wrist.
Rehabilitation & Assistive Robots

Projects
• COSMOSYS: Cognitive stroke therapy through wearable haptic interfaces
• Automated neuro-motor stroke rehabilitation device
• Assistive leg device for partial-paralysis patients
• Interactive mixed reality rehabilitation system

Commercialization
• Spin-off company: SynPhNePte Ltd
Spectrum of NTU Robotics Projects

Technology Readiness Level (TRL)

<table>
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<tr>
<th>Level</th>
<th>Description</th>
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<tbody>
<tr>
<td>1 – 3</td>
<td>Basic Research</td>
</tr>
<tr>
<td>4 – 6</td>
<td>Applied Research</td>
</tr>
<tr>
<td>7 – 9</td>
<td>Commercialization</td>
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- Auto tracheostomy
- Lightweight exoskeleton
- Capsule
- Robotic avatar
- Robot walker
- H-Man
- Endomaster
- SynPhNe
- Picking robot
- Nurse assistant
Triple Helix Innovation

Academia
- Administration and Deans
- Professors and PIs
- Students
- Churns out entrepreneurs
- Basic technology
- Technical assistance and education
- Supplies human capital
- Forges Partnerships

Industry
- Capital
- Event sponsorship
- Market expertise
- Corporations
- Venture Capital
- Chambers and Trade Associations
- Spinoffs and SME

Government
- Basic R&D Funding
- SBIR Grants
- State incentive programs
- Quality of life
- Ease of business
NTU Healthcare Robotics

Surgical robots & devices
Rehab/Assistive robots
Tele-medicine & interactive robots
Hospital process automation

Faculty PIs

- Prof Louis Phee (S)
- Prof Low Kin Huat (R)
- Prof Chen I-Ming (R, T)
- Assoc Prof Ang Wei Tech (S, R, T)
- Assoc Prof Cheah Chien Chern (R)
- Assoc Prof Domenico Campolo (R)
- Assistant Prof Lorenzo Masia (R)
- Assistant Prof Wu Kan (A)
- Dr. John Heng (R, T)
Thank You!

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