ROBOTICS IN MEDICINE: WHO’S HOLDING THE KNIFE?

Stuart Kozlick
RTI Advisory Board
## Why Robots?

**Table 1. Advantages and disadvantages of humans and autonomous robotic systems**

<table>
<thead>
<tr>
<th></th>
<th>Human</th>
<th>Robot</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td>Good judgement</td>
<td>Good mechanical precision</td>
</tr>
<tr>
<td></td>
<td>Adaptable and able to improvise</td>
<td>Untiring and stable</td>
</tr>
<tr>
<td></td>
<td>Able to use qualitative information</td>
<td>Can work in hazardous environments</td>
</tr>
<tr>
<td></td>
<td>Easy to train</td>
<td>Multimodal sensory integration</td>
</tr>
<tr>
<td></td>
<td>Easy communication with humans</td>
<td></td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
<td>Limited mechanical precision</td>
<td>No judgement</td>
</tr>
<tr>
<td></td>
<td>Prone to fatigue, tremor, inattention</td>
<td>No qualitative abilities</td>
</tr>
<tr>
<td></td>
<td>Cannot work in hazardous environments</td>
<td>Limited in haptic sensation</td>
</tr>
<tr>
<td></td>
<td>Limited quantitative abilities</td>
<td>Expensive</td>
</tr>
</tbody>
</table>

Surgical Robot Autonomy
Surgical Robot Autonomy

Operator performs all tasks including monitoring, generating performance options, selecting the option to perform (decision-making), and executing the decision made.

No autonomy
Robot assistance
Surgical Robot Autonomy

Operator performs all tasks including monitoring, generating performance options, selecting the option to perform (decision-making), and executing the decision made.

Operator maintains discrete control of the system, and the robot can perform certain operator-initiated tasks automatically.

No autonomy
Robot assistance
Task autonomy
Surgical Robot Autonomy

Operator performs all tasks including monitoring, generating performance options, selecting the option to perform (decision-making), and executing the decision made.

Operator selects and approves a surgical plan, and the robot performs the procedure automatically but with close surgical oversight by human.

Operator maintains discrete control of the system, and the robot can perform certain operator-initiated tasks automatically.

Operator maintains continuous control of the system while the robot provides certain assistance.

No autonomy
Robot assistance
Task autonomy
Conditional autonomy
Surgical Robot Autonomy

0. No autonomy
   - Operator performs all tasks including monitoring, generating performance options, selecting the option to perform (decision-making), and executing the decision made.

1. Robot assistance
   - Operator maintains continuous control of the system while the robot provides certain assistance.

2. Task autonomy
   - Operator maintains discrete control of the system, and the robot can perform certain operator-initiated tasks automatically.

3. Conditional autonomy
   - Operator selects and approves a surgical plan, and the robot performs the procedure automatically but with close surgical oversight by human.

4. High autonomy
   - Robot is able to make decisions but under the supervision of a qualified operator.
Surgical Robot Autonomy

0. No autonomy: Operator performs all tasks including monitoring, generating performance options, selecting the option to perform (decision-making), and executing the decision made.

1. Robot assistance: Operator maintains continuous control of the system while the robot provides certain assistance.

2. Task autonomy: Operator maintains discrete control of the system, and the robot can perform certain operator-initiated tasks automatically.


4. High autonomy: No human needs to be in the loop, and the robot can perform an entire surgery.

5. Full automation: Robot is able to make decisions but under the supervision of a qualified operator.
Medical Robotics

Challenges

• Near instantaneous Response
• Real-world model
• Modular
• Data-centric
### Market Segment Landscape

<table>
<thead>
<tr>
<th>Segment</th>
<th>2016</th>
<th>2022</th>
<th>CAGR% (2016 – 2022)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Global Medical Robotics Market</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>5.38</td>
<td>14.56</td>
<td>18.1</td>
</tr>
<tr>
<td><strong>Robotic Systems</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2.90</td>
<td>7.73</td>
<td>17.8</td>
</tr>
<tr>
<td>Laparoscopy Surgical Robotic Systems</td>
<td>1.30</td>
<td>3.40</td>
<td>17.3</td>
</tr>
<tr>
<td>Neurosurgical Robotic Catheters</td>
<td>0.69</td>
<td>1.75</td>
<td>16.8</td>
</tr>
<tr>
<td>Orthopedic Robotic Systems</td>
<td>0.49</td>
<td>1.51</td>
<td>20.6</td>
</tr>
<tr>
<td>Steerable Robotic Systems</td>
<td>0.42</td>
<td>1.07</td>
<td>17.1</td>
</tr>
<tr>
<td><strong>Surgical Robots</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1.12</td>
<td>2.85</td>
<td>16.9</td>
</tr>
<tr>
<td>Assistive Robots</td>
<td>0.39</td>
<td>0.92</td>
<td>15.3</td>
</tr>
<tr>
<td>Therapeutic Robots</td>
<td>0.32</td>
<td>0.71</td>
<td>14.2</td>
</tr>
<tr>
<td>Orthotics Robots</td>
<td>0.26</td>
<td>0.55</td>
<td>13.7</td>
</tr>
<tr>
<td>Prosthetic Robots</td>
<td>0.11</td>
<td>0.30</td>
<td>17.4</td>
</tr>
<tr>
<td>Exoskeletons</td>
<td>0.04</td>
<td>0.38</td>
<td>47.3</td>
</tr>
<tr>
<td><strong>Rehabilitation Services</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.80</td>
<td>2.32</td>
<td>19.5</td>
</tr>
<tr>
<td>Telemedicine Robots</td>
<td>0.34</td>
<td>0.91</td>
<td>18.0</td>
</tr>
<tr>
<td>I.V. Robots</td>
<td>0.28</td>
<td>0.89</td>
<td>21.3</td>
</tr>
<tr>
<td>Pharmacy Robots</td>
<td>0.18</td>
<td>0.52</td>
<td>19.1</td>
</tr>
<tr>
<td><strong>Instruments and Accessories</strong></td>
<td>0.56</td>
<td>1.66</td>
<td>19.7</td>
</tr>
</tbody>
</table>

Source: Scalar Market Research Analysis
Applications
Robotic Surgery

The Minimally Invasive Robotic Surgery (MIRS) system at DLR coordinates three robots to perform delicate heart surgery.

RTI enables new medical techniques.
Simulation & Augmented Reality
Mevion’s Proton-Beam Radiation Therapy system zaps tumors with accelerated protons. The treatment must be continuous for 30-40 days; downtime endangers treatment success.

With Connext DDS, Mevion delivers dependable treatment at low cost.
Medical Imaging & AI

AI supporting clinical decision-making

Initial focus of AI in medical imaging

• Inputs (images) and outputs (classification, segmentation) leverage AI foundations in computer vision
• Imaging data volume & availability
• Less variability in data format
• No patient interaction
Medical Imaging & AI

Ahead:
• Data access, privacy, security
• Black box
• Regulatory approval
• Healthcare & patient acceptance
Current Topics in Medical Robotics
Laparoscopic Robots

Titan Medical Sport
Applications:
- Abdominal
- Cardiac
- Urological
- Gynaecology

Intuitive Da Vinci

TransEnterix Senhance
Orthopaedic Robots

Applications:
• Partial & total knee arthroplasty
• Total hip replacement
• Spine procedures: pedicle screw insertion
Endoluminal & Endovascular Robots

Applications:
• Bronchoscopy
• Cardiovascular & stroke
• Electrophysiology
• ENT
Surgical Robotics Pros & Cons

**PROS**
- Precision and accuracy in executing surgical plan
- Improved access to intervention site
- Reduces orthopaedic stress on user
- Reduces radiation exposure
- Training & Education: 2nd console, simulation
- Enables telesurgery

**CONS**
- Limited clinical evidence
- Lack of tactile feedback
- Cost
- Bulk and limited access to patient
- Limited device/implant options
- Limited to subset of procedures
- System setup
Closing

• Number and variety of Medical Robotics applications are exploding
• Good data drives positive patient outcomes
• Developers want to focus their efforts on applications
  • They need a platform that allows them to do that
• RTI Connext DDS:
  • Enables autonomy in the real world
  • Provides super-reliable operation with high-speed control
  • Connects many heterogeneous system together
  • Enables (coming soon) high-fidelity remote WAN operation
• Connext DDS can provide a basis for all types of autonomy