Lessons from 15 years of medical robotics research

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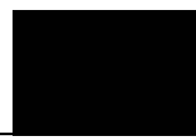
Introduction

- Born/raised in northern California
- Attended University of Oklahoma and Purdue University
- Entire career (15+ years) spent at University of Nebraska
- Fun facts:
  - I have friends/collaborators in France and enjoy visiting there, speaking French, and eating French food
  - I have 2 kids and neither one is very interested in engineering

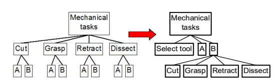
Outline

- Examples from the past 15 years (approximately chronological)
  - Surgical robotics
  - Rehabilitation robotics
  - Etc.
- With the benefit of hindsight…
  - Identifying problems worth solving in medical robotics
  - Solution approaches that (seem to) work

Example: multi-tool instrument for MIS

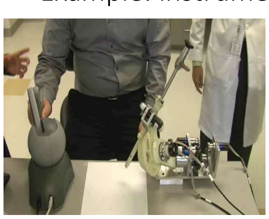


- Used known mechanisms (Geneva, cam…)
- Built on graph-theory background from PhD for tool sequencing
- Used functional decomposition and axiomatic design principles to reimagine instrument layout

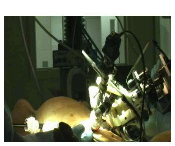


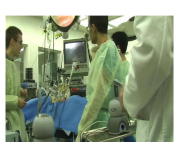
A = positioning, B = actuation

Example: instrument manipulators with RCM



- Leveraged knowledge of bevel gearing and spherical wrist mechanisms from MS research



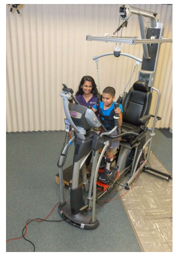


Example: infant surgical table

- Used functional decomposition and "voice of the customer" principles to identify need for *relative* motion between surgeon and patient
- Leveraged knowledge of bevel gearing and spherical wrist mechanisms from MS research

Example: rehabilitation elliptical machine (ICARE)

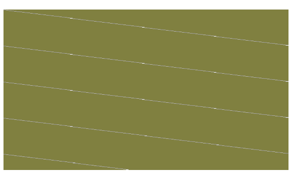
- Partnership with Madonna Rehabilitation Hospitals
- Grew out of the need for rehabilitation therapy equipment at more affordable prices
- Built on an already-existing elliptical machine
- Later adapted for pediatric use (smaller people)



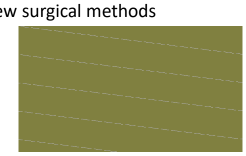
collaborator extraordinaire

Example: collaboration between RCM robot and in-vivo robot

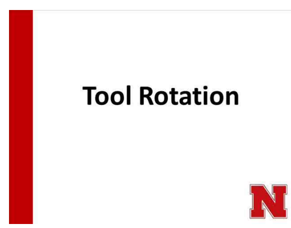
Example: material handling system for NOTES



- Uncovered new problems to solve based on emergence of new surgical methods

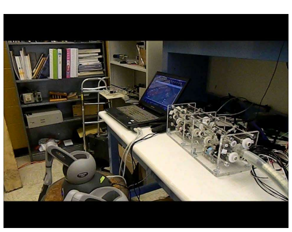


Example: multifunctional instruments



- Built on past experience with multifunctional instruments for MIS, but added a robotic twist

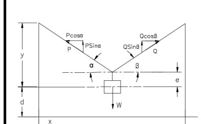
Example: single-incision surgical robots

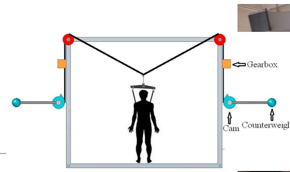


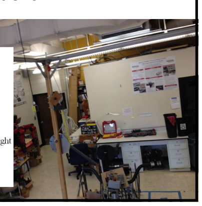
- Continued to expand to a more fully functional surgical system
- Combined functional requirements and solution approaches from previous projects

Example: passively balanced body-weight support using cable-suspended robot principles

- Built on learned experience from ICARE project
- Identified need for expanded capabilities
- Injected concepts from non-medical robotic applications







Example: surgical training using VR

- Collaboration emerged through surgical robotics "network"
- Comparison of existing technologies in a "reverse engineering" mindset revealed an unfilled gap

Too simple

Just right!

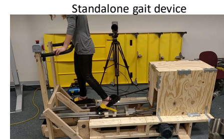
Too complex

Example: scaling gait rehabilitation for pediatric patients

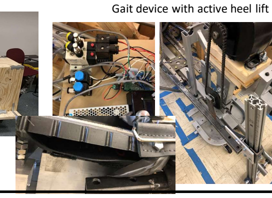
- A natural next step for the ICARE project – serve more patients
- Integrated elements of mechanisms theory and mechanical design

Pediatric ICARE

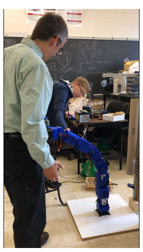
Standalone gait device



Gait device with active heel lift



Example: modular assistive robot for paralyzed patients



- Built on lots of previous projects in modular robotics
- Leveraged existing collaborations (ICARE)

Identifying good problems in medical robotics

- Meet people who know more than you
  - Collaborators
  - Clinicians
  - Friends of friends
- Ask what their biggest complaints are (relevant to your technology area)
- Find out their idealistic wishes (voice of the customer)
- Consider the potential impacts
  - Saving money
  - Saving time
  - Achieving better medical outcomes

Solution approaches that (seem to) work

- TRIZ/SCAMPER (substitute, combine, adapt, modify/magnify/minify, put to another use, eliminate, and reverse)
  - Draw on knowledge/strengths you already have
  - Reject/question the status quo
  - Ask "why not?" to idealistic wishes
  - Use analogies
- Lateral thinking
- Cross-pollination of ideas
- Functional decomposition
  - Understand and organize requirements
  - Verb (action-object) hierarchy
- Axiomatic design
  - Simplify, reduce complexity
  - Directly use design parameters/freedoms to address critical functional requirements in a decoupled way

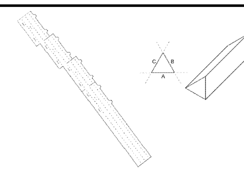
Elements supporting creative problem-solving

- Creative attitude (confidence in your creative abilities)
- Unlocked imagination (asking questions)
- Persistence
- Open-mindedness
- Suspense of judgment
- Clear problem boundaries (e.g., good problem statement)

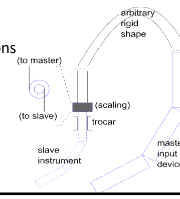
Obstacles to creative problem-solving

- Perceptual (stereotyping, information overload, limiting the problem unnecessarily, fixation, priming or cues)
- Emotional (fear of risk, unease with chaos, aversion to new ideas, lack of motivation)
- Intellectual (poor problem representation, memory block, insufficient knowledge base, incorrect information)
- Environmental (physical environment, criticism)

Most recent example



- Create link/joint structure
  - Kirigami/origami – cutting and folding of paper
  - Dashed lines for folds, solid lines for cuts
  - Standard processes (laser cutting) in planar materials
- Manual control
  - Master-slave with matched kinematics, tendon connections
  - Pulleys for size/motion scaling
  - WYSIWYG motion (no mirror/lever effect)



Conclusion

- Applying engineering principles to human well-being is great fun!
- Build collaborative networks and listen to others
- Identify high-value, high-impact problems to solve
- Learn to think creatively
- Go out and do good

- Questions?