“Preliminary Evaluation of a New Microsurgical Robotic System for Head and Neck Surgery”

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Project Team 2

Project Overview - Team 2

Title: Kinematic Simulation, Calibration, and Accuracy Assessment for the Galen Robot

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Mentors: Dr. Taylor, Dr. Munawar, Max Li, Henry Phalen

Goals:

- ➔ 1. Successfully model the kinematics and dynamics of the Galen in a simulation environment
- ➔ 2. Calibrate the Galen to improve end effector tool tracking accuracy

Figure 1: Full CAD assembly of the Galen Mk. 2 prototype platform [5]

Introduction and Background

To address precision and navigation challenges in otolaryngology, researchers at the LCSR developed the **R**obotic **E**NT **M**icrosurgery **S**ystem (REMS) robot in 2012.

Goals of the study:

1. Evaluate the REMS prototype through a clinical use case exercise
2. Conduct a technical evaluation to compare performance against design specifications [6]

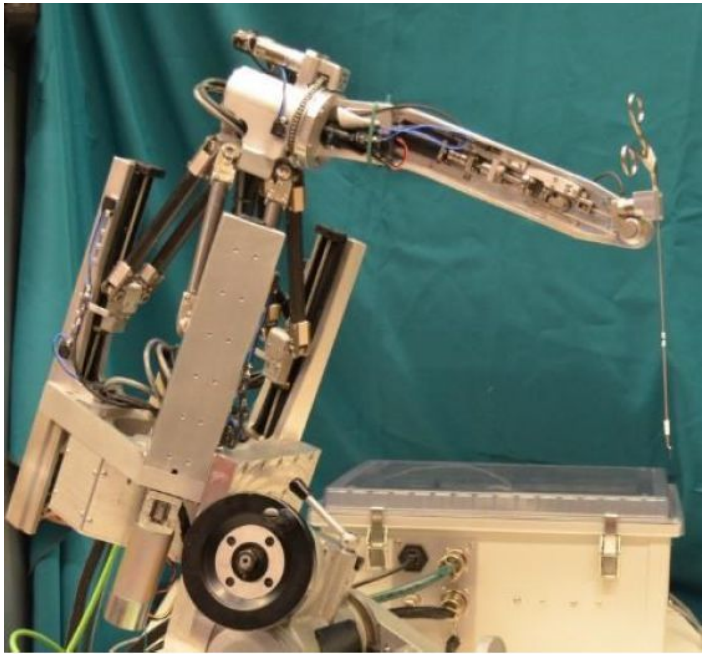


Figure 2: Prototype of the REMS microsurgery robot developed by the LCSR [2]

Why This Paper/Study?

1. Frames clinical problem and rationale behind REMS design
2. Describes REMS design in detail
3. Puts theory to practice for system validation and verification

REMS clinical use case

Importance of Galen Mk. 2 calibration

System Description: REMS Robot

- 5 DOF
- Admittance style, cooperatively-controlled robot
- Offers unique advantages in ENT surgery

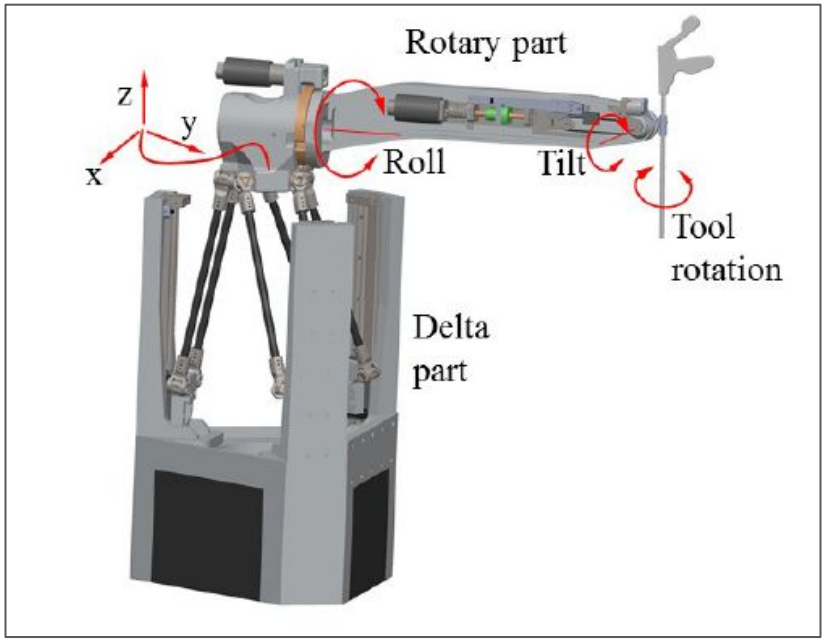


Figure 3: CAD model of prototype REMS platform with labeled delta, roll, and tilt stages [3]

Methods: Precision Augmentation Evaluation

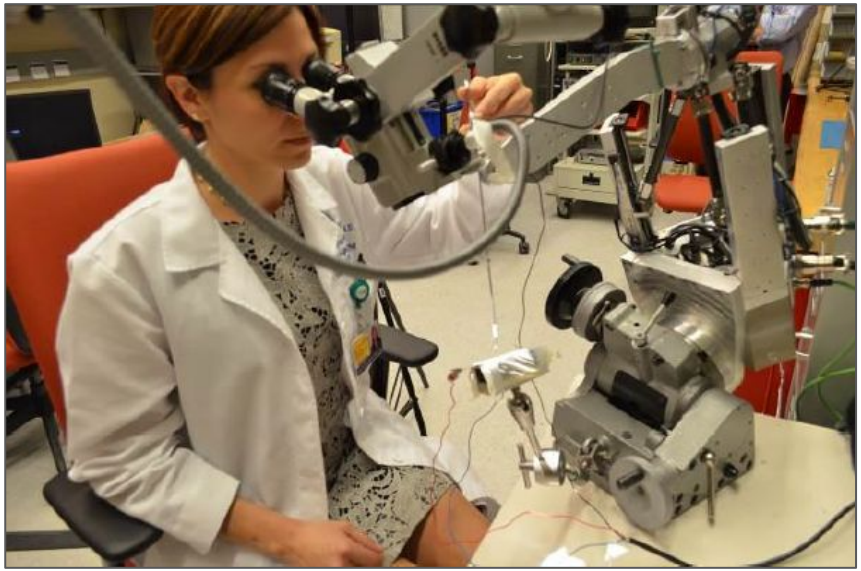


Figure 4: Surgeon performing REMS-assisted microlaryngeal phonosurgery exercise [1]

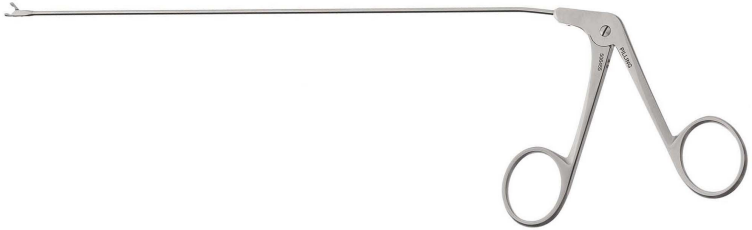


Figure 5: Example of microlaryngeal forceps used in this exercise; needle *fixed* to forceps [7]

Methods: Precision Augmentation Evaluation

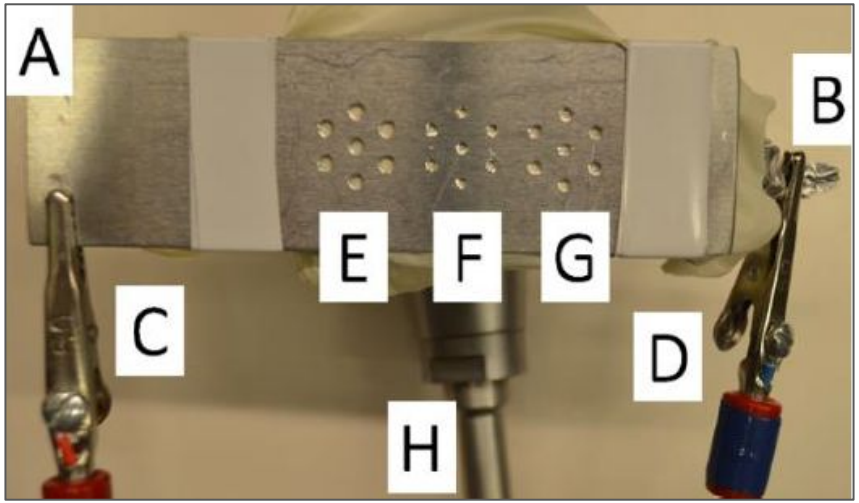
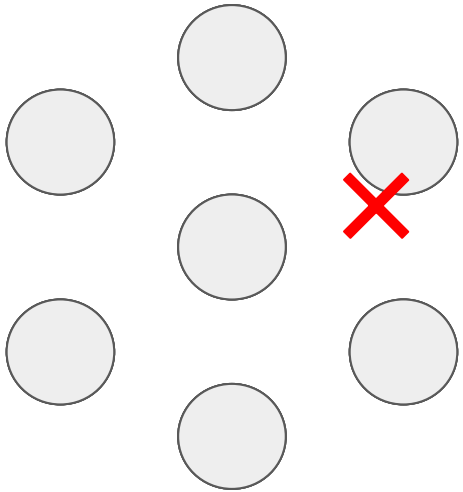


Figure 6: Microlaryngeal phonosurgery testing apparatus; perforated aluminum plate (A), foil sheet (B), failure electrode (C), success electrode (D), 2.0 mm holes (E), 1.2 mm holes (F), 1.5 mm holes (G), passive support stand (H) [1]



X - initial (home) needle tip position
X - successful needle insertion
X - failed needle insertion

Results: Precision Augmentation Evaluation

- ➔ REMS-assisted exercise more successful, but slower
- ➔ Significant differences in performance based on skill level

Methods: Technical Evaluation

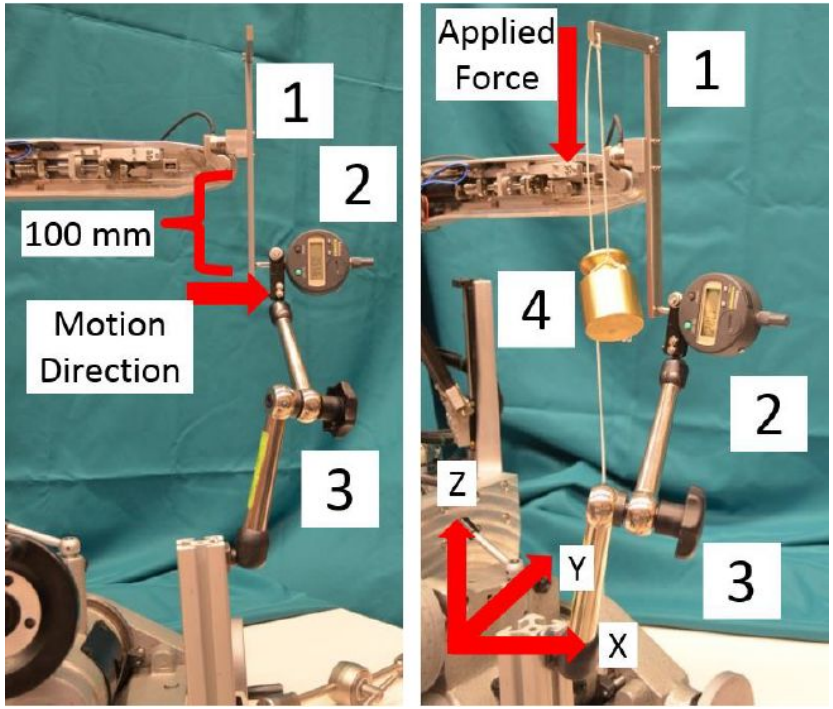
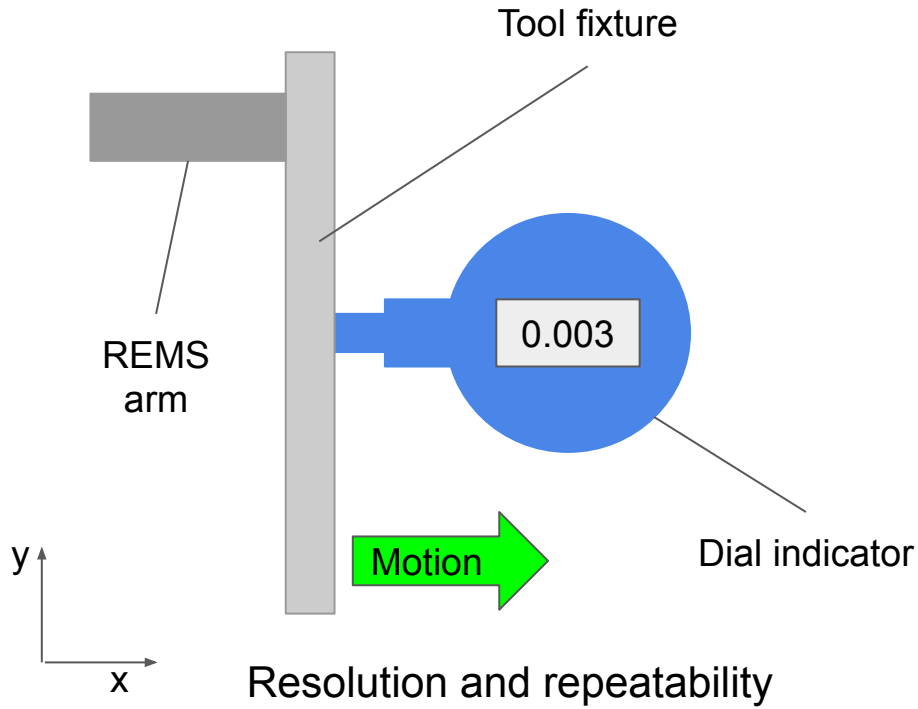
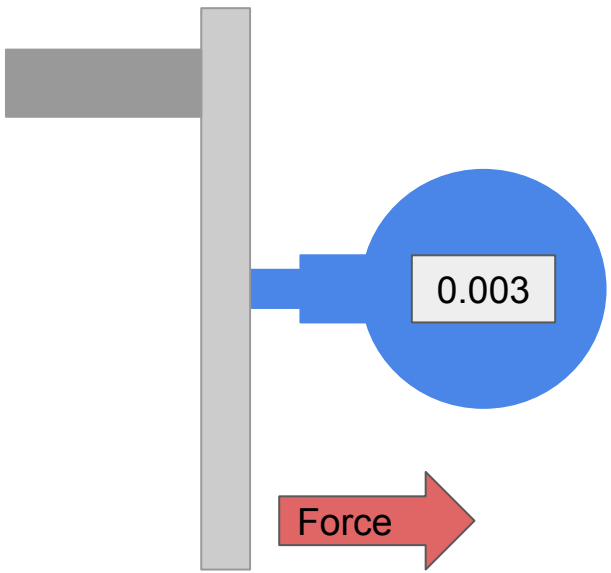


Figure 7: Experimental set-ups for resolution and repeatability tests (left) and stiffness test (right); tool fixture (1), micron resolution dial indicator (2), dial indicator support arm (3), weight for stiffness testing (4) [1]

Methods: Technical Evaluation



Resolution and repeatability (single DOF)



Stiffness (for a single DOF)

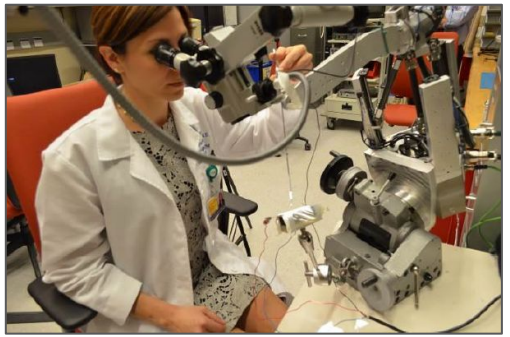
Results: Technical Evaluation

- ➔ REMS meets individual resolution, repeatability, stiffness requirements
  - Resolution: 0.011 mm < 0.025 mm
  - Repeatability: 0.105 mm ≅ comparable robots
  - Stiffness: 0.855 mm
- ➔ Worst-case error (combination of all sources) is a concern

Limitations

Precision augmentation evaluation

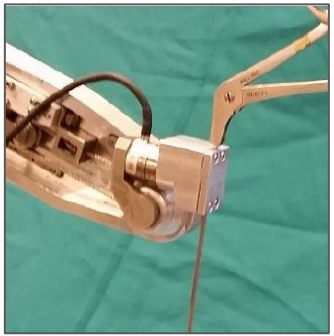
1. Small number of subjects
2. Subjects not well-acquainted with the robot
3. Set-up limitations



[1]

Technical evaluation

1. All experiments done with REMS in home position
2. Force sensor compliance

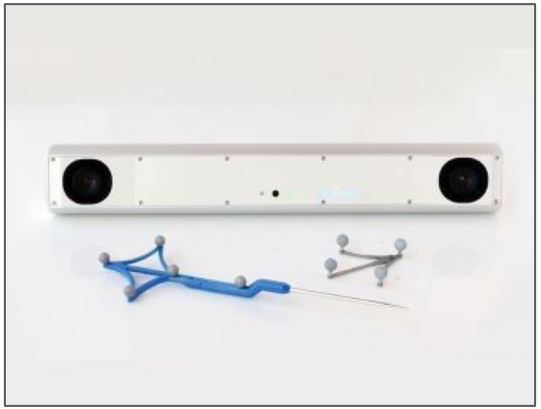


[2]

Future Works

[2]

Design changes!



[8]

Calibration!

[5]

Future prototypes!

Works Cited and References

[1] K. Olds, P. Chalasani, P. Lopez, I. Iordachita, L. Akst and R. H. Taylor, "Preliminary Evaluation of a New Microsurgical Robotic System for Head and Neck Surgery," in IEEE IROS, Chicago, 2014.

[2] K. C. Olds, “Robotic Assistant Systems for Otolaryngology - Head and Neck Surgery”, Ph.D Thesis, The Johns Hopkins University, 2015.

[3] C. He, K.C. Olds, I. Iordachita, and R. H. Taylor, “A New ENT Microsurgery Robot: Error Analysis and Implementation”, in Proc. IEEE Int. Conf. on Robotics and Automation (ICRA), 2013, pp. 1221-1227.

[4] I. Fleming, M. Balicki, J. Koo, I. Iordachita, B. Mitchell, J. Handa, G. Hager, and R. Taylor, “Cooperative Robot Assistant for Retinal Microsurgery”, in MICCAI, New York, 2008.

[5] Taylor, ”Kinematic Calibration and Improved Accuracy for Galen Robot”, CIS II, 2/2/2020, Baltimore

[6] C. He, K. Olds, L. Akst, W. Chien, M. Ishii, I. Iordachita and R. Taylor, "Evaluation, optimization, and verification of the wrist mechanism of a new cooperatively controlled bimanual ENT microsurgery robot," in Proc ASME IMECE, Houston, 2012.

[7] https://www.jedmed.com/products/laryngoscopy-forceps-1

[8] https://www.medicalexpo.com/prod/atracsys/product-100844-713103.html