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Project Background Reading Presentation on

"Cable Length Estimation for a Compliant Surgical Manipulator"

Sean M Segreti, Michael D.M. Kutzer, Ryan J Murphy and Mehran Armand

May 14-18, 2012 IEEE ICRA, River Centre,
Saint Paul, Minnesota, USA

Interfacing APL Snake End Effector to LARS

Group 3 **Piyush Routray** & Ashish Kumar

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Statement of Our Project

The main and static aim of our project is to interface the APL Snake end effector to the LARS and achieve end-point control.

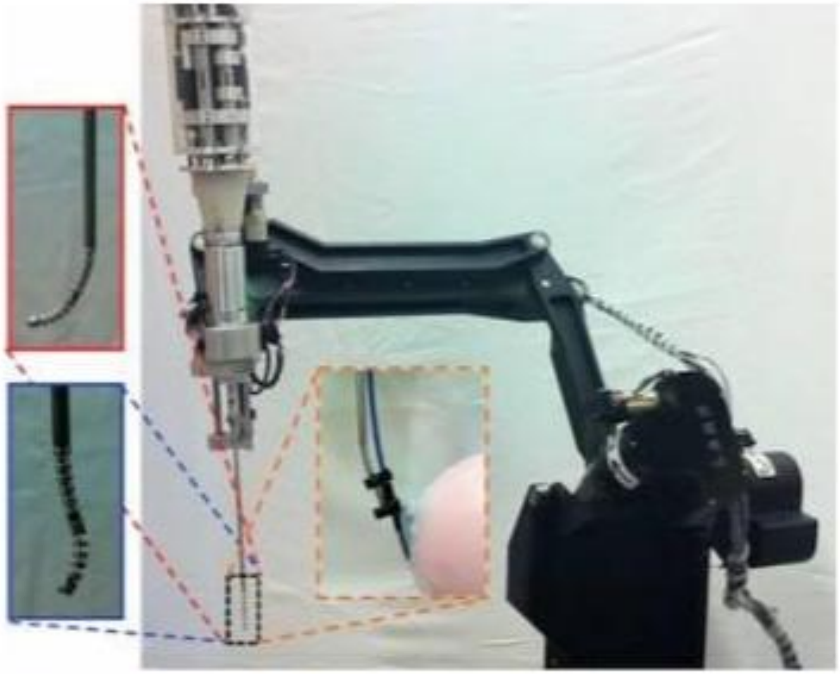

Image from: Tutkun Şen: *Elastography with LARSnake Robot*

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Title of Paper: **Cable Length Estimation for a Compliant Surgical Manipulator.**
Authors: Sean M Segreti, Michael D.M. Kutzer, Ryan J Murphy and Mehran Armand.
Affiliation: Johns Hopkins University – Applied Physics Laboratory.
Presented at: *IEEE Intl. Conf. On Robotics and Automation*, River Centre, Saint Paul, Minnesota, USA. 14th - 18th May 2012.

Reason for Selection of the Paper for Today's Presentation.

- Discusses 'APL-Snake', one of the key components of my project.
- Acquaints us with the initial challenges faced to control the movement of the manipulator.
- **Might help me in assisting in solving a dependency which comes into act in fairly later stage of our project.**
- Work done by our project mentors and thus, is a part of larger project, of which my and Ashish Kumar's project is also a part of.

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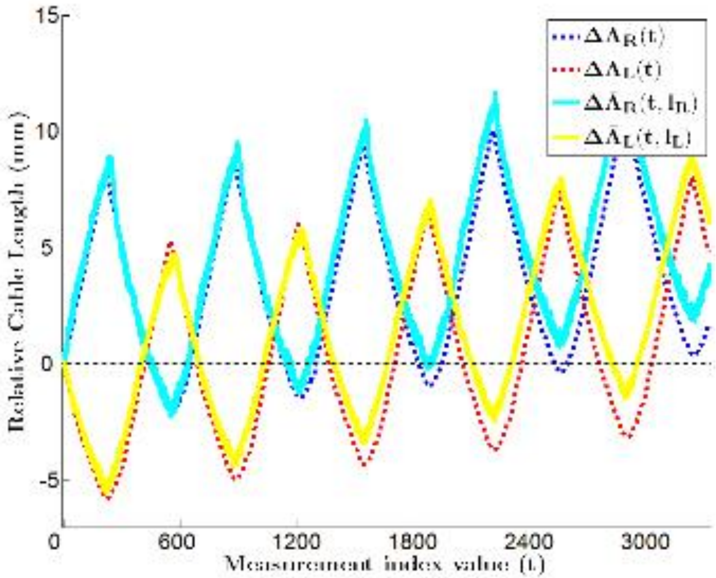
Summary of the Problem

In 2011, the authors had presented a design of an under-actuated, hyper redundant, snake-like manipulator for surgical removal of osteolysis behind total hip arthroplasties. Designed by researchers at the JHU and APL, the manipulator has been nicknamed the APL-Snake. It was primarily controlled in a single plane using two independently actuated cables. However, cable length estimation for the actuation remained a challenge. Optimum length of cable, limit points, material for the cable posed as several questions in the minds of the researchers.

Key Result

Effectiveness in predicting drive cable lengths from manipulator configurations was primary achievement. It paved way for achieving desired configurations from prescribed cable lengths with 'reasonable' accuracy. (please refer the plot below, presented in the paper.)



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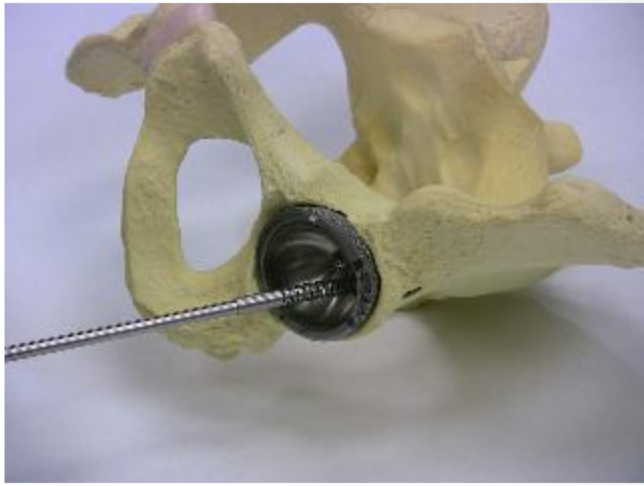
Significance of Key Result

- Detailed and articulated presentation of algorithm to deduce cable length for a desired manipulator configuration.
- Removes ambiguities about methods to estimate length of cables that control the manipulator configurations.
- Clarifies the reason for the use of '304 Stainless Steel' for manufacturing the cables.
- Addresses questions regarding related challenges such as:
  - Cable Slip and Elastic Deformation.
  - Cable Yielding.
  - Resistance in movement of cable between the drive channel.

Necessary Background



- The APL Snake was initially developed with an intention of use in hip osteolysis removal surgery. It is an improvement over existing tools to access the acetabular component of THA.
- Constructed from two interference-fit, thin walled super-elastic nitinol tubes to produce dexterity with an outer diameter of **5.99mm** and inner diameter **4mm**.
- Planar constrained bending preserves out of plane structural stability.
- The related work in this field enumerate ‘backbone curve algorithm’, ‘elephant trunk manipulators’ , use of virtual segments as possible solutions for control of manipulator motion.
- 28 pin joints are to used to achieve dual backbone kinematic model as the basic frame of the APL-Snake.
- Expected not to depend completely on visual feedback and hence, should compensate with other technique to estimate manipulator configuration.

What the authors have done?

- Review of the Manipulator and Kinematic Model. (refer fig.2)
- Cable Length Prediction. (refer fig.3)

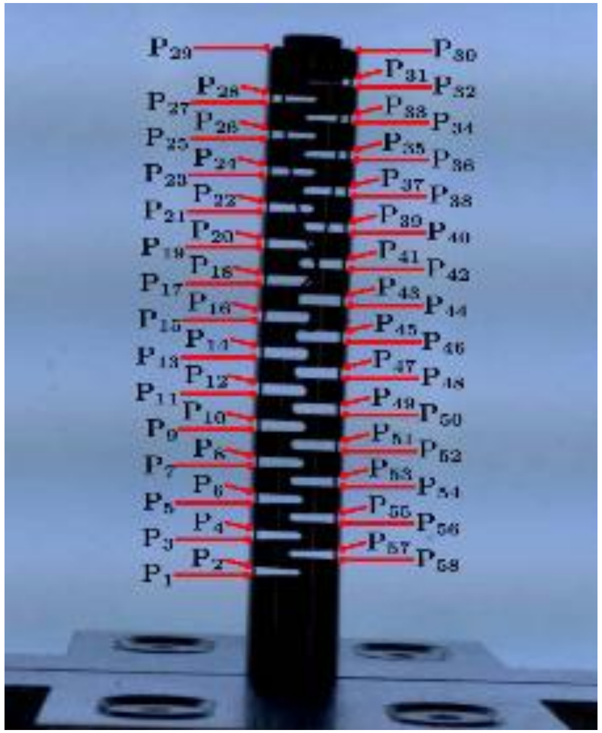


fig 2. 58 digitized points

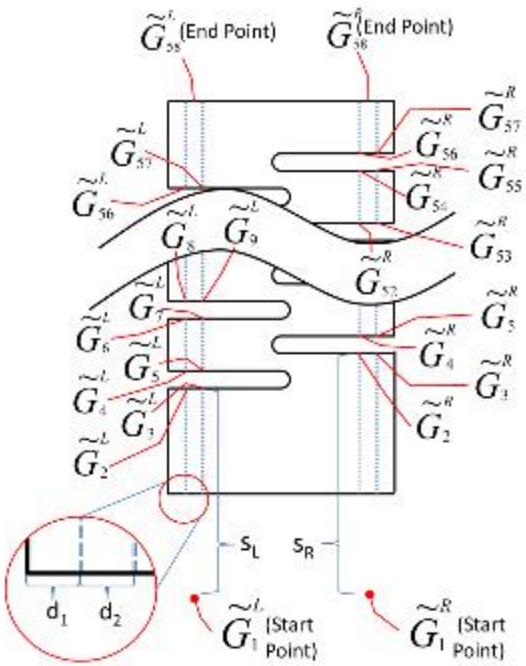
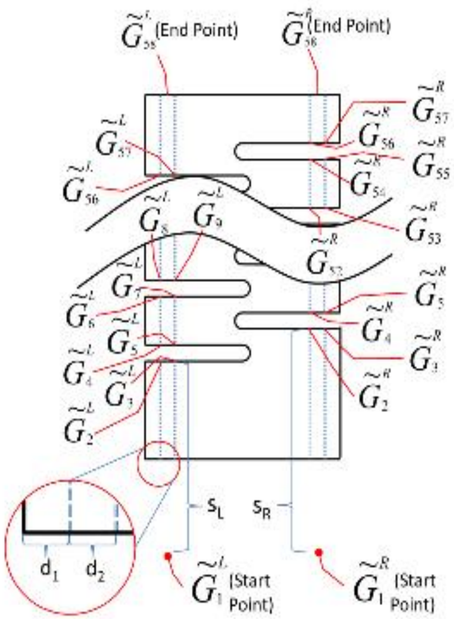


fig 3. depiction of cable channel boundaries.

(images used here are from the paper)

Cable length Prediction (cont…)

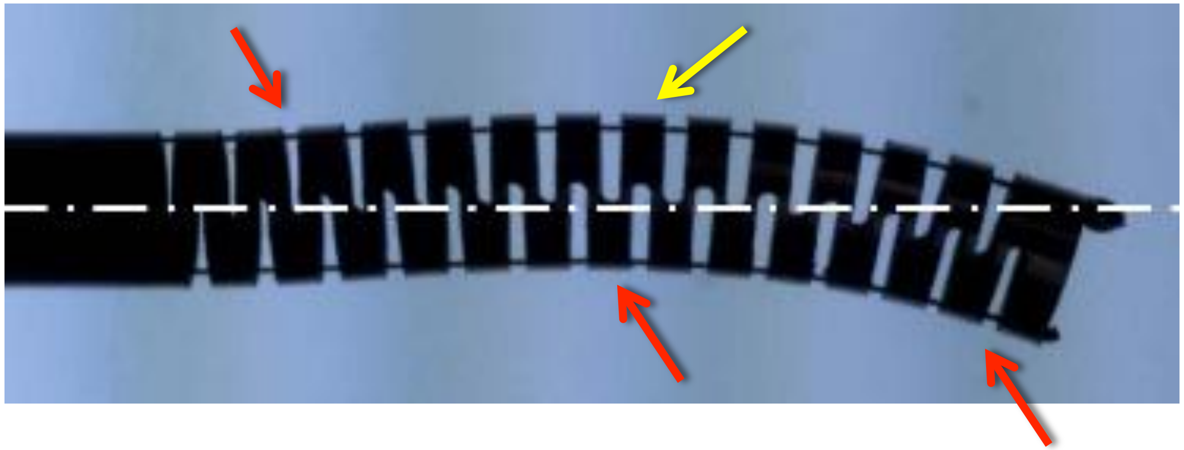
- Initial condition that when fixed to the ends of manipulator, the cables are centered in the top of their respective channels.
- 0.69mm diameter of the channels is more than 0.254mm diameter of cables, and thus facilitates resistance free movement. (refer to the figure below from the paper.)



Cable length Prediction (cont…)

- However, during bending, the cables rest along the edges with clear inflection points, thus making assumption of constant curvature invalid. (refer fig.5, taken from the paper)

fig 5.



Cable length Prediction (cont…)

- Dijkstra's algorithm is used to calculate the shortest path using distance weighted graph of valid connections between channel boundary points. For example, considering the two cases pondered over in the paper:

In the first, straight DM scenario, algorithm yields:

$$\tilde{\Lambda}_L = \|\tilde{G}^L_{58} - \tilde{G}^L_1\|$$
$$\tilde{\Lambda}_R = \|\tilde{G}^R_{58} - \tilde{G}^R_1\|.$$

In the second, left bent DM scenario, algorithm yields:

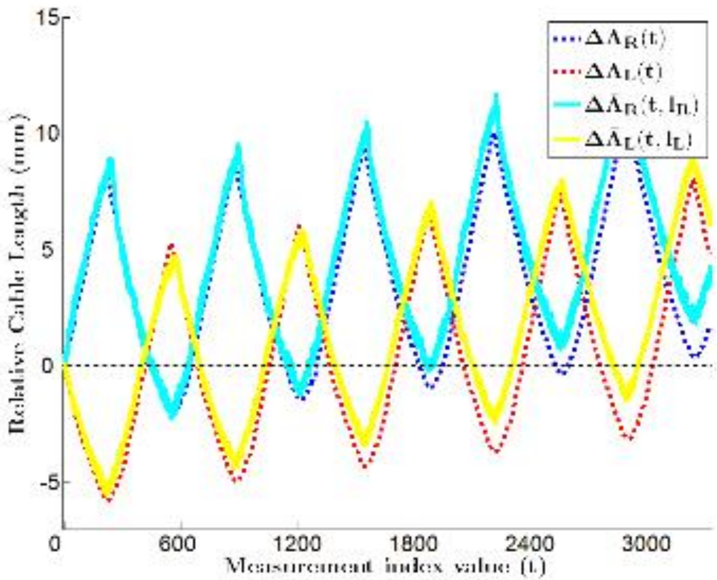
$$\tilde{\Lambda}_L = \|\tilde{G}^L_2 - \tilde{G}^L_1\| + \sum_i \|\tilde{G}^L_{i+2} - \tilde{G}^L_i\|$$
$$\tilde{\Lambda}_R = \|\tilde{G}^R_2 - \tilde{G}^R_1\| + \sum_i \|\tilde{G}^R_{i+2} - \tilde{G}^R_i\|$$

where $i = \{2, 4, 6, \ldots, 56\}$.

Assessment Of The Work

Strength(s)

- The work, as I have earlier expressed, is detailed and explanatory.
- Authors have taken utmost care while addressing problems such as cable yielding, cable slip and elastic deformation.
- Repeatability and accuracy of the algorithm have been verified by the authors over various set of experimental conditions. (refer adjacent figure)



Assessment Of The Work (cont…)

Weakness(s)

- Complications in this method would increase if more DoF is desired.
- The paper doesn't enumerate comparison with any other material for construction of cables.
- Assumption of zero friction between cable and manipulator is a very ideal case and may not be practically feasible.
- Mention of the specifications of stepper motors being used is unavailable.

Possible Next Steps for This Work

- Development of a new actuation unit to eliminate cable slip entirely.
- Incorporate estimation of cable-manipulator friction interaction.
- Consider case of a tool being guided through the Snake.

Conclusion

- The suggestions for improvement were discussed with our mentor Ryan Murphy and he shared draft of paper to be published this year.
- I was also made aware about the work that has been accomplished as of now and limitations regarding certain tasks.
- The algorithm provided in this paper however remains basis of future work and thus is very important.

THANK YOU!