Generalizable Pose Estimation for Soft Robots using RFID Tags

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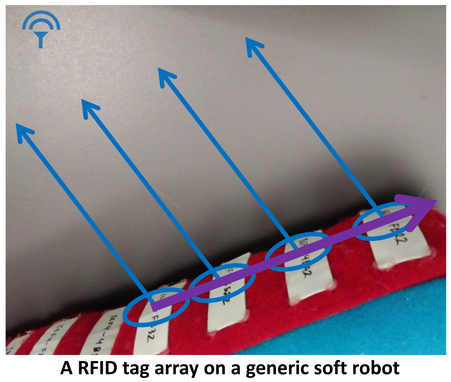
Soft robots need versatile sensing strategies for estimating position

- Encoders don't work on soft robots so most sensing is highly application-dependent
- We create a form-agnostic approach using RFID tags and finite element simulations

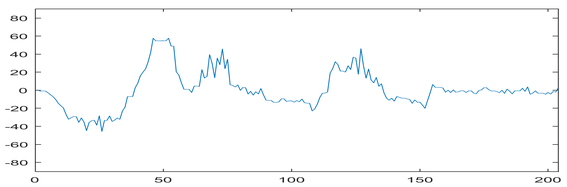
Arrays of RFID tags provide angular relations to an antenna

- We use an antenna to broadcasts a radio wave into the environment
- The tags modulated this signal and a reader decodes tag's unique ID and the phase angle and power of the received signal



A RFID tag array on a generic soft robot

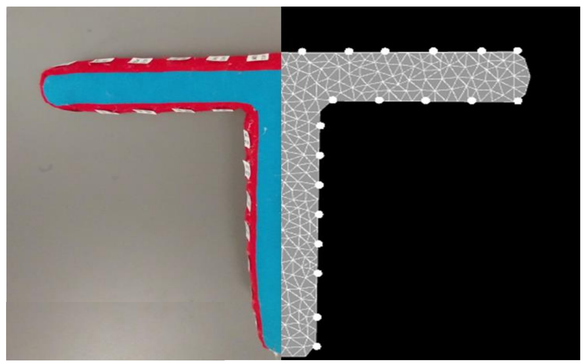
- The Multiple Signal Classification algorithm computes the angle between the **signal vector** and the **axis of a linear tag array**



Sensed angle vs. number of samples for one array

- The angle is updated as new data is collected

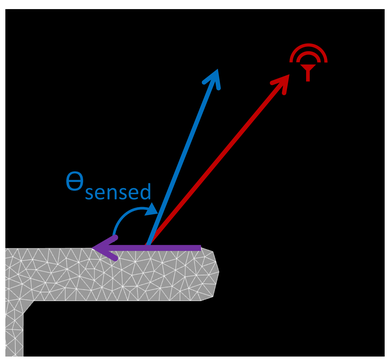
The sensed angle informs a finite element model



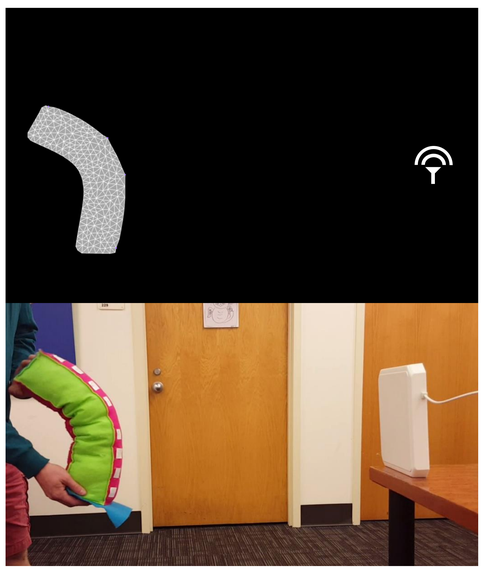
Real world robot vs. the finite element discretization

- Based on the boundary, we discretize the robot into small geometric elements that resist deformation.
- Using the locations of the nodes, we can map other elements, notably **arrays**, onto the mesh

For each **array** in the mesh, a vector, rotated by the **sensed angle**, is projected and compared to the **current** vector pointing to the simulated reader



An illustration of the sensing objective



Top: the simulated object
Bottom: real world

By minimizing the difference between **angles**, within the constraints of the mesh, we obtain a feasible pose

Soft constraints are robust, scalable, and stackable

- We use Newton's method to **compute the lowest-energy configuration** for the collection of nodes, based on mesh, angular and world-space constraints

$$E_{sensing}(x) = \alpha e^{-kt} \sum_{i=0}^{n} (\theta_{sensed} - \theta_{simulated})^2$$

Note that $\Theta_{simulated}$ is a function of nodal positions, x

- The sensing energy for each **array** is proportional to the squared difference between **angles** and how recently a real-world measurement was received
- Additional functions can be added for regularization, emergent behaviors, and sensor fusion

Discussion and Future Work

- This system can estimate the pose of soft robots with only low-cost RFID technology and a finite element model
- Future work will focus on filtering the data and validating the approach in 3D

Acknowledgements

- The author would like to thank Rachel Burcin and Dr. John Dolan for their incredible dedication to the Robotics Institute Summer Scholars program
- The National Science Foundation for funding this work

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