Generalizable Pose Estimation for Soft Robots using RFID Tags

David Russell, James Bern, Stelian Coros

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 broadcast a radio wave into the environment
- The tags modulated this signal and a reader decodes each tag’s unique ID and the phase angle and power of the received signal

The sensed angle informs a finite element model

- 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

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

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

Note that \( \theta_{\text{sensed}} \) 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