Joint Estimation of Position and Gain for RFID-Tag Assisted Surgery Support System

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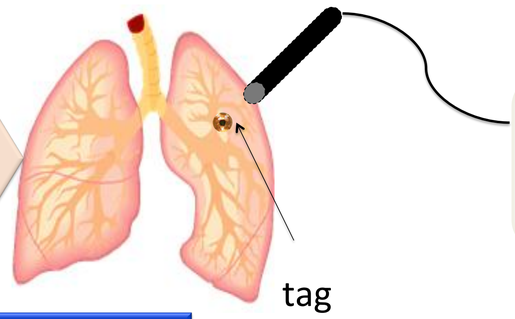
RFID-tag assisted surgery support system

the sensor antenna is inserted into body through an endoscopic channel, and it receives an RFID signal

The tag position is estimated from strength of the received signal

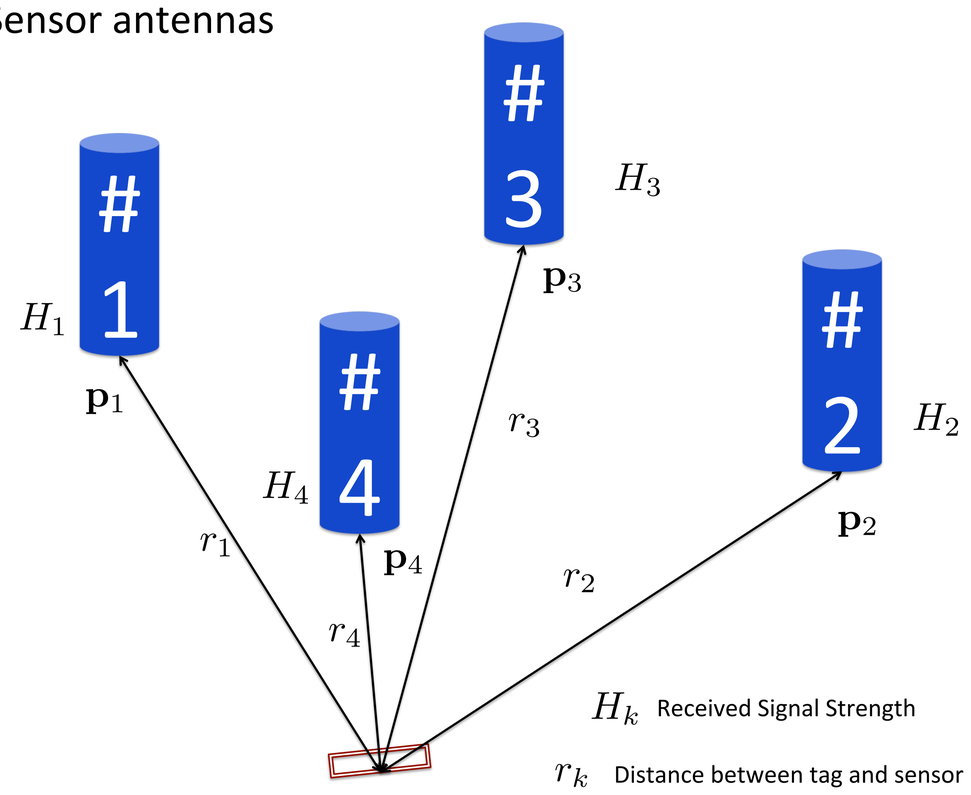


The tag is implanted near the lesion through bronchoscope before the operation

3D positioning is required

3D Positioning

Sensor antennas



H_k Received Signal Strength

r_k Distance between tag and sensor

$$\mathbf{p}_k = [p_{x,k}, p_{y,k}, p_{z,k}]$$ The position of the k-th sensor antenna

Problem in 3D positioning

The cost function is given by

$$J(\mathbf{t}, \alpha) = \sum_{k=1}^{N} \left(\sqrt{\frac{\alpha}{H_k}} - ||\mathbf{t} - \mathbf{p}_k|| \right)$$

Tag Position $\mathbf{t} = [t_x, t_y, t_z]$

Tag Gain α

The tag position is obtained by searching for $\mathbf{t}$ which minimizes the cost function.

$$\rightarrow \quad \tilde{\mathbf{t}} = \arg\min_{\mathbf{t}} J(\mathbf{t}, \alpha)$$

Problem

- Tag gain information α is unknown at the receiver.
- Without tag gain information, the distance is not estimated correctly.

Relationship between distance and signal strength

$$H_k = \frac{\alpha}{r_k^2}$$

Distance can be estimated by applying the measured signal strength to:

$$\tilde{r}_k = \sqrt{\frac{\alpha}{H_k}}$$

Solution

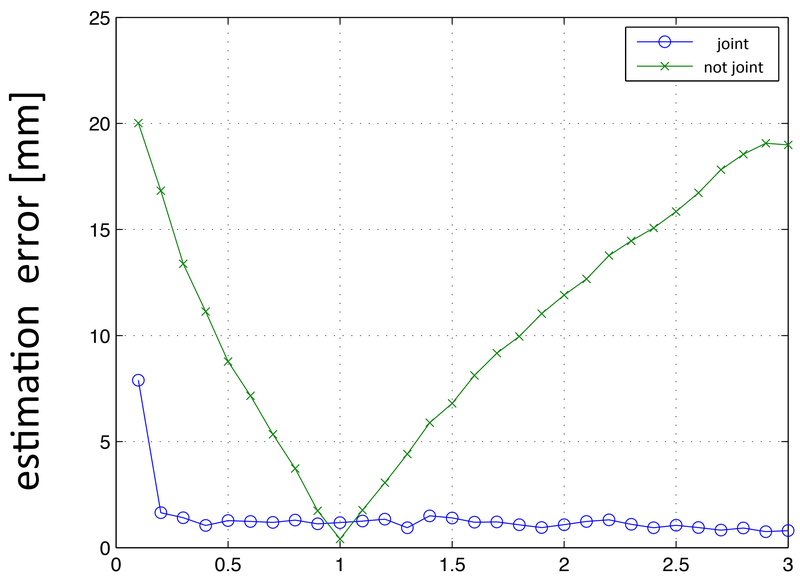
- the tag gain and the position are estimated simultaneously.
- the tag position and gain are estimated by minimizing this estimation error criteria.

$$\rightarrow \quad \tilde{\mathbf{t}}' = \arg\min_{\mathbf{t}'} J(\mathbf{t}')$$

Joint tag position and gain $\mathbf{t}' = [\mathbf{t}, \alpha]$

Result

The estimation error performance against the initial $\tilde{\alpha}$



- Proposed algorithm can estimate the tag position even if initial estimated tag gain tilde α is different from true tag gain α.
- This means that the proposed scheme is capable of estimating the tag position accurately even if the tag gain is not known at the receiver.

In order to evaluate the performance of the proposed solution, the sequential quadratic programming (SQP) is used for the minimization.