Adaptive Near-Field Imaging with Robotic Arrays

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Imaging and Robotics

Why imaging?
- Surveillance
- Search and rescue
- Archaeology

Why robots?
- Emerging in many fields
- Can go to hazardous places
- Flexible positioning

Robotics in Imaging

- How to benefit from robots in near-field imaging?

Near-field beamforming

- Difficult problem of considerable interest
- Optimization problem:
  - Combine image obtained from optimized array with the previous image
  - No prior information: additive fusion of images from arrays with any configuration
  - Example: four arrays at four different sides of workspace
  - Threshold the image using $\gamma_{th}$, which can be determined using Neyman-Pearson criterion
  - Create enclosing circles
  - Binary object mask $O(x)$

Point Spread function has a high spread

Multiview imaging improves imaging quality
- Multiplicative and additive fusion
- Relies on fixed array locations
- Robots can adaptively synthesize arrays to further improve imaging quality

Narrowband Phased Array Imaging

- Point Spread function has a high spread
- Multiview imaging improves imaging quality
  - Multiplicative and additive fusion
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Proposed Adaptive Imaging Algorithm

Initial Sensing and Imaging

- No prior information: additive fusion of images from arrays with any configuration
- Example: four arrays at four different sides of workspace

Finding Object Regions

- Threshold the image using $\gamma_{th}$, which can be determined using Neyman-Pearson criterion
- Detecting probability
- False alarm probability
- Create enclosing circles
- Binary object mask $O(x)$

Finding Most Uncertain Region

- Generate super-pixels for the remaining part of the image
- Choose super-pixel whose mean intensity is closest to $E(I(x)|I(x) < \gamma_{th}, H_2)$
- Binary uncertainty mask $U(x)$

Optimal Robotic Array

- Requirement 1: PSF Focus
  - PSF is concentrated inside a cone
  - $U(x)$ be inside the cone
  - $O(x)$ be outside the cone

Finding Optimal Robotic Array

- Requirement 2: proximity to uncertain region
  - Objects farther from array outpowered by closer objects
  - $U(x)$ preferred closer to array than $O(x)$

Conclusions

- New framework for adaptive imaging using robotic arrays
- Proposed a method for detecting object areas and areas of high uncertainty
- Optimized the best array to image the uncertain region
- Simulations show efficacy of algorithm to remove uncertainty

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Results

- Example 1: uncertain regions are empty regions
- Example 2: uncertain regions contain objects