Complexity Analysis of Massive Wireless Imaging

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Why Image at RF frequencies?

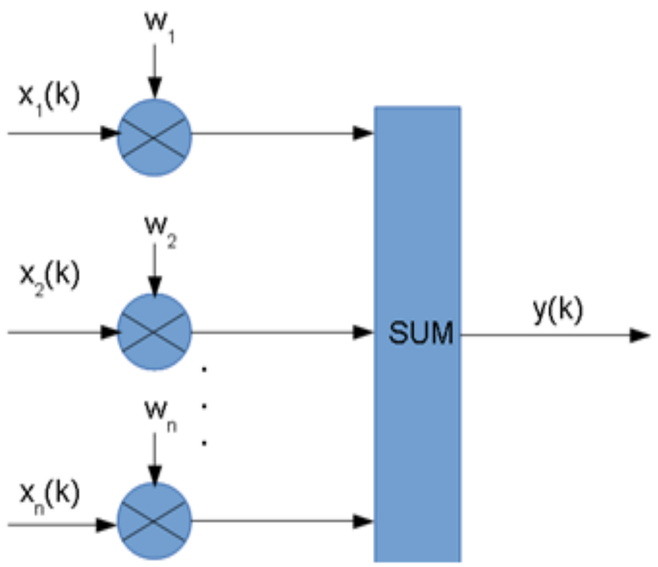
Modern digital hardware can obtain raw RF waves and process them to image beyond what is possible with traditional cameras.

Different physical properties allow new use cases, e.g. “seeing” through smoke.

How to Capture an RF Image

Angle of Arrival (AOA) Computations

Use beamforming to find intensity in the beam direction, combining intensities over all beams to form image.



Why Image with a Massive Array?

More antennas
→ Narrower beam width
→ Higher resolution image

Complexity Limits Frame Rate

What is complexity?

A measure of the amount of time and space required by an algorithm.

Why do we care about complexity?

More antennas → higher complexity
→ lower frame rate

Imaging Complexity

1. Compute array correlation matrix $\mathbf{R}$.

$O(TN^2)$, N is # of antennas

2. Compute inverse for Capon.

$O(N^3)$

3. Search 2D angular space (θ, φ).

$O(S_\varphi S_\theta N^2)$

S_φ : size of azimuthal search space

S_θ : size of elevation search space

Overall Complexity

Bartlett: $O\big((T + S_\varphi S_\theta)N^2\big)$

Capon: $O\big(N^3 + (T + S_\varphi S_\theta)N^2\big)$

Transport Complexity

Correlation matrix $\mathbf{R}$ must be computed in central processor.

$$\frac{NM_s b_{ADC}}{f_{transport}} < \frac{1}{60Hz}$$

Future Work

How can we reduce complexity?

Theoretical Work

Design a distributed algorithm and system, with each RF chain allocated a local processor. This will reduce both transport and imaging complexity.

Experimental Work

Implement distributed algorithm on multiple WARP v3’s onboard FPGAs .

Characterize entire system performance using experimental base station: Argos.

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