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THE UNIVERSITY OF HONG KONG

Project Code Homepage

ACM MobiCom 2026

RF-LEGO: Modularized Signal Processing–Deep Learning Co-Design for RF Sensing via Deep Unrolling

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Motivation & Design Principles

Classical signal processing

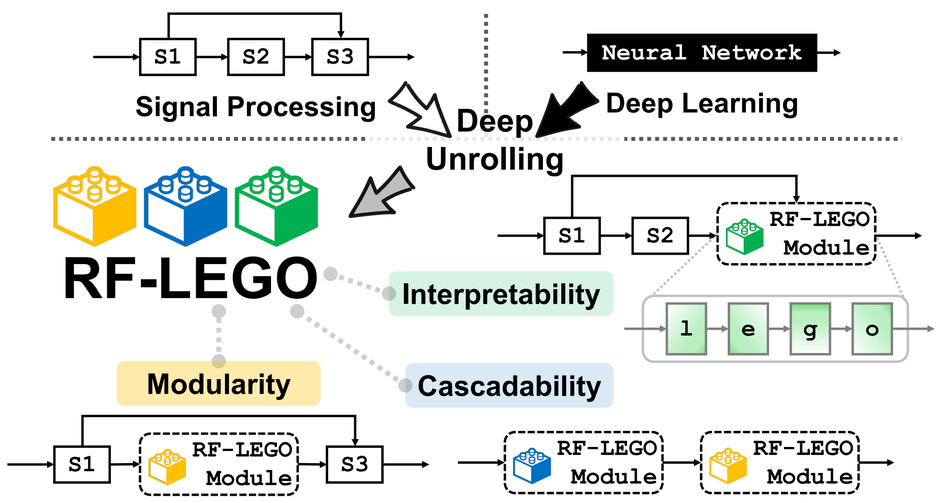
Explicit operators. Meaningful interfaces.

- ✔ Inspectable frequency and angle spectra.
- ✔ Blocks cascade into many sensing pipelines.
- ✖ Handcrafted parameters require manual tuning.

Task-specific deep learning

Learned adaptation. Entangled representations.

- ✔ Adapts to complex measurements.
- ✖ Often optimized end to end for one task.
- ✖ Internal features can be hard to reuse.

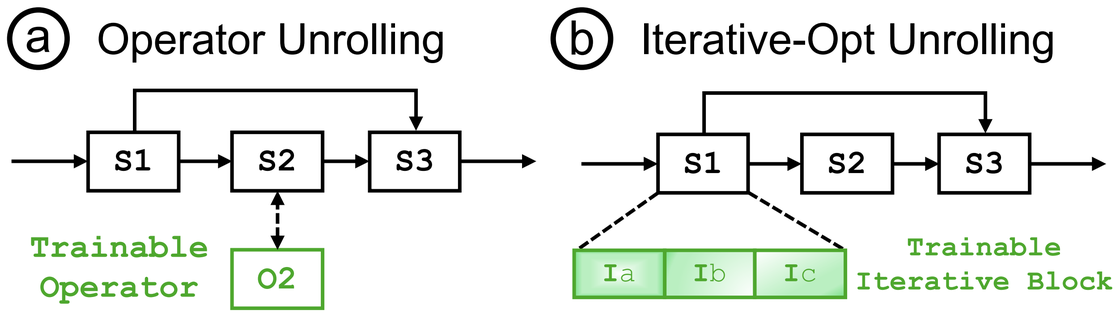


Modularity
Replace one classical operator.

Cascadability
Connect learned and classical blocks.

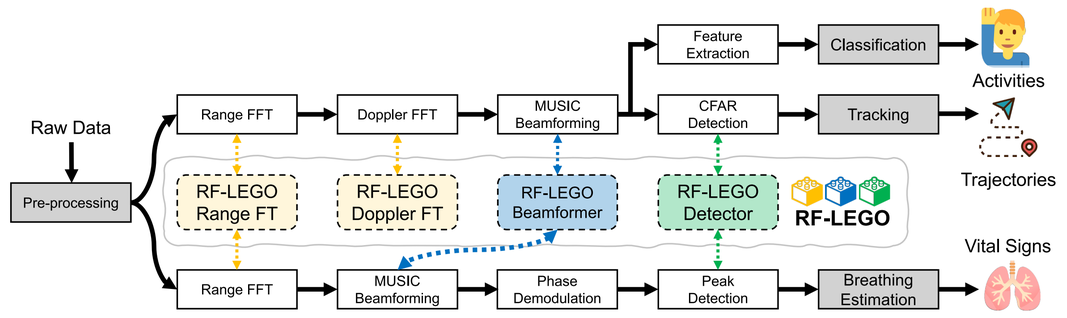
Interpretability
Retain meaningful operators and outputs.

Primer on Deep Unrolling



Operator unrolling learns a block's parameters. **Iterative unrolling** maps solver iterations to layers with learnable update rules.

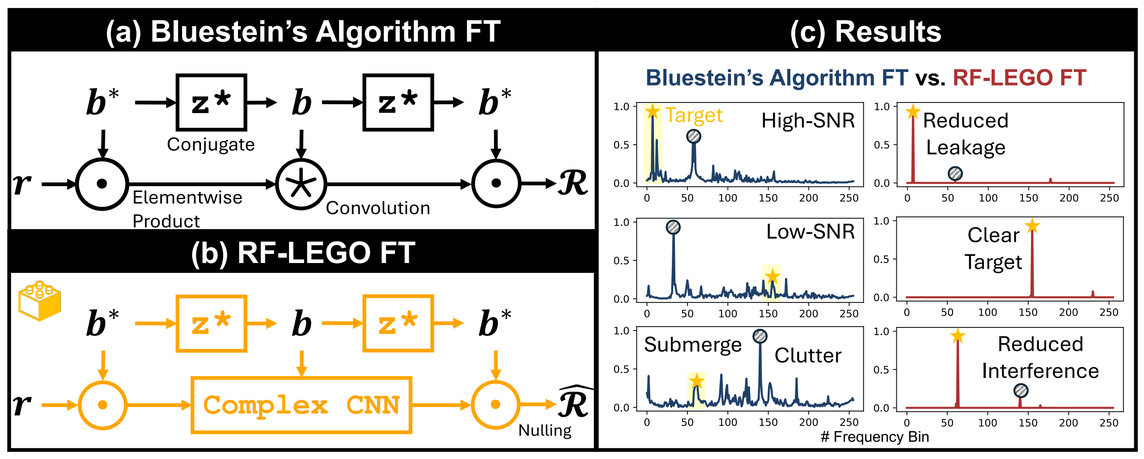
Case Study



Reuse the RF modules across three sensing pipelines.
Keep downstream algorithms and classifier architecture.

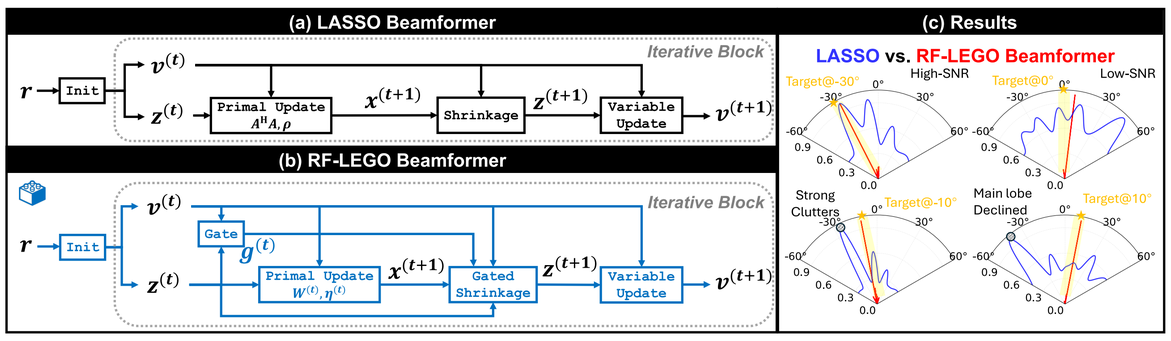
Three Trainable RF Modules

RF-LEGO Frequency Transformation



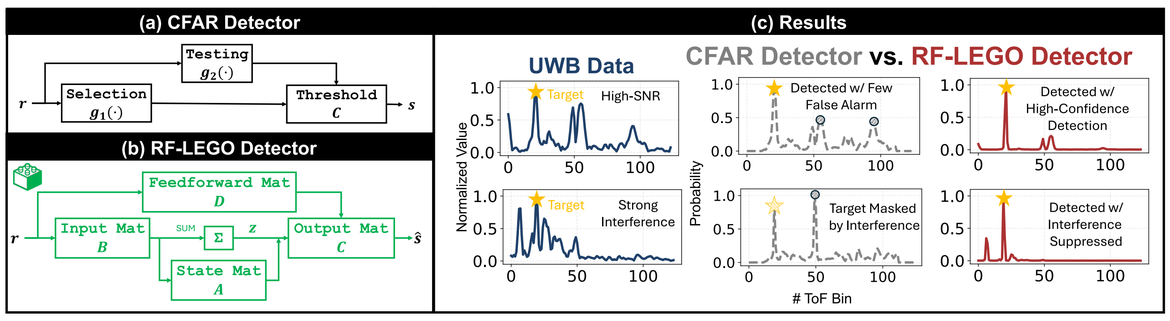
Complex samples → frequency spectrum. Preserve Bluestein's chirp multiplications; learn the complex convolution filter.

RF-LEGO Beamformer



Array samples → angular spectrum. Retain the steering model; learn ADMM update coefficients, shrinkage levels and gates.

RF-LEGO Detector

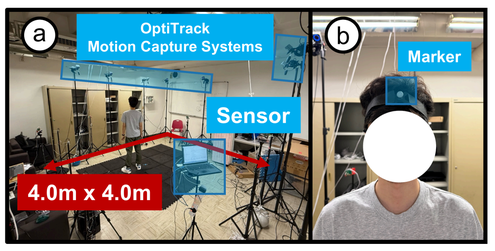


Spectrum → target detections. Preserve CFAR selection and testing; learn noise and clutter dynamics with a state-space model.

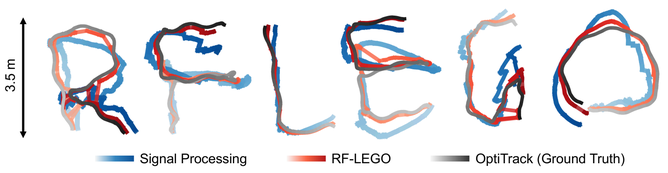
Trajectory Tracking

≈0.3 m median ATE

65 trajectories · 13 categories · 4 m × 4 m room



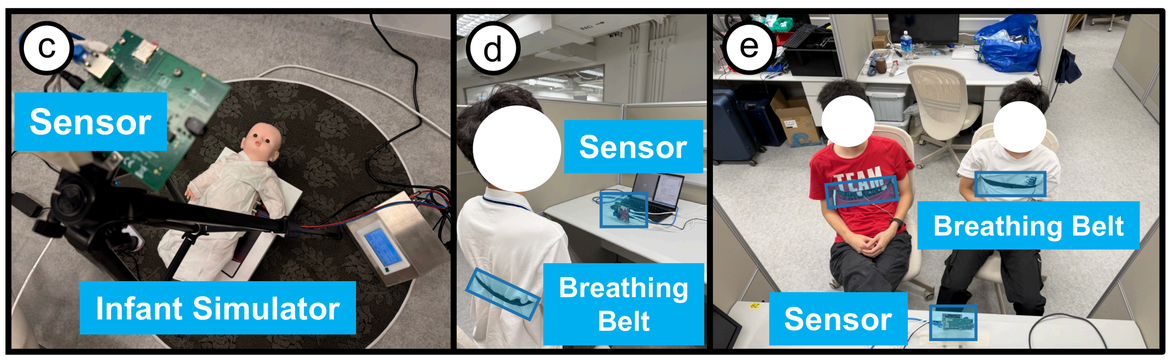
mmWave radar + OptiTrack ground truth

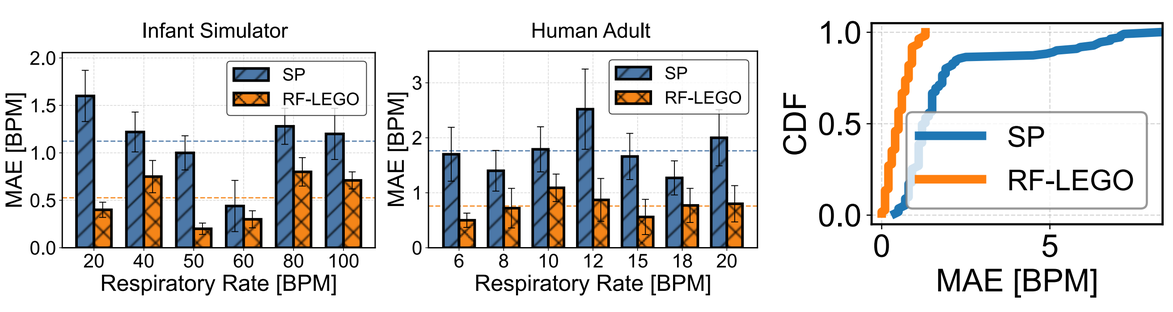


Vital Sign Monitoring

52.7% / 56.8% lower MAE

Infant simulator (20–100 BPM) and adults (6–20 BPM), versus SP





Infant simulator / adult breathing-rate MAE

Adult single- / two-person MAE CDF

Human Activity Recognition

93.92% / 84.15%

Mean 7-way / 13-way accuracy; SP: 91.88% / 79.31% MCD-Gesture

