ACM SenSys 2025

Argus: Multi-View Egocentric Human Mesh Reconstruction Based on Stripped-Down Wearable mmWave Add-on

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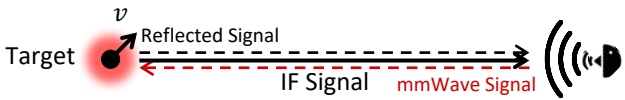
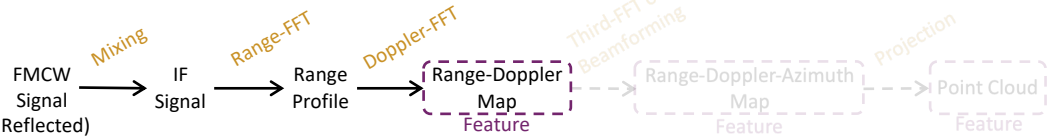
Background & Motivation

Background

LoRa zigbee Bluetooth WiFi UWB mmWave

(Frequency bands are arranged in ascending order from left to right)





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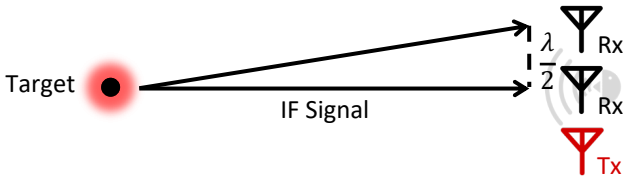
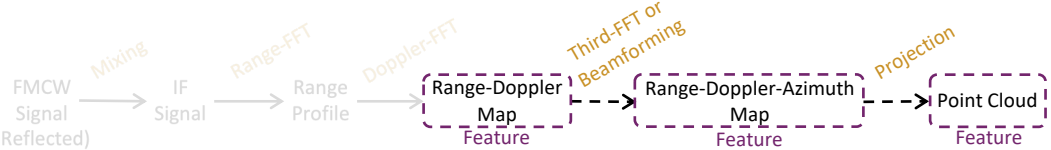




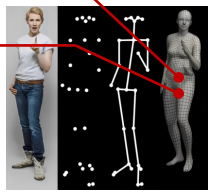
Background

LoRa zigbee Bluetooth WiFi UWB mmwave

(Frequency bands are arranged in ascending order from left to right)

More Intuitive

Complex Topology



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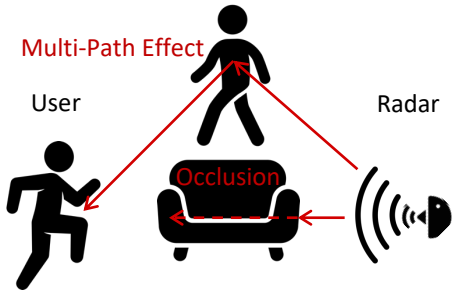
Human Mesh Reconstruction

Motivation

Existing Solutions



Out of Sensing Range (Low SNR)

[1] Xue et al. mmMesh: Towards 3D real-time dynamic human mesh construction using millimeter-wave. MobiSys'21
[2] Xue et al. M4esh: mmWave-Based 3D Human Mesh Construction for Multiple Subjects. SenSys'22
[3] Zhang et al. Synthesized millimeter-waves for human motion sensing. SenSys'22
[4] Kong et al. m3Track: mmwave-based multi-user 3D posture tracking. MobiSys'22
[5] Xue et al. Towards generalized mmwave-based human pose estimation through signal augmentation. MobiCom'23
[6] Lee et al. Hupr: A benchmark for human pose estimation using millimeter wave radar. WACV'23
[7] Zhou et al. SUPER: Seated Upper Body Pose Estimation using mmWave Radars. IoTDI'24

Key Idea

On-body mmWave Sensing

Key Idea

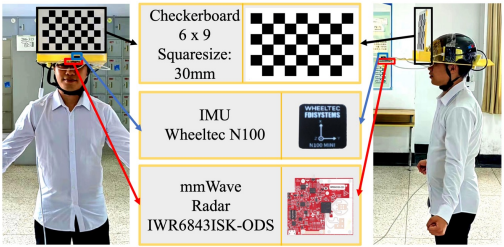
On-body mmWave Sensing

- Minimize the uncertainty between user and radar
- Always available (within sensing range)
- Reduce potential errors

Challenges & Solutions

Challenges

#1 Balancing Form Factor with Sensing Capability



Egocentric Human Pose Estimation using Head-mounted mmWave Radar. Li et al. SenSys'23

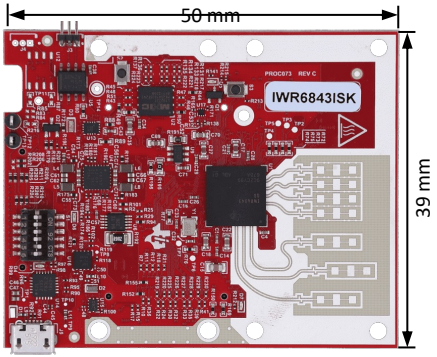
The design is bulky and not practical.

Solutions

#1: Stripped-Down Radar with Limited Antennas

3 Tx + 4 Rx

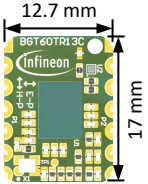
(high sensing capability)



IWR6843ISK-ODS

Only 1 Tx + 3 Rx

(limited sensing capability)



BGT60TR13C

Dime

Configure multiple compact, light-weight radars to achieve a balance.

Challenges

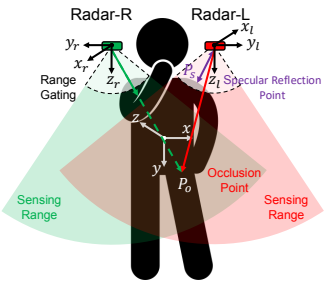
#2: Self-Occlusion Issue

Self-occlusion

The occlusion of the user's upper body messes up the lower-body reconstruction.

Solutions

#2: Multi-View Configuration with Complementary FOV



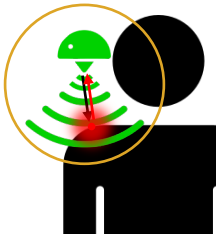
Multi-View Configuration

Two radars with complementary FOV go hand in hand to mitigate the limited sensing capability and self-occlusion issues.

Challenges

#3: Specular Reflection Issue

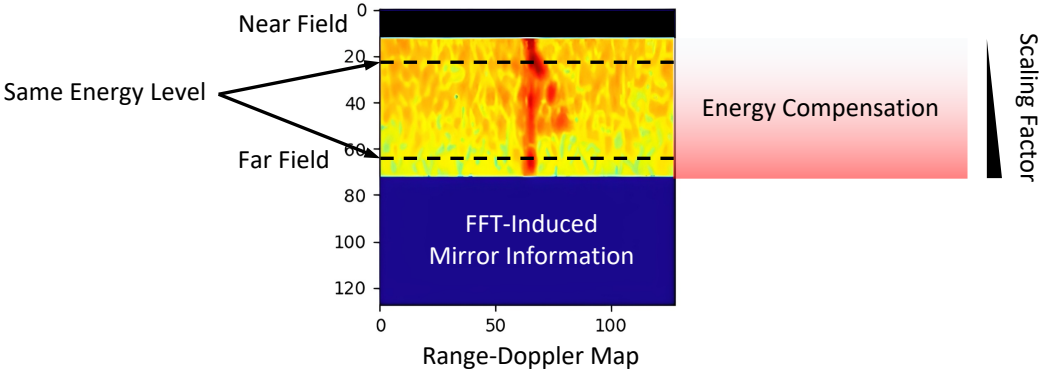
Specular Reflection



The radar is tough to focus on the right features tied to the user's lower-body movement.

Solutions

#3: Range Gating + Energy Compensation



Solutions

#3: Range Gating + Energy Compensation

W/O Energy Compensation

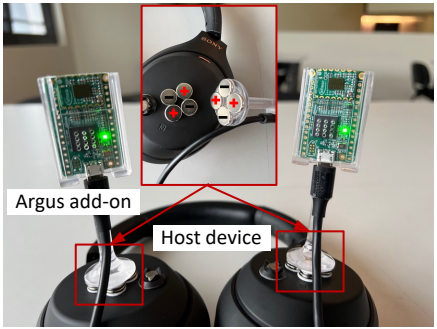
W/ Energy Compensation

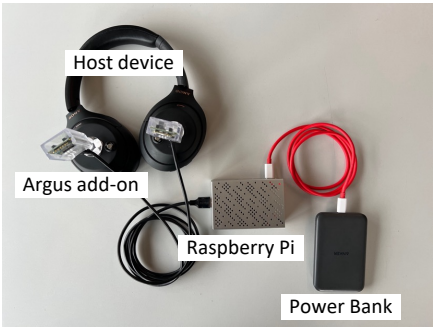
Using tailored countermeasures to suppress high-energy artifacts from specular reflection and compensate for the energy level of farther range bins.

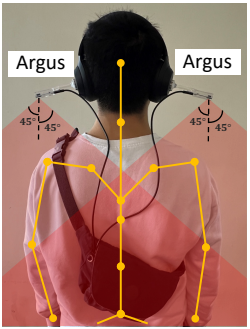
System Overview

Argus: Multi-View Egocentric HMR Solution

Detachable Magnetic Design

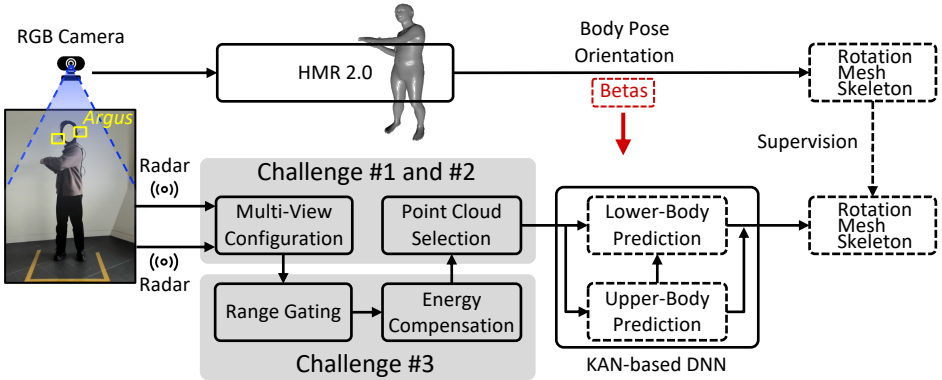






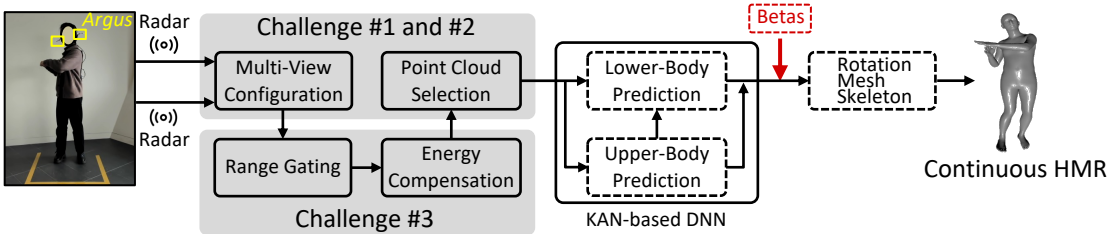
System Overview

Training Phase



System Overview

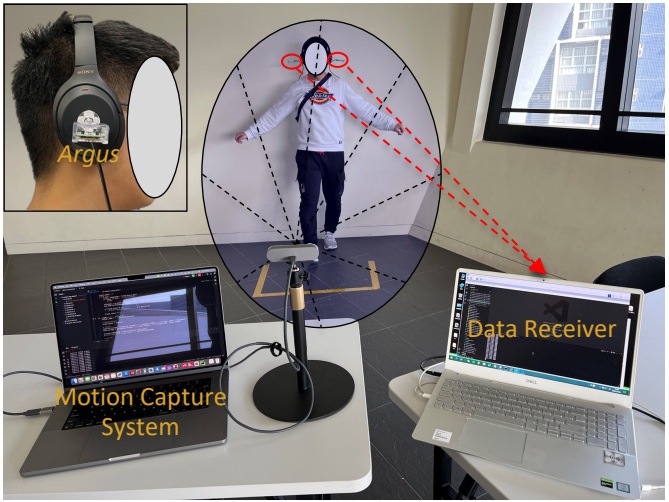
Testing Phase



Evaluation

Evaluation

Testbed



Evaluation

Activities

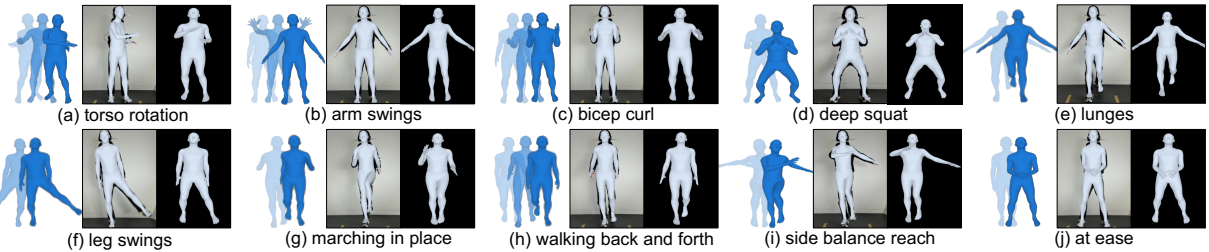
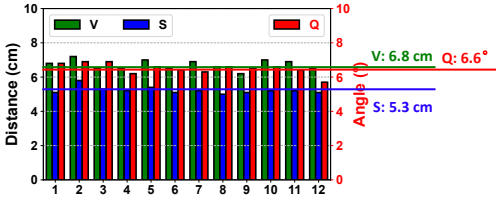


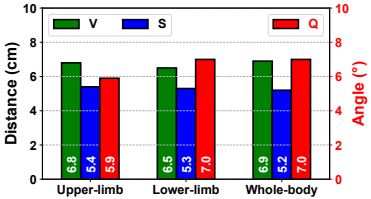
Illustration of activities (left), ground truth (middle), and prediction (right) by Argus. (a)–(c) are upper-body activities; (d)–(f) are lower-body activities; (g)–(j) are whole-body activities.

Evaluation

Overall Performance



Different Participants

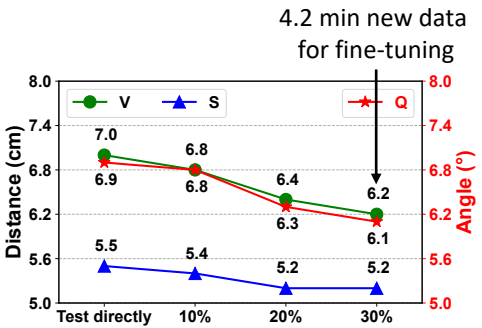


Different Regions

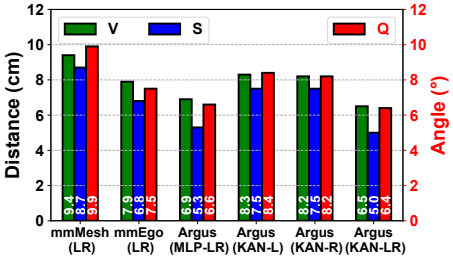
V: Average Vertex Error
S: Average Joint Localization Error
Q: Average Joint Rotation Error

Evaluation

Key Results



Unseen Users



Baselines

V: Average Vertex Error

S: Average Joint Localization Error

Q: Average Joint Rotation Error

Conclusion

Conclusion

(1) Argus is the first system realize the multi-view egocentric HMR by proposing a holistic solution.

(2) We propose a series of tailored techniques like range gating, energy compensation, and multi-view configuration to address the unique challenges in Argus.

(3) Main Takeaway: this paper demonstrates the feasibility of egocentric HMR using lightweight, limited-capability mmWave radars with complementary FOV, achieving performance comparable to those based on high-capability radars.

Thank you!
Q & A

Scan Me!

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