TARAF: Trail Recovery and Path Finding System

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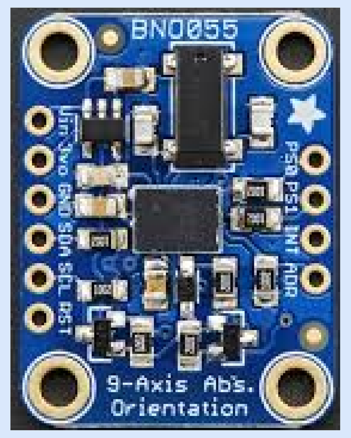
Thousands of hikers **get lost** each year!

When GPS, cell service, or visibility fails, hikers may not know how to retrace their path.

TARAF is an affordable, GPS-free navigation device that estimates and stores a user's walking path, then provides return guidance when needed.

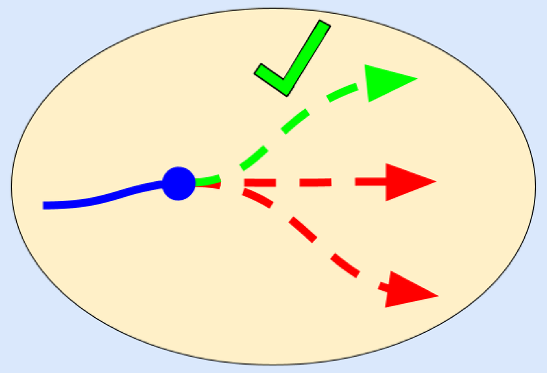
How does the solution work?

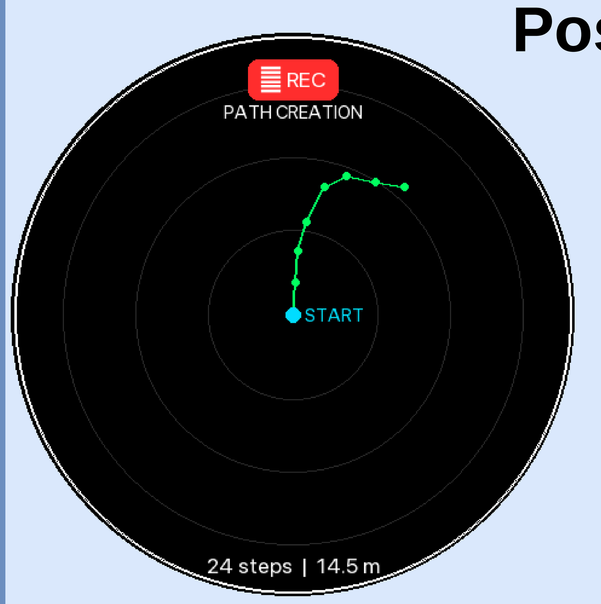
1. User Puts on **Foot** and **Wrist Mounted** Devices



2. As They Walk the **IMU Measures Motion**

3. Kalman Filter **Estimates Position**

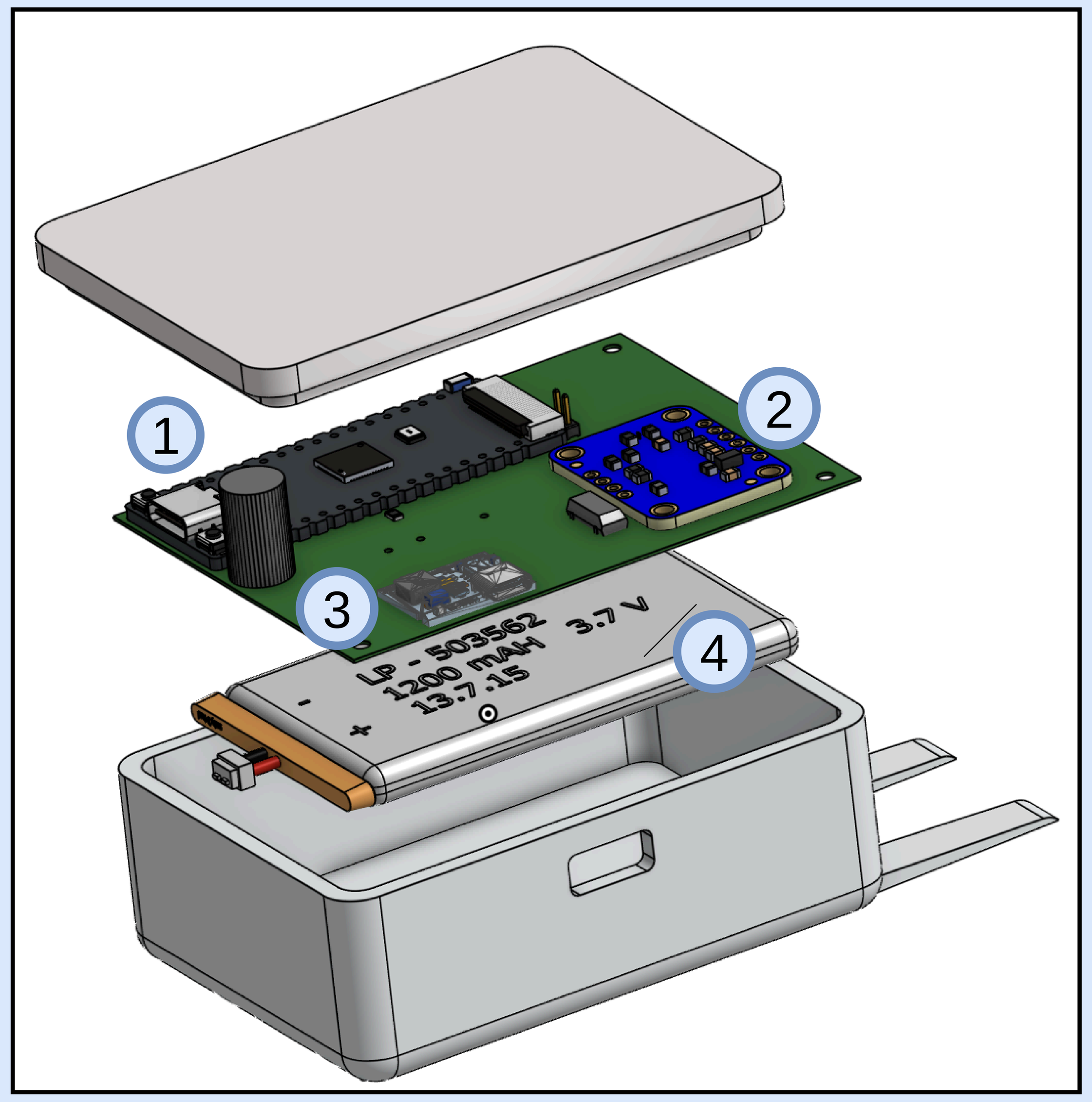




4. Positions Are Stored as the **User's Path**

5. Upon **User Request** Device Provides **Return Navigation**

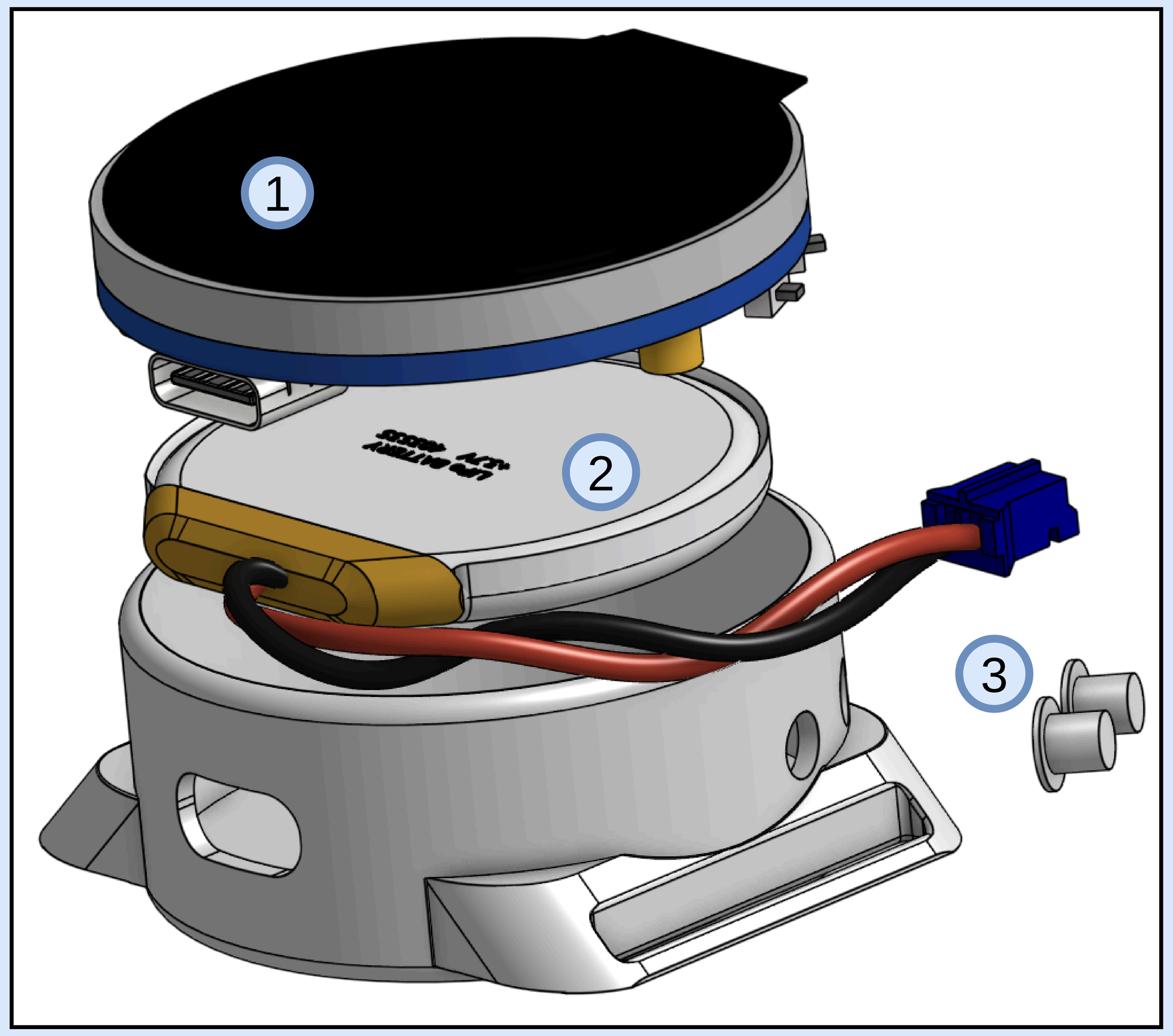
Foot Device Exploded View



1. MCU: ESP32-S3 Nano
2. IMU: BNO055
3. Boost Converter: TP4056 Module
4. Battery: 3.7V 1200 mAh LiPo

Wrist Device Exploded View

1. MCU: ESP32-C6 AMOLED round touch display board
2. Battery: 3.7V 450 mAh LiPo
3. Momentary press buttons



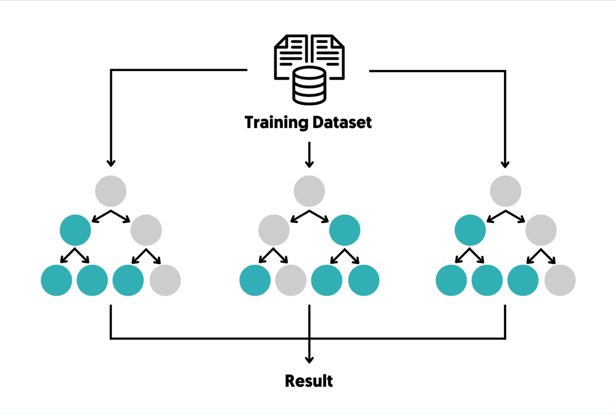
From Foot Motion to Position

We estimate position using a foot-mounted IMU, computer vision ground truth, and offline ML optimization.

Stage 1: Capture Ground Truth
Computer vision tracks the foot while the IMU records acceleration and rotation. This gives us the true position, step timing, and foot-swing behavior.

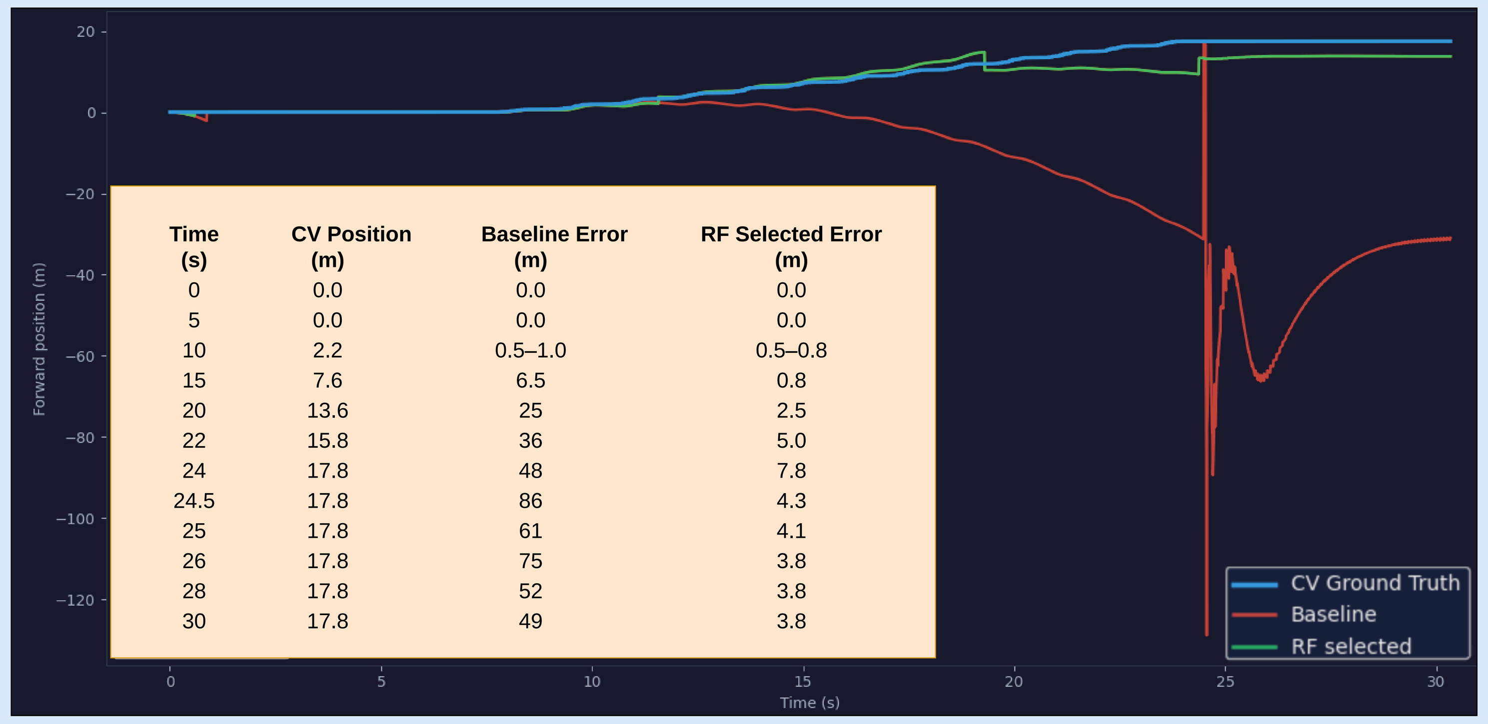
Stage 2: Build the State Estimator
Raw IMU data is converted into position through calibration, filtering, step detection, Zero-Velocity Updates, and an Error-State Kalman Filter.

Stage 3: Recognize Movement Type
Walking is separated into common trajectory patterns: straight paths, turns, curves, stops, and speed changes.



Stage 4: Optimize With ML
Offline machine learning (ML) compares estimated paths to computer vision ground truth and selects estimator settings that minimize position error.

Results (error metrics)



Time (s)	CV Position (m)	Baseline Error (m)	RF Selected Error (m)
0	0.0	0.0	0.0
5	0.0	0.0	0.0
10	2.2	0.5–1.0	0.5–0.8
15	7.6	6.5	0.8
20	13.6	25	2.5
22	15.8	36	5.0
24	17.8	48	7.8
24.5	17.8	86	4.3
25	17.8	61	4.1
26	17.8	75	3.8
28	17.8	52	3.8
30	17.8	49	3.8

The baseline estimator shows **severe drift** as the trajectory progresses, with error growing from near zero to roughly 49 m by the end of the trial. In contrast, the **RF-selected** (RF being random forest) configuration stays much closer to computer vision ground truth, maintaining **lower error across the trajectory** and ending at approximately 3.8 m. This demonstrates that offline ML-based estimator tuning can **significantly reduce position drift** compared to the untuned baseline.

Conclusion

- The system estimates movement using foot-mounted IMU data, a custom state estimator, and stored path history.
- Computer vision ground truth and offline machine learning helped validate and reduce position error.
- TARAF demonstrates a practical step toward low-cost return navigation for outdoor environments where normal tools may fail.

Find Out More about TARAF

TARAF — Wearable Inertial Navigation for Outdoor Rescue
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