

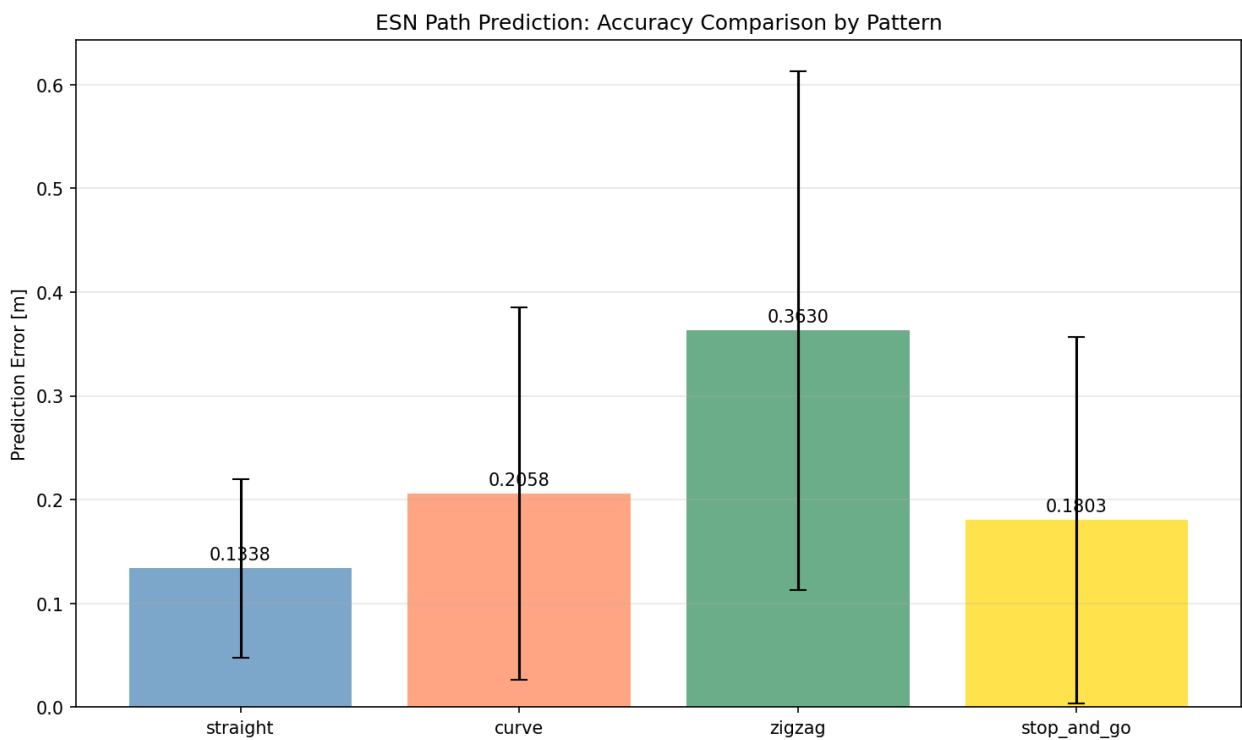
ESN Path Prediction Validation Results

Validation results of the Echo State Network (ESN) path prediction algorithm.

Validation Overview

- **ESN Models:** 10 (ensemble)
- **Prediction Horizon:** 20 steps
- **Warmup:** 5 samples
- **Trajectory Length:** 200 steps
- **Noise Level:** 0.015m

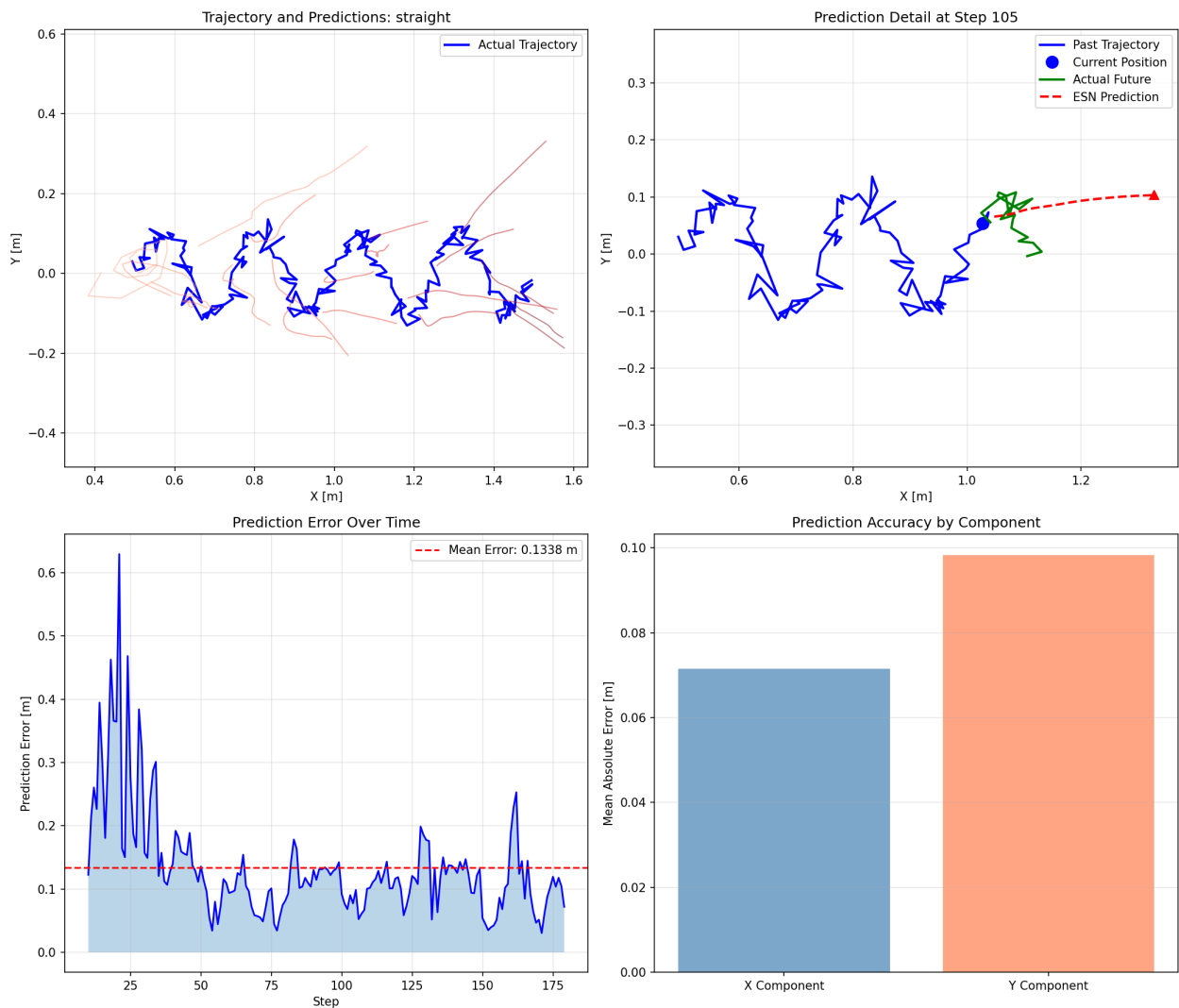
Accuracy Summary



Pattern	Mean Error	Std Dev	Rating
straight	0.134 m	0.086 m	Excellent
stop_and_go	0.180 m	0.177 m	Good
curve	0.206 m	0.179 m	Good
zigzag	0.363 m	0.250 m	Needs Improvement

Detailed Results by Pattern

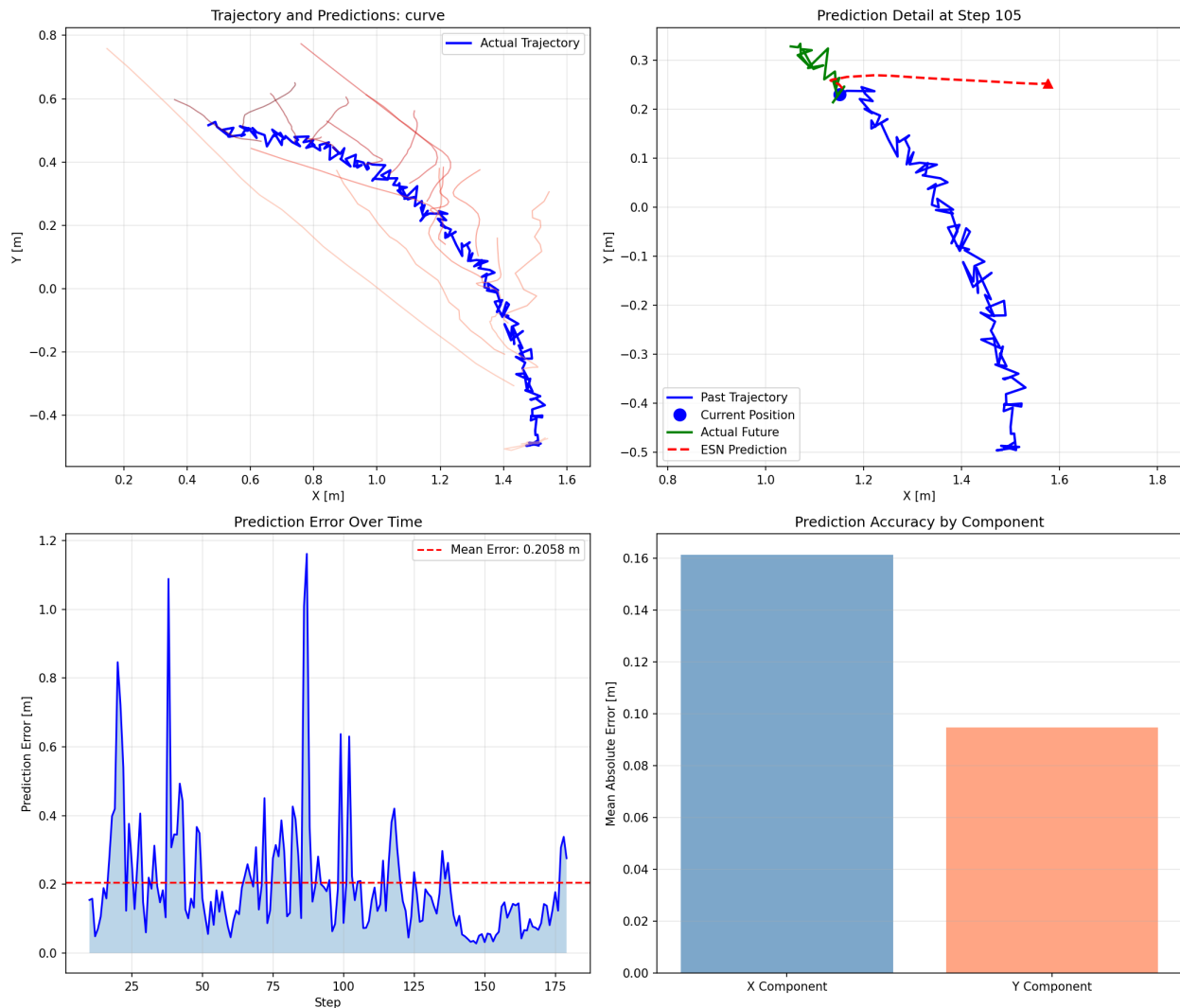
1. Straight Walking



Characteristics: - Highest prediction accuracy - X component (forward direction) particularly stable - Small Y component (lateral) sway captured

Analysis: - Mean Error: 0.134 m - Linear motion is ESN's strength - Online adaptation works effectively

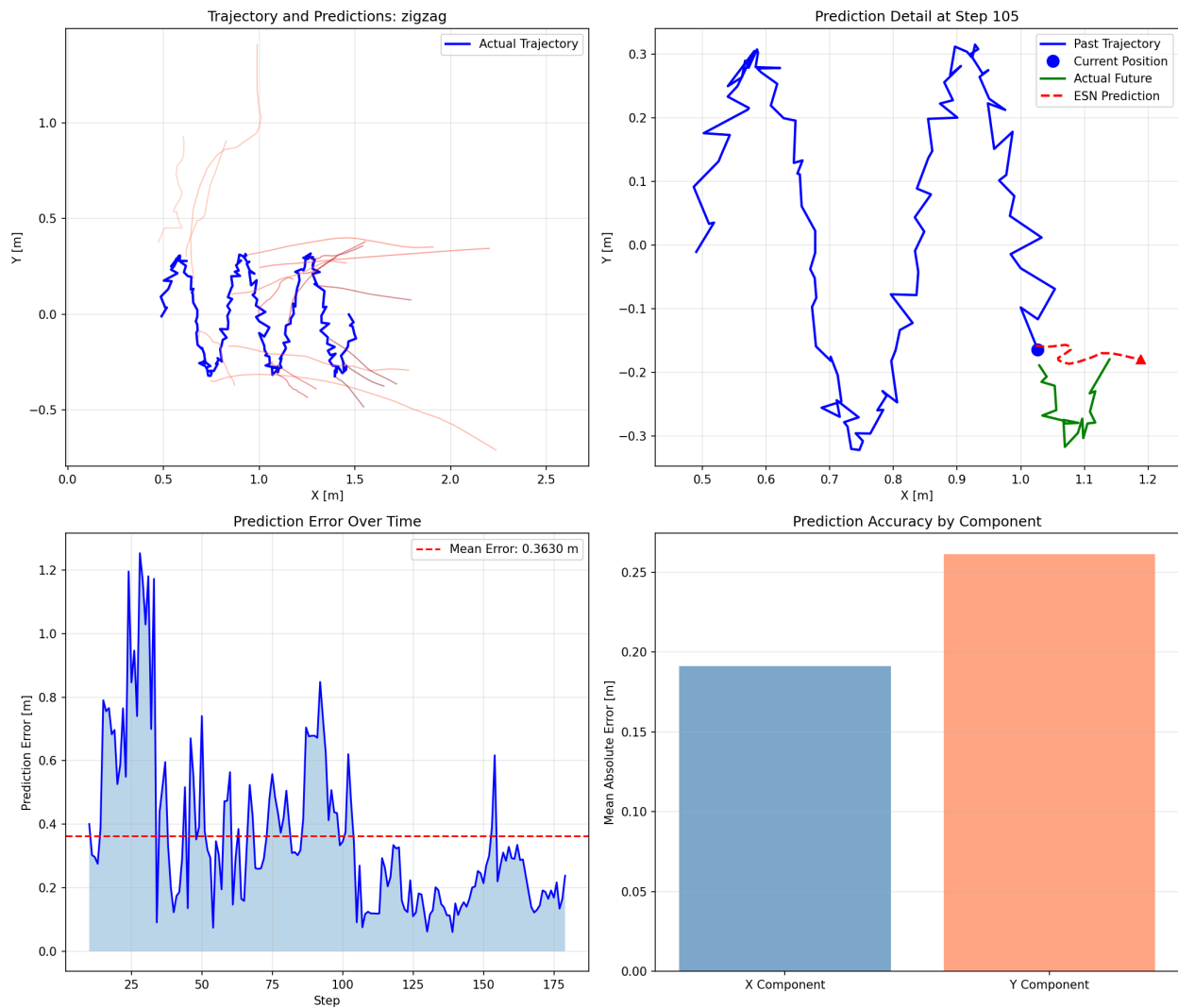
2. Curved Walking



Characteristics: - Slight delay in predicting turn initiation - Follows curvature changes - Accuracy improves in later stages

Analysis: - Mean Error: 0.206 m - Predicting turn direction is challenging - Gradual improvement through adaptive learning

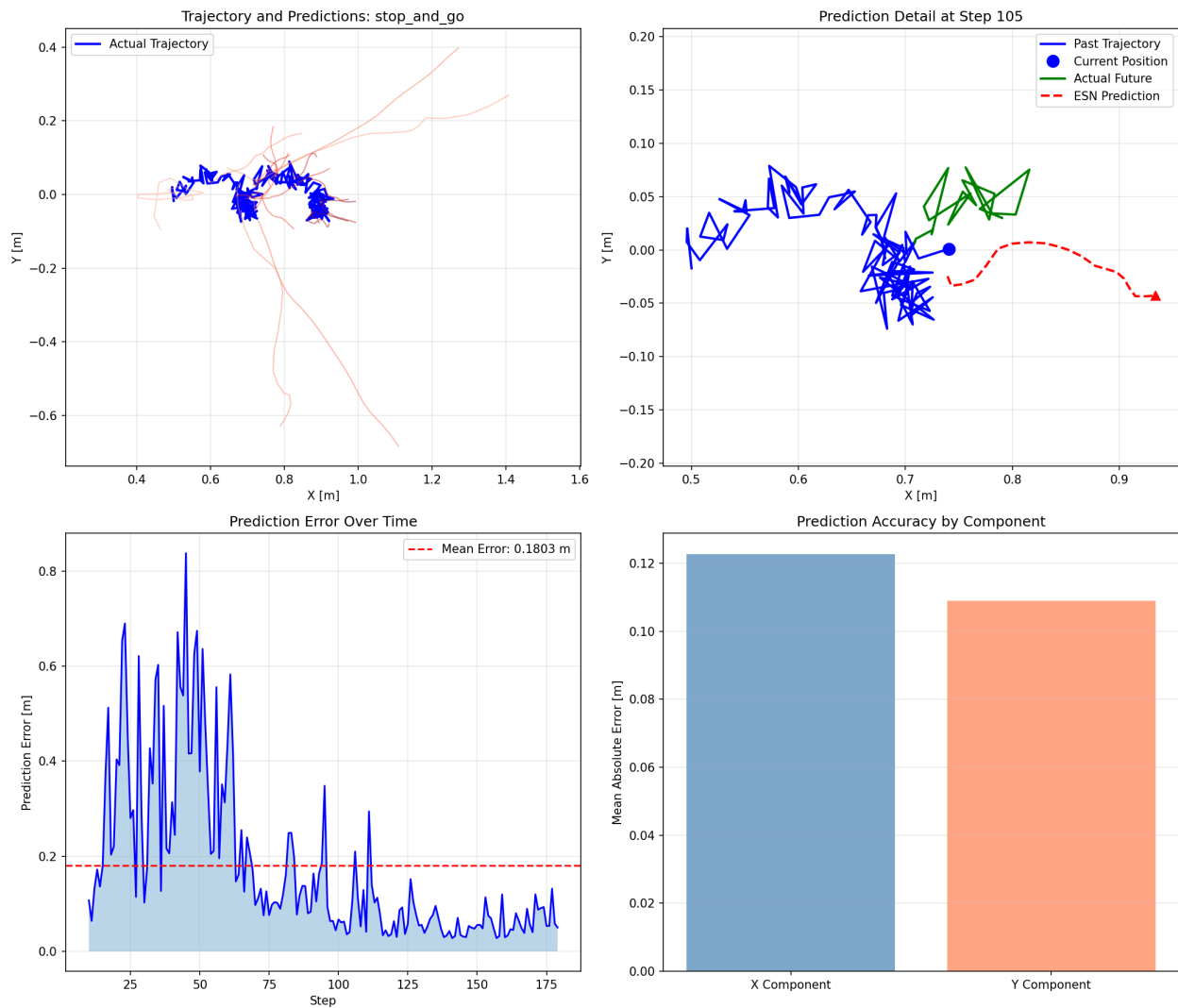
3. Zigzag Walking



Characteristics: - Periodic direction changes difficult to predict - Notable Y component errors - Error peaks at turning points

Analysis: - Mean Error: 0.363 m - Rapid direction changes are challenging - Shorter prediction horizon may help

4. Stop and Go



Characteristics: - High accuracy during stop periods - Temporary error increase at movement restart - Quick recovery through adaptive learning

Analysis: - Mean Error: 0.180 m - Stop detection works well - Room for improvement in motion onset prediction

Discussion

Strengths

1. **Linear Motion:** High accuracy predictions
2. **Online Adaptation:** Real-time model updates
3. **Ensemble Effect:** Stability through multi-model averaging

Challenges

1. **Rapid Direction Changes:** Prediction delay occurs
2. **Periodic Patterns:** Handling long-period variations
3. **Motion Onset:** Transition from static to moving

Improvement Suggestions

1. Dynamic prediction horizon adjustment
2. Enhanced direction change detection
3. Additional velocity input features

Test Environment

- **OS:** Ubuntu 22.04
- **Python:** 3.10
- **Dependencies:** NumPy, SciPy, Matplotlib
- **Script:** `tools/esn_visualizer.py`

Reproduction

```
python3 tools/esn_visualizer.py --pattern all --output output
```