

# ESN Path Prediction Validation Results

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

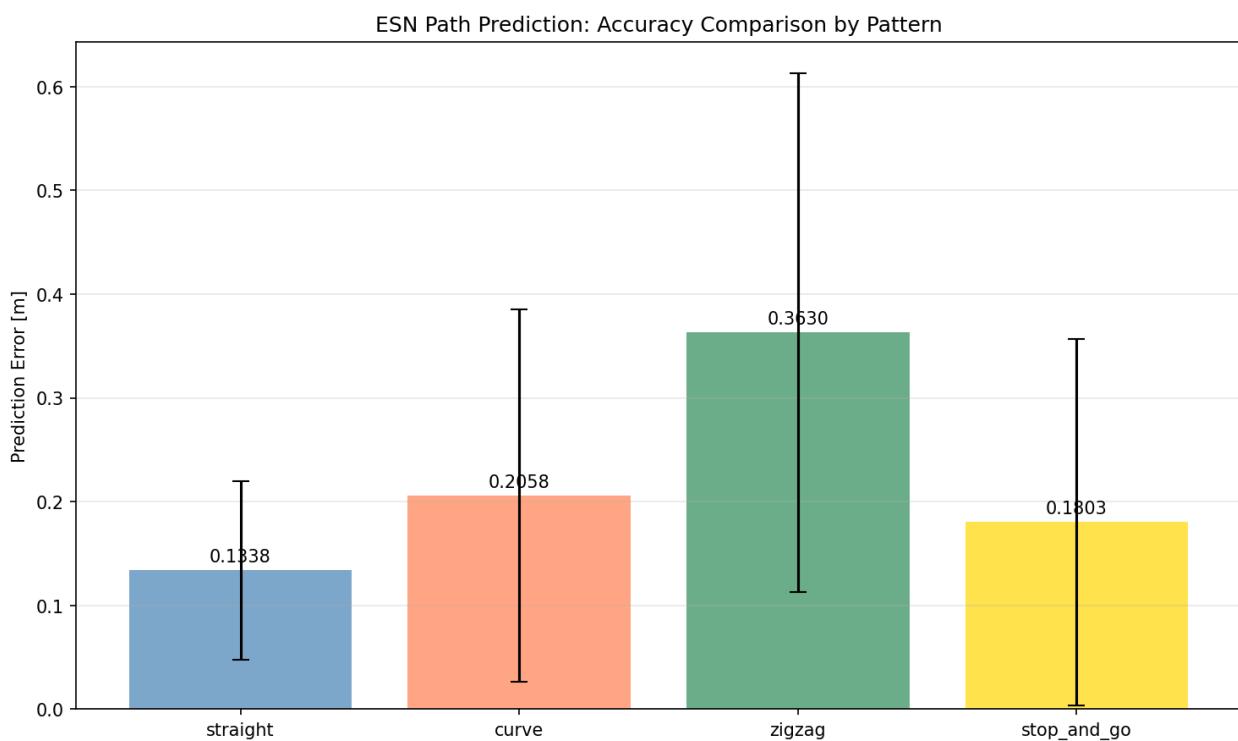
## Validation Overview

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

## Accuracy Summary

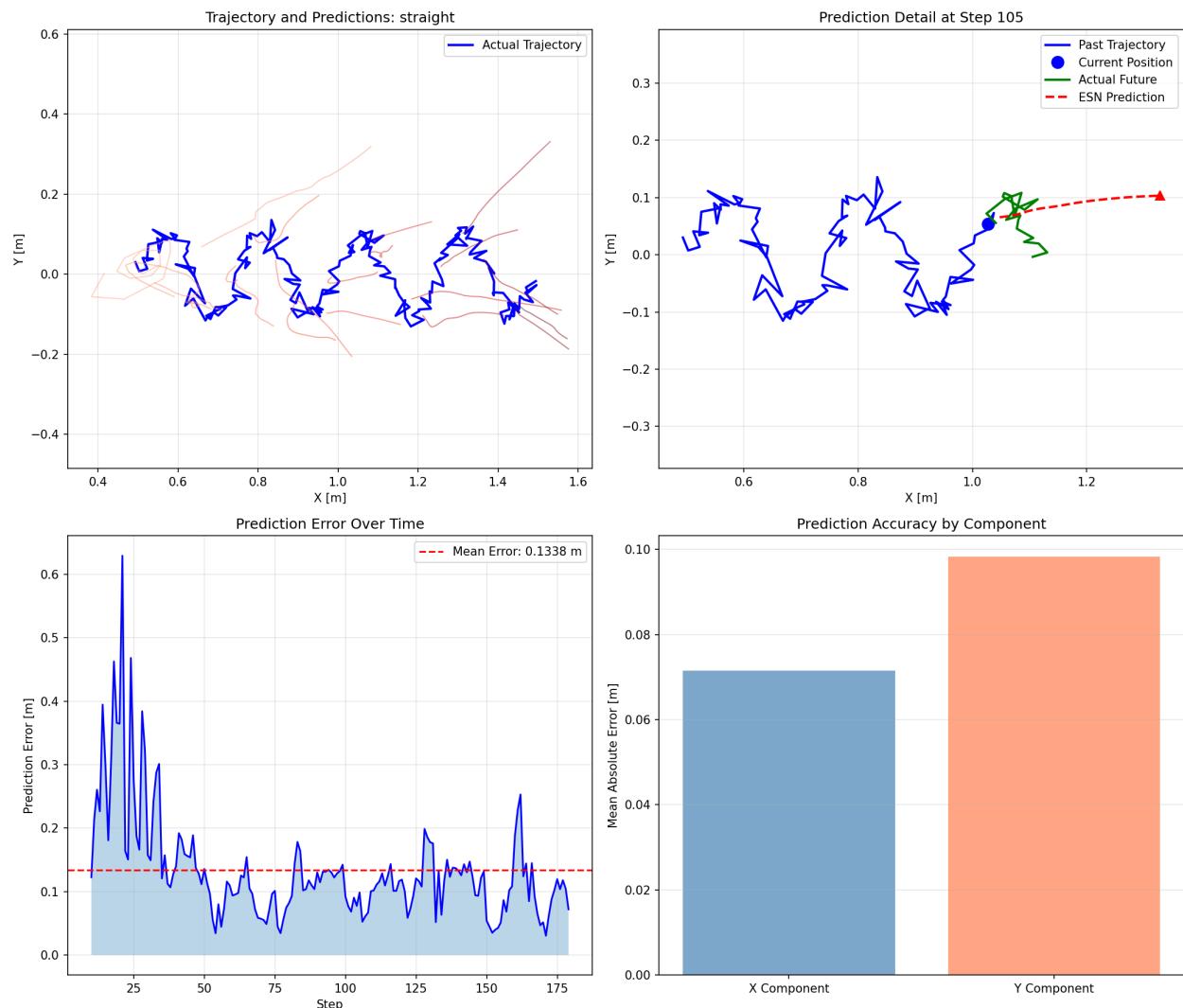
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Pattern	Mean Error	Std Dev	Rating
straight	0.134 m	0.086 m	Excellent
stop_and_go	0.180 m	0.177 m	Good
curve	0.206 m	0.179 m	Good
zigzag	0.363 m	0.250 m	Needs Improvement

## Detailed Results by Pattern

### 1. Straight Walking

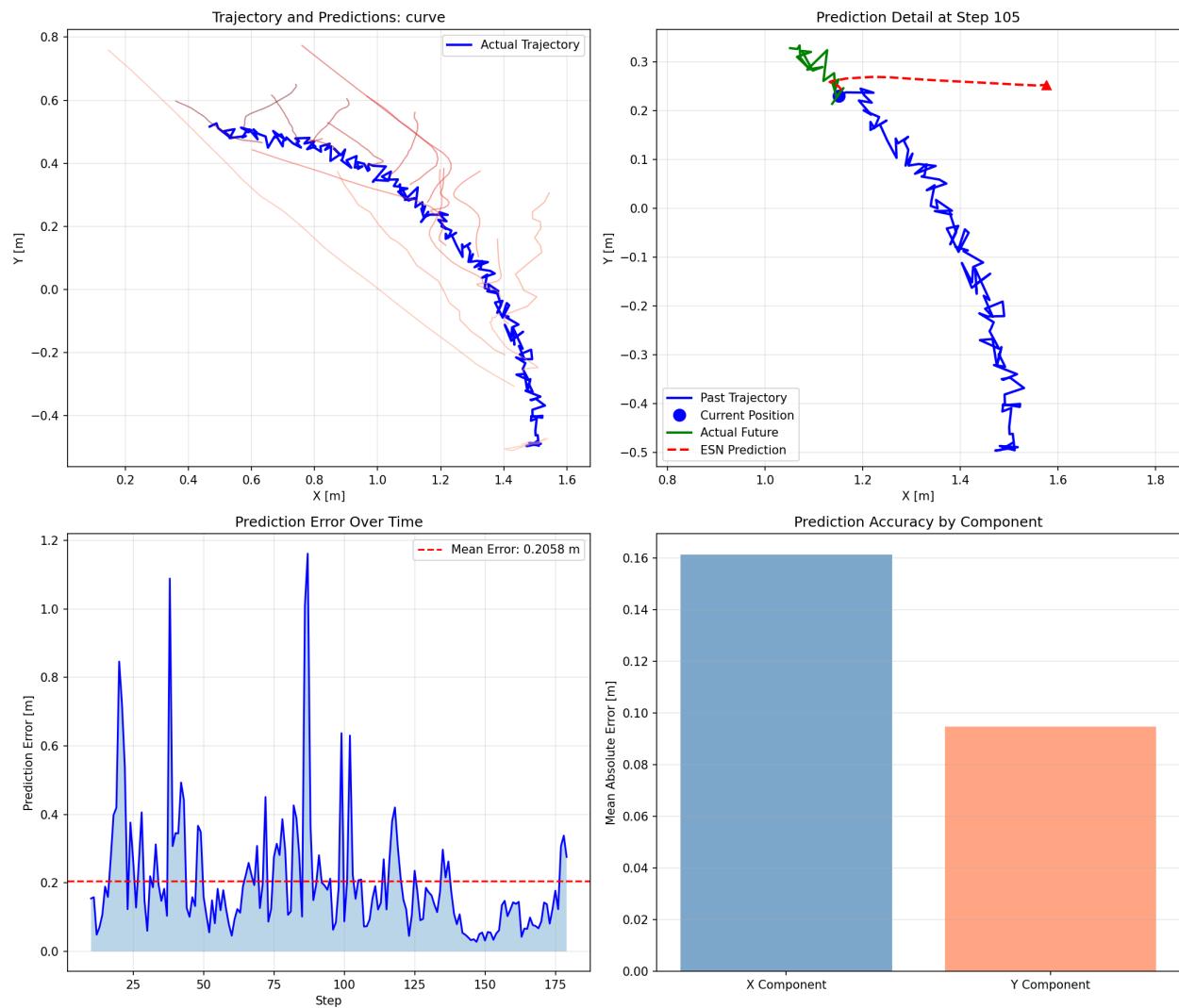


**Characteristics:** - Highest prediction accuracy - X component (forward direction) particularly stable - Small Y component (lateral) sway captured

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

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## 2. Curved Walking

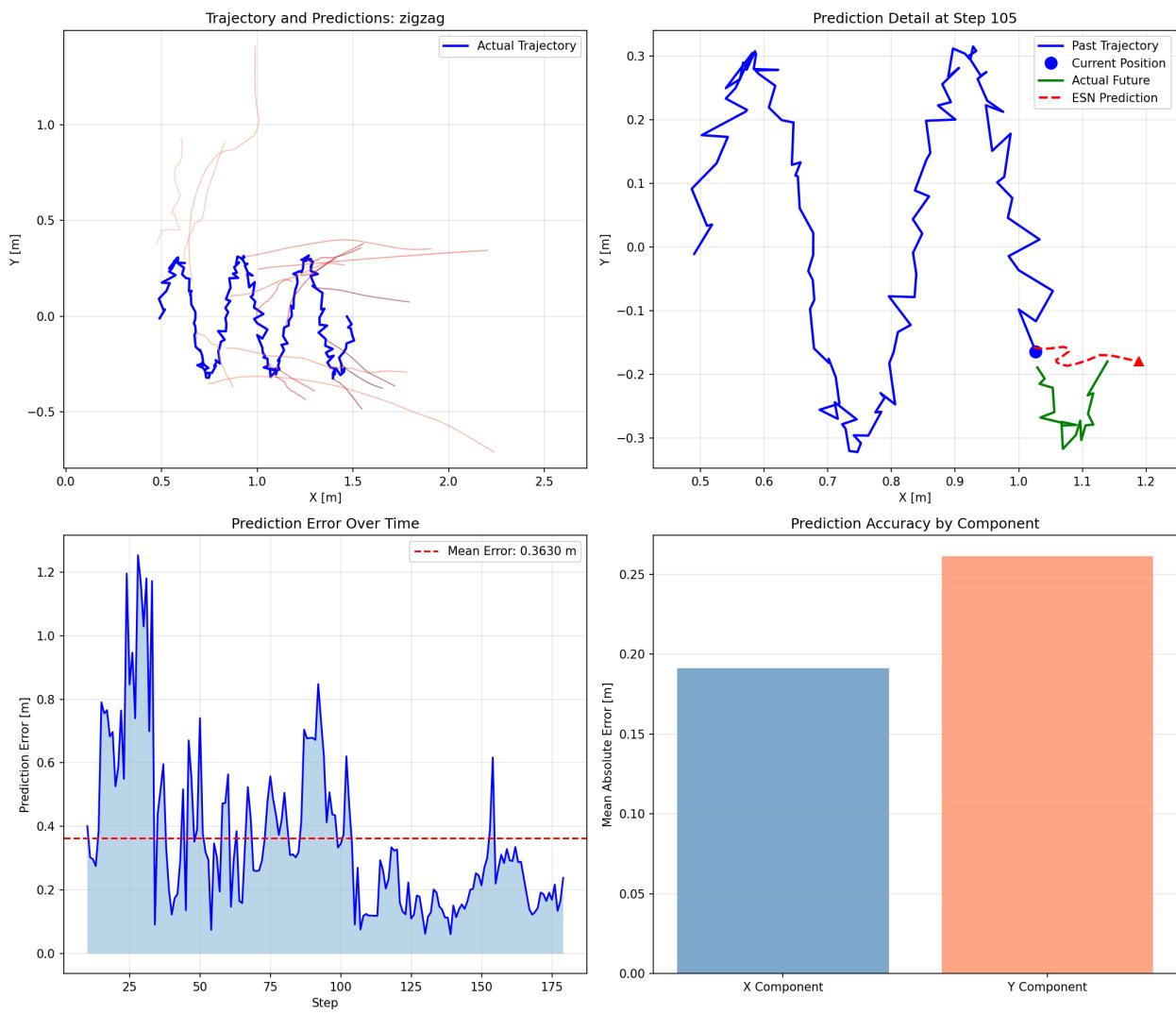


**Characteristics:** - Slight delay in predicting turn initiation - Follows curvature changes - Accuracy improves in later stages

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

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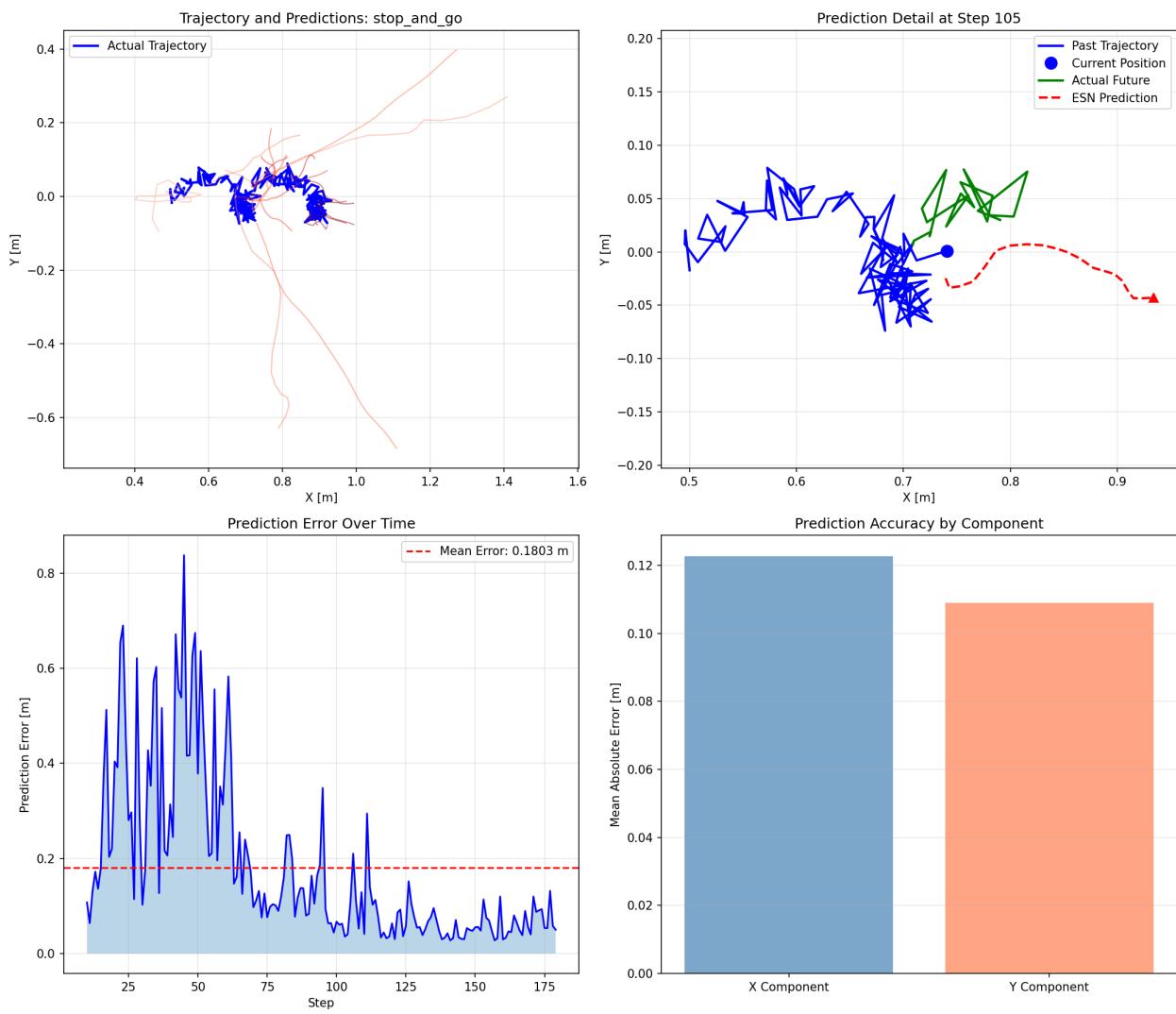
### 3. Zigzag Walking



**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

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## Discussion

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### Strengths

- Linear Motion:** High accuracy predictions
- Online Adaptation:** Real-time model updates
- 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

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

## Reproduction

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