## Zida Wu

**Zida Wu** is a master student in the Department of Electronic Engineering at Shanghai Jiao Tong University. His main research is in the areas of low-cost GNSS difference positioning.

第十届中国卫星导航年会
THE 10th CHINA SATELLITE NAVIGATION CONFERENCE

# PDR/GNSS Fusion Algorithm Based on Joint Heading Estimation

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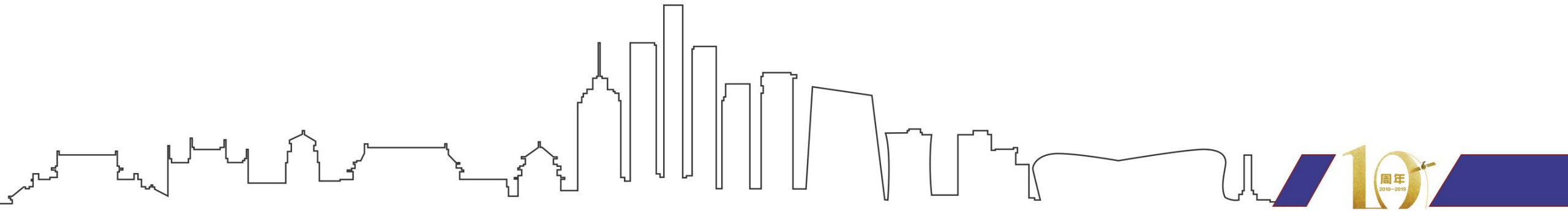
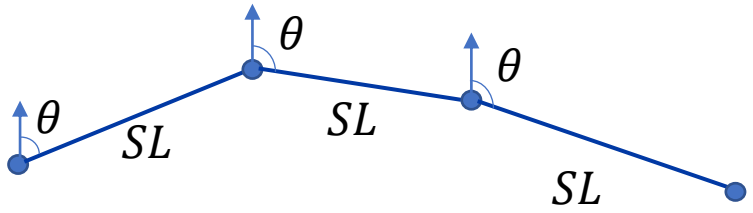
导航，遇见十年
NAVIGATION,10 YEARS AND BEYOND
CSNC 2019



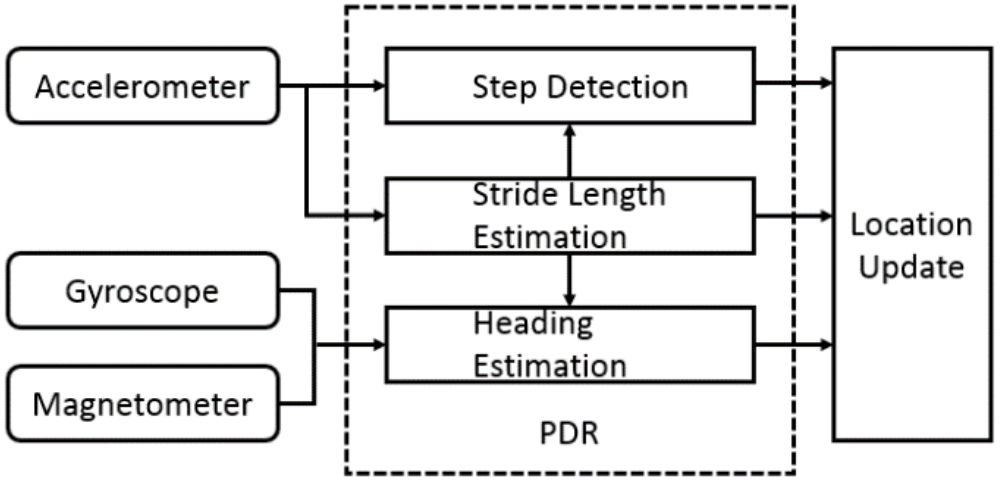
# Background

The performance of Pedestrian Dead Reckoning (PDR) based on a smartphone is limited due to the low-cost MEMS IMU. Heading and stride length estimation tend to accumulate errors over time and those errors lead to the failure of PDR. However, Global Navigation Satellite System (GNSS) provides absolute location information in outdoor applications, and the characteristics of estimation errors of GNSS are quite different from those of PDR.

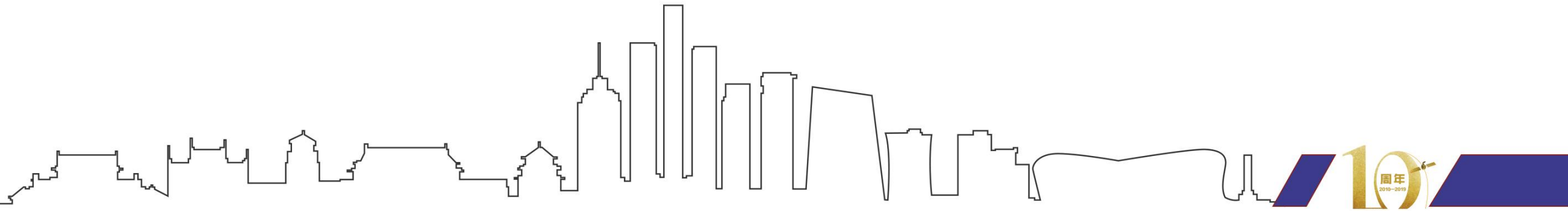



$$\begin{cases} x_{k+1} = x_k + SL_k \cdot \sin\theta_k \\ y_{k+1} = y_k + SL_k \cdot \cos\theta_k \end{cases}$$

**Equations of PDR**

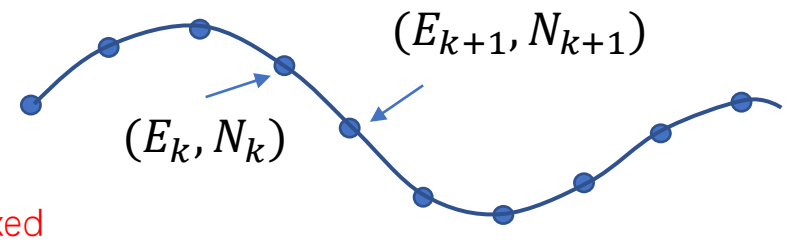



**Block Diagram of PDR**



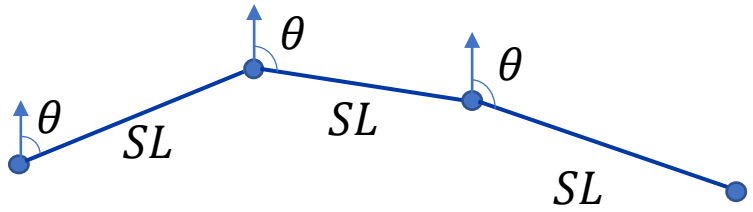
# GNSS Heading & Stride Length

**GNSS**




Output with Fixed Frequency

**PDR**




Output with Non-Fixed Frequency

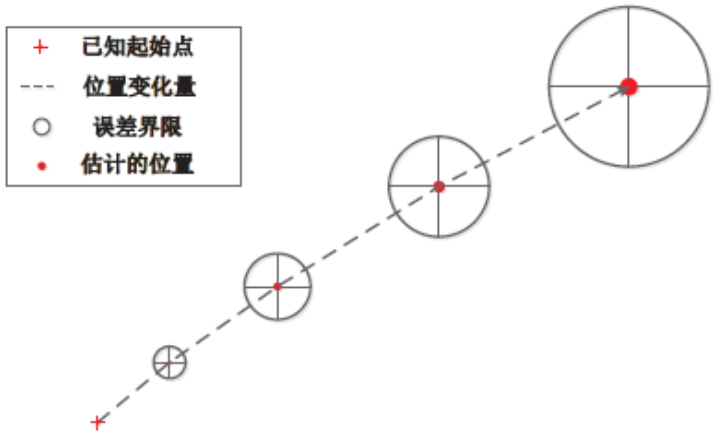
**GNSS Heading**

$$\theta_{k+1}^{GNSS} = arctan\left(\frac{N_{k+1} - N_k}{E_{k+1} - E_k}\right)$$

**GNSS Stride Length**

$$SL_{k+1}^{GNSS} = \left\| \begin{bmatrix} E_{k+1} - E_k \\ N_{k+1} - N_k \end{bmatrix} \right\|_2$$

# Error of Heading & Stride Length Estimation




**Estimation Error is accumulated during iteration!**

$$\begin{cases} x_{k+1} = x_1 + \sum_{i=1}^{k} (SL_i \cdot \sin\theta_i) \\ y_{k+1} = y_1 + \sum_{i=1}^{k} (SL_i \cdot \cos\theta_i) \end{cases}$$

**Two criteria：**

**Mean Cumulative Heading Error**

$$MCHE(k) = \frac{1}{k}\sum_{i=1}^{k} \varepsilon_k^{\theta-SYS}$$

**Cumulative Stride Length Error**

$$CSLE(k) = \sum_{i=1}^{k} \varepsilon_k^{SL-SYS}$$

**Accumulated Error of PDR**

**Another Equations of PDR**

SYS： PDR or GNSS

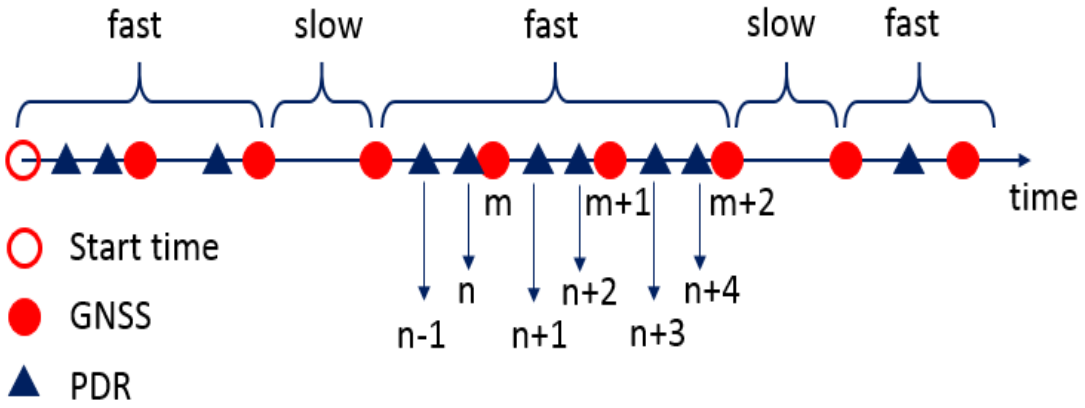
$\varepsilon_k^{\theta}$： Heading Estimation Error at time k

$\varepsilon_k^{SL}$： Stride Length Estimation Error

# Data Synchronization

**fast step**：at least one complete step can be completed within 1s

**slow step**：one complete step cannot be completed within 1s




**Data synchronization between PDR and GNSS**

**The basic idea of the data synchronization is to turn the data of PDR into a timing output, just like the output of GNSS.**

$$\begin{cases} \theta_m = \dfrac{\theta_{n+1} + \theta_{n+2}}{2} \\ SL_m = \sqrt{SL_{n+1}^2 + SL_{n+2}^2 + 2C} \\ C = SL_{n+1} SL_{n+2} \cdot \cos(\theta_{n+1} - \theta_{n+2}) \end{cases}$$

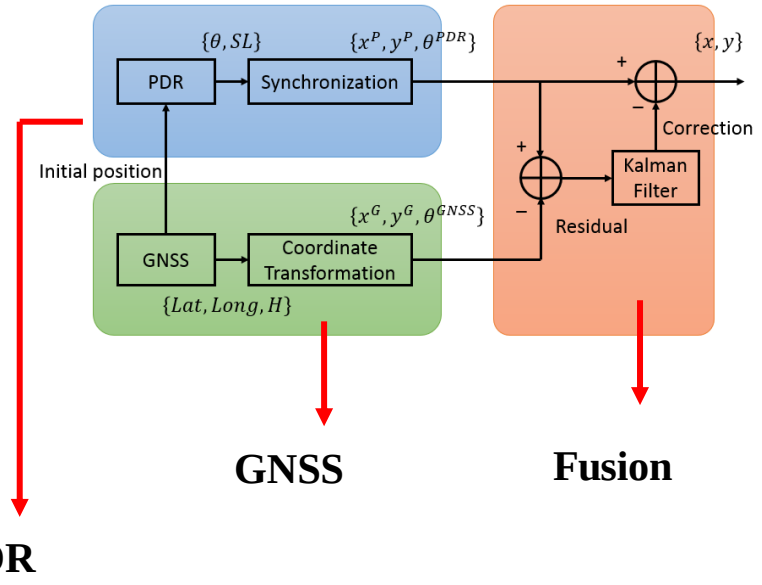
n：step n of PDR

m：time m of GNSS

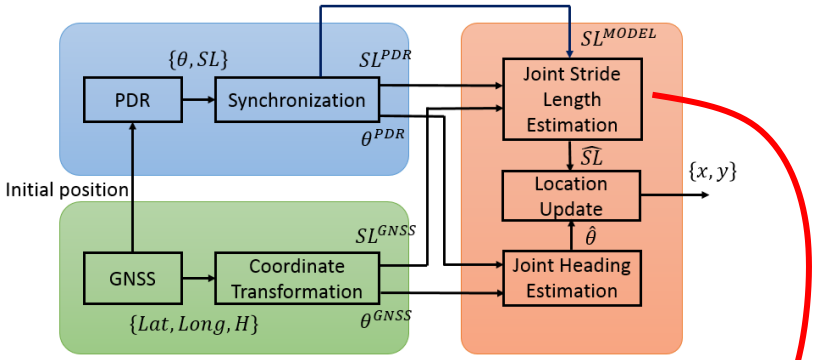
# Fusion Framework

**The objectives are to achieve the dual effect of reducing the cumulative error and the noise power.**

**Traditional Loosely Coupled INS/GNSS Integration**




**The proposed Fusion Framework**



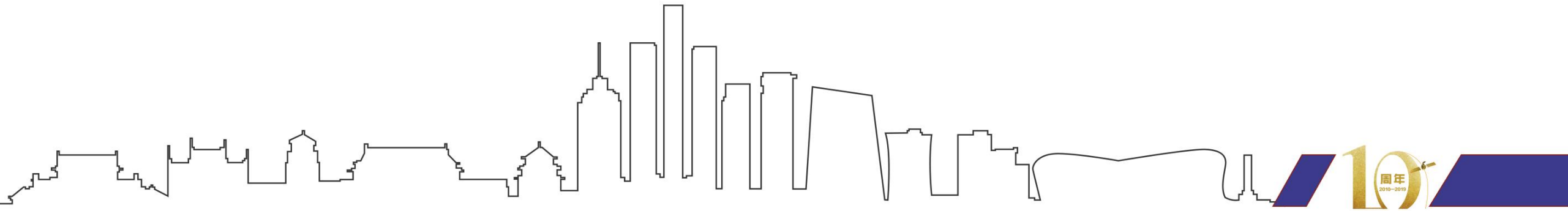

**Joint Heading Estimation:**

$$\hat{\theta}_{k+1} = \frac{1}{M}\Theta_{k+1} + \frac{M-1}{M}\left(\hat{\theta}_k + \theta^{PDR}_{k+1} - \theta^{PDR}_k\right)$$

**Smooth Coefficient**

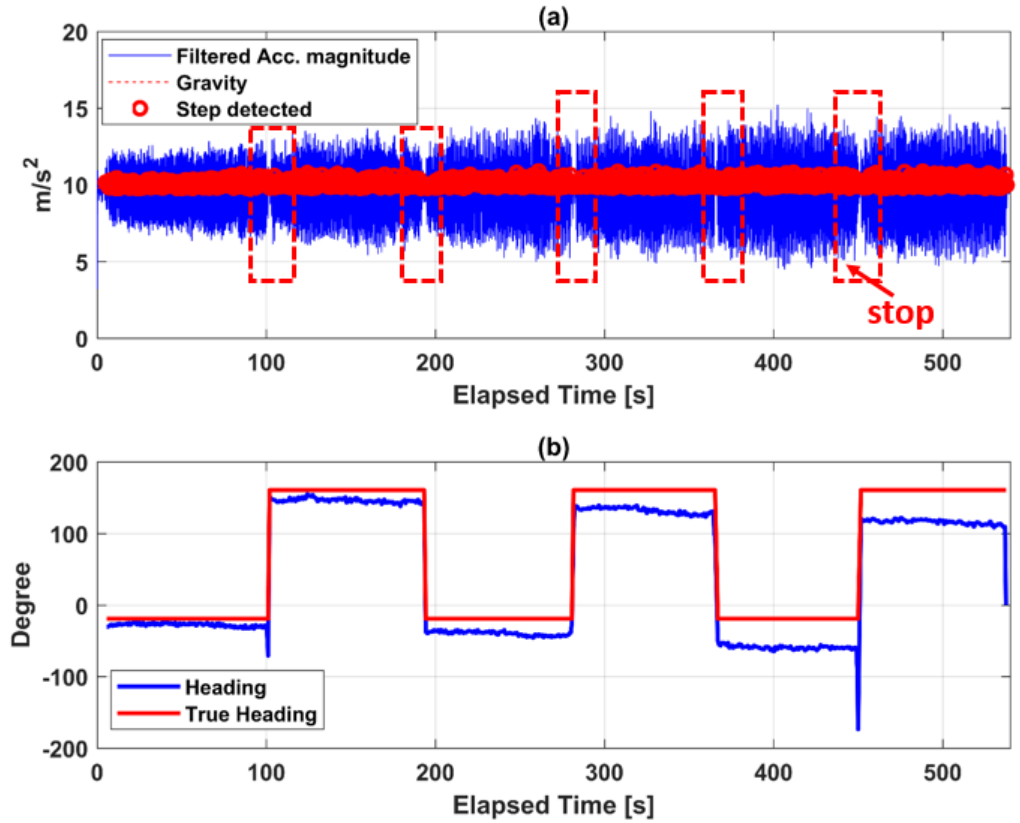
$$\Theta_{k+1} = p\theta^{GNSS}_{k+1} + (1-p)\theta^{PDR}_{k+1}$$

**weights**



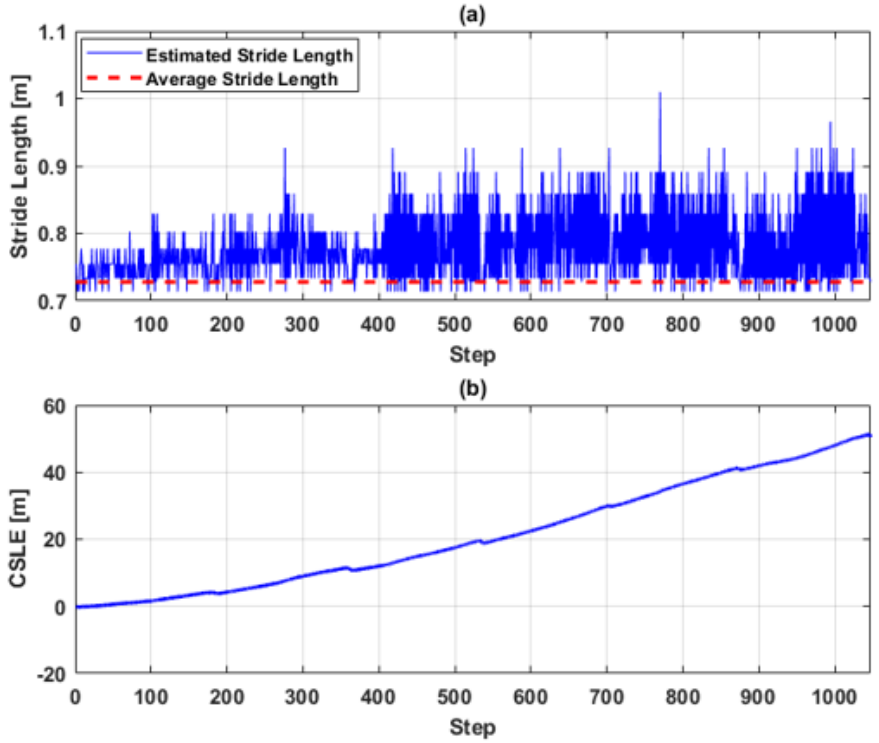
# Experimental Setup


Test Environments

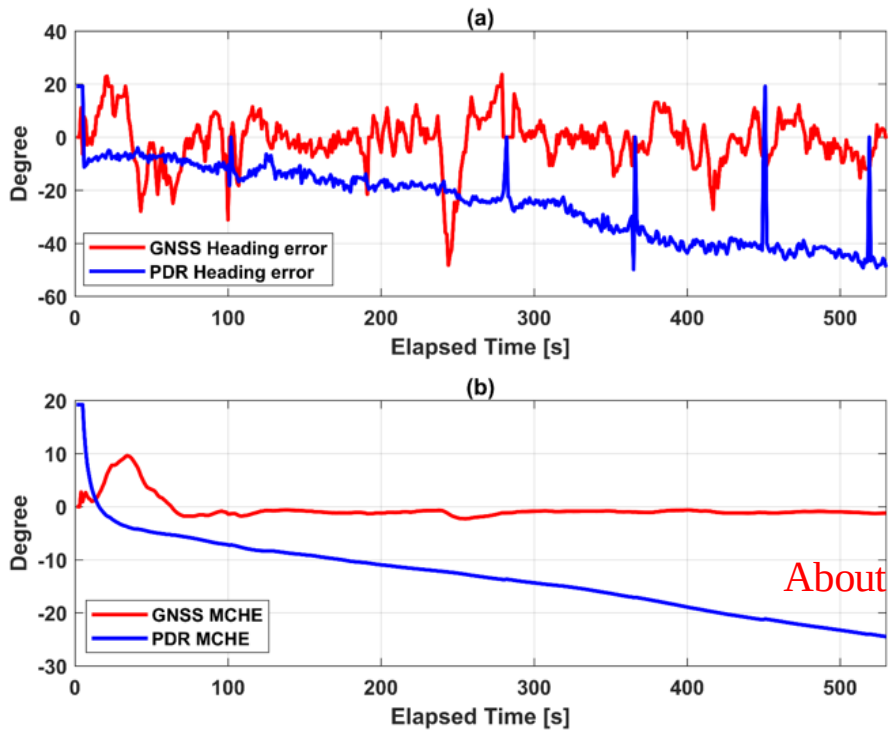



Step detection and heading estimation

# Evaluation of Estimation Errors




Mean: 0.73m

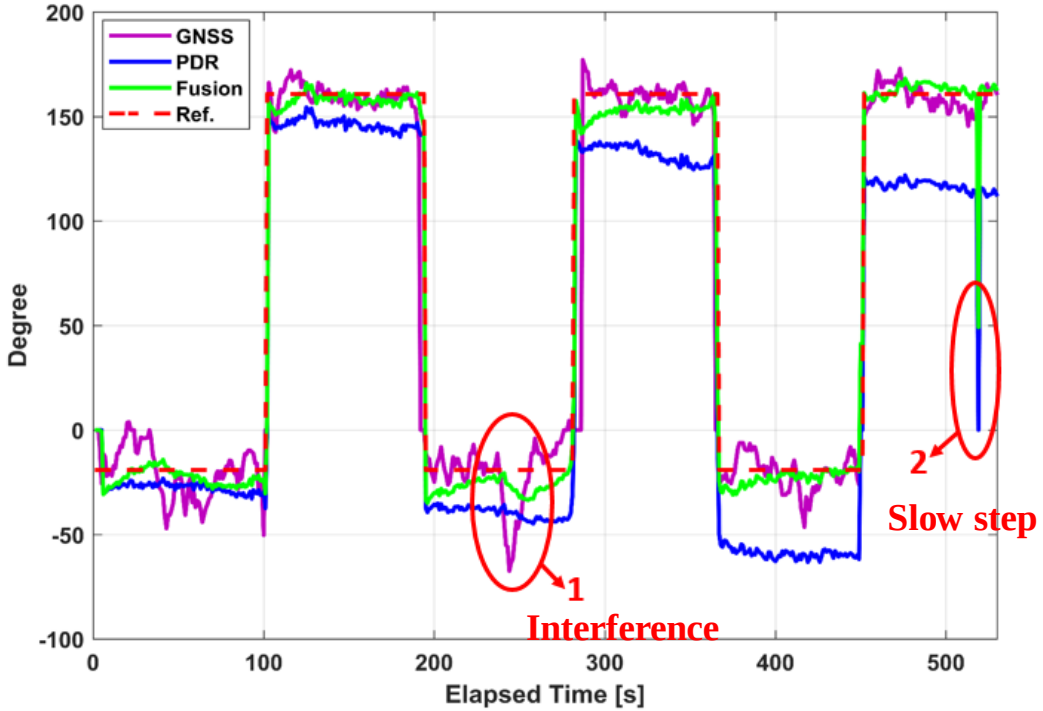



About 20°

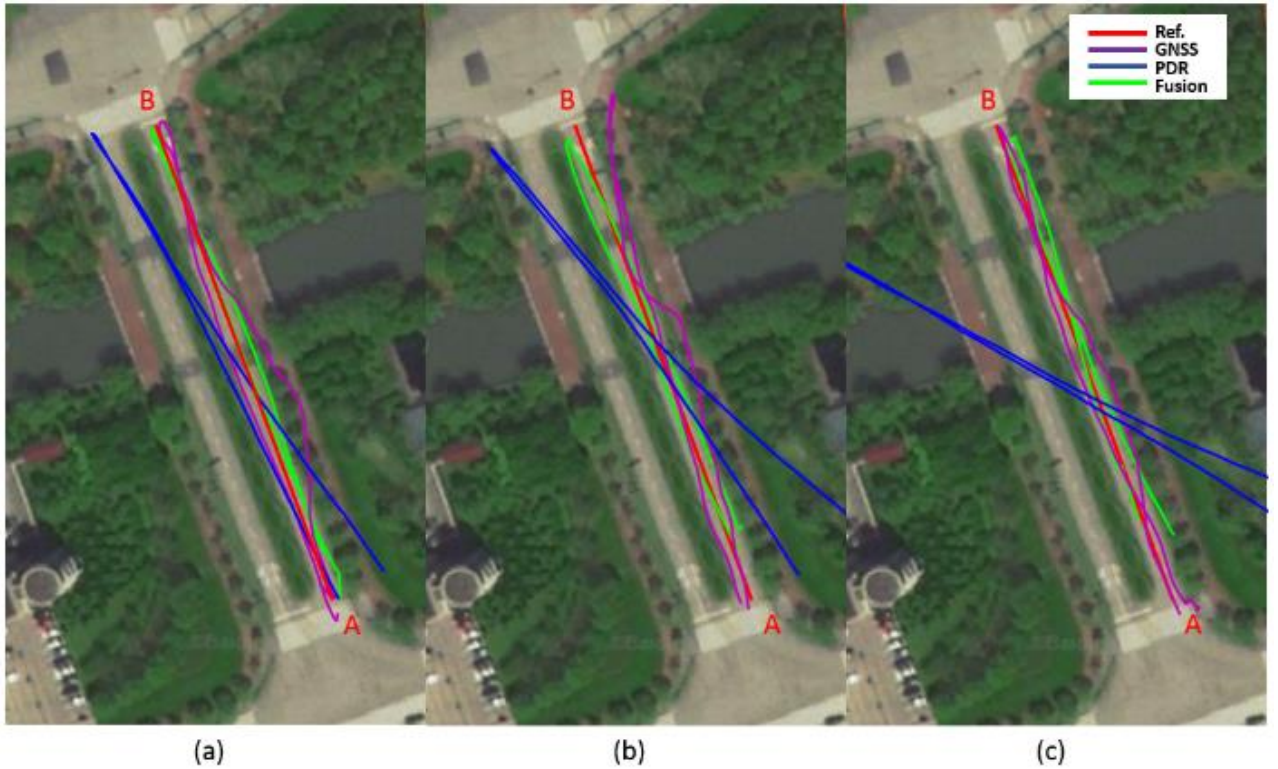
**Stride length error of PDR**

**Heading errors of PDR and GNSS**

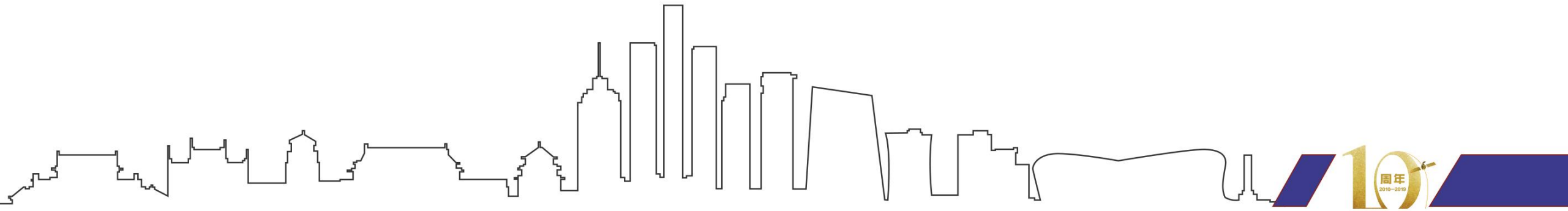
# Experimental Results




Comparison of heading estimation by three different methods




Comparison of trajectories by three methods



# Conclusion

- Error Analysis:
  - Comparing and analyzing the heading and stride length errors of PDR and GNSS
- PDR/GNSS Fusion:
  - The framework gives a synchronization scheme for PDR and GNSS data and the detailed heading and stride length fusion algorithm
- Improvements:
  - Fusion algorithm is better than the single GNSS or PDR algorithm in terms of heading estimation, anti-interference and noise performance, which reflects the complementary advantages of absolute positioning and relative positioning

# THANK YOU