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Institute of **Geodesy and Navigation**
Institut für Erdmessung und Navigation

A PEER-TO-PEER MODEL FOR INDOOR

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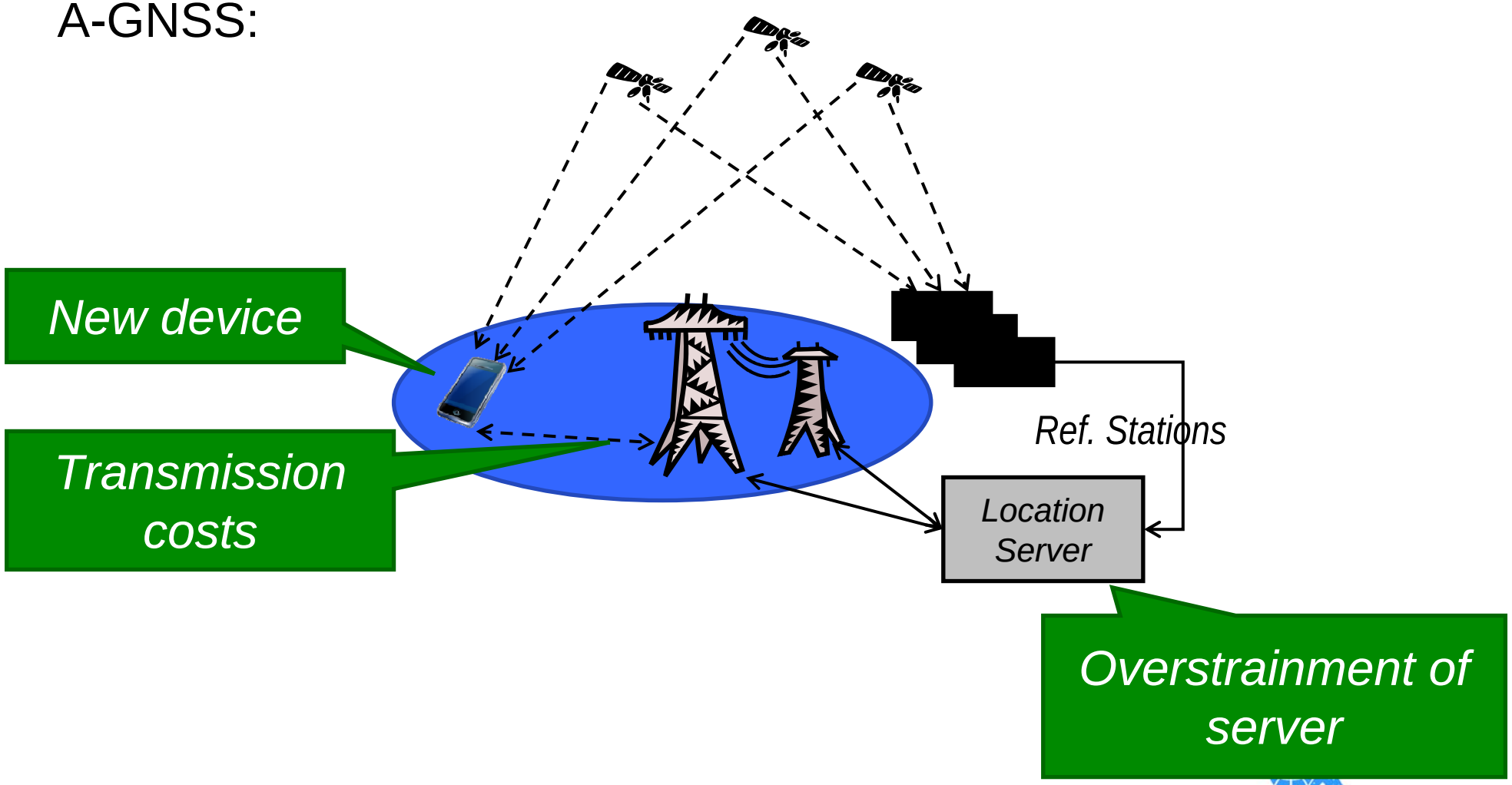
MOTIVATION

A-GNSS:

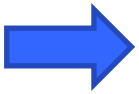


COMMON INDOOR & PEDESTRIAN NAVIGATION METHODS

- **Methods independent of satellite signals**
  - WLAN fingerprints
  - UWB
  - RF-ID-Tags
  - …
- **Drawbacks**
  - Area must be surveyed
  - Additional devices (RF-ID receiver)
  - Low accuracy

PEER-TO-PEER APPROACH

- **Using local ad-hoc networks instead of regional infrastructure networks**
- **Avoidance of additional fees for data transmission**
- **Cheap as based on few additional measuring units**



- Position estimation with satellite signals if possible
- Dead reckoning in weak-signal environment
- Peer-to-peer Kalman Filter with other users‘ devices using Bluetooth as communication link

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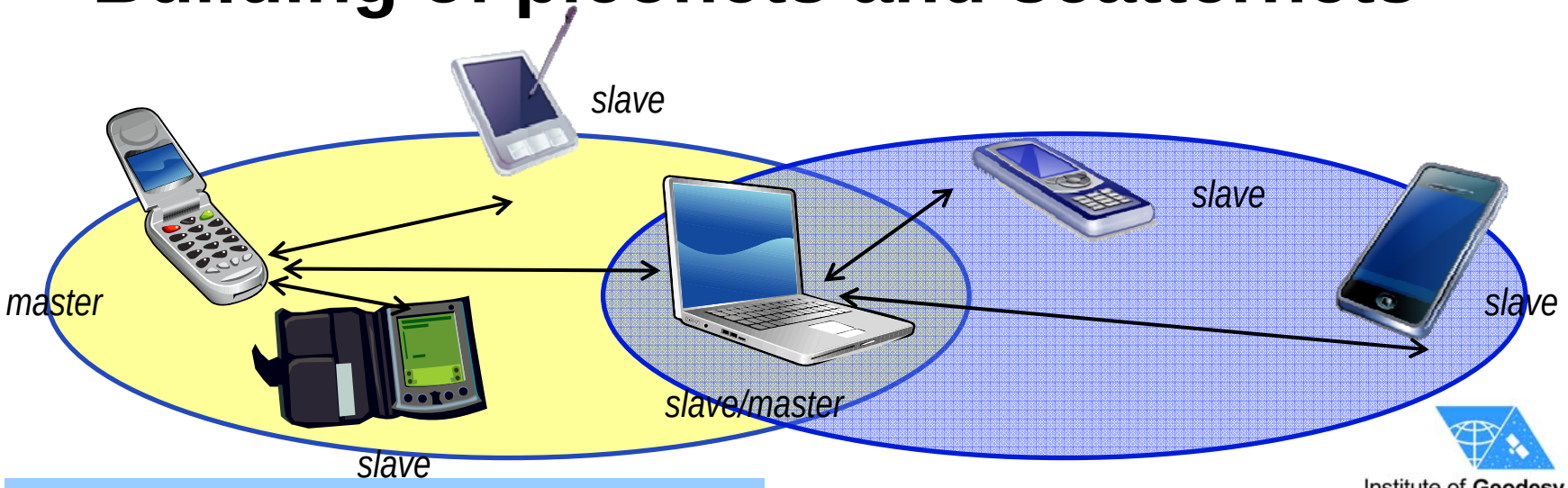
BLUETOOTH IEEE 802.15

- **Wireless network for connections between various types of mobile devices**
- **No infrastructure, no costs**
- **Uses Master / Slave architecture**
- **Building of piconets and scatternets**



DEAD RECKONING

- **Estimating user‘s position by**

$$X_k = X_{k-1} + s_k \cos(\psi_k)$$

$$Y_k = Y_{k-1} + s_k \sin(\psi_k)$$

s_k *is stride length*

ψ_k *is heading*

- **Requires**
  - Rough idea about pimary position
  - Compass to estimate the heading
  - Stride detector
  - Measurement unit to estimate the stride length

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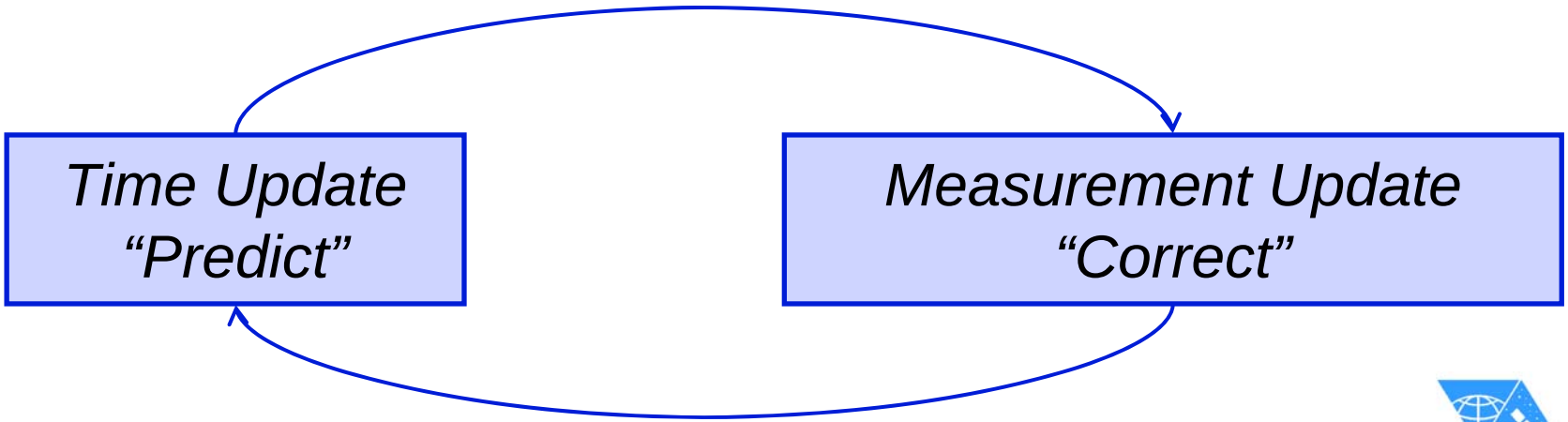
KALMAN FILTER

- **Problem of dead reckoning: Due to the accuracy of the measuring units the position degrades continuously**
- **Use of a Kalman Filter to correct the position**



KALMAN FILTER

- **Time Update:**
  - Calculation of the current state and the error covariance

$$\hat{x}_k^- = A\hat{x}_{k-1} + Bu_k$$

$$P_k^- = AP_{k-1}A^T + Q$$

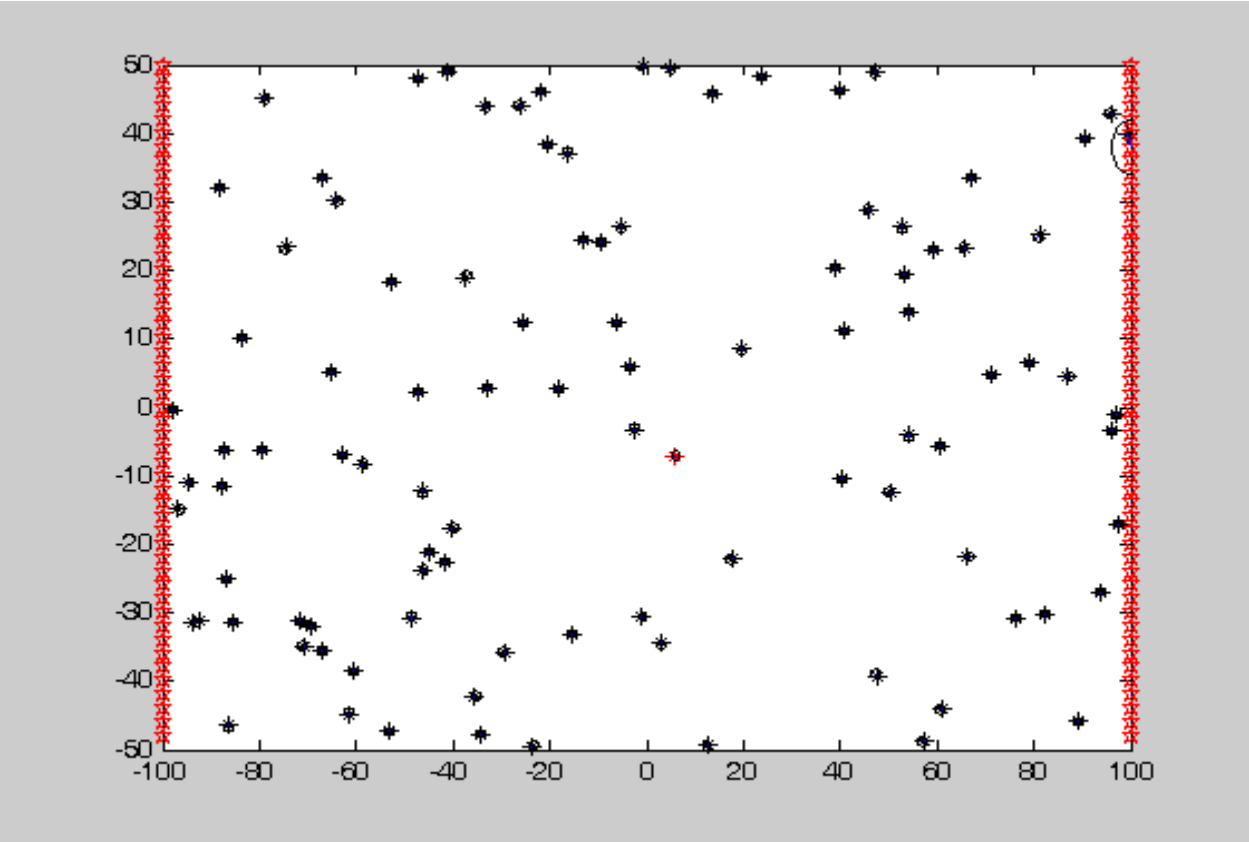
- **Measurment Update:**

$$K_k = P_k^- H^T (HP_k^- H^T + R)^{-1}$$ *Kalman Gain*

$$\hat{x}_k = \hat{x}_k^- + K_k(z_k - H\hat{x}_k^-)$$ *State after correction*

$$P_k = (I - K_k H)P_k^-$$

SIMULATED INDOOR-AREA



SIMULATION PROPERTIES

- **Known to the simulated walker**
  - Estimated position
  - Error variance
  - Estimated error
  - Estimated heading (compass) and standard deviation of heading: $\sigma_{compass} = 15°$
  - Constant stride length of 0.7 m and standard deviation of stride length: $\sigma_{stride} = 0.1[m]$

- **Known only to the simulation**
  - True position of each walker
  - True heading and stride length
  - True error

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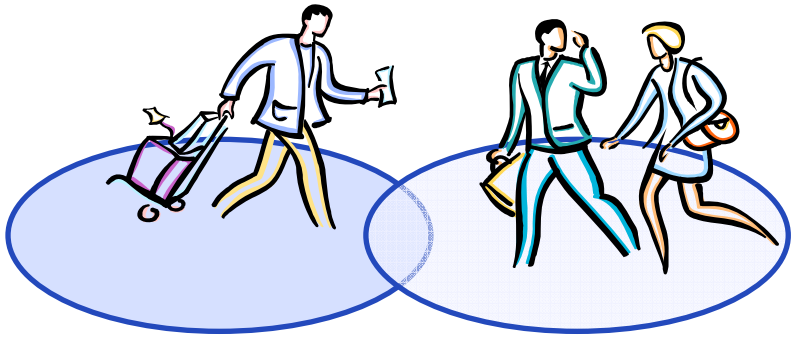
CORRECTION WITH REFERENCE POSITION

- **In each simulation step only one correction is allowed:**
  - with a reference position or
  - with one walker
- **Reference position is preferred against walker**
- **Distance to reference position for correction:<2m**
- **Calculation of the residual between reference position and estimated position of the walker and the error variance**
- **Storing of the residual in the walker's device as error**

CORRECTION WITH OTHER WALKER

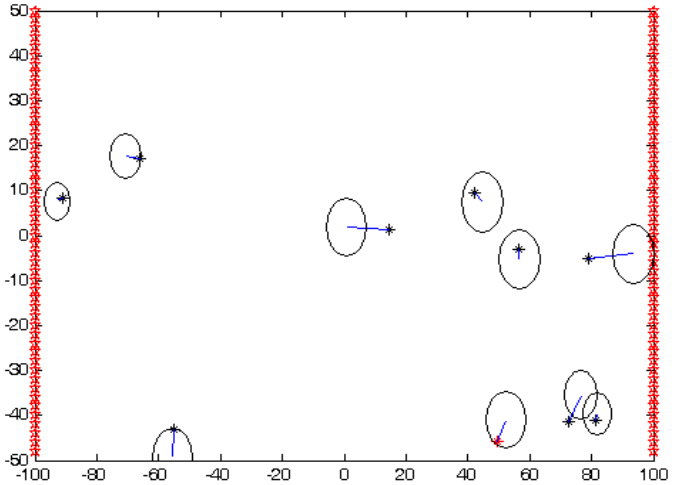


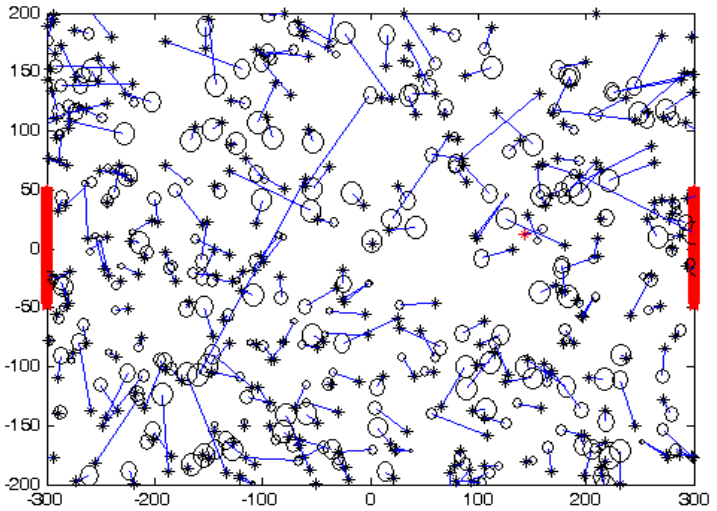
Maximum distance for correction:2 m
Choosing the nearest

1. **Re-Calculation of position based on error and estimated position**
2. **Calculate a new position for both walkers based on weighted average of the error variance and the recalculated position**
3. **Update the error variance for both walkers based on weighted average**

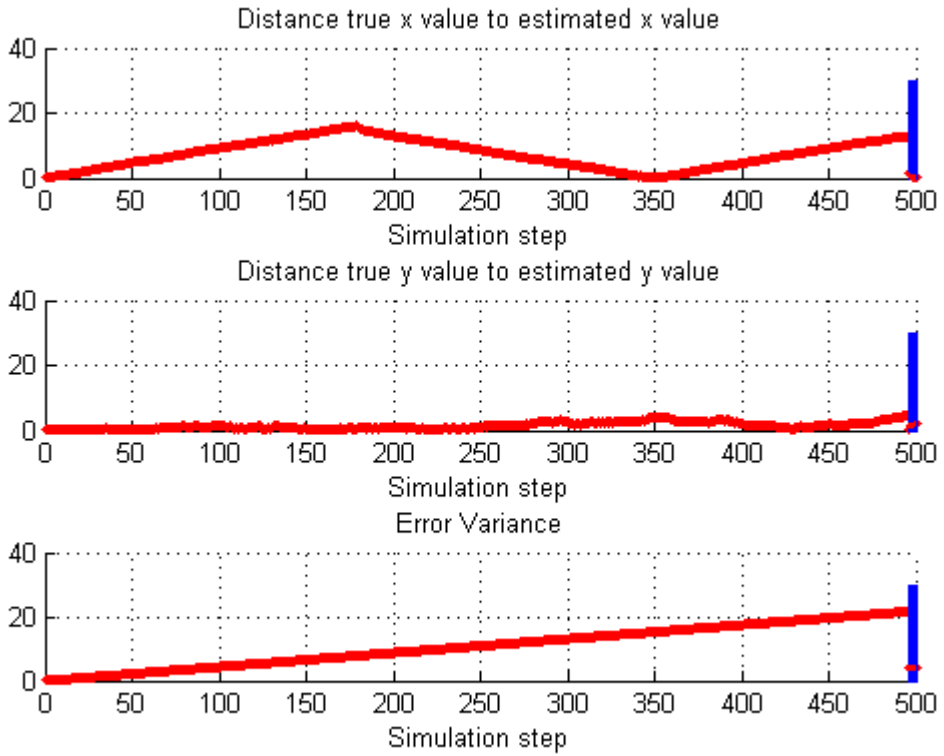
EXPECTATION & TEST SETUP

- **The more participants the better the overall position**
- **Two test setups**
  - Small Indoor Area: 100 x 200 [m] and 200 reference points
  - Large Indoor Area: 400 x 600 [m] and 200 reference points
- **Variation of number of walkers in simulation**

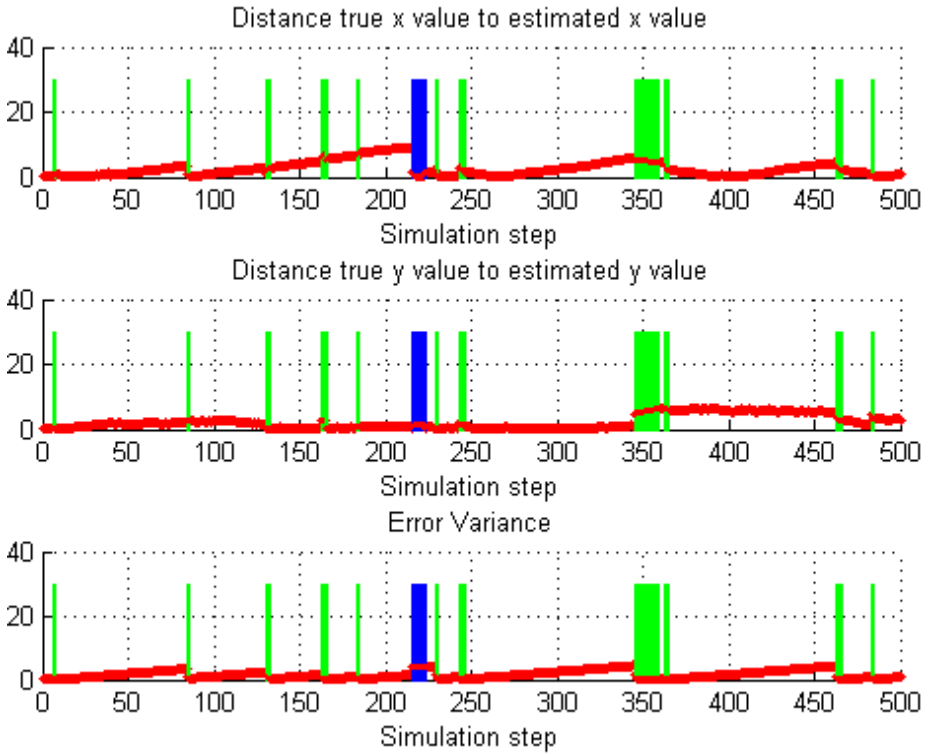




PERFORMANCE



Correction just at reference positions



Correction at reference positions and with other walkers

Significant reduction of error if peer-to-peer model is applied

DRAWBACKS AND SOLUTIONS

- **Privacy issues:**
  - Exchange of position information

  ⇒ Establishing a security protocol that makes it impossible for a user to read position related information from other users

- **Power consumption**
  - Keeping Bluetooth enabled all the time

    ⇒ Enabling Bluetooth only when error variance or error exceeds some threshold

SUMMARY

- **Innovative approach for enhancing indoor positioning based on peer-to-peer model is presented**
  - Sharing of estimated positioning information of close-by users significantly improves positioning accuracy
  - No additional infrastructure required
  - Utilization of communication link
    - Bluetooth already available in most modern user terminals
    - Combination of communication and navigation

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THANKS FOR YOUR ATTENTION!

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