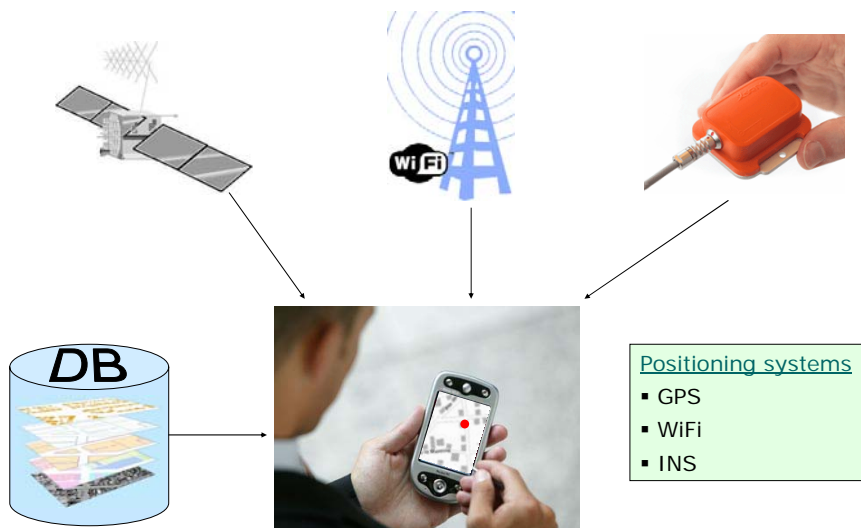


Map-based Autonomous Personal Localization and Tracking

Ivan Spassov
Michel Bierlaire
Bertrand Merminod

Overview and motivation



Inertial sensors and measurements

Inertial Measurement Unit (IMU)

- Compass
- Gyroscope
- Accelerometer
- Barometer

Measurements:

- Velocity
- Azimuth
- Altitude
- Time

(0,0,0)

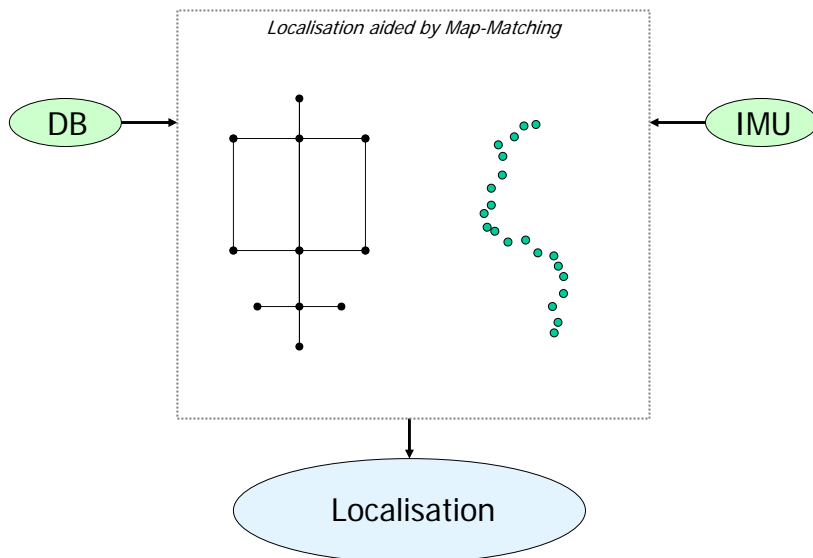
Length (d)
Direction (β)
Elevation (e)

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Problem formulation

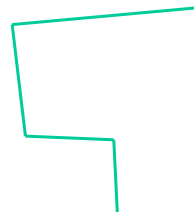
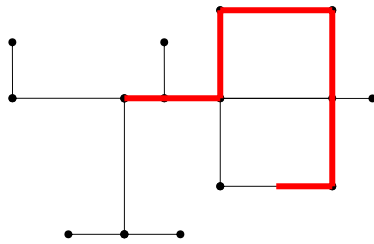
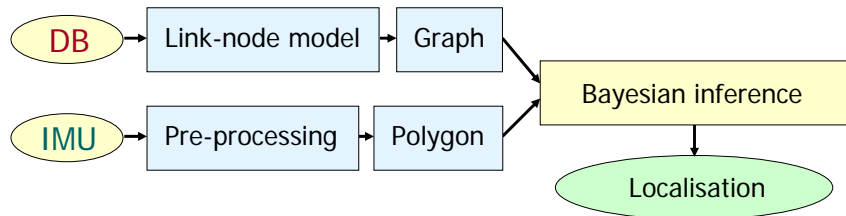


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Methodology

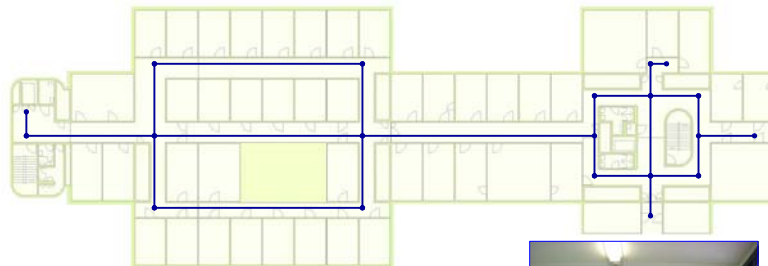


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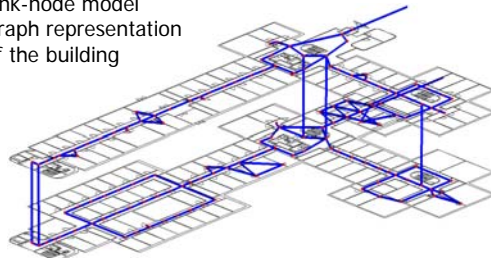
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Map database



- ❖ Link-node model
- ❖ Graph representation of the building



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Pre-processing of raw measurements

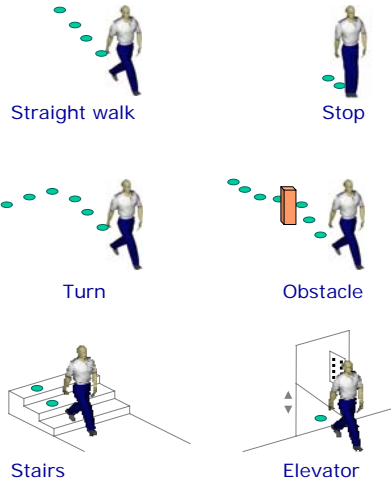
IMU measurements:

- Velocity
- Azimuth
- Altitude
- Time



Parameters:

- Stride length
- Stride direction
- Stride elevation
- Velocity variance



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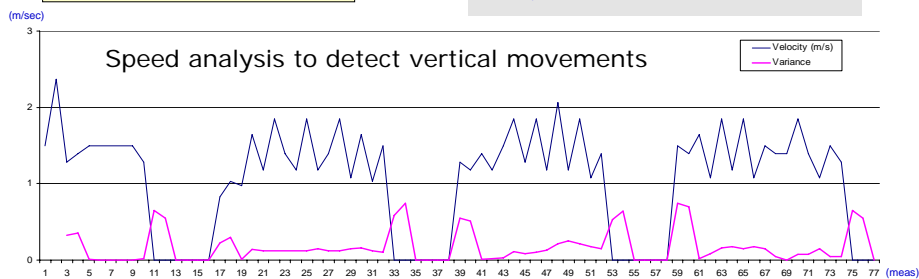
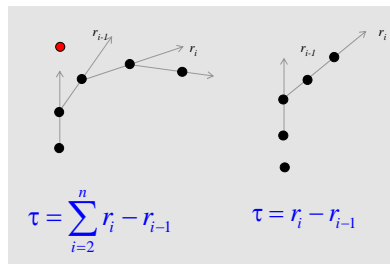
Pre-processing of raw measurements

Trajectory modeling

- Detect specific points
- Determine pivot points

Output

- Polyline



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Bayesian inference

❖ State space model :

$$x_t = f(x_{t-1})$$

$$y_t = h(x_t, x_{t-1}) + z_t$$

x_t - state vector, id of the edge at time t
 y_t - measurement vector from polyline
 $h(e^{(i)}, e^{(i+1)})$ - characteristics of pair (x_t, x_{t-1}) in DB
 z_t - measurement error

$$p(x_t | Y_t) = \frac{\overset{\text{likelihood}}{p(y_t | Y_{t-1}, x_t)} \overset{\text{prior}}{p(x_t | Y_{t-1})}}{\underset{\text{evidence}}{p(y_t | Y_{t-1})}}$$

posterior

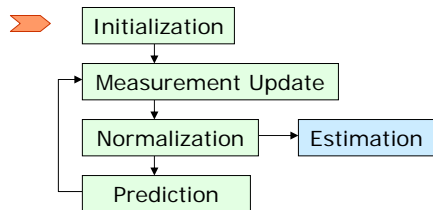
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Algorithm implementation

Recursive estimation of the weight of each edge when new measurements become available.



$$w_0^{(i)} = \frac{1}{n_e}, \quad i = 1, \dots, n_e$$



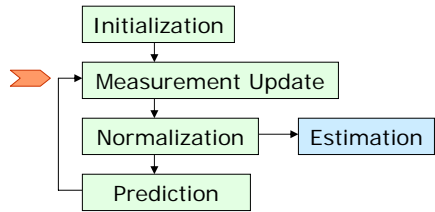
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Algorithm implementation

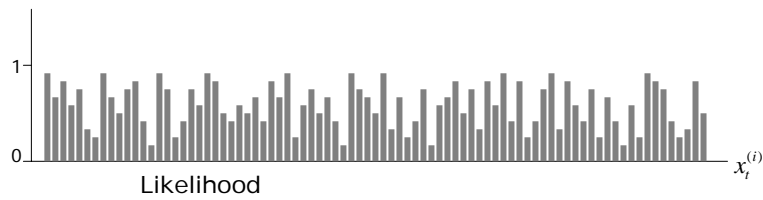
Recursive estimation of the weight of each edge when new measurements become available.



$$w_t^{(i)} = 1 - \frac{\Delta l^{(i)}}{\sum_{i=1}^{n_e} \Delta l^{(i)}}$$

$$w_\alpha^{(i)} = 1 - \frac{\Delta \alpha^{(i)}}{\sum_{i=1}^{n_e} \Delta \alpha^{(i)}}$$

$$w_m^{(i)} = w_t^{(i)} \cdot w_\alpha^{(i)}$$



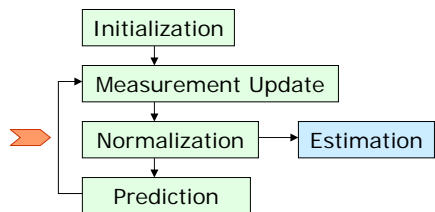
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Algorithm implementation

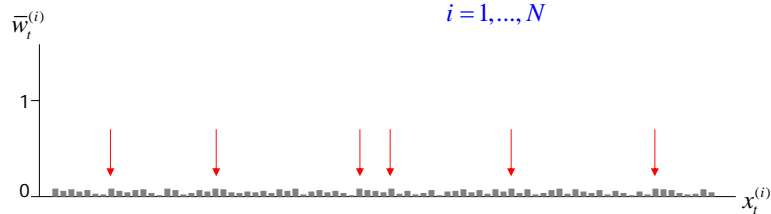
Recursive estimation of the weight of each edge when new measurements become available.



$$\bar{w}_t^{(i)} = \frac{w_t^{(i)}}{\sum_i w_t^{(i)}}$$

$$\hat{x}_t = x_t^{(i)} \left(\bar{w}_t^{(i)} = \bar{w}_t^{(MAX)} \right), \quad i = 1, \dots, n_e$$

$$i = 1, \dots, N$$



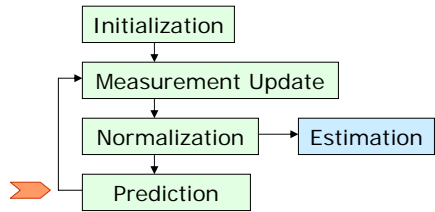
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Michel Bierlaire
Bertrand Merminod



Algorithm implementation

Recursive estimation of the weight of each edge when new measurements become available.



$$w_{t+1}^{(i)} = \begin{cases} 1 & \hat{x}_t \text{ is neighbor of } x_{t+1}^{(i)}, \\ 0 & \text{otherwise} \end{cases}$$
$$i = 1, \dots, n_e$$

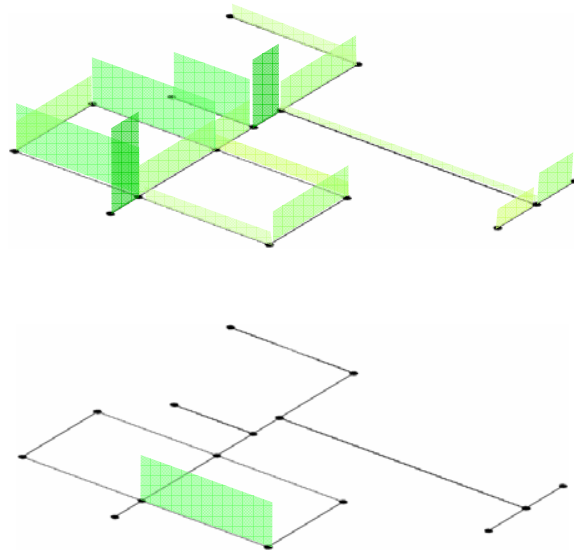


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Convergence



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Tests



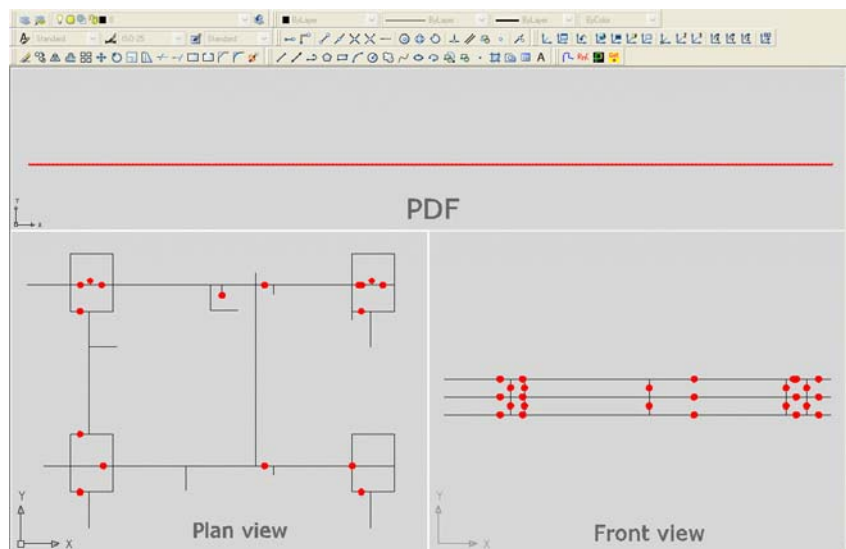
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Example

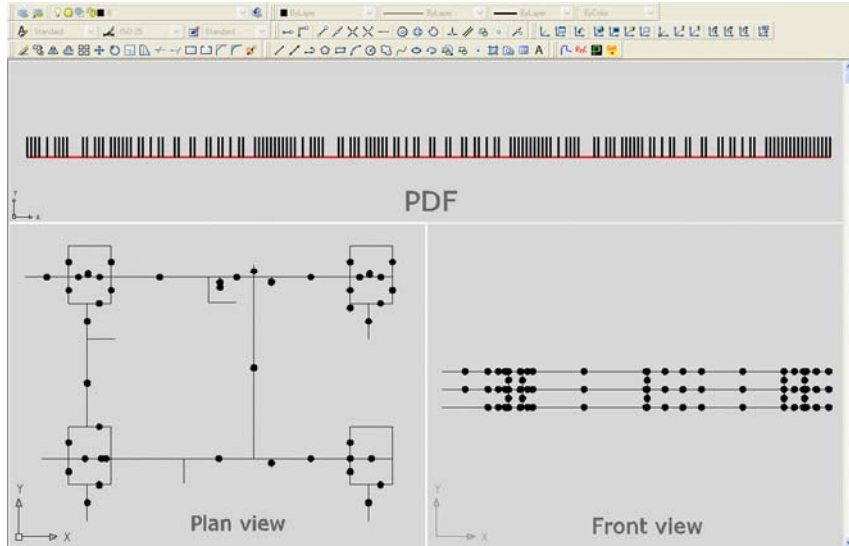
1/13



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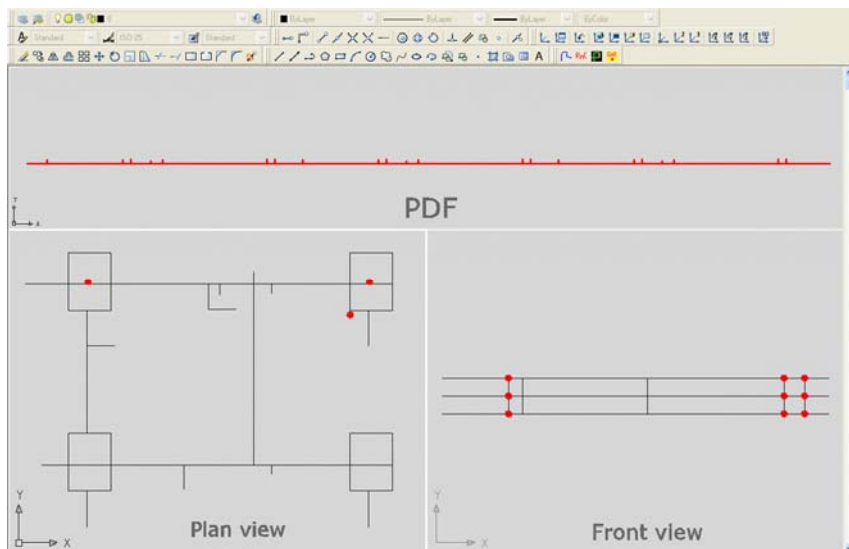
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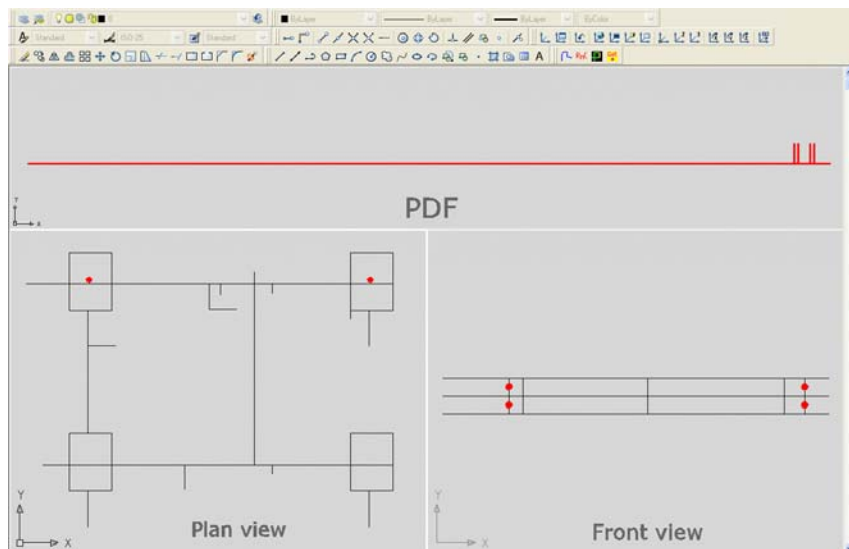
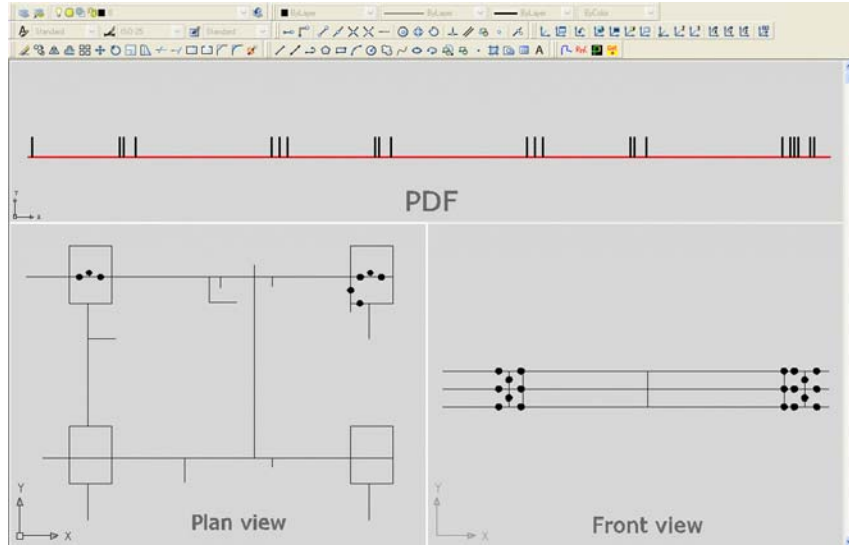
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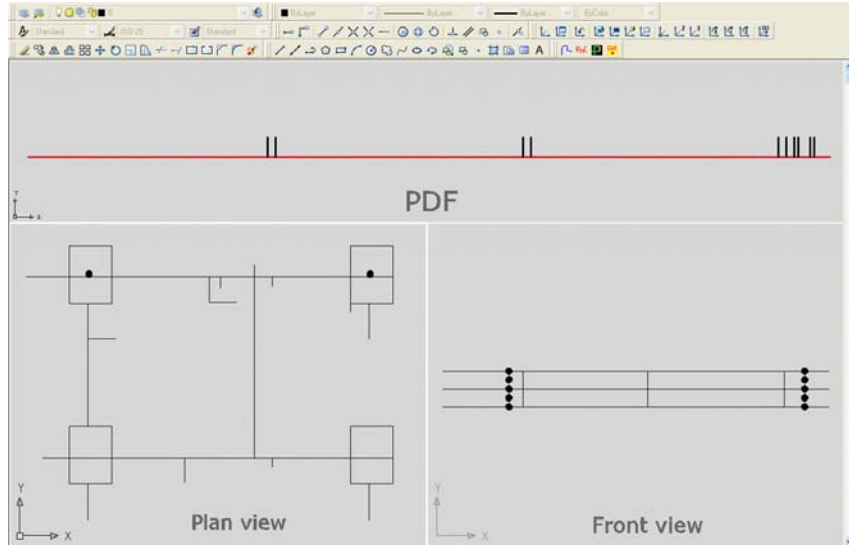
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Example

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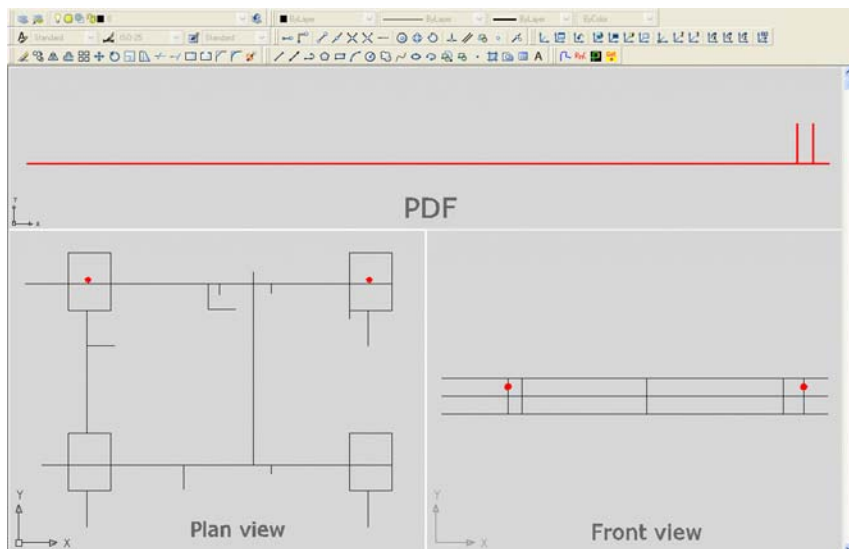
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Example

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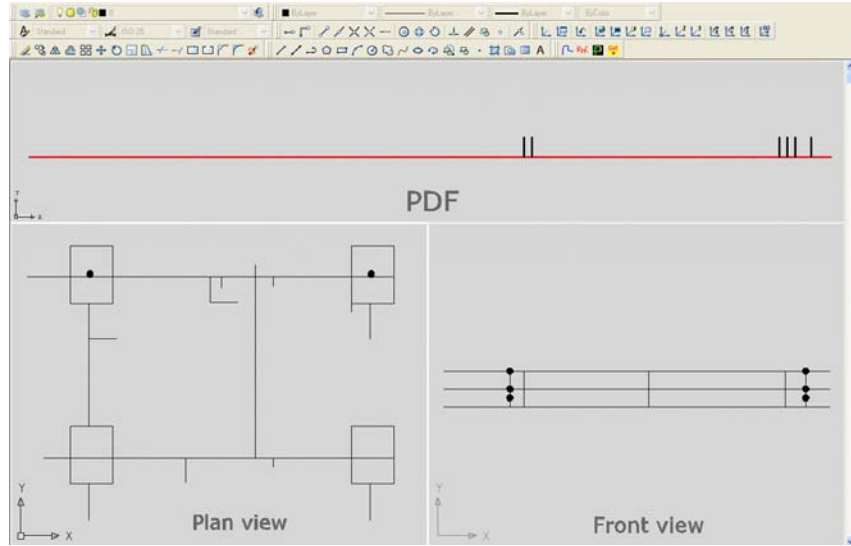
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Example

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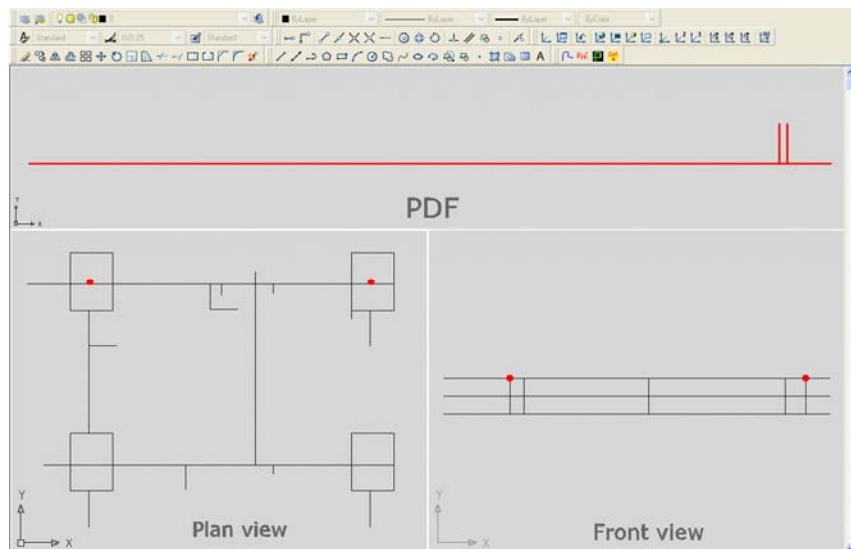
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Example

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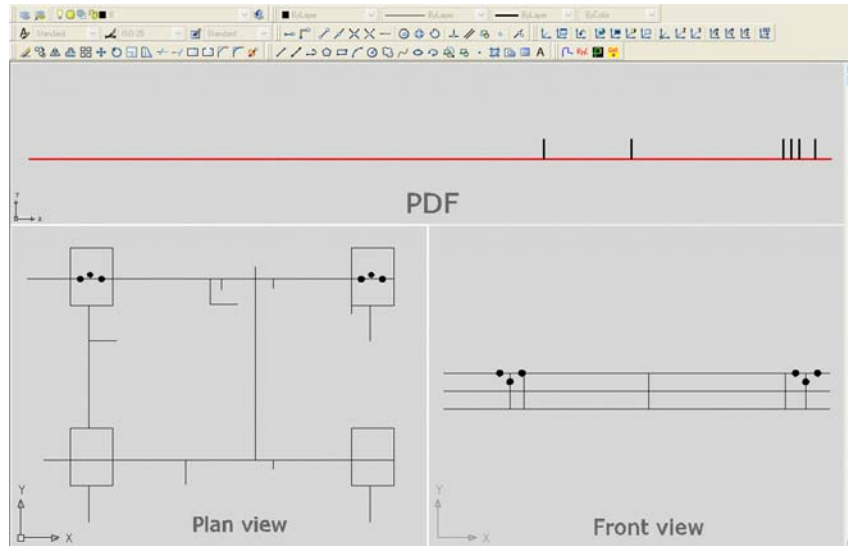
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Example

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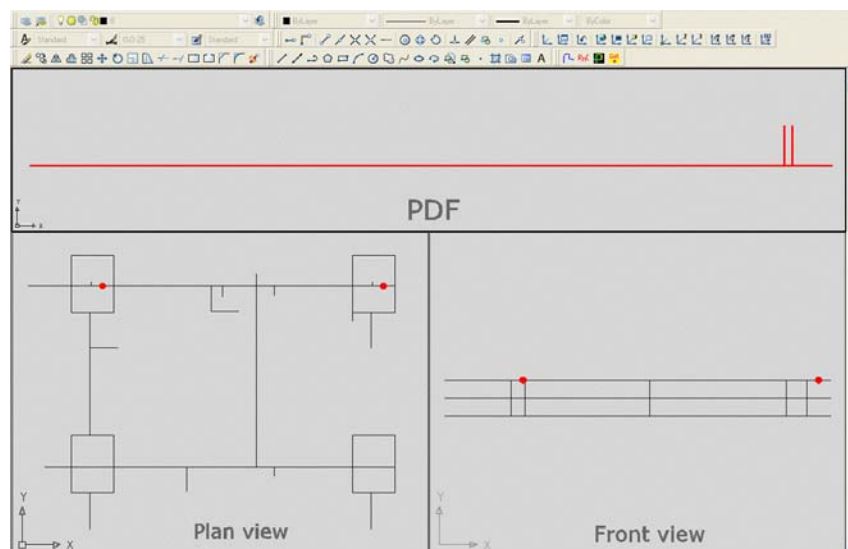
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Example

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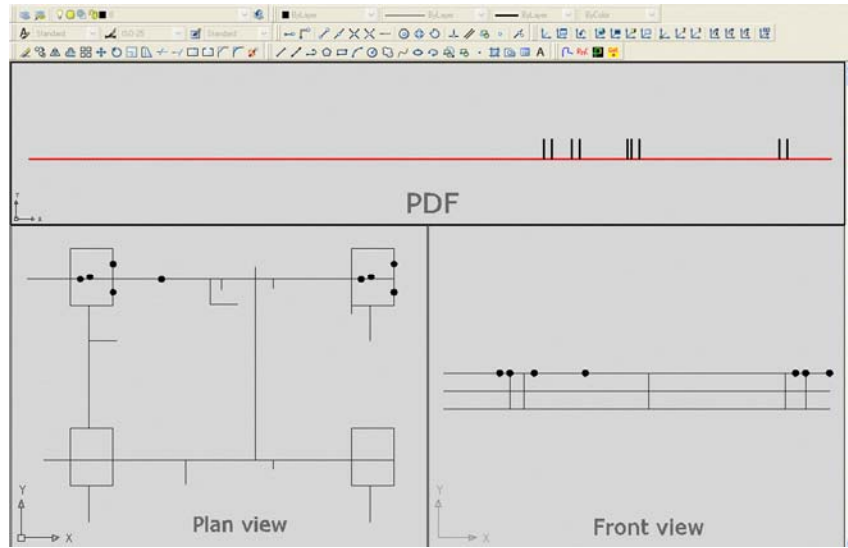
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Example

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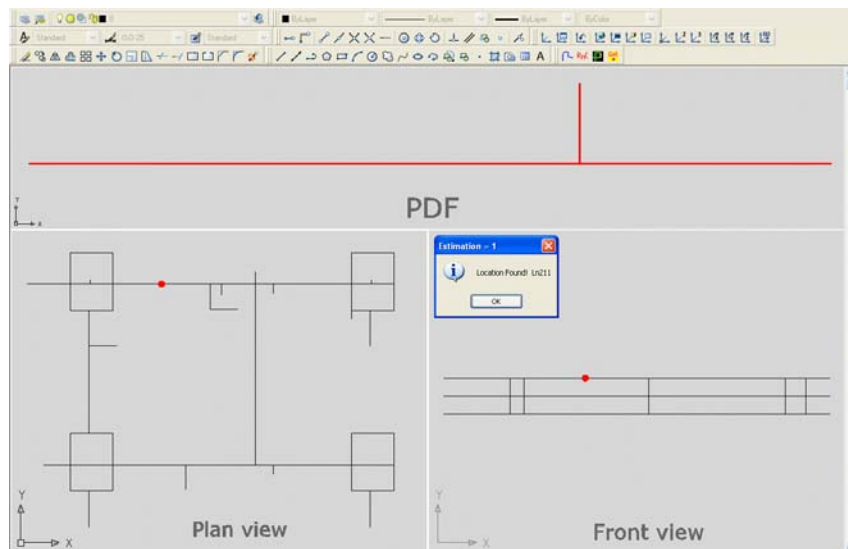
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Example

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Results localization

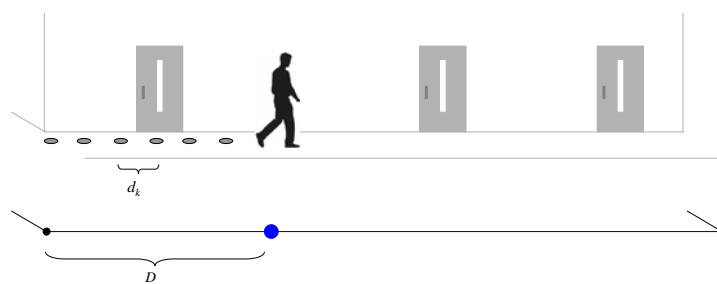
- ❖ Localization after 120m
DB total length : 1300m (202 links)
- ❖ Vertical links – crucial elements
- ❖ Precision
Function of the length of the estimated link

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Michel Bierlaire
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Personal Tracking



$$\gamma_t^{(D)} = A(e^{(D)}) - \sum (\hat{r}_t - \hat{r}_{t-1})$$

$$D_k = \sum d_k$$

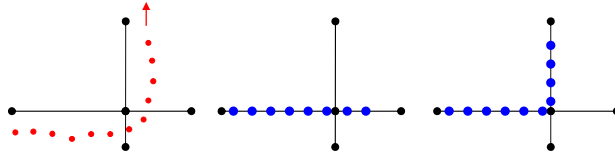
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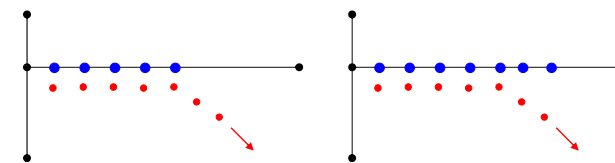


Tests

❖ Robustness



❖ Robustness



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Conclusions and perspectives



- Fully autonomous localisation process;
- Inertial measurements only;
- Entire PDF of location is used, involving all the samples into the computation at every moment;



- Modelling of more sophisticated movements of the person;
- Real-time implementation of the process;

Thank you for your attention

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Ivan Spassov
Michel Bierlaire
Bertrand Merminod

