

Summary of IPIN 2017 Competition Track4



Sponsors



Frameworkx



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Contributor: Ryo Shimomura (U. of Tsukuba)

Characteristics of Track4

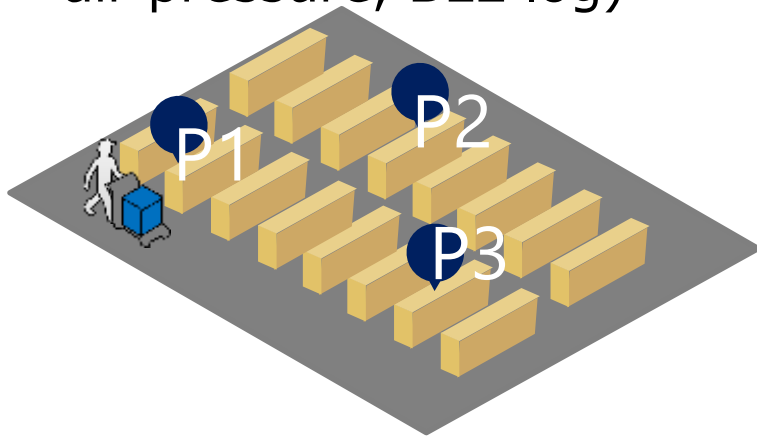
- **Competition using data measured in real warehouse**
 - 7 picking workers are measured for about 3 hours
 - Competitors submit trajectory of workers.
- **Multiple sources of localization**
 - Sensor data for PDR, WMS(warehouse management system) log, map and obstacles information, RSSI of BLE tag
- **Various actions**
 - Walking / Picking at shelves/ Operating the terminals / Carrying goods using carts
- **Realistic walking style**
 - free route, forward/side/back step, stop
- **Data measurement by smartphone**



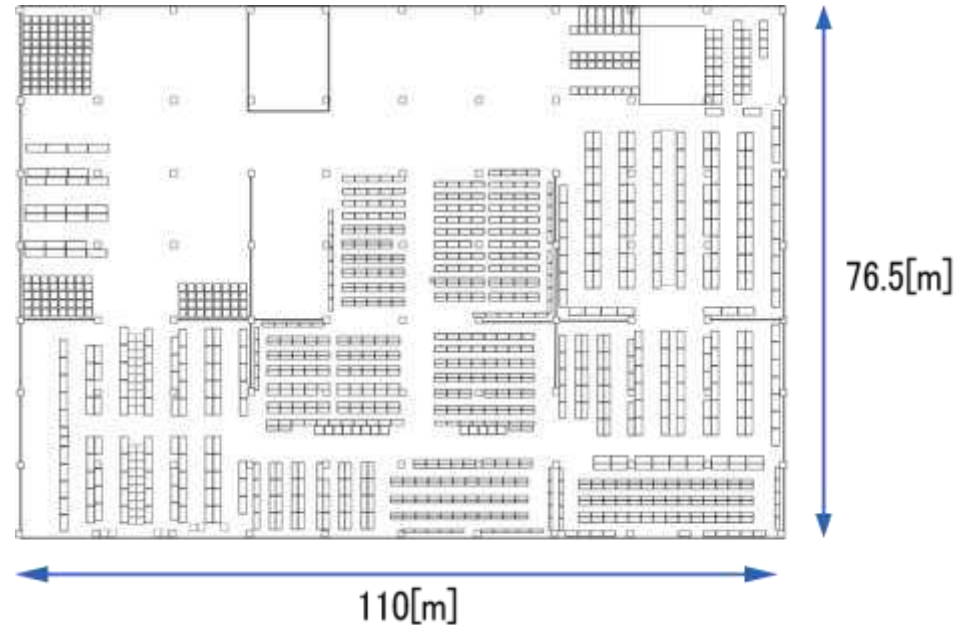
Data shared for competition



Smartphone Sensor data
(gyro. ,acceleration, magnetism,
air pressure, BLE log)

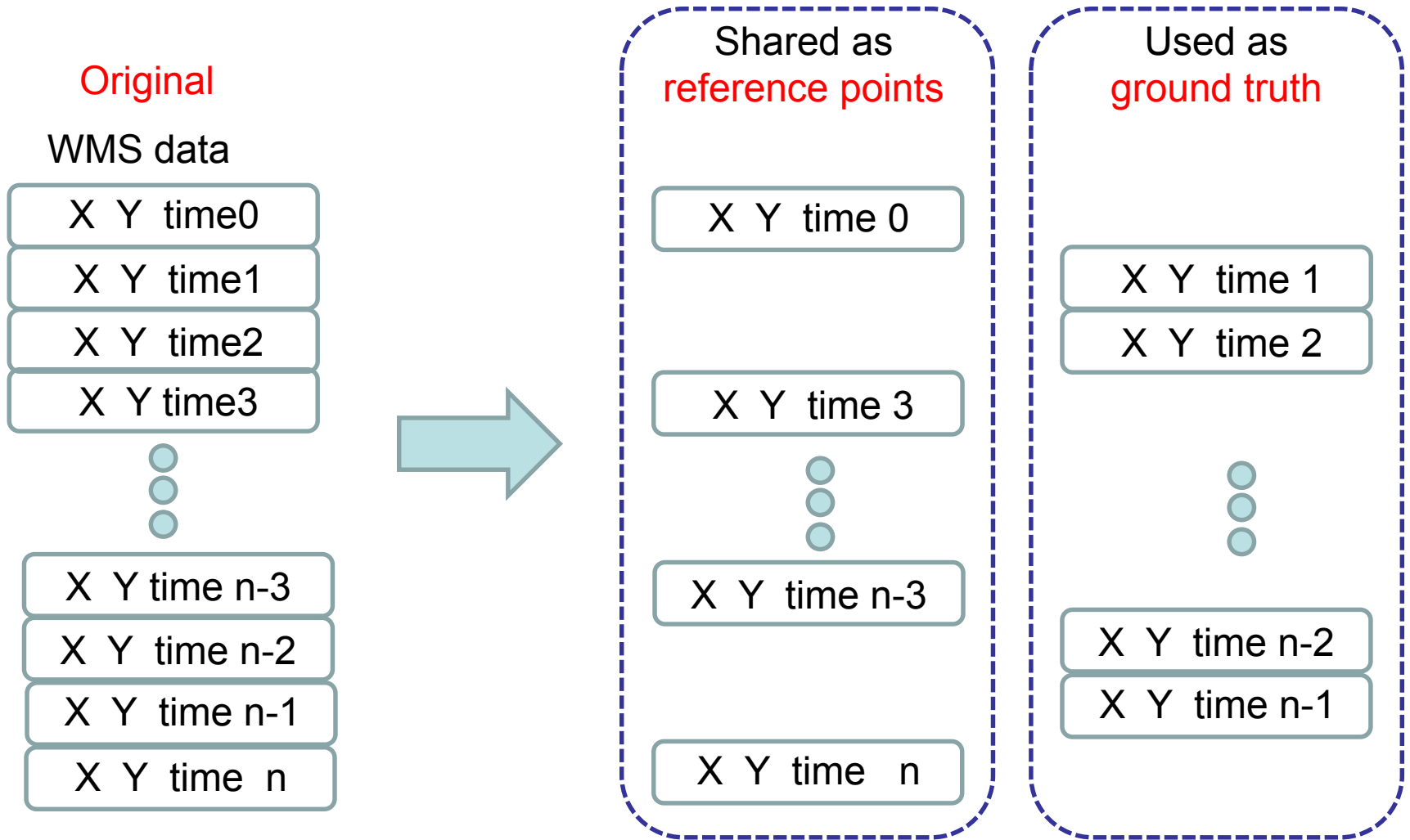


Picking log data from
WMS



Information about
Warehouse
(Map, Shelves, Obstacles)

Ground Truth: Selected WMS log



Ratio of Reference: Ground Truth \Rightarrow 1:1(Easy), 1:3 (Hard)

Evaluation Metrics

Accuracy metrics

- Integrated positioning error evaluation (E_d)
- PDR error evaluation (E_s)

Naturalness metrics

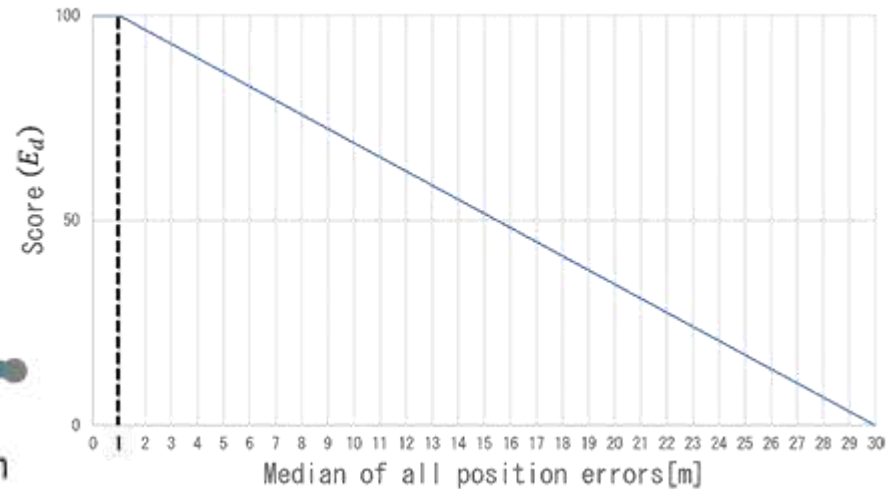
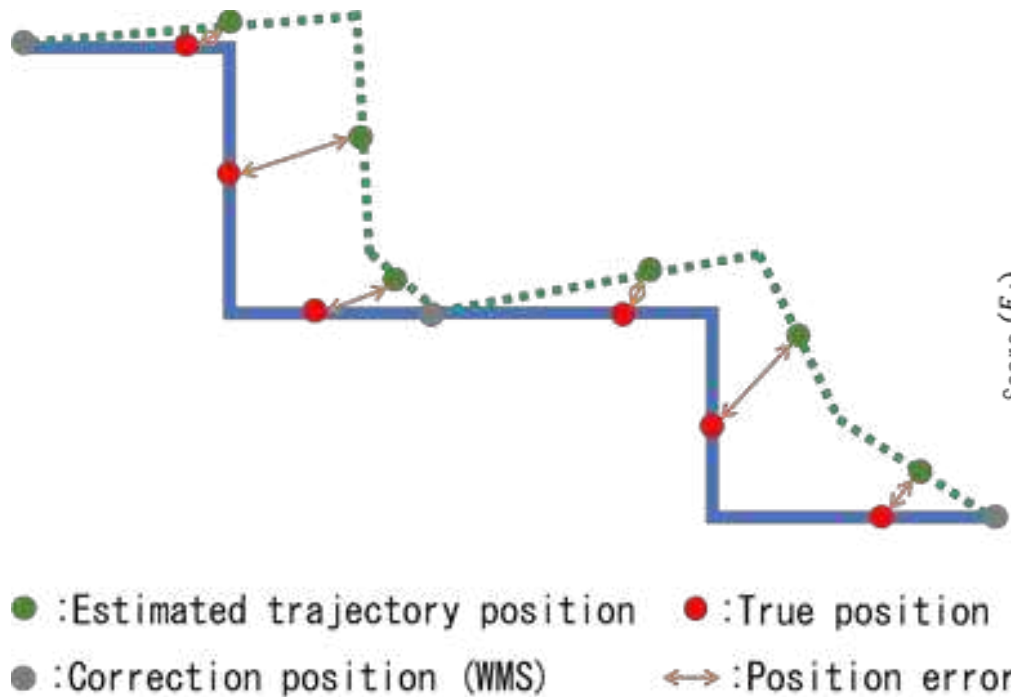
- Human moving velocity evaluation (E_v)
- Update frequency evaluation (E_f)

Warehouse-dedicated metric

- Obstacle interference evaluation (E_o)
- Picking work evaluation (E_p)

Integrated positioning error (E_d)

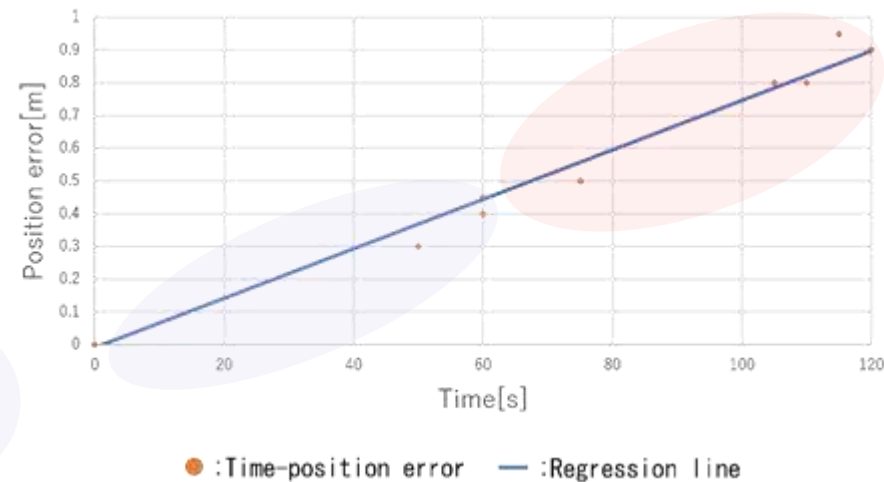
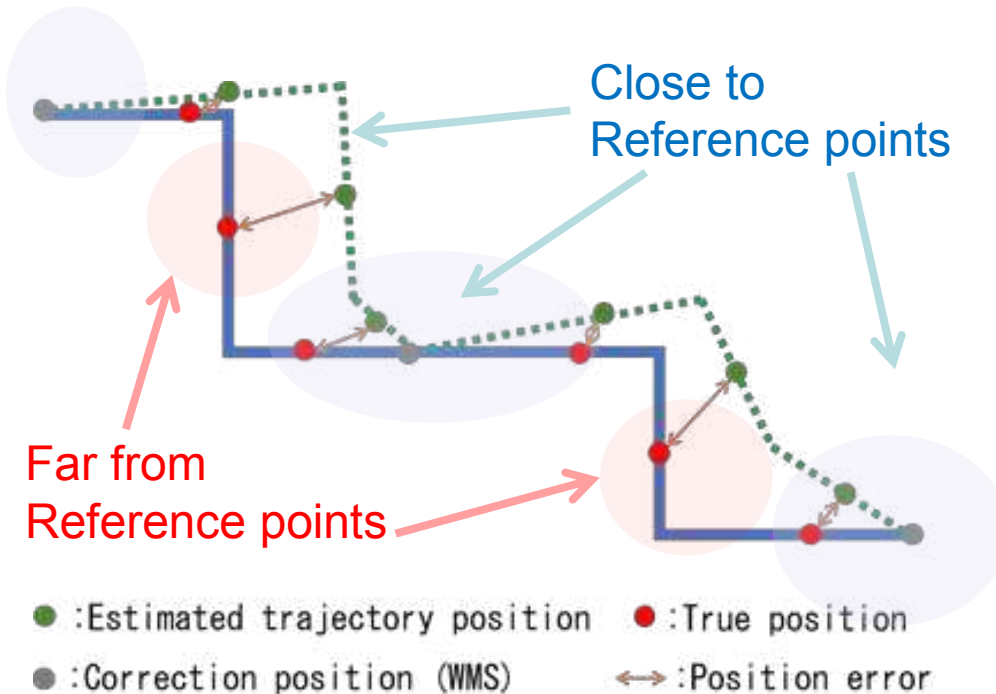
- Median of all positional errors at evaluation points (points with ground truth)



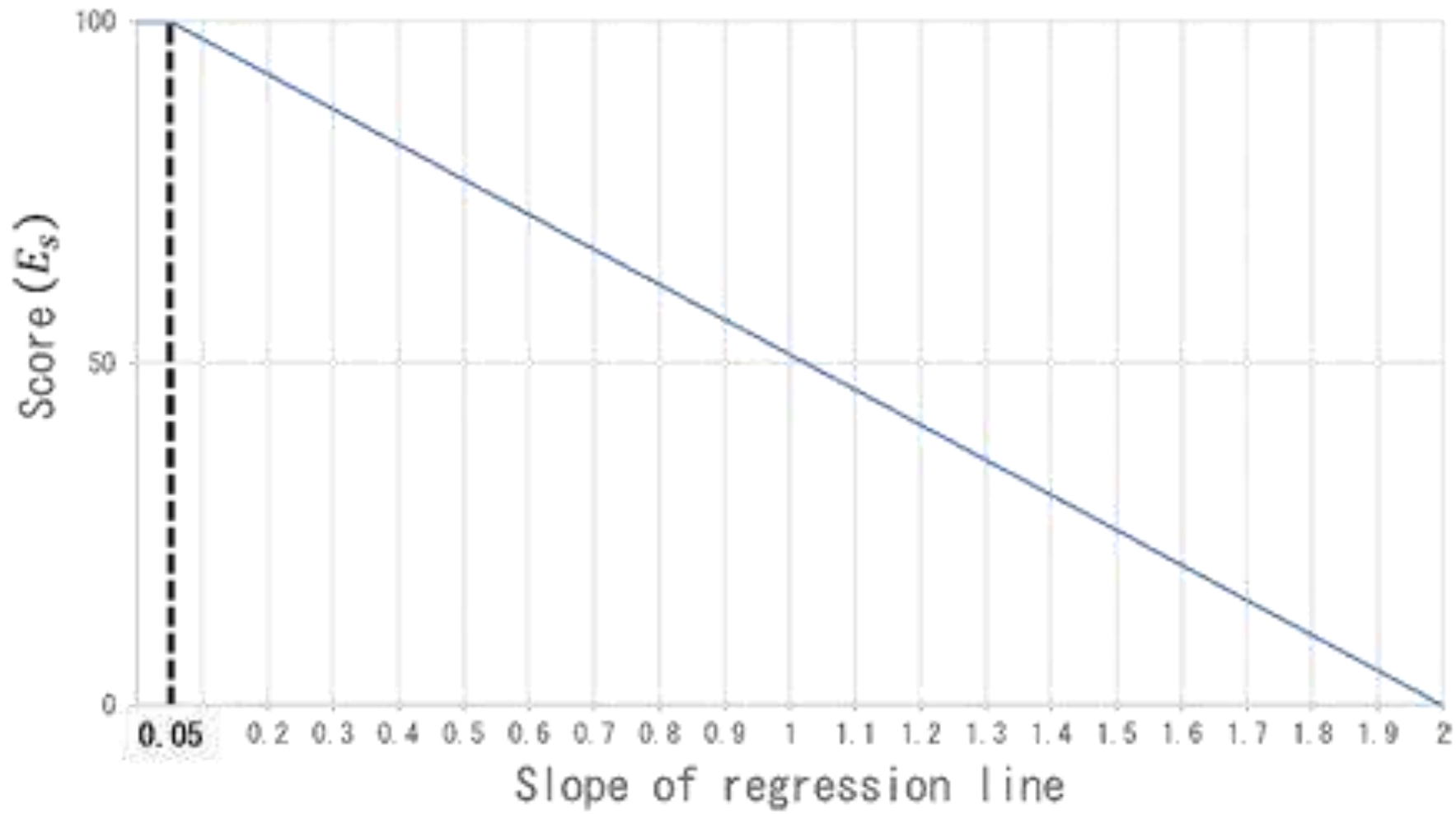
Score function

PDR error evaluation (E_s)

- Error metrics for accumulation error.
- Error accumulation can be evaluated by the slope of regression line [Abe et al. IPIN2016]



Score function of PDR error



Picking work evaluation (E_p)

- Metric for naturalness of trajectory around picking points
- Checks movements around picking (+/- 1.5 sec.)

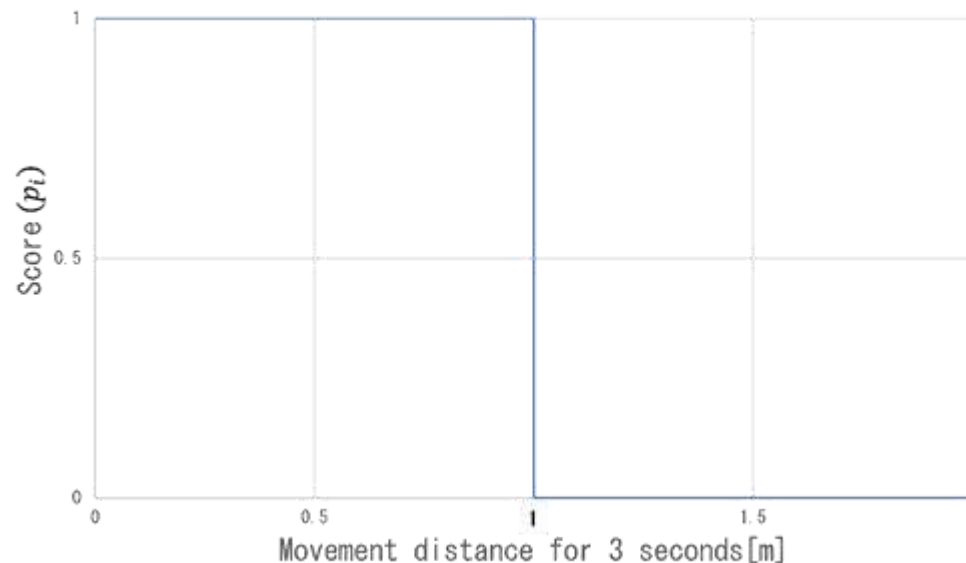
$$E_p = \frac{\sum_{i=1}^{max} p_i}{p_{max}} \times 100$$

P_i : Number of times of picking whose movement distance below 1m

P_{max} : Number of all true positions.

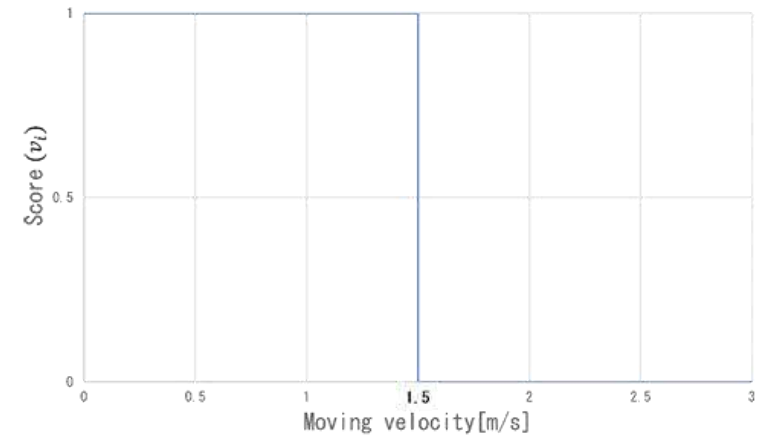
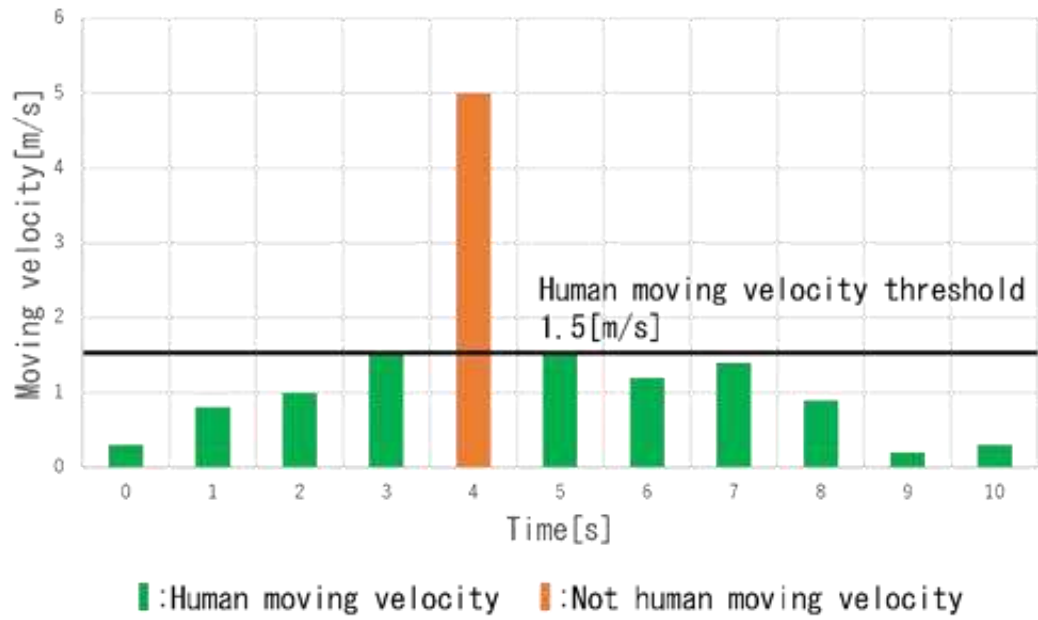


● : True position — : Estimated trajectory - - - : Estimated picking trajectory



Human moving velocity evaluation (E_v)

- Metric for naturalness of moving velocity
- Checks velocity compared to threshold [1.5m/s].

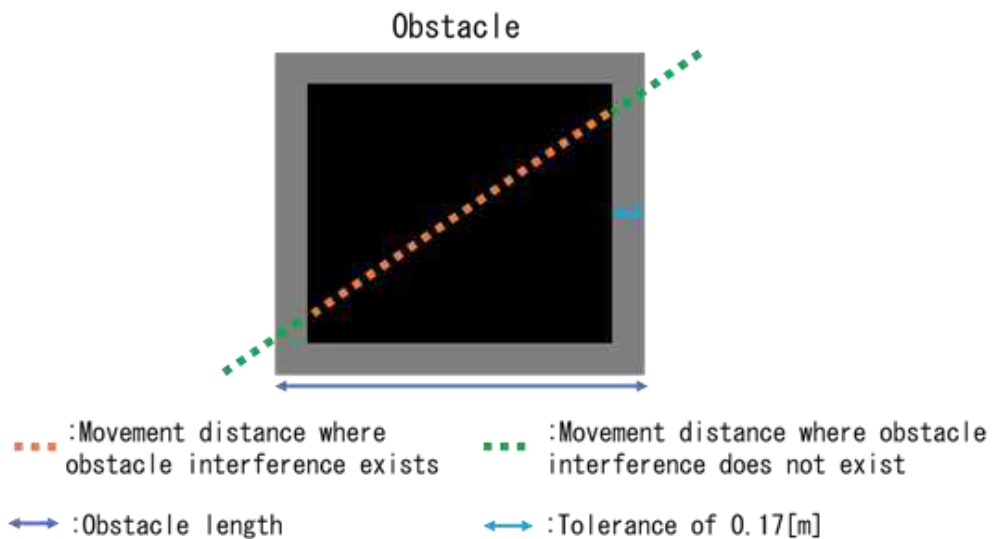


$$E_v = \frac{\sum_{i=1}^{max} v_i}{v_{max}} \times 100$$

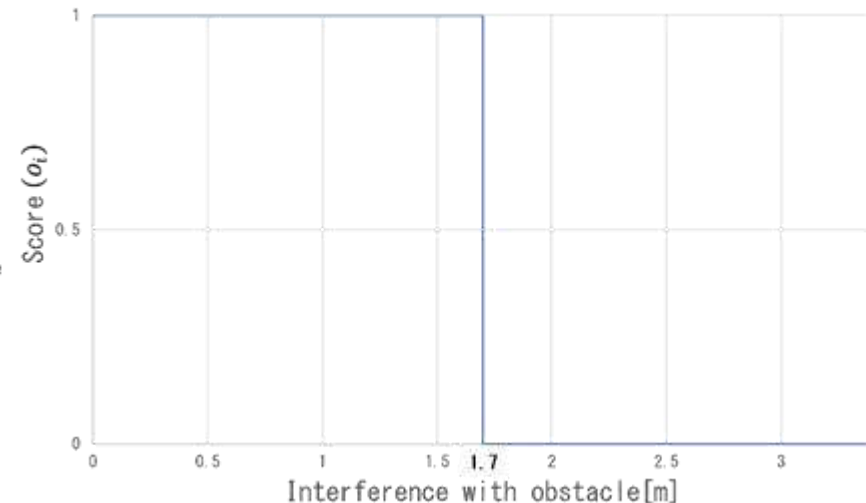
v_i : Number of times that it is determined to be a human moving velocity*. v_{max} : Number between all trajectory positions.

Obstacle interference evaluation (E_o)

- Metric for obstacle interference of trajectory
- Checks how many pixels of trajectory (not only submitted points) are in the obstacles area



$$E_o = \frac{\sum_{i=1}^{max} o_i}{o_{max}} \times 100$$



o_i : Pixels of trajectory without obstacle interference*. o_{max} : Total pixels of trajectory.

Update frequency evaluation (E_f)

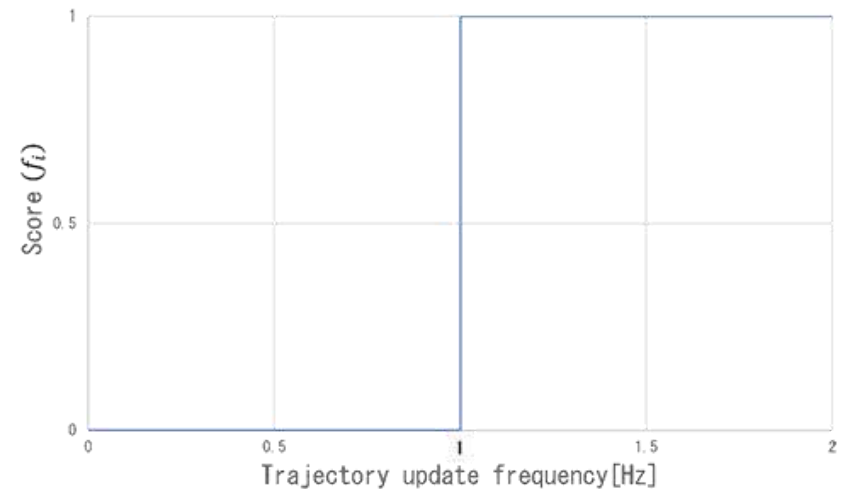
- Frequency of trajectories are expected to more than 1Hz.

$$\text{Trajectory update frequency} = \frac{1}{u_t - u_{t-1}}$$

$$E_f = \frac{\sum_{i=1}^{\max} f_i}{f_{\max}} \times 100$$

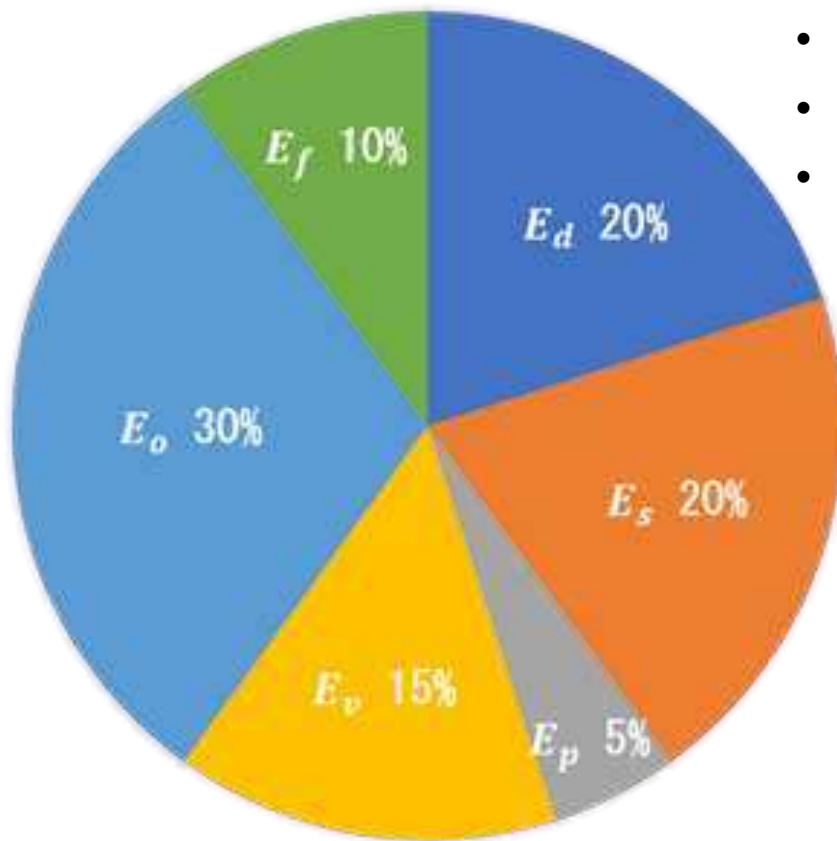
f_i : The number of frames whose updated frequency is more than 1[Hz]

f_{\max} : The total number of frames of trajectory.



Comprehensive evaluation (C.E.)

- Integrated positioning error evaluation (E_d)
- PDR error evaluation (E_s)
- Picking work evaluation (E_p)
- Human moving velocity evaluation (E_v)
- Obstacle interference evaluation (E_o)
- Update frequency evaluation (E_f)



Our competitors

<p>Team 1 (ETRI)</p>	<p><i>A Multi-Sensor Fusion Technique for Pedestrian Localization in a Warehouse</i> Youngjae Lee, Haemin Lee, Jinhong Kim, Dongyeop, Kang, Kiyoungh Moon (ETRI, Korea), Seong Yun Cho (Kyeongil University, Korea)</p>
<p>Team 2 (KDDI)</p>	<p><i>No PDR, No future</i> Yoshihiro Ito, Hisashi Hoshi (KDDI R&D Laboratories Inc., Japan)</p>
<p>Team 3 (XMU)</p>	<p><i>A Smartphone Based Indoor Positioning System</i> Lingxiang Zheng, Yizhen Wang, Ao Peng, Zhenyang Wu, Dihong Wu, Biyu Tang, Hai Lu, Haibin Shi (Xiamen University, China), Huiru Zheng (University of Ulster, Ireland)</p>
<p>Team 4 (Nagoya)</p>	<p><i>Trajectory Estimation Using PDR and Simulation of Human-Like Movement</i> Kotaro Hananouchi, Junto Nozaki, Kenta Urano, Kei Hiroi, Nobuo Kawaguchi (Nagoya University, Japan)</p>
<p>Team 5 (YZU)</p>	<p><i>Moving Trajectory Estimation Based on Sensors</i> Ho-Ti Cheng, Wen-Chen Lu, Chia-Min Lin, Yu-Shen Lai, Yun-Yeh, Huan-Wei Liu, Shih-Hau Fang (Yuan Ze University, Taiwan) Ying-Ren Chien (National Ilan University, Taiwan), Yu Tsao (Academia Sinica, Taiwan)</p>

Results

Submitted Trajectories

- Terminal 2

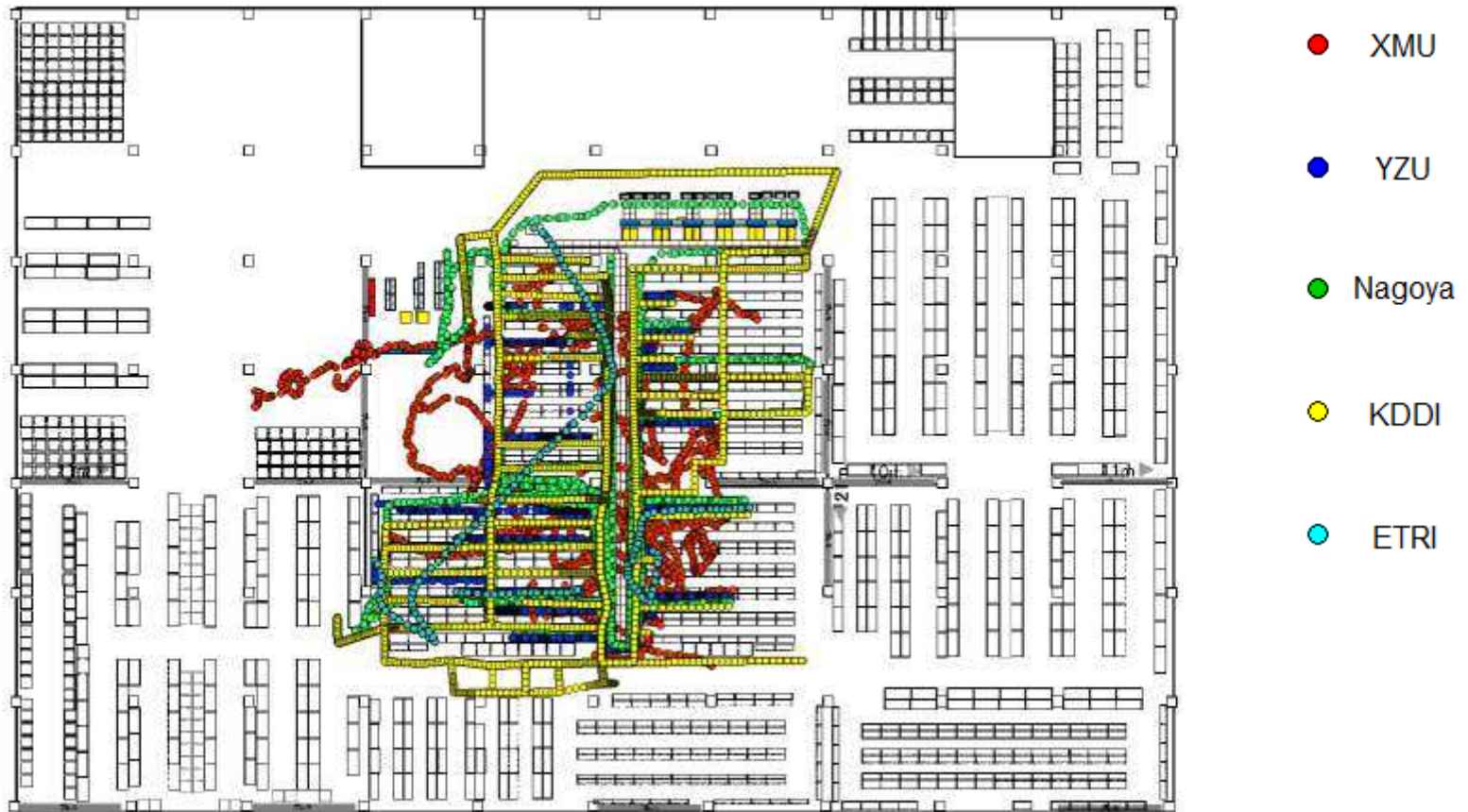


Our estimation (Terminal 2)

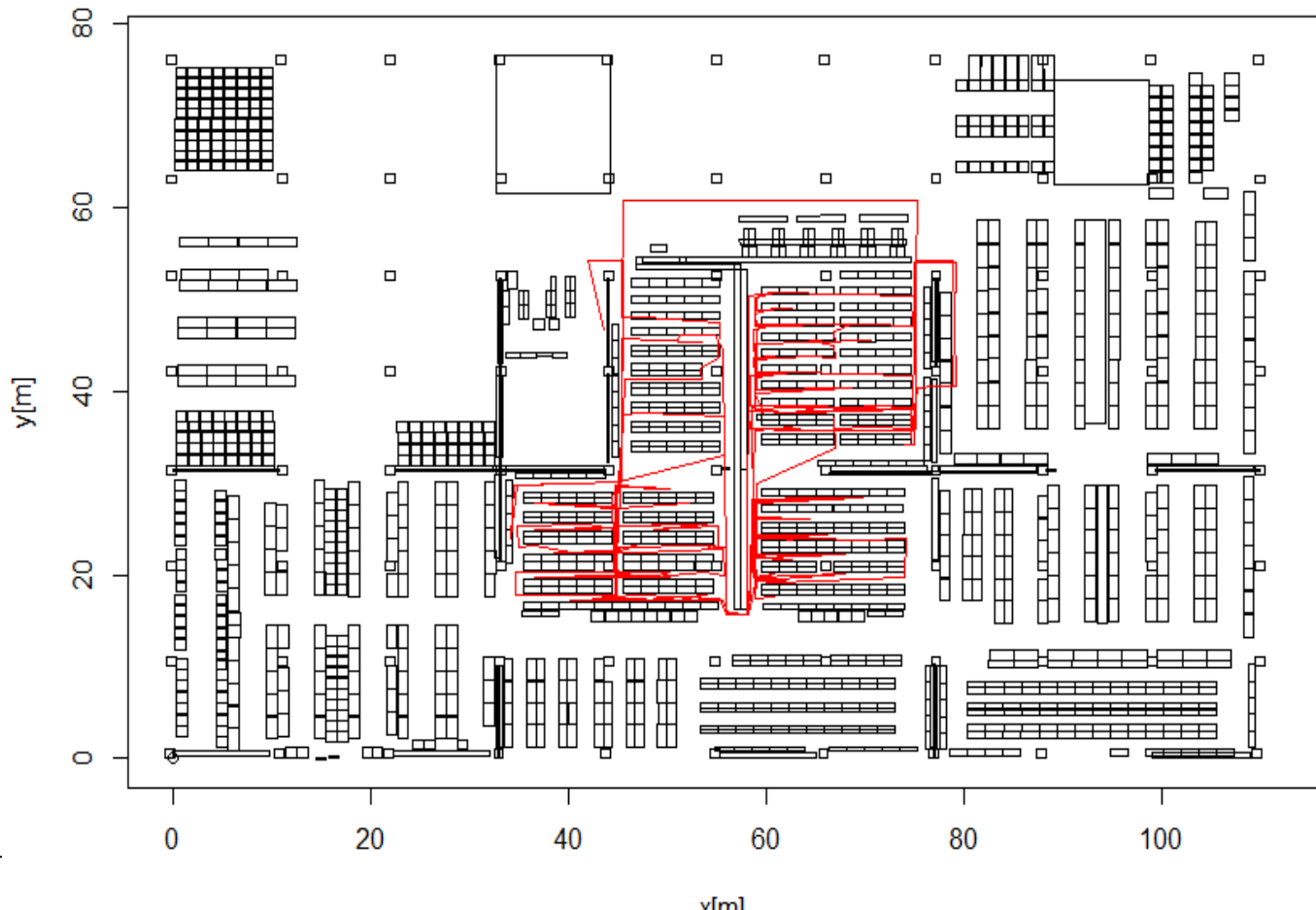


Submitted Trajectories

- Terminal 3

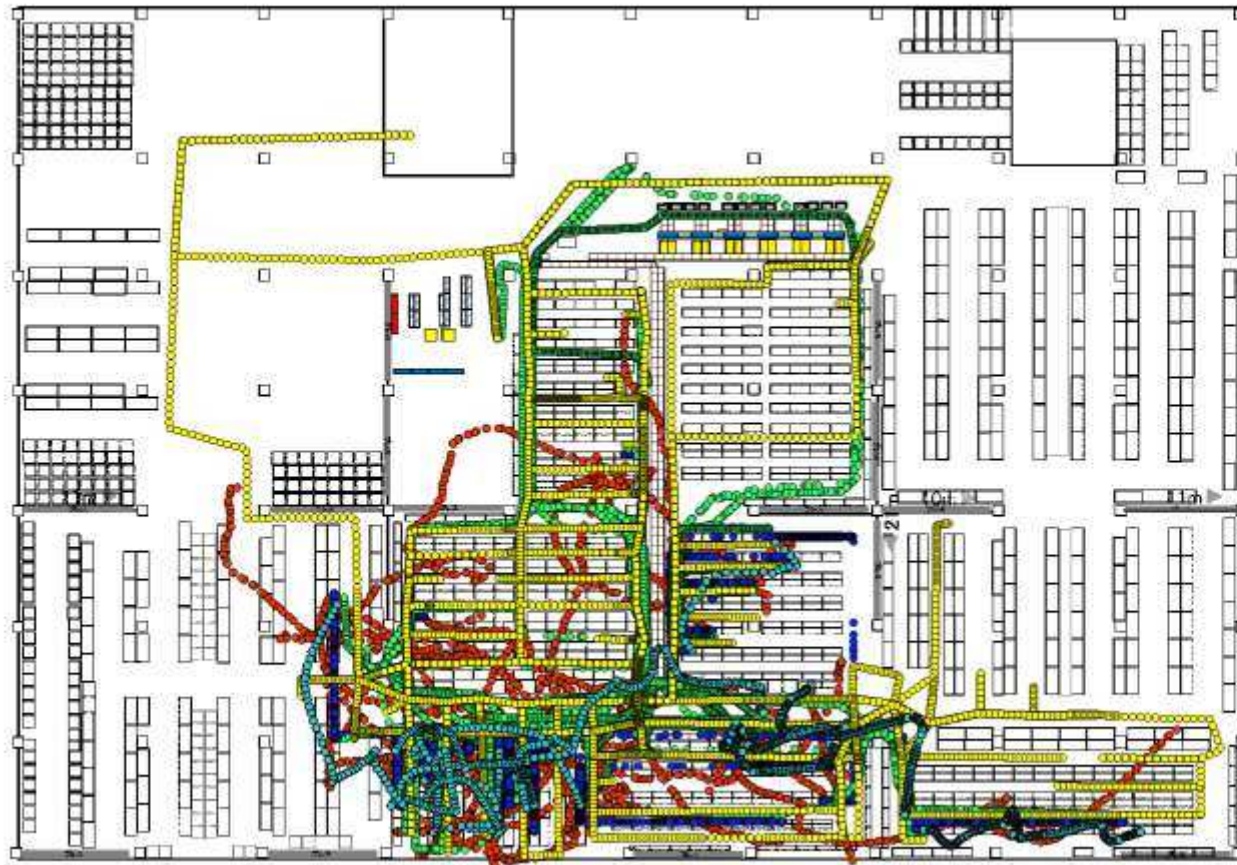


Our estimation (Terminal 3)



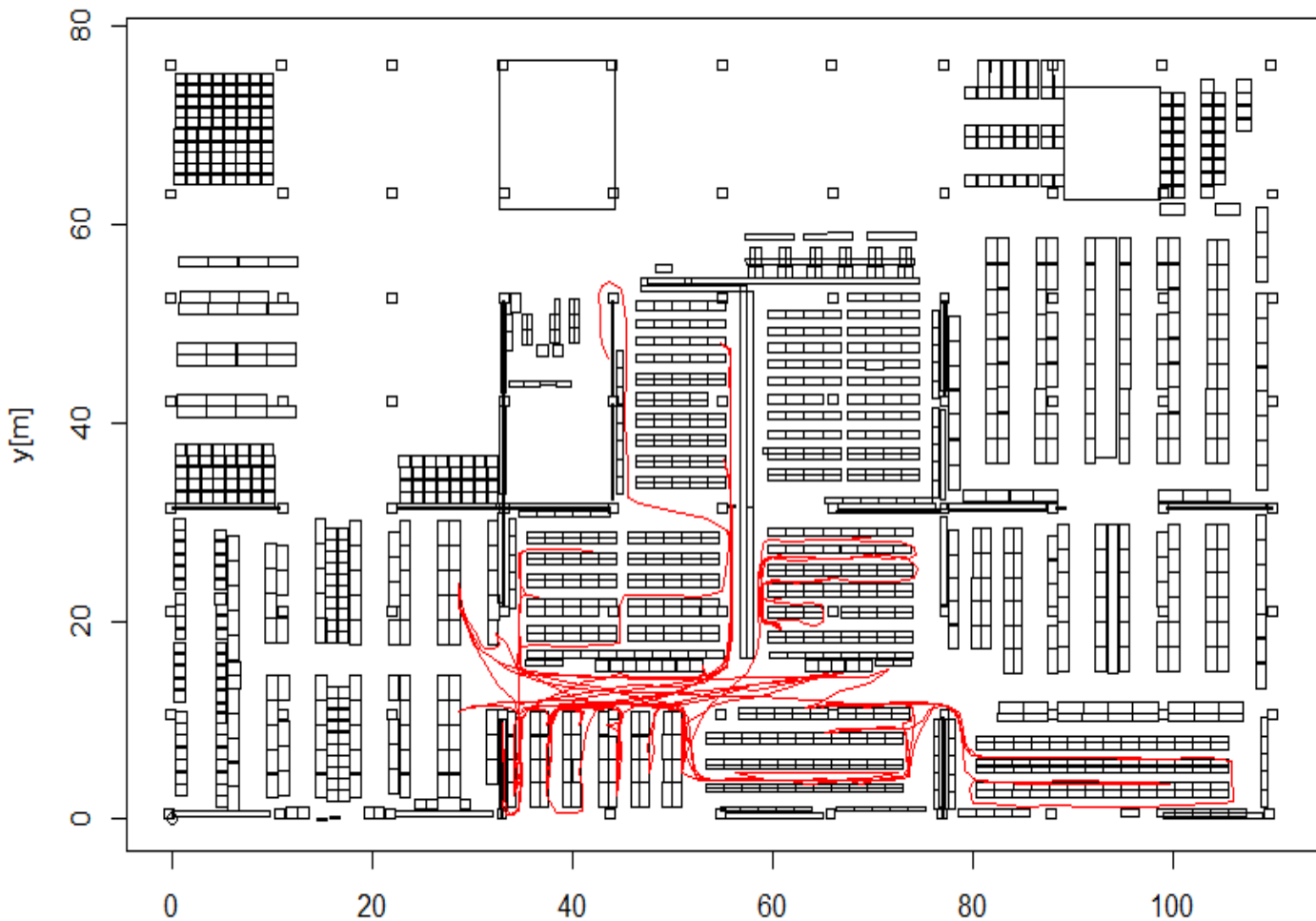
Submitted Trajectories

- Terminal 4



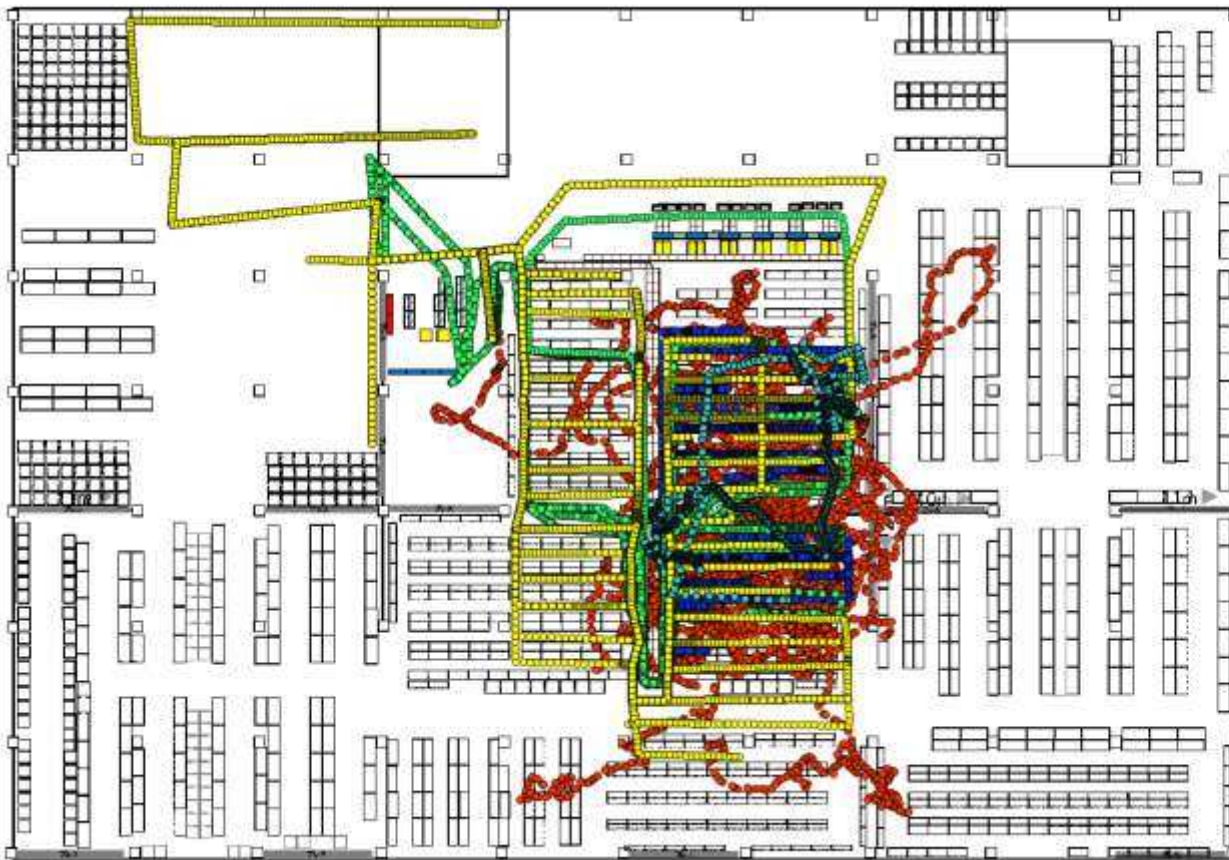
- XMU
- YZU
- Nagoya
- KDDI
- ETRI

Our estimation (Terminal 4)



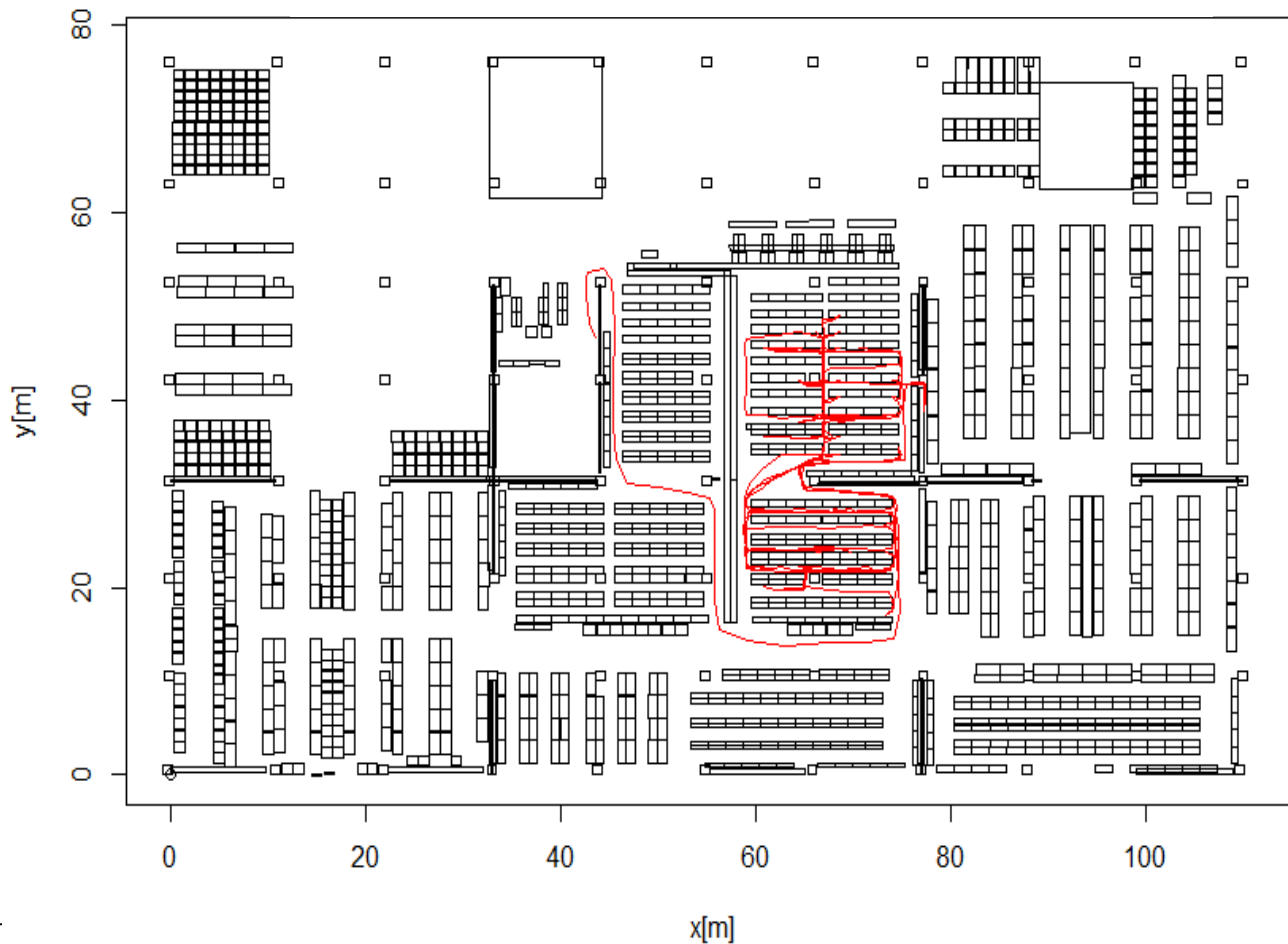
Submitted Trajectories

- Terminal 5



- XMU
- YZU
- Nagoya
- KDDI
- ETRI

Our estimation (Terminal 5)

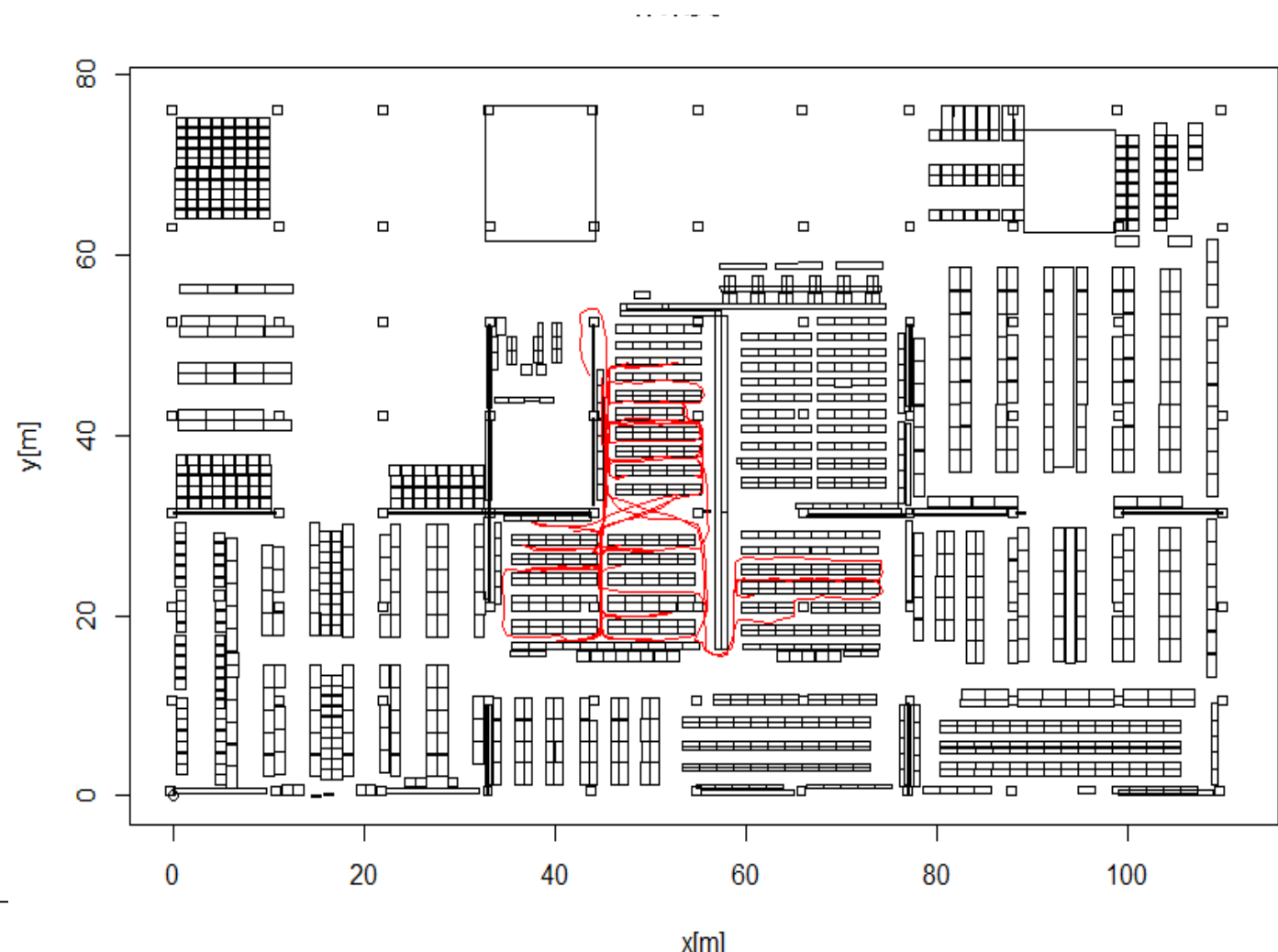


Submitted Trajectories

- Terminal 6

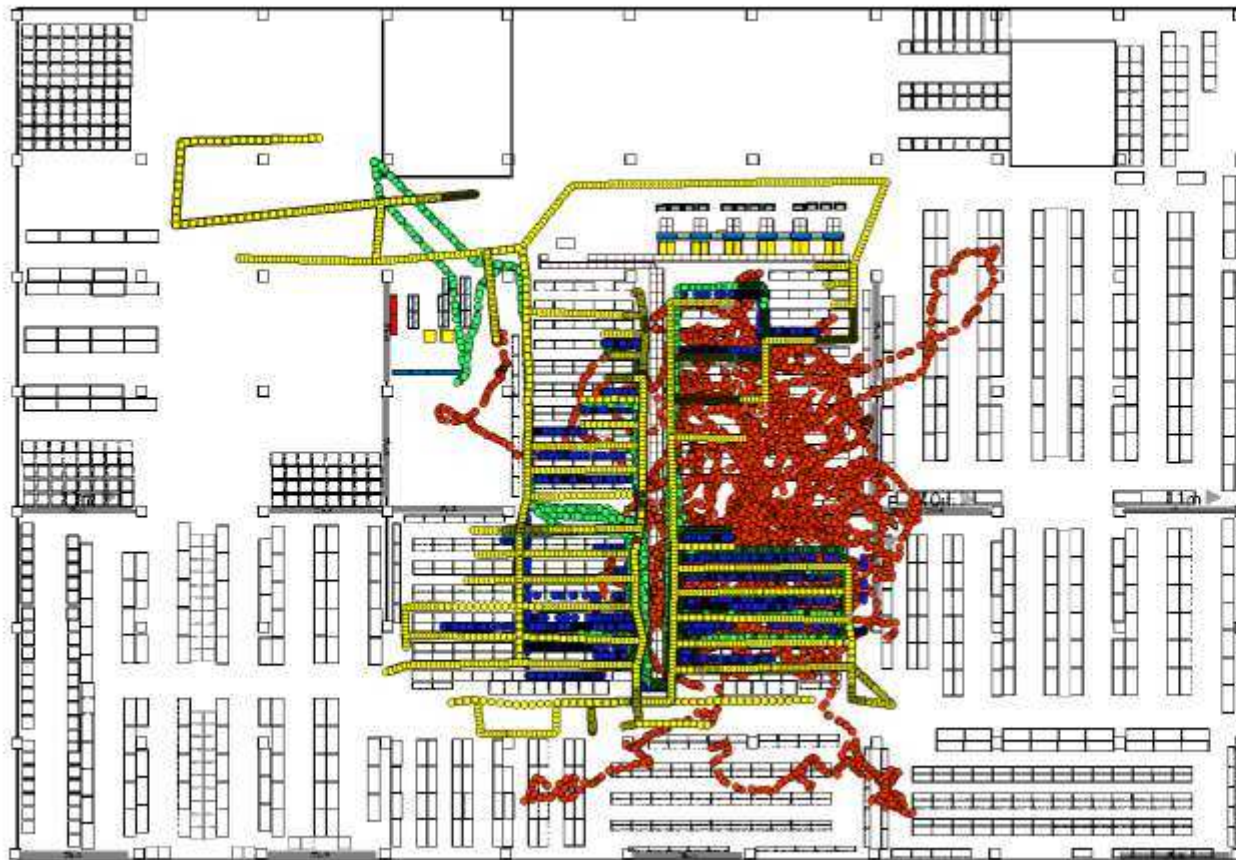


Our estimation (Terminal 6)



Submitted Trajectories

- Terminal 7



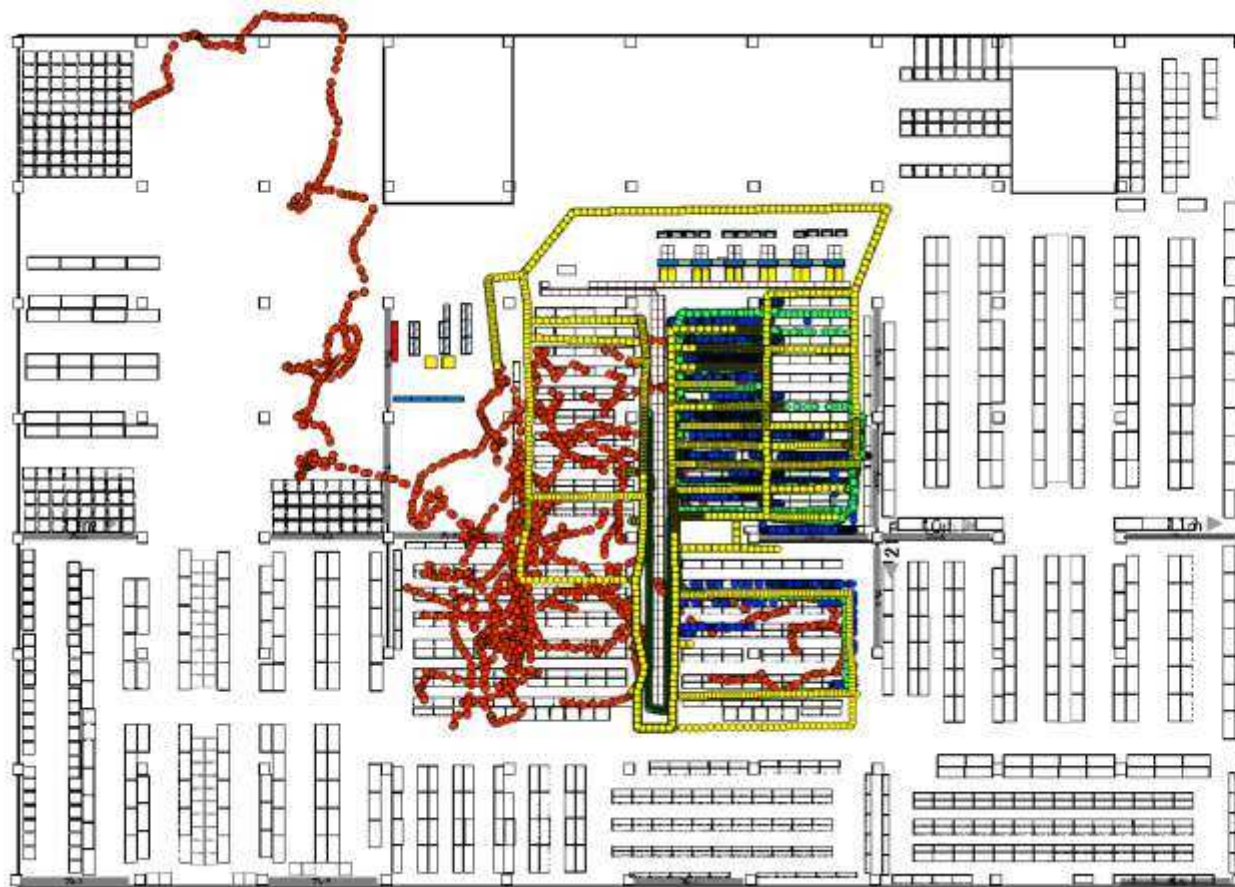
- XMU
- YZU
- Nagoya
- KDDI
- ETRI

Our estimation (Terminal 7)



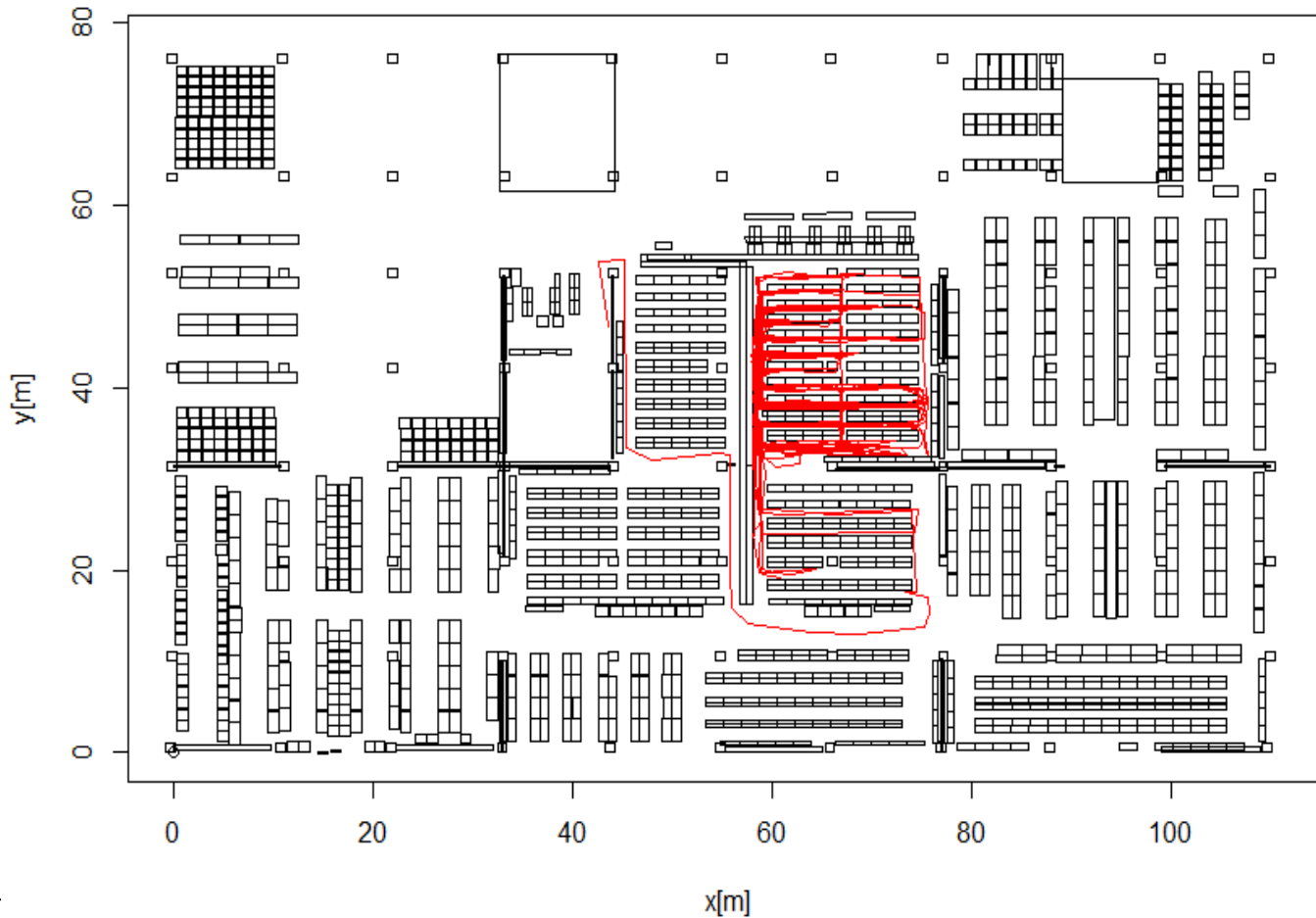
Submitted Trajectories

- Terminal 8



- XMU
- YZU
- Nagoya
- KDDI
- ETRI

Our estimation (Terminal 8)



Scores

Scores for Terminal 2

Team	Level	Ed	Es	Ep	Ev	Eo	Ef	Error median	C.E.
ETRI	Easy	66.875	96.028	100	99.995	46.375	17.335	10.606	68.226
KDDI	Easy	72.558	99.367	34.783	100	100	100	8.958	91.124
Nagoya	Easy	73.333	100	81.818	94.132	95.581	99.201	8.733	91.472
XMU	Easy	81.970	99.419	81.818	97.177	70.970	99.995	6.229	86.236
YZU	Easy	77.841	99.007	100	99.167	65.816	100	7.426	84.990

Scores for Terminal 3

Team	Level	Ed	Es	Ep	Ev	Eo	Ef	Error median	C.E.
ETRI	Hard	67.895	97.096	97.531	99.997	23.072	3.736	10.310	60.170
KDDI	Hard	64.811	97.926	53.086	100	100	100	11.205	90.202
Nagoya	Hard	68.639	100	77.215	79.382	94.470	98.345	10.095	87.671
XMU	Hard	84.049	98.811	82.927	97.172	71.450	99.992	5.626	86.728
YZU	Hard	79.346	98.196	97.436	99.197	44.607	100	6.990	78.642

Score for Terminal 4

Team	Level	Ed	Es	Ep	Ev	Eo	Ef	Error median	C.E.
ETRI	Easy	72.763	93.155	91.892	99.999	45.523	18.338	8.899	68.268
KDDI	Easy	72.078	96.349	35.135	100	99.944	100	9.097	90.425
Nagoya	Easy	61.929	98.569	63.888	76.866	89.704	99.144	12.041	83.650
XMU	Easy	78.043	95.052	89.189	95.526	69.168	99.992	7.368	84.157
YZU	Easy	62.918	93.986	100	98.922	61.038	100	11.754	79.531

Scores for Terminal 5

Team	Level	Ed	Es	Ep	Ev	Eo	Ef	Error median	C.E.
ETRI	Easy	60.493	99.915	96.551	100	80.028	15.257	12.457	77.444
KDDI	Easy	66.197	99.712	41.379	100	99.187	100	10.803	90.007
Nagoya	Easy	61.564	99.417	65.517	93.544	94.464	99.770	12.146	87.820
XMU	Easy	82.752	100	66.666	94.697	67.671	97.701	6.002	84.160
YZU	Easy	70.976	99.786	89.655	99.662	31.440	100	9.417	73.016

Scores for Terminal 6

Team	Level	Ed	Es	Ep	Ev	Eo	Ef	Error median	C.E.
ETRI	Easy	59.002	95.525	100	100	64.104	1.951	12.889	70.332
KDDI	Easy	85.239	100	44	100	100	100	5.281	94.248
Nagoya	Easy	72.843	97.139	61.905	86.017	94.006	99.389	8.876	88.135
XMU	Easy	81.450	99.399	92	95.164	46.881	99.638	6.379	79.072
YZU	Easy	78.335	99.187	100	98.492	35.990	100	7.283	76.075

Scores for Terminal 7

Team	Level	Ed	Es	Ep	Ev	Eo	Ef	Error median	C.E.
ETRI	Hard	-	-	-	-	-	-	-	-
KDDI	Hard	73.622	97.054	56.881	100	100	100	8.650	91.979
Nagoya	Hard	73.903	99.276	82.569	92.002	93.027	99.499	8.568	90.423
XMU	Hard	41.548	92.034	92.157	94.728	43.730	97.713	17.951	68.424
YZU	Hard	75.627	96.245	99.083	98.917	42.906	100	8.068	77.038

Scores for Terminal 8

Team	Level	Ed	Es	Ep	Ev	Eo	Ef	Error median	C.E.
ETRI	Hard	-	-	-	-	-	-	-	-
KDDI	Hard	71.963	95.375	39.552	100	100	100	9.131	90.445
Nagoya	Hard	81.768	100	76.119	92.901	93.593	99.548	6.287	92.127
XMU	Hard	23.646	87.706	90	95.133	47.490	99.641	23.143	65.252
YZU	Hard	82.347	97.746	96.212	99.292	36.909	100	6.119	76.796

Final Results

Prize

- 1) PDR module (Sugihara SEI Co. &Lt., 200,000 JPY worth) + 100,000 JPY

or

- 2) 150,000 JPY



Final Score

RANKING	TEAM	AVERAGE OF C.E.
Winner(1 st)	KDDI	91.163
Runner-up(2 nd)	Nagoya U.	88.921
3 rd	XMU	78.437

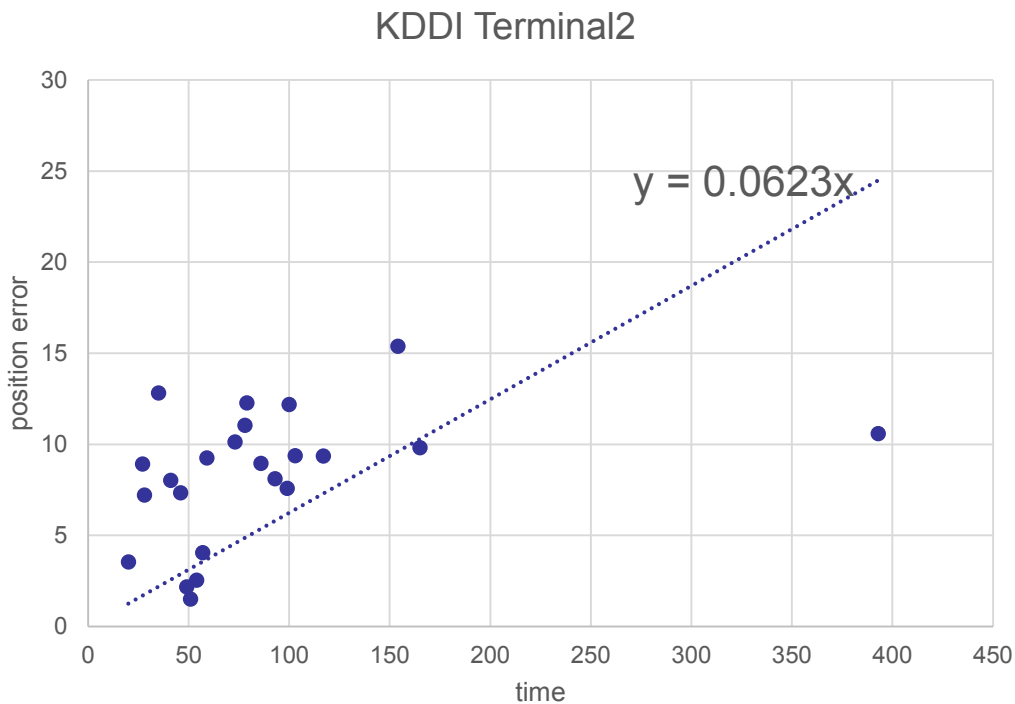
Ave. Scores for ALL Terminals

Team	Ed	Es	Ep	Ev	Eo	Ef	Error median	C.E.
ETRI	65.406	96.344	97.195	99.998	51.821	11.323	11.032	65.741
KDDI	72.353	97.969	43.545	100	99.876	100	9.018	91.163
Nagoya	70.569	99.200	72.719	87.835	93.549	99.271	9.535	88.921
XMU	67.637	96.060	84.965	95.657	59.623	99.239	10.385	78.437
YZU	75.341	97.736	97.484	99.093	45.530	100	8.151	77.947

Picture of Ed (1st)

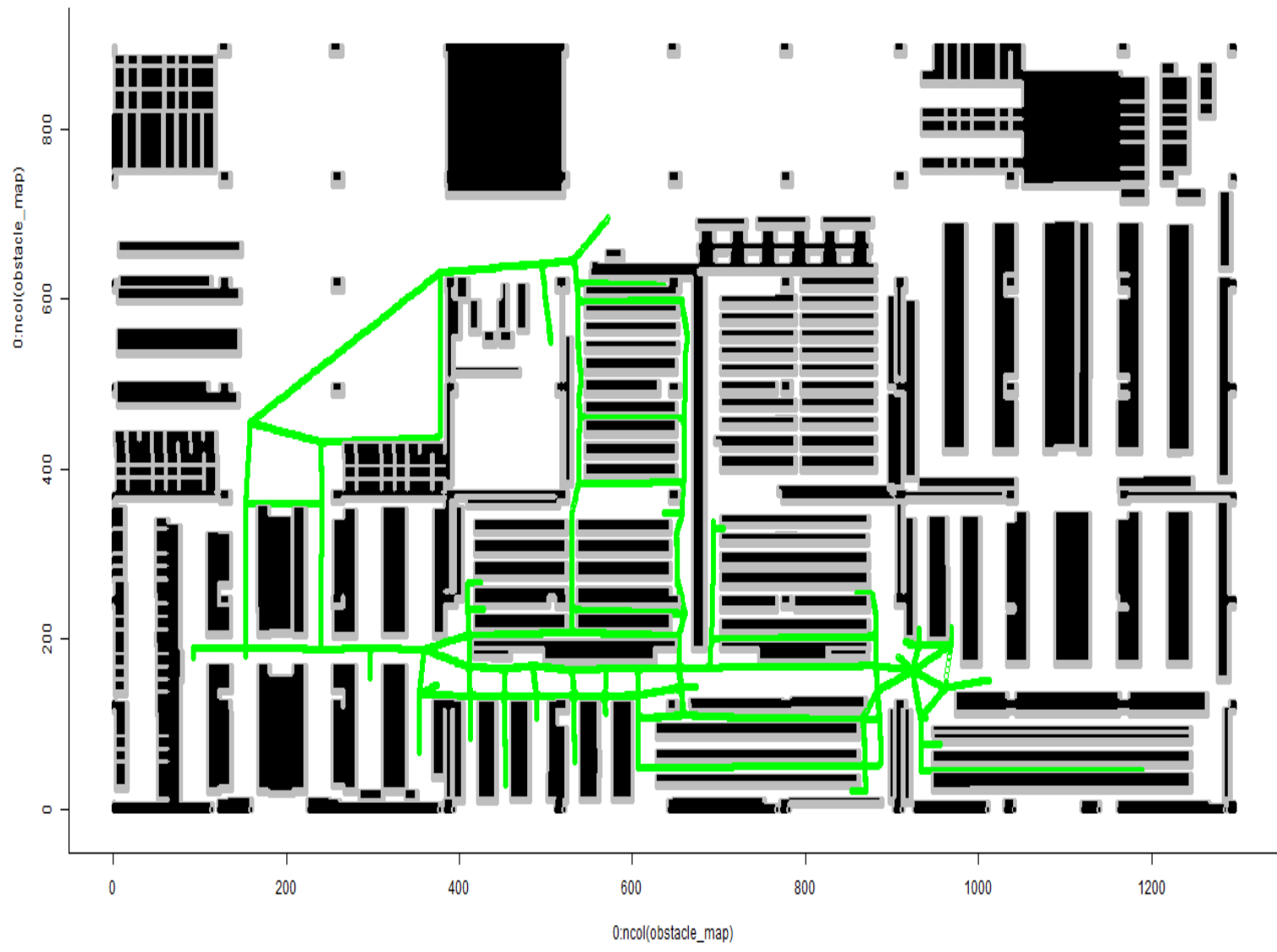


Graph of Es (1st)



Terminal ID	slop
Terminal2	0.06234699249 81115
Terminal3	0.090435326 4159421
Terminal4	0.121188344 408936
Terminal5	0.055607695 6764035
Terminal6	0.048479055 3534408
Terminal7	0.107438470 408959
Terminal8	0.140182398 620238

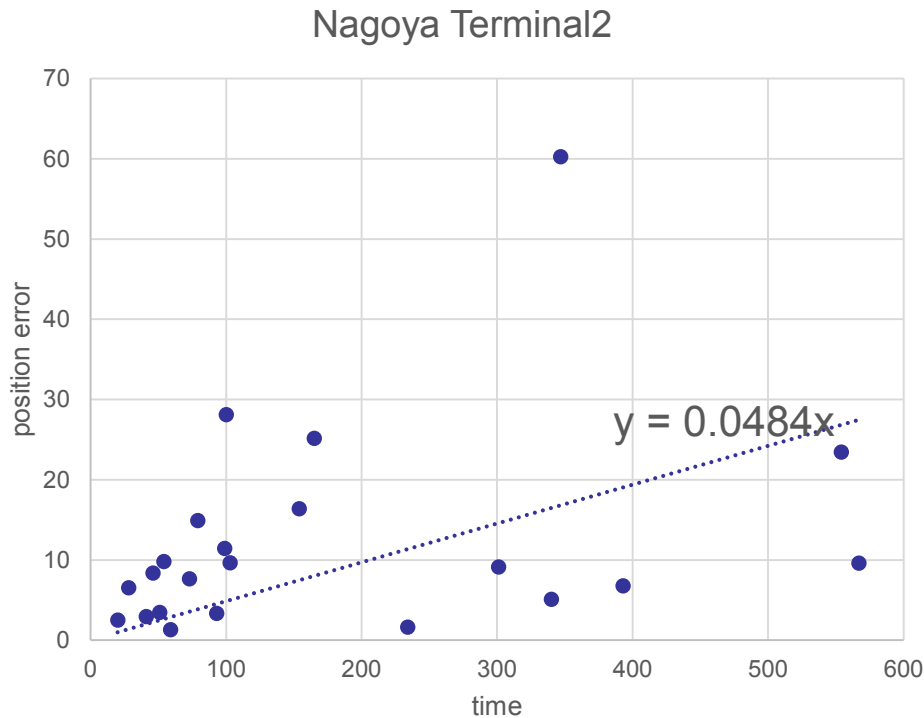
Picture of Eo (1st)



Picture of Ed (2nd)

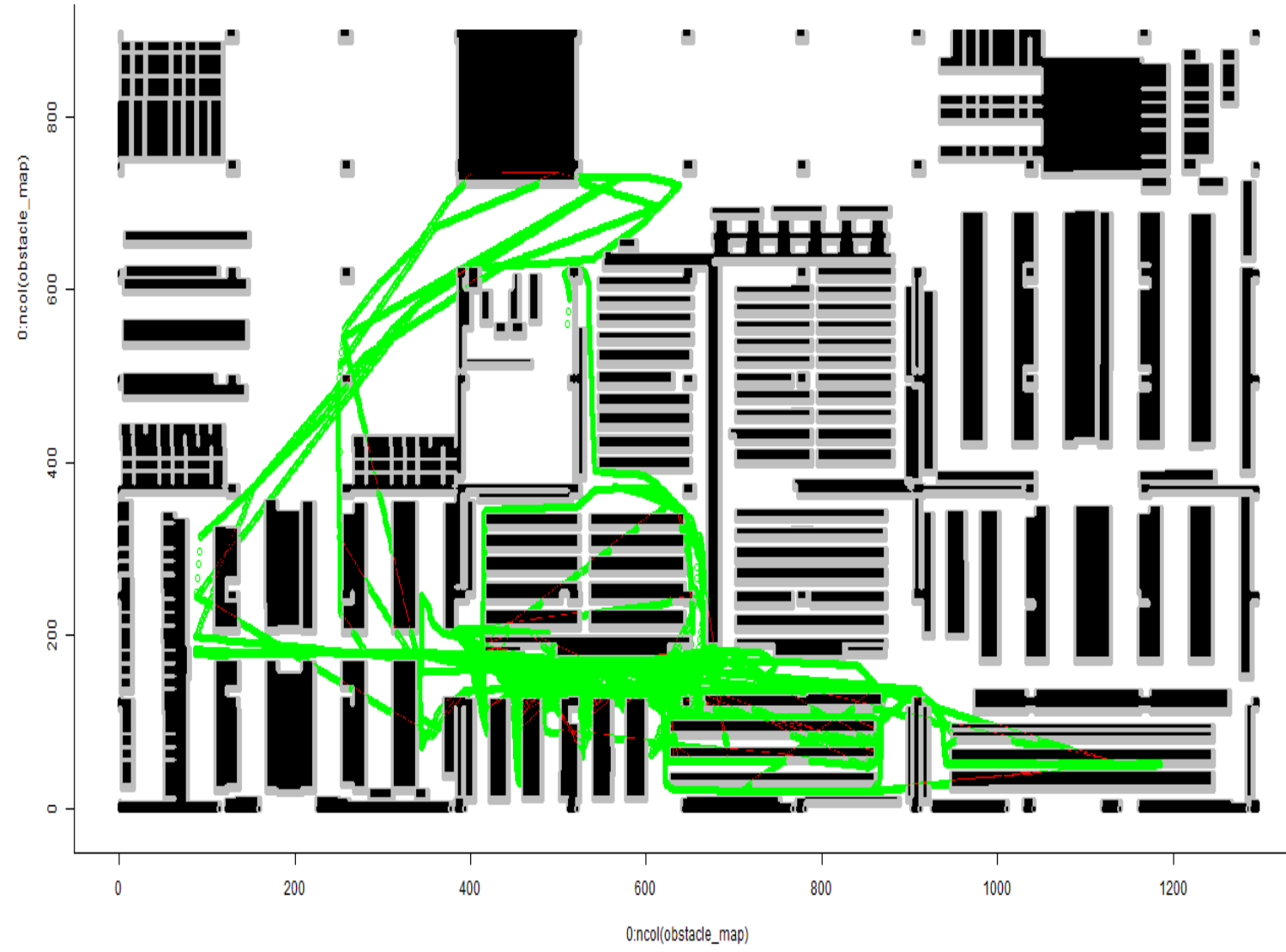


Graph of Es (2nd)



Terminal ID	slop
Terminal2	0.04842440929 53409
Terminal3	0.038564395 4126861
Terminal4	0.077903625 1886814
Terminal5	0.061358972 1000901
Terminal6	0.105793910 255521
Terminal7	0.064109388 7045351
Terminal8	0.039750897 7779014

Picture of Eo (2st)



Thank you for participation