IPIN 2020 Competition Track5 “xDR Challenge in Manufacturing 2020” award ceremony

Ryosuke Ichikari[1], Ryo Shimomura[1,2]

1:AIST, Japan 2:Univ. of Tsukuba, Japan

Benchmarking for Indoor Localization

- Fair evaluation and comparison between indoor localization methods is difficult because their performance depends on the technology and situation where they used
- Required to standardize evaluation method
- We established PDR benchmark standardization committee.
- Indoor localization competitions：
  Organizer prepare shared testing environment for comparing competitors' localization methods with evaluation method

Benchmarking Process ＋ Benchmark Indicators ＋ Trial Set (Dataset)

Characteristics of PDR/xDR Challenges

- Other Indoor localization competitions: Focusing of accurate evaluation of accuracy of the positioning methods
- PDR/xDR Challenges: Evaluating practical performance in industrial scenarios
  - Main characteristics: data measurement in actual industry and the integrated evaluation

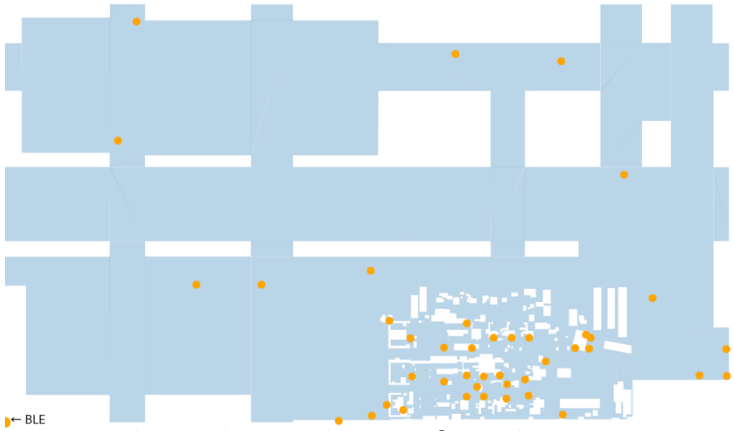
	PDR Challenge in Warehouse Picking 2017 	**xDR Challenge for Warehouse Operations 2018** 	**xDR Challenge in Industrial Scenarios 2019** 	**xDR Challenge in Manufacturing 2020** 
Scenario	Picking work inside a logistics warehouse	General warehouse operations including picking, shipping and driving forklift	General operations in a factory and a restaurant	General Operations in manufacturing including driving forklift
Walking/ motion	Includes many motions involved in picking work, not only walking	Includes many motions involved in picking, shipping operations and, not only walking. Some workers may drive forklift	Includes many motions in production line in a factory and service operations in a restaurant	Includes many motions of human and forklifts in production line in a factory
On-site or off-site	Off-site	Off-site	Off-site	Off-site
Target Methods	PDR+BLE+MAP+WMS	PDR/VDR+BLE+MAP+WMS	PDR+BLE+MAP, Area detection Action recognition	PDR/VDR+BLE+MAP
Number of people and trial	8 ppl, 8 trials	34 people + 6 forklifts, 170 trials (PDR) + 30 trials (VDR)	Manufacturing : 8 trials (4 ppl) Restaurant : 10 trials (10 ppl)	Operators:7 trials (3 ppl) Forklifts:2 trials (2 forklifts)
Time per trial	Operators: 3 hours	Operators: 8 hours Forklifts: 8 hours	Manufacturing : 3 hours Restaurant : 6 hours	Operators : 2~7 hours Forklifts : 15 min
Evaluation metric	Integrated Evaluation (integrated by accuracy, naturalness, warehouse dedicated metrics)	Integrated Evaluation (integrated by accuracy, naturalness, warehouse dedicated metrics)	Integrated Evaluation (integrated by accuracy, naturalness, area(manufacturing), action(restaurant))	Integrated Evaluation (Absolute error, error distribution, error accumulation, speed, obstacle)
Remark	Competition over integrated position using not only PDR, but also correction information such as BLE beacon signal, picking log (WMS), and maps	Consists of PDR and VDR tracks. Referential motion captured by MoCap. also shared for introducing typical motions.	Consists of manufacturing and restaurant sub-tracks. Adoption of evaluations related to area and action	Consists of PDR and VDR sub-tracks. Newly adopts evaluation indicators for accuracy

xDR Challenge in Manufacturing 2020 (Off-site Competition)

- Target industry: Manufacturing
- Two sub-tracks
  - PDR sub-tracks for tracking operators
  - VDR sub-tracks for tracking forklifts
- Dataset: Sensor data measured by Android devices
  MAP, Reference pos. data, BLE beacon
  pos. data (for localization with xDR and BLE)
- Devices:
  - BLE beacon: PulsarGum (FUJITSU)
    Battery Free, Interval of signal emission: longer than 1.26sec.
  - Sensor measurement: BL-02 (BIGLOBE)
- Organizers ：
  Ryosuke Ichikari, Ryo Shimomura, Satsuki Nagae, Nozomu Ohta, Takeshi Kurata (AIST, JP), Antonio Ramon Jimenez Ruiz (CSIC-UPM, ES)， Soyeon Lee(ETRI,KR）
- Sponsors:

PulsarGum

BL-02

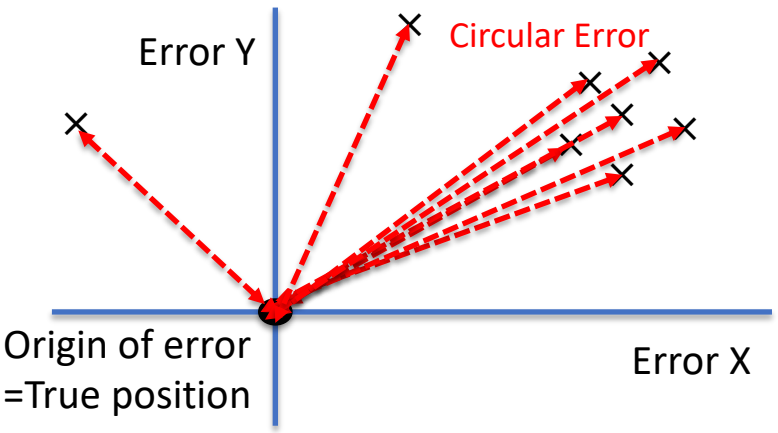


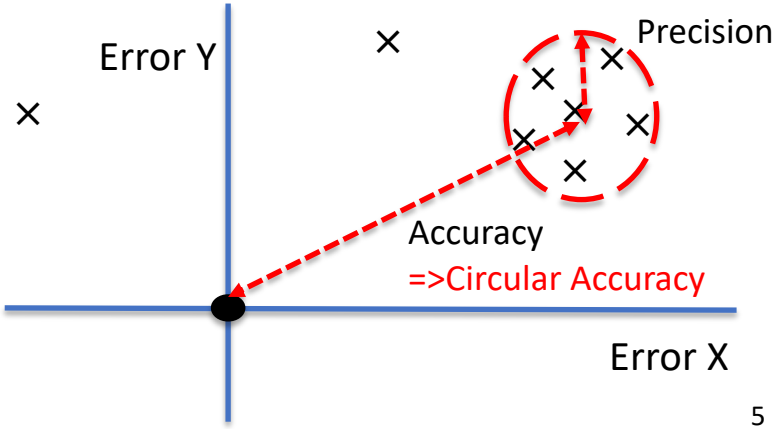
Floor plan and pos. of BLE beacon
(Size: 140m×80m）

“Accuracy” and “Precision” in localization

- Evaluation of error bias of localization method is demanded for staying area analysis in the industrial scenario.
- Error of localization can be divided into elements of “Accuracy” and “Precision”
  - Accuracy: degree of trueness or closeness to the correct position
  - Precision: degree of variability or repeatability of the estimation
- Common absolute positional error (Circular Error) includes elements both of Precision and Accuracy.
  - We call 2D absolute positional error as CE according to the terminology in ISO 18305
- We evaluate the element of Accuracy by a dedicated indicator (Circular Accuracy)

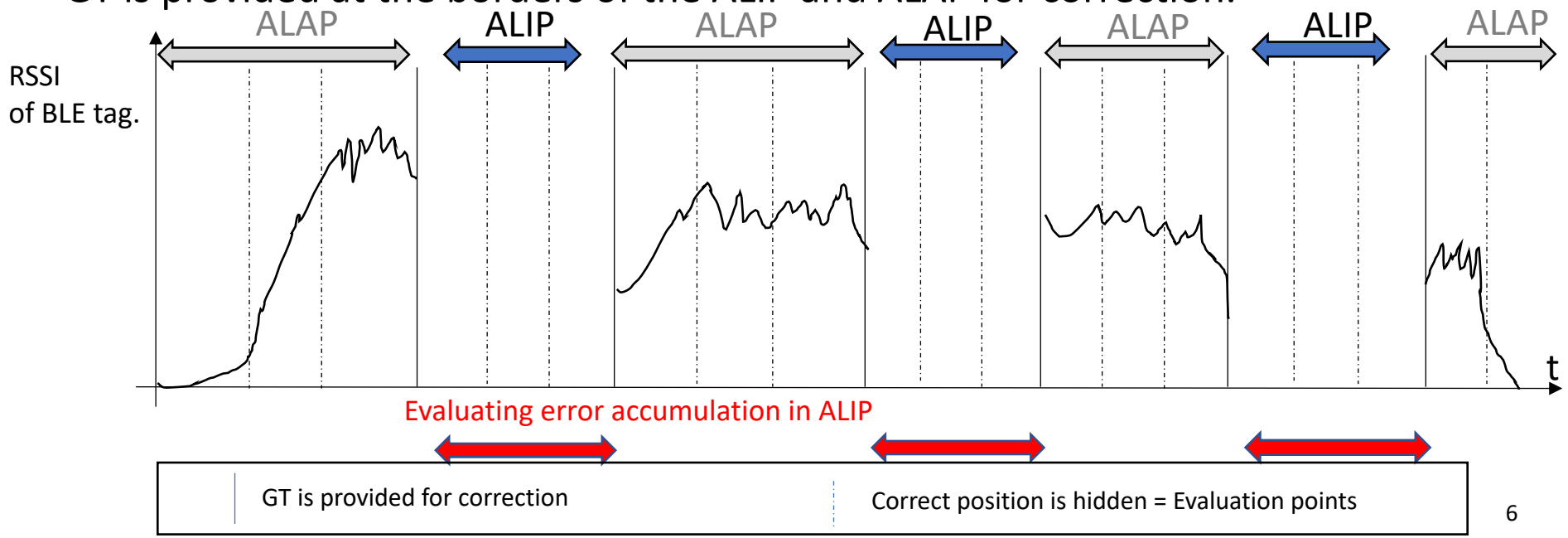
cf. Indicator related to accuracy in ISO18305 : The mean of the error vector
cf. Indicator related to precision in ISO18305 : Variances of magnitudes of various errors





Evaluation of error accumulation caused by xDR in ALIP (Absolute Localization Inapplicable Period)

- We would like to evaluate the error accumulation unique to xDR
- Dataset for our competition includes data for positional correction (BLE signals)
  ⇒ BLE signal is partially intentionally deleted for pure evaluation of xDR
- ALIP（Absolute localization Inapplicable period）
  ⇔ :ALAP（AL Applicable period）
  example of AL: BLE beacon
- GT is provided at the borders of the ALIP and ALAP for correction.



Evaluation indicators in xDR Challenge

- Three evaluation indicators about error ：
  - Absolute error：**CE**（Circular Error), unit：m
  - Error distribution bias：Circular Accuracy (**CA**), unit：m
  - Error accumulation：**EAG** (Error Accumulation Gradient), unit：m/s
- Three negative checks
  - **Requirements for Moving Velocity**: checking if moving velocity is within the decent range
  - **Requirements for Validity of the Trajectory**: checking if points consist of trajectory are in valid area
  - **Coverage Ratio**: checking if the positional estimation is submitted whole data

Calculation of the final score in xDR Challenge

Evaluation of errors (using evaluation indicators about error)

- I_ce: evaluation for absolute error with CE50
- I_ca : evaluation for error distribution bias with CA
- I_eag : evaluation for error accumulation with EAG50

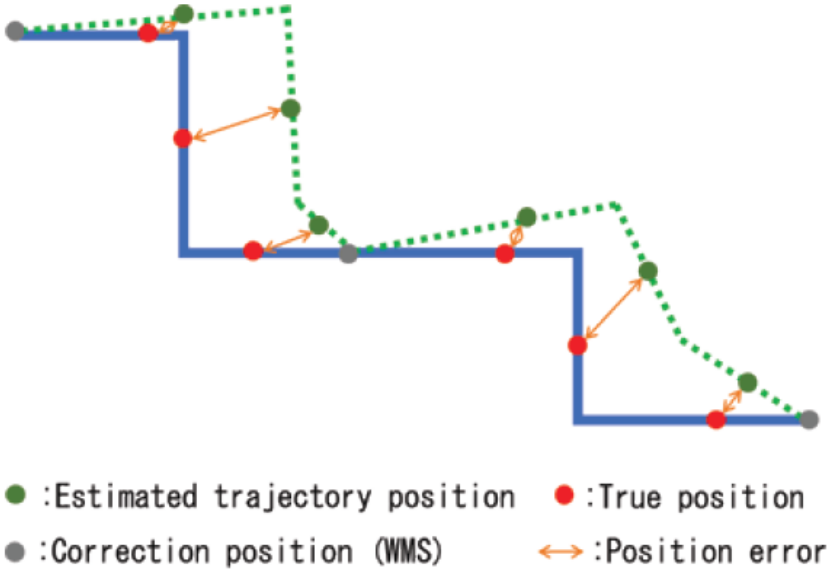
Evaluation with Negative checks

- I_velocity: speed evaluation with 1.5m requirement of moving velocity
- I_obstacle: evaluation for obstacle collision with requirement of validity of trajectory.
- I_coverage: evaluation for the coverage of result submission with coverage ratio.

Final Score = I_coverage (0.25 I_ce + 0.2 I_ca + 0.25 I_eag + 0.15 I_velocity + 0.15 I_obstacle)

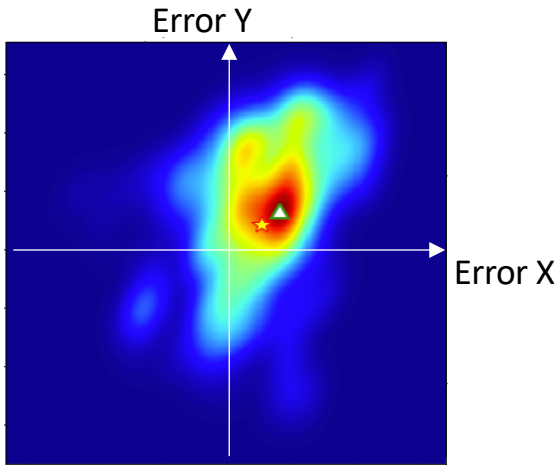
Indicator 1 : Circular Error (CA)

- Explanation : Absolute 2D positional error compared to Ground Truth
- Definition : 2D Euclid distances between evaluation points (Ground truth) and corresponding estimated positions at the closest time
- Unit : meter
- Adopted indicator : CE50（median of CEs）



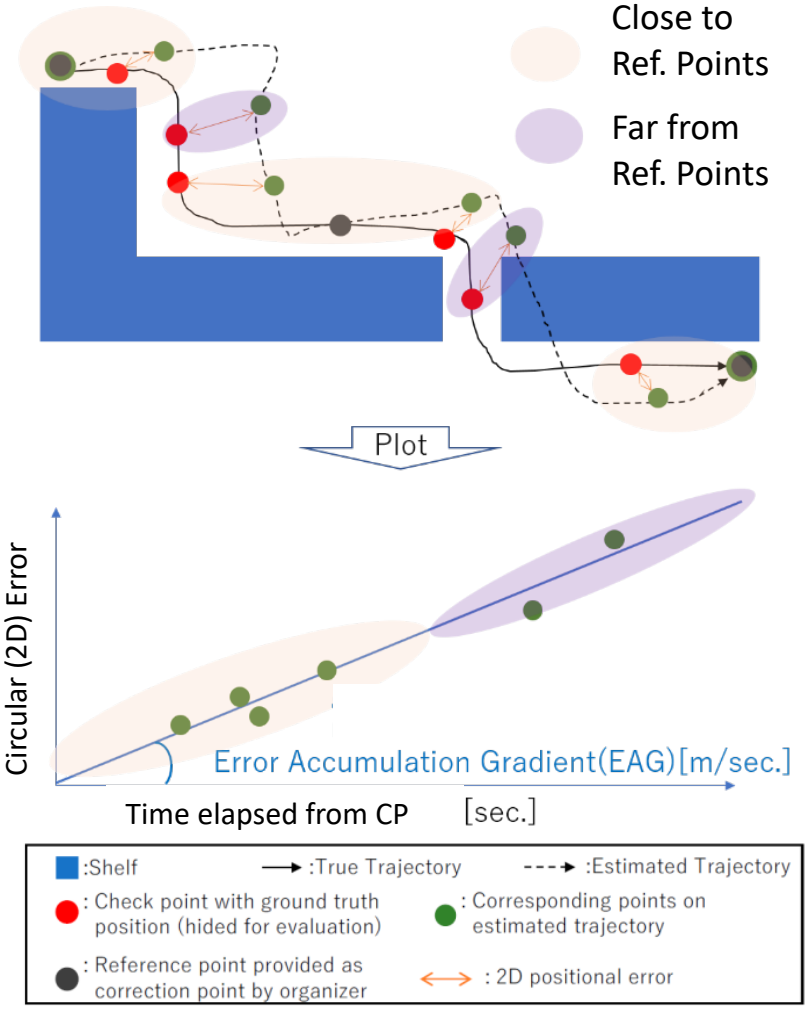
Indicator2 ： Circular Accuracy (CA)

- Explanation ： Degree of bias of error distribution in 2D error space
- Definition ： Distance between peak of the probability distribution of 2D error and origin of the error space
- Unit ： meter
- Adopted indicator ：
  As is or Area-Weighted CA



Indicator 3: Error accumulation gradient (EAG)

- Explanation： Speed of error accumulation from the correction points
- Definition： ratio. of error and elapsed time from the nearest correction points which are border of ALIP and ALAP
- Unit： m/s
- Adopted indicators： EAG50（median of EAGs）
- Our original indicator not introduced in ISO18305



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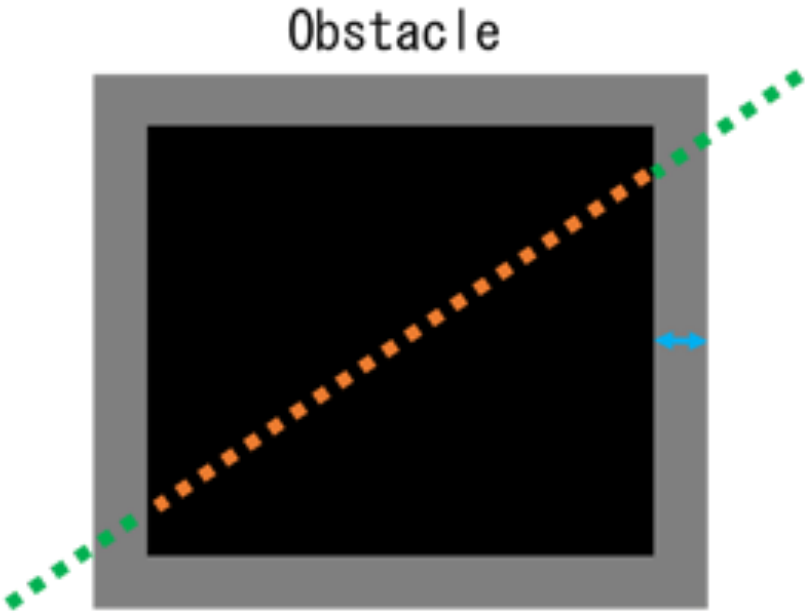
Negative Check1：Requirement of moving velocity

- Explanation：Requirement checking if local moving speed of the trajectory is in the decent range
- Definition：Checking the local moving speed (delta movement /delta time) is less than the defined valu
- Adopted requirement：1.5m/s requirement of moving velocity

Negative check 2 : Requirement for Validity of Trajectory

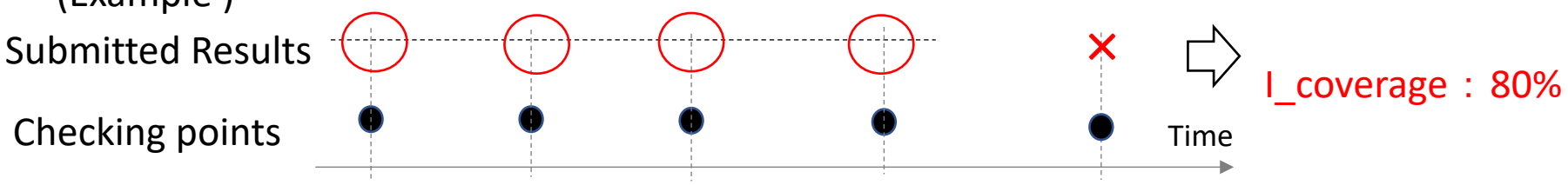
- Explanation : Checking the degree of incursion the trajectory of submitted result into un-walkable area
- Definition : Calculating ratio the incursion of trajectory into un-walkable area in the whole trajectory.



Negative check3 : Coverage ratio

- We stop using frequency evaluation because competitors have enough interest for submitting result as frequent as possible.
  - Time of the checking points are hidden
  - No indictor to deduct points for the uncompleted submission
- Adopting metric calculating ratio of the coverage of the submitted result to corresponding check points and multiply the ratio by the total score
  - I_coverage : Checking if each checking points have corresponding submitted results and calculate ratio in the whole trajectory.
  - Threshold : +/- 1 sec from the checking points

(Example)

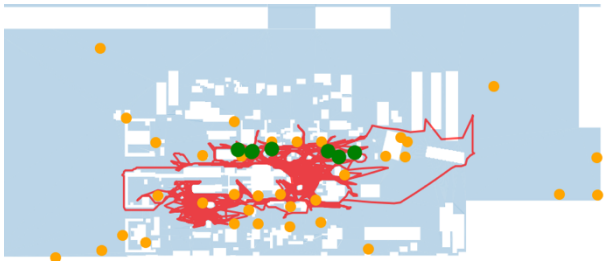


of application, competitors

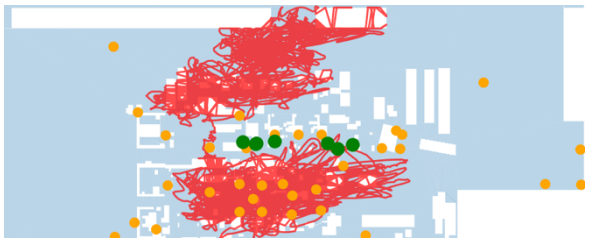
- Pre-admission(Required for providing sample dataset)：9
  (Ireland，Japan3，China3，Portugal，US)
- Admission(Required for providing test dataset)：4
  (Japan2，China 1，Portugal)
- Result submission：2
  (Japan2)
  - Kawaguchi Lab Team　(Nagoya University，Japan)
  - Yonayona Team（Keio University，Japan）

Example of Submitted Trajectories

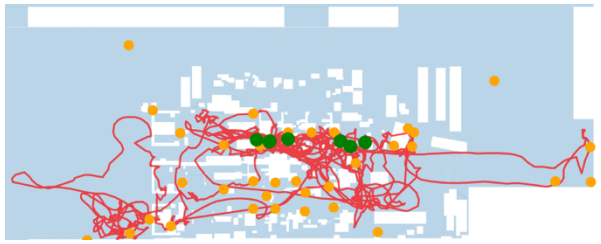
Trajectory of operator（PDR_No.5)



Kawaguchi Lab.

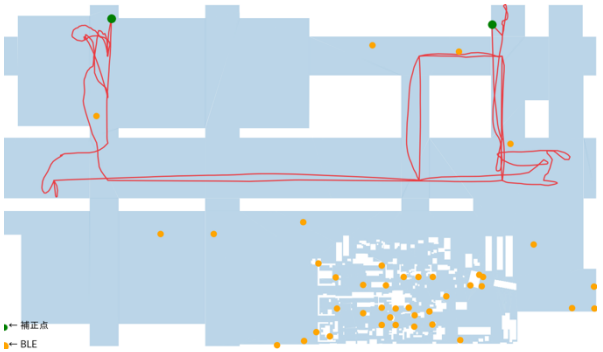


Yonayona



AIST(as reference)

Trajectory of forklift（VDR_No.2)



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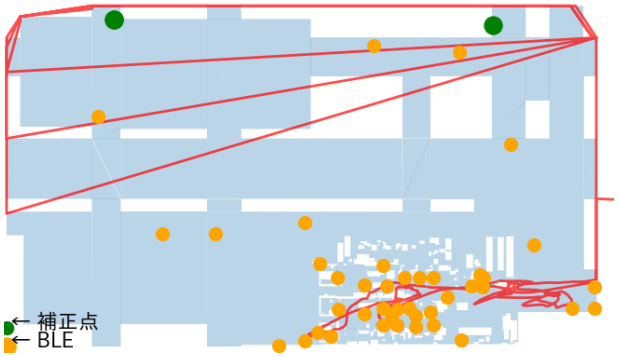
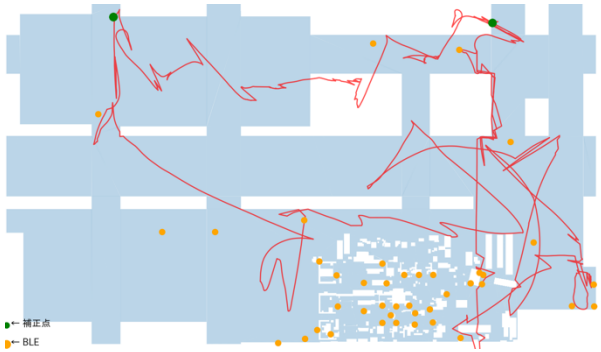


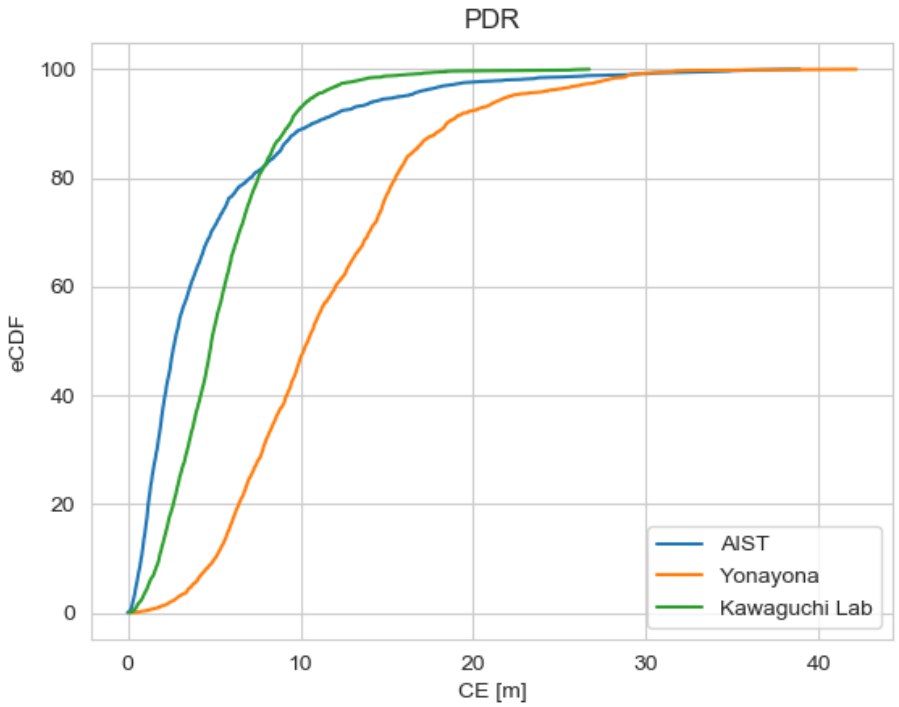
Yonayona

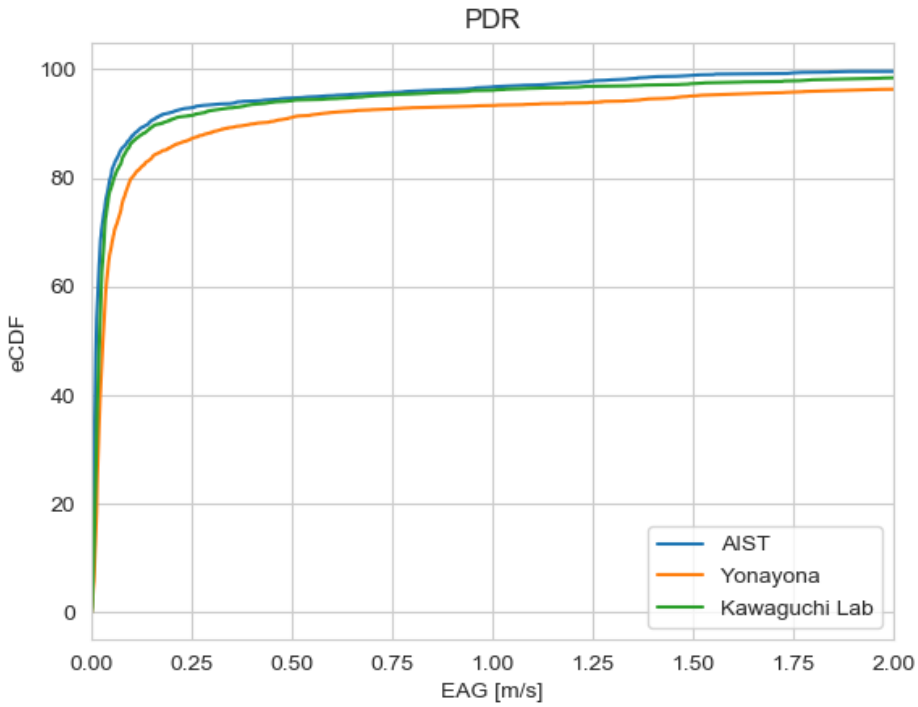


AIST(as reference)

eCDF

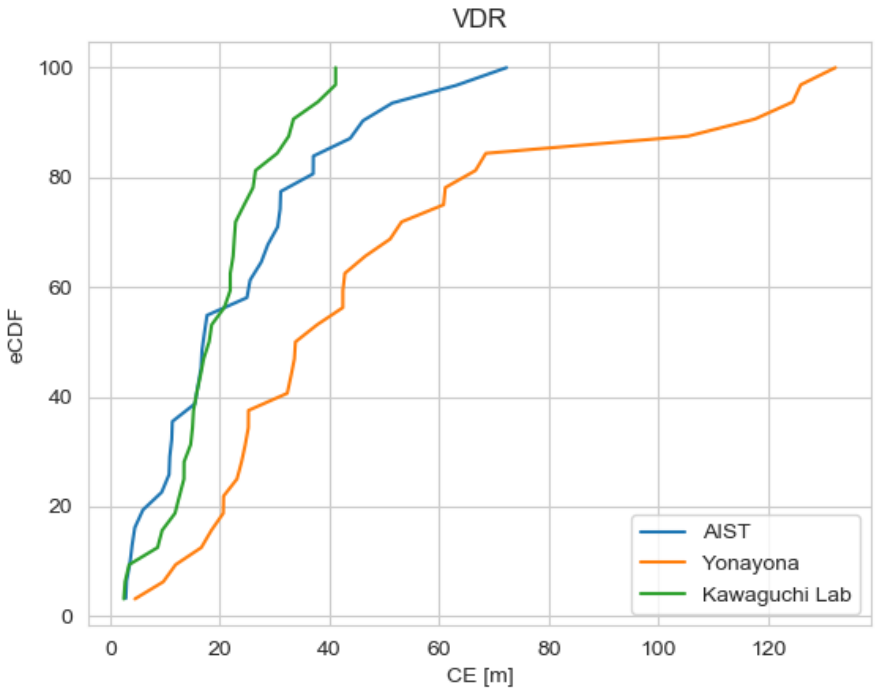
Operator（PDR）

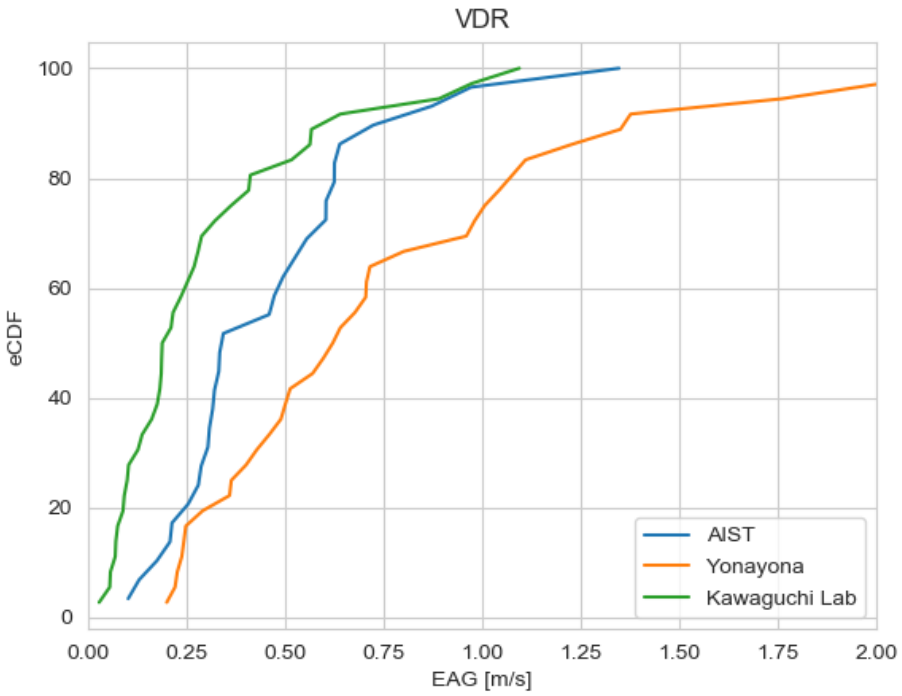




eCDF

Forklift（VDR）





Scores and indicators (Operator (PDR), average)

Team	I_ce (CE50) [CE75]	I_ca (CA)	I_eag (EAG50)	I_ velocity	I_ obstacle	I_ coverage	Final
Kawaguchi Lab.	87.00 (4.77m) [6.83m]	60.89 (3.91m)	99.84 (0.026m/s)	99.52	99.80	100	88.79 (Winner)
Yonayona	68.18 (10.23m) [12.36m]	21.90 (8.99m)	99.89 (0.033m/s)	94.51	93.45	100	74.59
AIST (Ref.)	90.61 (3.72m) [7.17m]	65.80 (3.42m)	100 (0.018m/s)	98.12	99.21	99.94	90.36

Scores and indicators (Forklift(VDR), average)

Team	I_ce (CE50) [CE75]	I_ca (CA)	I_eag (EAG50)	I_ velocity	I_ obstacle	I_ coverage	Final
Kawaguchi Lab.	34.24 (20.07m) [27.05m]	0 (18.58m)	92.01 (0.206m/s)	89.11	100	100	59.93 (Winner)
Yonayona	0 (34.63m) [60.23m]	0 (26.83m)	70.55 (0.624m/s)	79.55	73.47	100	40.59
AIST (Ref)	39.02 (18.69m) [34.20m]	40.71 (5.93m)	86.86 (0.306m/s)	72.92	95.73	100	64.91

Awards

Providing award for winner of sub-tracks with prize items

- PDR sub-track:

Winner: [JPY150,000] or [JPY100,000 + SSEI PDR-W]

- VDR sub-track:

Winner: [JPY150,000] or [JPY100,000 + SSEI VDR Module (SUC-VDR100)]

Prize items (Thanks to the our sponsor Sugihara SEI)

SSEI's PDR-W

SSEI's VDR Module.

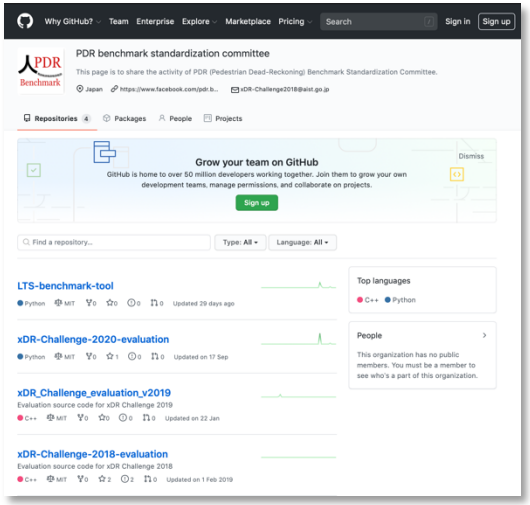
Thank you, all competitors and sponsors!

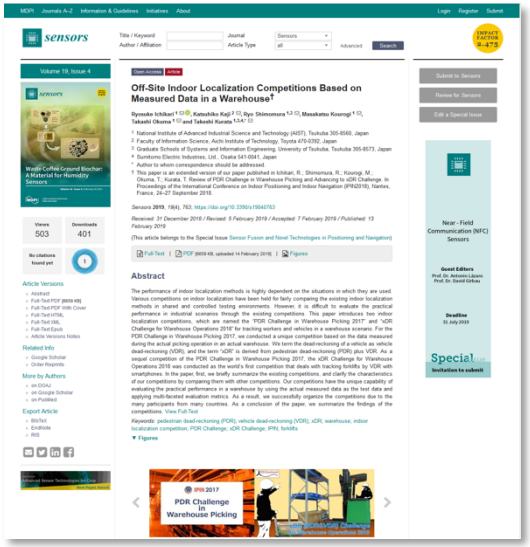
Findings from the results:

- Clarified the evaluation indicators which we would like to promote (CE,CA, EAG etc.) and used in the competition.
- EAG didn’t work well for evaluating the difference between the competitors
  - The length of ALIP (about 30min.) might be too long
- The results of trajectory of forklift were worse than we expected
  - Difficulty of the VDR and low-awareness of VDR
  - # of BLE beacons for forklifts area is small.
  - Parameters for calculating final score should be re-adjusted.
- Visibility and repeatability of the evaluation method are improved.
  - We evaluated the evaluation scripts by actually using for revaluation and sharing with competitors (Although minor changes exist during competitions)

Evaluation scripts and documents

- Evaluation scripts are available on github
  - For standardizing the evaluation method and getting feedback.
  - https://github.com/PDR-benchmark-standardization-committee/
- Open-Access paper available (MDPI's Sensors)
  - Previous xDR Challenge (2017, 2018) @ warehouse
  - Included a survey of existing indoor localization competition
  - https://www.mdpi.com/1424-8220/19/4/763





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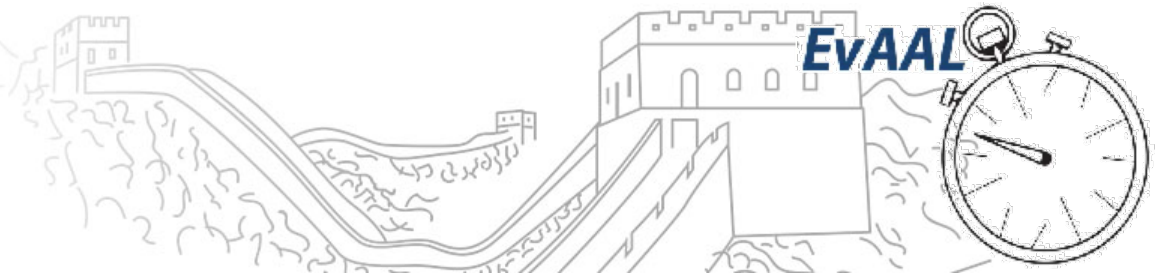

7th IPIN Competition
WINNER

Track 5: xDR Challenge in Manufacturing --- PDR sub-track

Takuto Yoshida, Kenta Urano, Hitoshi Matsuyama, Yusuke Asai, Nobuya Fukatani, Nozomi Hayashida, Yoshiteru Nagata, Yuto Fukushima (Kawaguchi Lab Team)

Sponsors:

Supporting communities:

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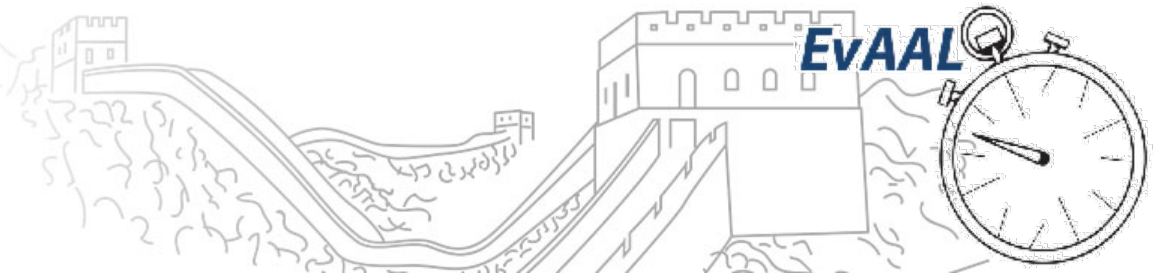

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Supporting communities:

Lisra

PDR Benchmark

HMHS CONSORTIUM

IPNTJ The Institute of Positioning, Navigation and Timing of Japan

HASC Human Activity Sensing Consortium