INTEL EDGE AI SW 8th

WAFFLE-FI

Wi-Fi Maintenance Robot

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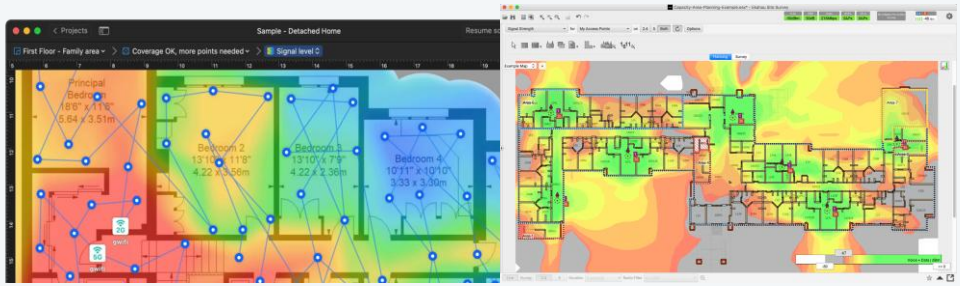
조민재

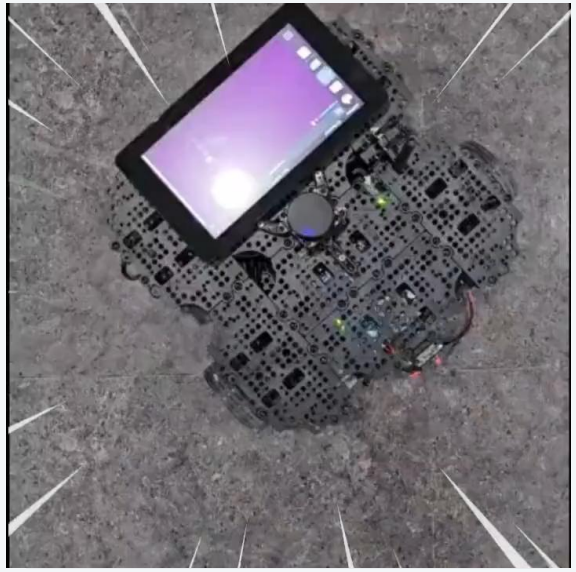
Index

Project Overview

“건물 안에 Wi-Fi 안 터지는 곳이 있던데요?” → **“AI Wi-Fi Maintenance Robot”**



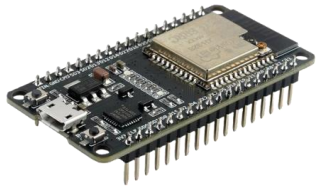
Project Objectives

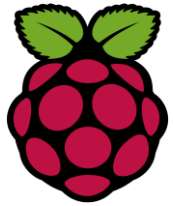


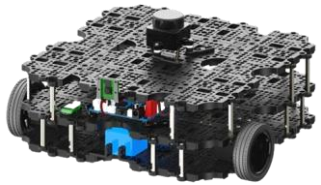
```
BEGIN
SSID:KCCI_STC_S,RSSI:-66
SSID:SK_WiFiGIGAFFF4_2.4G,RSSI:-78
SSID:iotB,RSSI:-45
SSID:turtle-mesh,RSSI:-70
SSID:embA,RSSI:-42
SSID:sindo,RSSI:-69
SSID:TP-LINK_288610,RSSI:-73
END
```

Project Architecture

Hardware & Sensor







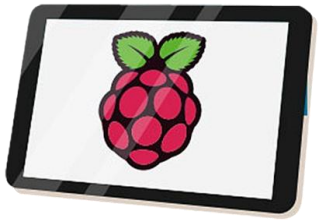
System Call & Data

SQLite

ROS

User Interface & Control

Qt



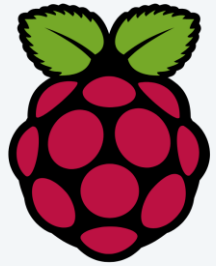
Wi-Fi

»» ESP32

```
// Async Scan
WiFi.scanNetworks(/* ... */);
int n = WiFi.scanComplete();

// SSID + RSSI 전송
for (int i = 0; i < n; ++i) {
    String line = "SSID:" + WiFi.SSID(i)
        + ",RSSI:" + String(WiFi.RSSI(i))
        + "\n";
    print(line);
}
```

```
SSID:KCCI_STC_S,RSSI:-61
SSID:KCCI_STC_S,RSSI:-66
END
BEGIN
SSID:KCCI_STC_S,RSSI:-56
SSID:SK_5F3C_2.4G,RSSI:-79
SSID:iotB,RSSI:-40
SSID:KT_GiGA_2G_Wave2_A541,RSSI:-70
SSID:turtle-mesh,RSSI:-49
SSID:turtle-mesh,RSSI:-51
SSID:kcciedu_P_3F,RSSI:-81
SSID:embA,RSSI:-43
SSID:robotA,RSSI:-55
SSID:KCCI_STC_S,RSSI:-62
SSID:kcciedu_P_3F_New,RSSI:-66
SSID:[LG_FloorStand A/C]6694,RSSI:-85
END
BEGIN
SSID:KCCI_STC_S,RSSI:-55
SSID:SK_WiFiGIGAFFF4_2.4G,RSSI:-83
```

UART



/dev/rssi_driver_table

48.ros × 50.ros

```
Every 1.0s: cat /dev/rssi_driver_table_test

BEGIN
SSID:KCCI_STC_S,RSSI:-66
SSID:SK_WiFiGIGAFFF4_2.4G,RSSI:-78
SSID:iotB,RSSI:-45
SSID:turtle-mesh,RSSI:-70
SSID:embA,RSSI:-42
SSID:sindo,RSSI:-69
SSID:TP-LINK_288610,RSSI:-73
END
```

Wi-Fi

»» RSSI

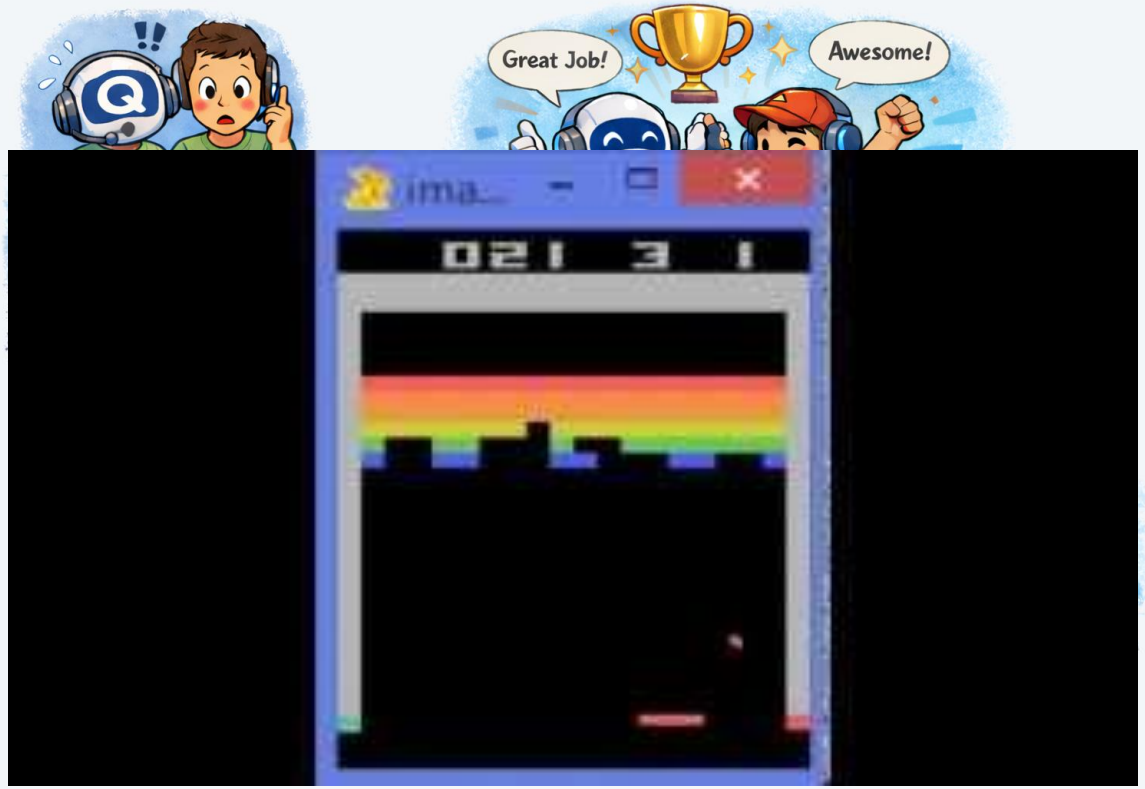
Received Signal Strength Indication 무선 통신 기기가 수신하는 신호의 강도를 나타내는 지표

$$\mathrm{dBm} = 10 \log_{10} \left(\frac{P}{1\mathrm{mW}} \right)$$

mW	dBm
1 mW	0 dBm
0.1 mW	-10 dBm
0.01 mW	-20 dBm
0.001 mW	-30 dBm
0.000000001 mW	-90 dBm

Reinforcement Learning

»» Concepts



Q	각 행동의 누적 보상 기대값 (점수)
Epsilon	탐험 비율 파라미터

DQN	**DNN + Q Learning**
DDQN	선택과 평가 분리
PER	**Replay Buffer / Prioritized Experience Replay**
PPO	**Policy-Based / Proximal Policy Optimization**

Reinforcement Learning

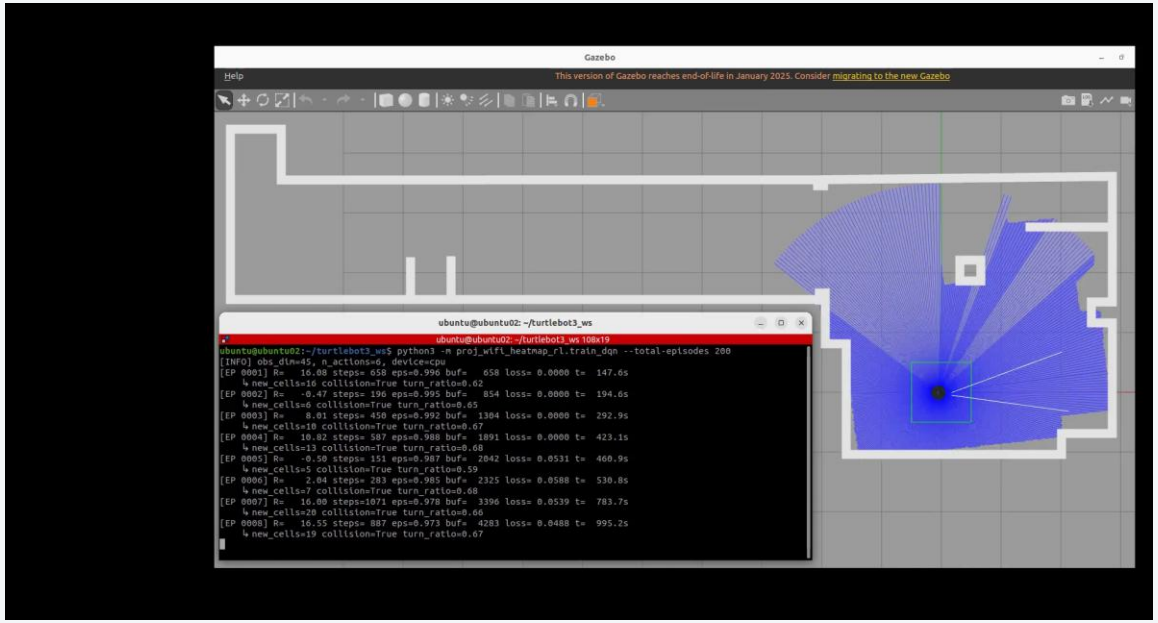
» Reward Function + Training Video (1/3)

```
reward_new_cell: float = 2.0
reward_forward_after_turn: float = 0.05
reward_cov_progress: float = 0.5
reward_frontier: float = 0.05
penalty_step: float = -0.01
penalty_arc: float = -0.0
penalty_turn: float = -0.03
penalty_turn_streak: float = -0.1
penalty_standing: float = -0.03
penalty_near: float = -0.01
penalty_very_near: float = -0.04
penalty_collision: float = -10.0
```

새로운 지역 = 리워드

제자리 회전 = 페널티

숲을 보는 눈 = 리워드



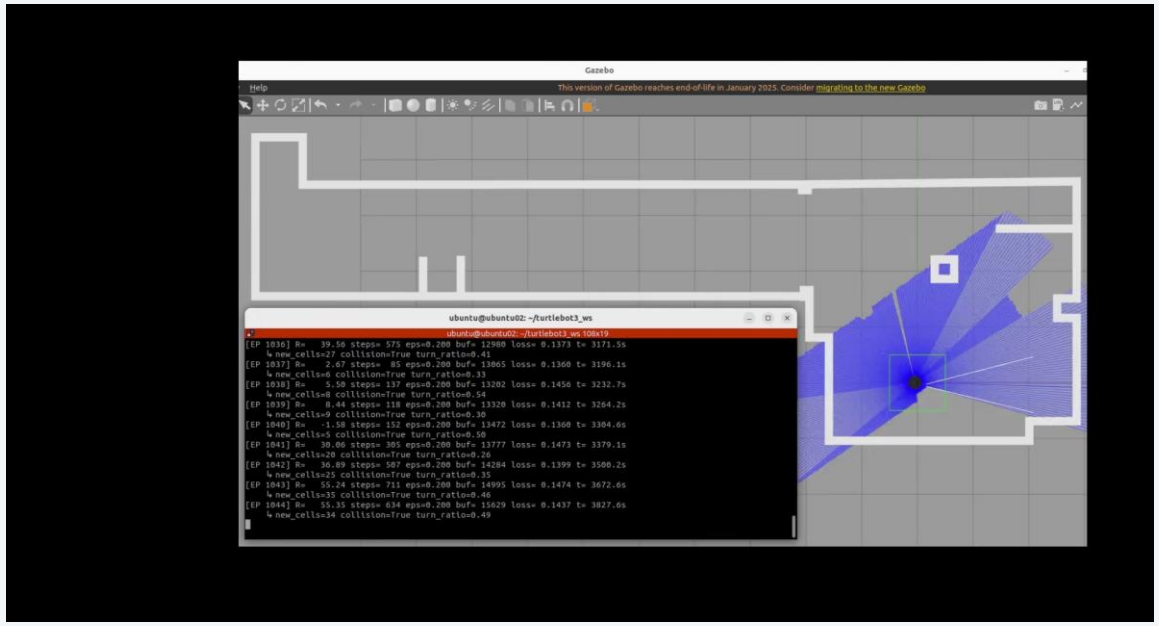
EP 1 ~ 50

50 EPs Avg Reward : 13.67

Turn Ratio : About 0.6

Reinforcement Learning

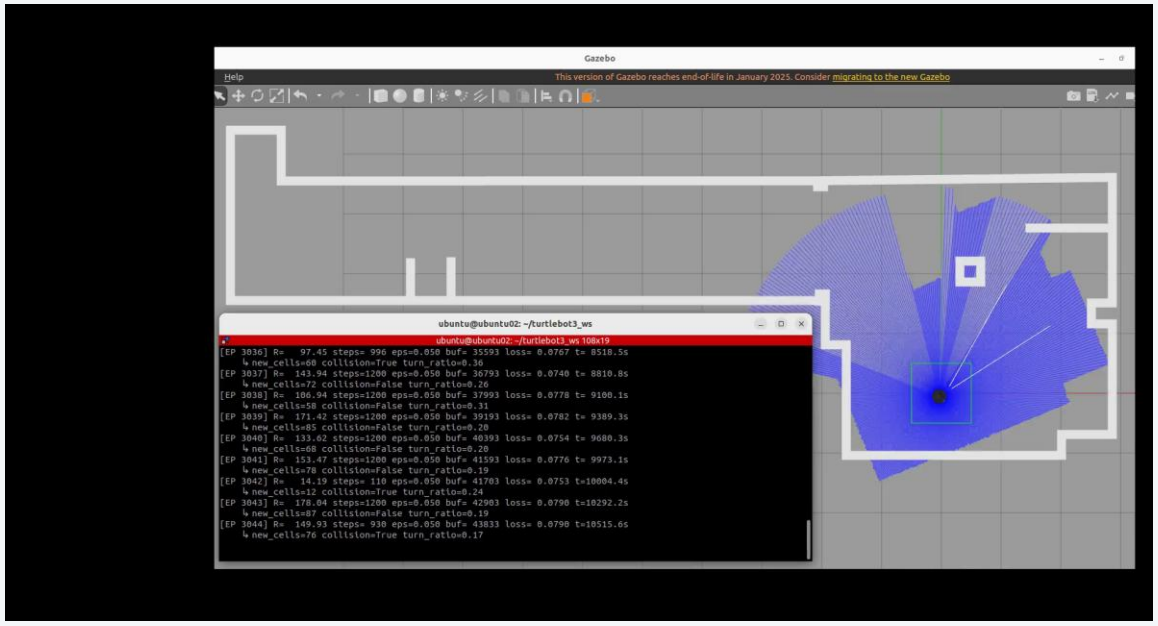
»» Training Video (2/3, 3/3)



EP 1001 ~ 1050

50 EPs Avg Reward : 51.89

Turn Ratio : About 0.3 ~ 0.5

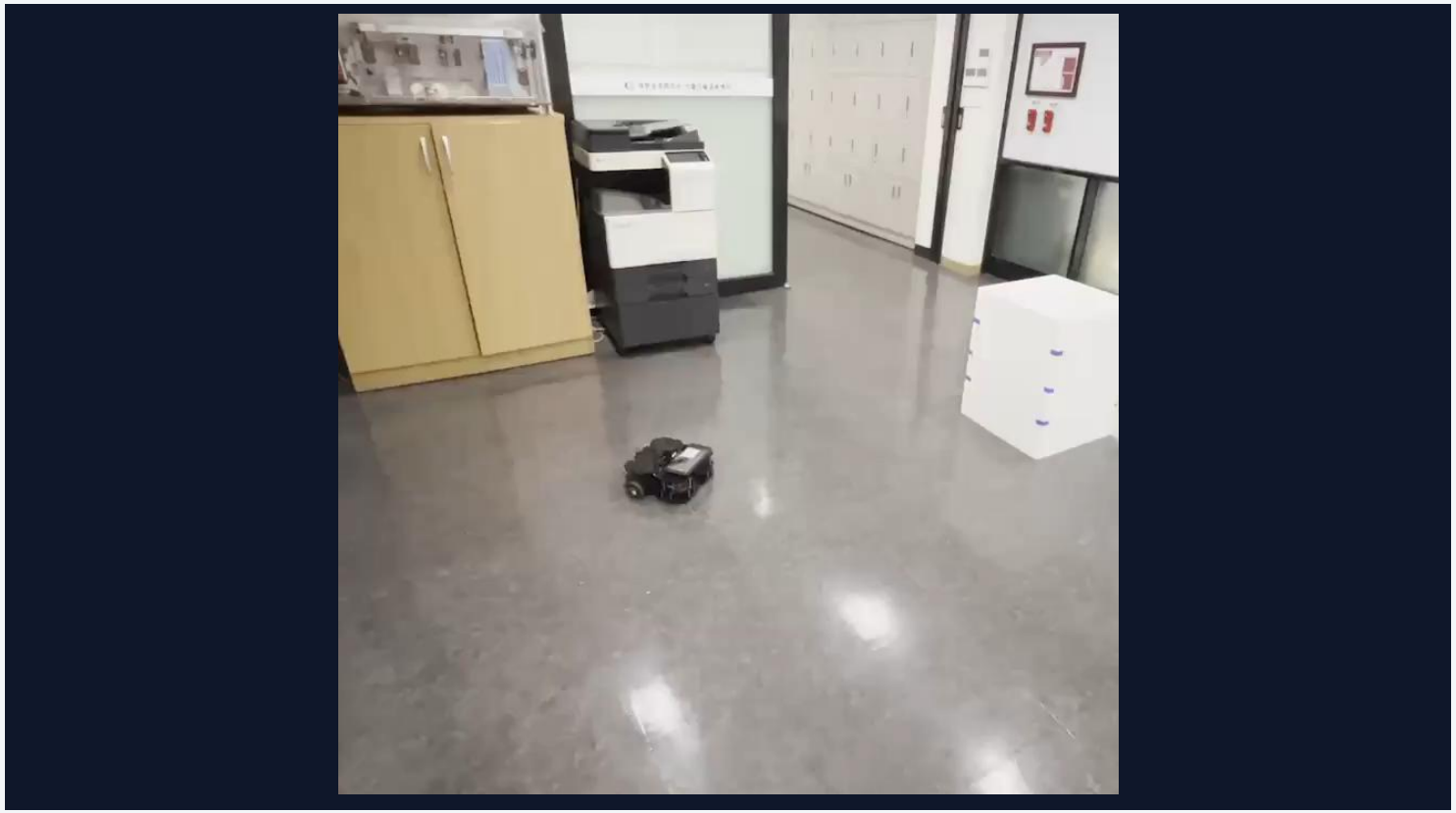


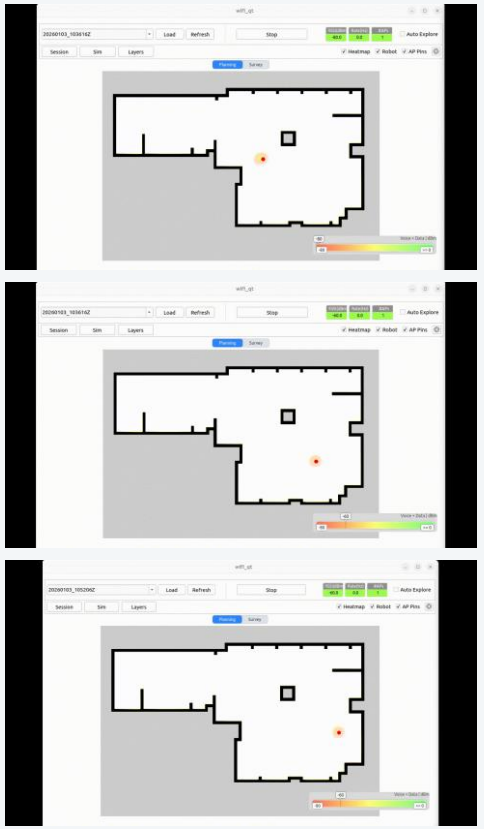
EP 3001 ~ 3050

50 EPs Avg Reward : 144.57
50 Eps Avg New Cell : 73.36
Turn Ratio : About 0.3

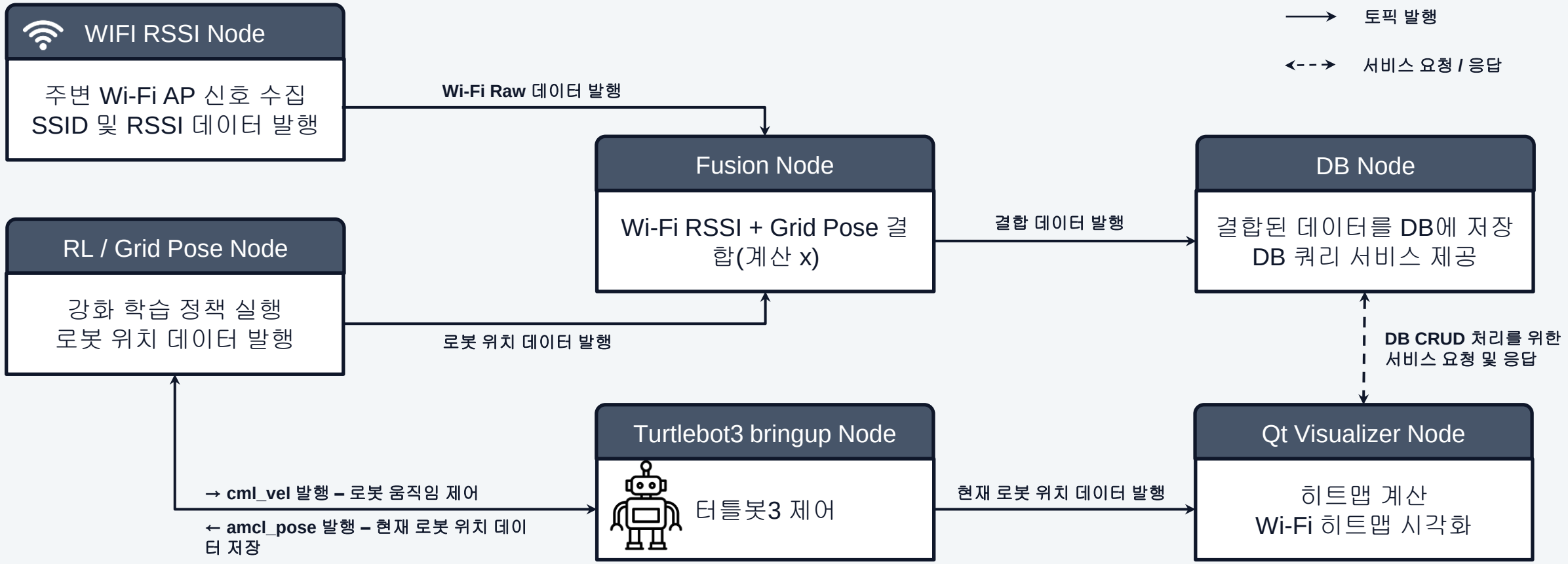
Reinforcement Learning

»» Driving Video





ROS


토픽 발행
서비스 요청 / 응답
WIFI RSSI Node
주변 Wi-Fi AP 신호 수집
SSID 및 RSSI 데이터 발행
Wi-Fi Raw 데이터 발행
Fusion Node
Wi-Fi RSSI + Grid Pose 결합(계산 x)
결합 데이터 발행
DB Node
결합된 데이터를 DB에 저장
DB 쿼리 서비스 제공
RL / Grid Pose Node
강화 학습 정책 실행
로봇 위치 데이터 발행
로봇 위치 데이터 발행
DB CRUD 처리를 위한 서비스 요청 및 응답
Turtlebot3 bringup Node
터틀봇3 제어
→ cmd_vel 발행 – 로봇 움직임 제어
← amcl_pose 발행 – 현재 로봇 위치 데이터 저장
현재 로봇 위치 데이터 발행
Qt Visualizer Node
히트맵 계산
Wi-Fi 히트맵 시각화

Qt GUI

»» Main

Main

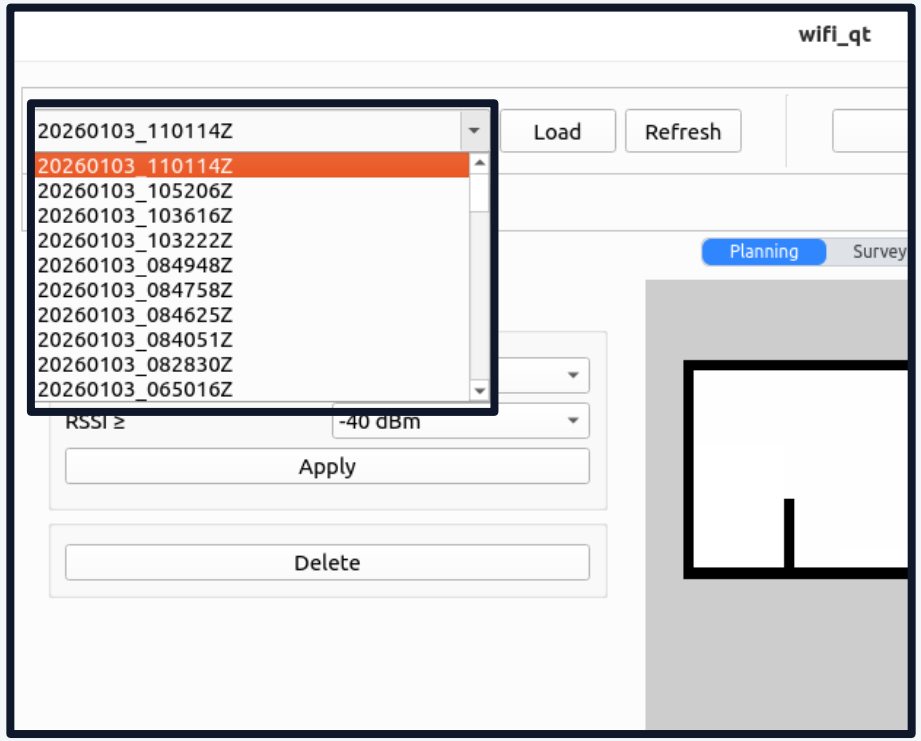
Robot **Heatmap**

Start : Create Session

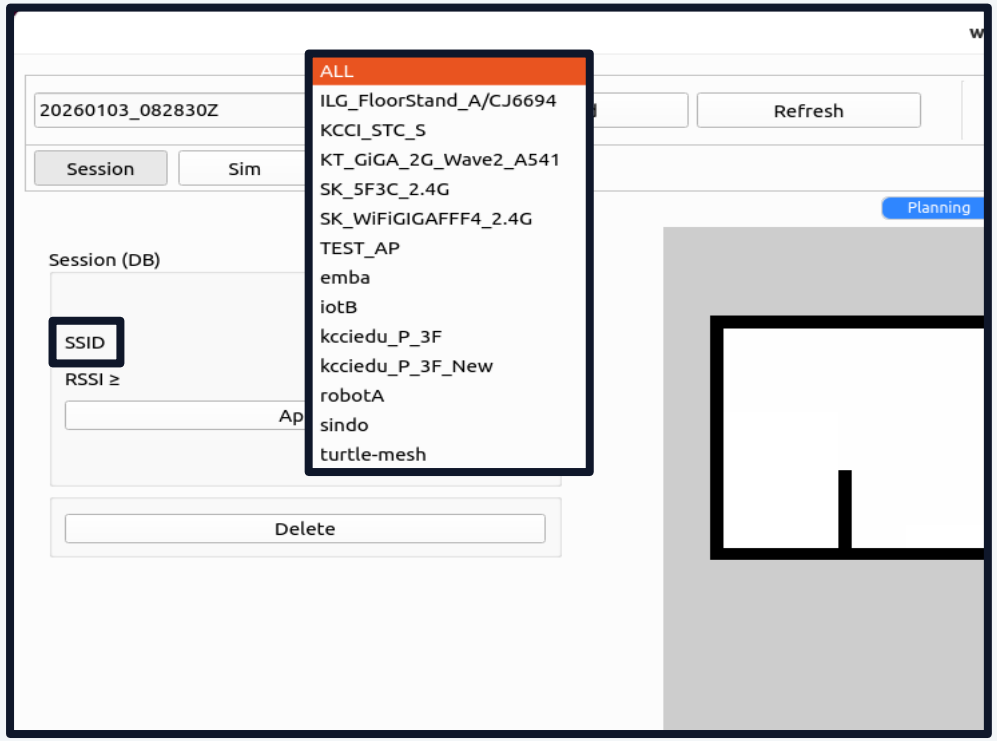
Qt GUI

»» Session & SSID

Session



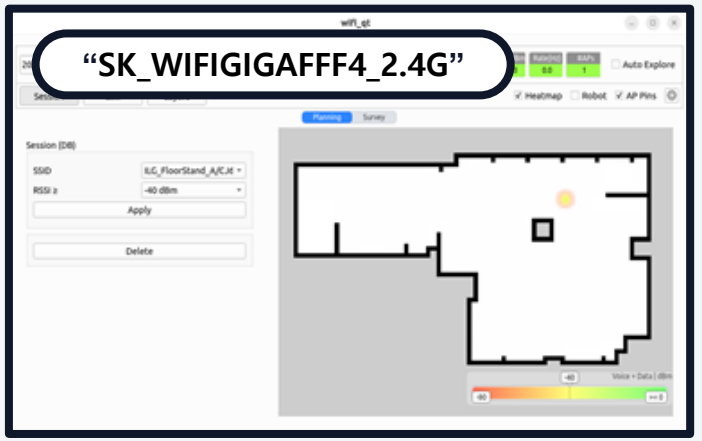
SSID



Qt GUI

»» Session & SSID

SSID



Qt GUI

»» Simulation

Simulation

Custom AP

Troubleshooting

⋙ ESP32

Issue

Wi-Fi 스캔 소요 시간 1.8s

```
13:44:23.295 -> END
13:44:23.295 -> BEGIN
13:44:23.423 -> SSID:KCCI_STC_S,RSSI:-46
13:44:23.423 -> SSID:KCCI_STC_S,RSSI:-59
13:44:23.423 -> SSID:KCCI_STC_S,RSSI:-72
13:44:23.749 -> SSID:iotB,RSSI:-46
13:44:23.295 -> BEGIN
13:44:23.423 -> SSID:KCCI_STC_S,RSSI:-46
13:44:24.200 -> SSID:KCCI501,RSSI:-68
13:44:24.200 -> SSID:robotA,RSSI:-69
13:44:24.200 -> SSID:KCCI_STC_S,RSSI:-70
13:44:24.200 -> SSID:kang_ap,RSSI:-74
13:44:24.200 -> SSID:U+NetE70C,RSSI:-90
13:44:24.200 -> SSID:sk,RSSI:-93
13:44:24.332 -> SSID:U+Net9DE0,RSSI:-78
13:44:24.332 -> SSID:SK_WiFiGIGAF25B,RSSI:-87
13:44:25.079 -> SSID:[LG_CeilingCassette
13:44:25.079 -> END
13:44:24.691 -> SSID:TP-LINK_28861C,RSSI:-73
13:44:24.724 -> SSID:SK_WiFiGIGADCD8_2.4G,RSSI:-79
13:44:24.822 -> SSID:SK_WiFiGIGAF2A0_2.4G,RSSI:-79
13:44:25.079 -> SSID:KCCI_STC_S,RSSI:-69
13:44:25.079 -> SSID:KCCI_STC_S,RSSI:-70
13:44:25.079 -> SSID:kcciedu_P_3F_New,RSSI:-78
13:44:25.079 -> SSID:U+Net8CEB,RSSI:-82
13:44:25.079 -> SSID:Barona,RSSI:-86
13:44:25.079 -> SSID:kcciedu_P_3F,RSSI:-89
13:44:25.079 -> SSID:[LG_CeilingCassette A/C]db2b,RSSI:-93
13:44:25.079 -> END
13:44:25.079 -> BEGIN
```

Cause

불필요한 Wi-Fi 채널 스캔
소요 시간 ↑

```
--- Scan Finished: 30 networks found ---
SSID:KCCI_STC_S,RSSI:-42, Ch:1
SSID:embA,RSSI:-42, Ch:9
SSID:iotB,RSSI:-45, Ch:3
SSID:turtle-mesh,RSSI:-48, Ch:6
SSID:KCCI_STC_S,RSSI:-52, Ch:11
SSID:turtle-mesh,RSSI:-54, Ch:6
SSID:robotA,RSSI:-57, Ch:11
SSID:KCCI_STC_S,RSSI:-58, Ch:1
SSID:sindo,RSSI:-58, Ch:9
SSID:KCCI_STC_S,RSSI:-63, Ch:1
SSID:KCCI_STC_S,RSSI:-63, Ch:6
SSID:KCCI501,RSSI:-65, Ch:3
SSID:KT_GiGA_2G_Wave2_A541,RSSI:-65, Ch:3
```

Solution

필요한 Wi-Fi 채널만 스캔

```
const int targetChannels[] = {1, 3, 6, 9, 11};
```

소요 시간 0.5s (- 1.3s)

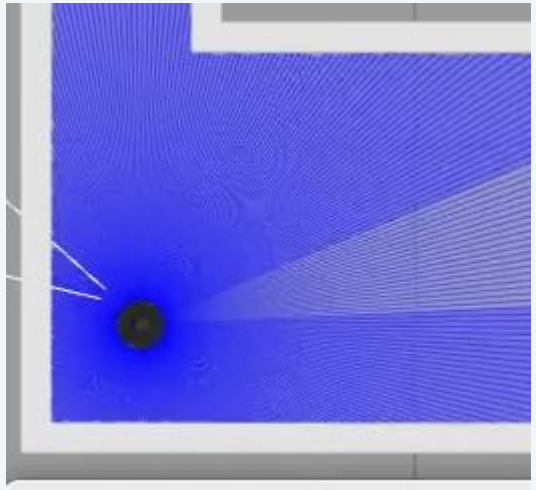
```
13:56:30.627 -> BEGIN
13:56:30.724 -> SSID:KCCI_STC_S,RSSI:-59
13:56:30.724 -> SSID:SK_5F3C_2.4G,RSSI:-72
13:56:30.627 -> BEGIN
13:56:30.724 -> SSID:KCCI_STC_S,RSSI:-59
13:56:30.853 -> SSID:iotB,RSSI:-47
13:56:30.853 -> SSID:KT_GiGA_2G_Wave2_A541,RSSI:-64
13:56:30.853 -> SSID:KT_GiGA_Mesh_94E3,RSSI:-88
13:56:30.950 -> SSID:turtle-mesh,RSSI:-55
13:56:30.950 -> SSID:turtle-mesh,RSSI:-61
13:56:30.950 -> SSID:robotA,RSSI:-65
13:56:30.950 -> SSID:KCCI_STC_S,RSSI:-72
13:56:30.950 -> SSID:kang_ap,RSSI:-76
13:56:30.950 -> SSID:sk,RSSI:-93
13:56:31.177 -> SSID:[LG_Ceiling
13:56:31.177 -> END
13:56:31.177 -> SSID:[LG_CeilingCassette A/C]db2b,RSSI:-86
13:56:31.177 -> SSID:Barona_2G,RSSI:-86
13:56:31.177 -> SSID:[LG_CeilingCassette A/C]bb10,RSSI:-87
13:56:31.177 -> SSID:[LG_CeilingCassette A/C]dafd,RSSI:-90
13:56:31.177 -> END
```

Troubleshooting

»» Reinforcement Learning

Issue

잦은 충돌
제자리 회전 多



Cause

행동 4개 → 충돌을 회피할 행동 부족
리워드 및 페널티 불충분

```
# Action (4):
#   0: forward, 1: left, 2: right, 3: stop
```

```
reward_new_cell: float = 2.0
reward_forward_after_turn: float = 0.05


penalty_step: float = -0.01
penalty_arc: float = -0.0
penalty_turn: float = -0.03

penalty_standing: float = -0.03


penalty_collision: float = -10.0
```

Solution

행동 4개 → 6개
충돌 근접 페널티 추가
회전 페널티 강하게 수정

```
Action (6):
  0: forward, 1: left-arc, 2: right-arc
  , 3: left-turn, 4: right-turn, 5: stop
```

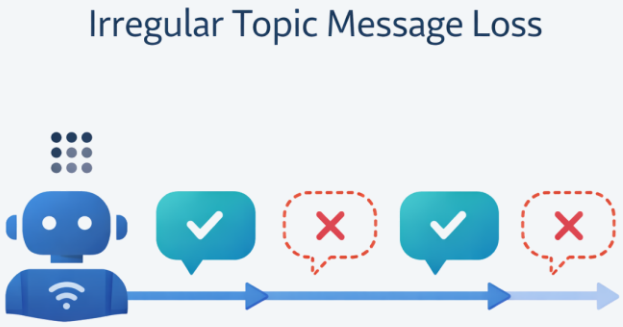
```
reward_new_cell: float = 2.0
reward_forward_after_turn: float = 0.05


penalty_step: float = -0.01
penalty_arc: float = -0.0
penalty_turn: float = -0.03
penalty_turn_streak: float = -0.1
penalty_standing: float = -0.03
penalty_near: float = -0.01
penalty_very_near: float = -0.04
penalty_collision: float = -10.0
```

Troubleshooting

»» ROS

Issue

불규칙적인 토픽 메시지 손실
Publisher / Subscriber 비정상 동작



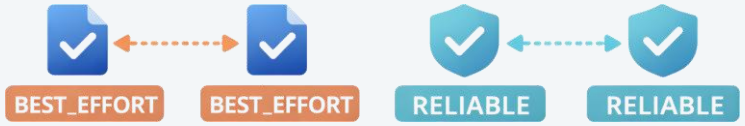
Cause

Publisher / Subscriber QoS 불일치
(RELIABLE / BEST_EFFORT)

```
QoS profile:
  Reliability: RELIABLE
  History (Depth): UNKNOWN
  Durability: VOLATILE
  Lifespan: Infinite
  Deadline: Infinite
  Liveliness: AUTOMATIC
  Liveliness lease duration: Infinite
```

Solution

QoS 통일
센서류/고주기 데이터 : BEST_EFFORT
제어/중요 명령 : RELIABLE

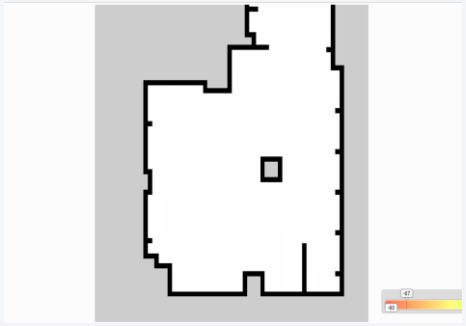


Troubleshooting

»» Qt GUI

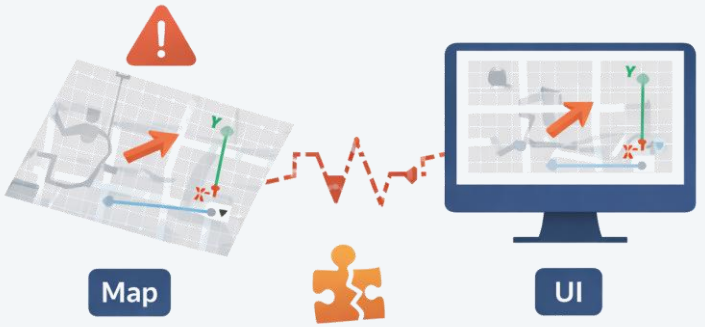
Issue

지도 회전 후
로봇 위치 손실
히트맵 손실



Cause

지도 회전 시 로직 상 오류로
좌표계 불일치 (맵 vs UI)



Solution

좌표계에 직접 회전 X
최종 렌더를 담당하는 View 만 회전

Meet the Team

김다현
Project Management Qt GUI

나지훈
ROS DB

문두르
Project Lead Reinforcement Learning

조민재
ESP32 Firmware Device Driver

THANKS