RV.Lab
Robot & Virtual Reality

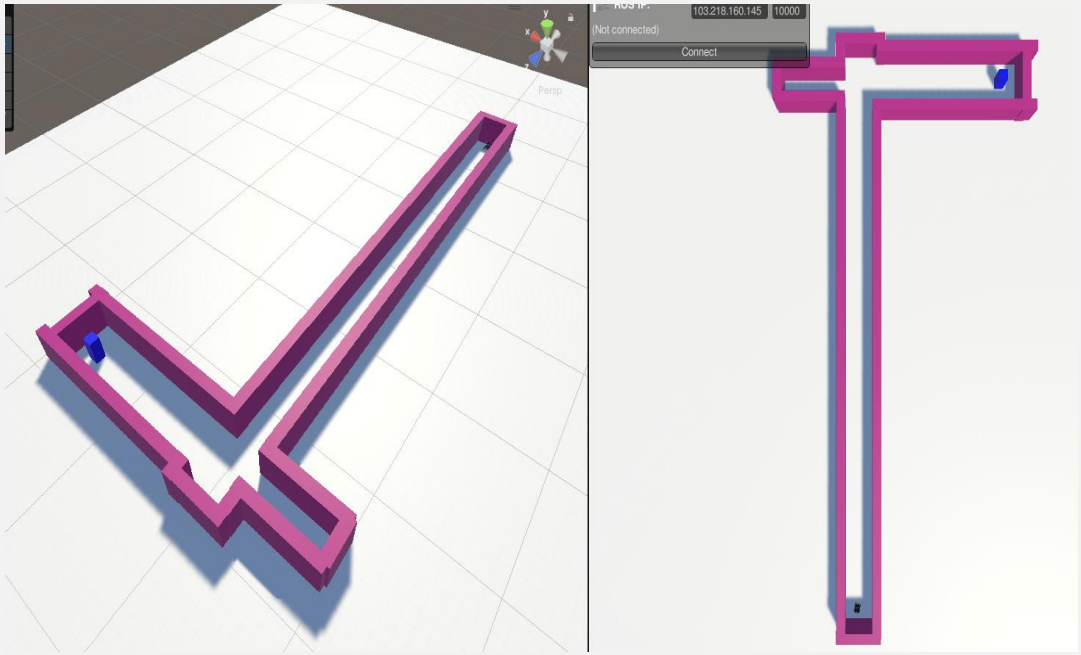
KONKUK University
Mechanical Engineering
Autonomous Robotics

연구 진행사항(husky)

전민경

KU 건국대학교 KONKUK UNIV.

강화학습 적용

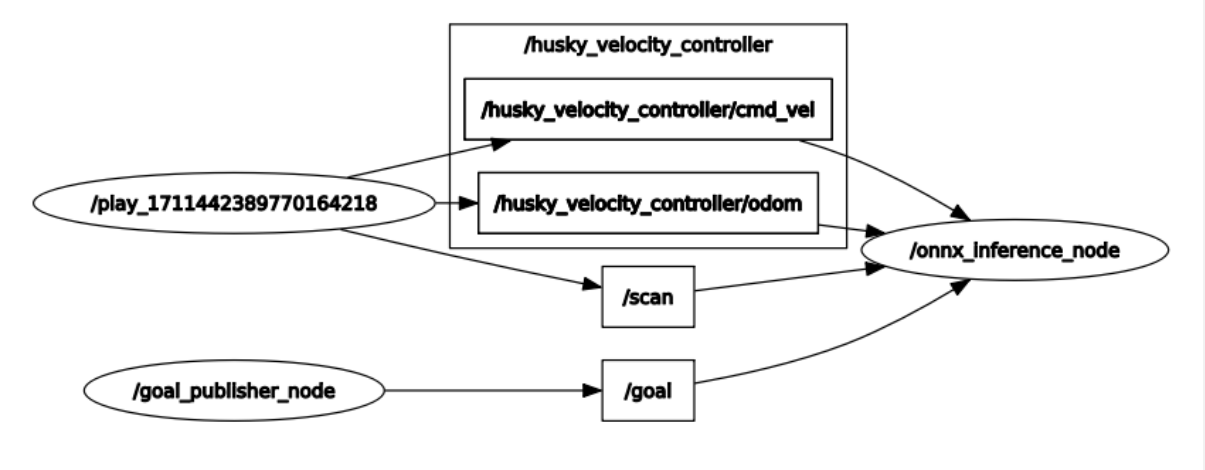



```
Model Inputs:
obs_0: Shape: [0, 905]

Model Outputs:
version_number: Shape: [1]
memory_size: Shape: [1]
continuous_actions: Shape: [0, 2]
continuous_action_output_shape: Shape: [1]
deterministic_continuous_actions: Shape: [0, 2]
```

- Velodyne의 /scan은 1도의 채널에서만 나오는 레이저의 ranges 데이터만 사용
- laser_scan_resolution = 0.007 rad → 1바퀴 360도 / 약 0.401도 = 897(내림 적용)개
- Unity ml-agent의 학습 모델은 onnx 파일 형식
- Onnx 파일의 입출력 데이터 형식

연구 진행사항

강화학습 적용




```
[INFO] [1711442520.526823]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[1.        , 0.11810557]], dtype=float32), array([2.], dtype=float32), array([[ 1.       , -0.1555708]], dtype=float32)]
[INFO] [1711442520.626868]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[nan, nan]], dtype=float32), array([2.], dtype=float32), array([[nan, nan]], dtype=float32)]
[INFO] [1711442520.726812]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[nan, nan]], dtype=float32), array([2.], dtype=float32), array([[nan, nan]], dtype=float32)]
[INFO] [1711442520.826741]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[nan, nan]], dtype=float32), array([2.], dtype=float32), array([[nan, nan]], dtype=float32)]
[INFO] [1711442520.926733]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[nan, nan]], dtype=float32), array([2.], dtype=float32), array([[nan, nan]], dtype=float32)]
[INFO] [1711442521.026759]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[nan, nan]], dtype=float32), array([2.], dtype=float32), array([[nan, nan]], dtype=float32)]
[INFO] [1711442521.126796]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[nan, nan]], dtype=float32), array([2.], dtype=float32), array([[nan, nan]], dtype=float32)]
```

```
[INFO] [1711442564.115613]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[0.16720754, 0.14051172]], dtype=float32), array([2.], dtype=float32), array([[0.05041727, 0.06362109]], dtype=float32)]
[INFO] [1711442564.215672]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[-0.06891506,  0.01305712]], dtype=float32), array([2.], dtype=float32), array([[0.05041727, 0.06362109]], dtype=float32)]
[INFO] [1711442564.315620]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[-0.14661725,  0.01295562]], dtype=float32), array([2.], dtype=float32), array([[0.05041727, 0.06362109]], dtype=float32)]
[INFO] [1711442564.415653]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[ 0.01355988, -0.15434791]], dtype=float32), array([2.], dtype=float32), array([[0.05041727, 0.06362109]], dtype=float32)]
[INFO] [1711442564.515652]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[-0.05093615, -0.15266185]], dtype=float32), array([2.], dtype=float32), array([[0.05041727, 0.06362109]], dtype=float32)]
[INFO] [1711442564.615632]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[3.7450859e-01, 3.1739473e-05]], dtype=float32), array([2.], dtype=float32), array([[0.05041727, 0.06362109]], dtype=float32
[INFO] [1711442564.715618]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[-0.4008145 ,  0.24372798]], dtype=float32), array([2.], dtype=float32), array([[0.05041727, 0.06362109]], dtype=float32)]
[INFO] [1711442564.815728]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[-0.03833059,  0.056924  ]], dtype=float32), array([2.], dtype=float32), array([[0.05041727, 0.06362109]], dtype=float32)]
[INFO] [1711442564.915669]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[0.4121629 , 0.12876962]], dtype=float32), array([2.], dtype=float32), array([[0.05041727, 0.06362109]], dtype=float32)]
[INFO] [1711442565.015719]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[-0.09601251,  0.102644  ]], dtype=float32), array([2.], dtype=float32), array([[0.05041727, 0.06362109]], dtype=float32)]
```

- Ros로 입출력 데이터를 주고 받을 수 있도록 연결
- 출력 데이터의 형태 분석이 필요함.(선속도와 각속도)

강화학습 적용

```
INFO] [1712021821.422280638]: correction angles: /opt/ros/noetic/share/velodyne_pointcloud/params/VLP16db.yaml
INFO] [1712021821.424723722]: laser_ring[ 0] =  0, angle = -0.261799
INFO] [1712021821.424744195]: laser_ring[ 2] =  1, angle = -0.226893
INFO] [1712021821.424754354]: laser_ring[ 4] =  2, angle = -0.191986
INFO] [1712021821.424763581]: laser_ring[ 6] =  3, angle = -0.157080
INFO] [1712021821.424773165]: laser_ring[ 8] =  4, angle = -0.122173
INFO] [1712021821.424782715]: laser_ring[10] =  5, angle = -0.087266
INFO] [1712021821.424791674]: laser_ring[12] =  6, angle = -0.052360
INFO] [1712021821.424807245]: laser_ring[14] =  7, angle = -0.017453
INFO] [1712021821.424832881]: laser_ring[ 1] =  8, angle = +0.017453
INFO] [1712021821.424847225]: laser_ring[ 3] =  9, angle = +0.052360
INFO] [1712021821.424864317]: laser_ring[ 5] = 10, angle = +0.087266
INFO] [1712021821.424879582]: laser_ring[ 7] = 11, angle = +0.122173
INFO] [1712021821.424894581]: laser_ring[ 9] = 12, angle = +0.157080
INFO] [1712021821.424909053]: laser_ring[11] = 13, angle = +0.191986
INFO] [1712021821.424921660]: laser_ring[13] = 14, angle = +0.226893
INFO] [1712021821.424935537]: laser_ring[15] = 15, angle = +0.261799
INFO] [1712021821.425099938]: Number of lasers: 16.
WARN] [1712021821.427216271]: No Azimuth Cache configured for model VLP16
INFO] [1712021821.436310390]: Reconfigure request.
INFO] [1712021821.436349649]: Target frame ID now:
INFO] [1712021821.436366149]: Fixed frame ID now:
INFO] [1712021821.436430466]: Initialized container with min_range: 0.4, max_range: 130, target_frame: , fixed_frame: , init_width: 0, init_height: 1, is_dense: 1, scans_per_packet: 384
WARN] [1712021879.711426317]: Packet containing angle overflow, first angle: 35988 second angle: 28
INFO] [1712021879.717134639]: VelodyneLaserScan: Latched ring count of 16
INFO] [1712021879.717162128]: VelodyneLaserScan: Extracting ring 8
```

☑ /scan	sensor_msgs/LaserScan	71.90KB/s	9.91	
angle_increment	float32			0.007000000216066837
angle_max	float32			3.1415927410125732
angle_min	float32			-3.1415927410125732
▸ header	std_msgs/Header			
intensities	float32[]			(1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0,
range_max	float32			200.0
range_min	float32			0.0
ranges	float32[]			(2.3036491870880127, 5.299
scan_time	float32			0.0
time_increment	float32			0.0

<VLP16의 데이터>

- Velodyne의 /scan은 1도의 채널(8번 ring)에서만 나오는 레이저의 ranges 데이터만 사용하고 있었음.
- laser_scan_resolution = 0.007 rad(각도 해상도: 약 0.401도), 600 rpm(1초에 10바퀴)

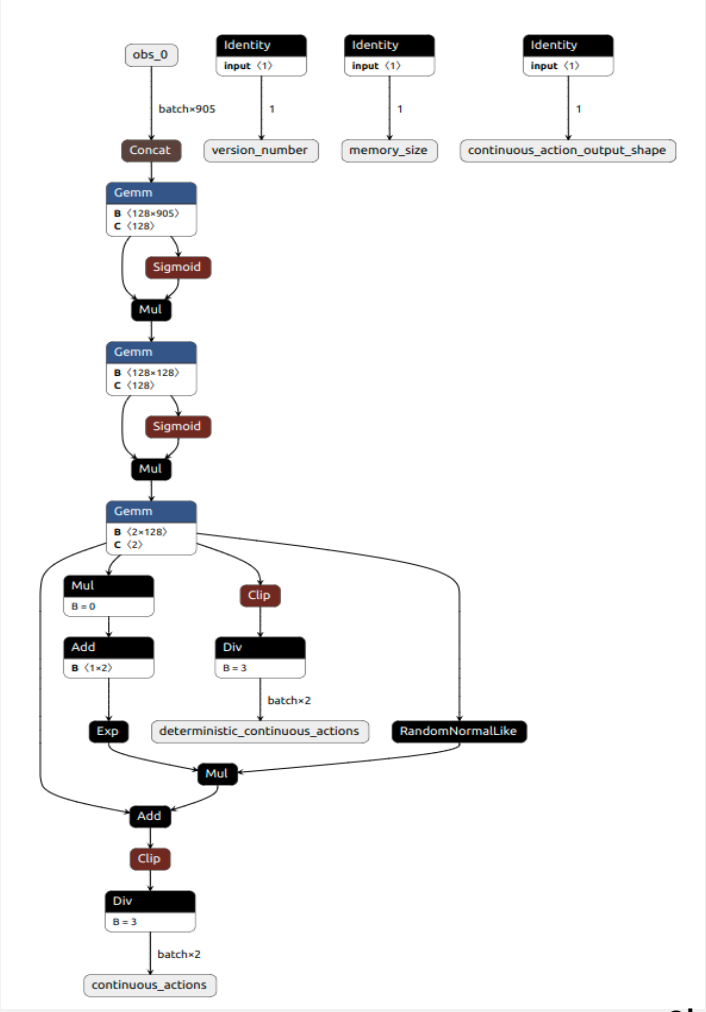
→ 1바퀴 360도 / 약 0.401도 = 897(내림 적용)개(1초에 8970개의 ranges 데이터 생산

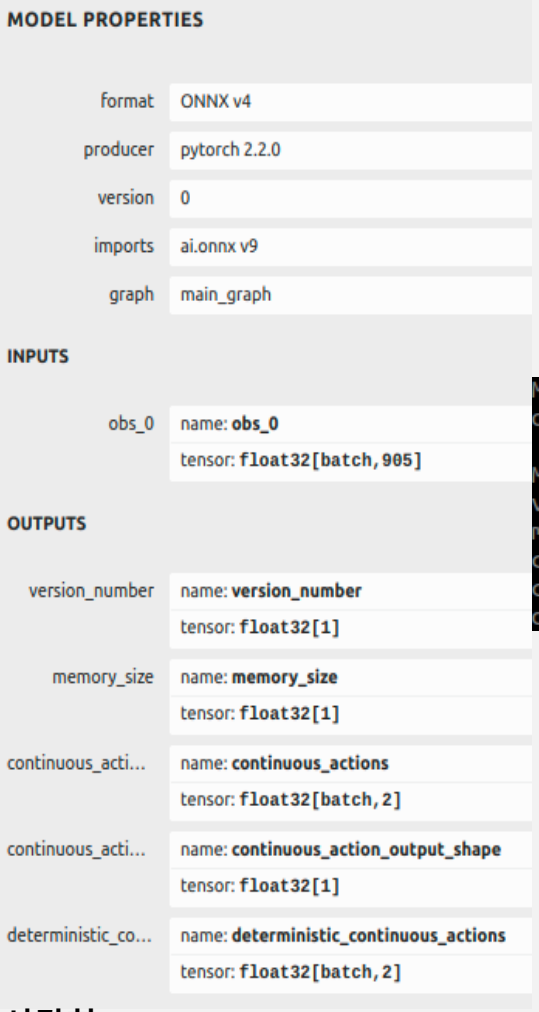
- range_min = 0.0, range_max = 200.0, angle_min = -pi, angle_max = pi, intensity = 0.0 ~ 100.0

→ 1채널(1도)에서 897개의 ranges 데이터가 나오도록 재설정하여 유니티에서 재학습.

연구 진행사항

강화학습 적용





<onnx의 시각화>

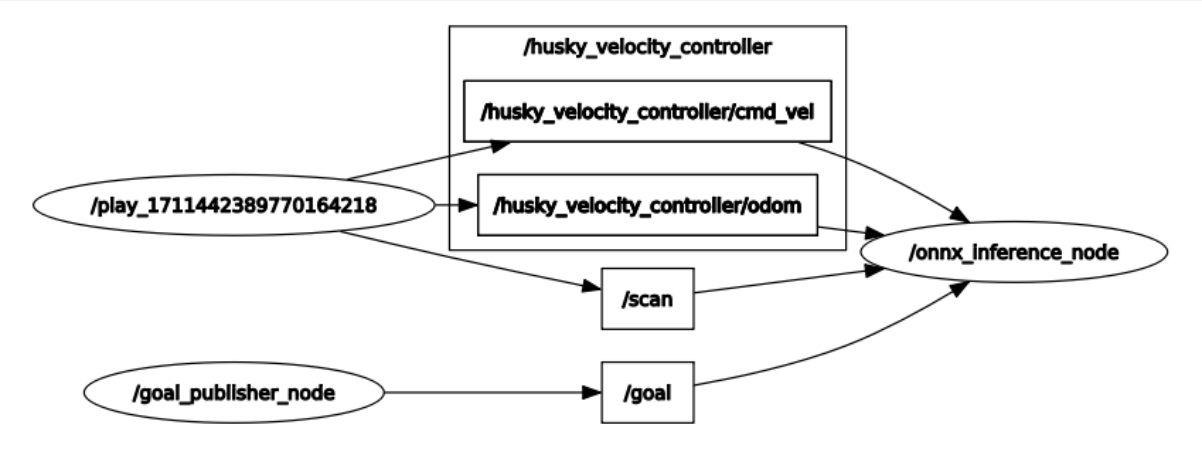
```
Model Inputs:
obs_0: Shape: [0, 905]

Model Outputs:
version_number: Shape: [1]
memory_size: Shape: [1]
continuous_actions: Shape: [0, 2]
continuous_action_output_shape: Shape: [1]
deterministic_continuous_actions: Shape: [0, 2]
```

<onnx의 입출력>

- Unity ml-agent의 학습 모델은 onnx 파일 형식
- Onnx 파일의 노드 구조를 시각화 or 코드를 통해 확인할 수 있음.

연구 진행사항

강화학습 적용




```
[INFO] [1711442520.526823]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[1.        , 0.11810557]], dtype=float32), array([2.], dtype=float32), array([[ 1.       , -0.1555708]], dtype=float32)]
[INFO] [1711442520.626868]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[nan, nan]], dtype=float32), array([2.], dtype=float32), array([[nan, nan]], dtype=float32)]
[INFO] [1711442520.726812]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[nan, nan]], dtype=float32), array([2.], dtype=float32), array([[nan, nan]], dtype=float32)]
[INFO] [1711442520.826741]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[nan, nan]], dtype=float32), array([2.], dtype=float32), array([[nan, nan]], dtype=float32)]
[INFO] [1711442520.926733]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[nan, nan]], dtype=float32), array([2.], dtype=float32), array([[nan, nan]], dtype=float32)]
[INFO] [1711442521.026759]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[nan, nan]], dtype=float32), array([2.], dtype=float32), array([[nan, nan]], dtype=float32)]
[INFO] [1711442521.126796]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[nan, nan]], dtype=float32), array([2.], dtype=float32), array([[nan, nan]], dtype=float32)]
```

```
[INFO] [1711442564.115613]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[0.16720754, 0.14051172]], dtype=float32), array([2.], dtype=float32), array([[0.05041727, 0.06362109]], dtype=float32)]
[INFO] [1711442564.215672]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[-0.06891506,  0.01305712]], dtype=float32), array([2.], dtype=float32), array([[0.05041727, 0.06362109]], dtype=float32)]
[INFO] [1711442564.315620]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[-0.14661725,  0.01295562]], dtype=float32), array([2.], dtype=float32), array([[0.05041727, 0.06362109]], dtype=float32)]
[INFO] [1711442564.415653]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[ 0.01355988, -0.15434791]], dtype=float32), array([2.], dtype=float32), array([[0.05041727, 0.06362109]], dtype=float32)]
[INFO] [1711442564.515652]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[-0.05093615, -0.15266185]], dtype=float32), array([2.], dtype=float32), array([[0.05041727, 0.06362109]], dtype=float32)]
[INFO] [1711442564.615632]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[3.7450859e-01, 3.1739473e-05]], dtype=float32), array([2.], dtype=float32), array([[0.05041727, 0.06362109]], dtype=float32
[INFO] [1711442564.715618]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[-0.4008145 ,  0.24372798]], dtype=float32), array([2.], dtype=float32), array([[0.05041727, 0.06362109]], dtype=float32)]
[INFO] [1711442564.815728]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[-0.03833059,  0.056924  ]], dtype=float32), array([2.], dtype=float32), array([[0.05041727, 0.06362109]], dtype=float32)]
[INFO] [1711442564.915669]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[0.4121629 , 0.12876962]], dtype=float32), array([2.], dtype=float32), array([[0.05041727, 0.06362109]], dtype=float32)]
[INFO] [1711442565.015719]: Model output: [array([3.], dtype=float32), array([0.], dtype=float32), array([[-0.09601251,  0.102644  ]], dtype=float32), array([2.], dtype=float32), array([[0.05041727, 0.06362109]], dtype=float32)]
```

<출력: version_number, memory_size, continuous_actions, continuous_action_output_shape, deterministic_continuous_actions>

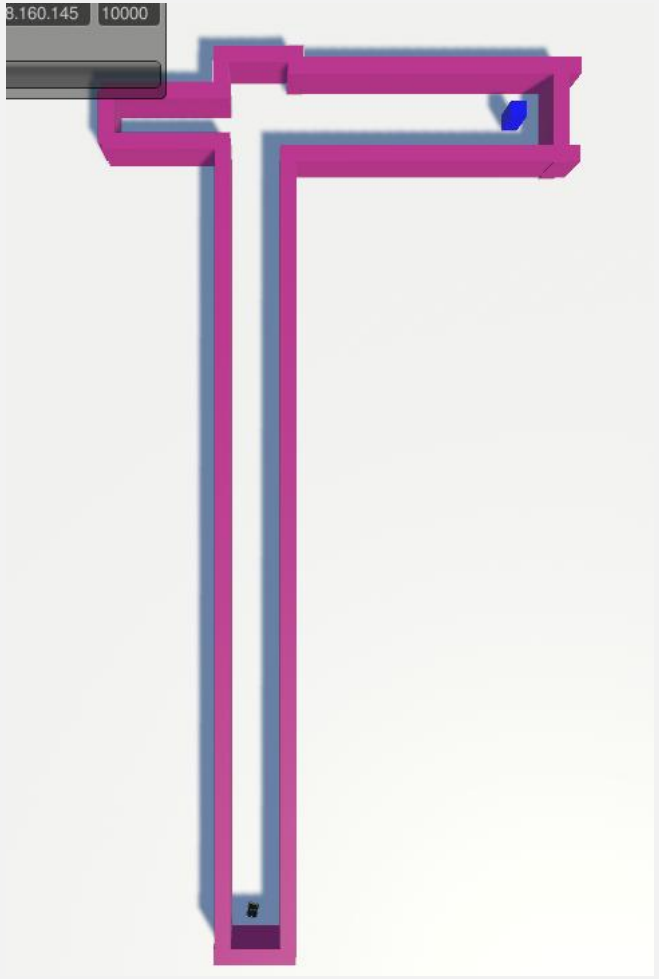
- VLP16의 ranges 데이터의 inf를 range_max로 치환한 다음, 가우시안 필터를 적용함.(inf로 인해 출력이 nan이 나옴.)

연구 진행사항

강화학습 적용

<test 1>

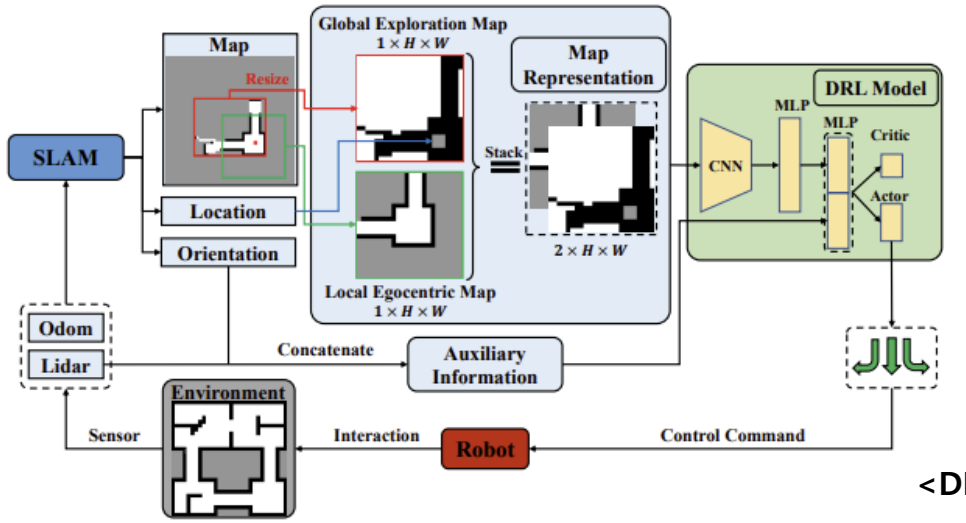
<test 2>



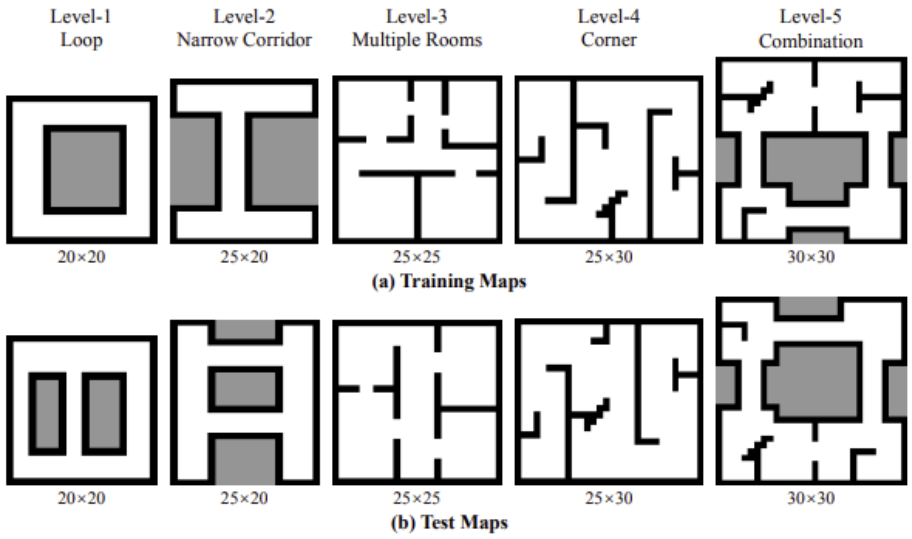
- 6~7m 정도 가고 벽에 박음.

→ 더 현실과 비슷한 map을 만들어야 할지 or 라이다의 ranges 데이터 Downsampling / ROI 설정

선행 연구(2023, IROS, Autonomous Exploration and Mapping for Mobile Robots via Cumulative Curriculum Reinforcement Learning)



<DRL-model>



<map>

Related Research

CCRL

- 이전 단계에서 습득한 지식을 이용하여 새로운 작업에 대한 학습
- 인공신경망 구조는 그대로, 환경의 복잡도만 증가

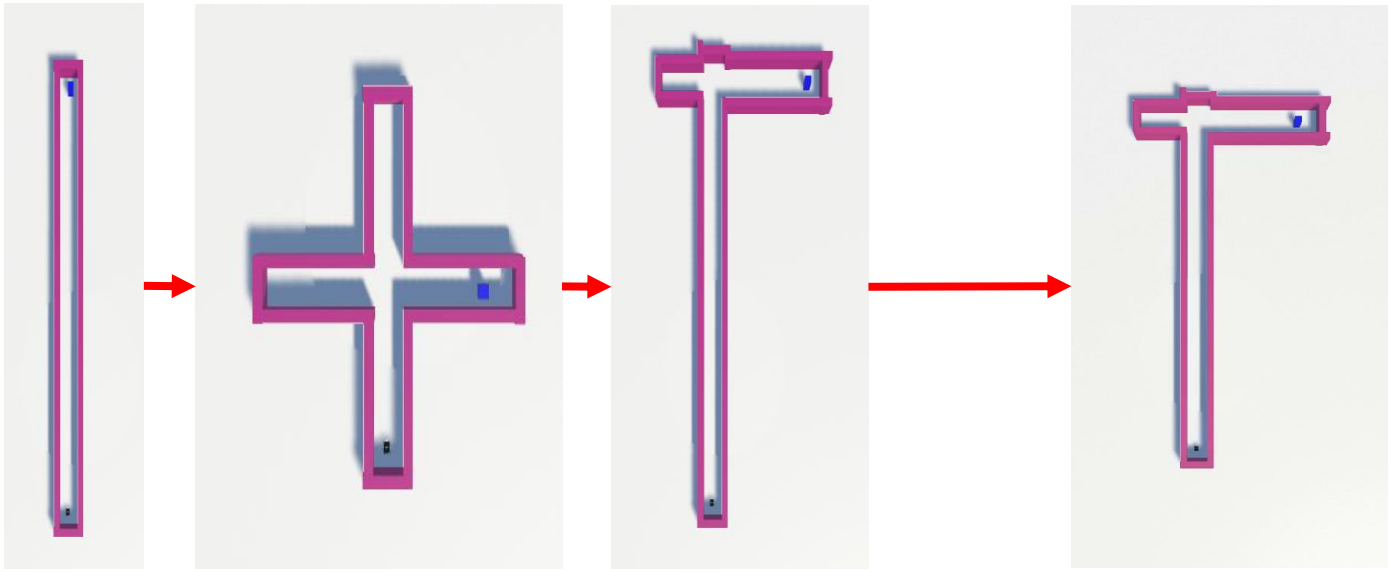
State Space

- LEM(Local Egocentric Map)
  - 로봇의 현재 위치를 기준으로 주변 환경 정보가 담긴 지도
- GEM(Global Exploration Map)
  - 로봇이 탐사한 전역적인 정보를 가진 지도
- Auxiliary Information
  - lidar ranging results
  - agent's orientation

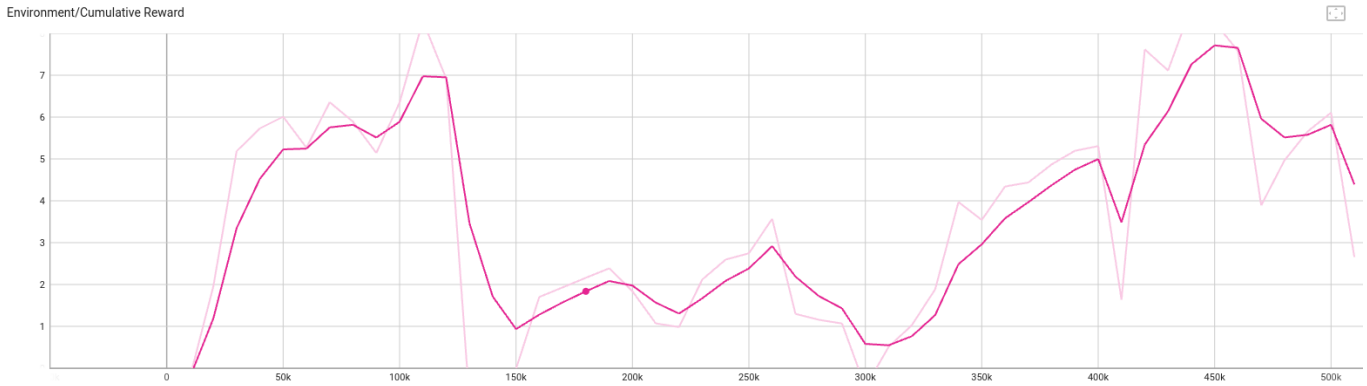
Reward

- Encouraging exploration
  - 새로운 영역을 탐사하여 미지의 영역을 발견(지속적인 보상)
- Successful exploration
  - 전체 지역의 일정 비율 이상을 탐사(탐사 완료)
- Obstacle avoidance
  - 장애물 충돌

강화학습 적용



<CCRL 적용>
(직선 → 교차로 → 신공학관 복도)



<누적 보상>

CCRL 적용

- 사용한 경로
  - 직선
  - 교차로
  - 신공학관 복도
- 학습
  - State: 로봇과 goal의 위치, 로봇의 x, z축 속도, 라이다의 range 데이터 → 905개
  - Action: 선속도, 각속도
  - Reward: goal 도착 = +5, 벽 충돌 = −1
  - Step: 500,000
  - 직선: 약 130,000번
  - 교차로: 약 270,000번
  - 신공학관 복도: 약 100,000번

강화학습 적용

<방향 잃는 모습>

<방향 잃는 곳>

문제점 분석

- **방향 잃는 곳**
  - 소화전
  - 분전함
  - 양쪽 문이 열려 있을 때
- **왜 방향을 잃을까**
  - 소화전, 분전함 → 스틸 재질 → 라이다에서 레이저가 반사될 때 데이터에서 이상한 값이 들어올까?
  - 양쪽 문이 열려 있을 때 → 라이다 데이터로 보면 양쪽이 장애물이 아닌, 갈 수 있는 곳으로 판단되기 때문

강화학습 적용

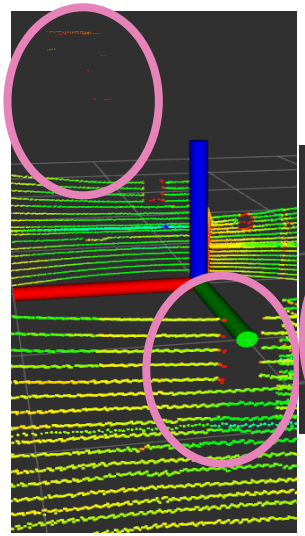
<코너를 확 꺾음>

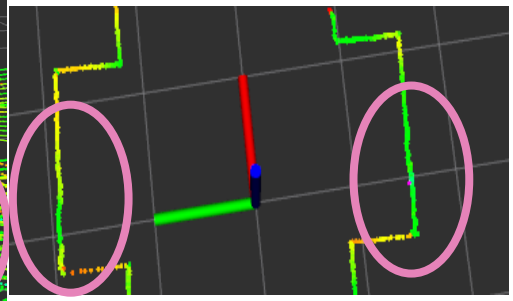
문제점 분석

- **재분석**
  - 소화전, 분전함, 문 열린 곳 → 방향을 잃더라도 극복할 때가 있음.
- **코너 돌기**
  - 유니티에서는 최적 경로를 찾아 코너에 아주 가깝게 인코스를 탐 → 실제: 너무 확 꺾어서 코너에 부딪힘.

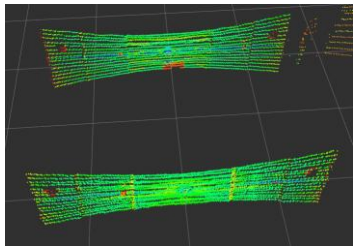
연구 진행사항

라이다 데이터





<연구실 창문>



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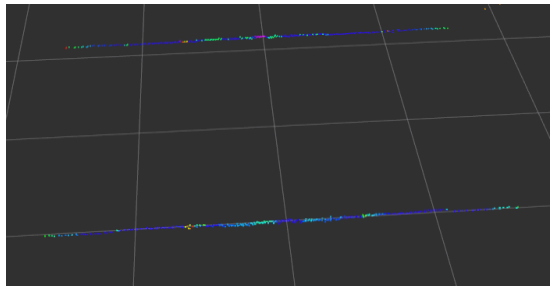
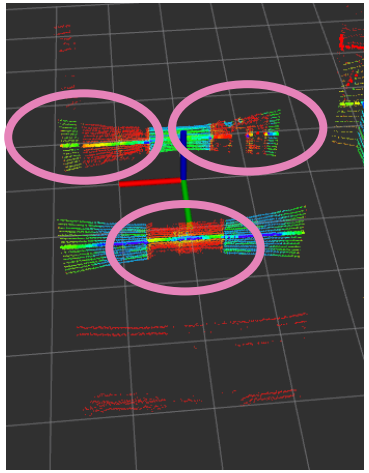
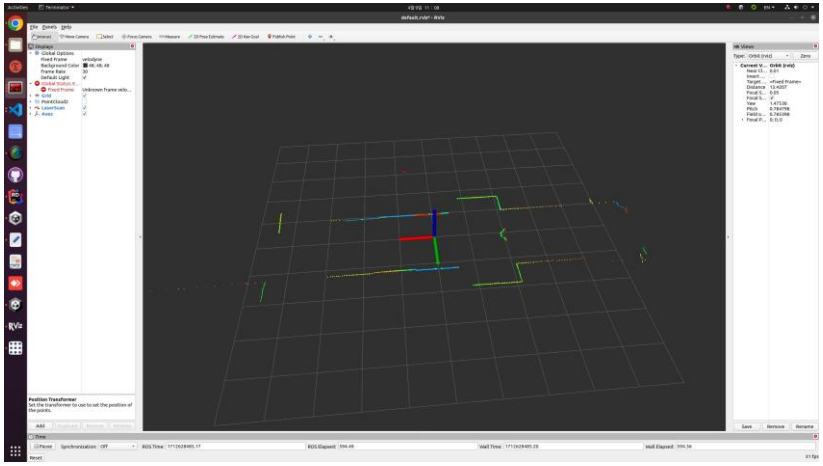






<소화전, 분전함>

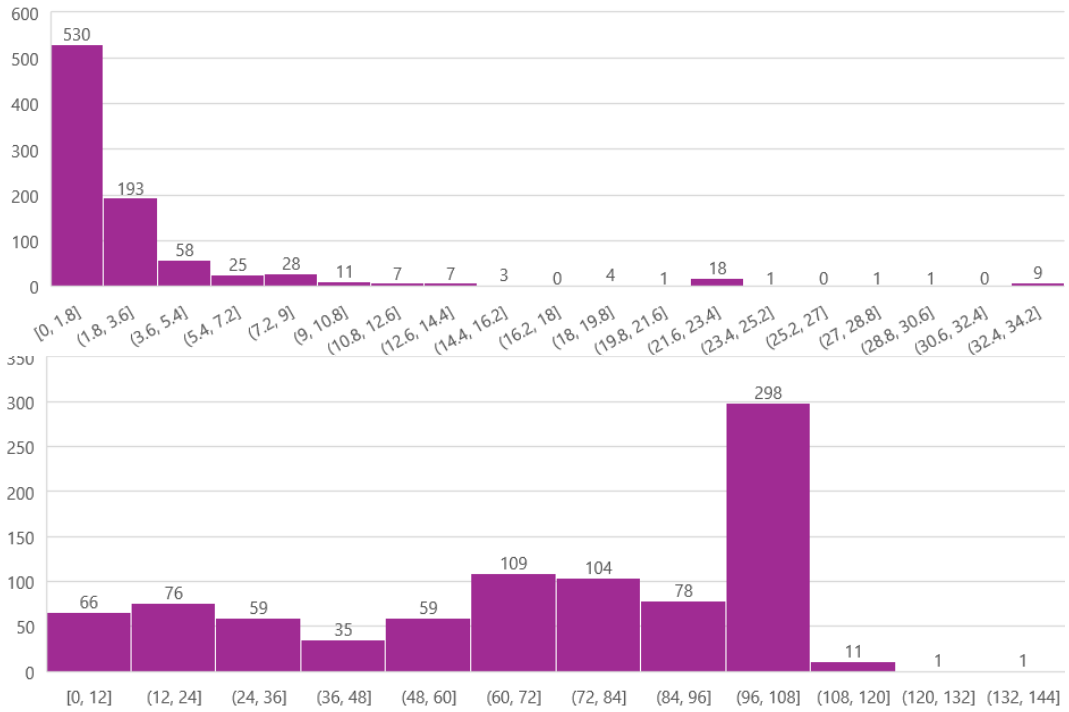
LiDAR 데이터 확인

- 연구실 창문, 소화전, 분전함
- 일반 벽

연구 진행사항

RV.Lab
Robot & Virtual Reality

라이다 데이터



<벽>(ranges)

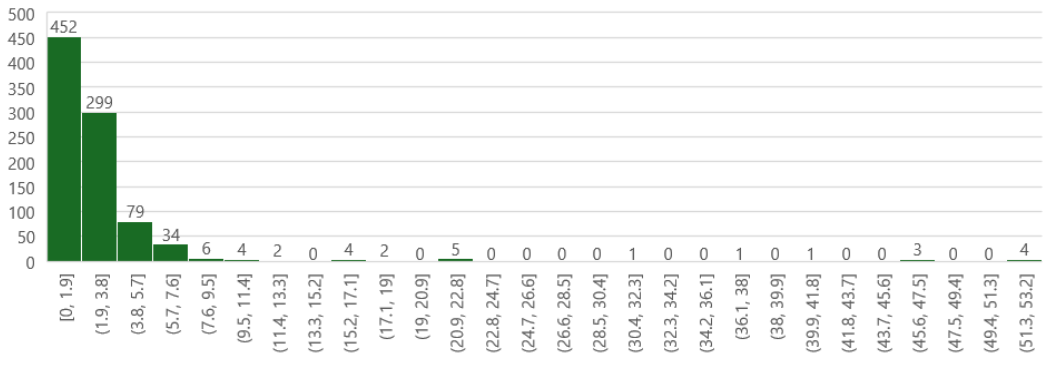
<벽>(intensity)

LiDAR 데이터 확인

- 벽
  - Ranges: 0.9 ~ 34(inf 5개)
  - Ranges 평균: 3.49412492
  - Intensity의 평균: 69.27201784

연구 진행사항

라이다 데이터



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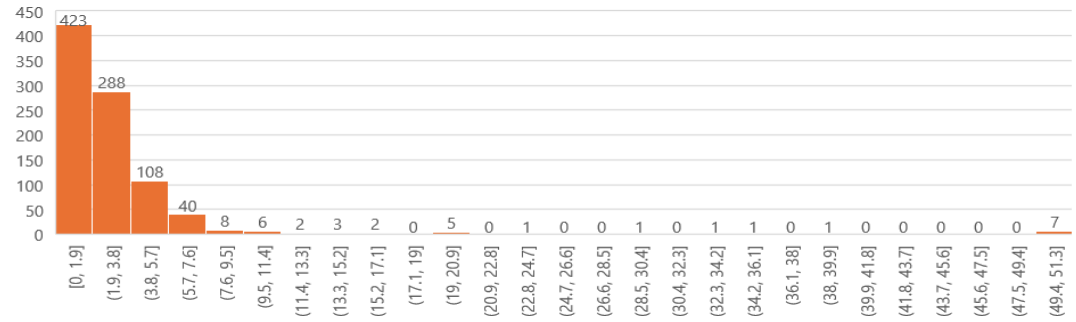

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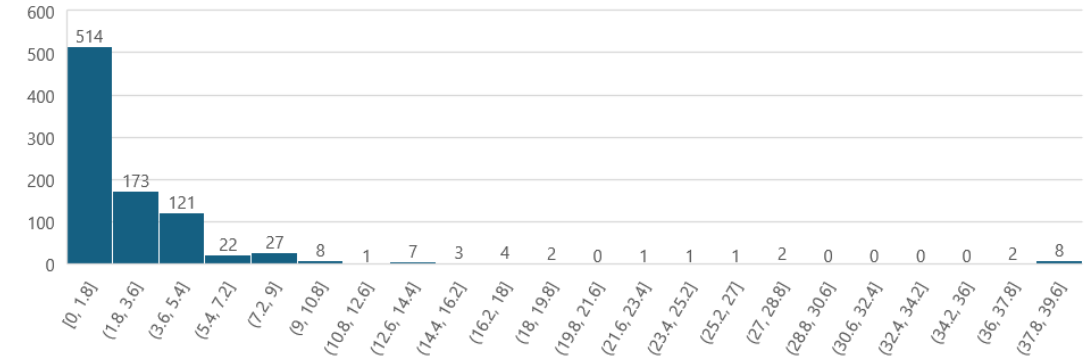


<분전함>(ranges)

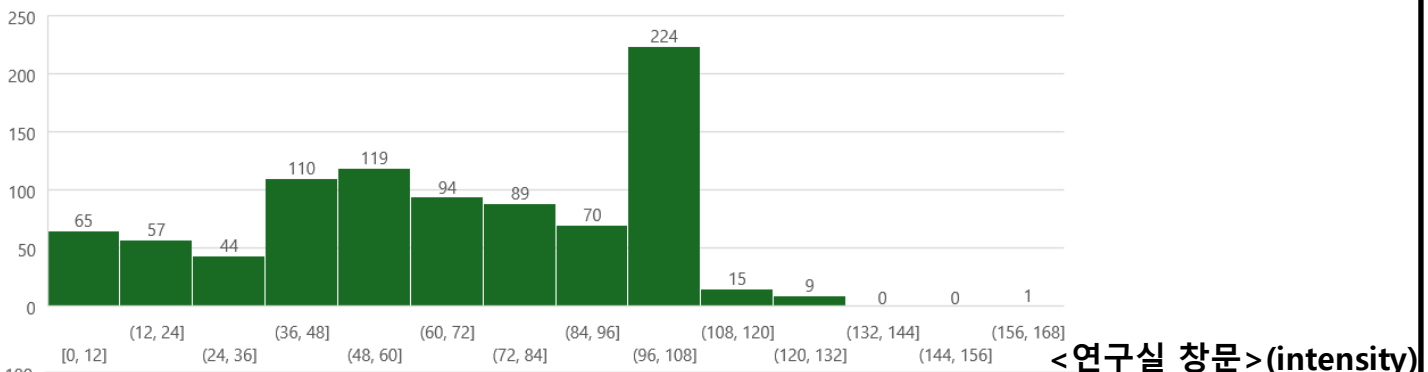
LiDAR 데이터 확인

- 연구실 창문
  - Ranges: 0.9 ~ 51.9(inf 5개)
  - 평균: 2.998960425

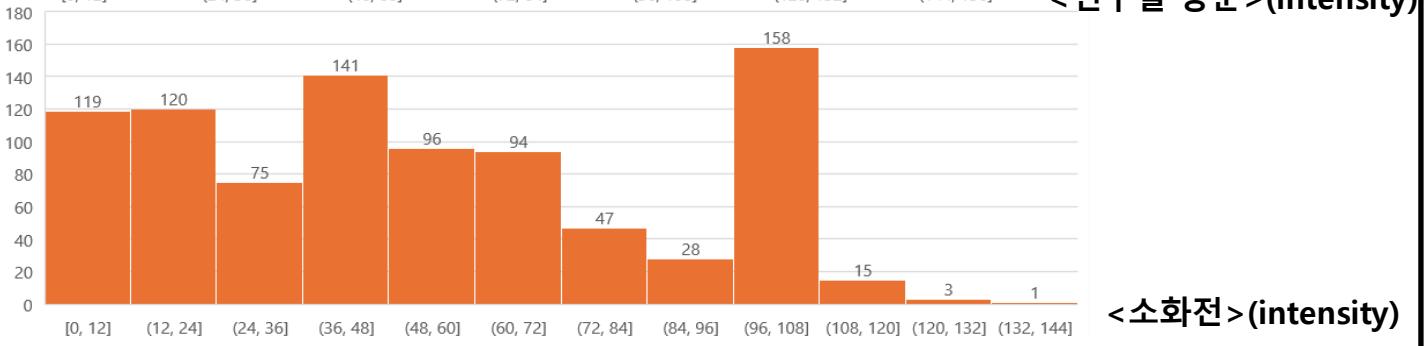
- 소화전, 분전함
  - 소화전
    - ranges - 0.8 ~ 49.8(inf, 3개)
    - 평균: 3.18305447
  - 분전함
    - ranges - 0.7 ~ 38.9(inf, 1개)
    - 평균: 3.090875327

연구 진행사항

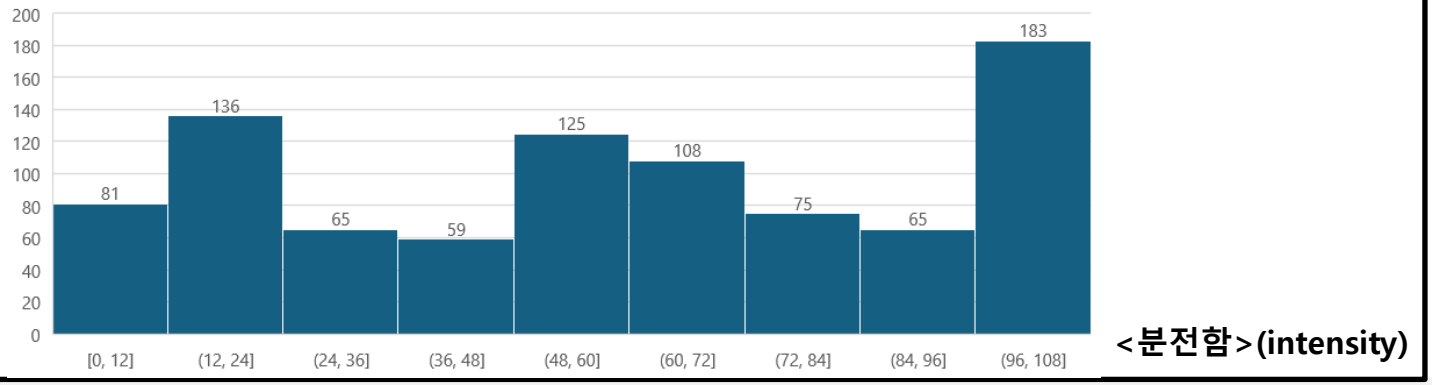
라이다 데이터



<연구실 창문>(intensity)



<소화전>(intensity)



<분전함>(intensity)

LiDAR 데이터 확인

- 연구실 창문
  - intensity의 평균 - 65.42363434
- 소화전, 분전함
  - 소화전: intensity의 평균 - 52.11954
  - 분전함: intensity의 평균 - 57.16054