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# Mapping and Object Detection

## Submission Specifications

**Mission:**

Teams will be given a period of 20 minutes to create maps of the area. A mapping run begins from a designated start position, and ends when a map is saved and cleared on the robot. Teams may reset their mapping run if they choose, and they may perform as many mapping runs as possible within their allotted time.

During preliminary rounds, teams will be expected to submit the data from what they believe to be their best mapping run ***(Subject to discussion)***. In later rounds, multiple maps up to a maximum of 4 will be accepted for scoring.

**Teams will be required to submit the following for each mapping run:**

### 2D Map:

Submitted in the specified GeoTIFF format.
An open-source implementation for ROS is available at http://wiki.ros.org/hector_geotiff.

### 3D Point Cloud Map:

Submitted in the specified [.PLY] format.
Recommended to use PCL to convert and save point cloud files.

### Identified Objects CSV File:

Submitted in the specified CSV format.
The list of official object names will be provided.

### Hand-in:

The files have to be automatically created - no editing by hand is allowed. The files have to be copied from the robot/ operating station within 5 minutes after the run.

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## Scoring Specifications

### 2D Map:

- Mandatory to submit, but will not be scored.
- Will not be scored directly, but will be used to help visualize other scoring metrics.

### 3D Point Cloud Map:

In comparison to our 3D ground truth cloud, two metrics will be calculated to score your point cloud:

- **Global Error (GE)** - Computed as average cloud-to-cloud distance (in meters).
- **Coverage (CV)** - Computed as the percentage of ground truth points for which the 3D Cloud contains a point within a threshold distance.
- **Bonus multipliers** will be awarded for having sensible RGB color data and/or heat data included in your map. (1.25x and 1.6x respectively, 2x for both) ***(Subject to discussion)***
- Scores will be combined as: **CV * (1 / (1 + GE)) * Bonus** ***(Subject to discussion)***

***Please note:***

- *These metrics require cloud alignment and identical scaling.*
- *Teams will be responsible for proper scaling of their 3D Cloud (see specification).*
- *Judges will be responsible for map alignment using ICP and manual point-pair alignment if necessary.*
- *The alignment used for evaluation will be made available to teams.*

### Identified Objects CSV File:

Teams will be expected to detect several different kinds of objects and localize them within their 3D map. These objects may include AprilTags (Standard41h12 family), Hazmat signs, physical objects (i.e. Backpack, Hard hat, fire extinguisher, victim (baby doll), propane tank (empty)), and a heat signature. Each object is unique in the arena - do not report multiple of the same type (in which case each additional detection will be discarded). Two metrics will be calculated from the list of detections:

- **Localization Error (LE)** - For all detections, this metric will represent the average difference in distance (in meters) between all detection pairs compared to the ground truth.
- **Detection Score (DS)** - The sum of various point denominations will be awarded (based on difficulty) for detections that are within an error threshold. (i.e., AR = 1, Hazmat Signs = 2, Object = 10, Heat = 15). Additionally, points will be subtracted for each detection above this error threshold (i.e. -3 points).
- Scores will be combined as: **DS / (1 + LE)** ***(Subject to discussion)***

***Please note:***

- *Detection coordinates should correspond to the center of mass of the detected object.*
- *These metrics are not impacted by global alignment between the ground truth and 3D Cloud.*
- *There will be an additional Detection Score penalty for reported detections for objects which are not present in the mapping area.*

**Overall mapping score will be the average normalized score contributions from 3D Map (0.5), Detection CSV (0.5). 2D Map must be submitted to receive a mapping score.**

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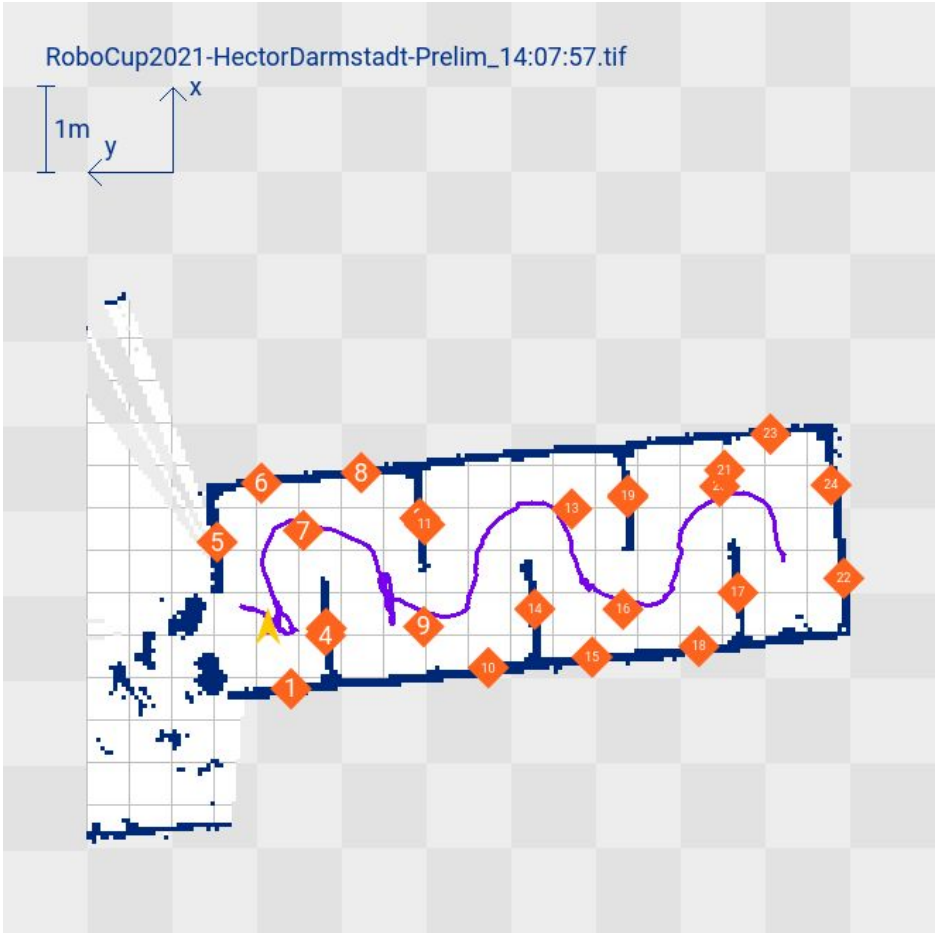
## Format Specifications

### 2D Map Format

2D maps have to be submitted in the specified GeoTIFF format. An open-source implementation for ROS is available at http://wiki.ros.org/hector_geotiff.

**Example map:**



In the following, all elements of the map are described:

- **Fileformat:** GeoTIFF
- **FILENAME:** DARK BLUE (RGB: 0, 44, 207) TEXT
  For example, “RoboCup2025-TeamName-Mission1.tiff” displayed in the upper left corner to identify the map, make it sort properly in a directory, and findable on a computer.
- **MAP SCALE:** DARK BLUE (RGB: 0, 50, 140) TEXT AND EXACTLY 1 METER LONG LINE
  Display this in the upper right corner to indicate the scale of the map.
- **MAP ORIENTATION:** DARK BLUE (RGB: 0, 50, 140) TEXT (“X” AND “Y”) AND ABOUT 50 cm LONG ARROWS
  Display this next to the map scale. It gives the orientation for the victim location in the victim file. Must be a right handed coordinate system: X points upwards, Y to the left.
- **UNEXPLORED AREA GRID:** LIGHT/DARK GREY (RGB: 226, 226, 227/RGB: 237, 237, 238) CHECKERBOARD WITH 100CM SQUARES
  This solid checkerboard pattern should show the unexplored area and provide scale on all sides of the mapped area. It should also print in black and white without ambiguity with other areas potentially turned grey in the process.
- **EXPLORED AREA GRID:** BLACK (RGB: 190,190,191) GRID WITH 50CM GRID AND ABOUT 1 CM THICK LINES (use a one pixel line in the map)
  This grid should only appear in the explored area, behind any walls, victim locations, or other information. The grid should be aligned with the checkerboard pattern of the unexplored area, but twice as fine to allow visual inspection of wall alignments.
- **INITIAL ROBOT POSITION:** YELLOW (RGB: 255, 200, 0) ARROW
  This should mark the initial position of the robot and always be pointed toward the top of the map.
- **WALLS AND OBSTACLES:** DARK BLUE (RGB: 0, 40, 120) FEATURES
  This should indicate the walls and other obstacles in the environment. The color should make the walls stand out from everything else.
- **SEARCHED AREA:** WHITE CONFIDENCE GRADIENT (RGB: 128, 128, 128 to RGB: 255, 255, 255)
  This should be based on the confidence that the area is really free. It should produce a clean white when seen as free by all measurements and nearly untouched when undecided, that is, nearly equally seen as occupied as free, to produce a dither effect.
- **CLEARED AREA:** LIGHT GREEN CONFIDENCE GRADIENT (RGB: 180, 230, 180 to RGB: 130, 230, 130)
  This should show the area cleared of victims with confidence. This should also factor in the actual field of view and range of onboard victim sensors – noting that victim sensors don’t typically see through walls!
- **VICTIM LOCATION:** SOLID RED (RGB: 240, 10, 10) CIRCLE WITH ABOUT 35CM DIAM CONTAINING WHITE (RGB) TEXT “#”
  This should show the locations of victims with a victim identification number such as “1” in the order they were found. Additional information about this victim should be in the victim file noted below. Make sure the victim location is always on top of everything else!
- **HAZARD LOCATION:** SOLID ORANGE (RGB: 255, 100, 30) DIAMOND WITH ABOUT 30CM SIDES CONTAINING WHITE (RGB) TEXT “#”
  This should show the locations of hazards with an identification number such as “1” in the order they were found. Additional information about this hazard should be in the hazard file noted below.
- **ROBOT PATH:** MAGENTA (RGB: 120, 0, 140) LINE ABOUT 2CM THICK
  This should show the robot path.

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# Identified Objects CSV Format

In addition to indicating identified objects in the map, they have to be submitted in a CSV list. In the following, the structure of the file is given:

**Filename**: RoboCup[Year]-[Teamname]-[Mission]-[Start Time]-pois.csv
*([Start Time] should be formatted as HH-MM-SS)*
Format for the file header:

```
"pois"
"1.3"
"[Your team name]"
"[Your country]"
"[Start Date]"
"[Start Time]"
"[Mission #]"

detection,time,type,name,x,y,z,robot,mode
```

Replace the placeholders "[...]" with your data. Please leave the quotes in the file, but not the brackets.

The file body contains one line for each found object in the following format:

```
[detection],[time],[type],[name],[x],[y],[z],[robot],[mode]
```

- **[detection]:** Unique integer counter for each object that is also printed on the geotiff map
- **[time]:** Time stamp when the object was found
- **[type]:** Type of the object: [ ar_code, hazmat_sign, real_object, heat_sig ]
- **[name]:** Unique ID for detection (i.e. ar_code number, hazmat label, object name)
- **[x], [y], [z]:** Coordinates of the object in meters
- **[robot]:** Name of the robot that found the object
- **[mode]:** Mode of the robot when it found the object: **A** for autonomous, **T** for teleoperated

Strings which include spaces should be enclosed with double quotes. Here is an example of a file which might be named "RoboCup2025-ReskoKoblenz-Prelim1-pois.csv":

```
"pois"
"1.3"
"Resko Koblenz"
"Germany"
"2018-06-23"
"14:37:03"
"Prelim1"

detection,time,type,name,x,y,z,robot,mode
1,14:28:01,"ar_code","2",-8.2992,-2.2904,0.49,"Robbie 1",A
2,14:28:02,"ar_code","34",-8.2993,-2.2902,0.4563,"Robbie 2",T
3,14:28:05,"hazmat_sign","poison",-5.7452,-7.0849,0.2130,"Robbie 1",A
4,14:30:14,"real_object","gloves",-6.0845,-0.1251,0.3561,"Robbie 1",A
5,14:32:56,"heat_sig","0",-9.2817,0.04968,0.7561,"Robbie 2",T
```

**IMPORTANT:** There will only be **one** instance of each object included in the mapping area at any time. Teams must only include **one** detection per unique object. If duplicate objects are contained in the submitted CSV, only the first instance of that object will be used for scoring.

A list of object labels will be provided to teams. **Mislabelled objects will not be scored.**

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## 3D Point Cloud Map

Teams will submit a 3D pointcloud representation of the mapped area to be scored with respect to a generated ground truth map. The submitted map should adhere to the following specification:

**Filename**: RoboCup[Year]-[Teamname]-[Mission]-[Start Time]-map.ply
*([Start Time] should be formatted as HH-MM-SS)*

Your point cloud should be formatted as an ASCII file.

The header of your file should adhere to the PLY file format.

At a minimum, your file should include float type fields for x, y, and z.

Teams may include additional fields such as:
- RGB Color Information
- Heat Information
- Point Normal Information
- Confidence Scalar

Maps which contain sensible color and/or heat data will be awarded a bonus point multiplier.

**IMPORTANT:** The scale of your map coordinates are expected to be in meters. (i.e. A distance of 1 unit in the submitted point cloud should correspond to 1 meter in the real world). **Improper scaling will severely penalize your score.**

The origin location (0,0,0) of the 3D Cloud should be set to the starting position for the robot which will be marked on the floor in the mapping area. More specifically, the origin should be set to be the center of the front of the robot, at floor height. Rotationally, the starting position will point the robot in the +Y direction, and the vertical axis will be Z.

More information on PLY format can be found here.
The format for the PLY header that should be included is shown below.
**NOTE:** You are not required to include all fields if you are not collecting those kinds of data

```
ply
format ascii 1.0
comment {Team Name}
comment {Start time}
comment {Mission #}
element vertex {Number of Vertices}
property float x
property float y
property float z
property uchar red
property uchar green
property uchar blue
property float nx
property float ny
property float nz
property float temp
property float confidence
end_header
{DATA}
```