METRICS 2nd RAMI CASCADE CAMPAIGN 2023

Marine Domain

Competition description

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This document is subject to change, refinement and development.

Please visit the METRICS official website https://metricsproject.eu for the current version.

Content

List of acronyms

AUV Autonomous Underwater Vehicle

CSV Comma Separated Values

EU European Union

GNC Guidance Navigation and Control

H Height

ID Inner Diameter

LG Length

METRICS Metrological Evaluation and Testing of Robots in International CompetitionS

OD Outer Diameter

OPI Objects of Potential Interest

RAMI Robotics for Asset Maintenance and Inspection

RIB Rigid Inflatable Boat

ROS Robotic Operative System

SAP Scenario Application Paper

S Sea

TBD To Be Defined

W Width

WP Waypoint

1. Introduction

The RAMI (Robotics for Asset Maintenance and Inspection) competition is organized in the framework of the METRICS (Metrological Evaluation and Testing of Robots in International CompetitionS) (https://metricsproject.eu/) EU project and aims at addressing I&M tasks achieved by aerial and underwater robots in risky and/or hostile environments where human intervention is challenging or impossible, where direct link with an operator could not be guaranteed and where autonomous decisions are necessary to reduce operational time of the inspection tasks and ensure repeatability while maintaining an appropriate safety level for the mission. The evaluation process of RAMI competitions mainly involves tasks related to autonomous navigation, data acquisition, detection, classification and autonomous decision-making for inspection purposes. Since aerial and underwater domains are very different, both domains will be evaluated separately in two different tracks.

The RAMI marine competition tasks are inspired by the following **user story**.

A gas&oil offshore site has to be investigated after that a malfunction has been reported by the plant safety systems.

From what is known, a pipeline has started leaking and an explosion may occur soon.

A robotics team composed of underwater robots (AUVs) is ready to intervene.

It is time for the emergency team to act. The priorities are to reach the area of the accident, and to assess and quantify the entity of the leak. Then the robots have to reach the pipe assembly area for quantifying the damage to the plant and for identifying which pipe has been damaged and is responsible for the leak.

Finally, the robots must intervene on the plant itself by closing a valve to stop the leak to prevent the explosion and further damages to the environment.

This document describes the rules for the second RAMI (Robotics for Asset Maintenance and Inspection) Cascade Evaluation Campaign dedicated to marine Autonomous Underwater Robots (AUVs) and focusing on OPI classification, identification and localization in the image plane. The Cascade Campaign is composed of the followed steps:

- Images of different underwater objects will be provided to teams as **training set**.
- Teams will have to provide to the RAMI Marine Robots Organizing Committee a software that is able to classify, identify and localize the OPIs present in the images.
- The team software will be evaluated by the Organizing Committee on a **test set** of images. From the evaluation, a scoring will be produced for each team and teams will be ranked.

Images are **divided into six classes**, each one containing a different type of OPI.

As the Cascade Campaign is meant to be carried out online, a Docker image will be provided to teams. This image will contain a training dataset containing images of all the five OPI classes, as well as useful files explaining the expected results.

Information about the competition can be found at https://metricsproject.eu/inspection-maintenance/rami-cascade-campaign-marine/.

2. Organizing Committee

The Organizing Committee (OC) is responsible for the rules, the preparation and the execution of the competition. Each member of the committee is involved in maintaining and improving the current rule set and also in the adherence of these rules.

The Organizing Committee has the authority to modify the rules at any time. The Organizing Committee will announce any modifications of the rules with an e-mail to all entrants and a corresponding statement on the page https://metricsproject.eu/inspection-maintenance/rami-cascade-campaign-marine/. The Organizing Committee may provide interpretation of the rules at any time and in any manner that is required.

Decisions of the Organizing Committee are final.

The Organizing Committee currently consists of the following members:

Chair

- Dr Gabriele Ferri (Centre for Maritime Research and Experimentation, CMRE, Italy)

Co-chairs

- Alessandro Faggiani (Centre for Maritime Research and Experimentation, CMRE, Italy)
- Dr Tommaso Fabbri (Centre for Maritime Research and Experimentation, CMRE, Italy)

3. Team registration

To enter the competition, applicant teams must send an e-mail to the Organizing Committee at *im@metricsproject.eu* expressing their intention to participate containing the following information:

Team Details

- Team Name.
- Institution/Company.
- Team Logo (optional).
- Team website/social media (if any).
- Name of team leader.
- Picture of team leader.
- When the team was established (year).
- Team Description (including names and nationalities of the team members).
- Brief CVs of the team members (please attach a pdf).
- Team Sponsors (if any):

Contact Details (will not be published):

- Team E-Mail.
- Address.
- Telephone.

The OC will reply the team leader stating that the team has become an official RAMI entry. Each official RAMI entry is enabled to upload their Docker image for the evaluation by RAMI OC (see next section).

4. Input data

Across this section, the data available for every participant will be detailed.

4.1 Docker image and practical guide

A Docker image will be released containing an image of Ubuntu 18.04 and the image training set, divided by class.

Official RAMI entries will be communicated login and password information to access the Docker image.

As participants may not necessarily be familiar with Docker, a detailed guide to get started with the required Docker concepts and commands is accessible from the official Metrics website (https://metricsproject.eu/inspection-maintenance/rami-cascade-campaign-marine/).

The Docker image is based on Ubuntu 18.04. Over the 'rami_marine_dataset' personal folder, you can find the following structure for the six classes of OPIs (the folder 2023 reports the new images added to the 2022 RAMI dataset for the RAMI 23).

```
rami_marine_dataset

    • class_1
        o red
            ▪ img1.png
              …
            o 2023
              ▪ img2.png
              …
        o white
            ▪ img3.png
              …
            o 2023
              ▪ img4.png
              …

        o yellow
            ▪ img5.png
              …
            o 2023
              ▪ Img6.png
                …
    • class_2
        o number_1
            ▪ img7.png
              …
            o 2023
              ▪ Img8.png
                …
        o number_2
            ▪ img9.png
              …
```

        - 2023
            - img10.png
            - …
    - number_3
        - img11.png
        - …
        - 2023
            - img12.png
            - …
    - number_4
        - img13.png
        - …
        - 2023
            - Img14.png
            - …

- class_3
    - number_3
        - img15.png
    - number_4
        - img16.png
    - number_5
        - img17.png
    - number_6
        - img18.png
        - …
    - number_7_2023
        - img19.png
        - …
    - number_8_2023
        - img20.png
        - …

- class_4
        - img21.png
        - …
        - 2023
            - img22.png

- class_5
    - manipulation_multiple
        - img23.png
        - …

- class_6
        - img24.png
        - …
        - 2023
            - img25.png

- output
    - example_output.txt

OPI images are divided by the special instance of that class, e.g. in the `red` folder inside `class_1` you can find images related to red buoys.

The `example_output.txt` contains an example of the output the team software has to produce once launched and will be described in section 6.

4.2 Training dataset

OPI images are .png files with dimension 1280x720 pixels. Images are divided into five classes.

1) **Class 1: colored buoys.**

Contains images of underwater buoys of three different colors: red, white and yellow.

Figure 1. Image of a red buoy.

2) **Class 2: black numbers on the yellow pipes.**

Contains images of three different numbers, “1”, “2”, “3”, “4”, painted in black over the yellow pipes.

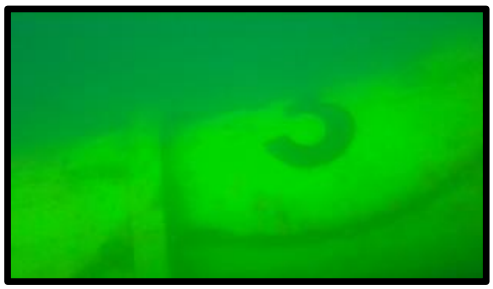

Figure 2. A “3” black number over the yellow pipe.

3) **Class 3: black numbers over red background.**

This class contains black numbers painted over a red background and located on a manipulation console. The possible numbers in the test set are “4”, “5”,

"6","7","8". **We remark that for numbers "4" and "8" no underwater images are provided, instead drawings are presented, as reported in the following figures.**

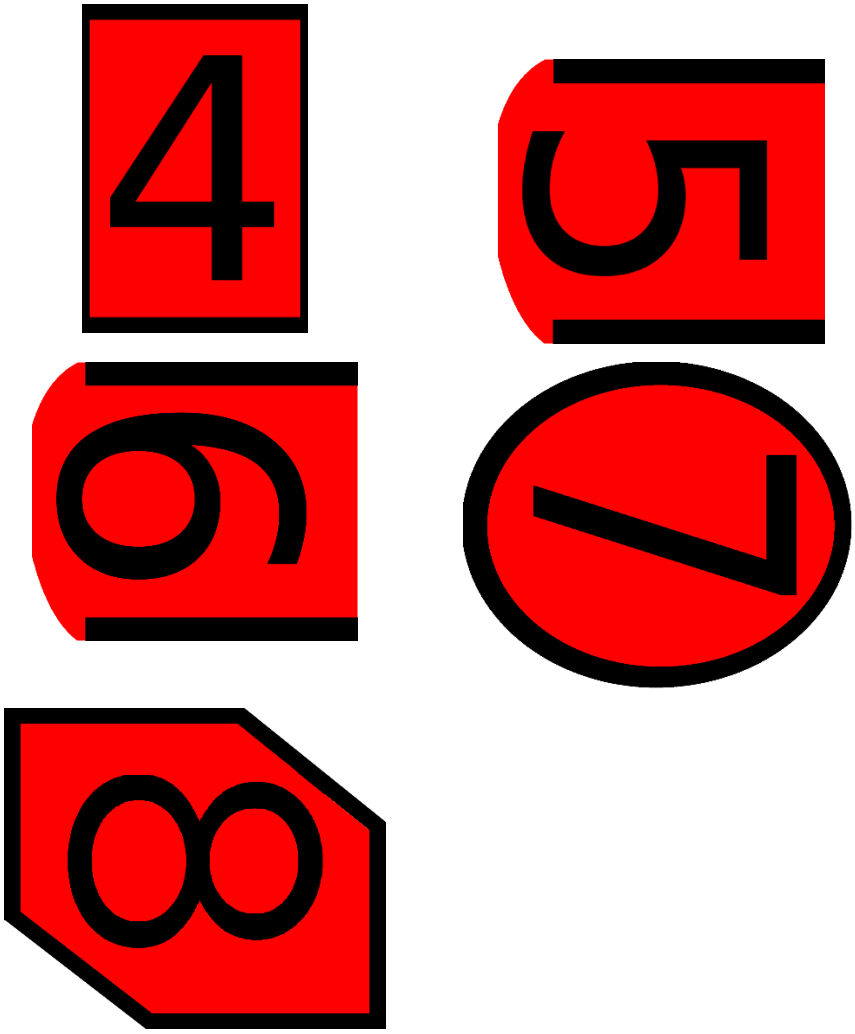

Figure 3. Drawing of the numbers that may be used in the test set.

Figure 4. Example image of the number "6" collected underwater.

4) Class 4: red maker over a yellow pipe.

The class contains underwater images of a red marker positioned over one yellow pipe.

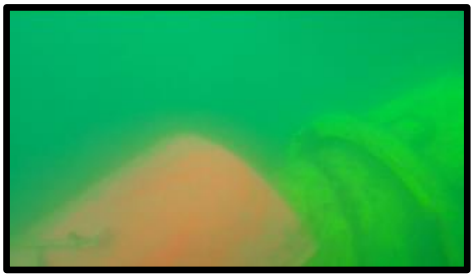

Figure 5. Red marker over a yellow pipe.

5) **Class 5: Manipulation objects.**

This class contains images of the manipulation console objects, specifically, the ring pole and the cross-shaped valve.

ATTENTION! In this class multiple OPIs may be present. Inside the image, the OPIs to be detected, classified, identified and localized are **only**:

a. Ring pole.

b. Cross-shaped valve.

Figure 6. An image of the yellow pipeline structure with no OPI.

6) **Class 6: no OPIs.**

Class 5 contains images not containing OPIs of the other classes. Images can contain water, pipes and the manipulation console without the black number.

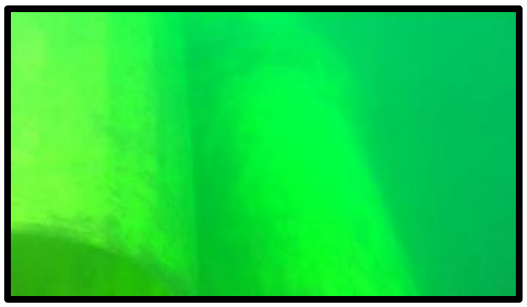

Figure 7. An image of the yellow pipeline structure with no OPI.

5. Required data from teams

In this section we describe how the teams must provide their data in order to be evaluated. Those teams that do not strictly meet the requirements described in 5.1 will not be evaluated.

5.1 Evaluation

First of all, every team must submit their Docker image as a Docker hub repository. To upload your Docker image, please refer to the Docker guidelines document, and make sure that you push the image with the corresponding tag. Then, send an email to *im@metricsproject.eu* containing the dockerhub user (<usr>) and repository (<repo>) names with the following subject:
"[MarineDomain] Results \TEAM NAME".
Docker Image **upload deadlines** will be reported on the Metrics official website.
The submitted Docker image, in turn, has to fulfil the following requirements:

- **Contain the end to end solution**. This means that it needs to contain every single file needed to run the solution from the dataset format (images folder) to resulting output txt file (mentioned below).

  This end to end solution must be placed over a *team_name_ws* folder. If my team were CMRE, our workspace will be named *cmre_ws* for example.
- **Contain every dependency installed and documented**. Every single dependency that was not installed in the provided Docker image must be installed and documented (download link/apt package name, and installation guide if it is non trivial) in a *dependencies.txt* file inside the *team_name_ws* folder.
- **Running script**. One bash script, named *run.sh*, must be placed in a *main* folder inside the *team_name_ws* folder, that is *team_name_ws/main/run.sh*. The script must take as arguments:
  - the evaluation image (a png image of the same dimensions of the training dataset) path and the resulting txt filename.

  Then, running the script has to produce the results .txt file with the passed filename in the *main/results* folder. The .txt file will be used to evaluate the team's performance according to section 6. The script will be used to process a **test set composed of 20 images**.

6. Results format and performance evaluation

Across this section, the evaluation metrics used for the evaluation of the software provided by teams will be described, together with the format of the produced output .txt files to be evaluated.

6.1 Output .txt file format

The produced file has to be a CSV file containing the following information for the processed image:

1) **timestamp**: epoch time at which the file has been produced;
2) **class:** the class to which the image belongs to (1-6);
3) **instance: the instance of the OPI. The possible instances for the different classes are:**
    a. **Class 1:** red, white, yellow;
    b. **Class 2:** 1,2,3,4;
    c. **Class 3:** 4,5,6,7,8;
    d. **Class 4:** Not Applicable;
    e. **Class 5:** ring pole, x-shaped valve (one of the two or both);
    f. **Class 6:** Not Applicable.
4) **centroid x coordinates:** x coordinate (can be only >=0) in pixel in the image plane. The point (0,0) is at the top-left corner of the imate.
5) **centroid y coordinates:** y coordinates (can be only >=0) in pixel in the image plane. The point (0,0) is at the top-left corner of the image.

If a certain field is not applicable or cannot be computed an empty field has to be inserted in the CSV.

In the following an example with all the fields present:

```
#timestamp   class   instance centroid_x  centroid_y [This line should not appear in your result]
1639511685,1,red,150,200.
```

In the following an example with some fields absent:

```
#timestamp   class   instance centroid_x  centroid_y [This line should not appear in your result]
1639511685,5,,,.
```

6.2 Scoring and metrics

For each image of the test set a score is produced by summing each accomplished achievement multiplied by its multiplier (if present).

For each image the achievements A are:

- Recognize that the image belongs to class 6 (no OPIs) (multiplier=1);
- Recognize that the image belongs to class 1-5 (some OPIs are present) (multiplier=1);
- Recognize the exact class the image belongs to (for classes 1-4) (multiplier=2);
- Recognize the exact class the image belongs to class 5 (class=manipulation objects) (multiplier=3);
- Recognize the instance of the image (for classes 1-2) (multiplier=3);
- Recognize the instance of the image (for class 3 and instance = “5”, “6”, “7”) (multiplier=3);
- Recognize the instance of the image (for class 3 and instance=”4” and “8”) (multiplier=5);
- Recognize the instance(s) of the OPIs inside an image of class 5 (multiplier 2 per each OPI possibly in the image). These achievements will be awarded only if the corresponding centroid of each identified OPI is correctly computed (at least one achievement is gotten for the centroid - see below for details on centroid computation).
  For example:
  `1639511685,5,ring pole,150,200, x-shaped valve, , ,.`
  In this example the achievements for the identification of the ring pole are awarded (x 2), since the centroid 150,200 is correctly reported. On the other hand, the identification achievements for the x-shaped valve are not awarded since the corresponding centroid is not computed.
- In case an OPI is present in the image (class 1-5), the centroid(s) must be localised.
- A point belonging to the OPI’s image is indicated as the centroid (multiplier=1);
- The distance error between the real centroid and that computed by the team is lower than a value R (computed as the half of the OPI’s major dimension) (multiplier=2);
  Centroids of the test dataset images are computed via momentum calculation. An example is reported in Figure 8. Distance is considered in pixels in the image plane.
- For class 5, the computation of centroid is necessary to get the achievements for the instance determination..

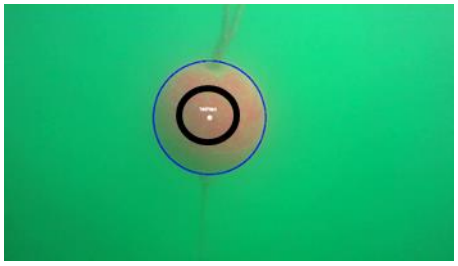

Figure 8. A red buoy with the computed centroid. In black is shown the inner radius R (defined as half of the buoy radius) that defines the maximum error for estimating the centroid position.

Some examples. If the OPI in one image is recognized as belonging to class 1 (a buoy) and of color red (instance) the scoring is: 1 (image belonging to class 1-4) + 2 (image class correctly detected) + 3 (instance correct – red colour) = 6 points.

The team score is considered as the sum of the scores accomplished on each image of the test set.

6.3 Awards

The team with the highest score will be awarded with a prize and a diploma ("RAMI Marine Robots. 2023 Cascade Evaluation Campaign Best-in-class").
If less than three teams participate, the corresponding task benchmark award will only be given to that team if the Organizational Committees considers the team performance of exceptional level.

7. Contact information

Official information concerning rules, interpretations, and information about the competition can be found on METRICS website, or you can contact us at *im@metricsproject.eu*.

Once one team becomes an official RAMI entry, the team leader will serve as the primary point of contact with the OC.