siar sewer inspection autonomous robot

D28.15 - Multimedia Report

SIAR Consortium

IDMind (IDM), PT
Universidad de Sevilla (USE), ES
Universidad Pablo de Olavide (UPO), ES

ECHORD

Table Of Contents

1. Introduction

This report presents videos and photos that summarize the experiments and achievements of SIAR team in Phase III. The purpose of this multimedia material is to illustrate the advances presented by the team in other deliverables.

The SIAR team has recorded a very significant amount of photos and videos in this last project period. This report presents just a small subset of these information. All the material presented in this report is located in the following public web-repository:

https://drive.google.com/open?id=0B-bCskQGnkviakszdFdrTEJNOGM

Additionally, this report includes a section with publicly available datasets. These datasets include odometry, IMU, images from the onboard cameras and robot state information. Some of the datasets were presented in the 2017 IEEE/RSJ IROS Conference at Vancouver (Canada). The datasets can be downloaded by using the following link:

http://robotics.upo.es/datasets/siar/

2. Summary of Experiments

This Section is a small report on the different experiments performed during Phase III of the Urban Challenge for Sewer Inspection. The main objectives set for Phase III were the improvement of performance and usability of the SIAR robot.

2.1. Preparation for the Serviceability Demo: Creu de Pedralbes scenario

We performed three visits (2 with the robotic platform) to a scenario in the Pedralbes area of Barcelona. The main objectives of the preparation were to check the mobility of the platform in a new scenario, to test communications and also to gather information and increase the diversity of the dataset generated in the project.

2.1.1 Visit of April 12, 2018

On April 12, 2018, David Alejo from the University Pablo de Olavide visited a new scenario located at Pedralbes Barcelona for doing the first set of experiments in Phase III. The main objectives of this experiment were to gather information about the new scenario on Pedralbes.

Figure 2.1 represents the location defined for experiments to be performed in May and June, 2018. In the figure, the red numbers signalise the manholes that were opened. The sequence of the numbers indicate the order of passage (under the manholes) defined for the course.

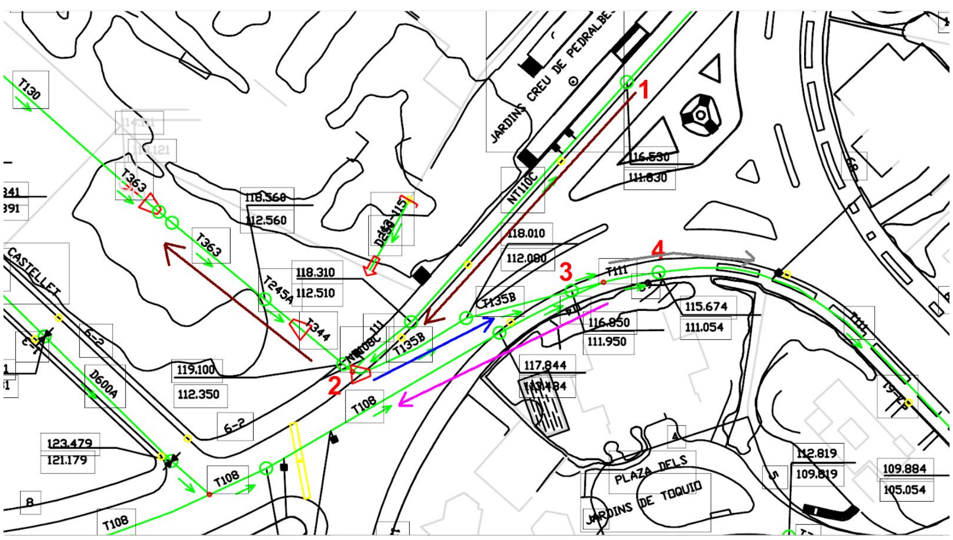
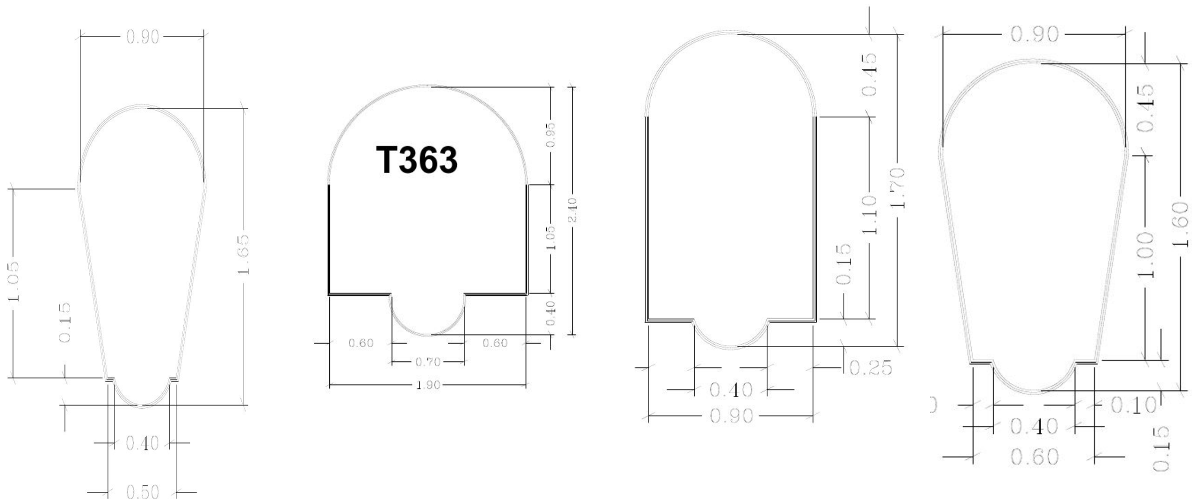


Figure 2.1: Location of the preparation experiments for the serviceability demo, 2018.

First segment of the course. NT110C

Figure 2.2 left represents the approximate section of the gallery in the first segment of the course. In practice, the section was a little bit wider (56 cm) than the predicted values given in the figure. The main problem in this section is that the clearance between the robot and each of the side walls is only 5 cm.

Therefore we have to make sure that the robot can pass in the section and evaluate the risk of getting stuck in the gutter.



NT110C T363 T135B T108

Figure 2.2. From left to right: sections of the tracks 1-4.

Second segment of the course. T344, T245A and T363

Figure 2.2 middle-left represents the section of the first part of second segment. This section was not constant: its height was gradually changing from the start to the end.

The T-shaped fork between segments 2 and 1 is represented in Figure 2.3 (left). It was easily handled by the robot.

Figure 2.3. (left) Fork between segments 1 and 2. (right) Start of the third segment.

Third segment of the course. T135B

Figure 2.2 middle-right represents the section of the third segment of the course. This section is more standard than the previous ones: it is approximately 90 cm wide with a gutter 40 cm wide. It connects the wider gallery with a very long line that we can more easily explore and make a very long mission of more than 600 m or so.

This section presents some accumulation of water in the middle with sediments as shown in Figure 2.4 (left). Just before the end of the segment, when it reaches segments 4 and 5 the sediments disappear as shown in Figure 2.4 (right). This figure was captured just below manhole 3. We measured the height of the sediments. They were 15 cm high approximately.

Figure 2.4: (Left) Sediments in the middle of segment 3. (Right) The sediments end just before reaching segments 4 and 5.

This segment meets with segment 4 with the opposite direction of the water flow (upwards) and segment 5 with the same direction of the water flow (downwards). Figure 2.5 (left) represents the fork while 2.5 (right) represents the place where segments 3 and 4 meet.

Fourth segment of the course. T108

This section did not present any difficulties besides some small curves along the track.

Fifth segment of the course. T111

The size of the section is represented in Figure 2.2 right. This section is a little bit narrower than the previous one and it has a singularity below the 4th manhole: the first step of the stairs is on the floor and it reduces the available space.

Figure 2.5: (Left) Fork between segments 3, 4 and 5. (Right) section where segments 3 and 4 meet.

2.1.2. May 17, 2018. Experiments in Creu de Pedralbes area

In these experiments we performed autonomous navigation from the surface in the Creu de Pedralbes Area. We moved the robot autonomously in almost all the test area. The robot behaved well in all curves and all the straight sections of many different types (including pipes). The manual mode was only used in the cross-sections. The robot was commanded by the operator that was following the robot in the sewer.

2.1.3. June 12, 2018. Last visit to the Creu de Pedralbes area

In the last visit, we managed to visit the track twice with the robot. Moreover, in the last visit, the operation was carried out in semi-autonomous mode from the surface without the need of any assistance from operators inside the sewer, with the exception of the deploy and retrieval procedures.

2.2. Serviceability demo: Virrei Amat area.

In June 21, 2018, BCASA informed us about two possible locations for the Serviceability Demo: Sol de Baix and Virrei Amat areas. In June 27, the Virrei Amat area was confirmed as the scenario for the Serviceability Demo. Figure 2.6 represents the inspection plan for the Virrei Amat area.

This area was visited in two rounds of experiments: the preparation experiments were carried out on the 27th and 28th of June. The actual demo was performed on the 4th of July, 2018. Below you can find details of these experiments.

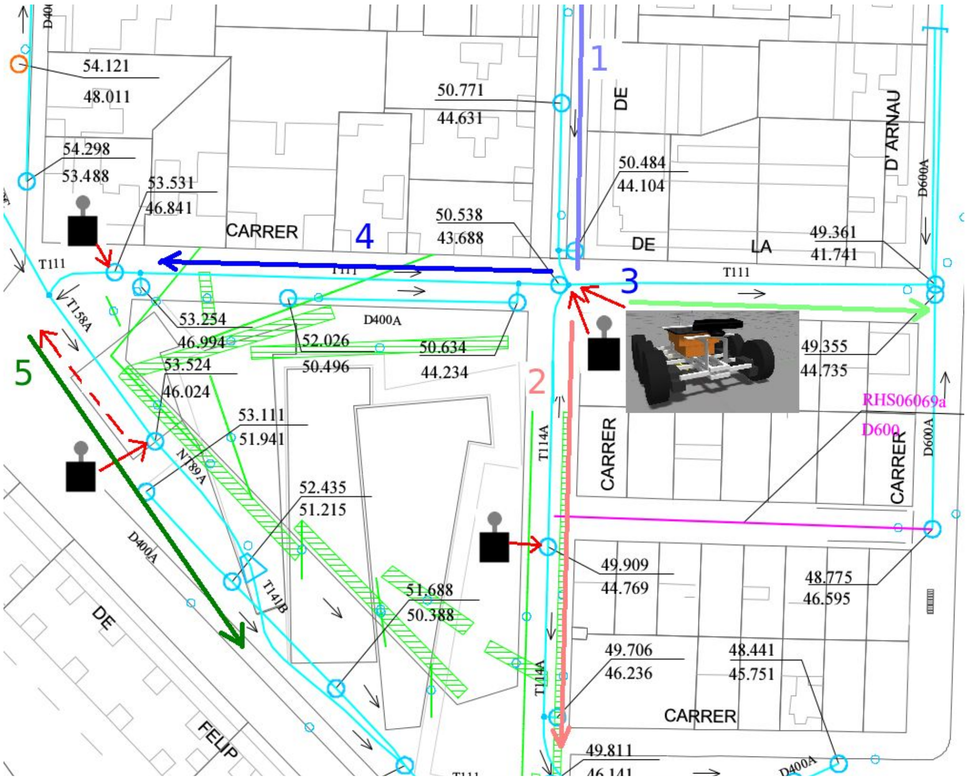


Figure 2.6: Inspection plan for Virrei Amat Area.

2.2.1. June 27, 2018. First visit to Virrei Amat area

This was a short experiment that was carried out in the first day in order to explore the area. The robot was deployed from the manhole marked in Figure 2.6 and then it was directed in the direction of the line labeled with a “4”. The mission ended unexpectedly when the robot tried to traverse the fork that connects the lines labeled as “4” and “5”. During the maneuver, one of the wheels of the platform got damaged and it had to be recovered from the closest manhole.

2.2.2. June 28, 2018. Preparation experiment Virrei Amat area

In this case the experiment was performed without any mechanical issues. However, the platform had to be recovered three times by operators inside the sewer due to the presence of unavoidable obstacles in the track, in particular in segment “2” of the track. The platform traveled by segment “2” (making the turn to the right in the fork up to the black square), “3” and “1” in this order.

2.2.3. July 4, 2018. Serviceability Demo

This experiment was performed during the Serviceability Demo of the Phase III of the Sewer Inspection Challenge. In this test, the whole track marked in Figure 2.6 was explored in ascending numbers of the tracks. The demonstration was a success, as the whole area to be explored was visited in less than two hours.

Figure 2.7: The SIAR V3.0 platform navigating in the Virrei Amat area.

2.3. Structural defects demo: Av Pearson area.

These were the first experiments that were carried out with the final version (V4) of the SIAR platform. The experiments were the shortest of Phase III (see Figure 2.8) as the goal was to inspect an area with noticeable structural defects: in a dead-end segment, part of the ceiling was collapsed.

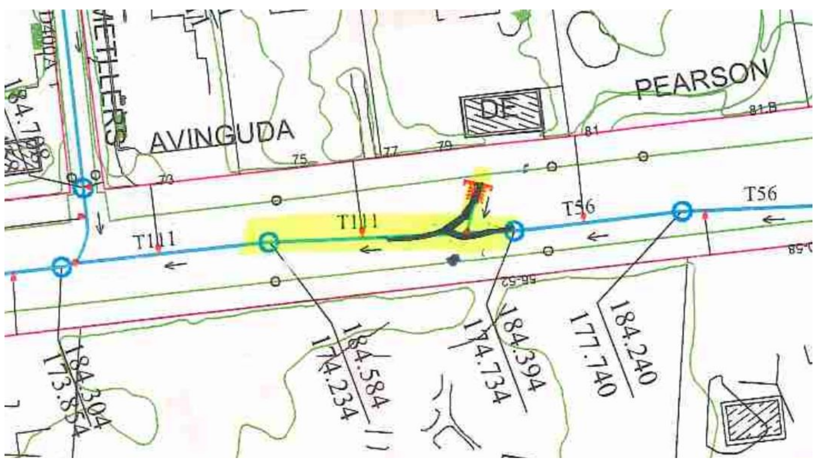


Figure 2.8: Inspection plan for Avinguda de Pearson area. The area with structural defects is marked in a red T.

2.3.1. October 17 and 18, 2018. First visit to the Av. Pearson area

In October 17-18, 2018, two visits to Av. Pearson area were carried out. The platform was able to visit the area with structural defects and return while being teleoperated from the surface. Valuable data was collected during the visit that allowed to perform partial 3D reconstruction of the area with structural defects. The data was recorded on the 18th of October, at 09:27:24, local time.

2.3.2. November 6, 2018. Preparation for structural defect demo.

A short experiment was carried out to further test the new platform in the structural defect scenario. The test started at 13:14 (local time), and it was carried out successfully in less than one hour. The new SIAR 4.0 platform is represented in Figure 2.9 during the course of the preparation experiments.

Figure 2.9: New SIAR 4.0 during navigation in the Av. Pearson area.

2.3.3. November, 7, 2018. Structural defect demo.

The new version of the SIAR platform was presented to different people of the organizing committee of the Challenge for Sewer inspection, including Lina Martinez (BCASA), Ana Puig Pey, Alberto Sanfeliu and Antoni Grau. The experiment was carried out twice to be able to present the results to all the evaluators. They were pleased with the new version of the platform and in particular they found very convenient the inclusion of a new arm with a camera on the end effector. This camera was used for navigation and inspection purposes during the demo. Figure 2.10 shows the platform while navigating in the area with structural defects.

Figure 2.10: New SIAR 4.0 during the Structural Defect Demo.

2.4. Final demo: Passeig Garcia Faria area.

The location where the final demo was carried out was a linear gallery at the Passeig Garcia Faria, as seen in Figure 2.11. The navigation presented less difficulties in this location as the section was constant and no forks were present in the track. This allowed us to perform the complete inspection procedure in autonomous mode and to travel about an half kilometer in less than one hour.

Figure 2.11: Inspection plan for *Passeig de Garcia Fària* area.The black boxes indicate the position of the repeaters and the robot points to the deployment manhole.

2.4.1. November 17 and 18, 2018. First visit to Passeig Garcia-Faria area

In the first two days we focused on adjusting the systems for the arm and for the autonomous navigation. To this end, we performed some small tracks near the deployment manhole and performed some corrections in the autonomous mode when needed.

Moreover, at the end of these days we performed longer tests to further test the autonomous mode and to test the range of the main communication device. This was needed to plan the disposition of the repeaters in the subsequent days.

2.4.2. December 11 and 12, 2018. Preparation for the final demo.

In these experiments, we performed the complete deployment of the system including the addition of two repeaters as presented in Figure 2.11. In both days of the experiments, we managed to drive the SIAR platform along a 300 m long path without any issues in autonomous mode.

2.4.3. December, 13, 2018. Final demo

In this day we performed the inspection of the gallery for the organizing consortium and external reviewers. Figure 2.12 depicts the presentation of the new platform to the reviewers.

The complete inspection procedure was carried out in semi-autonomous mode with the exception of the need to deal with a big obstacle. The robot traveled a total of 400 m in less than 40 minutes, which gives an average inspection rate of 0.18 m/s. Figure 2.13 shows the track that was actually inspected during the final demo.

Figure 2.12. Presentation of the siar platform to the external reviewers during the Final Demo.

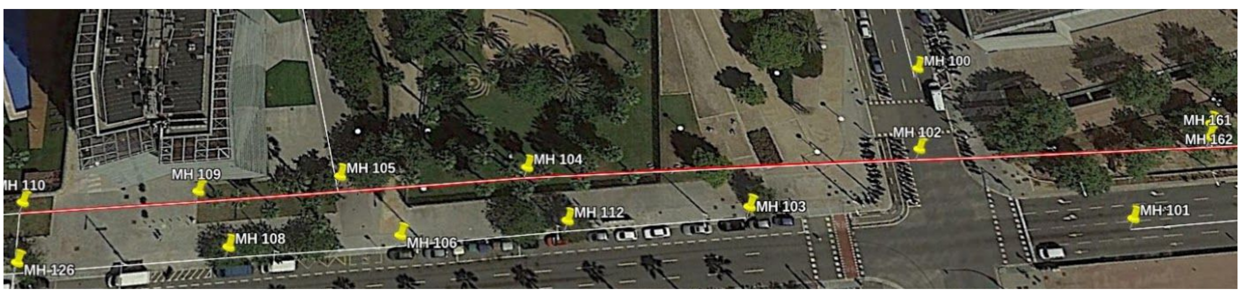


Figure 2.13. The inspected track on the Final Demo is shown in a red line.

3. Videos

This section links to videos demonstrating some of the experiments and/or capabilities of the robot. They can be found in the following web-folder:

https://drive.google.com/open?id=1nEVaumOtAkQKxmjoJjAFdqhh3gYvv5ml

3.1. Video compilation: serviceability demo

This video shows shows how the automatic serviceability defect inspection works. It can be seen how the gutter presents a serviceability defect that was automatically detected and marked into the image and geo-localized. These videos were generated for D28.10 and the reader is referred to that document to have an in-depth analysis of the detected defects. We include the videos of the most relevant alerts detected during the Serviceability Defect Demo.

- alert_2.mp4: Video containing the visual images for the Alert number 2.
- alert_3.mp4: Video containing the visual images for the Alert number 3.
- alert_4.mp4: Video containing the visual images for the Alert number 4.
- alert_5.mp4: Video containing the visual images for the Alert number 5.
- alert_10.mp4: Video containing the visual images for the Alert number 10.
- alert_11.mp4: Video containing the visual images for the Alert number 11.

3.2. Video: SIAR in Virrei Amat area

This video presents a portion of the SIAR V3.0 platform while navigating through the sewers in the Virrei Amat area.

Figure 3.1: The SIAR V3.0 platform navigating in the Virrei Amat area.

3.2. Video: Serviceability report

A summary of the report obtained in the serviceability demo and the technologies used inside.

Figure 3.2. Video of the serviceability report.

3.3. Video: introducing SIAR V4.0

On September 17th, the new version of the SIAR platform was ready to go to the sewers. The principal novelties were the new width adjustment mechanism, that allowed the SIAR to have a width ranging from 52 cm to 84 cm. Also, a new operator awareness camera was installed and mounted on a robotic arm, that allows the operator to gather more information of the possible defects found during an inspection and to have more information for guiding the platform in complex areas. The video also presents some excerpts of field experiments in Av. Pearson area.

Figure 3.3. Presentation of the V4.0 SIAR platform at IROS 2018

3.4. Videos: SIAR V4.0 deploy, SIAR V4.0 deploy 2

These videos show the new configuration found to easily deploy the robot in the Av. Pearson area. In particular, we found that the safest procedure was to push the wheels against the wall while deploying or retrieving the platform.

Figure 3.4. Deployment of the V4.0 SIAR platform. Left: Video 1. Right: Video 2.

3.5. Video: SIAR V4.0 robotic arm

Small video that shows the transition between the arm in rest position to a navigation configuration.

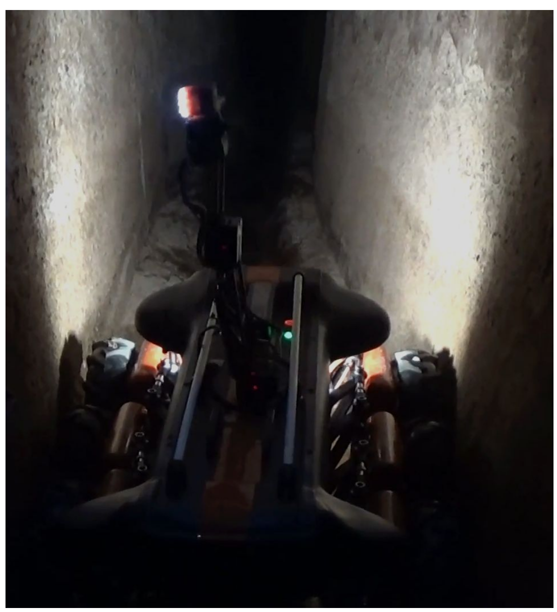


Figure 3.5. Detail of the inspection camera installed in the arm end.

3.6. Video: [SIAR V4.0 robotic arm 2]

This video is a compilation of images obtained from the robotic arm in the Passeig Garcia-Faria location.

Figure 3.6. Image obtained by the inspection camera installed in the arm end.

3.7. 3D reconstruction: [Structural Defect: Av. Pearson]

A 3D reconstruction of the Structural Defect found in the Av. Person Scenario can be found. Also, a [video] has been generated to illustrate the generation process.

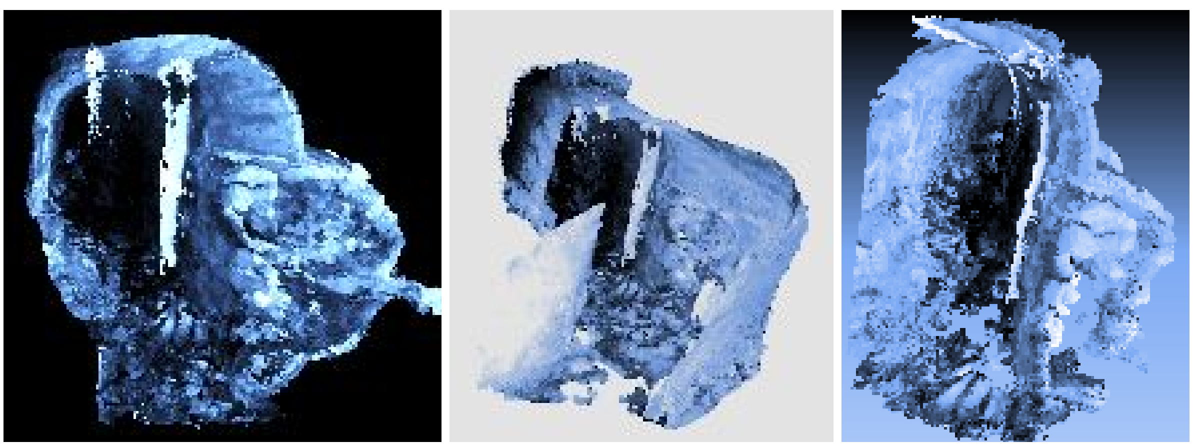


Figure 3.7. Snapshots of the3D reconstruction of the serviceability defect.

3.8. 3D reconstruction: [Structural defects and elements in Garcia-Faria]

In D28.13, we provided some partial reconstructions of structural defects and elements in the Passeig Garcia-Faria scenario.

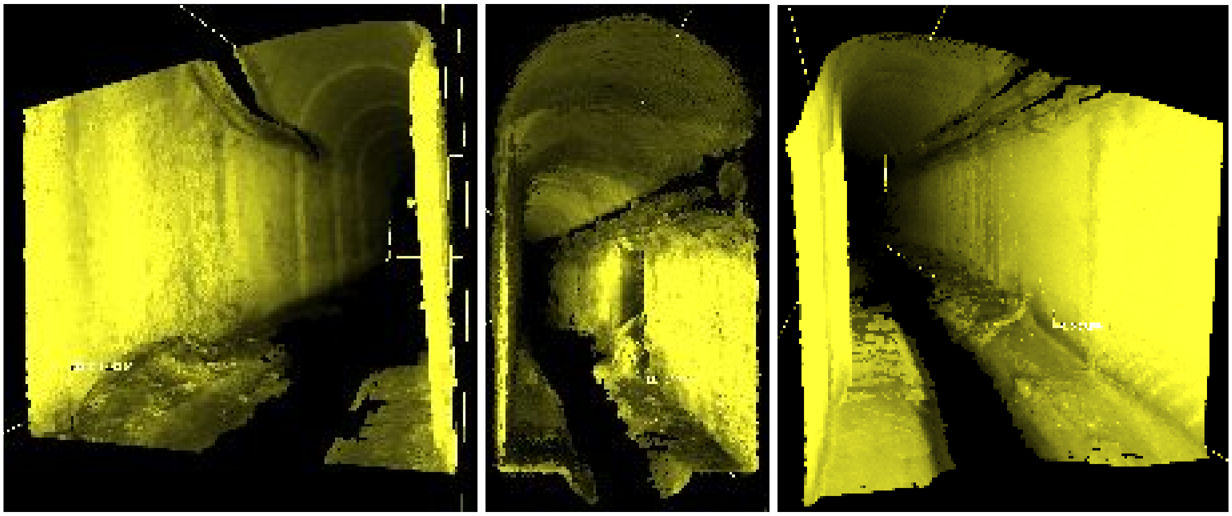


Figure 3.8. 3D Reconstructions of defects in Passeig Garcia-Faria scenario.

3.9. Video: Serviceability defect Passeig Garcia-Faria

At the beginning of the inspection, our serviceability analysis module detected a serviceability defect which is depicted in Figure 3.9.

Figure 3.9: Composed snapshot of three frontal cameras in the Serviceability Defect in the Passeig Garcia-Faria area.

3.10. Video: Deployment of a repeater

This video shows the deployment procedure of the new repeaters designed and manufactured in Phase III. With them, the deployment is easily made from the surface without the need to enter the sewer (see Figure 3.10).

Figure 3.10: Deployment of the new communication devices.

3.11. Video: SIAR Base Station

This video shows how the operator is able to guide the SIAR platform without any efforts and the real-time information offered to him.

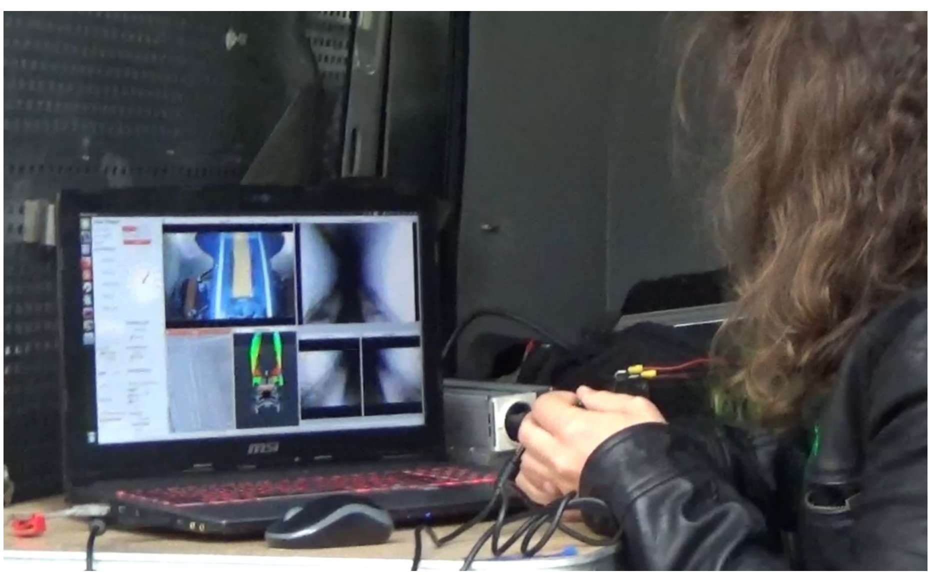


Figure 3.11: An operator guides the platform from the surface.

3.12. Video: [SIAR promotional video]

This video summarizes all the main features included in SIAR robotic platform.

Figure 3.12: Snapshot of the SIAR project promotional video.

4. Public datasets

The SIAR team is aware of the capital importance of datasets for robotics algorithms testing and validation. It is not common to have the opportunity to autonomously navigate a robot in a realistic setting as complex as a sewer. With this idea in mind, the SIAR team has released a total of four different datasets of the robot navigation in the sewers of Barcelona.

Some of these datasets were presented in the paper "RGBD-based Robot Localization in Sewer Networks" of D. Alejo, F. Caballero and L. Merino in the 2017 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2017) together with the source code developed for robot localization in sewers. The datasets are recorded as “rosbags”, the standard format for sensor data logging in the Robot Operating System (ROS) community.

The datasets are composed by the following information:

- RGB and depth images in JPEG format for all the onboard cameras;
- wheel odometry;
- inertial measurement unit;
- relative position of cameras and sensors using the ROS TF representation;
- information related with the radio-link.

All the information is time-stamped and can be easily reproduced using rosbag tool, which is a part of the suite ros that has become a de facto standard in the robotic academic community (http://www.ros.org/).

The datasets can be downloaded from the following link:

http://robotics.upo.es/datasets/siar/