sewer **i**nspection **a**utonomous **r**obot

D28.7 - Multimedia Report

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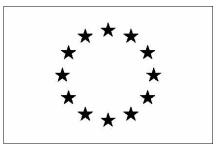

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1. Introduction

This report presents videos and photos that summarize the experiments and achievements of SIAR team in Phase II. 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 significand amount of photos and videos in this last project period. This report presents just a small subset of these information. All the videos related with this report are 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. The SIAR team has published four datasets of the robot navigating into the sewers of barcelona. These datasets include odometry, IMU, images from the onboard cameras and robot state information. These datasets were presented in the 2017 IEEE/RSJ IROS Conference at Vancouver (Canada). The datasets can be downloaded from the following repository:

http://robotics.upo.es/~daletei/SIAR/Dataset/

2. Summary of Experiments

This Section is a small report on the different experiments performed during Phase II of the Urban Challenge for Sewer Inspection. The main objective of Phase II is to develop a final version of the prototype that will be extensively tested during Phase III and its onboard software systems. To this end, experimentation in a real sewer system is vital for testing the developed hardware and software approaches and for gathering vital data to be able to design them.

2.1. December 2016. Mock-up experiments at UPO.

A sewer mock-up was built by UPO and USE and installed at UPO facilities. The main objective of this mock-up was to ease the parameterization of the navigation algorithms in a “gentle” environment, while keeping the same structure and limitations of the real sewer. Figure 1 shows some photos.

Figure 1: Photos of the 1-1 scale mock-up of the sewer used for navigation testing

From December 2016 to March 2017 the mock-up was used to perform experiments at UPO, adjusting and parameterizing the assisted navigation mode of the SIAR robot. Section 3 shows some videos of the robot moving automatically during these experiments.

2.2. January 17, 2017. First field experiments in Phase II.

On January 17th the full SIAR team (USE, UPO and IDM) visited for the first time the proposed scenario for the final experiments of Phase II.

The main objectives of this visit were to check the mobility of the platform in the new scenario, to test communications and also to gather a dataset as complete as possible in order to develop algorithms for 3D reconstruction and for localization in global coordinates.

The robot platform used for these experiments was the same as the one used for Stage I demonstrations experiments. The robot was manually controlled by an operator during the whole experiment. This

information helped UPO and USE to gather a valuable dataset of the real sewer used for scientific publications and also for software development.

2.3. May 17, 2017. First autonomous navigation experiments in Mercat del Born.

The SIAR team designed a new disposition of the RGB-D cameras for getting more information about the floor in the surroundings of the robot. It was necessary for developing the Assisted Teleoperation system that was first demonstrated in the 2nd Monitoring Period demo in Sevilla on March 30, 2017. However, we realized that the cameras were too high for the final prototype. Indeed this disposition of cameras would probably not pass a standard manhole, so they would have to be removed before entering the manhole and to be installed inside the sewer, which would not be very practical. For those reasons, we decided to place two sensors instead of one, but closer to the ground. In this way we have even more information of the surroundings when compared to the disposition tested on the demo of March.

In these experiments we performed autonomous navigation for the first time in Mercat del Born. 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.

We also performed autonomous navigation with the robot being commanded from the outside ground station. Two operators from BCASA were able to move the robot without any issues, see Figure 2.

Figure 2: BCASA operator commanding SIAR robot in assisted teleoperation from outside the sewer

2.4. July 11, 2017. Communication experiments in Mercat del Born

The experiments carried out in the 11th of July of 2017 were designed to test the communication devices. In these experiments the SIAR team installed communication repeaters in several positions of the sewer network to test how signal strength was affected by the environment: water, narrow spaces, not direct line of sight, etc.

Additionally, the new hardware for repeater were tested on site. The new hardware included new plastic boxes, power source and batteries for lasting the whole inspection operation.

Figure 3 shows the final placement of the repeaters according with the test to be carried out. They should be installed into the manholes directly, so that they can be easy and quickly installed by the operators.

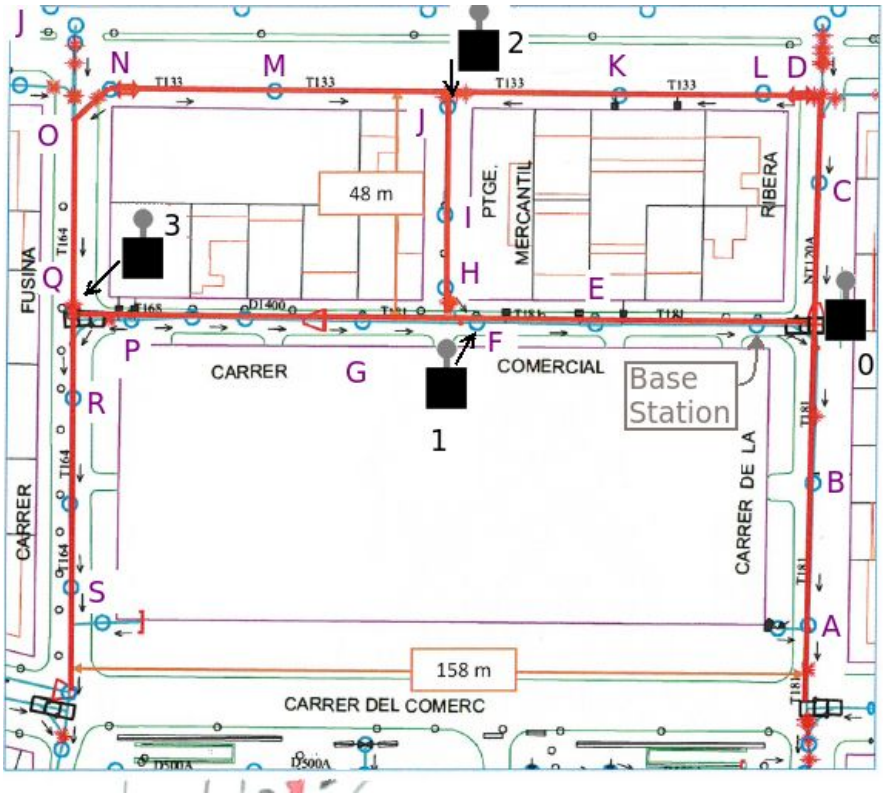

Figure 3: Disposition of the repeaters with manhole deployment

2.5. September 4, 2017. Testing of the new robot platform in Mercat del Born.

These experiments were carried out to test the new platform with adjustable width in the experimental field of the sewers of Mercat del Born. Thus, the new platform was deployed and tested during 4 days in Barcelona, Figure 4 shows some images of the robot deployment.

All the SIAR robot subsystems already developed were tested during the 4-day experiments: sensors, drivers, localization and navigation. The objective was to check that the system was still behaving as the previous platform. The tests were a success and all the system worked as expected.

These experiments allowed SIAR team to validate the new design and at the time to identify improvements in the locomotion frame and in the control software.

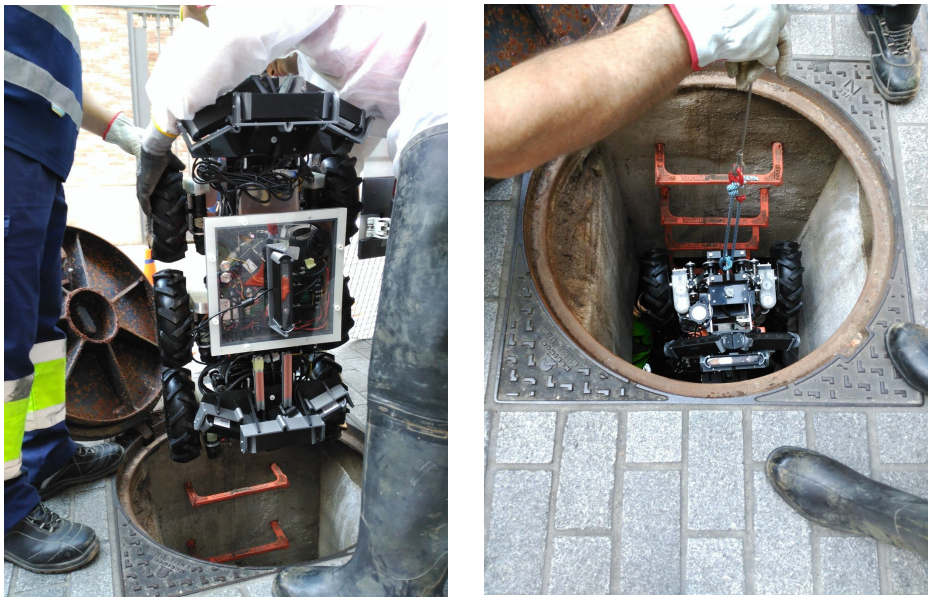

Figure 4: Deployment of the new robot platform in the sewers of Mercat del Born

2.6. September 20, 2017. Assisted navigation from outside the sewer.

These experiments stand as the first assisted navigation tests performed completely from outside the sewer without worker/operators accompanying the robot. Thus, the radio repeaters were installed in the positions marked in Figure 3 by the operators and the robot was deployed into the sewer.

During the experiments the robot was in permanent contact with the base station where images and telemetry data was being received. The robot traversed automatically ALL the Mercat del Born sewer network: straight lines, curves and, very important, cross-sections. The system behaved properly and only once required operator intervention in one cross-section where the robot was not able to automatically manage the passage.

While performing the experiments, the robot was commanded by BCASA operators. They realized how easy is to command the robot in assisted navigation, while at the same time the inspections images were gathered by the robot. Figure 5 shows one picture of the moment.

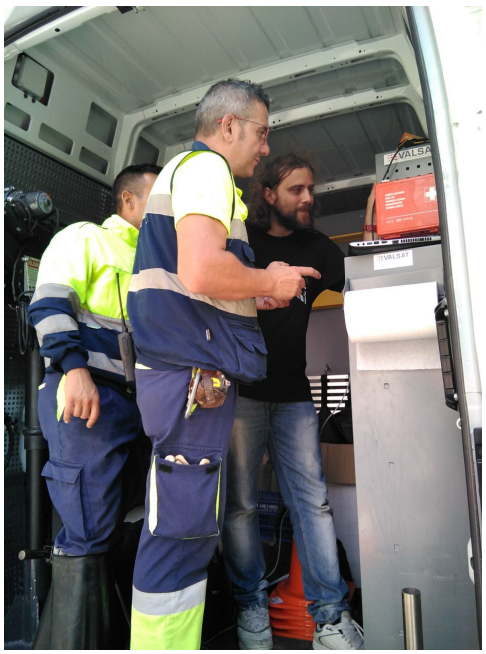

Figure 5: BCASA operators commanding the siar robot.

3. Videos

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

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

3.1. Video: siar_mock_up

This video shows the SIAR robot version 2 navigating automatically in the sewer mock-up in UPO's facilities. The robot was able to move forward and backward in straight lines and curves without risk. The operator only needs to indicate the direction of motion. The robot is able to adapt its maximum speed depending on the environment complexity.

Figure 6: Frames of the video in which SIAR robot navigates in UPO's mock-up.

3.2. Video: mapping_born_20x

This video shows the 3D reconstruction of the Mercat del Born sewer system. It was performed using the 3D mapping techniques developed by SIAR team and the images gathered by the robot during the inspections of January 17, 2017. The system was able to recover the full 3D structure and also the texture. Please notice that the textures are inaccurate due to the poor illumination from the robot.

Figure 7: Frame of the 3D reconstruction of the sewer video

3.3. Videos: siar_localization_born and siar_localization_20_sep

These videos show how the SIAR localization system works. The first video presented in Figure 8 describes how the data sensor gathered in January 17 is used to compute the robot localization based on fine RGB-D odometry and also automatic man-detection based on a Deep Learning Network. The video give details about the approach and presents two different experiments.

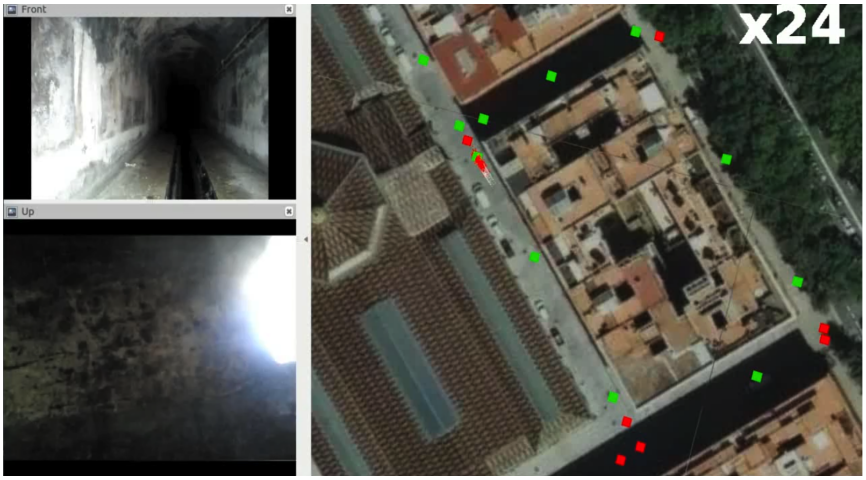

Figure 8: Frame of the video in which SIAR localization system is described.

The video was submitted as part of a paper accepted in the IEEE/RSJ International Conference on Intelligent Robots and Systems, IROS 2017. It has been presented during the conference, and can be also accessed in YouTube at https://www.youtube.com/watch?v=N_tUhdBN7Z4.

The second video also presents the localization in Mercat del Born, but this time using the new robot platform, with automatic width adjustment, crossing forks and pipe sections. This localization corresponds to the experiments developed in September 20th. Figure 9 shows an illustrative frame.

Figure 9: Frame of the video in which SIAR localization system works while navigating, crossing forks and pipes.

3.4. Video: cross_section_born

This video shows a small clip in which the robot autonomously navigates through one cross-section in the sewers of Mercat del Born. These preliminar experiments were performed in September 20th. We can see how the robot autonomously passes the cross-section and continues through the curve. Also interesting to see is that the robot passes below the pipe section, a section with very low-clearance.

Figure 10: Frames of video in which SIAR robot is commanded to navigate over a cross-section in the sewer.

3.5. Video: siar_deployment

This video shows the process of deployment of the robot into the sewer. The inspection van (with the robot) arrives at the defined manhole. The robot is lowered into the sewer my means of an electric winch

installed in the inspection van. It can be seen how the robot fits perfectly through the manhole without the need of disassembling any robot part. The robot electronic width adjustment allows to reduce its dimensions to the minimum prior to manhole insertion.

Figure 11: Frames of the video in which the deployment operation is shown.

3.6. Video: defects_born

This video shows shows how the automatic defect inspection works. It can be seen how different defects/inlets/holes are automatically detected and marked into the image. The image sequence corresponds to one of the streets of Mercat del Born. While there are some false detections, it can be seen how the system properly detects many defects in the walls.

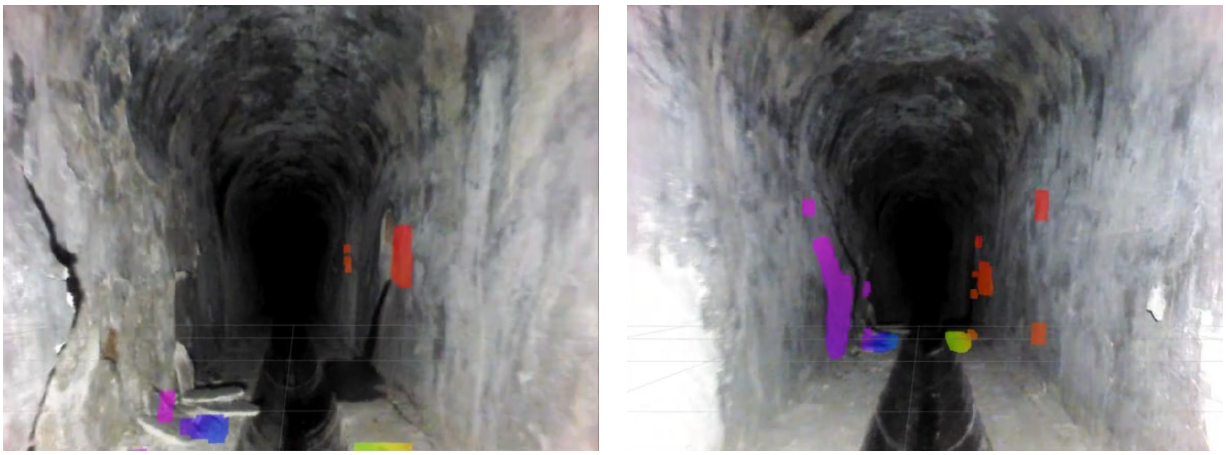

Figure 12: Frames of the video in which a set of defects are automatically detected by the robot.

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.

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 tools.

The datasets can be downloaded from the following link:

http://robotics.upo.es/~daletei/SIAR/Dataset/