Advanced Robot 3D Simulation Interface for Disaster Management

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***Abstract*—Recent progress in modern technology can enhance the definition of disaster recovery management strategy. Rescue teams can rely on Autonomous Systems (A.S.) during recovery operations, dispatching to them various tasks. A.S. can reach locations that may be unattainable or dangerous for humans. Yet, correctly configuring A.S. for a specific mission is an open issue. Incorrect configurations can lead to imprecise or erroneous data, that could result in wrong information provided to rescuers. We propose a set of steps to validate the configuration running the A.S. in a virtual environment through 3D simulations. These steps shall be performed during the deployment of rescue teams in order to speed-up the definition of a rescue management strategy. The expected results are: (i) adequacy assessment, (ii) mission success expectancy and (iii) A.S. survival probability. Moreover, we propose a set of integration to better support disaster-management in the existing 3D virtual simulator.**

***Keywords*—Autonomous Systems, disaster management, sensors, simulation**

I. Introduction

The context of this work is a disaster environment. A disaster environment is chaotic, dangerous and it is necessary to act rapidly to increase chances of survival. In this respect, usage of Autonomous Systems brings benefits. However, mission-specific configuration is an essential condition for effective response.

This section presents the context of the work, the use of A.S. and the purpose of our approach to simulation. Section II describes the simulation system that is used. Section III is devoted to modelling. Future work and conclusions are presented in section IV.

A. Disaster Management

Disaster recovery management strategy can now be enhanced thanks to recent progress in modern technology. More precisely, these techniques shall help in settling plans, processes and techniques in order to save life, to find survivors or to restore life conditions as they were before the disaster [1]. After a disaster, the impacted area could have suffered huge mutations (e.g., ground alterations, presence of rubbles). Disaster environments are chaotic and dangerous, not only for victims but also for rescuers. Obviously, some information can be obtained only after in-site reconnaissance, but this is not always easy to perform. Indeed, communications with the local inhabitants may be hindered by physical constraints or by people abandonment of the hit zone. But actually, even a local inspection presents strong limitations. Indeed, for example, the poor visibility range can result in erroneous decisions based on incomplete or erroneous data. However, the completeness and the correctness of this information are necessary for the decision-making process required by emergency intervention [2]. Depending on the circumstances of each event, it is important to rapidly select the suitable means to respond to the emergency intervention.

B. Usage of Autonomous System

In this respect, the usage of autonomous systems (A.S.), such as Rovers or Drones, can assist the recovering operations for many tasks. For instance, A.S. can be used for Rapid-Mapping or to scan the affected area to find survivors, among others. The need for measurement systems operating in total autonomy has existed for a long time, but accurate enough measurement technologies were not yet available. In the past, acquired data were not frequently updated, probably because previous technologies were only producing environment snapshot rather permanent monitoring. Nowadays, wired and mobile communication networks allow us to easily gather distributed measurement and acquisition systems dedicated to data collection in real-time [3, 4]. However, these systems require the deployment of a fixed infrastructure that has to be well-maintained to operate.

The advent of autonomous vehicles, incorporating modern technology sensors (LIDAR, Radar, Ground Penetration Radar, Camera, etc.) [5, 6], offers new opportunities in this field. These facilities provide more sophisticated ways to acquire information of heterogeneous types and to explore a given environment. This approach allows operations overcoming the constraints given by the existence of a fixed infrastructure. Moreover, it tolerates communication difficulties [7], e.g. in case an existing infrastructure is down or destroyed due to accidents or disasters.

In order to integrate the capabilities of modern sensors it is necessary to define new approaches. Capturing information helps (i) understanding and thus modelling the environment (in real-time) for a successful accomplishment of the mission, (ii) reusing the same information for settling decision-making processes for intervention teams [8, 9]. Data is produced by a set of heterogeneous sensors deployed for real-time collection: distance values are computed through ultrasonic, micro-waves and LIDAR sensors, location and attitude values are obtained through Inertial Measurement Units (IMU), control data by odometers [10], etc. Moreover, the usage of Radar for Ground Penetration (GPR) allows new sensing such as detection of victims buried after an earthquake [11, 12, 13, 14] thus increasing the probability to locate survivors.

Yet, precisely defining the architecture and the configuration of the A.S depends not only on sensors but also on:

1. The configuration of the devastated area,
2. The main objectives of the SaR (Search and Rescue) mission such as damage assessment, people research and location, etc.

C. Main objectives

In this critical context, inappropriate A.S. configuration can lead to imprecise or erroneous data and, consequently, erroneous decisions could result from them. The choice of the adapted set of sensors to be equipped for the specific situations as well as their physical placement is a non-trivial task. The same for the mechanical configuration: for instance, the diameter of the wheels mounted on a Rover can be unsuitable for the roughness of a target terrain. A bad choice in this step may make the A.S. not reliable enough for targeted missions.

In this regard, we propose a new approach, based on a 3D simulation of the real world, which speeds-up the definition of a recovery management strategy. Our research aims to set the goals immediately after a disaster arises, e.g. during rescue teams' deployment. The objective is to acquire up-to-date information on the area and its alterations due to the event. Once rescue teams are deployed in zone, A.S. can start producing data, thus helping to define complex strategies or modifying run-time an existing plan [2, 3].

II. Simulation System Description

The schema of the selected simulation system is depicted in Figure 1. It consists in a network of computational blocks that communicate through high-level messages. Each block is responsible for a specific operation (i.e., black continuous-line shape blocks) or modelling aspect (i.e., red dashed-line shape blocks). We chose an existing simulation environment named Gazebo-3D [15]. It comprises a large set of physics engines (i.e., Open Dynamics Engine - ODE for dynamics simulations [16]) and Open Gestures Recognition Engine - OGRE to provide a realistic rendering of the scenario [17].

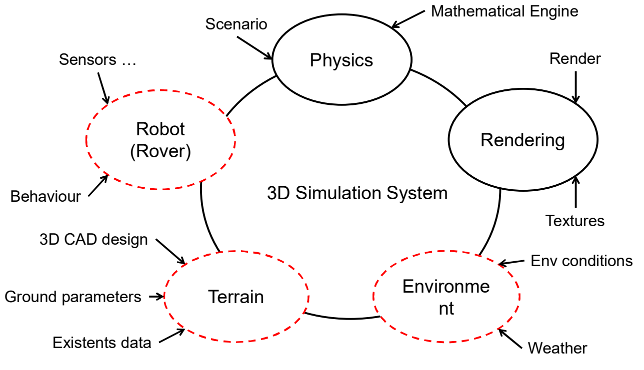

Figure 1 – 3D simulation system principle

We use Gazebo-3D to the adequacy assessment of robots in realistic scenarios. This with the final goal to increase knowledge on the A.S expected mission. The input requirements are realistic and rigorous models of the different elements of the mission. In this regard the terrain, the environmental conditions, A.S. architecture and behaviour, the set of sensors must be modelled.

Considering Figure 1, computational blocks characterized by a continuous-line shape provide a complete support with respect to simulation for disaster management. Some integration are required for blocks that address modelling aspects (i.e., dashed-line shape blocks) though. These are part of our contribution and they will be listed and explained in section III. Some of them have been addressed in this paper; the rest is part of our future work.

III. Modelling Process

The modelling of each element of the scenario has to be done by specifying its physical characteristics as precise as possible.

A. Ground

World modelling, especially ground modelling, takes a crucial role in our work. In this sense, there is a strong interest in testing the configuration of an A.S. in a simulated environment able to reproduce the behaviour of the A.S. and that matches as much as possible the real world. Figure 2 gives an overview of terrain generation process. In order to have a realistic simulation ground surface of the impacted area, we start from existing data sources. They can come from satellites (e.g., optical/micro-waves, terraSAR, photogrammetry, etc.), airborne images produces by drones, images produced by LIDAR or Radar, Geographical Information System (GIS) data, and so and so [18]. Thus, the input terrain is provided to the simulation system by processing these existing input data. Indeed, starting from them we generate Digital Elevation Models (DEMs) that are the real input of the simulation system.

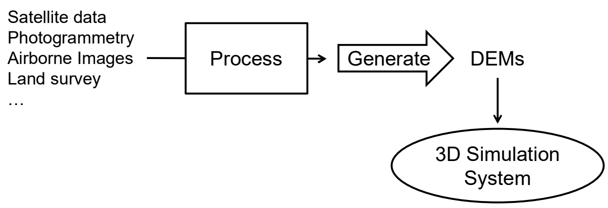

Figure 2 – Terrain acquisition process

This allows to perform some preliminary physical analysis (e.g., probability of a Rover to overcome all the depressions of terrain) but the presence of external obstacles in the terrain is a key-point in simulation for disaster management.

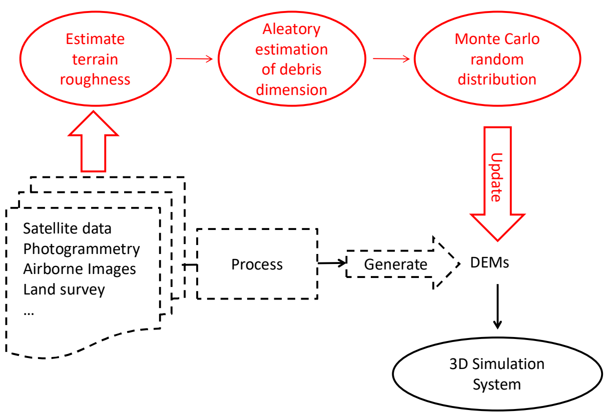

Figure 3 – Enrichment of the DEM realistic aspect based on a random mathematical approach

We addressed this issue integrating simulated punctual objects (such as rocks, debris, fails, etc.) after the generation of the main DEM. This approach permits to enhance the realism in terrain representation. We can add obstacles from low-altitude Drone flight or generating them in a random manner. The latter method is illustrated in Figure 3. We use mathematical functions, classical in remote sensing, to estimate the roughness of the terrain. After that, physical properties ranges of obstacles (e.g., density, hardness, etc.) have to be defined and Monte Carlo function can be used to generate a random sampling of these obstacles distributed over the generated terrain.

B. *Autonomous System*

To realize such missions our laboratory has designed ArcTurius Rover [reference ArcTurius], illustrated in Figure 4. ArcTurius is an autonomous rolling system whose purpose is the precise location of buried people after an earthquake. Its design derives from its operations (i.e., progressing under debris or in very tight spaces) and the length of the mission (i.e., up to a week in complete autonomy). Figure 5 shows a representation of ArcTurius model.

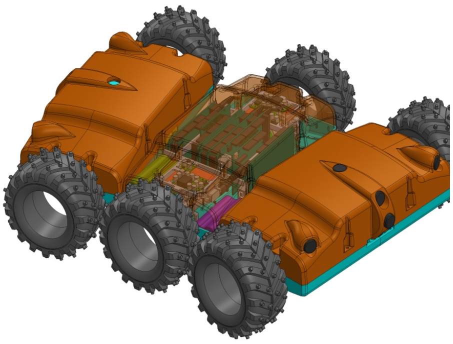

Figure 4 – ArcTurius Rover, 3D CAD view

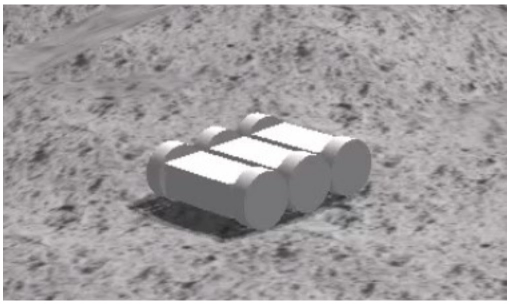

Figure 5 – Preliminary model for ArcTurius Rover

1) *Components*

From simulation system point of view, A.S. can be seen as a set of rigid bodies, named links, connected through junctions, named joints. With respect to A.S. modelling, it is important to well model both links and joints. For each link (such as the Rover chassis or wheels) it is necessary to explicit at least its geometry, its pose with respect to the surrounding environment and its inertia. More fine-grained models also take into account physical parameters that regulate better the contact between two links.

Joints connect a father link with a child link. While modelling joints, it is necessary to explicit their type. For instance, a wheel is connected to a chassis through a continuous joint that is a continuous hinge that rotates on a single axis without upper or lower spatial limits. Bodies are connected each other through a spherical joints characterized by 6 degrees of freedom. From the simulation point of view, safety limits of a joint are important. For example, it is possible to limit the maximum effort of a joint as well as its maximum velocity.

2) *Sensors*

Sensors are active components of the rover and they have to be modelled carefully. From a geometry point of view, it is necessary to specify in the model their shape, size and mass in addition to their relative position with respect to the collision domain of the rover. However, each sensor has custom parameters, that can be modelled precisely starting from the data-sheets of real constructors. Taking as a reference a LIDAR, we have to describe its resolution, the number of samples per units of time, the angular resolution, the minimum and maximum distance and the size of its range, among others. Sensors are noisy components, and noise has to be modelled as well, with respect to the external environment.

C. *Environment*

The environment is composed by all the agents, different by the autonomous system, that are active within the scenario. They are, for example, particular light sources that can perturb the measurement taken by a LIDAR. However, environment modelling is a wide topic and it will not be part of this paper.

IV. Conclusion

The use of autonomous systems (A.S.) either on the ground (i.e., Rover) or flying (i.e., Drone) constitutes a major progress. They are able to reach unattainable and dangerous locations for human rescuers. Moreover, they are less sensitive to both environmental conditions (such as meteorology) and situations that can be stressful for humans. However, several difficulties have to be resolved in order to achieve the expected autonomy. In the first hours after a disaster, during the rescue team deployment, our 3D-based simulation steps allow a real gain in terms of timing.

Our future work consists in a series of integration to better support disaster-management simulations. For instance, we will work on the reaction of the terrain, intended as the modification of its physical parameter, in response to an external agent such as rain, that has to be modelled as well. A better integration of mechanical components is necessary, e.g. the ball junction among bodies. To do that, we require a better integration of physical parameters. Beyond the modelling point of view many features require a particular development to be integrated in the system.

Finally, from the proposed approach we can expect to increase the knowledge of the devastated area, to validate the A.S. behaviour (moving, data acquisition, etc.) and finally to validate the adaptation of the payload sensors configuration for this (these) mission(s).

We retain that these works will open the door to many others scenarios in the context of simulation in support to disaster risk reduction.

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