SolarCleano INGENIARIUS

TOWARDS THE NEXT GENERATION OF MULTI-ROBOT SYSTEMS FOR SOLAR POWER PLANTS INSPECTION AND MAINTENANCE

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RIMA ROBOTICS FOR INSPECTION AND MAINTENANCE

ABSTRACT

Solar panels cleaning has always been a key task in solar power plants inspection and maintenance, being directly related to the overall performance of the system. A wide range of cleaning setups have been tested and commercialized over the years, most of them being manual or semi-autonomous, and usually dedicated to only one PV module bank. The importance of cleaning is emphasized even more with the ever-growing installation of large utility-scale PV plants in desert regions. This short position paper introduces a fully autonomous, battery-powered, multi-robot system designed for infrastructure inspection and maintenance of large solar power plants, thus drastically reducing the costs needed for those services up to now. The heterogeneous system includes both unmanned ground and aerial vehicles, fully integrated within the same architecture. Despite being a work-in-progress, the experimental results demonstrate the performance of the multi-robot system, addressing the decision-making as a sequence modeling problem.

Keywords: Multi-robot systems, SPARC I&M, Fleet management, Decision making.

CONTRIBUTIONS

This work describes the use of a multi-robot system (MRS) [1] capable of working, collaborating, and allocating tasks autonomously to each other, to provide inspection and cleaning (I&C) services to multiple PV solar banks. A sophisticated coordinating architecture [2] is described to deal both with the task allocation along the fleet and the decision-making process, which is not only usually affected by local weather and soiling conditions, but also the cleaning strategy adopted to meet the established goals (Fig. 1).

The coordinator integrates a Nakama-ROS server, which communicates with a Unity3D User Interface (UI) [3] client, ensuring a safe machine-to-machine connection between robots and clients.

Four types of robotic platforms are involved in the experiment, namely two PV cleaning UGV's, one marsupial UGV [4], that transports cleaning robots in-between different solar panels and back and forth to the base station for charging and a UAV used for PV inspection.

EXPERIMENTAL RESULTS

The experimental layout was chosen to encompass a large range of panel tilting, to create challenging conditions in which the system would have to respond in a safe way.
A sequence of actions contemplates the execution of the cleaning service by an F1A (action 1), its completion and coordination through the FMS to move the F1A and T1A to a rendezvous predefined position (action 2), the successful pick-up of the F1A (action 3), and, at least, the transfer to the charging station (action 4). In parallel, the UAV performs a series of predefined flight routes for PV defects detection.
This sequence of actions was carried out on a repetitive basis (50 trials) to quantitively assess the performance of the system. Data obtained from weather stations and soiling measurement sensors, were considered in the decision-making process, while an alarm system was able to monitor and report possible malfunctions. 50 trials were performed for each inclination of the panels, varying between 0 and 25 degrees, with 5-degrees steps, leading to the results illustrated in Fig. 2.

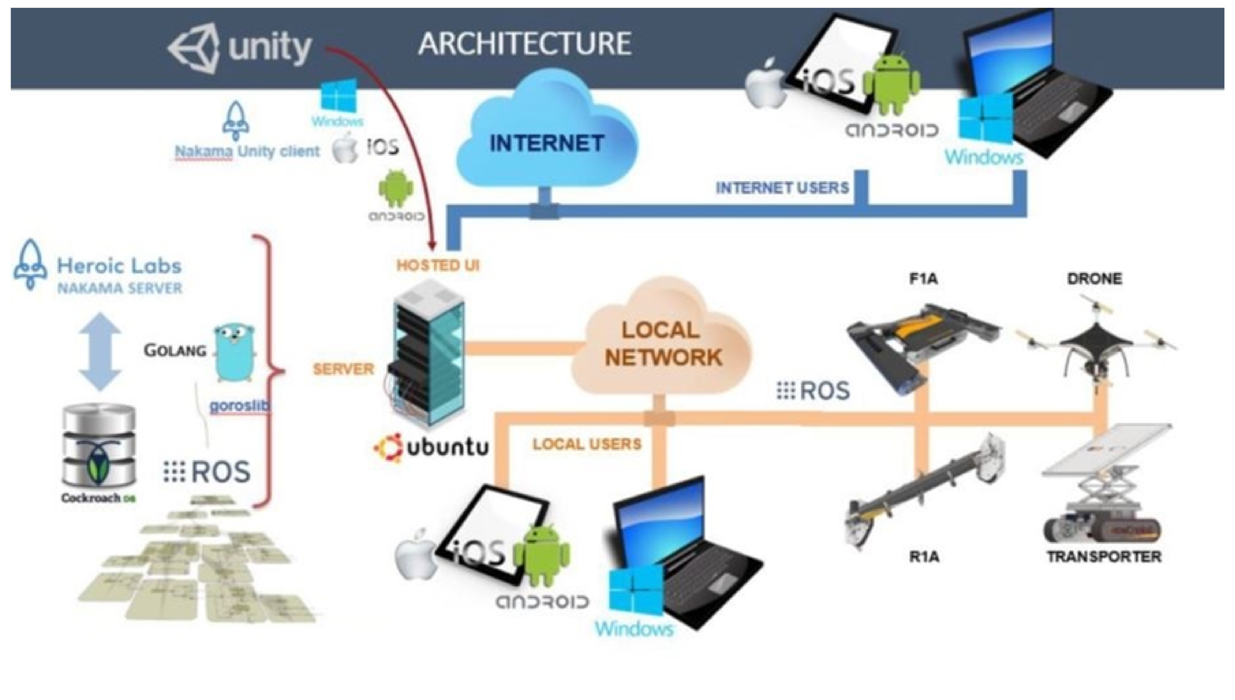

Figure 1: System architecture of the MRS for PV I&M.

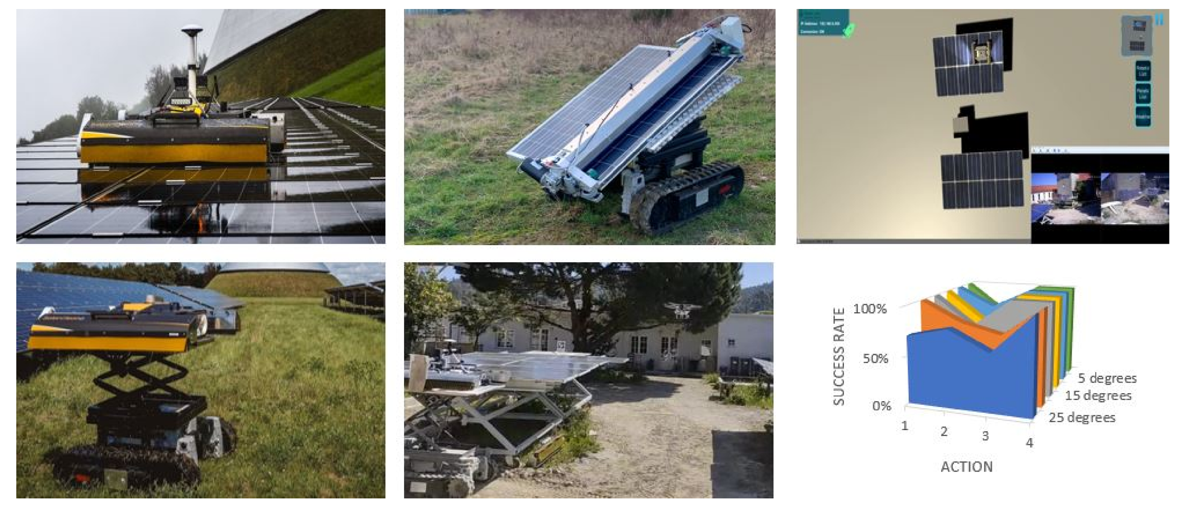

Figure 2: MRS agents coordinated by the FMS and supervised through the UI. The results retrieved from the performed trials are shown in the bottom right figure.

[a]https://www.youtube.com/watch?v=6KOWYNIzaL4

SOLAR PLANTS AUTONOMOUS ROBOTIC CLEANING, INSPECTION & MAINTENANCE (SPARC I&M)

SPARC I&M is a cooperative robotic system adopting ROS, integrated within an IoT infrastructure and involving 4 types of UGV's and UAV's for cleaning and inspection in PV plants. The optimal cleaning strategy is guaranteed by having a Nakama-ROS server to autonomously manage fleets of robots by providing high-level goals for coordination purposes. It is noteworthy that Nakama has been solely used before as a game server engine. In this work, we have adopted Nakama not only to manage multiple users and sessions but also to be the central coordinator of the MRS. This has been possible by implementing an extension to Nakama server, which additionally offers full low-level access to the server and its environment. When it comes to the introduction of new decision-making into the robot, we have once more adopted the behavior engine. In the central coordinator, however, behaviors are triggered by the Linux OS CRON job scheduler. This means that, whenever a new behavior is required, it can be implemented as a single state of the FSM, or "broken" into smaller states, keeping it as generic as possible and reusable.

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FUTURE RESEARCH

Further improvements on the decision-making side for cooperative cleaning are foreseen as future work. Furthermore, more real-life tests are also needed in installations with harsh environmental conditions. As the size of PV plants grows bigger, the scalability of the framework would be part of our future research, since numerous robots operating in parallel will be the case.

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