Toward Semi-Autonomous Terrestrial Robots for Atmospheric Electricity Measurement

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Abstract. We explore the use of a rover robot carrying an electric field mill for ground-based atmospheric electricity measurement. The robot platform includes a 2D LiDAR and stereo image camera for terrain mapping, with the aim of generating new insights into atmospheric electricity processes. Initial teleoperated experiments allowed for the plotting of measured voltages on a map using GNSS. We plan to explore the possibility of cooperative 3D mapping behaviours in a 'sparse swarm' configuration of around six robots, with expert-in-the-loop oversight. Ultimately, we intend for this research to inform opportunities in atmospheric electricity research on other planets, such as Mars.

Keywords: Electrostatics · Terrain Mapping · Sparse Swarms

1 Introduction

Atmospheric electricity is still poorly understood, on Earth and other planets [2]. Developments in robotics technology, especially in Unmanned Aerial Vehicles (UAVs), are leading to increased interest in atmospheric electricity research opportunities with aerial robotic platforms (e.g. [4], [7]). Relatively little work has been done with terrestrial robots (see [1] as a first example). Here, we present initial findings from experiments using one rover robot carrying an electric field mill for ground-based atmospheric electricity measurement. Beyond this initial phase of the research project, ultimately we aim to deploy a 'sparse swarm' [8] of multiple rovers dispersed across a wide geographic area, operating with some level of autonomy to propose their movement through the environment with expert input and oversight. This should generate new insights into atmospheric electricity processes: for instance tracking of dust devils and storms on Mars, or comparing electrostatic weather phenomena between Earth and Mars.

2 Robotic Platform

The use of robot platforms for scientific survey presents several potential advantages [3], including the efficient and precise measurement of physical processes across wide areas, especially if multi-robot systems can be deployed.

Our base robotic platform is a ‘Leo Rover’: a 4-wheeled rover controlled by a Raspberry Pi. Designed as a Mars-type rover, it has a linked rocker suspension, making it well-suited to outdoor exploration (Figure 1). On top of the rover, we add a sensor payload, including: a 2D LiDAR (RPLIDAR A1); stereo image camera (Intel RealSense D455); a GNSS receiver (global navigation satellite system) with RTK (real-time kinematic positioning) capabilities; and an upward-facing electric field mill (JCI-140). To provide extra computing power for the above-mentioned sensors a LattePanda Delta (a single-board computer with an integrated Arduino) is connected to the Raspberry Pi controller over Ethernet.

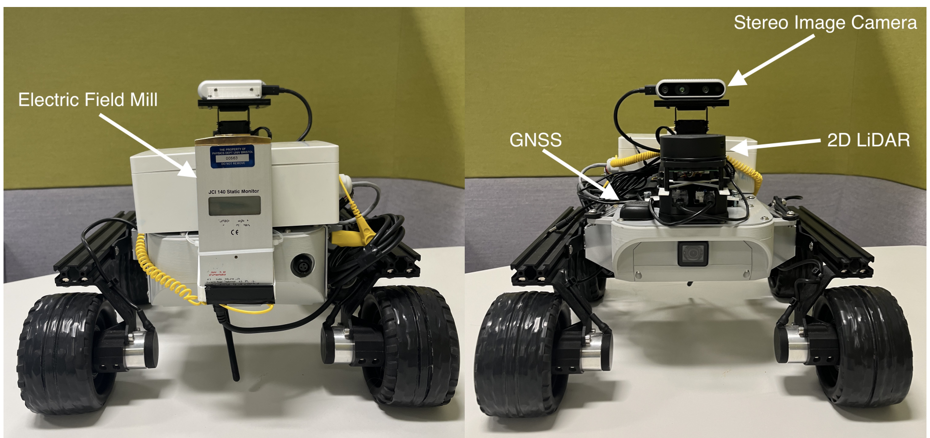

Fig. 1: Leo Rover (back and front) with labelled sensors

The Raspberry Pi operates as the ROS (Robotic Operating System) master, connected to the LattePanda running sensor processing nodes. The Pi is used to do all the physical control of the robot, and it also publishes nodes for both the IMU (inertial measurement unit) and wheel encoders. The LattePanda handles the more computationally intensive tasks of combining the stereo image camera and LiDAR to do Visual SLAM(Simultaneous localization and mapping). The ROS package RTAB-Map [6] is used for this task and allows the creation of a detailed 3D terrain map as the robot moves, which along with the readings from the electric field, will allow the generation of a composite electrostatic map of the outdoor environment [5]. With the deployment of multiple robots (e.g., up to six across an area of multiple kilometres square), this map can be created more rapidly, and also give novel insight into phenomena in atmospheric electricity, for instance in how it interacts with the local terrain.

Fig. 2: Trial 1, Date: 21/07/2023, Start time: 09:24 AM UTC, Scattered clouds

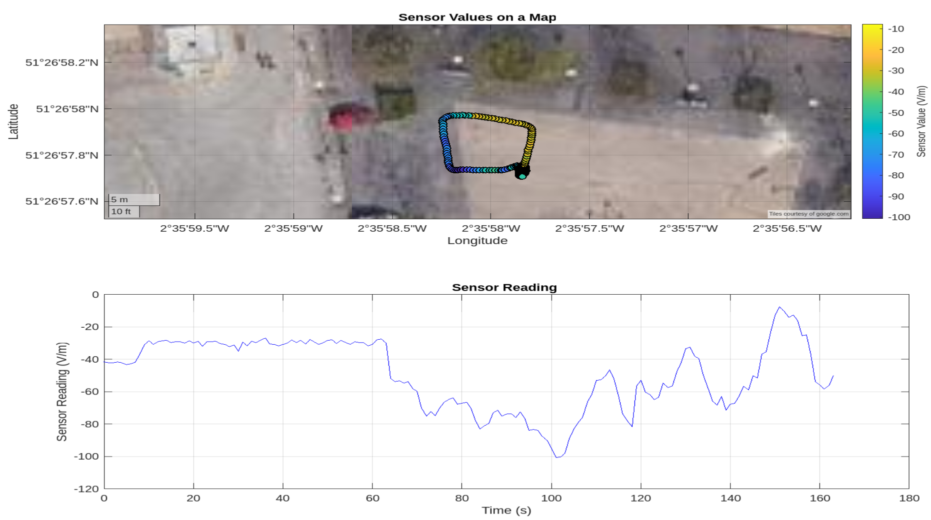

Fig. 3: Trial 2, Date: 21/07/2023, Start time: 09:30 AM UTC, Scattered clouds

3 Initial Trials

Initial teleoperated experiments across a relatively small area (around 20 m^2) used one robot and allowed the plotting of measured voltages on a geographic map using GNSS. Two trials were conducted in the same location, an open urban space. The results of the trials can be seen in Figure 2 and Figure 3, whereby the dots show the electric field measured at each GNSS location, and the line graph shows the electric field meter reading over time. The robot travels in a counterclockwise loop. Plausible voltage readings were obtained in the range -100 to 15 V. A good comparison source is Reading Atmospheric Observatory station[1] which provides daily meteorological data. As we measure the electric field and not the potential gradient a negative value is expected in fair weather.

4 Future Plans

There are several planned work packages to further this research. First, we will calibrate the electrostatic sensor, using a setup where the robot is placed between two metal plates applied with a set known voltage, to determine the relevant correction. Second, we will use *Ansys Maxwell* software electromagnetic field modelling to obtain an appropriate geometric field enhancement factor for the robot, to crosscheck the experimental correction. Third, we will deploy multiple robots with an intermittent communication architecture to create a sparse swarm [8] of electrostatic robots. We will demonstrate cooperative swarm behaviour using (semi-)autonomous choices on where to focus mapping, including the use of expert user input. Fourth, we will develop a simulation of robot swarm electrostatic field measurement on Mars, with a view to the long-term potential of this research in space missions.

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[1] https://research.reading.ac.uk/meteorology/atmospheric-observatory/