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HUMAN NAVIGATION IN PLANETARY EXPLORATION: FINDING YOUR WAY WITHOUT A COMPASS OR GPS

Abstract

The lack of substantial magnetic fields and GPS infrastructures on the Moon and Mars significantly constrain the navigation techniques that can be utilized during planetary exploration. In this paper, we explore how traditional navigation techniques based on celestial navigation can be applied by astronauts in the field to estimate their position relying only on physical hand-held angle measurement devices and printed or digital topological maps. These techniques were tested in the field during a Mars analog simulation at the Mars Desert Research Station (MDRS). The first technique used a hand-held protractor to measure angles between the sun and several prominent identifiable landmarks. These angles were converted to true bearings by referencing the bearing to the sun at the time of observation – determined through solar ephemeris data in a local topocentric frame and through sight reduction tables from a celestial almanac. These bearings were used to draw lines of position on the map to triangulate the observer's position at their intersection. The second technique measured angles between pairs of prominent landmarks. For each pair, a triangle was constructed on the map with the baseline between the two landmarks, and the third point subtending the measured angle. The circumscribing circle of this triangle defines a locus of possible observer locations. This locus was drawn programmatically on a custom web-map application. The observer's position on the map is triangulated by the intersections of loci from multiple pairs of features. During the two-week simulation, EVAs were conducted to various locations, where position-fixes were determined using these two navigation techniques. At each location, a GPS position was recorded as a true value for validation. Both techniques showed promising results, with estimates within 100m of the true positions. The accuracy was primarily affected by the selection of landmarks and the accuracy in angle measurement, which was made difficult by vision and dexterity limitations imposed by the EVA suit. Experiments were made with varying methods of sighting landmarks along the protractor arms. Experiments were also conducted utilizing an android theodolite-like application that uses a phone's gyroscopic sensors to display azimuth angles on the phone's camera display. This provided an useful tool for measuring angles, however provided additional challenges in operation in EVA gloves. This paper analyses results of the accuracy of position-fixes using these various techniques, and discusses lessons learned and best practices for future implementations of these techniques in the field.