Design and application of swarm robotics system using ABCO method for off-Earth mining.

Joven Tan[1], *Noune Melkoumian*[2]

1.PhD student, The University of Adelaide, Adelaide SA 5000. Email: joven.tan@student.adelaide.edu.au

2.Senior lecturer, The University of Adelaide, Adelaide SA 5000. Email: noune.melkoumian@adelaide.edu.au

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ABSTRACT

The concept of in-situ resource utilization (ISRU) was proposed by the National Aeronautics and Space Administration (NASA), and aims to extract and use off-Earth resources from the Moon, asteroids and Mars for long-term manned space missions. Water is one of the most important resources required for maintaining successful long-term manned space missions, and for ISRU in general. The focus of this paper is to develop optimal swarm robot system design and operation strategies for water extraction from superfrozen craters on the Moon's poles. For this, geomechanical characteristics of superfrozen lunar regolith and the specificities of the lunar environment have been considered. Analytical studies and numerical modelling and simulation have been applied to design and evaluate the performance of the swarm robot fleet for off-Earth mining. This involved identifying the optimal number and dynamic interaction of robots in the fleet to achieve the best swarm performance for the considered environment and task. The proposed swarm robot system has been designed based on both behaviour-based and automatic design methods. The performance of the swarm robot systems has been evaluated through the taxonomy of swarm intelligence: both natural swarm intelligence and artificial swarm intelligence using numerical simulations. To achieve nature-inspired design the behaviour of two different insect colonies, namely the ant and the bee colonies have been considered, and the methods of biomimicry have been applied to investigate corresponding swarm robot fleet behaviours. After comparative evaluation of these methods the swarm was built in artificial bee colony optimization (ABCO) method since this was deemed to be better suited for the considered task. The findings from this study can also be utilized and beneficial for on-Earth mining and other geotechnical engineering activities.

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