Automated Design of Off-world Multi-Robot Mining Base Using L-Systems/Bio-inspired Methods

Multi-robot mining operations are being actively considered for offworld locations such as the lunar surface where resources are estimated to be worth trillions. The applications of these resources are numerous. They can be used for in-situ support of other offworld missions such as enabling manufacturing or refueling along a cis-lunar railroad. They can also be used for potential export to Earth to supplement the limited supply of precious metals, which when extracted from The Earth cause environmental concerns. However, for the exploitation of these resources to be in any way profitable, the methods applied to extract and process them must be efficient, and low risk. These concerns are addressed through the use of multi-robot mining which allows for the efficient extraction of material while also limiting the toll that losing part of the system can have on the overall success of the method. Losing one mining robot is not the end of a mission. Still, for a helpful amount of materials to be mined and processed the infrastructure of a multi-robot mining base must be well designed. Earth-brought resources must be minimized while simultaneously the hardiness is maximized. An approach to this base design and the focus of this research is to use L-systems and algorithmic generation for the design of a multi-robot mining and processing facility. Such a system would allow said base to scale organically to its resources available, taking bioinspiration from plant growth and the regenerative properties displayed by some amphibians. An L-system also allows base design to evolve within the constraints of machinery and technology available, growing in increments as more equipment is sent to the base. The alphabet of the L-system can also be outfitted with structures capable of being made using in-situ resources, such as regolith, so that the viability of such structures can be thoroughly tested prior to deployment on a mission. As a multi-robot mining mission would be a long-term effort with multiple stages, the use of an L-system also allows for adaptability to developments that occur throughout the lifetime of the mission. Rules and alphabets can be edited halfway through and the base can make the most of its current design. Much like how trees can recover from falling and continue growing using the fallen trunk for structure. Efficient use of available resources is vital in exploitation of offworld materials to maintain the worthfulness of such an endeavor. Whereas in mining on Earth a great deal of preparatory work may be done in laying the foundation of mining and material processing, in an offworld location such work would be a major hurdle. L-systems allow for the base design to grow organically around the natural topography of whatever site is chosen for a mission. Additionally, the base must have sufficient redundancy and hardiness to be low risk, lest the cost be unjustifiable. L-systems are well suited for not only generating designs with redundancy, but for the redundancy of separate designs to be easily compared, allowing a design to use the same resources and reiterate over itself until it has found a best solution. The result is a tunable and easily adapted algorithmic generative design for a multi-robot offworld mining base. Although specified as being for offworld bases, as more effort goes into proving the efficacy of multi-robot systems a similar methodology may be applied in designing infrastructure to support research operations or Earth-based mining and construction. The design method may also be integrated with distributed control systems, allowing robots within the system to navigate more efficiently and safely.