VIRTUAL LANDSCAPE ASSESSMENT AND ROBOTIC ALLOCATION WITHIN EXTREME ENVIRONMENTS

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Abstract. The paper describes an iterated system, which explores the concept of a surveying, deploying, self-assembling robotic swarm system within an extreme environment, in a virtual robotics platform named VREP. The pure geometries that are the basis of this species, through study of locomotion in Fauna and energy transformations, produce several iterations of the proposed robot. The created species are used to generate a process in which the robotic swarms are able to make initial scans of landscapes using a series of visual and proximity sensors attached to each exposed face, in order to determine proper deployment zones for the making of a research facility. The explorations in locomotion and transfer of potential to kinetic energy would allow the geometrically pure robot to hop, flap, walk, flip or turn in order to move to achieve the desired location.

The intent of such swarming nature of the robots is to create a cohesive unit of operation that is able to overcome the journey of deployment and remove the need for site surveyors and construction workers in order to initiate and construct a research facility. In this manner, the robots then would become the very building blocks that constructs these research facilities and are able to be repurposed to meet certain environmental concerns such as a light construction footprint, reusability and the provision of certain amenities.

With SDA (Survey, Deployment and Assembling) robots, the paper explores the steps needed in order to attain a functioning process from landing and deployment, to surveying and construction; with consideration of the difficulties and potential opportunities of this proposal.

1. Introduction

Having a surveying and deploying robot allows us to venture to many frontiers that are yet to be fully researched and explored either due to the harshness of the environment or the difficulty of setting up in order to conduct the research. Environments such as the Arctic, speak volumes when pitted against projects such as AECOM's Hayley VI. The extreme winters and unpredictable change in weather allowed the constructions workers to operate during summer months only until the project completed (Broughton et al., 2005). The advanced nature of the construction and maintenance required to keep operation of the mobile, modular research facility proved difficult and costly especially in times of crisis (Sawer, 2015).

With the SDA (Survey, Deployment and Assembling) robots approach, we might finally have an opportunity to mass manufacture smart building units that bring about the age of exploration, into areas like the deep ocean trenches which have only been 0.05% explored (Copley, 2014); or extreme deserts, where finding an appropriate area to study then settle into is difficult. This might aid us in the understanding of our planet, especially in the wake of climate change. Perhaps we could even send these robots to the stars; to new planets or moons to survey and construct facilities which astronauts could visit and inhabit upon arrival without the need for construction nor surveying. The mass manufactured nature of these robots would allow a lower cost of manufacturing, while providing a lower risk factor in its line of operation, and unlike very expensive tech like the NASA rovers, these robots are easily replaceable, re-used and relocated and repurposed.

Focusing on desert climates: the research engages a test following a methodology that is taken from a simple idea, yet complexly executed approach. As seen in nature, bees or ants usually send a scout to determine the best locations to find resources for the hive and are possible locations for migration and settlement. In this manner, a scout robot would be sent out to survey the land to find an appropriate landing zone for the swarm of SDA robots. Through teamwork, landscape surveying and assessment, these robots would then be able to determine a flat zone for building a research facility near potential analysis and potent resource zones prior to human inhabitation.

2. Methodology

Methodologically, two approaches to tackle the question of exploration arise; one is to use existing technology as a means to investigate a solution to the proposed problem. The other is to explore a new form of robot that is able to operate in a swarm configuration in order to coordinate and move through obstacles in order to survey and reach a proper operation site for erecting a research facility.

In both approaches, there are two criteria to achieve in order to be successful in the operation:

1. Surveying and measuring the degree of appropriateness of site selection for construction and settlement.
2. Registration of nearby robots in order to assess proper teamwork, overcoming obstacles and laying foundation for construction.

2.1. EXISTING TECHNOLOGY AND SENSORY ENDEAVOURS

Experimenting with rough desert terrain, a Quadricopter is used to test sensor types appropriate for surveying and landscape measurement. Firstly, we attach a ray type, proximity sensor to the belly of the Quadricopter, using a simple mathematical script. The return data of ray casting is in the form of angle degree sets that are used to roughly determine the relative percentage of flatness of the landscape. Using a triangulation method, returning a degree percentage of 0 or 180 equals a relatively flat surface. Though accurate in perceiving flatness, the surge of data input on miniscule changes causes long processing buffer times.

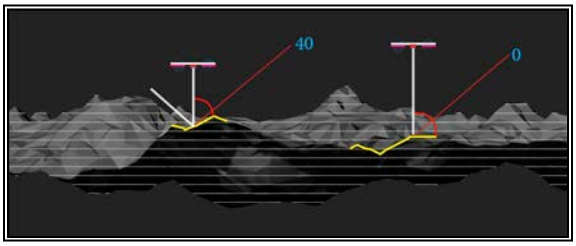


Figure 1. Ray casting and angle measurements.

An alternative method and the focus of this study is to project a 16 x 16-slot grid using a vision sensor located beneath the drone. The projected grid will act as a coordinate pixel plane. Each pixel will have a specific sequence and coordinate, i.e. pixel [1]'s coordinate is equal to (1, 1) on the grid and pixel [2] equals (2, 1), etc. These pixels will act as registration rebound points: when four or more points register as a flat plane, it will trigger a beacon release to mark the zone valid for deployment and construction.

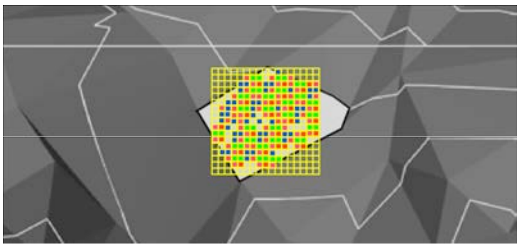


Figure 2. Vision grid casting & registration of positive points.

In the Virtual Robotics Experimentation Platform (VREP), using a virtual landscape and programmable assets, the validity of the proposal is trialed. The Quadricopter's vision sensor is linked to a graph sensor that registers depth by calculating the depth difference between a fixed ray projection from a ray type proximity sensor and the cutoff point. The ray proximity sensor aids to correct several irregularities produced by the current script and its function is to allow the drone to autonomously and randomly scan the landscape for possible valid locations. The main irregularity it tackles is the frequent incorrect hover height when pausing in between movements to scan and survey, thus the addition of the ray proximity sensor helps to recalibrate the *Z*-axis while the drone moves in the *X*- and *Y*-axes. Furthermore, the capping of pixilation counts aids to emit anomalies on the landscape from incorrectly registering as a valid zone for deployment. In Figure 5, the graphs illustrate correct and incorrect registers of planes, while the spike in the graph is a bug that occurs when the proximity sensor intersects the three-dimensional terrain model.

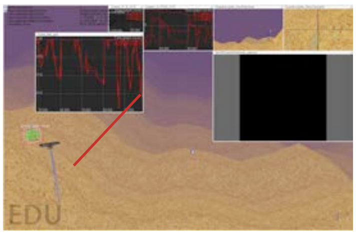
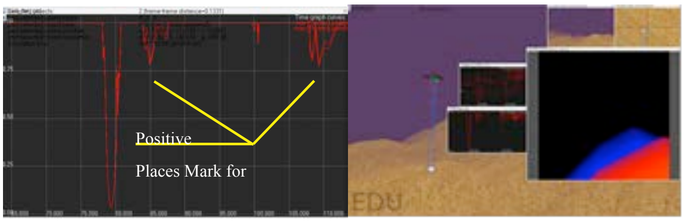


Figure 3. Malfunction of the vision sensor as it fails to gain proper height, causing the laser to intersect heavily with the ground.



Figures 4 & 5. Correct ground registration vie ray and vision sensors.

2.2 SCANNING, DEPLOYMENT AND EXPANSIVE ATTACHMENT

Within any environment, there exists a set of challenges that might create difficulty for proper equipment or construction elements to reach the site; either due to extreme terrain or weather or simply because of resources and expense. The exploration in mind is to be able to overcome all of those possibilities by providing a system in which smart building blocks are set in motion at locations at which it is easier to drop off. This becomes important in scenarios where the drone itself cannot really do much other than the surveying of land. The robots then are delivered to a designated area and would guide themselves to the beacons or designated areas tagged by the survey drone.

Figure 6. The robot in the spawn matrix.

Using a three-dimensional (3 x 3 x 3) matrix projected using a series of vision and proximity sensors, the surrounding of the robot is registered and processed to a receptor that by script is able to register solid from void, neighboring robot or a landscape element. Following the precedent of army ants and weaver ants, the robot relies on collective behavior in order to overcome obstacles and build structures. While currently at a preliminary phase of development, the scheme relies on finding void area within its matrix, that when responding to the call of a beacon would continue fill with other robots as it creates unique structurally stable schemes, which aids it to continue its journey until it reaches the construction site.

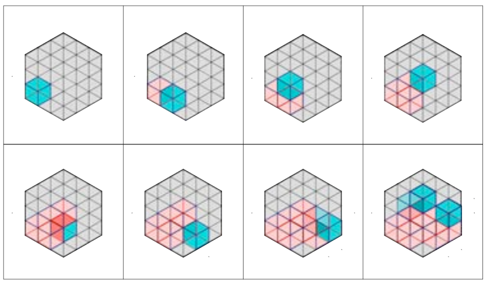


Figure 7. Example process of filling the deployment matrix.

Upon simulation, we created a spawn point at the origin point (0, 0, 0) in VREP, and a script for status display to document the matrix spawn sequences to be called back whenever needed. The sequences (Figure 9), work as a labelling system for each robot, in case one needs to be reproduced for maintenance and/or repurposing to accomplish specific tasks.

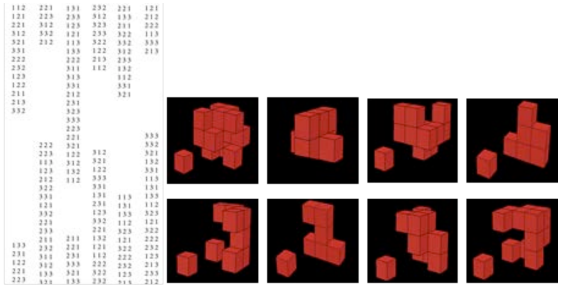


Figure 8. Sequence charting and several iterations of matrix spawning using VREP

Furthermore, the coordinate system within the robot when analyzing the voids, calls upon these iterations in order to decide the best structurally stable scheme to proceed with and eliminate all other options. Once a suitable answer arrives, the script stops further analysis, even if there are other possibilities available.

It is worth noting that if anything challenging occurs as the research develops, the robot's ability to interpret elements of the landscape within the matrix as structural elements, could aid overcoming obstacles and provide foundation support for facilities.

2.3 PROPOSED TECH AND OPERATIONAL LOGIC

Looking at the possibility that these robots would be applied to multiple setting including interstellar exploration, drone usage would not always be viable in many situations; the proposed pure shaped robot would have to accommodate the sensing, surveying and construction as a single holistic approach. Using the several iterations that the project evolved from, the robot could then be registered as a combined approach. Being highly influenced by the intelligence made possible by having overcome the aforementioned obstacles. In the spirit of continuing with using pure shapes as catalysts to the design, the idea calls for two cube shapes that have latches, one positive and the other negative. These cubes are able to topple, toggle and flip in order to move and arrive towards a certain goal, attach and construct.

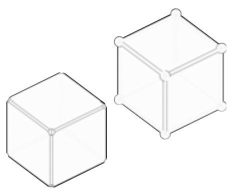


Figure 9. Negative and position set

Actuators attached to the cube allow it to be able to conduct its motion but what is more important is the sensors that would able to register viable ground rather than the having a secondary system like a drone do the scouting. In essence, all the robots have to do then is be delivered to a location on site, or nearby if conditions do not permit.

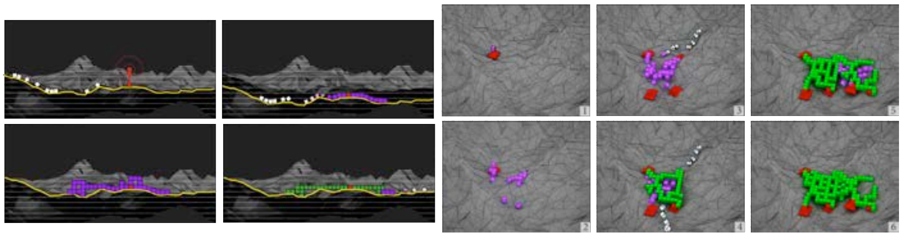


Figure 10. Process of arrival to beacon location to platform completion

3. Possible Applications

The main intent of the project is that rather than using robots as a means to build – a tool rather than the building block – we start to use robots as the builders, the building tools and building material. The approach allows these building block robots to establish research facilities or spaces of occupation in remote and extreme areas. Inspired by the reinvigorated age of exploration on both Earth and the big upcoming Mars mission, this project imagines the settings where the act of construction and of remaining outside is difficult, and surveying land for appropriate locations of settling grueling. With this in mind, instead of approaching the problem by designing deployable structures/architecture, combining the act of research with the act of settlement on the band of mass produced, geometrically simple robots brings much possibilities for automated construction and smart buildings. The modularity of the units allows for the creation of multiple units all with a designated function of operation. An example would be a unit for solar absorption, another for sanitation, air filtering, heating, cooling or insulation, and so on. Specificity perhaps might detract from flexibility of having these units as purely manufactured building blocks (robotic bricks perhaps) but the outcome allows for these robots build a fully functional space geared towards human well-being, especially in extreme environments.

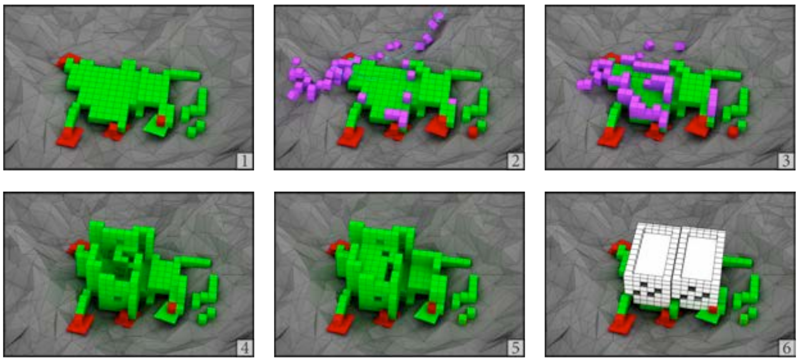


Figure 11. Process of building self-assembly

4. Challenges Ahead

Calibration of the sensors along with the scripting that creates the rules of SDA needs further revision in order for the robots to perform all tasks required of them without relying on satellites or drones. This is nowhere more evident than in the case of the proximity sensors nested in the robot. These sensors attached to each external surface to scan and analyze the landscape face difficulties when the proximity of the sensor to the landscape becomes a stone's throw away. In this situation, the data input might faze up and create confusion on how to proceed and how to register what is nearby.

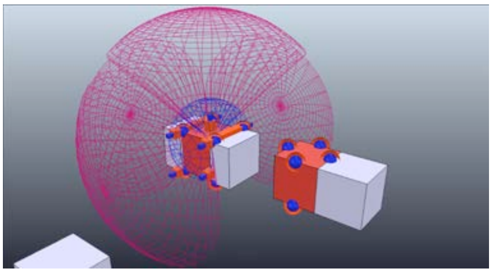


Figure 12. Robot test for proximity sensors and motion through a motor.

The second challenge to solve would be the design of the robot to appropriately accommodate the environment it is deployed to. The use of pure geometric shapes, e.g. a cuboid, hexagon, dodecahedron, etc., in this study was a progressive iterative process, starting with the simplest to manufacture (the cuboid) to the relatively complex (the dodecahedron). The eventual outcome of this search in shapes is to create a series of robots with shapes unique to the environments explored and researched, e.g. a sphere or a tube with half-spherical ends best responds to deep ocean trenches as it withstands the increase in pressure due to increase in ocean depth.

Choosing the triangle (can generate many other shapes, e.g. square, octagon, trapezoid, etc.) as a base shape to generate several species that are able to latch, move, and aid one another to achieve certain tasks, yielded several interesting results. The two most prominent were the hexagon-shaped robot and the dodecahedron robot.

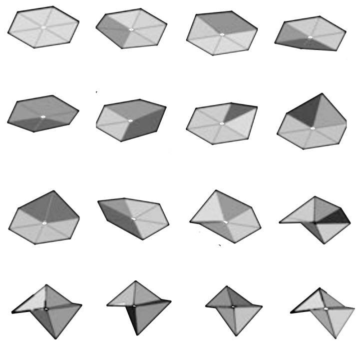


Figure 13. Hexagon robot iteration, studying transformation and locomotion possibilities.

The use of the triangular outlines of the hexagon as joints and their tip points as placements for actuators creates a flexible and malleable robot, capable of moving by flapping, jumping and walking by manipulation of form to determine the best possible method to succeed in its task. The iteration may lead to answering to several needs and services, from transport, to building units and energy harvesters (robot surfaces as solar panels).

Though the dodecahedron offered a multitude of ways to move and navigate through environment, two notable ways is by rotation and the use of angular motion and peristalsis, i.e. a snake-like motion. The ability it has to pull or rely on other dodecahedrons allows it overcome vertical obstacles or even stack up in rows without any extra aid, allowing it to create platforms, walls and even columns.

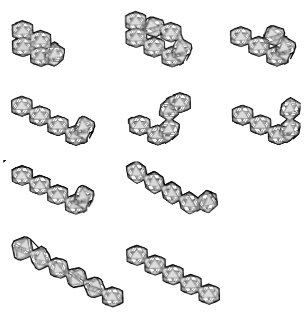


Figure 14. Dodecahedron robot iteration, study in motion, flexibility and assembly.

5. Conclusion

The attempt to allow robots to become buildings blocks offers many opportunities and restrictions to design approach and methodology. The research here limited such approach to architecture of the extreme, in environments where construction would be difficult. In these conditions, the design aesthetic would become less important since this eliminates design restrictions and the need to justify culture type. Instead, it is driven by the need and necessity to achieve a goal and a task. Such design problems allow extreme solutions to occur. The heavy reliance of modular self-assembling robots would allow for ease of manufacturing, processing and even assemblage. In that regard, parts could both remain permanent until in need of replacement due to age or malfunction or be a recyclable element that can be used at other locations when needed. These species then would allow for a future of architecture that is automated and iterative by nature's decree as a robot responds to that environment, bringing us to an age of sensitive design ruled by the troubleshooting brain of an elemental robot.

Acknowledgements

Mark Collins
Toru Hasegawa

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