BloomBot, a Creative and Autonomous Land Art Robot

James Sham, Mark L. Jennings, and Ashish D. Deshpande

***Abstract*— The majority of artistically skilled robots share two conventional premises: (1) they produce creative works that are entirely two-dimensional and (2) they use art historical precedents as exemplars for replicating human creativity. In this paper, we present the plans for BloomBot, a mobile Land Art robot designed to explore beyond these conventions. BloomBot will use the landscape as its canvas and a variety of seeds and bulbs as its medium, learning from both the actions of artists and an updating art database to autonomously create compelling 3D Land Art installations. BloomBot has the potential to bridge the gap between artistic and agricultural robotics, forming an intersection between industrial and creative research problems. This paper will present the planned mechanical design of BloomBot followed by its software in regards to contemporary art robotics.**

I. Introduction

Land Art, or Earthworks (a term coined by Robert Smithson) has a rich history both within the conventions of canonical art history as well as in many non-canonical traditions. From Robert Smithson's Spiral Jetty [1], to the Nazca Lines in Peru [2] and the newly popularized Tambo āto (Rice Paddy Art) in Inakadate, Aomori, Japan [3], artists have gravitated towards using the earth and land as a creative medium throughout history [4]. Contemporary artists continue the lineage of this history in a variety of forms, from James Turrell's long-awaited Roden Crater project, to Daniel Bozhkov's crop circle portrait of Larry King [5] (Fig. 2). Typically, artists use the tools and methods of construction and agriculture to produce such works, although there has been some integration of computer modeling to plan and stage the Rice Paddy Art of Inakadate, Aomori.

The design for BloomBot, currently in fabrication, was conceived to explore the possibilities of artificial intelligence and automation within the Land Art tradition, with dual purposes in mind. Firstly, BloomBot will function as a tool for contemporary artists to generate creative Land Art projects with more precision and specificity than previously possible without sacrificing scale. Secondly, in this role BloomBot will function as an apprentice to contemporary artists, learning directly from their creative processes rather than solely from historical exemplars. This represents a novel approach to robotics research in the creative fields, where creativity is

J. Sham is a professional artist and Assistant Professor of Innovation Arts at George Washington University, 801 22nd Street, NW, Room 101 Washington, DC, 20052, USA jamesthesham at gmail.com

M. Jennings is an undergraduate student of Mechanical Engineering, The University of Texas at Austin, 3.130, ETC, Austin, Texas, 78705, USA markjennings at utexas.edu

A. Deshpande is an Assistant Professor of Mechanical Engineering, The University of Texas at Austin, 3.130, ETC, Austin, Texas, 78705, USA ashish at austin.utexas.edu

Figure 1. BloomBot is a 4WD, 200lb robot capable of planting a variety of seeds and bulbs in rough terrain. It can plant in the pattern of a user-inputted image or generate its own creative works. Due to its organic curves and facial features, it bears resemblance to an insect.

(a) Robert Smithson. *Spiral Jetty,* 1970, 15' x 1500', Mud, precipitated salt crystals, rocks. Photo Credit: Ray Boren

(b) Daniel Bozhkov. *Learn How To Fly Over A Very Large Larry,* 2002-2003, 300ft x 400ft crop sign, flying lessons, AP wire, CNN broadcast, botanical survey

(c) The Nazca Lines, Nazca, Peru

(d) *Portrait of Naoe Kanetsugu*, Inakadate village, Aomori prefecture, Japan

Figure 2. Land Art is one of the most globally and historically present forms of art. Due to its large scale, complex geometry, and unusual materials, it is not as often pursued in robotics research as image-based art styles such as painting and drawing. In contemporary art, Land Art continues its legacy in increasingly eclectic and unconventional materials and methods.

defined not only by the end result of a process, but also by the process itself.

II. Mechanical Design

A. Function of Aesthetic Design

The most common first impression of BloomBot's design is its resemblance to a primitive insect (Fig. 1). Among first design principles was the edict to create something in a liminal state of evolution, like a creature having just crawled from the ancient waters to walk on land. The combination of this aesthetic with contemporary materials was chosen to convey design cues from either side of our current evolutionary position; BloomBot is both primordial and space-age. This personifies the robot as both familiar and alien, a design strategy geared towards producing a symbiotic relationship with the user. This relationship will encourage the user to consider BloomBot as both a tool and a semi-autonomous apprentice, supplying data behind artistic processes to help BloomBot form an independent creative profile.

B. Profile

The curved profile of the robot's shell was designed to complement the functionality of its inner components in a variety of manners (Fig. 3). The shell design is comprised of an upper and lower half. The upper half accommodates a lithium-ion battery, a center drill assembly and "seed tubes", which function as cartridges for a variety of seeds and bulbs. The lower half of the shell houses dual funnels that direct each seed or bulb to precise planting locations. The suspension system has two rods hinged on a central axle, optimized for a wide variety of terrains, while also bearing a resemblance to insect legs. At the front of the robot is the control center, or "head", while in the rear is the battery, balanced for weight distribution to provide traction during drilling and locomotion. The head area has room for microcontrollers, a touchscreen display, sensors, and prototype boards in an easily accessible area.

C. Mobility and Suspension

BloomBot is designed with a four-wheel drive (4WD) system operating at a walking speed of 5kmph (3.1mph), with a battery life of 2hrs or more. A tank-style turning system will turn the tires on opposing sides in opposite directions at the same speed, allowing it to rotate in place. Each 25.4cm (10in) wheel will be powered by a 216 RPM gearmotor at 12V DC.

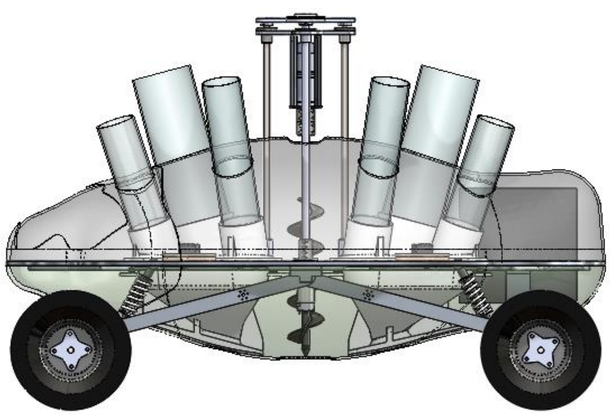

Figure 3. The vacuum-formed shell of BloomBot rises and falls to be a compact container for the parts within.

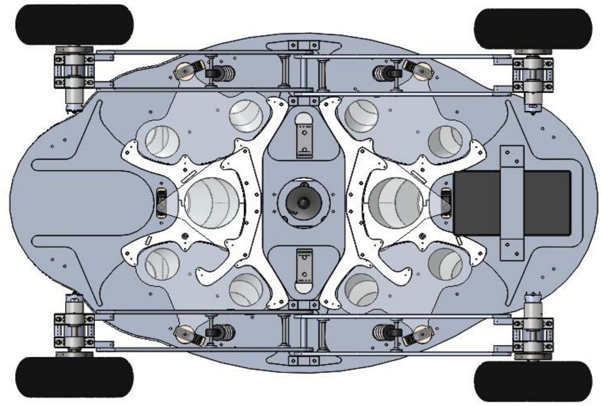

Figure 4. A series of 4 coupled and 2 individual radial acrylic flaps control when, why, and which seeds are dispensed from BloomBot's 10 tubes.

In order to maximize traction and minimize vibration, the design incorporates a suspension system to ensure that all 4 wheels are in contact with the ground at all times. The mechanism will use rear bicycle shock absorbers (with stiffness 150lb/in) connected to hinged rods for individual support of each wheel and motor system.

D. Drill Mechanism

Protruding from the top of the shell is a 78 RPM gearmotor coupled to a 7.6cm by 70.0cm (3" by 24") earth auger. A custom linear actuator made from a ball screw, 2 linear rails, and a 512 RPM gearmotor will control the height of this drill through encoder feedback. The drill is designed to be lowered incrementally to bring dirt to the surface in stages, decreasing the average load on the gearmotor. This mechanism can drill holes up to 30.5cm (12") deep.

E. Seed Distribution

BloomBot will store seeds in 10 acrylic tubes, clear so that the amount of remaining seeds can be easily discerned. The tubes will come in two sizes, so that the robot is optimized for seeds less than or equal to 7.6cm (3") in diameter, but can also handle small quantities of 12.1cm (4.75") bulbs. The seed tubes connect to 3D printed mounts that are bolted to the frame. The 8 smaller tubes on the edge of BloomBot will be opened and closed by 4 acrylic flaps rotated by high torque servos. The 2 larger tubes will have acrylic flaps that are actuated by individual servos and checked by limit switches (Fig. 4). Once a seed is released from a tube, the flap moves back to its neutral position, and the seed falls into the previously drilled hole. After planting the seed or bulb, the robot will drive over the hole to push the topsoil back in, completing the planting process.

III. Software

A. Sensors

BloomBot is designed to be GPS guided, receiving signals from an antenna on the drill assembly and processing them with a GPS breakout module. Unfortunately, GPS signals are only accurate up to 4m, so position and orientation must be double-checked. Encoders on the drive shafts output the angle of the rotating shaft, which can be translated into speed, relaying the robot's position as a function of time and orientation. While the encoders can also sense if the shafts are moving in opposite directions (an indication that the robot is turning), they are not an accurate indication of the direction the robot is facing due to slippage and accumulated error. [6] In order to derive orientation, an Inertial Measurement Unit (IMU) will be implemented. The orientation, outputted in Euler angles, will give BloomBot both the direction it's facing as well as the pitch of the ground below it, especially useful when planting on an incline of up to 40°. Using orientation, distance traveled, and vector geometry, BloomBot's position can be mapped as a Cartesian point to be compared with the GPS reading.

While BloomBot plants Land Art installations, it has the practical ability to measure many important data points, a useful tool to decide what to plant and how to monitor it. Some of these sensors will include: temperature, humidity, sunlight intensity, ground color, and soil moisture. All of these values are passively stored in an SD card to be used for future processing. More importantly, all of these data values influence BloomBot's programmed behavior. Just like a human, BloomBot will react to changes in heat, humidity, and sunlight, altering its artificial mood and ultimately where and what it decides to plant.

B. Programmed Behavior

Before BloomBot attempts to make research breakthroughs in original creativity, it needs to be equipped with practical guidance software. One of the most common and necessary functions is obstacle avoidance. Three ultrasonic rangefinders will detect obstacles up to 6.5m away, locating objects and communicating with the drive system to maneuver around them. Moreoever, while BloomBot's 100Ah battery can last several hours, the scale of a typical Land Art project often takes more time and energy than this allows. Rather than stalling in the middle of a field, BloomBot is designed with a "Return to Home" function by which it can navigate to a predetermined location at a specified low battery percentage. In future models, this location will house a combination solar charging/battery swap docking station, equipped with a seed refill module. When BloomBot interrupts a planting routine to charge or refill seeds, it can return to where it left off and immediately continue. In order to finish planting as quickly as possible and preserve the most energy, BloomBot will determine the layout of its routine and pre-calculate the quickest route possible with movement vectors.

One of the highest priority goals with BloomBot is to make it function and relate both as an apprentice and as a tool. From a data gathering perspective, BloomBot is designed to fill the role of an apprentice in order to learn from creative processes rather than outcomes. In her discussion on computer-generated art, Margaret Boden distinguishes between a tool and an apprentice. A tool, for Boden, merely provides aid rather than assistance because it remains under the control of the user. An apprentice acts as an assistant by offering new strategies for creativity [7]. BloomBot has both a "tool" mode and an "apprentice" mode. In "tool" mode, the artist can simply upload an image file for BloomBot to plant/print into the landscape in an unsupervised manner. In "apprentice" mode, BloomBot uses the aforementioned distance and GPS sensors to follow an artist and execute a planting on site, taking orders from the user to create the artwork. During this process, BloomBot will stop periodically to ask questions of the artist, as would a human apprentice. BloomBot compiles these answers, as well as movement data, to create a profile for each artist. This profile includes both quantitative and qualitative metrics, such as results from a Myers-Briggs personality test, canine or feline preferences, and irritability patterns. Like a typical human apprenticeship, there will be times when the artist will dismiss questions by telling the robot apprentice to continue working in a raised voice. When a user's voice is raised beyond a threshold decibel level, BloomBot quietly gets back to the task at hand. This type of repeated interaction however, will result in a slower development in the learning module of the robot; the more a user invests in the relationship, the more questions get answered, and the more data is collected. Over time, BloomBot will develop its own creative profile and preferences, enabling it to correlate factors behind the creative process with finished artworks.

BloomBot will also be equipped to learn from creative exemplars by using a database of perpetually updating images. These images will be sourced from contemporary art magazines, historical archives, and even prehistoric works. Once BloomBot has analyzed this database, it can use the data to manipulate its art practice, involving current trends and paying homage to past ones. If for instance it perceives a slight trend in the images found in contemporary art journals towards certain formal elements, such as color preference and line weight, it will correspondingly incorporate these elements in the visual vocabulary it uses to produce its own works.

Another important design feature of BloomBot's software is a lively and personable interface. The goal of this is to enable users to relate to BloomBot, treating it more like a companion than a robot. Like a human apprentice, BloomBot will have a "mood", generated by several factors, such as the weather, time of day, battery life, urgency, and personal history. The robot's "mood" is even affected negatively if a user yells too often at it. BloomBot develops a "mood" profile based on these internal and environmental factors and on the experiences it accumulates over time. For instance, if a BloomBot is activated and spends most of its early life in cold wet climates, it will be "happier" in such environments. After working with artists, BloomBot might learn that people exhibit a certain creative preference when happy, such as a predilection to warm colors. BloomBot will then translate this color partiality to its own practice, exhibiting these preferences when in the climates that it has correlated to a state of "happiness". If a BloomBot experiences "unhappiness", it will favor battery efficiency over action, requiring positive user input (in the form of questions and answers) to overcome its lethargy.

A 127mm (5”) LCD touchscreen will be embedded in BloomBot’s control center, with a “Doodle” function allowing users to draw a picture on the screen and send BloomBot to quickly disperse bird feed in the pattern drawn. This function does not require the use of the drill, and it produces patterns and shapes for the enjoyment of birds and bystanders. This feature was important to develop in order to enable a relationship between the artist and robot based on play. When a robot functions solely as a tool, artists use the robot with more direction and less improvisation. The “Doodle” function allows BloomBot to quickly create images on a smaller scale.

IV. Discussion

A. Challenges Facing the Research Paradigm

While there have been impressive advances in the field of artistically skilled robots, there are several acknowledged challenges to developing research around the task of automating creativity. One of the most notable challenges is that there is an unexplained bias in artistically skilled robotics research towards Painting and Drawing as a medium. One suggested explanation is that Painting and Drawing are easier forms of art to replicate via machine, and can be finished relatively quickly for feedback. Regardless of the reason, the majority of artistically skilled robots begin with an image-based input, and produce like image-based outputs. BloomBot is a half-step in the direction of 3D media, but still functions largely on an image-based platform. With some creativity, BloomBot can be utilized to incorporate alternative inputs (i.e. it can follow a performance artist or modern dancer through a site and create installations based on positional movement rather than image).

As research tools, the major drawback to Painting and Drawing robots is that they do not generally facilitate widespread engagement with contemporary artists as a research demographic. There are increasing trends in contemporary art towards reinventing processes and using increasingly eclectic materials, making the task of designing a “contemporary art robot” akin to aiming for a constantly shifting target. Furthermore, for artists who are strictly interested in Painting and Drawing, art robots often displace the artist, rather than create a role to work alongside the user. In most platforms, artistically skilled robots replicate, and thereby replace the artist as a mode of production. In more exploratory platforms, creative robots function more as a tool for which to automate artistic processes; they function as an extension of the artist’s will. Artistic robots such as cloudPainter, developed by Pindar van Arman, are programmed to work with an audience of users via the internet and crowd-sourced mouse and keyboard controls (Fig. 6). The Painting Fool, another collaborative robot, learns from artists around the world [8] with the ambition of generating emotionally aware artworks that may have meaningful content for a human audience [9].

As we have suggested earlier in this paper, an approach that combines learning from both the creative process and the corresponding end result is better than one based solely on art historical imagery. There are a plethora of admirable robots that learn from such historical imagery, such as Vangobot [10] and The Next Rembrandt [11] (Fig. 7, Fig.8). Curiously, they seem to have a predilection for European and American

Figure 6. *Crowdsourced Washington*, created by cloudPainter with hundreds of online collaborators.

painting traditions, perhaps reflecting user biases towards conservative trends in art history. On the other hand, there are incredible research advancements in the subfield of machine learning, where robots can learn from human processes as much as from outcomes. This is especially true for robots designed for physical rehabilitation [12] and medical application [13]. Future artistically skilled robots could benefit from crossover between these subfields of research. If reinforcement machine learning, or at least supervised learning models can be utilized in artistically skilled robots, they might better replicate the more virtuosic and unanticipated results of the human creative process.

B. Problematizing Creativity

Creativity in the human species already has an elusive definition, and determining the necessary features of creativity in robotics presents a philosophically complex task. It is questionable for instance, whether producing original images simply by replicating art historical styles and precedents in new combinations truly constitutes a creative act. The educational norm is to teach creativity beyond the act of visual mimesis. Creativity might require moments of interpretation, or even still, self-interpretation. It is unclear as to how this might be achieved in robotics beyond a visual image-based analysis.

Creativity in the contemporary arts increasingly involves decision-making and problem-solving in nonvisual, conceptually-based methodologies. In short, replicating the “look” of an artwork is not the equivalent of understanding

Figure 7. Vangobot is a flatbed painter that recreates paintings in a variety of programmed styles.

Figure 8. *The Next Rembrandt* replicated the famous Dutch painter's work by digitally analyzing 346 of his known paintings.

the creative process of any particular artist. The appearance of creativity is not creativity. This is especially true of contemporary art trends where conventions in media, concept, production, fabrication and exhibition have become increasingly decentralized from the historical norm. Consequently, much of the research in the field of robotics and creative automation has produced an odd and unnecessary gap between artistically skilled robots and fine arts as a practice. Many robot-made paintings and drawings are impressive for the fact of how they were made, but may not pass contemporary fine arts litmus tests of connoisseurship and criticism. Something like an art-related combination Turing/Lovelace test is required, where contemporary critics evaluate robot-made and human-made artworks alongside each other based on human values and accepted models of criticism. The logistics of this task seem complex on the face of it, as art criticism generally relies on having much of the information regarding the artwork, including provenance, authorship, and method of fabrication.

The BloomBot project endeavors to demystify the processes behind creative pursuits by working alongside contemporary artists in a reinforced learning model. Artistic processes often appear to outsiders as inefficient, illogical or sporadic—qualities commonly found in creative practice. Artists often intentionally choose processes that are less than efficient, non-linear, and exploratory for the specific purpose of producing unanticipated results. It remains an elusive task for a robot to surprise itself, a defining element in Margaret Boden's formulation of creativity. Notably, Boden's rubric of Exploratory and Transformative creativity offers possible pathways for producing future robots that can engage in practice with conceptual and contemporary art.

BloomBot attempts to do so in the subfield of Land Art, correlating the inefficiencies of the human creative process to actual end results. By using apprenticeship as a model of learning, BloomBot is a small step in the direction of prioritizing the creative process in robotics research. The notion of a robotic apprentice might be developed further by incorporating machine learning, as well as defining a task open-ended enough to be repurposed creatively by artists. One of the greatest challenges to creating an artistic robot is predicting how an artist will use it. Artists like Harold Cohen, writer of the celebrated creative AI program AARON, constantly recast their role towards automation in creativity. At times in his career, Cohen treated AARON as an independent entity, a program that designs and executes artworks autonomously. At other times Cohen redefined his relation to AARON, treating the program as a tool to create underpaintings to be finished by hand. [14]

To research the creative process fully requires learning from encounters with actual working artists. Creativity itself is a notoriously complex and difficult concept to define, and enabling artificial intelligence platforms to learn directly from artists in practice, in addition to learning from finished artworks, goes a long way towards the goal of producing a more comprehensive creative robot.

REFERENCES

[1] R. Boren, "Spiral Jetty and Great Salt Lake," in http://epod.usra.edu, 2010.

[2] D. Delso, "Líneas de Nazca, Nazca, Perú," in http://commons.wikimedia.org, 2015.

[3] "Sengoku Busho of Rice Field Art," in https://commons.wikimedia.org, 2009.

[4] B. W. Survey and B. Wallis, Land and Environmental Art, J. Kastner, Ed. London: Phaidon Press, 2005.

[5] K. Johnson, "Learn How to Fly Over a Very Large Larry," in The New York Times, Arthur Ochs Sulzberger, Jr., 2003.

[6] I. Zunaidi, N. Kato, Y. Nomura, and H. Matsui, “Positioning System for 4-Wheel Mobile Robot: Encoder, Gyro and Accelerometer Data Fusion with Error Model Method,” *CMU. Journal*, vol. 5, no. 1, pp. 1-14, 2006.

[7] M. A. Boden, Creativity and Art: Three Roads to Surprise. Oxford: Oxford University Press, 2010.

[8] S. Colton, “The Painting Fool Teaching Interface,” Dep. of Comp., Imperial College, London, UK. 2012.

[9] S. Colton, *The Painting Fool: Stories from Building an Automated Painter*. 2011. ch. 1, sec. 1, pp. 1-4.

[10] J. Gurney, "Vangobot," in http://gurneyjourney.blogspot.com, 2013.

[11] B. Korsten and E. Flores, "The Next Rembrandt," in https://www.nextrembrandt.com/.

[12] J. Snoek *et al*., “An Automated Machine Learning Approach Applied to Robotic Stroke Rehabilitation,” Univ. Toronto, ON, Canada. 2012.

[13] K. Kourou, T. Exarchos, K. Exarchos, M. Karamouzis, and D. Fotiadis, “Machine Learning Applications in Cancer Prognosis and Prediction,” Comput. Struct. Botechnol. Journal, vol. 13, pp. 8-17, Nov. 2014.

[14] L. Sundararajan, "Mind, machine, and creativity: An artist’s perspective," The Journal of Creative Behavior, vol. 48, no. 2, pp. 136–151, Dec. 2013.