Ant Paintings Based on the Seed Foraging Behavior of *P. barbatus*

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Abstract

We describe our conversion of a simulation of the seed foraging behavior of the ant species *P. barbatus* to a generative art technique for creating ant paintings. We also show how the key parameters involved influence the results.

1 Introduction

Ant paintings trace their origins to the ant colony simulation experiments of Ramos [18, 19]. These experiments led directly to the physically embodied collective robotics paintings of Moura [15, 16]. Monmarché et al. [2] appear to be the first to have actually used the term “ant painting” to describe abstract images made by *virtual* ants that roam over a toroidal grid. In their model, 4 to 6 virtual ants paint by depositing “scent” in the form of one color while searching for scent in the form of a different color. Greenfield [7] evolved ant paintings using a very similar model but with 8 to 12 ants. Urbano [21] considered an ant painting model where individual cells in the environment exuded virtual scent to attract ants. Because cells ceased to exude scent after they were first visited by an ant, once all cells are visited and painted according to the colors assigned to the ants, the painting was finished. Greenfield [6][7] further developed this model by having the ants also exude virtual scents which acted as ant attractants or repellants. A gray scale version of an ant painting model from Greenfield [10] was also used by Greenfield and Machado as part of an artists and critics simulation [13].

The first ant paintings faithful to a biological model were executed by Urbano. He appealed to a model for nest construction by the ant species *T. albipennis* [22]. Here, virtual ants use a stochastic virtual sand grain foraging, collecting, and depositing algorithm in order to construct circular walls defining their nest’s outermost boundary. By carefully specifying radii, centers, and sand grain color preferences, Greenfield used this same technique to develop ant paintings composed of symmetric patterns of circles [11, 12]. Greenfield [5] has also modified an ant colony model proposed by Jones [14] for visualizing evolution and formation of plasma transport networks of the slime mold *Physarum* to develop ant paintings which he called called “network transport overlays”. For both of these these physically motivated ant painting models the environment is toroidal.

In this paper we develop an ant painting technique based on the seed foraging behavior of the ant species *P. barbatus*. It does not use a toroidal environment.

2 *P. barbatus* Seed Foraging Behavior

The guiding theme of a recent book on ant behavior by biologist D. Gordon [4] is that many ant behaviors are governed by the *rate* of interaction with other ants. In particular, for the species of harvester ant *P. barbatus*, seed forager recruitment is controlled by the rate of return of seed bearers. Although, certain specifics and technical details are scattered in the literature [1, 3, 17, 20], the general nature of the seed foraging behavior is summarized in [4] as follows:

To initiate foraging patroller ants leave the nest to determine the days foraging trails. The patrollers meander around the foraging area, and eventually return to the nest. The patrollers put down a short chemical on the nest mound only about 20 centimeters long that shows the foragers which direction to take when they leave the nest. Foraging begins when patrollers return at a rate of about 6 per minute. When a forager follows a patroller marked direction, it may travel another 20 meters in that general direction. Once a forager goes out, it searches until it finds and brings back a seed. The forager then waits inside the nest entrance until it meets enough foragers returning with food to be stimulated to go out again. Interestingly, for all subsequent trips after the first one, "a forager proceeds directly to the site where it first found food that morning, and then searches around for another seed. Once it finds food it goes directly back to the nest" [4, p. 60].

A visualization of the foraging pattern that occurs from simulating the search phase in shown in Figure 1 which is reproduced from Greenfield [9]. It simulates one hours' worth of foraging by 3780 foragers on a 2000×2000 grid of cells. Only about half the foragers are actively foraging outside the nest at any one time. It is important here that the environment is not toroidal.

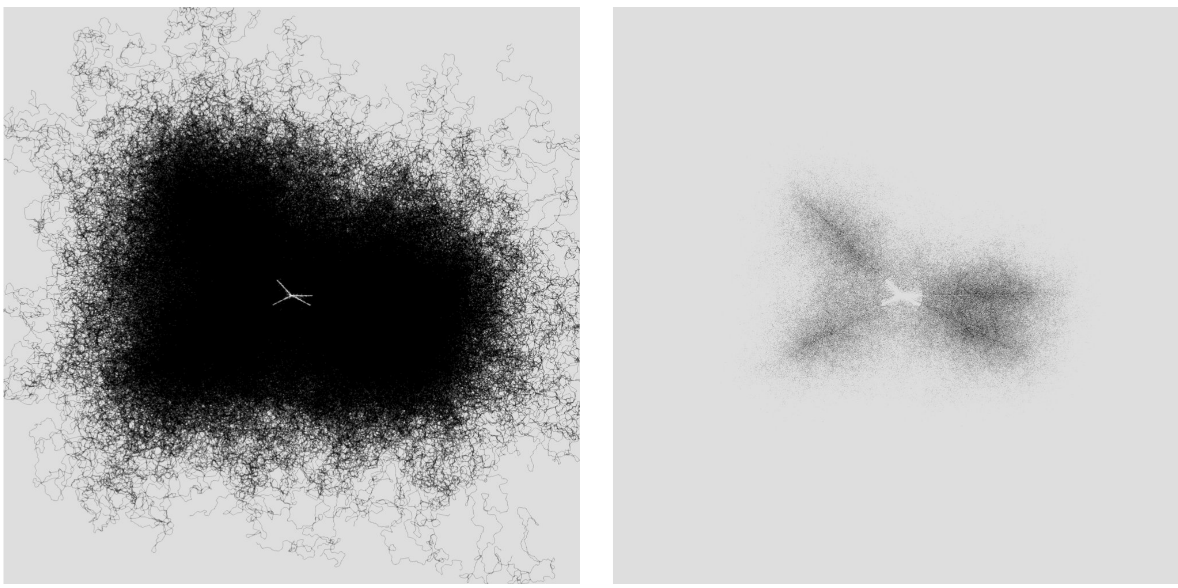

Figure 1: Left: The grid cells visited during the *search* phase of one hours' worth of foraging. Right: Those same grid cells weighted by visitation frequency in order to reveal the areas where seed foraging is concentrated.

3 Stylization of the Foraging Pattern

Our goal is to visualize in a more aesthetic way the underlying complexity of the pattern that occurs when the initial wave of foraging ants streams out of the nest, finds their *first* seed of the day, and then returns to the nest.

In order to do so, we simulate the release of 1000 ants over the course of 500 time steps. Each ant follows one of n patroller trails. Since it tends to look "wrong" from a compositional standpoint if the patroller trails are simply arbitrary as in Figure 1, we "symmetrize" the pattern of patroller trails by spacing them uniformly so they are separated by $360°/n$. Ants streaming out along the same trail do so in a tight beam that is only $1.5°$ degrees wide. The ants "break off" from the patroller trail in such a way that the distribution of their distances from the nest entrance located in the center of the canvas are approximately normally distributed.

Once they break off from the trail, the ants then initiate a quasi-random walk — they meander — in search of seeds. Seeds are uniformly distributed in the 1000×1000 cell environment in such a way that the number of seeds per cell (the seed density) is 0.02. At this density, in order for the simulation to remain faithful to empirical results obtained from field studies regarding the length of time it should take to find a seed, the decision as to whether or not to award the seed to the ant when it is encountered must be stochastic. A seed is collected from a found seed dispenser with probability 0.4.

It is not known if ants sense seeds in some way or just stumble upon them, hence it is clear that some version of a random walk is called for. From observation, it is obvious that an ant's random walk is not "truly" random in the sense of changing direction at each time step, thus we call the algorithm we use a "quasi random walk" to indicate that ants actually travel a few cells before changing direction. Moreover, change in direction is restricted so that an ant veers up to at most 60 degrees off its current heading.

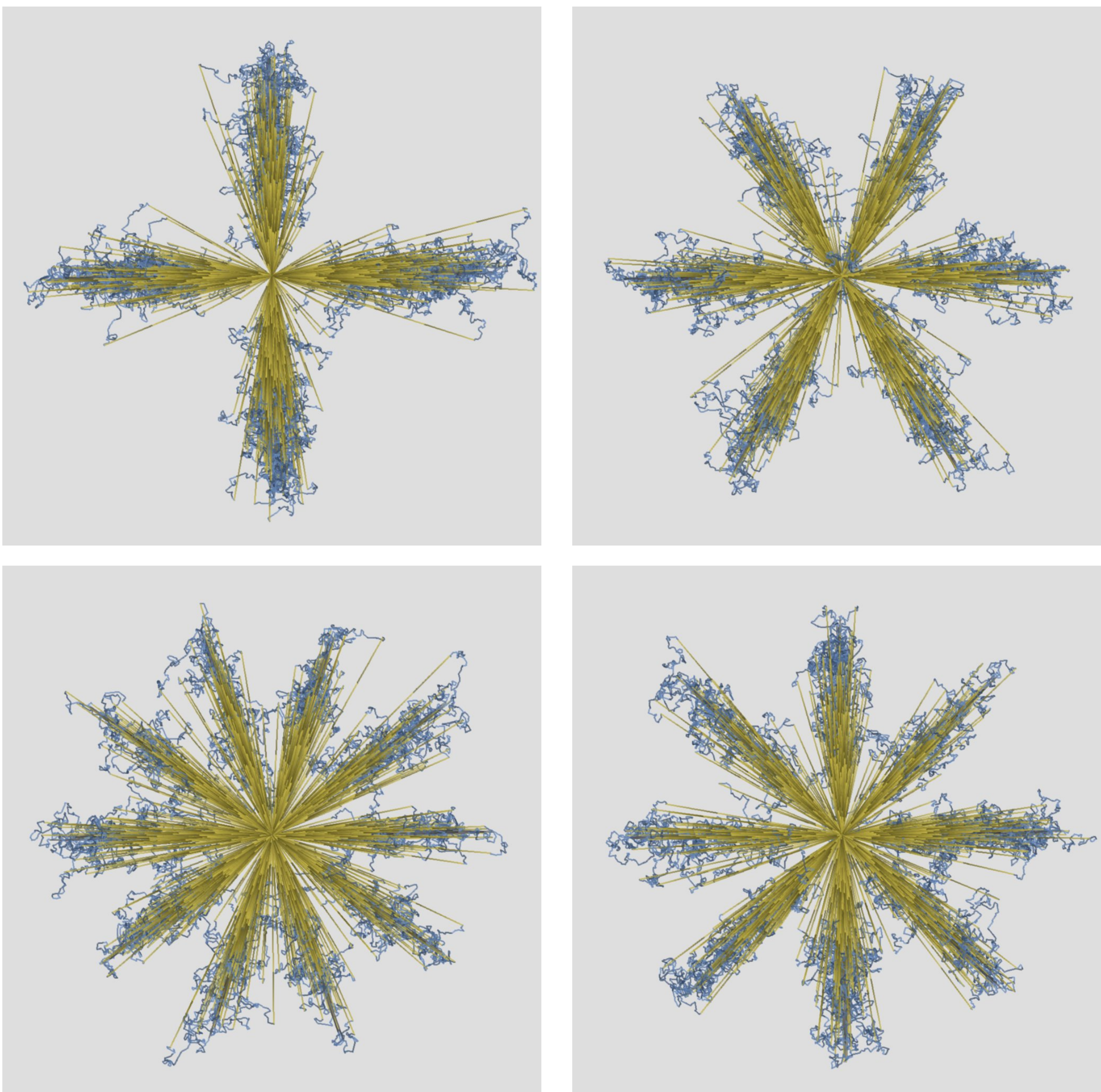

Figure 2: Clockwise, seed foraging patterns using 4, 6, 8, and 10 patroller trails.

The precise mechanism that ants use to return directly to the nest after they have found the first seed is also not known. It has been suggested that they are able to navigate by the angle of the sun. We use two different colors to distinguish between the search phase and the direct return phase to the nest. Further, we modulate the color for better definition of the trail. Figure 2 shows foraging patterns using 4, 6, 8, and 10 patroller trails.

To return to the key parameter that governs the quasi-random walk search phase — the number of cells an ant is expected to traverse before it veers — using a slightly thicker line, Figure 3 shows how the foraging pattern is affected as this parameter takes on the values 2, 4, 6, and 8. Note that the default is 6.

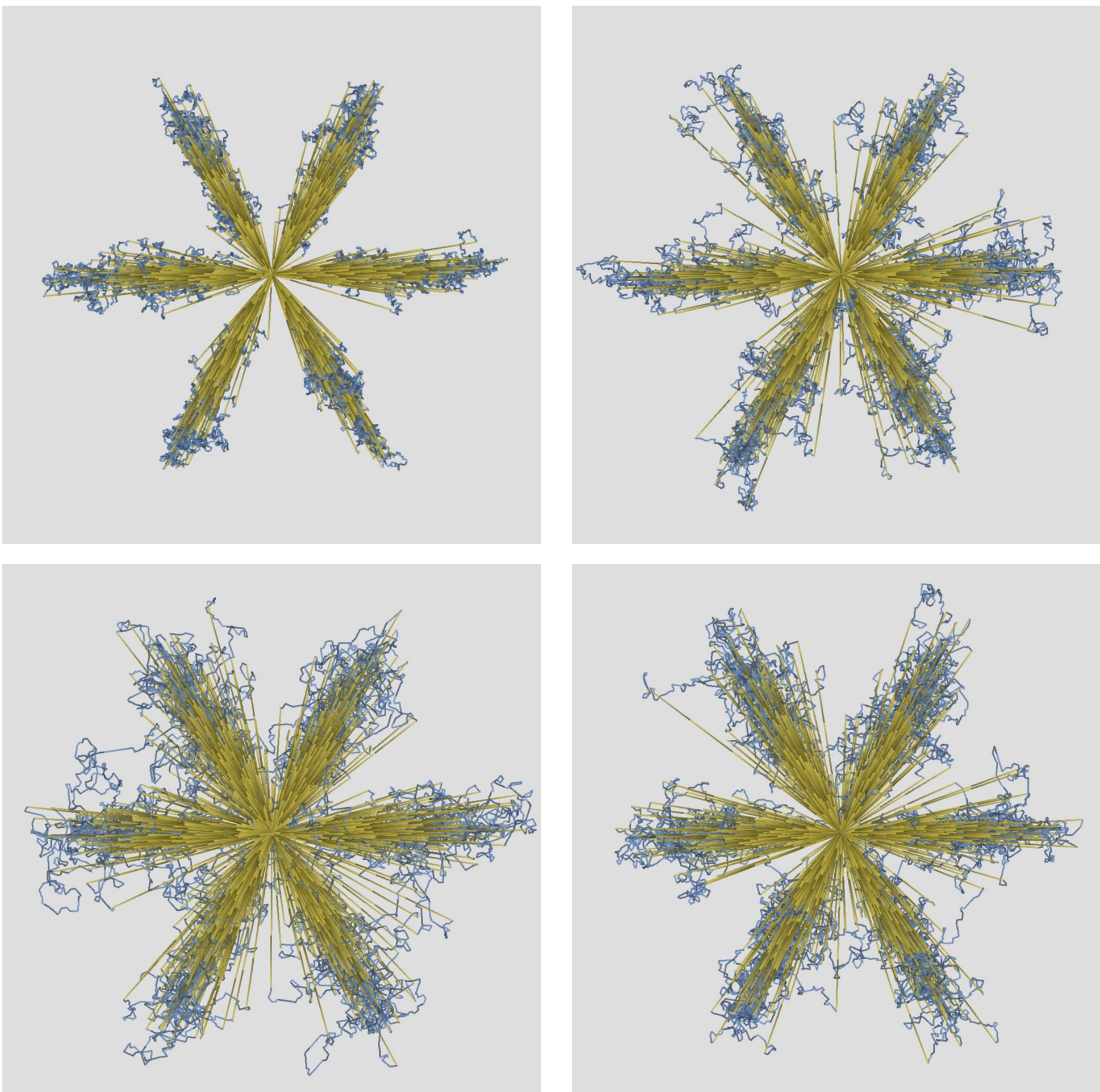

Figure 3: Clockwise, seed foraging patterns using six patroller trails resulting from setting the meander parameter set to 2, 4, 6, and 8.

4 Summary and Future Work

We have described how we converted the *P. barbatus* seed foraging model implemented in [9] to a generative technique for ant paintings on a nontoroidal grid. One shortcoming is that although the virtual ants mark their *outward* journey from the nest using narrow pre-assigned trails, those outward bound paths get obliterated by ants who quickly find seeds and returm to the nests using essentailly the same paths. Another drawback is that the paintings to not convey a strong sense of the outbound-search-inbound flow patterns that actually place. Timing, and the fact that paths may span several pixels, complicate addressing these shortcomings. Perhaps better use of color or modulating color shades and path widths could help.

It would also be interesting to extend the techniques here so that the paintings could also visualize the autonomous nature of the foraging ants whereby after the *first* foraging excursion ants return to a dedicated location, and to convey the return-rate induced nature of their repeated forays from the nest.

References

[1] Adler, F.R., Gordon, D.M., Optimization, conflict and non-overlapping foraging ranges in ants. *American Naturalist*, vol. 162, 2003, 529–543.

[2] Aupetit, S., Bordeau, V., Monmarché, N., Slimane, M., Venturini, G.: Interactive evolution of ant paintings, *2003 Congress on Evolutionary Computation Proceedings* (eds. B. McKay et al.), IEEE Press, vol. 2, 2003, 1376–1383.

[3] Gordon, D. M., The development of an ant colony's foraging range, *Animal Behaviour*, vol. 49, 1995, 649–659.

[4] Gordon, D., *Ant Encounters: Interaction Networks and Colony Behavior*, Princeton University Press, Princeton NJ, 2010.

[5] Greenfield, G., Abstract overlays using a transport network model, *BRIDGES 2011 Conference Proceedings*, (eds. C. Sequin and R. Sarhangi), 2011, 45–50.

[6] Greenfield, G., Ant paintings using a multiple pheromone model, *BRIDGES 2006 Conference Proceedings*, (eds. R. Sarhangi and J. Sharp), 2006, 319–326.

[7] Greenfield, G., Evolutionary methods for ant colony paintings, *Applications of Evolutionary Computing, EvoWorkshops 2005 Proceedings*, Springer-Verlag Lecture Notes in Computer Science, LNCS 3449 (eds. F. Rotlauf et al), 2005, 478–487.

[8] Greenfield, G., On evolving multi-pheromone ant paintings, *2006 IEEE World Congress on Computational Intelligence*, Vancouver, BC, Canada, IEEE Press, WCCI06 Conference Proceedings, (DVD-ROM ISBN: 0-7803-9489-5), 2006, 7425–7431.

[9] Greenfield, G., On simulating seed foraging by red harvester ants, 2013 IEEE Symposium Series on Computational Intelligence Proceedings, to appear, 2013.

[10] Greenfield, G., On variation within swarm paintings, *Proceedings of ISAMA 2009, Eighth Interdisciplinary Conference of the International Society of the Arts, Mathematics, and Architecture*, (eds. E. Akleman and N. Friedman), *Hyperseeing*, Spring 2009, 5–12.

[11] Greenfield, G., Stigmmetry prints from patterns of circles, *Bridges 2012 Conference Proceedings*, (eds. R. Bosch, D. McKenna and R. Sarhangi), 2012, 291–298.

[12] Greenfield, G., The computer art of Manuel Quejido revisited, submitted for publication, 2013.

[13] Greenfield, G.. Machado, P., Simulating artist and critic dynamics — an agent-based application of an evolutionary art system, *Proceedings of the International Joint Conference on Computational Intelligence, Funchal, Portugal, 5-7 October 2009*, (eds. A. Dourado, A. Rosa and K. Madani), 2009, 190–197.

[14] Jones J., Characteristics of pattern formation and evolution approximations of *Physarum* transport networks, *Artifical Life*, 16, 2010, 127–153.

[15] Moura, L., Pereira, H., *Man + Robots: Symbiotic Art*, Institut d'Art Contemporain, Lyon/Villeurbanne, France, 2004.

[16] Moura, L., Ramos, V., Swarm paintings — nonhuman art, *Architopia: Book, Art, Architecture, and Science* (eds. J. Maubant et al.), Institut d'Art Contemporain, Lyon/Villeurbanne, France, 2002, 5–24.

[17] Prabhakar, B., Dektar, K.N., Gordon, D.M., The regulation of ant colony foraging activity without spatial information, *PLoS Computational Biology*, vol. 8, no. 8, 2012, e1002670. DOI:10.1371/journal.pcbi.1002670

[18] Ramos, V., Almeida, F., Artificial ant colonies in digital image habitats - a mass behaviour effect study on pattern recognition, *Proceedings of ANTS'2000 - 2nd International Workshop on Ant Algorithms: From Ant Colonies to Artificial Ants* (eds. M. Dorigo et al.), Brussels, Belgium, 2000, 113–116.

[19] Ramos, V., Merelo, J., Self-organized stigmergic document maps: environment as a mechanism for context learning, *AEB 2002, First Spanish Conference on Evolutionary and Bio-Inspired Algorithms* (eds. E. Alba et al.), Mérida, Spain, 2002, 284–293.

[20] Sturgis, S.J., Greene, M.J., Gordon, D.M., Hydrocarbons on harvester ant (Pogonomyrmex barbatus) middens guide foragers to the nest. *Journal of Chemical Ecology*. 2011. DOI 10.1007/s10886-011-9947-y

[21] Urbano, P., Playing in the pheromone playground: experiences in swarm painting, *Applications of Evolutionary Computing, EvoWorkshops 2005 Proceedings*, Springer-Verlag Lecture Notes in Computer Science, LNCS 3449 (eds. F. Rothlauf et al.), 2005, 478–487.

[22] Urbano, P., The *T. albipennis* sand painting artists, Applications of Evolutionary Computation, Springer-Verlag Lecture Notes in Computer Science,LNCS 6625, 2011, 414–423.