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Creative or Not? Birds and Ants Draw with Muscles

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Abstract. In this work, a novel approach of merging two swarm intelligence algorithms is considered – one mimicking the behaviour of ants foraging (Stochastic Diffusion Search [5]) and the other algorithm simulating the behaviour of birds flocking (Particle Swarm Optimisation [17]). This hybrid algorithm is assisted by a mechanism inspired from the behaviour of skeletal muscles activated by motor neurons. The operation of the swarm intelligence algorithms is first introduced via metaphor before the new hybrid algorithm is defined. Next, the novel behaviour of the hybrid algorithm is reflected through a cooperative attempt to make a drawing, followed by a discussion about creativity in general and the ‘computational creativity’ of the swarm.

1 Introduction

In recent years, studies of the behaviour of social insects (e.g. ants and bees) and social animals (e.g. birds and fish) have proposed several new metaheuristics for use in collective intelligence. This paper explores an artistic application of this collective intelligence, which emerges through the interaction of simple agents (representing the social insects/animals) in two nature-inspired algorithms, namely, Particle Swarm Optimisation (PSO) [17] and Stochastic Diffusion Search (SDS) [5]. Additionally, the mechanism of muscle activation is utilised to introduce the drawing with another layer of detail.

Natural examples of swarm intelligence that exhibit a form of social interaction are fish schooling, birds flocking, ant colonies in nesting and foraging, bacterial growth, animal herding, brood sorting etc. The parable of the blind men and the elephant suggests how social interactions can lead to more intelligent behaviour. This famous tale, set in verse by John Godfrey Saxe [30] in the 19th century, characterises six blind men approaching an elephant. They end up having six different ideas about the elephant, as each person has experienced only one aspect of the elephant’s body: wall (elephant’s side), spear (tusk), snake (trunk), tree (knee), fan (ear) and rope (tail). The moral of the story is to show how people build their beliefs by drawing them from incomplete information, derived from incomplete knowledge about the world [18]. If the blind men had been communicating about what they were experiencing, they would have possibly come up with the conclusion that they were exploring the heterogeneous qualities that make up an elephant.

Following other works in the field of swarm painting (e.g. [22, 3, 33, 34] and ant colony paintings [14, 21]), this work, in addition to exhibiting the cooperation of birds and ants as a new way in making a drawing, benefits from the mechanism used in skeletal muscles.

In this paper, each of the swarm intelligence algorithms used are first explained (Sections 2 and 3), and an approach to their possible integration highlighted (Section 4). Subsequently the simplified mechanism of muscle activation is described (Section 5), followed by an explanation of how the new hybrid algorithm produces a drawing; a process initially inspired by an input sketch and the role that muscle activation mechanism plays (Section 6). In Section 7 the similar individualistic approach of the swarm and their importance in making a drawing is highlighted, followed by future research in the field.

Lastly, despite the novelty of this hybrid approach, it is not the intention of the authors to use the results outlined in the work to make either strong epistemological claims of computational creativity or strong aesthetic claims of style.

2 Birds: Particle Swarm Optimisation!

Particle Swarm Optimisation (PSO), first developed in 1995 by Kennedy and Eberhart [17, 12], is a population-based, optimization technique which came about as a result of an attempt to graphically simulate the choreography of fish schooling or birds flying (e.g. pigeons, starlings, and shorebirds) in coordinated flocks that show strong synchronisation in turning, initiation of flights and landing. Despite the fact that members of the swarm neither have knowledge about the global behaviour of the swarm nor a global information about the environment, the local interactions of the swarms triggers a complex collective behaviour, such as flocking, herding, schooling, exploration and foraging behaviour [27, 19, 4, 16].

A high-level description of PSO is presented in form of a social metaphor – Lost Child in Jungle \footnote{Please note that this metaphor is presented here to give the reader an idea of how the algorithm works, without getting involved in detailed technical issues and mathematical equations.} – demonstrating the procedures through which the communication exchange is facilitated between members of the swarm in its simplest possible form (for detailed, formal explanation and mathematical equations, see [17, 12]).

2.1 The Lost Child in Jungle

A group of villagers realise that a child is lost in a jungle nearby and set off to find the child. Each one of the villagers is given a mobile phone equipped with GPS that can be used to communicate with the head of the village. Each villager is also provided with a diary to record some data, as explained below:

The villagers should log the location where they find the best information so far about the child in their diaries (Personal Best, p\textsuperscript{best} position) and inform the head of the village about it. Whenever they find something better that might lead to the location of the child (a location with a better fitness than their current p\textsuperscript{best}), they should provide the head of the village with the update.

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The head of the village is responsible to contrast all the pbest’s he has received so far from all the villagers and pick the best one (Global Best, gbest position). The resultant gbest is communicated back to the villagers.

Each villager, on the other hand, should log the following three in his diary throughout the search:

- position
- speed (velocity) in walking
- pbest position (which is also called memory)

Additionally, they should be able to access the gbest position from the head of the village.

In the next step, when villagers decide about their next move from their current position, they need to consider their two bests (pbest and gbest) and their current velocity.

Thus, while each villager does not neglect his personal findings, he has extra knowledge about its neighbourhood through gbest; therefore, preserving a balance between exploration of the search space (e.g. jungle, in this case), and exploitation of potentially good areas around each villager’s personal best.

In this example, villagers are analogous to particles in PSO, where optimisation is based on particles’ individual experience (pbest) and their social interaction with the particle swarms (via gbest).

Algorithm 1 describes the metaphor chronologically.

At the convergence of the search process, villagers are most likely to congregate in the area of jungle where the child is most likely to be found; so hopefully, using this algorithm, the child is brought back to his family in the village.

### Algorithm 1 The Lost Child in Jungle

1. **Villagers spread in the jungle**
2. **While (the child is not found)**
   1. **For all villagers**
      1. **Evaluate the fitness of the current location**
         1. **(how good the current location is to lead to the child)**
      2. **If (current location is better than pbest)**
         1. **pbest = current location**
      2. **If (pbest is better than gbest)**
         1. **gbest = pbest**
      3. **Villager decides about his next move**
3. **End**

### 3 Ants: Stochastic Diffusion Search!

This section briefly introduces a multi-agent global search and optimisation algorithm called Stochastic Diffusion Search (SDS) [5], whose behaviour is based on simple interaction of agents.

SDS introduced a new probabilistic approach for solving best-fit pattern recognition and matching problems. SDS, as a multi-agent population-based global search and optimisation algorithm, is a distributed mode of computation utilising interaction between simple agents [11].

Unlike many nature inspired search algorithms, SDS has a strong mathematical framework, which describes the behaviour of the algorithm by investigating its resource allocation [24], convergence to global optimum [25], robustness and minimal convergence criteria [23] and linear time complexity [26]. A social metaphor, the *Mining Game* [1], is used to describe the mechanism through which SDS allocates resources.

#### 3.1 The Mining Game

This metaphor provides a simple high-level description of the behaviour of agents in SDS, where a mountain range is divided into hills and each hill is divided into regions:

- A group of miners learn that there is gold to be found on the hills of a mountain range but have no information regarding its distribution. To maximize their collective wealth, the maximum number of miners should dig at the hill which has the richest seams of gold (this information is not available a-priori). In order to solve this problem, the miners decide to employ a simple Stochastic Diffusion Search.
  - At the start of the mining process each miner is randomly allocated a hill to mine (his hill hypothesis, $h$).
  - Every day each miner is allocated a randomly selected region, on the hill to mine.
  - At the end of each day, the probability that a miner is happy is proportional to the amount of gold he has found.

As this process is structurally similar to SDS, miners will naturally self-organise to congregate over hill(s) of the mountain with high concentration of gold.

In the context of SDS, agents take the role of miners; active agents being ‘happy miners’, inactive agents being ‘unhappy miners’ and the agent’s hypothesis being the miner’s ‘hill-hypothesis’.

#### Algorithm 2 The Mining Game

1. **Initialisation phase**
   1. Allocate each miner (agent) to a random hill (hypothesis) to pick a region randomly

2. **While (all miners congregate over the highest concentration of gold)**
   1. **Test phase**
      1. Each miner evaluates the amount of gold they have mined (hypotheses evaluation)
      2. Miners are classified into happy (active) and unhappy (inactive) groups
   2. **Diffusion phase**
      1. Unhappy miners consider a new hill by either communicating with another miner or, if the selected miner is also unhappy, there will be no information flow between the miners; instead the selecting miner must consider another hill (new hypothesis) at random

4 **Cooperation: Birds and Ants!**

In ongoing research [2], an initial set of experiments aimed to investigate if the information diffusion mechanism deployed in SDS (“ants”) on its own improves PSO (“birds”) behaviour. Early results demonstrate the high potential of this integration.
In the hybrid algorithm, each PSO particle (villager in the Lost Child metaphor) has a current position, a memory (personal best position) and a velocity; each SDS agent (miner, in the Mining Game metaphor), on the other hand, has hypothesis (hill) and status (happy or unhappy).

In the experiment reported here, every PSO particle is an SDS agent too – together termed pAgents. In pAgent, SDS-style hypotheses are defined by the PSO particle positions, and an additional boolean variable (status) determines whether the pAgent is active or inactive (see Figure 1).

The behaviour of the hybrid algorithm in its simplest form is presented in Algorithm 3.

**Algorithm 3 Hybrid Algorithm**

```
Initialise pAgents
While (stopping condition is not met)
    For all pAgents
        Evaluate fitness value of each particle
        If (evaluation counter MOD n == 0)
            // START SDS
            // TEST PHASE
            for pAg = 1 to No.of-pAgents
                rAg = pick-random-pAgent()
                if (pAg.pbestFitness() <= rAg.pbestFitness())
                    pAg.setActivity(true)
                else
                    pAg.setActivity(false)
            end if
            end for
            // DIFFUSION PHASE
            for ag = 1 to No.of-pAgents
                if (pAg.activity() == false)
                    rAg = pick-random-pAgent()
                    if (rAg.activity() == true)
                        pAg.setHypo(rAg.getHypo())
                    else
                        pAg.setHypo(randomHypo())
                    end if
                end if
            end for
            // END SDS
            If (current fitness is better than pbest)
                pbest = current fitness
            If (pbest is better than gbest)
                gbest = pbest
            Particle decides about its next move
        End
    End
End
```

5 The Simplified Mechanism of Muscle Activation

Motor neurons activate the skeletal muscle mainly through the neurotransmitter Acetylcholine (Ach) at the neuromuscular junction (NMJ). This junction is a synapse where the unmyelinated motor nerve terminals are separated from the postsynaptic membrane by a cleft that contains a basal lamina [28]. This cleft includes many proteins including acetylcholine esterase (AChE) which hydrolyse Ach. The postsynaptic membrane at the NMJ forms a series of deep folds. The acetylcholine receptors (AChRs) are found at the top one-third of these folds, whereas the voltage-gated sodium channels are anchored at the bottom of the folds [29, 15].

The nerve action potential from the motor neuron opens voltage-gated calcium channels that are located at the motor nerve terminal of the NMJ. The resulting influx of calcium leads to the release of acetylcholine (ACh) from the motor end of the junction into the synapse. Nearly 65% reaches the ACh receptors (AChR) on the postsynaptic membrane. Binding of two ACh to each AChR leads to the opening of the AChR-associated ion channel, influx of cations (mainly sodium) and generation of an endplate potential (EPP) [31].

The EPP rapidly depolarises the postsynaptic membrane and, this depolarization should pass a certain threshold so that enough voltage-gated sodium channels are activated for the propagation of an action potential along the muscle fiber, once this happens the muscle contracts [10]. The extent to which the EPP exceeds that necessary threshold to initiate the action potential is usually called the safety factor for neuromuscular transmission [37]. The EPP is short-lived because the AChRs close spontaneously, ACh dissociates and escapes by diffusion or is hydrolysed by AChE.

In this paper, the effect of the activation of voltage-gated sodium channels on muscle contraction and the way motor neurons activate the skeletal muscle are used for an artistic purpose.

6 The Drawing Mechanism

In this section, first the drawing made with the hybrid swarm algorithm (PSO-SDS) is presented and then the influence of the muscle activation mechanism on the drawing is explored.

6.1 Birds and Ants Set off to Draw

Once the swarm (birds and ants) are presented with a sketch (see Figure 2), they use it as inspiration and begin making a drawing based on the sketch, but utilising their own ‘style’.

The goal of “birds” (PSO algorithm) is to trace the lines (series of points) in the sketch, and “ants” (SDS algorithm) help the birds in this process as explained in Section 4. The trace of the birds and the footprints of the ants stay on the canvas, creating a drawing inspired by the initial sketch, followed by a signature of the swarm at the corner of the canvas (see Figure 3).

6.2 How Muscle Contraction Shapes the Drawing

The simplified mechanism of muscle contraction is used in the drawing to reflect the relation between the time spent for drawing each part (e.g. each line) and the form (spikes’ diameter) of the disks representing the contracted muscles, which are visible around each member of the swarm.

Here, in drawing, the concept of duration (for drawing a line), is reversely analogous to the idea of the activation of voltage-gated sodium channels in the mechanism of muscle contraction, which –
for this artistic purpose – indicates, the shorter the time, the higher the activation voltage-gated sodium channels, which in turn leads to a bigger contraction (or shock) in each member of the swarm.

When a line is drawn faster than the other in a drawing, the spikes formed around each member of the swarm (while drawing that line), is bigger (more spread on the canvas), but when a line is drawn slower (i.e. the pressure is higher), it will have smaller, more intense (concentrated on the canvas) disk around the member of the swarm. See Figure 4.

Having the concept of contraction or ‘shock’ derived from muscle activation, Figure 5 shows the sketches drawn by the swarm, using birds, ants and the mechanism of muscle contraction.

Although even if the hybrid swarm mechanism (of birds, ants and muscle) processes the same sketch several times it will not make two identical drawings; furthermore the outputs it produces are not merely randomised versions of the input. This can be demonstrated qualitatively by comparing the output of the hybrid swarm system with a simple randomised tracing algorithm (e.g. contrast Figures 6 with Figure 7). The reason why the hybrid swarm drawings are different from using random lines and spikes (shocked muscles) following the lines of a sketch, is that the underlying algorithms and mechanism [used to coordinate the concentrations at any particular point on the canvas] employ proven swarm intelligence techniques; a method which is better (more ‘loyal’ to the original sketch) than a simple randomisation, but which still has enough ‘freedom’ to ensure originality in the resulting drawing (i.e. the swarm mechanisms ensure high-level fidelity to the input without making an exact low-level copy of the sketch). Thus, despite the fact that the swarm are constrained by the rules they follow (see Sections 2 and 3), the stochastic parts of the algorithms allow them to demonstrate a “regulated difference” rather than a simple “random difference”.

Figure 2. Sketches Provided to the Swarm

Figure 3. The Drawings of the Hybrid Swarms

Figure 4. Muscle Contraction (shock) on Drawing
6.3 Regulated difference versus random difference

The drawings in Figure 6 (top and middle) show two outputs from the simple randomised algorithm when configured with limited ‘artistic’ freedom (i.e. there is a only small Gaussian random distance and direction from the lines of the original sketch); comparing the two drawings we note a lack of any significant difference between them. Furthermore, when more ‘artistic freedom’ is granted to the randomised algorithm (by further increasing the variance in the underlying Gaussian, which allows the technique to explore a wider areas of the canvas), the algorithm begins to deviate excessively from the original sketch. I.e. Excessive randomisation results in a poor - low fidelity - interpretation of the original sketch (Figure 6-bottom). In contrast although the agents in the hybrid ‘bird, ant and muscle swarm’ are free to access any part of the canvas they naturally maintain recognisable fidelity to the original input. Thus it can be seen that simply extending a basic swarm mechanism by giving it simply more randomised behaviour (giving it more ‘artistic freedom’) fails to demonstrate that more creative drawings would be produced.

Thus the ‘controlled freedom’ (or the ‘tincture of madness’) exhibited by the hybrid swarm algorithm (induced by the stochastic side of the algorithms) is crucial to the resultant work and is the reason why having the same sketch does not result in the system producing identical drawings.

Figure 6. The Drawings of the Swarms with Random Behaviour

Figure 7 shows a few drawings made by the hybrid swarm system, inspired by a single input sketch. Interestingly, and irrespective of whether the hybrid swarm is ‘genuinely creative’ or not, its individ-

6 This freedom emerges, among other things, from the the stochasticity of SDS algorithm in picking agents for communication, as well as choosing agents to diffuse information (see Algorithm 2); and the tincture of madness in PSO algorithm is induced via its strategy of spreading villagers in the jungle as well as the stochastic elements in deciding the next move of each villager (see Algorithm 1).

7 Although the algorithms (PSO and SDS) and the mechanism (skeletal muscle activation) are biologically inspired we do not claim that the presented work is an accurate model of natural systems. Furthermore in designing the algorithm there was no explicit ‘Hundertwasser-like’ attempt - by which we mean stress on using curves instead of straight lines, as Hundertwasser considered straight lines not nature-like and ‘godless’ and tried not to use straight lines in his works - to bias the style of the system’s drawings.
ualistic style is not totally dissimilar to those of the ‘elephant artists’ [36]):

“After I have handed the loaded paintbrush to [the elephants], they proceed to paint in their own distinctive style, with delicate strokes or broad ones, gently dabbing the bristles on the paper or with a sweeping flourish, vertical lines or arcs and loops, ponderously or rapidly and so on. No two artists have the same style.”

Figure 7. Different Drawings of the Hybrid Swarms off a Single Sketch

7 Discussion on Creativity

In this section, the aim is to discuss whether the hybrid swarm algorithms can in some sense be ‘computationally creative’ in what they draw. In our discussion we emphasise the importance of: ‘controlled freedom’ (cf. unregulated randomness) and the combinatorial creativity of the hybrid swarm system and contrast it with examples of potential non-human assessment of aesthetic judgment and suggestions of creativity in natural distributed systems. In order to deflect the charge that computational systems cannot be sensitive to emotion we subsequently briefly discuss recent work from Simon Colton. Finally, we complete the section with a demonstration of the provenance of the use of [real-world] swarm-systems in successful exhibited artworks (e.g. by Julie Freeman). Our modest conclusion is that ‘controlled freedom’ (pace unconstrained randomness) - as for example exhibited in the hybrid bird, ant and muscle algorithm presented herein - can be useful in generating interesting and intelligible drawing outputs.

7.1 On Freedom and Art

For years, it has been argued that there is a relationship between art, creativity and freedom, among which is the famous German prose, by Ludwig Hevesi at the entrance of the Secession Building in Vienna:

“Der Zeit ihre Kunst
Der Kunst ihre Freiheit”

Or a quote by Aristotle (384-322 BCE) [13], which emphasises on the link between creativity and freedom (here, having “a tincture of madness”):

“There was never a genius without a tincture of madness.”

Boden, in [7], also argues that creativity has an ambiguous relationship with freedom. Among several definitions that have been given to creativity, around sixty of which (as stated by Taylor [32]) belong to combinational creativity, which is defined as “the generation of unfamiliar combinations of familiar ideas” [6]; a category that the presented work fits in. Considering the existence of many influencing factors in evaluating what is creative, raises questions about how humans evaluate artistic creativity. Galanter in [20] suggests that perhaps computational equivalent of a bird or an insect (e.g. in evaluating mate selection) is “all” that is required for computational aesthetic evaluation and furthermore states:

“... this provides some hope for those who would follow a psychological path to computational aesthetic evaluation, because creatures with simpler brains than man practice mate selection.”

In this context Dorin and Korb [20] suggest that the tastes of the individual in male bowerbirds is visible when they gather collections of bones, glass, pebbles, shells, fruit, plastic and metal scraps from their environment, and arrange them to attract females [8]:

“They perform a mating dance within a specially prepared display court. The characteristics of an individual’s dance or artefact display are specific to the species, but also to the capabilities and, apparently, the tastes of the individual.”

However the underlying question - of whether ‘mate selection behaviour in animals entails making a judgement analogous to aesthetic judgements in humans’ - is perhaps (pace Nagel’s famous discussion in Philosophical review (1974) of ‘What it is like to be a bat?’), a question whose answer can never be known.

In contrast the role of education (or training) in recognising ‘good’ and ‘bad’, ‘creative’ and ‘non-creative’ has been more experimentally probed. A suggestive study investigating this topic by Watanabe [33], gathers a set of children’s paintings which adult humans are asked to label ‘good’ or ‘bad’. Pigeons are subsequently trained

8 To time its art, to art its freedom.
through operant conditioning to only peck at good paintings. After
the training, when pigeons are exposed to a novel set of [judged]
children’s paintings, they show their ability in the correct classifi-
cation of the paintings; emphasising the role of training in aesthetic
government and the door to computational (machine learning)
explanations in this area.9

A further area relating swarm intelligence and creativity is that of
social, distributed and extended systems. For example Bown in [20]
argues that our creative capabilities are contingent on the objects and
infrastructure available to us, which help us achieve individual goals,
in two ways:

“One way to look at this is, as Clark does [9], in terms of the
mind being extended to a distributed system with an embodied
brain at the centre, and surrounded by various other tools, from
digits to digital computers. Another way is to step away from the
centrality of human brains altogether and consider social
complexes as distributed systems involving more or less cogni-
tive elements.”

7.2 On the Emotional Sensitivity of Computer
Artists

Can a computer program be sensitive to real emotion is directing
its artistic output? Certainly Simon Colton’s work at Imperial Col-
lege suggests this may be so. Simon describes his ‘Painting Fool’
as follows; “Firstly, we used software developed by Maja Pantic,
Michel Valstar and other members of the vision group at Imperial
to take a video sequence of someone expressing an emotion (such
as smiling, frowning, looking surprised, etc.). The software then: de-
dected the emotion; determined where the features of the face were;
and found the image in the video sequence where the emotion was
being expressed the most. This information was then passed to the
second piece of software in the combination, namely The Painting
Fool, which proceeded to paint a portrait of the person in the video
sequence. It based the portrait on the image provided from the emo-
tional modeling software, and chose its art materials, colour palette
and abstraction level according to the emotion being expressed. For
instance, if it was told that the person was expressing happiness, it
chose vibrant colours, and painted in simulated acrylic paints in a
 slapdash way. If, on the other hand, it was told that the person was
sad, it chose to paint with pastels in muted colours.” Such behaviour
clearly suggests at least some sensitivity to [human] emotion is pos-
sible in computational systems.

7.3 Fish: Real-World Swarm Art!

An example of the use of real-word swarm in computer art come
from the artist, Julie Freeman10. In 2005 Julie completed a site in-
station ‘Swarm Intelligence’ art work at Tingrith Fisheries (a 4000
square meter lake bordering the Woburn Abbey Estate). For the art-
work - The Lake - Julie implanted 16 fish (four each of four species)
with electronic transducers that could be tracked in real time 24/7 by
6 audio transponders and their real-time movements used to develop
electronic soundscape and concomitant computer generated images;
different behaviours were initiated by fish schooling (swarming) and

by individual forays through the lake. This work is very success-
ful and has been extensively installed and exhibited internationally.11
The success of this work by Freeman clearly demonstrates that there
is at least one niche for the [real-world] swarm aesthetic in art.

8 Conclusion

In this paper, we make no strong claim about the ‘computational cre-
ativity’ of the work presented, neither do we try to tackle the infa-
mous question on whether computers can be creative at all or gen-
erate creative art. This specific work described herein merely em-
phasises the importance of ‘controlled freedom’ in the production of
‘drawings’ by computer. The computational artist so described is the
outcome of a novel marriage between two classical swarm intelligi-
genesis algorithms (PSO and SDS)12 and a simplified mechanism of
muscle activation. In an ongoing research, the application of the new
hybrid algorithm to make a ‘swarmic’ drawing ‘as though through a
human’s gaze’ is currently being investigated.

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10 Artist in Residence at the Microsystems & Nanotechnology Centre, Cran-
field University and Associate Artist, Goldsmiths Digital Studios

11 The work has also been shown in the Truman Brewery, London, UK;
FILE, Sao Paulo, Brazil; FILE, Rio, Brazil; Arts Bioethics Network, Ri-
jeka, Croatia; The National Centre for Contemporary Arts, Kaliningrad,
Russia and in lastly in 2009 at MediaArtLab Center for Art and Culture,
Moscow, Russia

12 The scientific value of the new hybrid algorithm is currently being investi-
gated via standard optimisation benchmarks [2].


