Swarm Chemistry Evolving

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Extended Abstract

We report several recent extensions of Swarm Chemistry (Sayama 2008; Sayama 2009), an artificial chemistry model that uses kinetically interacting particle swarms as chemical reactants. Major modifications we newly implemented in the Swarm Chemistry model are as follows:

1. There are now two categories of particles, active (moving and interacting kinetically) and passive (remaining still and inactive). An active particle holds a recipe of the swarm (i.e., a list of kinetic parameter sets) in it (Fig. 1(a)).
2. A recipe is transmitted from an active particle to a passive particle when they collide, making the latter active (Fig. 1(b)).
3. The activated particle differentiates randomly into a type specified by one of the kinetic parameter sets in the recipe given to it (Fig. 1(c)).
4. Active particles randomly re-differentiate with small probability.

It has been demonstrated that these model extensions enable morphogenetic processes starting with a single particle containing a recipe (zygote) that grows into a fully developed self-organizing swarm pattern by "eating" other passive particles as raw materials through local recipe transmission (Sayama 2010). In addition, the stochastic re-differentiation introduced above (4) naturally achieves self-repair capability of swarms with simple open-loop linear control mechanisms (Sayama 2010).

Moreover, to demonstrate that macro-level ecological/evolutionary dynamics of self-organizing swarm patterns can arise out of micro-level processes embedded in particle interactions, we further introduced minimal mechanisms for variation and competition of recipes when they are transmitted between particles. Specifically, we implemented the following mechanisms to the model:

5. A recipe is transmitted between active particles of different types when they collide (*inheritance*). The direction of recipe transmission is determined by a competition function that picks one of the two colliding particles as a source (and the other as a target) of transmission based on their properties (*selection*) (Fig. 1(d)).
6. The recipe can mutate when transmitted (as well as spontaneously at other times) with small probability (*variation*) (Fig. 1(e)).

With these additional mechanisms, the Swarm Chemistry world has become capable of producing fully autonomous ecological and evolutionary behaviors of self-organized "super-organisms" made of a number of swarming particles. With a finite amount of resources (i.e., fixed number of particles) provided in a closed environment, we have observed behaviors of those macroscopic patterns that could be interpreted in ecological/evolutionary terms, such as reproduction, chasing, and predation, all emerging out of local interactions among individual particles (Fig. 1(f)).

We have tested a couple of different principles for the competition function, e.g.:

(i) The faster (or slower) particle wins (i.e., becomes the source).
(ii) The particle that hit the other one from behind wins.
(iii) The particle surrounded by more of the same type wins.

Each condition produced unique, distinct evolutionary dynamics. The most recent findings obtained from those different conditions are presented and discussed comparatively.

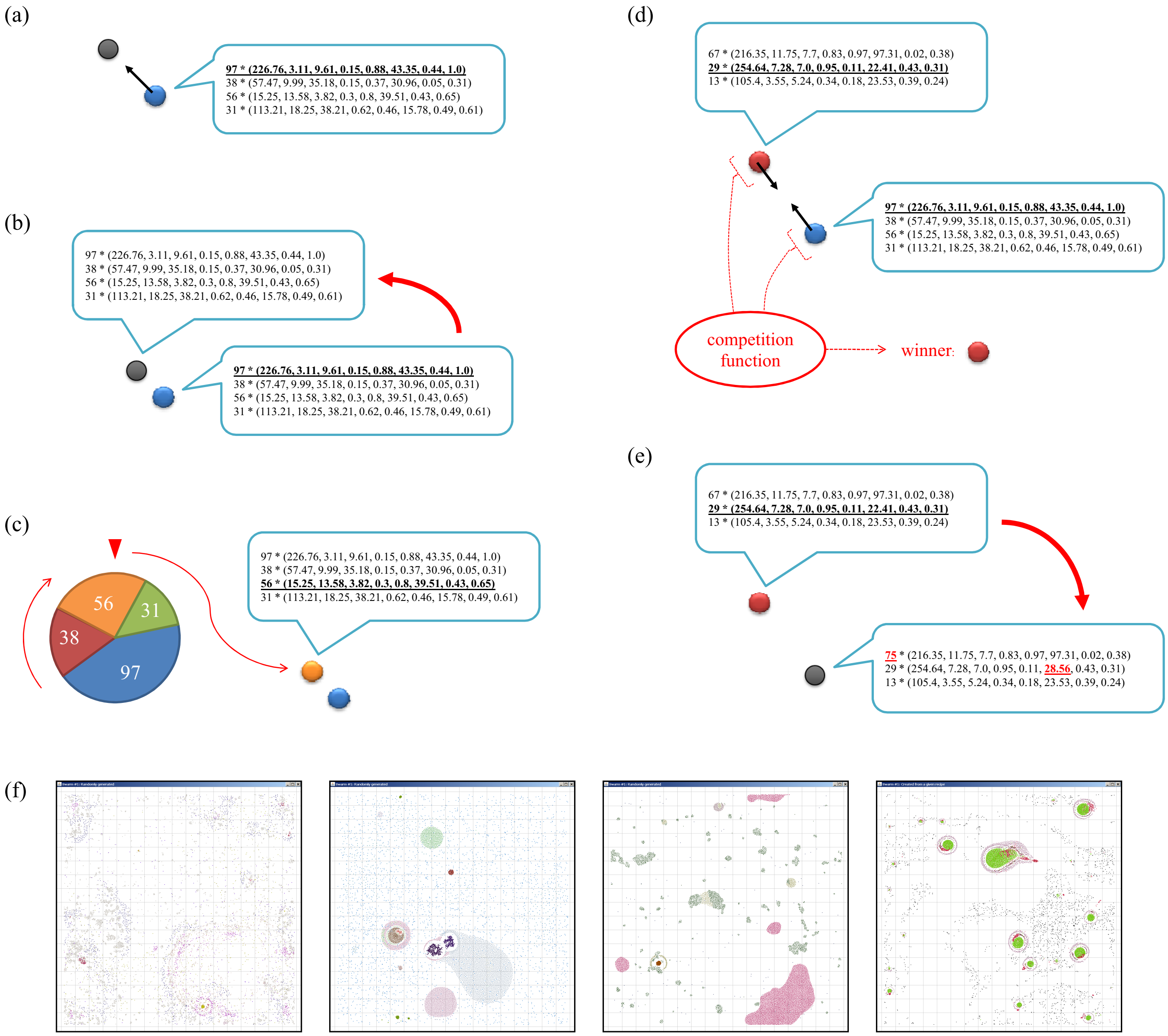

Figure 1: How particle interactions work in the revised Swarm Chemistry. (a) There are two categories of particles, active (blue) and passive (gray). An active particle holds a recipe of the swarm in it. (b) A recipe is transmitted from an active particle to a passive particle when they collide, making the latter active. (c) The activated particle differentiates randomly into a type specified by one of the kinetic parameter sets in the recipe given to it. (d) A recipe is transmitted between active particles of different types when they collide (*inheritance*). The direction of recipe transmission is determined by a competition function that picks one of the two colliding particles as a source (and the other as a target) of transmission based on their properties (*selection*). (e) The recipe can mutate when transmitted with small probability (*variation*). (f) Examples of ecologies of self-organizing patterns spontaneously formed in the Swarm Chemistry world (made of 10000 particles each).

References

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