Properties of a Swarm Intelligence System

The typical swarm intelligence system has the following properties:

- it is composed of many individuals;
- the individuals are relatively homogeneous (i.e., they are either all identical or they belong to a few typologies);
- the interactions among the individuals are based on simple behavioral rules that exploit only local information that the individuals exchange directly or via the environment (stigmergy);
- the overall behaviour of the system results from the interactions of individuals with each other and with their environment, that is, the group behavior self-organizes.

The characterizing property of a swarm intelligence system is its ability to act in a coordinated way without the presence of a coordinator or of an external controller. Many examples can be observed in nature of swarms that perform some collective behavior without any individual controlling the group, or being aware of the overall group behavior. Notwithstanding the lack of individuals in charge of the group, the swarm as a whole can show an intelligent behavior. This is the result of the interaction of spatially neighboring individuals that act on the basis of simple rules.

Most often, the behavior of each individual of the swarm is described in probabilistic terms: Each individual has a stochastic behavior that depends on his local perception of the neighborhood. SI systems are typically made up of a population of simple agents interacting locally with one another and with their environment. Although there is normally no centralized control structure dictating how individual agents should behave, local interactions between such agents often lead to the emergence of global behavior. Examples of systems like this can be found in nature, including ant colonies, bird flocking, animal herding, bacterial growth, and fish schooling.

Wisdom of Crowds

Four elements required to form a wise crowd

Not all crowds (groups) are wise. Consider, for example, mobs or crazed investors in a stock market bubble. Refer to Failures of crowd intelligence (below) for more examples of unwise crowds. According to Surowiecki, these key criteria separate wise crowds from irrational ones:

Diversity of opinion
Each person should have private information even if it's just an eccentric interpretation of the known facts.

Independence
People's opinions aren't determined by the opinions of those around them.

Decentralization
People are able to specialize and draw on local knowledge.

Aggregation
Some mechanism exists for turning private judgments into a collective decision.

[edit] Failures of crowd intelligence

Surowiecki studies situations (such as rational bubbles) in which the crowd produces very bad judgment, and argues that in these types of situations their cognition or cooperation
failed because (in one way or another) the members of the crowd were too conscious of the opinions of others and began to emulate each other and conform rather than think differently. Although he gives experimental details of crowds collectively swayed by a persuasive speaker, he says that the main reason that groups of people intellectually conform is that the system for making decisions has a systematic flaw.

Surowiecki asserts that what happens when the decision making environment is not set up to accept the crowd, is that the benefits of individual judgments and private information are lost, and that the crowd can only do as well as its smartest member, rather than perform better (as he shows is otherwise possible). Detailed case histories of such failures include:

Too homogeneous
Surowiecki stresses the need for diversity within a crowd to ensure enough variance in approach, thought process, and private information.

Too centralized
The Columbia shuttle disaster, which he blames on a hierarchical NASA management bureaucracy that was totally closed to the wisdom of low-level engineers.

Too divided
The U.S. Intelligence community failed to prevent the September 11, 2001 attacks partly because information held by one subdivision was not accessible by another. Surowiecki's argument is that crowds (of intelligence analysts in this case) work best when they choose for themselves what to work on and what information they need. (He cites the SARS-virus isolation as an example in which the free flow of data enabled laboratories around the world to coordinate research without a central point of control.)

The Office of the Director of National Intelligence and the CIA have created a Wikipedia style information sharing network called Intellipedia that will help the free flow of information to prevent such failures again.

Too imitative
Where choices are visible and made in sequence, an "information cascade" can form in which only the first few decision makers gain anything by contemplating the choices available: once past decisions have become sufficiently informative, it pays for later decision-makers to simply copy those around them. This can lead to fragile social outcomes.

Too emotional
Emotional factors, such as a feeling of belonging, can lead to peer pressure, herd instinct, and in extreme cases collective hysteria.

[edit] Is it possible to be too connected?

Surowiecki spoke on Independent Individuals and Wise Crowds, or Is It Possible to Be Too Connected?
The question for all of us is, how can you have interaction without information cascades, without losing the independence that’s such a key factor in group intelligence?

He recommends:
- Keep your ties loose.
- Keep yourself exposed to as many diverse sources of information as possible.
- Make groups that range across hierarchies.

Tim O’Reilly[11] and others also discuss the success of Google, wikis, blogging and Web 2.0 in the context of the wisdom of crowds.

That’s how swarm intelligence works: simple creatures following simple rules each one acting on local information. No ant sees the big picture. No ant tells any other ant what to do. Some ant species may go about this with more sophistication than others. But the bottom line no leadership is required - Even complex behavior may be coordinated by
relatively simple interactions

The bees' rules for decision-making—
- seek a diversity of options, identify all the possibilities
- encourage a free competition among ideas, kick their ideas around for a while,
- use an effective mechanism to narrow choices, vote by secret ballot

"It's exactly what the swarm bees do, which gives a group time to let the best ideas emerge and win. People are usually quite amenable to that."

members are diverse, independent minded, and use a mechanism such as voting, auctioning, or averaging to reach a collective decision.

The birds don't have a leader. No pigeon is telling the others what to do. Instead, they're each paying close attention to the pigeons next to them, each bird following simple rules as they wheel across the sky. These rules add up to another kind of swarm intelligence—one that has less to do with making decisions than with precisely coordinating movement.

1) avoid crowding nearby boids,
2) fly in the average direction of nearby boids, and
3) stay close to nearby boids.

"It's much harder for a predator to avoid being spotted by a thousand fish than it is to avoid being spotted by one," says Daniel Grünbaum, a biologist at the University of Washington. "News that a predator is approaching spreads quickly through a school because fish sense from their neighbors that something's going on."

When a predator strikes a school of fish, the group is capable of scattering in patterns that make it almost impossible to track any individual.
- It might explode in a flash,
- create a kind of moving bubble around the predator,
- or fracture into multiple blobs, before coming back together and swimming away.

That's the wonderful appeal of swarm intelligence. Whether we're talking about ants, bees, pigeons, or caribou, the ingredients of smart group behavior—decentralized control, response to local cues, simple rules of thumb—add up to a shrewd strategy to cope with complexity.

Such thoughts underline an important truth about collective intelligence: Crowds tend to be wise only if individual members act responsibly and make their own decisions. A group won't be smart if its members imitate one another, slavishly follow fads, or wait for someone to tell them what to do. When a group is being intelligent, whether it's made up of ants or attorneys, it relies on its members to do their own part. For those of us who sometimes wonder if it's really worth recycling that extra bottle to lighten our impact on the planet, the bottom line is that our actions matter, even if we don't see how.

Basic flocking is controlled by three simple rules:
1. Separation - avoid crowding neighbours (short range repulsion)
2. Alignment - steer towards average heading of neighbours
3. Cohesion - steer towards average position of neighbours (long range attraction)

With these three simple rules, the flock moves in an extremely realistic way, creating complex motion and interaction that would be extremely hard to create otherwise.
SWARM TACTICS - When a dispersed group of people (or people who 'blend in' with a bigger crowd) suddenly converge to do an action in a single place. The place and time can be predetermined, like the 'ballpark' strategy in Cancun. Or, it can be more spontaneous, or revealed at the last second, similar to a 'flash mob'.

DISPERsal TACTICS - when a crowd of people suddenly separate and disperse quickly in different directions. This spreads the opposition thin and keeping them off guard and unprepared for what you have coming up. This is also good for when people get cornered and surrounded by cops. Cops like it when you sit still. New opportunities are created the second you start moving.

DECOY TACTICS - making them think you are going somewhere else [by stating it in an open meeting, or chanting aloud "shut down the x"] or staging a fake action somewhere else at the same time as your main action.

RANDOM TACTICS
The general idea is keep moving at all times. Never sit still, even when they blocked your way. Even when you don't have a plan for what do next, just keep moving as it creates new possibilities you did not forsee. Their sense of order and control inevitably breaks down. The challenge is how to capitalize on opportunities as a group, once they appear. What contingency plans were made? How do you communicate this to the larger group? Flags? low Power Radio? SMS? Random tactics can incorporate lots of carnival-like elements.

Improved decision-making as a force multiplier

Swarming ties in well with the theories of John Boyd, the "high-low mix" in which a large number of less expensive aircraft, coupled with a small number of extremely capable "silver bullet" aircraft, had the effect of a much larger force. Boyd's concept of quick action is based on the repeated application of the Boyd loop, consisting of the steps

- Observe: make use of the best sensors and other intelligence available
- Orient: put the new observations into a context with the old
- Decide: select the next action based on the combined observation and local knowledge
- Act: carry out the selected action, ideally while the opponent is still observing your last action.

Boyd's concept is also known as the OODA Loop, and is applicable to all military operations, as well as to civilian competition from sports to business. These are a realization of Boyd's theories. A swarming case is any historical example in which the scheme of maneuver involves the convergent attack of five (or more) semi-autonomous (or autonomous) units on a targeted force in some particular place. "Convergent" implies an attack from most of the points on the compass.\[1\]

[edit] Swarming avoids fratricide

Principles of Modern Swarming

Swarming requires autonomous or semi-autonomous operating agents, with strong synchronization and communications among them. Senior commanders release resources to
the swarm, but do not control them once released. If the agents are semi-autonomous, there will be an on-scene commander giving general direction to the swarming agents.

[edit] Communications and Synchronization are Critical

For combatant units to use swarming efficiently, they must be closely coordinated. A distributed control mechanism, where peer units keep one another notified of their location, status, and intention, is much more fault-tolerant than relying on a single command post. One of Napoleon’s combat advantages was the introduction of both terrain maps and reliable timepieces, which let him synchronize widely separated actions. When a central command post, especially with backups, can coordinate, it can allow combat units to be even more effective, if the units need not use radars and other easily detectable units in order to locate their targets.

The evolution of modern swarming

Swarming was present in the operations of Alexander the Great and Genghis Khan, but were generally replaced by melee and mass in the pre-industrial era. More synchronized maneuver was paced by the availability of mobile communications. Blitzkrieg was certainly a use of maneuver, but it was less flexible than later operations in which every tank and aircraft had radios, and far less flexible that forces that have effective networked information systems.[12] They define swarming, in a military context, as "...seemingly amorphous, but it is a deliberately structured, coordinated, strategic way to strike from all directions, by means of a sustainable pulsing of force and/or fire, close-in as well as from stand-off positions."

One aspect of swarming is that it moves away from the traditional model of a rigid chain of command.[13] This paper suggests abandoning the term command and control in favor of:

- ·· agility: "... the critical capability that organizations need to meet the challenges of complexity and uncertainty"
- ·· focus: "provides the context and defines the purposes of the endeavor"
- ·· convergence. "convergence is the goal-seeking process that guides actions and effects."

Agility is a characteristic of an organization or unit capable of swarming. Focus can be designation of a goal by a higher-level commander, by a peer unit detecting a target, or by intelligence systems that feed information to the swarming units. Convergence is the key feature, which, while it can be distributed, causes swarming units to coordinate their actions, apply force, and know when to stop applying force.

Edwards holds that several axioms of military doctrine[14] change with the use of swarming:[15]

- Edwards on Principles of War Changed by Swarming
  Traditional Principle of War         Redefinition with Swarming
  Mass                               Dispersed mass
  Economy of force                   Simultaneity
  Unity of command                   Unity of effort

Osgood points out that swarming is not new, although the means of coordination and synchronization are going through significant changes.[16] Howard Rheingold cites mobile communications technology as a key enabler: The bees sense each other’s buzzing and instinctually move in concert in real time. Text messaging on mobile devices and instantaneous file sharing off the internet via PDAs allows groups of people to receive their instructions, move in unison, nearly instantaneously, without prior planning or forethought.
And, the technology allows groups to do so without a central leader. One modern example is the protesters at the World Trade Organization meetings in Seattle, in 1999, who were able to orchestrate their movement effectively in this way.