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Swarming. Science Fact and Science Fiction of Collective Intelligence

Abstract

Swarms have frequently been portrayed as rather terrifying agent collectives. Moreover, in Science fiction media texts, they often disturb the transmission of visual data being themselves transmission events: Oscillating between a hidden, distributed, decentralized order and a seemingly chaotic swarming, they designate the boundaries of the code of central perspective and likewise exhibit the swift and flexible organizational capabilities of a collective intelligence.

At the same time, graphical visualization and animation of swarms in feature films usually rely on efficient agent-based computer simulations. These are informed by the biological research of swarms, flocks, and schools, whilst on their part provide the models, computer simulations and visualization technologies that open up new epistemic perspectives for this very biological research. This article states – from a media historical and epistemological perspective – that it is graphic animation design which efficiently renders the operations within the diffuse epistemic object of swarms more distinctive, hence short-circuiting science fiction and science fact.

1. "Bodies without Surface"

From ancient times, swarms[1] have been described as agents of disintegration, challenging the (hierarchical) organization of civilized human society and individual life. Contemporary Hollywood films such as *The Mummy* (Stephen Sommers, USA 1999) with its Scarabaeus attacks or *Indiana Jones and the Kingdom of the Crystal Skull* (Stephen Spielberg, USA 2008) with its Red Ant sequence refer to this archaic form of peril where a multitude of simplest individuals wreck havoc through coordinated collective motion. *Starship Troopers* (Paul Verhoeven, USA 1997) with its massive Arachnae onslaught sequences already links this resistless and overwhelming collective motion to a concept of collective intelligence, and at the latest with the 'sentinels' attack sequence in *Matrix Revolutions* (Andy and Larry Wachowski, USA 2003), the former archaic dimension is replaced by notions of a technologically highly developed form of collective or collective intelligence. However, be it the antediluvian threat of insects or a collective machine intelligence, swarms realize their menacing potential as a form of noise which subverts any synthesis of perception. What insinuates itself in the above examples is a fundamental epistemic horror facing something which resists to take shape or form in its dynamic processes of anti-stasis.

Leonardo da Vinci categorized such 'objects' as bodies without a surface, distinguishing them from "perceptible bodies." Unlike the latter, the fluid or etheric bodies without a surface become "barely perceptible, even if present"[2] and reveal – as stated by

[1] The word swarm is etymologically rooted in the sound of a "cloud of bees or other insects," derived from Proto-Germanic *swarmaz* and its Proto-Indo-European-based notion of a humming sound. The *Oxford English Dictionary* suggests yet another possible connection with the base of *swerve* and ground sense of "agitated, confused, or deflected motion" (see Harper, Douglas. 2001. "Swarm." *The Online Etymology Dictionary*. URL: http://www.etymonline.com/index.php?term=swarm). In this regard, it has to be mentioned that the German notion of 'swarm' encompasses moving collectives like flocks and schools, as well – the term in this article is used in this broader sense of an oscillation between diffusion and alignment.

[2] da Vinci, Leonardo. 1938. C.A., 132rb. *The Notebooks of Leonardo da Vinci*. Ed. Edward MacCurdy. Vol. 2. London: Jonathan Cape, pp. 363-364

French art historian Hubert Damisch – the “limitations of the perspective code.”[3] The adherent Euclidean (and later Newtonian) concept of space was able to contain objects, surfaces, volumes and outlines, but not the bodies without a surface. Understood as dynamic events, they resist a geometrical objectification and produce a veritable data drift. According to German media theoretician Joseph Vogl, they assign in a chaos of incoming data the “general incapability of defining objects, the inability to empirically experiencable objects.”[4] Clouds, smoke or swarms thus subvert the transmission of sensual data in their constant *Becoming* (Vogl refers to Gilles Deleuze’s notion of the term) of overwhelming data generators. Rather than being determined by a rigid set of geometrical properties, these data generators cast an observing subject and its perceptions into a malleable space – the subject is confronted with a nervous geometry, with a perpetual *Becoming-Swarm* (in analogy with Vogl’s concept of *Becoming-media*[5]) fueled by local dis- and rearrangements. Spatial positions and geometric reference systems become fuzzy, the identifiable location of an object in space and time gets lost.

2. Parasitic Noise

Here we arrive at a first and media-theoretical dimension inherent in swarms. They do not appear as geometrically synthesized, objectified entities, but rather as diffuse and gradual physical transmission events which make a pure and 1:1 transmission of events impossible. Thus, swarms impose the media dimension of mediality, acting as multiagent-systems of an exemplary parasitic noise which can be instantiated – referring to French mathematician and

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[3] Damisch, Hubert. 2002. *A Theory of /Cloud/. Toward a History of Painting.* Trans. Janet Lloyd. Stanford: Stanford University Press, p. 124

[4] Vogl, Joseph. 2004. “Gefieder, Gewölk.” *Media Synaesthetics. Konturen einer physiologischen Medienästhetik*. Eds. Christian Filk/Michael Lommel/Mike Sandbothe. Cologne: Herbert von Halem, pp. 140-149: 145 (Trans. SV)

[5] See Vogl, Joseph. 2007. “Becoming-media: Galileo’s Telescope.“ *Grey Room 29: New German Media Theory*: 14-25.

philosopher Michel Serres – as the beginning of all media theory.[6] Relations, in Serres's sense, build up only in processes of excluding or eliminating a third party, a parasite and parasitic noise not only inhabiting all sorts of communication channels, but preceding any form of communication. "In the beginning there is noise" – this apodictic notion suggests the inevitable instances of noise attending every media relation. It zeroes in on a productivity of noise, of the bruit parasite: Deviation and noise are no longer imagined as accidental, secondary or supplementary processes contaminating an original, absolute or pure relation between a sender and a receiver or an observer and an object.[7] Quite contrarily, Serres' theory depicts a breakout of dialectic schemes an escape from dialectical thinking in favor of one of dynamic relations. With noise being an inevitable element of communication, the figure of the parasite propels a thinking in gradients and fuzzy logics rather than in clear-cut (logical) categories.

3. From Poetry to Psycho-Physics

The second dimension inherent in swarms and swarming which is of interest in this investigation consists of the biological research in swarms, flocks and fish schools. Such a media history can be affiliated to the approach outlined above: It can be written as a media history of different apparatuses, of optical and acoustical field- and laboratory settings which constituted itself based on questions on how to eliminate the noise, the interferences which the scientific 'object' school or swarm produces while being objectified. The American Ichtyologist Charles Breder noted in 1953: "Truly schooling fish are notoriously difficult

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[6] See Serres, Michel. 2007. *The Parasite*. Trans. Lawrence R. Schehr. Minneapolis, London: Minnesota University Press.

[7] See Siegert, Bernhard. 2007. "Cacography or Communication? Cultural Techniques in German Media Studies." *Grey Room 29: New German Media Theory*, pp. 26-47.

laboratory material."[8] And Marine Biologist Julia Parrish stated for open water experiments: "Tracking requires a known frame of reference within which the object moves. If an object moves very fast, the rate at which its position is sampled must also be fast to accurately record changes in speed and direction. [...T]racking a fish in the ocean is [even] more difficult, as it is likely to swim away."[9] The media technologies of biological research in schools and swarms always try to dampen and filter the noise that their fuzzy object constitutes in order to gain an epistemic access to the other amplitude of the oscillatory relation inherent in swarms: to their likewise often as fascinating and adorable described coordination capabilities.

Against earlier theories of a centralized control through leading swarm members, versus ill-defined 'social instincts' and against explanations of swarm cohesion by means of thought-transference, at least since the late 1920s, biological swarm research attempted to verify that the collective movements of swarms resulted from massive parallel, but only locally organized interindividual interactions of swarm individuals. Interested in the operationality of the interplay between local movements and the overall dynamics of swarms as a whole, biologists applied visual observation systems (film and video cameras) to their object of inquiry, both in the open water or in the artificial environments of tanks and aquariums. With this individual-based approach, starting from film stills and chronophotographic images, the manual (and later semi-automatic) tracking and analysis of individual paths in the collective was attempted. Moreover, led by fisheries research, acoustic

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[8] Breder, Charles M. "Studies on the Structure of the Fish School. *Bulletin of the American Museum of National History* 98 (1951), pp. 1-28: 7.

[9] Parrish, Julia K./Hamner, William M./Prewitt, Charles T. 1997. "Introduction – From Individuals to Aggregations. Unifying properties, global framework, and the holy grails of congregation." *Animal Groups in Three Dimensions*. Eds. Julia K. Parrish/William H. Hamner. Cambridge: Cambridge University Press, pp. 1-14: 7.

imaging technologies have been developed to scan whole fish schools under water, engaging in their global reactions to environmental stimuli.[10]

As an outcome, the fascination of swarms no longer relied on the phenomenologically 'sublime' of their forming and transforming on winter skies or under the water line, described by writers such as Jules Michelet, Maurice Maeterlinck or John Steinbeck.[11] When the latter describes an encounter with a fish school in his novel *The Log from the Sea of Cortez*, it resonates with a rather romanticist undertone which recalls the notion of the 'spirit of the bee-hive' that Maeterlinck emphazised at the end of the 19th century: "The school swam, marshaled and patrolled. They turned as a unit and divided as a unit. In their millions they followed a pattern minute as to direction and depth and speed. There must be some fallancy in our thinking of these fish as individuals. Their functions in the school are in some as yet unknown way as though the school were one unit. We cannot conceive of this intricacy until we are able to think of the school as an animal itself, reacting with all its cells to stimuli which perhaps might not influence one fish at all. And this larger animal, the school, seems to have a nature an drive and ends oft its own. It is more than and different from the sum of its parts."[12]

Contrarily, the biological research in swarms, flocks and schools became fascinated by the ability of a system of multiple individuals – in which each individual had only a very limited knowledge of its environment – to be physically able to perform maneouvers or adapt to environmental changes in such a swift, dynamic, and coordinated way.

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10 For a more detailed media history of these approaches, see Vehlken, Sebastian. 2009. "Fishy Business. Mediale Durchmusterung von Schwärmen unter Wasser", in: Brandstetter, Thomas/Harasser, Karin: *Grenzflächen des Meeres*. Wien: Turia und Kant. (Forthcoming)

11 See Michelet, Jules. 1864. *The Sea*. New York: Follet, Foster; Maeterlinck, Maurice. 1901. *The Life of the Bee*. Trans. Alfred Sutro. URL: http://www.ibiblio.org/eldritch/mm/b.html. Steinbeck, John. 2000. *The Log from the Sea of Cortez.* (Reprint). London: Penguin.

12 Steinbeck 2000.

4. Science Fiction and Swarm Intelligence

In more recent examples of the depiction of swarms in Science Fiction movies – and here we arrive at a third dimension inherent in swarms – we find this new fascination for coordinated behavior in biological swarms reflected in animated sequences of moving collectives – for example in the collective destructive power of the 'sentinels' in Matrix Revolutions. In addition, we here perceive a thoroughly cyberneticized agent collective: what once had been chaotic swarms of insects, greedy piranhas or marauding flocks of birds in classical swarm horror films – e.g. in *The Swarm* (Irwin Allen, USA 1978), *Piranha* (Joe Dante, USA 1978), or *The Birds* (Alfred Hitchcock, USA 1963) – transformed into swarms of 'intelligent machines,' challenging human concepts of intelligence and strategies of warfare. But despite of this metamorphosis, the depiction and animation in recent Science fiction movies seem to follow in a lot more 'realistic' way the rules of movement and the operationality displayed by biological swarms, flocks and schools. At a time certain ethologists, entomologist and computer programmers almost simulateously began to speak of a "swarm intelligence" emerging out of multiple local interactions of many dumb individuals, *The Matrix* or *Star Trek*'s Borg Collective (though before the introduction of the 'Borg Queen') instantiate precisely such a collective intelligence as a powerful if not superior adversary of mankind in film.

Let us briefly recapitulate the three dimensions of swarms at stake: First, with swarms we are facing fuzzy objects or 'non-objects' of an uncanny state: it is not quite clear whether one encouners – to use a distinction made by Austrian media theorist avant la lettre Fritz Heider in the early 1920ies – 'things' being transmitted or 'media' transmitting only themselves as transmission events.[13] Hence, swarms are agents of a decomposition of spaces, places and orientations. Second, we are facing epistemic objects, resulting in an ongoing process of applying various media technologies in biological swarm research. Not until recently, not before the advent of computer simulation and sufficient calculating power, the sheer abundance of data streaming into these media technological setups constrained significant improvements in this field. And third, since the mid-1990s, a discourse of the possibilities and capabilities of "swarm intelligence" somewhat superseded the notion of swarms as chaotic and panicking collectives with an idea of a superior collective coordination technique based on many distributed, parallel interactions of simple individuals without the time-lags of centralized or hierarchically organized collectives.

However, the question remains how these three dimensions of swarms and swarming are bound together and how Science fiction film is establishing and arranging this specific relationality. To meet this question, we are going to engage this relationality – in the context of Computer Graphic Imaging (CGI) for feature films – effectuated by something which can be called a computer graphics a priori. We visit a scene, where a biologization of computer science intersects with a computization of biology, building up a technological amalgam which initially rendered possible the dynamic discourse around and the to date exuberant metaphorical use of 'swarm intelligence' in various scientific and social areas.

5. Particle Swarms and Bird-oid Objects

Swarms as "bodies without a surface," as precarious objects with diffuse boundaries associate an aesthetic with an epistemic borderline experience. Not only the painters of the Renaissance faced the conundrum to represent fuzzy objects such as clouds, smoke, dust, or

[13] See Heider, Fritz: *Ding und Medium*. Berlin: Kadmos.

fire, but also – some centuries later – developers in the digital graphics and animation design. Starting in the early 1980s, Particle Systems, a tool first introduced by Lucasfilm graphic designer William T. Reeves, realized visualizations of dynamic relational objects by the defined behavior of multiple virtual particles, introducing a representation technique utterly different from those normally used image synthesis. First, instead of primitive surface elements like polygons or patches designating the boundaries of an object, in Reeves' software tool clouds of primitive particles defined its volume.[14] Second, he conceptualized particle systems as dynamic entities, suggesting that the particles changed form and moved over time. And third, particle systems did not represent the modeled objects in a deterministic way: their shape and form was not completely specified but replaced by stochastic processes to generate and alter an object's appearance and shape.

As an outcome, particle systems showed significant advantages over classical surface-oriented techniques when it comes to the animation of fuzzy objects. Since a particle is much more simple than a polygon as the simplest primitive of surface representation, in the same amount of computation time a lot more of the basic primitives can be computed, resulting in a more complex image. A second advantage is that the model definition is procedural, controlled by random numbers. Accordingly, a model high in detail does require significantly less human design time in comparison with the surface-based systems in use at that time. And as a further effect, a particle system can adjust its level of detail to suit a specific set of viewing parameters, for example for modeling zooming. Finally, particle systems are suited to model objects that are 'alive,' as Reeves stated: that is, objects which change their form over a period of time, cutting off the difficulties which surface-based methods had with the representation of complex dynamics. On this background, Reeves designed for Lucas Arts

[14] See Reeves, William T. 1983. "Particle Systems – A Technique for Modeling a Class of Fuzzy Objects." *ACM Transactions on Graphics* 2 (1983, April), pp. 91-108: 91

the famous Genesis Sequence for *Star Trek II: The Wrath of Khan* (Nicholas Meyer, USA 1982), which has Kirk, Scottie and Spock watch the simulation of a particle-system-generated firestorm circling a planet and preparing it for terraforming – one of the first graphic animation sequences covering the whole big screen.

Some years later, at 1987's SIGGRAPH Conference in Anaheim, CA, *Symbolics Graphics Division*'s Animator Craig W. Reynolds presented a seminal paper which referred to Reeves' particle systems and at the same time turned it from physical to biological operation modes. In his talk, he set forth the very swarm animation model often quoted as a sort of 'original text' of computer-based biological swarm research. However, initially Reynolds explicitly was not interested in exact, realistic individual behavioral rules, but only in a realistic performance of his bird-oid objects, short-termed and popularized as "boids".[15]

For such a realistic animation of a collective of multiple agents, Reynolds writes, it was a bug-producing Sisyphean task to separately program the individual paths of a large number of particles. With such an approach, it was very unlikely to obtain a coherent formation of multiple particles over time and simultaneously avoiding any collision in every frame of a sequence. Furthermore, it would prove exceedingly inflexible since the alteration of one individual path had an impact on those of other swarm.[16] Instead, Reynolds asked himself how natural swarms would accomplish their coordination tasks, since relatively simple individuals like birds or fish would likewise organize themselves without time-consuming and advanced mathematics.

Reynolds in his multi-agent system replaced the dot-like particles of the Reeves model with entire geometrical objects, defined by a individual local coordinate system and a

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[15] Reynolds, Craig W. 1987. "Flocks, Herds, and Schools: A Distributed Behavioral Model." *Computer Graphics* 21 (1987), pp. 25-34: 25
[16] See Reynolds 1987, 25

reference to a geometrical shape model, resulting in the addition of individual orientation in space. Unlike the only stochastic diffusion processes in Particle Systems, the Reynolds-Boids now were able to coordinate themselves in accordance with a simple algorithm consisting of three defined traffic rules: First: Collision Avoidance, Second: Velocity Matching and Third: Flock Centering. Reynolds tested his model with different values for his three parameters and got a quite interesting result: A cohesive movement was only obtained if the Boids oriented themselves at the solely locally perceived center of their nearest neighbors. "[T]he aggregate motion that we intuitively recognize as 'flocking' (or schooling or herding) depends upon a limited, localized view of the world."[17] Due to their simplicity and flexibility, computer-graphical Boid-collectives soon were applied in CGI, namely for the animation of bats in *Batman Returns* (Tim Burton, USA 1992), or for stampedes in *The Lion King* (Roger Allers/Rob Minkoff, USA 1994). Again, the disposal of control and rigid programming initially led to the complexity of the model and the efficiency of the modeling process.

At this point, swarms in the movies not solely appear as deformations and decompositions of space, places, and the individual. They become visible not just as image interferences, but at the same instant as the organizing principle of animation, of imaging. What we find here is the nexus of a perspective on swarms as fuzzy phenomena while they become a precondition for their own feasibility: in order to simulate realistically looking swarms in CGI, graphic designers 'experiment' with distributed behavioral parameters which subsequently are advocated as possible biological behavioral rules. Or, as Eugene Thacker puts it: "The 'bio' is transformatively mediated by the 'tech' so that the 'bio' reemerges more fully biological. [...] The biological and the digital domains are no longer rendered

[17] Reynolds 1987, 29-30

ontologically distinct, but instead are seen to inhere in each other; the biological 'informs' the digital, just as the digital 'corporealizes' the biological."[18]

Even if Reynolds' distributed behavioral model was – as some biologists remarked – 'biologically improbable' in some details, the dynamic CGI of his swarm simulations put forward an epistemic strategy beyond the "technological morass" that biological swarm research was trapped in in the late 1980s.[19] Biological swarm simulations, referring to Reynolds' original model, present a procedual way of knowledge production. They replace the precarious representations of the classical geometric code of central perspective, which collapsed when facing the diffuse "bodies without a surface," with a code not designed to localizes an object, but intended to enable the swarm individuals to independently localize and orientate themselves. Euclidean geometry is substituted by a topological system which creates its own space and shape, and which opens up an episteme of computer experiments. Computer-simulated swarms are not a representation of natural swarms, but can be conceived of as visual presentations issued from agent-based-modeling whose rules are manipulated in a process of trial and error until the simulated system shows an adequate ressemblance with the natural.

Thus, they extend the classical epistemological paradigma with its notions of theory on the one and experiment on the other hand. The very same CGI technology that depicts the massive swarming sequences of Science fiction film and makes mankind literally facing this different notion of a collective intelligence on the other hand can be put to operation in biology and in other sciences for the production of new Science facts.

6. Epistemic Outlook: Science Fact and Swarm Intelligence

[18] Thacker, Eugene. 2004. Biomedia. Minneapolis, London: University of Minnesota Press, pp. 6-7
[19] See Parrish/Hamner/Prewitt 1997.

This article briefly highlighted (or rather spot-lighted) some lines of thought concerning a theoretical and technological double-bind of CGI visualisations of agent-based simulations: These at the same time became utterly relevant for the production of Science fiction film sequences involving notions of an uncanny 'swarm intelligence,' and for a research in, for example, biology which was becoming more and more dependend on the use of computer simulations regarding the production of Science fact. A nexus for this bind, as we have seen, can be identified in Reeves' and Reynolds' dynamic animation models and their successors.

This chiasm may remind the media historian of a scene where the scientific use of chronophotography was contrasted with the representational qualities of the cinematograph. It was Étienne-Jules Marey who distinguished the former from the "perfect illusion" of Cinema. Marey states: "In the final analysis they [the cinematic images, SV] show what the eye sees directly; they add nothing to the power of our sight, remove none of its illusions. But the true character of a scientific method is to supplement the weakness of our senses or to correct their errors."[20] In contrast, the generation of chronophotographic pictures included a "technological seeing" of what Marey called "living pictures" on a whole new level compared with human perception.[21]

Agent-based modeling and simulation today does a similar split. On the one hand, it permits a presentation of the non-perceptable in cinematic CGI sequences, whilst on the other it allows for a synthesis of non-analyzable multiplicities constantly moving in three spatial dimensions plus time, such as flocks, schools, and swarms in biology. Furthermore, as biomedia, within the last years they became operational as tools in the context of

[20] Marey, Étienne-Jules. 1899. "Introduction." In: Eugene Trutat. *La photographie animée*. Paris: Gauthier-Villars.
[21] See Marey, Étienne-Jules. 1902. The History of Chronophotography. Annual report of the Board of Regents of the Smithsonian Institution, pp. 317-340.

mathematical optimization problems (e.g. under the acronym PSO for Particle Swarm Optimization), or in fields like crowd control and traffic digestion. As an effect, a genealogy of swarms associates the horror of the many with a level of control via programming of these collectives in CGI. And it binds together biological research in swarms with optimization applications in various fields tagged with the label 'swarm intelligence.' As an outcome, the collective intelligence of swarms mainfests as an intelligence of animation in a double sense: as an intelligence of movement, and as an intelligence decisively developed in animation design.