Collective Autonomy

Incentives And Chances for Humans to Benefit From a Collective Surplus

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Swarm, Swarm Behaviour, Human Swarming, Collective Autonomy, Individual Autonomy, Swarm Organisations

The biological phenomenon of swarms remains a challenge to many researchers. The complexity that emerges from combining relatively simple individual behaviour yields many questions. The emerging apparent perfection has not yet been investigated satisfactorily. This paper presents an elucidation of the term swarm, both for animal and human swarms. Autonomy as a possible bonding force in swarms is the focus of the analysis. A considerable difference between individual and collective autonomy will be outlined. The potential that arises from the high degree of collective autonomy has to become more obvious in order to benefit further from the hyper organism.

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1. Introduction

They are moving as if by command, as if they were one single organism, though there is no obvious commander in this system. Many individuals are part of it but at the same time it is just one: the swarm, a system without steady hierarchy or central guidance. One of the most noticeable things when observing a swarm of animals is its beauty while moving. It appears like a perfect play but there is no director. Not only animals form swarms but human beings do as well. In other words: fish and human beings have more in common than previously thought. Being part of a swarm means copying the behaviour of one another and living in a type of super-organism. The collective of a swarm is a system that attracts attention due to its elegance and its almost perfect coordination. Imagine a swarm of herring that reacts incredibly quickly in the presence of potential danger (for example, a natural enemy such as a whale).

The swarm's quick movements as well as its ability to match its opportunities and challenges are fascinating. Approaching the issue from a rather normative perspective, the possible basis on which properties this super organism exists will be examined; does the swarm only has a functional value or does it possess a sort of intrinsic value? The focus of this paper will be the notion of autonomy in swarms: Could autonomy be a swarm's driver and somehow its social kit?

Firstly, five constituting features of a swarm will be derived from the behaviour of animal swarms. To understand the concept of a swarm, including the matter of swarms in working life, it will be demarcated from other existing systems, such as networks. In order to emphasise the chances that autonomy can generate in organisational structures, a business network will be described. The matter of autonomy will be introduced by describing moral autonomy according to Kant. Autonomy constitutes a central value in his moral philosophy. The reason for choosing Kant's reference of autonomy is that he provides a rigorous deontological account of it. Viewing autonomy as an intrinsic value for the individual seems to contradict the idea of losing individuality and following other's behaviour in a swarm. It is therefore a challenge to analyse whether the individuals in the swarm and the swarm itself can be seen as autonomous in an account of autonomy that centres on the individual's freedom and liberty.

The analysis will reveal certain tensions that arise between individual autonomy in swarms (negative autonomy) and collective autonomy of swarms as a whole. For the purpose of the argument, several ad hoc hypotheses will be specified, e.g. concerning the notion of autonomy. It must be clear, though, that the purpose of this paper is not to deliver a detailed approach to fundamental

philosophical questions, but rather to draw attention to and seek inspiration from a hardly tangible phenomenon to deliver a basis on which further empirical research can be based.

2. Swarms in everyday life – observable phenomena

2.1 Features of a swarm

Closer observations of everyday life reveal that swarm behaviour assumes an important role in people's lives. Consider, for instance, the decision-making process of individuals who participate in a mass event like a festival. In deciding whether or not to head for the entrance (in anticipation of the beginning of a concert), each individual will be guided by the behaviour of others. Individuals anticipate that the crowd has to know whether the event starts or not and they rely on its wisdom.

Swarm behaviour could be characterised as the reflexive reaction to one's surroundings. The mirroring of one's neighbour's behaviour can occur either consciously or unconsciously. Jansen terms this system "leadership of neighbours" (Jansen 2008: 166).[1] A fish swarm is one of the most obvious examples for swarm behaviour in nature (in addition to the collective of honeybees and ants): it moves quickly and reacts incredibly fast to potential threats by successfully dodging them. The principles that enable a swarm to react quickly have been investigated in 1986 by the American programmer C. Reynold. By means of computer simulations, he could show that a herring swarm works according to just three swarm principles:

1. Always keep your minimum distance of one third of your length.
2. Always balance your distance to an average of one time of your length towards your neighbour.
3. a) Try to match the speed and direction of your neighbour …
   a) If discovering food, swim towards it. (cf. Jansen 2008: 167).

Following these three simple principles is sufficient to create something very similar to self-organisation, resulting in the impression of perfect movement that is characteristic for fish swarms. The question why herring are shoaling fish can be answered very easily: a swarm has emergent

1 Jansen calls this phenomenon heterarchy (leadership of the neighbours) – the opposite of hierarchy. According to him, a swarm is superior due to its heterarchic structures.

properties with respect to enemy protection and assistance in searching food. In other words, the reason for the emergence of the herring swarm is most probably a degree of efficiency that no individual could attain on its own. A swarm's challenge is to act permanently and to make decisions immediately. The results are continuous movement and changes in density. Hence, one of the constitutive swarm features is flexibility.[2]

The fact that there is no leader among the herring means that the swarm is decentralised. It faces the complex task of continually deciding on the direction of the swarm without an external governing entity directing it. From this, we can derive the second constitutive feature of swarms: Self-organisation, meaning that all formative or restrictive influence comes from the elements of the system itself (here, the members of a swarm). There is no centralised control but a governance for each subunit, that is to say, for each individual respectively herring. Self-organisation in biology can be described as follows:

> "In biological systems self-organisation is a process in which pattern at the global level of a system emerges solely from numerous interactions among the lower-level components of the system. Moreover, the rules specifying interactions among the system's components are executed using only local information, without reference to the global pattern" (Camazine/Deneubourg 2003: 8).

A certain underlying mechanism somehow makes it possible that the swarm organises itself. The self-organisation, in turn, results in the incredibly strong cohesion (cf. Kneser 2008: TC00:04:22). The fact that a swarm of herring incessantly changes its density and form does not affect its cohesion. In a swarm, there is no regulative centre – such as a "herring king" – that is needed, for example, to punish in case of disobedience. Instead, every herring that is part of the swarm adapts itself to its neighbour's behaviour. This adaption may be illustrated as the leadership of the neighbours. Fast adaption works according to the aforementioned principle: Regulate the distance to your neighbour in a way that you are on average one length away from him. The individuals of a swarm, which could consist of up to 10,000 members, are determined by their neighbours. Consequently, the average speed does not result from a central command but is the intuitive behaviour to swim as fast as one's local neighbour (cf. Topaz/Bertozzi 2004: 152). Researchers at the University of Rome

2 These following five swarm features are referring to the consulting company 1492 GmbH, which originally developed them.

found out that the copying behaviour affects a constant number of neighbours. This means that, however, the swarm density may change, while the number of neighbours an individual orientates to remains constant. The four, five or six closest neighbours are always the ones that determine an individual's behaviour in swarms and not – as it is sometimes assumed incorrectly – individuals within a certain radius away from the individual (cf. Ballerini et al. 2007: 1232).

A further step in describing the super-organism would be to characterise it as self-regulating. Self-regulation means that a system adapts constantly to new circumstances (both to challenges and to chances). A self-regulating system thereby entails constant evolution. Changing the blood pressure of humans, for instance, reveals the fact of a self-regulating human system, respectively organism. An observable phenomenon of the herring swarm is collision avoidance (cf. Jansen 2008: 166). It illustrates the matter of self-regulation as a feature. Every individual avoids collision and thereby guarantees the functioning of the swarm as a whole. The swarm optimises itself by neglecting inexpedient or inefficient behaviour of individual members, such as swimming faster than one's neighbour or ignoring food thus adapting to various circumstances. In this way, members realise a high degree of efficiency to the advantage of the mass. The swarm manages to reach goals that no individual on its own is able to reach, like fighting off larger predators. There seems to be an area of tension between the individuals' capacity and the level of collective goal attainment, which will be dealt with later in the paper.

Another salient feature of the swarm is robustness. It does not matter if some individuals do not swim towards food. The masses compensate for the disturbances and are still able to locate the food. It does not matter if a whale attacks a swarm of herring; the swarm remains intact. There certainly is a critical number of disturbing individuals that would lead to a breakdown of the swarm system, but the capacity of compensation of single individuals' incorrect behaviour can still be called very robust. The cohesion works under incredibly aggravated conditions.

One last swarm feature that should be emphasised is the swarm as a fractal system. It is a system where every subunit constitutes of an independent, minimised copy of the whole system regarding its capabilities and competencies. All members of the herring swarm are animals of the genus Clupea, for instance. By identifying some characteristics of a fractal, it becomes more obvious why a swarm can be called a fractal system: Self-optimisation, self-organisation, goal orientation, dynamism and self-similarity are properties of a fractal (cf. Gienke/Kämpf 2007: 118). Regarding the swarm's individual members, the fractals, all these features match. They organise and optimise required processes to fulfil their task and to eliminate disturbances without external

aid. It is the herring's own decision in which direction to swim. The herring decides on its own where to swim (apart from the unconscious leadership of the neighbours) and whether to be part of the swarm or not. All an individual needs are some neighbours. Every animal defines food and survival as primary goals even though they are theoretically free to have different objectives. The advantages emerging from moving in a swarm lead to transparent, similar targeting. Furthermore, the fractal neglects inefficient behaviour according to the swarm principles and thereby contributes to optimising the swarm as the whole – the fractal system. Dynamism just means that all fractals are interconnected; thus, individuals can be seen as fractals. The five swarm features that now have been exhibited serve as a definitional basis for understanding a swarm: flexibility, self-organisation, self-regulation, robustness and fractal system.

2.2 Swarm vs. Network

Can we find human networks or social systems that meet the requirements and therefore can be called a swarm? Before answering these questions, it is necessary to specify what exactly a network is and where its difference compared to a swarm lies. One could define a network as a system with much less hierarchic structures than other organisations, probably the most non-hierarchic system commonly known. A network is composed of informal groups or cliques that are amalgamated into an organisational construction with focus on a non-hierarchical form of cooperation and coordination. As soon as a party, for example an enterprise, searches for and keeps up relations with other parties, the emerging tangle of relations can be called a network (network of enterprises or economic network). In considering a business network, it is essential that connections between organisations are closer than they would be on the free market. A network is more than just a clustering, since it is not just about the existence of connections between elements, but about the kind of connections (cf. Corsten 2001: 2). Similarly, Schulte-Zurhausen describes a network organisation as an "organisation consisting of relatively autonomous members that are connected by their common aims and that work co-ordinately together" (Schulte-Zurhausen 2005: 286). Dynamisation of cooperation structures in many companies leads to a higher demand for looser organisation models with a focus on coordination and cooperation. Networks constitute that sort of organisation. In the days of a more and more virtualised working environment accompanied by the increased importance of e-mobility, network structures become increasingly important, not only in business organisation theory. Network organisations exist since they can realise synergy

effects and competitive advantages. Every kind of a network, no matter whether social, political, technical or business, represents a form of loose organisation (cf. Neef 2003: 1).

A swarm, however, distinguish itself in its capacity to emerge extremely fast and to act flexibly and co-ordinately without any planning. A swarm is perceived as a system with extraordinarily perfect organisation. Observers often fail to notice that unintended self-organisation leads to its perfect appearance. A network is made by humans and can be destroyed by them. A swarm is not constructed artificially but it emerges spontaneously. It is not as sensitive as a network and its robustness is overwhelming: These complementary features are also recognised by bestselling author Frank Schätzing (2004) in his book Der Schwarm. A simple network and its communication system can be destroyed by natural catastrophes, whereas a swarm is robust and superior. Even though a network is weaker than a swarm, its structures constitute essential conditions for the existence of a swarm. The highly coordinated network culminates in a swarm with perfect coordination. As already mentioned, networks can simply collapse. It is necessary to examine the manner of cohesion to see why a human-made network can break down. How does the cohesion in a network function? Considering the incentives of being part of a network, respectively being part of a swarm, it becomes obvious that an individual in a network still faces an incentive to deviate. Networks are confronted with a likely dilemma situation, since a one-sided defection could also guarantee the advantages of a network. This free-rider problem, pretending to cooperate but in fact intending to defect, does not occur in swarms. Both swarm and networks are purposeful systems. The former is characterised by a transparent goal that is visible and the same for each member. In principle, a network shares these characteristics but a common objective does not seem to be a sufficient remedy to get cohesion. A swarm's fractal would not deviate from the cooperation strategy, since it would be disoriented acting as a separate individual. Without its affiliation, a swarm animal would neither be successful enough in avoiding enemies nor in finding food. Consequently, it probably would perish. If the existence as a swarm member were not that essential, the individuals would not be part of it. Why should a person decide to head to the entrance of a festival without further information when she did not anticipate something pleasant by following her neighbours?

2.3 Human Swarms

After considering the difference between swarms and networks, the existence of how this perfect appearance performs considering humans or more precisely human swarms will be examined. Swarm behaviour can be found in many social phenomena. The above-mentioned behaviour on mass events (see page 2) constitutes an example. The fact that usually two distinctly opposed trails are formed on highly frequented sidewalks is also such a phenomenon. Here, humans seem to coordinate themselves without anybody who tells them where to go. They communicate without verbal communication, that is to say they communicate silently, just through their movements. However simple the examples of swarm phenomena might be, so useful and efficient are human swarms. Another example for human swarms is a so-called smart mob.[3] Smart mobs are anonymous and mobile processes of cooperation functioning according to the principles of social swarming. The term social swarming means rather technologically based swarm behaviour. These more complex kind of human swarms strongly rely on communication. Mobile and ubiquitous technologies make it possible and attractive to act co-ordinately with even unknown people (cf. Neef 2003: 2). So-called critical mass movement is totally non-hierarchic and self-organised via Internet or mobile phones, such as bicycle demonstrations that try to paralyse all traffic.[4] Critical mass is an example for social swarming. The human swarm behaviour or social swarming culminates in the World Wide Web. Each Wiki,[5] for example, constitutes swarming individuals who try to collaborate in sharing their knowledge. Each individual on its own could never be able to create a Wiki, as the format results from letting everybody participate (or at least a certain group of members; for example, concerning captive Wikis). Human swarms emerge since they also, as a herring swarm, provide a high degree of efficiency. As pointed out already, there is no incentive for swarm individuals to deviate, because they profit from the cooperation strategy. This applies to the cited examples also. Smart mobs reach their goal by acting and communicating spontaneously and without having a leader. Their self-organisation is highly timesaving and thus more efficient than other organisations that have the same objective. The crowd at a festival would not know when head to the entrance without trusting the neighbour's behaviour.

3 The term is invented by Howard Rheingold (cf. Neef 2003: 2).

4 "Critical Mass is not an organisation, it's an unorganised coincidence. It's a movement ... of bicycles in the streets" (www.critical-mass.org quoted in Neef 2003: 2).

5 A Wiki is a hypertext-system for websites that enables their users not only to read the content but also to modify it online.

The enormous potential of animal swarms has inspired researchers to assess human swarms under experimental conditions. Swarm experiments are constructed in a way that swarm behaviour emerges in groups of humans. Researchers try to clarify to what extent humans are similar to animals and how human swarm behaviour can be influenced. Certain groups of people are instructed to follow some typical swarm principle as e.g. "Don't let your neighbour get closer to yourself than one body length." Jens Krause and John Dire from the University of Leeds are initiators of the world's largest swarm experiment with humans that took place in 2007 in Cologne. 200 people participated and were asked to walk through a huge fair hall. The tasks for the participants were firstly to move constantly without communicating and secondly to stay close to one's neighbours (at around one arm length). The experimenters found a number of parallels between human and animal swarms. Even the torus-movement that is typical for animal swarms could be recognised that day. However, it has to be noted that the researchers also found that a critical number of individuals can disturb a swarm's robustness. In a modification of the experiment in which a small number of group members were instructed to move in a certain direction,[6] Krause and Dire found out that 5% (10 people out of 200 participants) are sufficient to direct the movement of the swarm and thus, to lead it (cf. Kruse et al. 2008: 786). It becomes obvious that the functioning of the swarm is dependent on participation (acting according to the principles) and thus fragile, howsoever robust it may be when acting according to the rules.

It is easy to figure out that the five determined swarm features fit into the human swarm emerging in the experiment: The masses move flexibly and each individual stays close to his neighbour but avoids collision. There is no organiser that modifies the game by giving spontaneous instructions. The experimenter only instructs the participants to act according to simple principles. Once the experiment has started, he does not interrupt the process anymore. The experiment's swarm shares the feature of being self-regulated. There is no external force that regulates the swarm but the movements according to the simple instructions are sufficient to regulate the masses. Whereas a herring swarm does not even need simple instructions but manages to regulate and organise itself due to the so-called lateral organ, the human swarm in Cologne first needed a short instruction. Robustness is not as obvious as the other features because Krause and Dire did not modify the experiment in a way that individuals stopped moving according to the principles (move constantly, do not communicate and stay close to your neighbours). However, if a certain number of individuals

6 The instruction to move towards a certain direction was only known by the individuals concerned.

stopped moving, it would most probably not have any effect on the swarm and its movement as a whole. The individuals simply would no longer be part of a swarm. The robustness of a swarm, presumably, would then be maintained since a few outliers would not disturb the swarm. The non-participating individual would just not reach the targeted direction and thereby not profit any longer from being part of the swarm. Therefore, the swarm is robust in the sense that individuals do not have influence on the swarm as a whole. This fact is also underpinned by the empirical result that a critical number of approximately 5% is needed to influence the swarm.

The case is more difficult if we assume that a critical number of individuals try to lead the swarm by actively trying to direct it (see above). It must be said that this case seems a bit farfetched since 5% of the group would have to develop their own group-norm and act strictly according to it. The crucial point is that it is not sufficient if 5% of the members decide not to follow the swarm principles. Rather, the 5% must act as a subgroup in a coordinated fashion according to their own principles to influence the whole. The robustness is therefore not dependent on the individual behaviour of 5% of its members but dependent on the coordinated behaviour of 5%. These different cases must be strongly demarcated from each other, since the latter feature of the swarm can be seen as a condition of flexibility. Considering the herring swarm, it is obvious that a certain number must have influence on the direction of the swarm since its aim is to find food. The ones who detect the food must be able to some extent to influence the movement. The robustness of the swarm must therefore be understood as being independent of individual's behaviour.

The last feature, the fractal system – can be slightly misleading because human beings obviously are highly differentiated beings and their unique character traits lead to totally different reactions under common conditions. Recalling the fractal feature makes clear that the human swarm also displays a fractal system: The individuals all have the same capacities needed (to accord principles, to move freely etc.) and all are Homo sapiens. They definitely share the goal that per instruction is known by everybody. Self-similarity in goal orientation is a feature of a fractal and matches the human swarm phenomenon observed here.

3. Intrinsic Cohesion

3.1 Autonomy as a Non-Material Incentive

Five important swarm features have been presented so far and it has been shown that these criteria even concur with human swarms. The further question now is whether there is more than that constituting the swarm. Is there some kind of a value of a swarm besides its functional and highly efficiency-raising features? Does the fact that there is no functional centre in a swarm mean that a normative control centre cannot exist – a normative telos? A high degree of autonomy, for instance, could work as an appeal for one's involvement in a swarm or, to put it in other words, to join a swarm. Up to this point, the incentives of a swarm have been degrees of efficiency that could not be reached on one's own. Being part of a herring swarm diminishes the risk of getting preyed upon considerably. Individuals join a swarm because it increases the probability of survival. Being nourished and diminishing the risk of enemies are the most obvious advantages of animal swarms. What exactly are the incentives for an individual to join a swarm? Concerning human swarms, it is no longer just a matter of mere survival; it is rather a question of how to improve one's circumstances of life and how to benefit from one's neighbour.

3.2 What Is Autonomy? – Three Criteria

Autonomy basically means governing oneself. Self-administration, independence, self-reliance and freedom of choice are some of the words coming to mind while considering the meaning of autonomy. The reason why being autonomous seems to be an important objective within society is that when acting autonomously people can be held accountable for what they do. Additionally, autonomy is connected with some kind of self-integration: people do not want their intentions to be controlled by somebody else. People initiate their actions themselves and usually want to be held responsible for it. It is often argued that in absence of autonomy, our private sphere is threatened (cf. Rössler 2001: 34). Autonomy seems to be something fundamental that everybody aspires to some degree and that deserves a central value in everybody's life. Autonomy often is discussed in terms of personal autonomy – the ability to lead one's life in a sense of one's own choices.

Immanuel Kant described autonomy as important to human beings since it is the foundation of human dignity and the source of all morality. It is called "moral autonomy" (Hill 1989: 99)

when people are able to impose the moral law on oneself. According to Kant's Critique of Practical Reason, morality is conditioned by autonomous practical reason. Autonomous practical reason for Kant means freedom:

> "The autonomy of the will is the sole principle of all moral laws and the duties appropriate to them ... So the moral law expresses nothing else than the autonomy of pure practical reason, that is, of freedom, and this is itself the formal condition of all maxims, under which they can only harmonise with the supreme practical law" (Kant 1778:1, §8).[7]

Consequently, there is a fine line between freedom and autonomy. Kantians often talk about autonomy understood as freedom. Keeping in mind Kant's examination, the freedom of will is considered. Kant's notion of the freedom of will is based on autonomy of one's practical reason. For Kant, the individual will is the initiator of all acts; it is self-legislating and not obedient to any foreign but only to its own laws (cf. dos Santos 2007: 103). The fact that reasonable humans can choose their doings and thereby their lives, presupposes a will. The autonomy of the will means that all acts only obey one's own principles or laws. Decisions are not obedient to exogenously given principles.

One's own moral principles must be chosen according to the categorical imperative[8]. In broad terms, the categorical imperative demands that the maxim of the will must be consistent to serve as a universally applicable principle. The question of whether a principle is suitable to serve as universal legislation can be judged by humans when practicing moral reasoning. The crucial point is that there is no exogenous entity that determines the principles. Practicing moral reasoning is an autonomous process during which the individual has to define its (moral) principles. Thus, if one's principles are chosen by practicing moral reasoning then acting autonomously equals acting morally (cf. Schneewind 1998: 515). Moreover, the distinction between autonomy and heteronomy

7 In the original: "Die Autonomie des Willens ist das alleinige Prinzip aller moralischen Gesetze und der ihnen gemäßen Pflichten […] Also drückt das moralische Gesetz nichts anderes aus, als die Autonomie der reinen praktischen Vernunft, d.i. der Freiheit, und diese ist selbst die formale Bedingung aller Maximen, unter der sie allein mit dem obersten praktischen Gesetse zusammen stimmen können."

8 "Handle so, daß die Maxime deines Willens jederseit zugleich als Prinzip einer allgemeinen Gesetzgebung gelten könne." (Kant 1788: 54, § 7) Can be translated as: "Act in such a way that the maxim of your will could always be held at the same time as a principle of a universal legislation".

is fundamental in Kant's notion of autonomy. Heteronomy means determination by others or to express it in Prauss' words, "causal-determined legality". To act heteronomously means acting according to foreign principles. Consequently, the autonomy of will is not given. Autonomy, however, constitutes a form of freedom and is the antonym to heteronomy. According to Kant, freedom (or autonomy of will) is anomy or lawlessness (cf. Prauss 1983: 58).[9] As autonomy is the base for freedom and the former is the condition of acting morally, heteronomy means acting unmorally. To put Kant's conception of autonomy more simply, it should be noted that autonomy of will means self-legislation and the freedom to create one's own principles.

Another understanding of autonomy constitutes the concept of personal autonomy. Fundamental is that a person does not act autonomously (even if she performs the act herself) when her point of view does not coincide with her act. In some way, the act is not consistent with one's personal conceptions (cf. Buss 2008: 2). Motives are no longer authentic. Acting autonomously, therefore, means having authentic motives behind one's doings. The concept of personal autonomy emphasises the authenticity of one's doings. The debate about autonomy extends over a wide area of research and is not easy to grasp. In this paper, three criteria that appear in different discussions about both moral and personal autonomy shall serve as working hypotheses for the understanding of autonomy.

- Freedom.
- (Self-)reflectivity.
- Responsibility.

Freedom in this sense is to be understood as freedom of will or freedom of choice respectively. It must therefore be distinguished from (absolute) freedom of action. This notion of freedom refers to Kant's account of autonomy: Freedom means autonomy of one's practical reason in a sense that one is free to self-legislate within the frame of the categorical imperative. Kant considers negative freedom[10] on the level of generating moral principles. In the following, the criterion of freedom shall be considered on a less abstract level, e.g. freedom of choosing one's individual lifestyle and of making decisions. Freedom revives the idea of an authentic will or choice to act in a certain

9 "Wenn der Wille...in der Beschaffenheit irgend eines seiner Objekte, das Gesetz sucht, das ihn bestimmen soll, so kommt jederseit Heteronomie heraus". Kant, I. (1785) in Prauss 1983, 58. Can be translated as: "If the will […] in the nature of any of its objects examines the law that shall determine it, heteronomy always emerges."

10 Negative freedom refers to freedom from external and internal constraints.

manner. It means that a decision can be made independently, in the absence of foreign constraints and influence. The second criterion, self-reflectivity, implies that people are able to reflect upon their values, desires and emotions. As soon as a person is able to weigh up possible consequences to others, she acts in a (self)-reflected manner and adapts her comportment to her aims. Autonomous decisions require knowledge about the consequences. Being aware of possible consequences means that people are conscious of what they can expect. Self-reflection, thus, serves as a condition for authenticity. Authenticity means identifying with one's decisions, values and desires. Authentic doings, thus, presuppose self-reflectivity. As long as a person's doings are authentic, they can be autonomous. Authenticity in turn can be guaranteed through (self)-reflection.

The connection between autonomy and self-reflectivity becomes even clearer when assessing autonomy on a non-individual level. Self-reflectivity is needed to determine the constraints set by the autonomy of others.

Responsibility constitutes a third condition, which gains relevance for autonomous acts. Acting autonomously is intimately connected with the notion that a person can be held responsible for what she does. For Paul Benson (1994), responsibility entails a certain self-worth that we trust our capacities of decision-making to be responsible. Kantians would argue that responsibility is an unavoidable implication of exercising practical reason. The main idea is that if an individual acts autonomously in the sense that he reflects on his own principles, then autonomous acts presupposes that individuals can be held responsible for what they do. Therefore, only if people are able to act autonomously can they have moral, social or political responsibility. Thus, responsibility and autonomy must be seen as mutually dependent.

In the following, the extent to which individuals within a swarm and the swarm as a whole act autonomously will be examined. That is why those criteria of autonomy just identified have been given different degrees of relevance. Freedom from now on serves as a fundamental criterion, as an absolutely necessary condition for autonomy. Self-reflectivity and responsibility are complementary conditions for autonomy. They have to be examined only if freedom can been considered as fulfilled.

3.3 Autonomy in Swarms

A commonly asked question in swarm research is how an individual has to act so that a perfect whole results (cf. Kneser 2008: TC00:04:57). What role does autonomy play in a swarm? How autonomously do swarm individuals act and what does the degree of autonomy induce? One could

suppose that autonomy gets lost in swarms, even more than in networks because being part of a swarm means to be guided by others. Orientation towards one's neighbours or leadership of the neighbours is a fundamental feature of a swarm. The autonomy criterion of freedom is obviously injured. To argue in a Kantian way, one could say that to be determined by others will lead to heteronomous and thus unmoral acts. As soon as the autonomy of the will is affected, morality can no longer be taken for granted (cf. Preuss 1983: 56). A Kantian could argue that the obvious foreign control prevalent in a swarm undermines autonomous practical reason. Not only Kantians but also our intuitions would have a problem concerning freedom in swarms: At first sight, autonomy in swarms seems to be something counterintuitive that cannot exist simultaneously. As we have seen, some external forces come into effect in swarms. The neighbour-orientated behaviour applies to both animal and human swarms. By moving towards food (in case of the herring swarm), the individuals are automatically forced to share the hidden food. A potential decision not to share the food is restraint since all the neighbours are encouraged to follow one's behaviour. To the extent that freedom means being able to act against the swarm principles, this seems to violate the first criterion of autonomy. What if any one individual does not want to share the food that it found? Then participation in the super-organism would force it to act against free will. Considering this problem thoroughly, it becomes obvious that every individual has a free choice on a higher level which equally expresses its free will; that is a condition of being part of the swarm and accepting its rules. At this point, it is important to underline that the above-expressed understanding of autonomy (three autonomy criteria) does not include Kant's strict notion of freedom, which excludes any form of determination by others. The determination in swarms is voluntary and indeed consistent with one's freely chosen personal concept of life (for example, to maximise utility). To participate voluntarily in a swarm does not restrict the autonomy of the will, which according to Kant forms the source of all morality. The argument that because of the determination by others, the idea that swarm individuals do not act autonomously can therefore be rejected. Swarms do not imply a loss of freedom if one can be part of them or not by choice.

It has become clear that the criterion of freedom as part of the available definition of autonomy is not restricted. What about the other criteria that has been determined above? Can self-reflectivity or responsibility be fulfilled? Self-reflectivity seems to be missing. Coming back to the swarm experiment in Cologne, none of the 200 people is able to observe the immediate consequences of one's behaviour when being a part of the swarm. To act self-reflectively without being able to see the results of one's behaviour seems to be impossible. The individuals follow two simple rules that

lead to a phenomenon but it is no longer possible to figure out the origin of the result. This effect applies not only to the swarm experiment but also to swarm behaviour in enterprises that will be explained in more detail later in this paper. To find the origins of relevant information and to assign an individual to some element of an innovation might be impossible. Consequently, self-reflectivity is no longer given and the individuals might not act authentically. The individuals make decisions even though they cannot keep an overview of the swarm as a whole and hence cannot foresee possible consequences. This effect of a loss of reflectivity becomes very clear when regarding the point of view of the individual at the centre of the swarm. From the centre of the swarm, it is impossible to have an overview over the swarm and to determine how extensive a particular behaviour's consequences may be. It can be supposed that the degree of loss of self-reflectivity is the highest in the middle of the swarm. Positioned further away from the centre, one could at least assess the effects on one's local neighbours (obviously, there are fewer neighbours) and in this way act in a more reflective manner – that is to say autonomously. Individual autonomy, regarding self-reflectivity is restricted and there might be a different degree of autonomy depending on the position in a swarm.

Looking at the third autonomy criterion, the influence on responsibility, it seems to be difficult to hold people in a swarm responsible for their doings since it is impossible to figure out the source or individual whose movements cause the swarm to change direction. The individuals go with the flow and follow some fundamental rules. As soon as they decide to be part of the swarm (respectively, part of the artificial swarm in the fair halls), they agree that their behaviour is no longer assigned to their own decision but is just the result of following some simple rules. Furthermore, the results can only be observed as a whole from outside the swarm (e.g. the masses change direction) and not in particular individuals. The larger the swarm, the more difficult it is to find the origin of an observable phenomenon. It becomes almost impossible to define the source of a swarm's movement. Even though individuals in a swarm probably still want to be held responsible for their doings (as mentioned in the definition of swarm made at the beginning of the paper), it is extremely difficult to assign the consequences of individual actions to a certain individual. However, individuals get real-time feedback in swarms since they can observe the immediate results of collective doings. The swarm changes direction as a result of collective movements and each individual participates in this process as the smallest unit. Real-time feedback thus constitutes an incentive to act in a certain way, i.e. to follow the principles. Considering the criterion of responsibility from this perspective, one could argue that individuals have an incentive to act responsibly due to the real-time effect.

Nonetheless, responsibility as a criterion for autonomy cannot be taken for granted since individuals in swarms cannot be held responsible for their doings.

It has been elucidated that freedom and independence can be guaranteed in a swarm whereas both reflectivity and responsibility are restricted. The degree of freedom cannot compensate for the intense constraints of the other criteria. Consequently, these criteria are the reason for a loss of autonomy in swarms. Nonetheless, the high level of freedom and independence that individuals benefit from in swarms has to be underlined. Later in the paper, this advantage will be elucidated by considering swarm organisations.

3.4 Swarm Structures in Organisations

Assuming that some kind of swarm organisation, respectively swarm enterprises, exists, would their employees be autonomous? Swarm organisations would be enterprises that display the five swarm features: Flexibility, self-organisation, self-regulation, robustness and fractal system. The absence of any kind of hierarchy (impressed through the swarm criterion of self-organisation) would be indicative for a higher degree of individual autonomy. The principles by which a swarm organisation can work are clarified later in the paper. Voluntary participation clearly applies to swarms in working life. Nobody is forced to act in a certain manner and thereby to participate in the swarm. Employees are free to decide whether to follow the swarm principles or not. The latter would imply an exclusion from the swarm. Having experienced the advantages of a swarm, one's desire would rather be to participate, even though the choice to join is completely free. One could suppose that swarm structures in organisations create the greatest possible degree of autonomy compared to other organisational structures, such as a network. The necessary condition for autonomy, namely freedom, is not granted in network organisations. Self-organisation structures are not very common in business which is why there are only a few examples. Google Maps is the innovative result of an enterprise's internal self-organisation: Google employees were told to spend 15%-20% of their working hours on any project they want to. Swarm features come into effect during this working period at one's free disposal. Through continual evolution, evaluation by fellow employees and circulating information, Google Maps has been created. Google meets the conditions that C. Wentz considers as essential for creating self-organisation: An enterprise needs to have a surplus of resources to be able to create innovation; and there are more workers than necessarily needed who work at full capacity. These circumstances enable the employees to choose different tasks in

accordance with their abilities. Secondly, Wentz describes the appearance of natural hierarchies. They arise based on the underlying problem and are not fixed, which strengthens the first condition by also leading to a structure in which everybody acts in an appropriate manner with respect to one's abilities. A third assumption made by Wentz is that information is redundant. A huge amount of information circulates between the workers who facilitate accessibilities of relevant information. Employees are able to assimilate the information. The same principle is referred to problem solving. Employees accomplish a task simultaneously and hence alternatives are created, with the best alternative accepted (cf. Wentz 2008: 221). Furthermore, the Google example demonstrates the other swarm criteria. Self-regulation can be fulfilled through the non-hierarchic communication process. Information and ideas that are not needed or not considered as useful will be rejected. This communication process also guarantees flexibility. Individuals adapt quickly to new information and ideas and could, if possible, completely change their direction (here: direction of developing and not of movement), since there is no surveillance that would prohibit a change. The matter of robustness becomes clear by imagining that a few people participating in the swarm would use their time for playing video games instead of participating in the developing process. The remaining employees still would be able to create innovation in this timesaving, efficient way. Certainly, there is a critical number of employees that could let the innovation collapse. After all, innovation relies on collective information, ideas and thus collective intelligence. However, assuming the majority is willing to share its knowledge, robustness can be guaranteed. The last swarm feature, fractal system, also is fulfilled. It means that the individuals all have the same, transparent goal and are in general self-similar. Their common goal is to profit from an added value generated by knowledge sharing and thereby to create innovation. The case of Google Maps as a successful result of implemented swarm structures illustrates the high degree of freedom and independence that the individuals enjoy as soon as they are part of this kind of organisation.

The advantage a swarm features concerning its degree of autonomy compared to a network becomes clearer by imagining a swarm organisation rather than by considering Krause's swarm experiment. The more independently an employee works, the more innovative the results (see the Google Maps example above). Likewise, the constraint of reflectivity and responsibility can be observed: The higher the number of people working independently and the more participants the working swarm counts, the more difficult it becomes to reflect one's doings. That means that individuals never know who will further develop their thinking and their initial stages. Due to a redundancy concerning information flow, everybody is able to access the necessary information

to be innovative. The probability that several employers use circulating information increases and to maintain an overview of the potential consequences becomes more or less impossible. This redundancy also leads to a loss of responsibility. It is no longer possible to determine the source of a result as it is no longer an individual who acts but rather a group of employees as a whole who creates innovation. Even though individual autonomy is restricted in swarms, a swarm organisation still constitutes an organisational form that allows people to work independently and non-hierarchically. The organisational form is not a top-down hierarchy but rather a bottom-up one that appears and disappears in accordance to specific problems. It is assumed that a swarm, compared to other organisations, is a highly autonomous (concerning individual autonomy) system. Other hierarchic organisation structures do not satisfy the freedom criterion for autonomy.

How can a swarm, no matter whether an organisational or an experimental one, be so efficient while providing such a high degree of individual autonomy in comparison to other organisation forms? After all, the fundamental and necessary condition of autonomy, i.e. freedom, can be taken for granted. The individual autonomy (respectively the degree of freedom, thus only one out of three criteria) helps reaching a swarm's goal. Everybody is free to leave the swarm. By being part of a swarm, the individuals clearly demonstrate that they share the common goal and have an individual interest in this goal being fulfilled. It is important to underline that the common goals have to be transparent. Otherwise, swarm individuals would not be able to feel capable of being part of the swarm by participating in the goal achievement. Consequently, they probably would not confirm a high degree of freedom and independence, hence of autonomy. The fact that self-reflectivity and responsibility are constrained does not seem to impact the efficiency of the whole. At this point, an analogy to John Stuart Mill's essay On Liberty can be drawn: One's liberty is restricted according to Mill's harm principle (cf. Mill 1991: 16). Individuals are restricted via law. However, freedom makes life worth living, according to Mill. Nevertheless, freedom has to be constrained by law in order to avoid harm to others. Mill understands freedom in a negative way. Individuals are free to act as long as they do not violate the rights of others. Being free from interferences as much as possible make their lives worthy. Consequently, freedom is an essential condition for Mill. Individuals enjoy freedom within the frame of law that ensures the functioning of the harm principle. Therefore, the state functions because of individual restrictions via law. Individual restrictions lead to a collectively more efficient result, respectively a more efficient society. In every eastern society, most inhabitants tolerate following rules and accepting laws. After having recognised that everybody benefits from the resulting mutual advantages, the majority accepts laws. People within

the society would presumably even describe themselves as acting freely. Understanding autonomy, as Mill understands liberty, one could speak about negative autonomy. To make the collective work, one's individual autonomy is restricted.

3.5 Collective Swarm Autonomy

Even though individual autonomy in swarms is restricted (called negative autonomy from now on), a certain force may have an effect on the swarm's cohesion and leads to a collective phenomenon: collective autonomy. The swarm functions in spite of great individual restrictions on autonomy. It is to be found out what role autonomy plays for a swarm as a whole, as a collective.

What could collective autonomy, respectively swarm autonomy, mean? It becomes clearer that something like swarm autonomy may exist by considering the following paradox: As shown above, the first criterion is fulfilled. Every individual that is part of the swarm decides freely and independently. However, nobody is able to maintain an overview over the whole. As a result, this leads to a severe restriction of criteria two and three (self-reflectivity and responsibility). The observable swarm behaviour is the result of individual decisions even though they cannot explain the former. Swarm behaviour is not just the sum of individual decisions. Swarm autonomy, therefore, seems to be more than just the sum of individual autonomy (the sum of its parts). This phenomenon can be described using the concept of the methodological collectivism. It proceeds on the assumption that individual behaviour can be derived from macro-sociological explanations and that collective behaviour cannot be explained by the behaviour of the individuals (cf. Rönsch 1973: 345). Swarm intelligence constitutes an example for methodological collectivism: Individuals are simple and equipped with a limited degree of intelligence. The collective, however, has impressive potential and its capacities exceed the sum of all individual capacities. Assuming that collective autonomy might be more than the above-examined individual autonomy, one difficulty of swarm autonomy might be diversity. How could a group of different individuals act autonomously as a whole (or collectively autonomously) if each individual is able to act autonomously on its own? It might be easier to conceive concerning the animal swarm since they seem to be much more similar than human beings. Even a human swarm is a fractal system consisting of Homo sapiens (see above) but still has very diverse members. All members, howsoever different, share a goal and a diversity of opinions does not impede a swarm's efficiency, as the experiment in Cologne and the Google Maps example have both shown. The tension between possessing a collective property, i.e. collective

autonomy, and the diversity of the swarm members remains. Explaining the collective phenomenon in terms of the methodological collectivism would, however, include such tensions.

Does the swarm as a whole fulfil the autonomy criteria freedom, reflectivity and responsibility? A swarm collective matches all three criteria. It acts freely, independently and sets itself its own goals. No one tells the swarm to move in a certain direction (to refine an idea or innovation). Neither is the herring swarm told to evade enemies, nor is the human swarm told to move in a certain direction (or to create innovation – talking about the organisational swarm). A swarm still has an exit option, is able to stop existing and faces several courses of action. Its decision-making is independent and uninfluenced. A swarm can act in a reflective manner since it interacts as a whole with its environment and learns, for example, to evade dangers or to use information in a more efficient way (see the Google Maps example). By means of experience, the swarm optimises its behaviour and adapts to different circumstances. Reflectivity of a swarm as a whole cannot result from individual reflectivity as shown above. One of the swarm criteria presented – self-regulation – could already have indicated the issue of reflectivity: Inefficient acts in swarms are eliminated and thus swarms are exposed to permanent evolution. Reflectivity of the swarm as a whole constitutes a condition for evolution in swarms. Responsibility can also be fulfilled in swarms but poses some complications. Actions and consequences can be assigned to a swarm; a certain movement or certain innovations can be declared to be a result of the doings of a group of individuals, regardless of whether it is herrings or people. To put it in other words, superficially or visually, a swarm as a whole can be held responsible for its acts. Consequently, it has to be the collective, the swarm, which is responsible and thus has to be brought to account. At this point, theory does not coincide with practice. The German penal law, for example, does not contain criminal sanctions for enterprises and other legal entities. Only fines are possible. This is based on the principle that an act can only be criminally sanctioned if the agent is culpable in moral terms (nulla poena sine culpa). The reasoning behind this argument is that collectives are not able to act morally (cf. Dannecker 2001: par. 3). This very strong assumption is blurred in the light of collective autonomy. The fact that an International Criminal Court exists speaks for an increasing awareness of collectives and a necessity to be able to punish states. However, the juristic debate about collective penal law is an extensive one and is not treated here. Additionally, the question of responsibility and guilt would need to be revised and examined from a juristic point of view. The matter of collective responsibility is not easy to grasp and needs to be used carefully. Nevertheless,

the swarm as a whole fulfils the three criteria of autonomy better than a swarm's individuals do. The surplus of swarm autonomy may foster a swarm's cohesion.

4. Forecast And Future Aspects

As autonomy is highly esteemed in liberal-democratic societies (cf. Rössler 2001: 15) swarm autonomy must be seen as a chance. A high degree of collective autonomy (and likewise already of individual autonomy, e.g. compared to other forms of organisations) constitutes an incentive to participate in a swarm. It is supposed that the individuals are aware of the surplus of autonomy that a swarm as a whole enjoys. Individuals may presume that a swarm thus reaches its highly efficient results.

The revealed tension existing between individual autonomy and collective autonomy can also be considered from an institutional, economical point of view. Individual rationality would demand that swarming be avoided because of the restrictions of individual autonomy.[11] Collective rationality, however, would demand to aspire to participate in a swarm because of the increased degree of collective autonomy and the highly efficient results.

The prisoner's dilemma, a part of game theory, shows similar structures. Individual rationality conflicts with collective rationality. In the case of a one-sided defection, the defecting individual would be better off if both cooperate: Since it is individually rational to defect, the game presumably ends up in the dilemma situation where both players are worse off than they would be if they both cooperated.

	C	D
C	2 / 2	0 / 3
D	3 / 0	1 / 1

TABLE 1: THE PAYOFF MATRIX OF A PRISONER'S DILEMMA (OWN SOURCE)

11 Reflectivity and responsibility are restricted (see page 15). The fact that it could still be rational to join a swarm – when facing a decision between swarm and a hierarchic organisation – (since the latter would not guarantee freedom and independence to the same degree) is not taken into account here.

Since the payoffs in the dilemma situation of the prisoner's dilemma are higher than the payoff of one-sided cooperation, it becomes obvious that the rationality problem in swarms can better be modelled by means of a chicken game.

	C	D
C	2 / 2	1 / 3
D	3 / 1	0 / 0

TABLE 2: THE PAYOFF MATRIX OF A CHICKEN GAME (OWN SOURCE)

One-sided defection means that person A refuses to be part of the swarm because of the alleged low degree of autonomy (since the individual's autonomy is restricted, person A assumes that he will improve his situation by not participating). Person B would still enjoy more advantages if both persons rejected swarming. Nevertheless, his payoff decreases from the socially optimal level since there is a loss of the advantage through ideas and innovation that person A would contribute to the swarm. Consequently, the payoff of person B decreases in the case of one-sided defection. A mutual defection would lead to an outcome that falls both below the outcome of one- sided defection and of mutual cooperation. Therefore, the (Nash)-equilibrium would be the strategy of one-sided cooperation. Individual rationality undermines a socially desirable result.

The awareness of collective phenomena has to be generated and moreover reinforced in order to make people – in spite of their restricted individual autonomy – rely on the swarm and its collective autonomy. Thereby swarming could be one's attitude to life and simplify (make it more efficient) both personal and working processes. Being aware of collective forces and the potential swarm could become a service.

Regarding swarms, individual autonomy makes way for collective autonomy. Swarms are hyper-organisms, not only on the functional level but also on a normative one, which cannot be explained by the sum of its parts. A further challenge would be to examine how to skim off this surplus of autonomy and how to use it more purposeful.

It can be concluded that the matter of collective autonomy of swarms (that exceeds individual autonomy in swarms) constitutes one of the non-investigated causes of the highly efficient results.

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