

Computational Swarming: A Cultural Technique for Generative Architecture

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We can think about form simply as organization.
(Roland Snooks)¹

Shaken or Stirred: Do I Look Like I Give a Damn?

Mies van der Rohe, a notoriously heavy drinker who allegedly asserted that architecture is no cocktail, most certainly would have been surprised by the theoretical and aesthetical mixtures that came along with the advent of digital technologies in architectural design and construction.² From the early 1990s onwards, novel approaches such as *digital tectonics* paralleled the invention of *spline modeller* software tools. Architects started manipulating continuous curved lines directly on computer screens. They mass-produced blob-like forms and challenged former modernist concepts of ordering space by introducing notions of foldings (Greg Lynn) or field conditions (Stan Allen) that adhered to the effects of dynamic environmental conditions on the process of shaping.³ Accompanied by poststructuralist philosophical thought, such as Gilles Deleuze's conceptions of the fold, morphogenesis, involution/evolution and the objectile, or Bernard Cache's and Manuel DeLanda's advancements in topological architecture – or even a 'biology of cities' – the digital turn in architecture fostered a fascination for time-based, multiple, highly interconnected and evolutionary processes.⁴ The crucial design choice became how to set adequate limits for variations, changing the role of the architect from designing a static result to arranging various dynamic processes with multiple instantiations of possible outcomes.

An effect of this was that parametricism allegedly became the ultimate 'new global style for architecture and urban design'.⁵ However, this early and influential cocktail of poststructuralist philosophy and digital architecture often diluted the specific 'materialities' of computer technology, design software, or animation tools which only enabled the handling of such complex agglomerates of data. It expressed, rather metaphorically, a conceptual shift towards the generative aspects of non-linear feedback processes, towards emergent characteristics and towards self-organising systems.

This became even more obvious when architects such as Kas Oosterhuis took these approaches further during the last decade. He not only emphasised the ongoing gamification of architectural design, but also, in a rather counterintuitive way, referred to *swarming* as a novel mode of conceptualising architectural design.⁶ Swarm Architecture, Oosterhuis claimed, would replace substantial forms and orderings with an encompassing notion of architecture as information flow. It centred on the structuring of various movement vectors within a distributed system of different interacting agents (people, materials, environmental forces, etc.). Moreover, with its appeal to the bottom-up principles and emergent global behaviour of Agent-based Modelling and Simulation (ABM), it also transcended the generative principles of spline modelling and parametric design. As Australian architect Roland Snooks adds:

I consider parametric and emergent as polar opposites. Within parametric hierarchical tools all possibility is given within the starting condition, while emergent conditions arise from non-linear systems such as multi-agent models. [...] What we are interested in is looking at design from the smallest element and the way that generates order at the macro level.⁷

Or, as Oosterhuis put it in his paper on swarm architecture: 'An individual architect will no longer be tempted to have the illusion of complete control over the process. [...]. Now in the beginning of the twenty-first century architecture is going wild [...].'⁸ Such architectural concepts were embedded in a recent boom of swarming phenomena in many cultural and socio-historical debates. From this continuing discourse stems, once again, a certain reflex in architectural thought to mix together (philosophical) concepts of emergence,⁹ rhizomatic networks,¹⁰ socio-political multitudes,¹¹ and social swarming phenomena in humans.¹² If, for instance, architect Neil Leach in a recent article sketches out the potentials of *Swarm Urbanism*, this might well provide an instructive reading, but it nevertheless neglects important differentiations between these concepts.¹³

Hence, in seeking to avoid a repetitive application of imprecise philosophical cocktails informed by a metaphorical understanding of swarming and the related notions of collective dynamics, this article proposes to examine swarm architecture and urbanism from another angle. It follows a media-technological perspective that complements a broader *Philosophy of Simulation* and its significance for contemporary architectural theory.¹⁴ The hypothesis of this paper is that Swarm Intelligence (SI) and ABM have become fundamental cultural techniques for understanding and governing dynamic processes. These techniques hold tremendous potential for (generative) architectural design. Today's widespread distribution of SI and ABM software tools is therefore based on a reciprocal computerisation of

biology and the biologisation of computer science, which have to be understood less in a philosophical sense than in a media-historical perspective.¹⁵ Thus, the second part of this paper, *Neighbourhood Technologies*, briefly introduces the concepts of SI and ABM and sketches out their aptitude for generative and data-driven architectural approaches. In the third part, these media technologies will be situated in a broader contemporary cultural theory called *Cultural Techniques*. This enables the description of novel architectural concepts like swarm architecture to find their place in a theoretical alliance between technologies and cultural practices, thus challenging and complementing the mere conventional philosophical connotations of architectural theory. The fourth part, *From Insect Media to Bodies with a Vector*, examines more closely possible media-technical groundings and genealogies of multi-agent approaches in generative architecture. Finally, the fifth and last part, *Superconnected Idiot Savants*, critically evaluates some political implications that adhere to the seemingly democratising structure of these distributed design systems.

Neighbourhood Technologies

Computational Swarm Intelligence, according to a common notion, is a kind of science from the bottom-up. Or, to put it another way, '[U]sing swarms is the same as "getting a bunch of small cheap dumb things to do the same job as an expensive smart thing".'¹⁶ It is grounded in the idea that the complex adaptive behaviour of a system at the global level can be effected by multiple, parallel interactions of very simply constructed individuals at the local level, when they follow a set of only a few behavioural rules like avoidance (avoid collision with local flock mates), alignment (steer towards the average heading of local flock mates), and cohesion (steer towards the locally perceived centre of the flock).¹⁷ Collectives possess certain abilities that are lacking in their component parts. Whereas an individual member of a swarm commands only a limited understanding of its environment, the collective as

a whole is able to adapt nearly flawlessly to the changing conditions of its surroundings. Without recourse to an overriding authority or hierarchy, such collectives organise themselves quickly, adaptively and uniquely with the help of their distributed control logic. Within swarms, the quantity of local data transmission is converted into new collective qualities.

Although it has often been stated that SI has been inspired by biological phenomena such as bird flocks, ant and termite swarms, beehives or fish schools, it is important to understand that these phenomena first emerged as operational collective structures by means of a *reciprocal* computerisation of biology, and a biologisation of computer science. In the case of swarms, it is not simply animals that serve as a socio-biological model for mankind and its *technē*. What is noteworthy is rather the reciprocal interference of biological principles and the processes of information technology. Swarms should be understood as *zootechnologies*.¹⁸ In contrast to biotechnologies or biomedica, they derive less from *bios*, the concept of ‘animated’ life, than they do from *zoē*, the unanimated life of the swarm.¹⁹ *Zoē* manifests itself as a particular type of ‘vivacity’, for instance, the dynamic flurry of swarming individuals. It is a vivacity that lends itself to technological implementation because it can be rendered just as well into orderly or disorderly movement. This capacity, in turn, is based on rules of motion and interaction that, once programmed and processed by computer technology, can produce seemingly lifelike behaviour among artificial agents. Swarm research combines this *zoē* with the experimental epistemology of computer simulation. In a recursive loop, swarms inspired agent-based modelling and simulation, which in turn provided biological researchers with enduring knowledge about dynamic collectives. This conglomerate led to the development of advanced, software-based ‘autonomous particle systems’ and turned it into one of the most fruitful sources for the development of distributed models

in the ABM software paradigm. One can designate this a *media-emergence* whose decisive impact oftentimes came neither from biology nor from computer science, but rather, for instance, from graphics and animation design.²⁰

As an effect, SI and ABM help to configure environments that are increasingly confronted with the task of organising highly engineered and interconnected systems, as well as that of modelling complex correlations. They can be applied wherever there are ‘disturbed conditions’, wherever imprecisely defined problems present themselves, wherever system parameters are constantly in flux, and wherever solution strategies become blindingly complex. Swarm intelligence, according to one standard work, ‘offers an alternative way of designing “intelligent” systems, in which autonomy, emergence, and distributed functioning replace control, preprogramming, and centralization’.²¹ With this access, they deeply permeate a vast number of different scientific and cultural fields. SI and ABM appear in economic simulations and models of financial markets, in simulations of social behaviour, in simulations of crowd evacuations, and in the field of panic studies. They have become essential to epidemiology, to the optimisation of logical systems and to transportation planning. They are used to improve telecommunications and network protocols and to improve image and pattern recognition. They are a component of certain climate models and multi-robot systems; they play a role in the field of mathematical optimisation, and, not least, in generative architecture and design.

Architectural design can benefit from the algorithmic logics of SI and ABM in the following ways. First, software of this nature extends the possibilities of handling and optimising the complex interplay of various input variables for building processes. It integrates the levels of individual movements of particles (simulated humans, traffic flows, winds, etc.) at the mesoscale of single buildings and at

the global level of urbanscapes. Second, the agent collectives – if appropriately tuned – will self-organise in a number of probably interesting or desirable forms over the iterated runs of numerous scenarios, thus transforming the understanding of planning and construction processes. From this change of perspective, architecture now becomes based most notably on movements. Moreover, this generation of forms develops in ways that would not be comprehensible without the media-technological means of agent-based computer simulation. Third, it introduces a novel kind of futurology into architecture. With computer experiments in ABM software, a great number of different scenarios can be tested and evaluated against each other, offering insight into a variety of different desirable futures. Fourth, a zootechnological and post-humanist element enters the design process. It coalesces more traditional (human) cultural practices of architectural design with novel media technologies. And fifth, the capacity of adding ever more elements to ABM allows for a seamless synthesis of multiple ideas, or for a feedback of opinions by customers or future users during an ongoing design process.

If we consider the deep permeation of the above-mentioned vast number of application fields, we can understand zootechnological swarming as a more general technique of operationalising formerly unknowable and indistinct problem spaces. Furthermore, if we acknowledge the shift from an analytical to a synthetical approach as the central element of computational SI and ABM, then this might indicate the emergence of a novel cultural technique to dispose of and arrange the world we live in.

The next part of the article will depict the significance of the concept of Cultural Techniques for architectural theory, and elucidate more precisely the meaning of computational swarming as a novel cultural technique.

Cultural Techniques

The term *Cultural techniques* (German: *Kulturtechniken*) originates from an agricultural discourse from about 1900 that has been revived for cultural analysis by a number of German cultural theorists in order to put emphasis on the dimension of *techné* inherent in cultural practices.²² Instead of perceiving cultural practices as connected merely to human actors, or processes of culturalisation as an anthropomorphic treatment of objects and things, *techné* makes use of a different understanding of culture. *Cultures* in this sense (in contrast to the notion of a singular, typically ‘high’ culture) are characterised by a humanoid-technical hybridity. They are conceived of as actor-networks that comprise humans, technical objects, and the respective chains of operations between them. In these operation chains, not only do humans *make use* of technical things or design them according to habitualised body techniques, but also technical objects situate humans in their environment and take an active agency in shaping their self-conception. Cultural techniques seek to describe and analyse ‘how signs, instruments, and human practices consolidate into durable symbolic systems’.²³ Or, as media historian Bernhard Geoghegan notes, ‘Put in terms familiar to German media theory of the 1980s and 1990s, cultural techniques concern the rules of selection, storage and transmission that characterise a given system of mediation, including the formal structures that compose and constrict this process.’²⁴

But why should architectural theory care about such a concept taken from cultural analysis? This becomes clear very quickly if one takes a definition from sociologist Dirk Baecker: in an interpretation that follows Niklas Luhmann’s system theory, he assigns to architecture the principal distinction of distinguishing between an *inside* and an *outside*.²⁵ If this is considered the basic (cultural) operation of architecture, then different media and cultural practices that process this distinction can be

examined – a distinction which automatically also relates to material and technical aspects. Thus, a simple fence could be perceived as an architectural invention that discriminates between inside and outside, but it could also be seen as an initial technique that transformed early nomadic cultures into settler cultures. As Bernhard Siegert proposed in a recent article, even a mere door can give rise to a whole system of cultural operations and symbolic, epistemic, and social processes. A door, writes Siegert, not only connects two rooms, it also principally defines a relation between an inside and an outside. According to Georg Simmel, a closed door not only separates two rooms but also functions at the same time as a *sign* of that separation. As a consequence, it both discriminates between physical spaces and designates, for instance, arcane or private spheres. And finally, a door can be operated in various ways that induce different cultural practices: either in an anthropomorphic sense; for instance, by the use of a doorknob and corresponding practices of, say, quietly closing office doors, or in a machinic sense, as in the case of automated doors. Hence, doors can be seen as a (material) architectural medium that becomes a medium for cultural codes and modes of operation.²⁶ A first argument for an awareness of cultural techniques in architectural theory, then, is their capacity to connect these material, social, symbolic and practical aspects of architecture.

A second argument pertains to the relation of time and space. In another instructive article, Siegert analyses grids as a fundamental cultural technique with close links to architecture. As he points out, grid patterns serve as a technique that helps to structure and control space, as, for instance, in the development of a central perspective, cartography, or architectural construction. But they also help in inventing and generating a future space: for example, by providing an exact layout for the accretion of Roman military camps, or, later, for developing reliable address systems in colonial city

planning. These systems are also able to document still empty spaces, and thus enable a rigidly controlled, possible future extension of cityscapes. Grid patterns, as another material form of distinguishing inside/outside relations, thus operate as cultural techniques that can be used both to *represent* and to *generate* (architectural) realities.²⁷

To return to architecture's main distinction between inside and outside spaces, the data-driven generative techniques of SI and ABM can be perceived as a novel and synthetic way of mediating between these. SI and ABM build upon a potentially unrestricted number of movement processes that only define the emergence of boundaries between inside and outside during the simulation runs. Their synthetic character is founded on an underlying algorithmic structure that defines neighbourhoods among all kinds of objects. In this case, space as such no longer has to be organised or constituted by a defined geometric grid, but self-generates out of the multiple local interactions of point clouds or particle swarms. Single individuals, architectural bodies of all sizes, their interiors and exteriors and the urban landscapes they populate, can be tentatively modelled on the same algorithmic principle of autonomous neighbourhood interaction along simple rules. And the emerging 'wild' architectures (Oosterhuis) can be made perceivable and manipulable with the help of advanced Computer Graphic Imagery (CGI). As an effect, SI and ABM generate a number of possible future states of buildings, traffic flows or urban spaces under changing environmental influences. Likewise, they enable a comparison between these possible futures.

SI and ABM are novel cultural techniques because they approach complex organisation problems by means of artificial *populations* of agents, and the behaviour of these in time. The movement paths and vectors of populations – not geometric principles – account for this novel architectural approach. Swarming introduces animals into the

discourse on Cultural Techniques (and thereby into the discourse on architectural design) – in this case as a multitude or collective – and thus addresses a zotechnological relation. Produced between the fields of biology and computer science, a system's knowledge of self-organising collectives assists us, in a way that anthropology cannot, in our treatment of certain problems and regulatory issues that are normally regarded as opaque. In response to the abovementioned question concerning the operative interconnections between body techniques and media techniques, swarms contribute the element of dynamic collective bodies. Thus, they co-author processes within our knowledge culture that previously were unable to be addressed without their media-technological means. But how, and to what ends, is such software concretely applied in contemporary architectural design?

From Insect Media to Bodies with a Vector

If we consider SI and ABM systems to be novel cultural techniques that help to treat complex architectural problems, we have to distinguish between two strains of self-organisation principles: one looks at the dynamic generation of (architectural) forms in social insects, the other is occupied with the dynamic movement and adaptive capacities of flocks or swarms on the move (such as birds or fish). In terms of architectural design, they serve several functions: first, they can be used to produce idea models; that is, they can inspire new shapes for further design measures as an outcome of emergent processes. Such idea models would not take shape without the algorithmic logic of SI and ABM. Second, they can be used to represent the dynamics of existing architectural spaces in a simulation system, facilitating a play with parameters and a testing and evaluation of different scenarios. And third, novel fabrication techniques that translate virtual models into material fabric can be attached to these computational tools.

The social insects principle relies on a communication structure that uses *stigmergy*, or the more general *sematectonic communication*.²⁸ This means that the locally defined agents orient themselves not only according to the behaviour of a number of neighbours but also according to traces that the agents place in, and read from, their environment. For instance, pheromone trails to a food source produce a positive feedback for individuals following, and nest structures such as honeycombs determine and incite the building of subsequent structures. This distributed organisation has been formalised in computer simulation models like *Ant Colony Optimisation (ACO)* and initially gave rise to the field of SI.²⁹ In this ABM paradigm, agents collectively transform the incoming information into behavioural patterns, and at the same time into concrete building structures. 'Here, perception of an environment is transposed from an animal characteristic to an information relation with the aid of a visual interface to make it understandable to the human operator,' points out media historian Jussi Parikka.³⁰

In a seminal publication on SI, Eric Bonabeau, Marco Dorigo and Guy Theraulaz devote a chapter on the computer simulation (CS) of nest building in social wasps. With a three-dimensional Cellular Automaton and carefully evaluated rule sets, they simulated the emergence of a nest architecture equivalent to that found in wasps in nature.³¹ Stemming from this, computer scientists sought to transform the use of the respective CS technologies from confirming scientific hypotheses to the generative and semi-autonomous development of, for example, *Swarm-Driven Idea Models*. Here, the simulation environment works as a virtual test bed for the 'breeding' of complex emergent architectural constructions.³² In order to produce constructions that are in some way a suitable response to a given architectural problem, the simulators integrate an evolutionary algorithm into the CS, which rates the

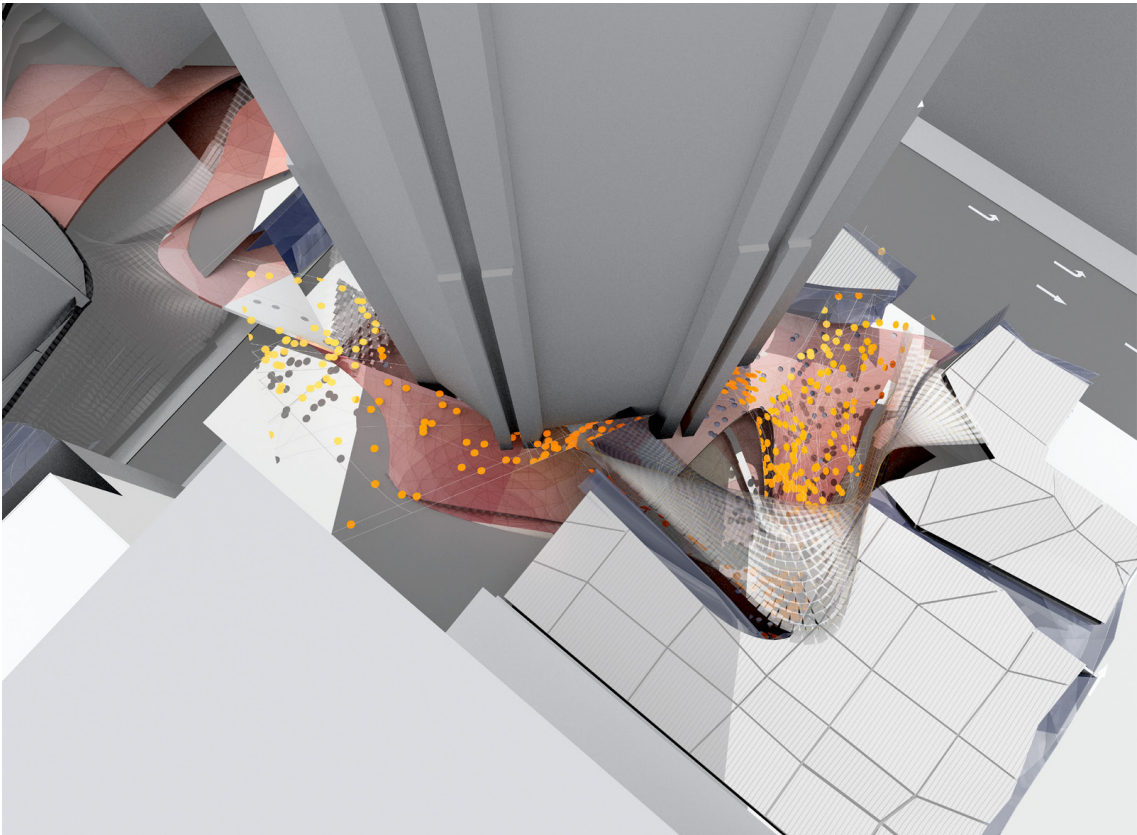


Fig. 1: Kokkugia's *Emergent Field* Project (2003). Modelling of the plaza surrounding Nauru House in Melbourne's CBD as a gradient field of environmental influences. © Roland Snooks

constructional activities of a population of randomly chosen swarms. This consecutively leads to a new population based on the rate-dependent selection of the previous generation of swarms, whilst random changes and recombinations of successful swarms enable the development of unforeseen constructions. In a repetitive process, the CS system yields interesting architectures according to a set of pre-defined evaluation criteria.³³ Thus, SI enables an integration of architecture into the site-specific environmental context, and takes into account aspects of the building's ecological and economic performance.³⁴ Although one should be rather cautious regarding tendencies to overemphasise the 'natural integrity' of such outcomes of biologically inspired CS, in terms of a generative approach to the creation of architectural idea models, *Insect Media* of this kind seem to accomplish rather interesting outcomes. However, these are highly dependent on the processually defined boundary conditions of the CS, the design of the learning algorithm which defines the development and 'optimisation' of the generation of forms, and, not least, the expertise of the meta-modeller: the architect.

The second principle in SI is based on the above-mentioned movement vectors of flocking individuals defined by local neighbourhoods. Here, the focus lies in the emergence of a dynamic and mutable swarm-space, an intermediate layer between local information processing and collective adaptation to the constantly changing exterior forces of an environmental space. This technique is used for the time-based and dynamic generation of formerly unknowable global forms through the non-linear interactions of many mobile individuals. Fuelled by sophisticated CGI techniques, ABM software was soon embraced by a number of architectural design teams. They transformed creation into merely developing adequate rules to govern the assembly of components, thus leaving the architect in the role of meta-designer of self-organising systems.³⁵ On the

one hand, control is thereby handed to the bottom-up self-organisation of non-linear agent systems, while on the other, it is reintroduced by architects and experts who evaluate the generated forms with respect to certain criteria:

'With the centrality of population thinking, the emphasis shifted from both individuals and generalized types to the primary of variation and deviation. [...] [D]ifference and process become comprehensible and hence controllable.'³⁶

Roland Snooks, one of the collaborators in an architectural project called *Kokkugia*, explains how ABM methods deal with explicit architectural problems, and how this differs from many of the earlier approaches to digital architecture:

[*Kokkugia*] has been focused on agent-based methodologies [...]. This started as an interest in generative design, not necessarily as a specific interest in computational, algorithmic or scripted work, but as an interest in understanding the emergent nature of public spaces [...] of Melbourne and how we could develop emergent methodologies. That led us to develop swarm systems and multi-agent models.³⁷

But this raises the question of how exactly to define the architectural problem. [fig. 1] Due to the non-linear relationality of all objects in a public space, the meta-designers seek to describe in simple rules all sorts of relations pertaining to those objects.³⁸ In this way, the micro-relations of individual agent behaviour connect with a mesoscale that gives form to single buildings, and to a macroscale of generative urban planning. With ABM software, as Oosterhuis states, such a system will display real-time behaviour, and the parameters may change continuously over time. The crucial point is that comprehensiveness only emerges by running the processes. Therefore, using the tentative technologies of SI and ABM in generative architecture

always seems to be a question of how to shape the bottom-up system behaviours with target functions in a gamified, trial-and-error process, otherwise reasonable results or idea models would merely be a matter of luck (or patience):

The challenge for the designer is to find those rules that are effective and which are indeed generating complexity. Some design rules produce death, others proliferate life. Some design rules create boring situations, other rules may generate excitement. You can only find the intriguing rules by testing them, by running the process.³⁹

Moreover, instead of working with black box modules of commercial architecture software like *Maya* or *Rhino*, people like Snooks advocate the development of open source programmes specific to the respective design intention: '[T]he algorithm should emerge from the architectural problem rather than simply the architecture emerging from the algorithm.'⁴⁰

To broaden this understanding, the collaborators of the *Kokkugia* project describe swarm-based urban planning as a simultaneous process of self-organising agents which would no longer result in a single, optimum solution or master-plan, but in a 'near-equilibrium, semi-stable state always teetering on the brink of disequilibrium. This allows the system to remain responsive to changing economic, political and social circumstances'.⁴¹ [figs. 2-3] In addition, for *Kokkugia*, the objective of understanding urban dynamics by means of swarm intelligence systems coalesces with generative measures of their non-linear methodologies to produce shapes for buildings, and with the ensuing development of novel fabrication techniques. These could lead to a rethinking of tectonics and form on the basis of ABM.⁴² [fig. 4] An effect of SI and ABM models, with their focus on moving patterns and dynamic flows, is that the relationship between locally acting

autonomous agents and the material composition of architectural buildings and sites can take on novel operational forms. As Neil Leach states, these computer simulation systems integrate the effects of spatial practices (the agents' movements) into the material urban fabric, and, likewise, the constraints imposed on those practices by its (computer-simulated) physicality.

At this point, the effects of SI and ABM as cultural techniques become apparent:

The task of design, therefore, would be to anticipate what would have evolved over time from the interaction between inhabitants and city. If we adopt the notion of 'scenario planning' that envisages the potential choreographies of use within a particular space in the city, we can see that in effect the task of design is to 'fast forward' that process of evolution, so that we envisage – in the 'future perfect' sense – the way in which the fabric of the city would have evolved in response to the impulses of human habitation.⁴³

SI and ABM can be defined as cultural techniques that facilitate the apprehension of future states of buildings or urban space under varying environmental impacts, which have the potential to deeply change and enhance the procedures of urban planning. However, it has to be kept in mind that such forms of scenario building also become a part of the reality they try to model. And in contrast to weather simulations, for instance, the modelled systems (for example, people using an urban plaza in Melbourne) would certainly react to the scenarios produced by urban planning tools of this kind if these were on display, say, at a community meeting. Such an interaction between the public and computer simulations that *model* this public would likely add a novel layer of unpredictability to the process. In the final section, this paper will briefly address such leverages of concrete cultural practices in relation to the Cultural Technique concept of swarm architecture.

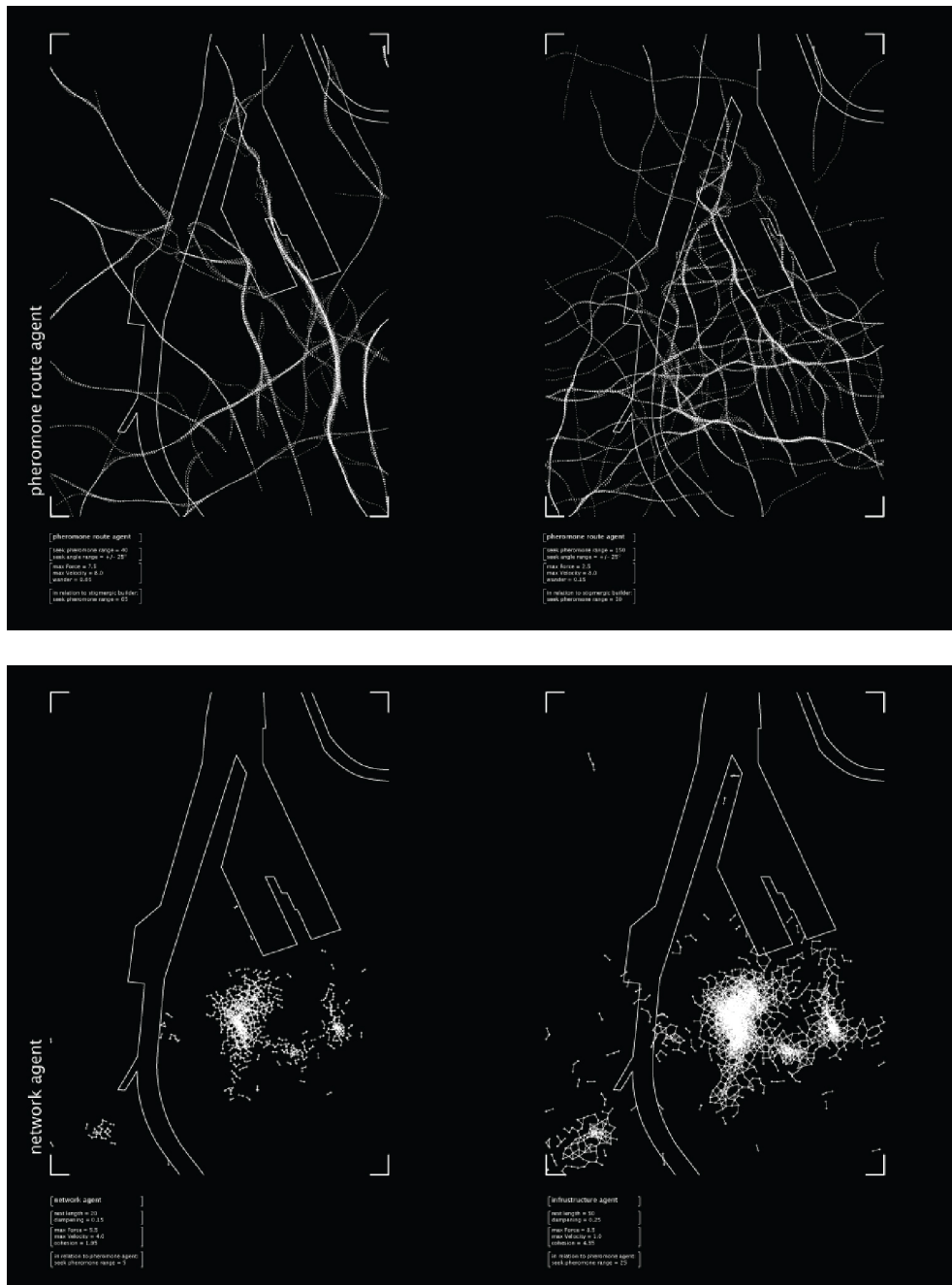


Fig. 2: Kokkugia's *Swarm Urbanism* Project (2009). The illustration shows a category of agents that aggregates matter to form in a stigmergic process, following rules of interaction similar to termite swarms. © Roland Snooks

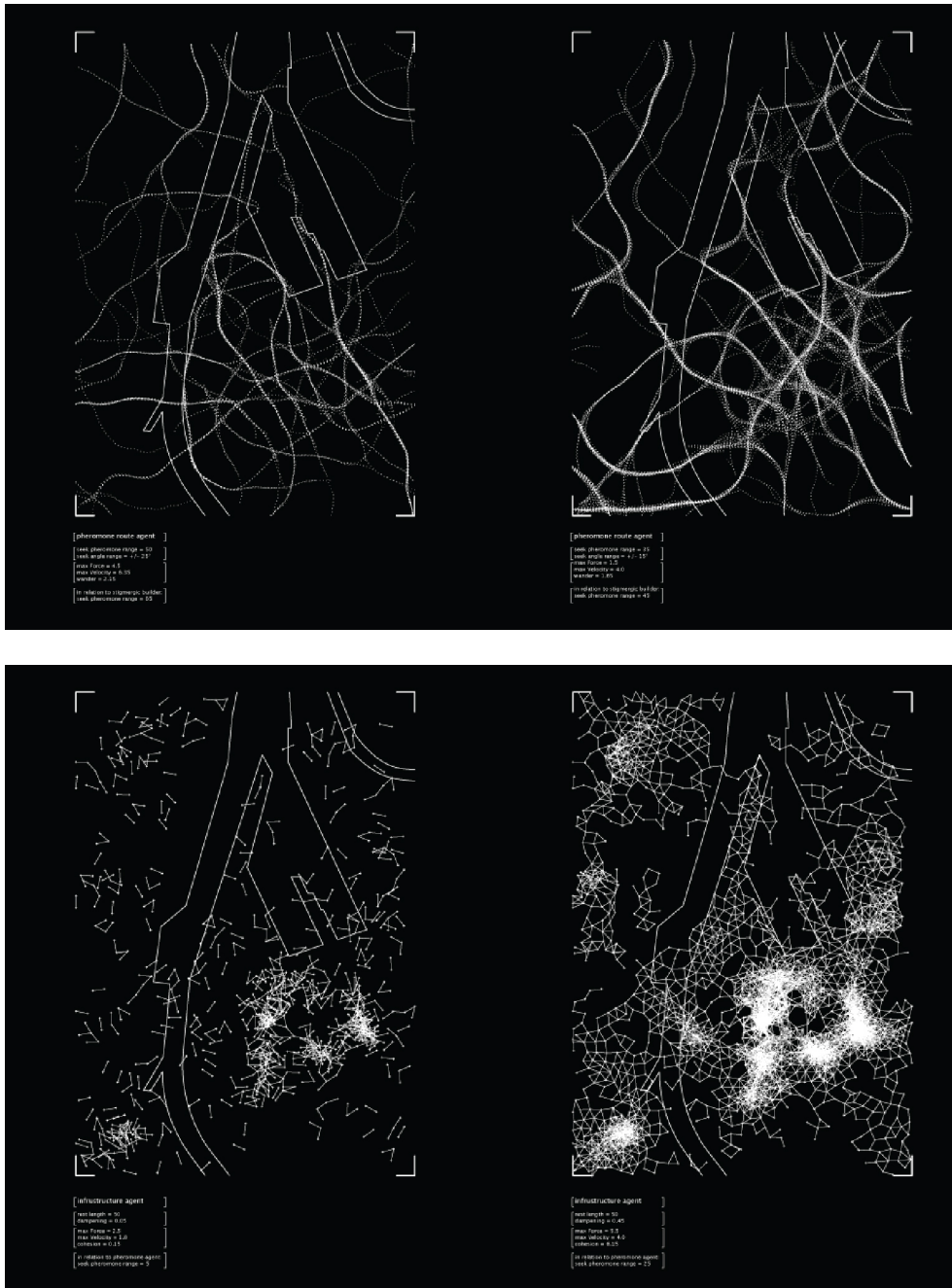


Fig. 3: Kokkugia's *Swarm Urbanism* Project (2009). The illustration shows a category of agents that connects various pathways to infrastructural and circular networks, using an algorithm based on the movement of slime mould.
© Roland Snooks

Super-Connected Idiot Savants

From its inception, the concept of swarm architecture – apart from its computer-technological aspects – has also been closely tied to novel collaborative working practices that came about with the broadband-connected workforce of contemporary digital architects.⁴⁴ The collective intelligence of computational ABM systems seems to be repeated on the level of everyday architectural practices. This can be perceived in terms of computer-supported cooperative work (CSCW) software, and remote and dispersed co-working places. It becomes apparent in a mutable and open-ended design and construction process that allows for integrating feedback loops and adjustments to a constructor or customer's objectives during the ongoing realisation process of a project. It can likewise be seen in the object-oriented programming logic of architectural design and construction tools, whose usage can even be described as a stigmergic process in itself.⁴⁵ The issue, writes Oosterhuis, in perfect accordance with the relationality of SI technologies, is about 'not just being creative individuals, but building creative relationships', where the design process becomes an 'on-line and on-site testing [...] in the swarm of flocking stakeholders'.⁴⁶ The computational cultural technique of swarming in SI and ABM outlined in the previous sections also penetrates the working cultures of contemporary architects. Architects whom Oosterhuis says would engage as 'hyper-conscious idiots [*sic*] savants' in a constant flux of information processes from project databases, and would act merely as 'assistants' to their self-organising computational tools, in other words, creating novel humanoid-technical hybrids.⁴⁷ Moreover, he insinuates a possible basic democratic function: by integrating open interfaces with the public, ordinary citizens could become participators in a 'design game', extending the cultural technique of swarming to a wider public.⁴⁸

However, and in contrast to all the techno-euphoria that thrived in the early heydays of a swarming

discourse, such socio-political implications remain a subject of continuing inquiry. First and foremost, an implicit question concerns Eugene Thacker's crucial disposition of *pattern* or *purpose* in SI. Thacker asks about the likelihood of swarm collectives defining a strategic agenda by their own means, in contrast to their unquestionable skills in reacting to changing, but pre-existing, environmental conditions.⁴⁹ Or, to put this more bluntly: to what extent are generative technologies in SI and ABM dependent on a top-down definition of *ex ante* boundary conditions and target functions, or *ex post* evaluations by experts? Are they not always embedded in other, more classical hierarchies of decision-making, and hence working as 'tactical' problem-solving tools rather than being able to generate original purposes? And secondly, one should carefully observe where exactly SI and ABM are employed in architectural, engineering or scientific processes, and how they correspond with other, neighbouring organisational formats and processes. How closely do certain idea models correspond with fabrication and manufacturing technologies? How exactly can the decisive relations and parameters for urban planning be evaluated?

Nevertheless, as this article has shown, SI and ABM applications can be perceived as cultural techniques well suited to handling complex planning problems as these emerge in architectural design. Swarm architecture takes advantage of the problem-solving intelligence that emerges from the self-organisational capacities of agent collectives and thus originates novel human-zoo-technical hybrids in the architectural design process. Computer graphics enable a visual comparison of various universal structures, both with respect to parameter adjustments within the rule sets of the simulations, and also in terms of empirical data taken from concrete architectural sites. The underlying function of this scenic knowledge is the act of *seeing in time*. Computer science is capable of animating mathematical models by endowing them

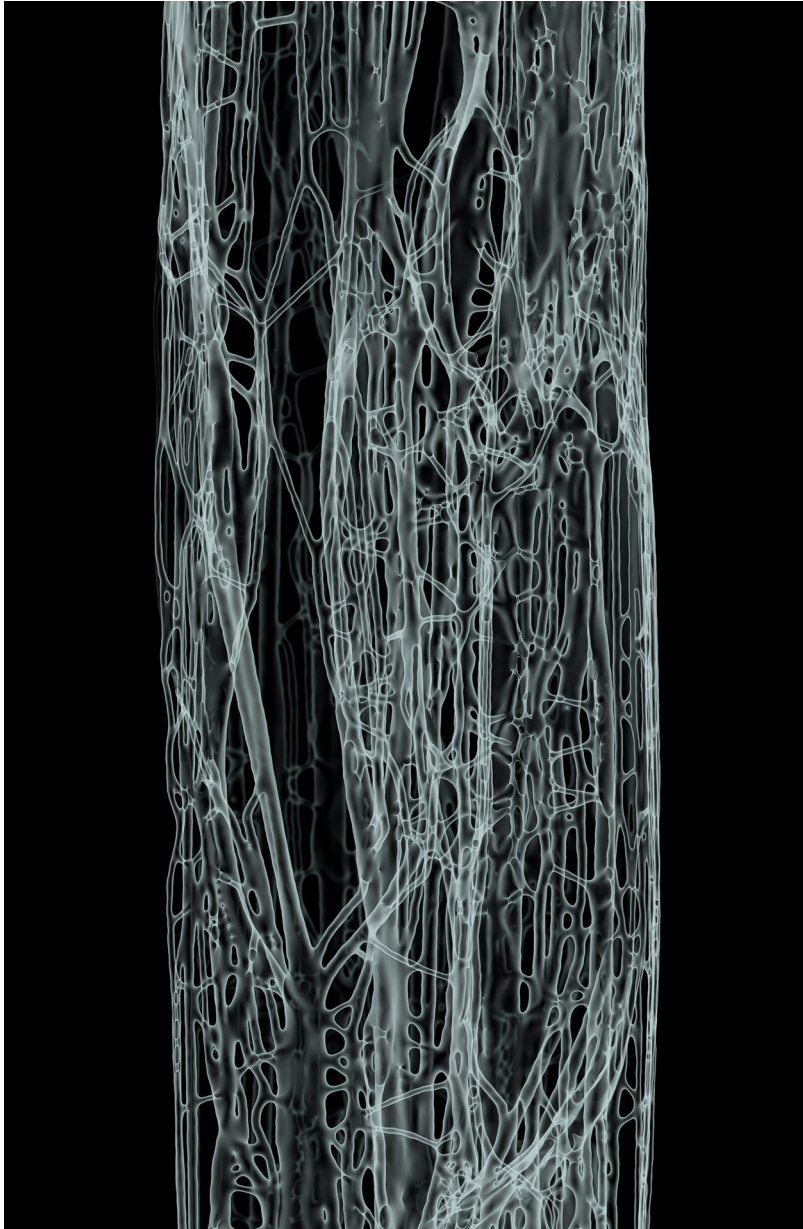


Fig. 4: Kokkugia's *Fibrous Tower 2* Project (2008). Exploration of ornamental, structural and spatial orders through an agent based algorithmic design methodology. © Roland Snooks.

with life in *run time* and exploiting certain gaming characteristics. And instead of coalescing into architectural master plans, they preserve the potential to generate a spectrum of opinions, viewpoints, and 'near-equilibriums'.

The extent to which the idiot savants of generative swarm architecture are able to claim the bottom-up potentialities and operational scope of their computational ABM for use in their working practices might also be a question of their environment: a participatory, 'basic-democratic' perspective – for instance, one enabled by virtually demonstrated dynamic architectural models of buildings or urban sites – might well be a very realistic part of generative architecture. It sounds more than feasible or necessary to integrate a critical public into the decision-making processes of urban planning, not least in order to moderate possible resistance. But this only seems to hold true as long as it takes place within a democratic society and not in those countries that have regrettably attracted a good number of the idiots (savants) of digital architecture in recent times.

Notes

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1. *suckerPUNCH*: 'Interview with Roland Snooks', 25 April 2010, <<http://www.suckerpunchdaily.com/2010/04/25/interview-with-roland-snooks/>> [accessed 01 April 2014].
2. Thomas Hine, 'One Architect Who Left His Mark On Cities', *The Philadelphia Inquirer*, 9 February 1986. <http://articles.philly.com/1986-02-09/entertainment/26088680_1_ludwig-mies-van-der-architectural-training> [accessed 28 March 2014]
3. Mario Carpo, 'Introduction: Twenty Years of Digital Design', in *The Digital Turn in Architecture 1992-2012* ed. by Mario Carpo (Chichester, UK: Wiley, 2013), pp. 8-14 (p. 9).
4. Stephen Perella, 'Bernard Cache/Objectile: Topological Architecture and the Ambiguous Sign', *Architectural Design* 68 (May-June 1998) (Hypersurface Architecture, AD Profile 133), pp. 66-9; Manuel DeLanda, 'The Biology of Cities', Lecture Series at The European Graduate School, 2011. <<http://www.egs.edu/faculty/manuel-de-landa/videos/>> [accessed 28 March 2014]
5. Patrik Schumacher, 'Parametricism: A New Global Style for Architecture and Urban Design', in *Architectural Design* 79 (July-August 2009) (Digital Cities, AD Profile 200), ed. by Neil Leach, pp. 14-23.
6. *Game, Set and Match II. On Computer Games, Advanced Geometries, and Digital Technologies*, ed. by Kas Oosterhuis and Lukas Feireiss (Rotterdam: Episode Publishers, 2006).
7. *suckerPUNCH*: 'Interview with Roland Snooks'.
8. Oosterhuis, Feireiss, *Game, Set and Match II*, p. 76.
9. Steven Johnson, *Emergence: The Connected Lives of Ants, Cities and Software* (New York: Scribner, 2001).
10. Gilles Deleuze, Félix Guattari, *A Thousand Plateaus* (Minneapolis: University of Minnesota Press, 1987).
11. Michael Hardt and Antonio Negri, *Multitude: War and Democracy in the Age of Empire* (New York: Penguin, 2004).
12. Cf. James Surowiecki, *The Wisdom of Crowds* (New York: Anchor, 2005); Howard Rheingold, *Smart Mobs: The Next Social Revolution* (Cambridge: Basic Books, 2002); Len Fisher, *The Perfect Swarm: The Science of Complexity in Everyday Life* (New York: Basic Books, 2010); Peter Miller, *Smart Swarm: Using Animal Behaviour to Organise Our World* (London: Collins, 2010).
13. These are, for instance, minutely discussed in Eugene Thacker, 'Networks, Swarms, Multitudes', in *CTheory*, 18 May 2004. <<http://www.ctheory.net/articles.aspx?id=423>> [accessed 28 March 2014]; see also

- Neil Leach, 'Swarm Urbanism', *Architectural Design* 79, (London: Academy Press, July-August 2009), pp. 56-63.
14. Manuel DeLanda, *Philosophy and Simulation: The Emergence of Synthetic Reason* (London/New York: Continuum, 2011).
15. Sebastian Vehlken, *Zootechnologien. Eine Mediengeschichte der Schwarmforschung* (Zurich/Berlin: Diaphanes, 2012).
16. Joshua J. Corner and Gary B. Lamont, 'Parallel Simulation of UAV Swarm Scenarios', in *Proceedings of the 2004 Winter Simulation Conference*, ed. by R. G. Ingalls et al., pp. 355-63 (p. 335).
17. Andries P. Engelbrecht, *Fundamentals of Computational Swarm Intelligence* (Hoboken, NJ: Wiley, 2005); Joshua M. Epstein, *Generative Social Science: Studies in Agent-Based Computational Modeling* (Princeton: Princeton University Press, 2006).
18. Sebastian Vehlken, 'Zootechnologies. 'Swarming' as a Cultural Technique' in *Technology, Culture and Society*, 30 June 2013, pp. 112-33.
19. Eugene Thacker, *Biomedias* (Minneapolis/London: University of Minnesota Press, 2004).
20. Joseph Vogl, 'Medien-Werden: Galileos Fernrohr', in *Mediale Historiographien*, ed. by Lorenz Engell, Bernhard Siegert, Joseph Vogl (Weimar: Archiv für Mediengeschichte, 2001), pp. 115-23.
21. Eric Bonabeau, Marco Dorigo, Guy Theraulaz, *Swarm Intelligence: From Natural to Artificial Systems* (New York: Oxford University Press, 1999), p. xi.
22. Thomas Macho, Sybille Krämer, Horst Bredekamp, Hartmut Böhme, and more recently Bernhard Siegert, Harun Maye and Erhard Schüttpelz (among others).
23. Bernard Geoghegan, 'After Kittler: On the Cultural Techniques of Recent German Media Theory', in *Theory, Culture and Society* 30 June 2013, pp. 66-82 (p.67).
24. *Ibid.*, p. 69.
25. Dirk Baecker, 'Die Dekonstruktion der Schachtel: Innen und Außen in der Architektur', in *Unbeobachtete Welt. Über Kunst und Architektur*, ed. by Niklas Luhmann, Frederick D. Bunsen, Dirk Baecker (Bielefeld, 1990), p. 83.
26. Bernhard Siegert, 'Türen. Zur Materialität des Symbolischen', in *Zeitschrift für Medienphilosophie und Kulturforschung* 1, 2010, pp. 151-70; Georg Simmel, 'Brücke und Tür'in *Der Tag. Moderne illustrierte Zeitung* Nr. 683 (15 September 1909) (Morgenblatt), Illustrierter Teil no. 216, p. 2.
27. Bernhard Siegert, '(Nicht) am Ort. Zum Raster als Kulturtechnik'in *Thesis* 49 (2003), 3. Heft (9. Internationales Bauhaus-Kolloquium Weimar 2003: Medium Architektur. Zur Krise der Vermittlung, ed. by Gerd Zimmermann, Vol. 1: *Plenarvorträge*), pp. 92-104.
28. Pierre-Paul Grassé, 'La reconstruction du nid et les coordinations inter-individuelles chez *Bellicositermes natalensis* et *Cubitermes* sp. La théorie de la stigmergie: Essai d'interprétation du comportement des Termites constructeurs', *Insectes Sociaux* 6 (1959), pp. 41-83; Edward O. Wilson, *Sociobiology: The New Synthesis* (Cambridge: Harvard University Press, 1975), p. 186; *Artificial Life* 5, 2 (1999) (Special Issue: Stigmergy, ed. by Eric Bonabeau).
29. Bonabeau et al., *Swarm Intelligence*.
30. Jussi Parikka, *Insect Media* (Minneapolis: University of Minnesota Press, 2010), p. 156.
31. Bonabeau et al., *Swarm Intelligence*, pp. 205-52.
32. Sebastian von Mammen and Christian Jacob, 'Swarm-Driven Idea Models – From Insect Nests to Modern Architecture', in *WIT Transactions on Ecology and Environment* 113 (2008), pp. 117-26; Yifeng Zeng, Jorge Codero, Dennis P. Buus, 'SwarmArchitect. A Swarm Framework for Collaborative Construction', in *Proceedings of the 9th Annual Conference on Genetic and Evolutionary Computation* 2007, p. 186; Pablo Miranda Carranza and Paul Coates, 'Swarm Modelling. The Use of Swarm Intelligence to Generate Architectural Form', <http://www.generativeart.com/on/cic/2000/carranza_coates.htm> [accessed 28 March 2014]; Julian Nembrini et al., 'Mascarillion: Flying Swarm Intelligence for Architectural Research', <<http://infoscience.epfl.ch/record/50996>> [accessed 28 March 2014]
33. Mammen and Jacob, 'Swarm-Driven Idea Models',

- p. 118.
34. Ibid., p. 122-24.
 35. Cf. Dennis P. Buus, 'Constructing Human-Like Architecture with Swarm Intelligence', 2006. <<http://projekter.aau.dk/projekter/en/studentthesis/constructing-humanlike-architecture-with-swarm-intelligence>> [accessed 28 March 2014]; Nembrini et al., 'Mascarillion'.
 36. Parikka, *Insect Media*, p. 167.
 37. *suckerPUNCH*, Interview with Roland Snooks.
 38. Thacker, 'Networks, Swarms, Multitudes'.
 39. Kas Oosterhuis, 'Swarm Architecture II' in *Game, Set and Match II*, (Netherlands: Episode Publisher, 2006) pp. 14-34 (p. 25).
 40. *suckerPUNCH*, Interview with Roland Snooks.
 41. Leach, 'Swarm Urbanism', p. 61.
 42. *suckerPUNCH*, Interview with Roland Snooks.
 43. Leach, 'Swarm Urbanism', p. 62.
 44. Oosterhuis, 'Swarm Architecture II', p. 61ff.
 45. Lars Rune Christensen, 'The Logic of Practices of Stigmergy: Representational Artifacts in Architectural Design', in *Proceedings of the CSCW 2008*, November 8-12th, San Diego, CA.
 46. Oosterhuis, 'Swarm Architecture II', p. 62.
 47. Ibid., p. 58.
 48. Ibid., p. 62.
 49. Thacker, 'Networks, Swarms, Multitudes'.

Biography

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