Review of Miller & Scott's Book
Complex Adaptive Systems
An Introduction to Computational Models of Social Life
Chapters 1-2,4-7,final

A Review from the Point of View of the DAAI Paradigm
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Abstract

This text discusses ideas about the relationship between the DAAI paradigm and the concept of complex systems as described in the book of Miller and Page (2007) [MP07]. Miller[1] and Page[2] are both rooted in the mind-web of the Santa Fe Institute.[3]. In this review the methodological aspects of the theory will be analyzed and discussed. This includes chapters 1-7. Another important part of the book the examples illustrating the main theoretical view from chapter 7 - 11 will not be discussed here.

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[1] `https://www.cmu.edu/dietrich/sds/people/faculty/john-miller.html`

[2] `https://sites.lsa.umich.edu/scottepage/`

[3] For the history and vision of the Santa Fe Institute see `https://www.santafe.edu/about/history`

1 Introduction: Chapters 1-2

The guiding question is whether there exists some relationship between the view of *complexity* provided in the book of Miller & Page with the view followed within the *DAAI paradigm*.

Miller & Page begin their journey into complexity with the basic distinction between 'complicated' and 'complex' systems. The basic definitions can be rewritten in the following format[4]:

SYSTEM: A system is a set of *elements* [E] which are embedded in some *relations* [R].

COMPLICATED System: A complicated system is a system, but despite the observable relations between the elements these elements are *widely independent* from each other (cf. p.9)

COMPLEX System: A complex system is a system and the observable relations between the elements are *widely important*, i.e. a change in these relations changes the system. (cf. p.9) Thus the reduction of a complex system to only its elements destroys the system. (cf. p.10)

INPUT-OUTPUT SYSTEM [IO-System]: An io-system is a system with a *behavior function* ϕ which maps *input values* [I] from the *environment* [ENV] of the system into *output values* [O] to the environment of the system:

$$IOSystem(x)\ iff\ x = \langle I, O, \phi \rangle \tag{1}$$

$$\phi : I \longmapsto O \tag{2}$$

ADAPTIVE SYSTEM [L-System]: An adaptive system is an io-system with a behavior function ϕ which can *learn* which is used in this text as synonym for being *adaptive*. Thus a learning io-system is the same as an adaptive system.

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[4] The formalizations below are not given in the text of Miller & Page. They are given in accordance with the formalizations in the DAAI paradigm.

To be able to adapt an io-system has to have *internal states* [IS] which can be *changed* during the life time of the system:

$$LSystem(x)\ iff\ x = \langle I, O, IS, \phi \rangle \tag{3}$$
$$\phi : I \times IS \longmapsto IS \times O \tag{4}$$

COMPLEX ADAPTIVE SYSTEM [CL-System]: A complex adaptive system is a *set* of adaptive systems whose interactions are constitutive for their behavior, i.e. separating the individual adaptive systems from each other destroys the behavior of the complex adaptive systems; lacking the characteristic inputs disables the characteristic outputs (cf. p.7,p.9):

$$CLSystem(x)\ iff\ x = \langle ENV, LS, EV \rangle \tag{5}$$
$$ENV := Environment \tag{6}$$
$$LS = \{s | LSystem(s)\} \tag{7}$$
$$EV := Events \tag{8}$$
$$EV \subseteq LS \times ENV \times LS \tag{9}$$

Thus in adaptive complex systems the elements/ components not only have to cope with a multitude of relations recognized in their environments but they have also to adapt/learn the implicit dependencies in these relations by adapt their inner states and their behavior function to improve themselves. (cf. p.10) This implies that the environment is a *dynamic* environment. Within this general view any number of heterogeneous agents can interact in a dynamic environment.

During the process of a complex adaptive system different kinds of *law-like* patterns can be *observed* depending from the way how an observer *evaluates* the observed phenomena. While the intention of classical science is to make the observable world *simple* to improve *understandability*, the way how adaptive complex systems behave requires a kind of *representation* which does not allow the separation of the constitutive systems.

SOCIAL SYSTEMS: In the light of these definitions it becomes clear that *social* systems are by definition *adaptive complex* systems. Trying to describe social systems therefore implies that one has to consider any kind of circumstance which perhaps can influence behavior and learning.

Thus, as the example with 'standing ovations' is showing there are different kinds of 'contagion phenomena' between the visitors of a concert which can influence their behavior (cf. pp.10-14) In another example with bees regulating the temperature of the hive the hidden fact of genetic heterogeneity – some *internal states* [IS] of the individual systems – is important that a population of bees can react sufficiently well to temperature change. (cf. p.14f) The same shows up in the example with the killer ants where a heterogeneous answer of the bees built into the genes is much better than an average one. (cf. p.15f) In the example with two cities it is illustrated by which kinds of behavioral rules the satisfaction of citizens can be improved. (cf. pp.17-25): while changes are generally induced by choices (p.19) this can lead into a situation, where the situation is somehow 'locked into a less attractive state'. To overcome this locked-state the induction of some 'noise' through more choices can 'un-lock' the less satisfying situation. (p.20)

OVERCOME CLASSICAL ANALYSIS: What these first thoughts reveal is that *classical analytical models* are *strongly inadequate* in front of complex adaptive systems. Classical analytical models have no possibility to represent a multitude of coupled systems which can adapt internally and which therefore can change their behavior depending from their inputs continuously. (cf. p.20f) Luckily there exists an alternative approach for the modeling of complex adaptive systems with the aid of computational models: more preferences, more choices, more different issues... a much more heterogeneous population ... (cf. p.20f)

THE ALGORITHMIC TURN: With the aid of computational models it is possible to reveal that two well known strategies for the representation of the 'will' of citizens, the (i) democratic strategy by using the majority rule or (ii) by using the party-based strategy with the two options: 'winner takes all' or 'proportionally' have clearly different effects. In the *one town* situation the *democratic* strategy is the best one; in the *multiple town* situation the *proportional-party* strategy is the better one increasing the success with the number of towns. (cf. pp.21-23)

Both strategies can be integrated into one integrating strategy called *annealing*. The general idea is that if there is a *diversity around* then the political systems should respond to this diversity by 'jumping around'.(p.24) But the idea of 'jumping around' is driven exactly by the idea of 'annealing' meaning 'balancing', 'compensating' between the different positions. Thus, using the appropriate rules then the different institutions can become *natural annealing devices* that ultimately result in a decentralized complex adaptive social system seeking out global social optima.(cf. p.24) Those systems show additionally a strong robustness.

BLINDED BY CONVENTIONS: The characterization of complex adaptive systems so far enables some understanding why complex phenomena are often *invisible*. Some of the responsible factors being responsible for causing a 'falling through the cracks' of some interesting complex phenomena P are given here (cf. p.26):

1. P is in the domain of other fields then the known ones.
2. P lies on the boundaries between two fields.
3. Questions related to P are too hard and therefore get ignored or are considered unimportant.
4. It is too difficult to apply known tools to P.

2 Discussion

How do these first concepts relate to the DAAI paradigm?

If one looks to the DAAI paradigm then we have a kind of a *conceptual hierarchy* with the *actor story* [AS] at the top level, then we have the *states* [S] of the actor story with the *change statements* [X] connecting an actual state s with a follow-up state s', and as part of a state we have sets of *facts* [F] where a fact f can be a statement about an *actor object* [A]. The *behavior function* ϕ of an actor can appear as part of a change statement describing some *input* [I] to the behavior function of an actor object and describes an *output* [O] of the actor, translated into an observed change in the follow-up state s'.

With regard to this conceptual framework the concept of an *adaptive system* [LSystem] can be implemented as an actor object. Because a state can contain many adaptive systems one can implement a *complex adaptive system* [CLSystem] as a state! Thus every state in an actor story can be a complex adaptive system and therefore a state together with the change statements $\langle s, x \rangle$ with

$s \in S$ and $x \subseteq X$ can represent a *social system*!

The behavior function ϕ of an actor can either be completely *random* or – if not random – either *deterministic* without learning or 'time bound' deterministic and *learning*. The term 'time bound deterministic' describes the property that an adaptive system is a *hybrid* system: with regard to the learning capability an adaptive system is *not deterministic*. But every learning system extracts through the learning process certain kinds of patterns, rules, laws, which the system will apply to its input. As long as an adaptive systems *applies* its *learned rules* it is *deterministic*, but in a *time-bound* fashion. This observable determinism is bound to some *time window* as long as the system either does not change the learned rule or as long as the system does not alter between different rules. Both is possible.

SUMMARY Chapt.1-2: It shows up the the DAAI paradigm is capable to model social systems or – with different wordings – complex adaptive systems.

3 Modeling: Chapter 3

In my view this chapter is widely wrong. But to describe this in details I would need too much time. In the actual text of the DAAI paradigm I have already applied an alternative approach. Perhaps this is answer enough for the moment.

4 Emergence: Chapter 4

Emergence: In this chapter the authors talk about the phenomenon often called *emergence*. The starting point is the distinction that a collection of *individual* systems, which can show a behavior as individual systems, also can show a behavior as a *collection* of systems (cf. p.44f). A first formalization could run as follows:

$$\begin{aligned} EMSystem(x)\ iff\ x &= \langle ENV, S, \Phi \rangle & (10)\\ ENV &:= Environment & (11)\\ S &= \{s | IOSystem(s)\} & (12)\\ S &\subseteq Events & (13)\\ \Phi &: S \times ENV \longmapsto ENV & (14) \end{aligned}$$

This formalization assumes that an emergent System [S] is a set of input-output systems within an environment [ENV] and there exists an overall behavior function Φ which describes the behavior of the whole set S in the environment.

Then the authors make further distinctions: (i) the behavior of the individual systems is *independent* from each other which leads to the classification of such individual systems as *disorganized* complexity (cf. p.47f). (ii) the behavior of the individual systems is *dependent* from each other, which is called by them *organized* complexity.(cf. p.50)

Disorganized Complexity:

$$DisSystem(x)\ iff\ EMSystem(x)\ \& \tag{15}$$

$$\bigcup rn(\phi_i) \neq rn(\Phi) \tag{16}$$

These distinctions reminds at the before introduced concepts of complicated and complex systems. *Complicated* systems are per definition independent from each other and *complex* systems are per definition interdependent.

Weak Emergence: To state that a collection of systems shows the characteristic of a *disorganized complexity* therefore states that the observable macro-behavior can not be induced by the individual systems as such. Thus this kind of emergence is a kind of *'outer' or 'weak' emergence* which is independent from the individual systems and therefore can only be associated with some properties of the environment which are interacting with the individual elements 'from the outside'.

$$WEMSystem(x)\ iff\ EMSystem(x) \tag{17}$$

$$\&\ DisSystem(x) \tag{18}$$

Thus, a *weak emergent system* [WEMSystem] is an emergent system which is simultaneously a disorganized complexity on account of its complicated subsystems.

Organized Complexity:

$$OrgSystem(x)\ iff\ EMSystem(x)\ \& \tag{19}$$

$$\bigcup rn(\phi_i) = rn(\Phi) \tag{20}$$

Strong Emergence: In the case of an *organized complexity* the macro-behavior Φ depends on the individual behavior ϕ_i of each individual system. This then represents an *inner* or a *strong emergence*. Probably this is the main meaning of the *intuitive* notion of emergence.

$$SEMSystem(x)\ iff\ EMSystem(x) \tag{21}$$

$$\&\ OrgSystem(x) \tag{22}$$

Superimposition of Weak and Strong Emergence: The interesting point here is – which is not mentioned by the authors – that there can be a *superimposition* of both kinds of weak and strong emergence because even in the case of the strong emergence the individual systems [S] are part of the environment and simultaneously to the effect of the inner, strong emergence there happens inevitably an interaction with the environment which can trigger some weak emergence phenomena. An impressive example is the *usage of language*. While the individual speakers of a language L interact in a language communication it is known from *linguistics* that in the course of the time the material of the language is changing in many respects without depending on the behavior of a single speaker. The kind of words, the way they are pronounced, the way how words become connected etc., all these phenomena are subject to the overall usage by a big number of speakers.

Warren Weaver: The authors cite in their chapter a report from Warren Weaver (1958) [Wea58] printed in an annual report of the Rockefeller Foundation. In this report Weaver outlines the format of scientific models from about 1600 until 1900 and thereafter.

In the time before 1900 the physical sciences dominated science and because the variables in the domain of the physical sciences have been *independent* from each other one could simplify nearly all problems by investigating only two variables.(cf. p.7f)

After 1900 the *physical sciences* according to Weaver did extend the number of variables to big numbers, but a main characteristic was kept constant: these variables have been *not dependent* from each other, nevertheless they showed a kind of *collective behavior* which was the more likely to be observed as the number of included variables was growing. The domain of statistics became important. Weaver calls this kind of complexity on account of the interdependence *disorganized complexity.*(cf. p.10f)

Comparing the physical sciences with comparable *simple* problems describable with roughly two variables the new live sciences emerging after 1900 had to deal with systems showing more than two parameters simultaneously, and these variables were *dependent from each other*. Thus the observable overall behavior of such collections was directly dependent from the behavior of the individual variables. Weaver calls these collections *organized complexities.*(cf. p.13f)

5 Chapters 5: Computation as Theory

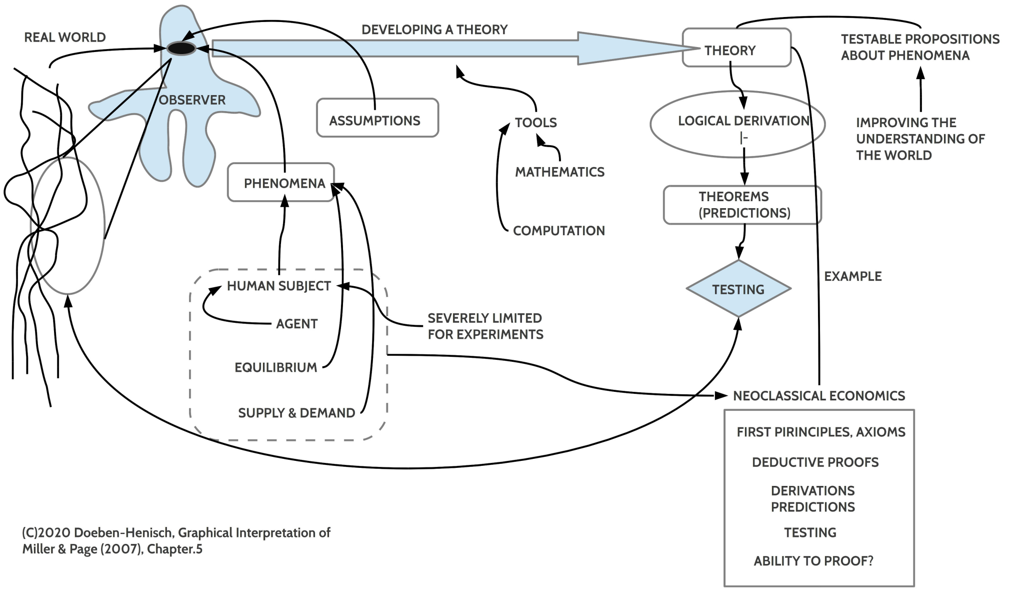
5.1 The Text

Introduction: On the first two pages the authors delineate the history of house building from individual building processes to an increasing standardization, which results in 'safer houses', but with less user related aspects, and then again, quite new, a return of individualization by modern technology, especially by computers.

This could be a theme for the whole *overall process of digitization* as we experience it in 2020. Against the 'knocking out of the individual' there are everywhere tendencies, initiatives, to bring the user back in the center of the development. But one can ask, why the authors write an introduction to the chapter with this historical example?

The authors close the introduction to the chapter with the statement, "*... that tools like mathematics and computation are complements rather than substitutes in the development of sound theory.*"

Tools and Theories: The rest of the text of this chapter talks about the role of a theory and how so-called tools like 'mathematics' and 'computation' are related to the job of a theory.



(C)2020 Doeben-Henisch, Graphical Interpretation of
Miller & Page (2007), Chapter.5

Figure 1: Graphical Interpretation of Miller & Page (2007), Chapter 5

In the figure 1 I have outlined the ideas of the chapter in a drawing. To transfer the meaning of a text into a drawing is always a kind of an interpretation. Thus perhaps by doing this I missed eventually an important point, but everybody who can see this and who is reading the text can give me some advice that this is the case.

Theory: Although the concept of a *theory* plays a central role in the considerations of the authors they spend only a few lines of text to describe this concept. The main statement is the following one: *"A theory is a cohesive set of testable propositions about a phenomenon and it can be created by a variety of tools."*(p.59) And the other statement:*"Theories need to be judged by how well they are able to improve our understanding of the world around us..."*.(p.60) The – for me – irritating point in this view of a theory is the emphasis on the *informal character* of a theory expressed by the authors. Thus not only distinguish the authors between a theory and the mathematics called a tool but they claim that it is enough that a theory is *withstanding testing* even without first principles, axioms, or a *rigorous prove.*(cf. 63)

Grounding a Theory: It is clearly stated by the authors that a theory is *about a phenomenon*, but it is open *what* a *phenomenon* is, under which conditions phenomena do *occur*. In my graphical interpretation I have 'filled this gap' with that model which I am using. And in the modern view phenomena are rooted in the brains as *conscious events*, which are triggered by real world events transmitted by the body to the brain. And these phenoena are *not isolated*, individual events but they are always embedded in different kinds of relations, frameworks, space and time. Thus phenomena are related to different sets of *assumptions*. The *boundary* between actually induced event properties and those which result from past experiences, past categorizations etc. is *fuzzy*.

Neoclassical Economics: The authors are using as examples economical theories and physical ones. In the realm of economics they take the example of neoclassical economics using rigorous mathematical models which allow derivations and predictions. These have to be tested.(cf. p.59ff) Because the possibilities to test real persons are very limited there is some need for additional methods, which are called tools by the authors. Thus there seem to be two main sources of problems: (i) the translation of phenomena occurring in the field of economics into the right axioms as well (ii) the testing of derived predictions. Without a completely formalized theory and derivation process this whole process is not working.

5.2 Critical Comments

The above outlined view of the authors invites to some comments.

Informal Stuff: The preference for the *informal character* of a theory with a strong emphasis of *intuitive understanding* is strange. This irritation is even more enforced by the classification of 'mathematics' as a *tool*, which one can use to generate a theory or to proof something, but not as the theory itself.

Besides the requirement for a theory to *improve our understanding* of the world there is also the requirement, that the set of propositions of a theory shall be *cohesive*. This is a very strange concept, not explained in logic, meta-theory or philosophy of science.

The main problem is the requirement, that a theory is not more than a collection of *propositions* about *phenomena*. Every everyday talking about something can be classified as a set of propositions about phenomena, and it is well known that such an everyday talking is highly fuzzy, can lead to misunderstandings, is clearly not usable for *hard sciences*.

Empirical Measurement: The minimum requirement for empirical sciences is that there exist *procedures of measurement* M which include well accepted *standards for measurement* which can be used as benchmarks to be compared with the some interesting subject. The *measurement data* M_{Data} are then the basic ground for further relations, functions, models, theories. And already these measurement data have to be expressed in a suitable *language for measurement* L_{meas}. These measurement data will be related *in the head of the observer* with different kinds of phenomena related to the measurement procedure, but that what counts are the measurement data.

Formal Theory: Because measurement data are always *individual points* in some space and time, disconnected from other measurements, it is necessary to *connect* these points in relations, mappings, regularities to enable some causal meaning embedded in space and time. This is the *generation of a theory* by thinking. The thinking as such is invisible, is creative by nature, but to communicate the *content of thinking* to themselves as well as to others one needs a *theory language* L_{th} which is flexible enough but at the same time simple enough to work. In a historical movement this language has become the *set theoretical language* – L_{set} with $L_{th} \subseteq L_{set}$ – including formal logic. The set theoretical language enables modern mathematics as well as engineering as well as theoretical computer science. All meta-theoretic concepts like correctness, completeness, being sound, decidability, etc. are only possible within this formal framework.

Empirical Testing: Whether a formal theory T is *empirically sound* can only be judged by comparing the set of *possible theorems* $TH = \{t : T| - t\}$ (= logical derivations) of the theory with the *empirically measured data*. Some minimal requirement could be that $M_{Data} \subseteq TH$. Then all known data would be 'explained' by the theory T in the light of their theorems TH, but the set of theorems TH is usually much larger then the available set of data. Thus every theory has a *surplus* of possible meaning whose status as *true* or *false* is not clear.

Language and Logical Apparatus: These simple considerations show that the whole machinery can only work if there exists appropriate languages to compare measurement data with theory expressions. Furthermore one needs a logical apparatus to enable theorems as derivations. Then one needs a procedure to check measurement data against theorems.

Creativity: Because theories do only arise by *thinking* which is located in the human brain and this thinking process is completely *invisible*, there exists a substantial amount of *non-rationality* in the process of theory building. And it is from the outset by far not clear whether a new theory is empirically sound. This can only be clarified by empirical testing in a transparent, reproducible way.

Computation: In the text of the authors it is more or less unclear how computations are related to a theory. They talk about computation as a possible *tool* for theory generation or testing, but they do not really explain it. Following a strict formal approach one can describe this relationship as follows:

1. *Software*, computer programs, are finally algorithms, and algorithms are mathematically *functions*.
2. A *theory* is a set of testable *statements* which can become *true* or *false*.
3. A *function* as such can *never* become *true or false*. In the light of *formal languages* are functions so-called *terms* and terms can be *part of statements*.
4. In this context are functions those parts of statements which can compute complex operations, which wouldn't be possible otherwise. Therefore are functions in the format of algorithms *valuable extensions of the theory language*.

Summary chapter 5: The chapter 5 shows a great lack of knowledge with the authors in understanding the formal apparatus of theories, computations and mathematics and thereby they can not really explain the relationships between these concepts.

6 Chapter 6: Agent Based Modeling

6.1 Thesis of the Book

In this chapter the authors argue why an *agent-based* approach is a good approach. The main arguments are summarized in the following list, already extended with some critical comments by the reviewer:

1. *Flexibility* in the description is played against *mathematical precision*. This sounds a bit strange because the specification of agents is done with algorithms which are part of a formal machinery which finally is part of mathematics. Thus mathematics allows the description of agent-based processes. The main point here is therefore not the symbolic description as such but the possibility to translate a formal specification by a machine (computer) into a *real process* which in a *concrete way* can make all those *concrete computations* which are allowed in a specified space of possible states. Therefore the opposition between mathematics and an agent-based approach has to be understood rather as a cooperation of two distinct modes of reality: the *symbolic* space and the *real object* space.

2. An agent-based approach is *process oriented*; this enables more *detailed descriptions* and more *clarifying experiences* than without such an explicit modeling. This is the fact because process oriented descriptions are closer to the everyday experiences and – if implemented on a computer – can demonstrate the circumstances very concretely in a way, which the human brain never could manage on themselves.

3. Another point is, that agents can be *adaptive*. This allows the modeling of adaptation and learning of real biological systems as part of biological evolution or social and/ or economical systems. Although it is possible to describe such agents formally, the different concrete states, which these agents can enter, nor the manyfold kinds of interactions with their specific effects can be computed by a normal human brain. Thus a physical machine like a *real* computer is needed to do such kinds of computations described *formally*. The distinction of the authors between *symbolic* approaches to learning and *low-level* approaches is from a theoretical perspective unimportant. The so-called 'low-level' approaches[5] are also given with formal specifications which are not different to other kinds of formal specifications of algorithms. The difference is only in the *presupposed ontological models*. But this difference is only a relative one: if one wants to describe

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[5] Usually understood as artificial neural networks

the cognitive structure of an agent then one has to describe formally the whole structure with some components shaped as neural networks. Then the 'low-level' components are part of an overall formal theory and are as formal as everything else. Older computational models using *rules* to describe cognitive processes are in the same manner part of an overall formal framework. For some applications it can be helpful to work with rules, but this is not so different from artificial neurons which are formally also rules.

4. The authors criticize classical analytical approaches which prefer the description of *equilibria of dynamic systems* instead of their real dynamics. An agent-based approach clearly can focus on the dynamics itself.
5. They emphasize too that an agent-based approach can handle a variety of *heterogeneous agents*.
6. Contrary to analytical approaches an agent-based approach is also capable to *scale* from only a few agents to nearly infinite many, including all the numbers between the few and the many.
7. Another point is the *possibility of re-run* the system as often as wanted. This allows the exploration of states unknown otherwise. Formally it is always possible the infer every possible state, but for a human brain this is impossible. And even a real computer is not able to explore everything theoretically possible bounded by space and time.
8. From the point of a formal theory it is formally specified, what is a *proof* for some *theorems*, which can be used as *forecasts*. But the process of constructing such a proof can be too demanding for a human brain. With a computer-based formal model the computer can do in some cases the construction of such a proof *constructively*.
9. The usage of computational modeling can *reduce the costs* for development drastically.

6.2 Discussing the Relationship to DAAI

Formal Theory: As described in the DAAI text the DAAI paradigm can be handled as a full fledged formal theory which can be turned into an empirical theory be keeping the formal structure as the kernel of the theory.

Dynamics: The layout of the DAAI theory is such, that one can describe any kind of a process understood as a sequence of states connected by changes.

Actors: Every state can contain any number of actors, which are the DAAI equivalent to the concept of 'agent'.

Adaptive: The format of actors within the DAAI theory assumes only, that the actors are input-output systems having a behavior function. Everything else is open for specifications. Thus the introduction of every kind of adaptive or learning actors is possible.

Simulation: The *formal* layout of the processes specified within a DAAI theory is such, that these *formally* specified processes can automatically be translated into a *formal* description of an automaton, which can simulate these formally specified processes. These formal specifications can automatically be transferred to a *real computer* doing the *real computation*. Whether these computers are working with rules, neural networks or whatever is physically possible, this does not matter.

Embedded in the Real World: Because the state descriptions include possible interfaces to some assumed context (certain parts of the assume real world) it is additionally possible to connect the simulating computer (which can be a network, a cloud, ...) with arbitrary physical interfaces to other parts of the real world too. Therefor one can use the DAAI paradigm too to simulate so-called *smart cities*, *smart factories*, *smart enterprises*, etc.

Simulation Games: The enhanced need for better learning processes for people today can use the DAAI paradigm as a framework for improved learning for instance in schools, universities, companies etc. The interface between the DAAI theory and the real people in real environments is the format of a simulation game. This allows different modes: (i) developing the game based on the experience of the participants; (ii) playing a game; (iii) evaluating the playing process; (iv) improving the original game.

7 Chapter 7: A Basic Framework?

7.1 Thesis of the Book

The authors, looking for a *simple framework* from which they plan to discuss their approach of a *network of interacting agents*, take as a kind of *training partner* the so-called *eightfold way* of Buddhism. Although the semantics of this concept of the 'eightfold way' is hidden behind very told texts written in different many old languages, which to translate is highly difficult, the authors want to use this as a point of reference, to clarify their own concept (which at the beginning of chapter 7 is not yet embedded in a clear formal framework!). Nevertheless they are convinced that such a "destructive transformation is insightful".(cf. p.93)

Whatever the texts about the eightfold way – the authors of the book call it also the *eightfold path*(cf. p.93f) – can tell us, the reviewer goes directly to the interpretations of the authors of the book, how they want to understand the eightfold way/ path. For this one can start with the *translation table (lexicon)* of the main concepts of the eightfold path and the concepts of the authors presented in a simple table on p.94.

1. The *eightfold-path* expression *right view* is interpreted by the authors as *information* which an agent *receives* from the world.(cf.p.94) It is then annotated by the authors that there are complex inner states which can influence the way how an agent interprets the input. Furthermore it is pointed to the fact, that a perceiving (and interpreting) agent can be part of a *network of agents* which can induce some effect onto each member.

2. The *eightfold-path* expression *right intention* is interpreted by the authors by terms like *goals, desires, motivations*. And the authors stress the importance of these inner states of the agents for their observable behavior. If these inner states *change* then the behavior can change and thereby the whole network can change. Then it can happen that the motive of one agent ('micro motive') can be confront with an overall situation ('macro behavior'), which is just the opposite of what has been intended.(cf. p.95f)

3. The *eightfold-path* expression *right speech* is interpreted by the authors as the *information* which *sends* an agent *to others*. The authors use expressions like *behavior, channels, models, kind, flow, allowed* in connection with the term *information* to speak about information. And they point back to the book of Shannon (1948) [Sha48] as a "sound basis from which to think about primitive issues of information". And one can interpret their text as if the usage of agent-based models does allow a more advanced concept of information as *strategic* information as part of *complex* systems.(cf.p.96)

4. The *eightfold-path* expression *right action* is interpreted by the authors as *all of the interactions that occur* among the agents. The authors see the interactions realized by actions as associated with the information which can flow between the agents and this flow of information as well as the actions or inactions *dependent* in may ways from the physical or abstract

space in which the agents are embedded. The behavior can be *simultaneously* or *asynchronously* depending from the kind of *synchronization*.(cf. p.96f)

5. The *eightfold-path* expression *right livelihood* is interpreted by the authors as the *payoffs* that *accrue to the agents*. To the extend agents can manage the circumstances of payoffs the expected payoffs can trigger the behavior.(cf. p.97f)

6. The *eightfold-path* expression *right effort* is interpreted by the authors as embracing *agent strategies and actions*. The main term here is 'strategies' which become either *visible* or will be *realized* through sequences of actions. These strategies can be *fuzzy* or can be mapped into *sets of rules* which are directing the behavior. To the extend one can define *good outcomes* one can relate strategies to such good outcomes and one can try to optimize such strategies.(cf. p.98-100)

7. The *eightfold-path* expression *right mindfulness* is interpreted by the authors as the *level of cognition* employed by an agent. The level of cognition is dependent from the context. Often cognition is accompanied by *mental models* which *inform* the behavior. Because simple rules can create a complex behavior as well as simple behavior can hide complex rules it is difficult to reconstruct underlying mental models.(cf. p.100f)

8. The *eightfold-path* expression *right concentration* is interpreted by the authors as *the focus of the model*, which is understood as the ability of the system, *to be just sufficient to capture the phenomenon of interest*. This becomes important if the context embraces a certain amount of *heterogeneity* which requires many selections to take the 'right' option.(cf. p.101f)

7.2 Comment on Chapter 7

The different translations of the authors amount in a collection of terms which all together outline the shape of an agent model. Mostly these terms are in this context a bit vague but despite this vagueness one can see some kind of a structure. The following text is therefore to be understood as a first kind of a summary of these terms shaping a preliminary agent-model. In a follow-up part this preliminary model will be discussed with regard to the DAAI paradigm.

7.2.1 Preliminary Agent Model of the Authors

1. An agent can be part of a *network of agents* which can induce some effect onto each member.
2. The agent is an *input-output system*[IOSys] which can *receive information* from the world.
3. This input can become associated with *inner states* [IS] which can influence the way how an agent *interprets the input*.
4. The inner states of an agent are often described by additional terms like *goals, desires, motivations*. When these inner states *change* then the behavior can change and thereby can the whole network change.
5. The term *information* is traced back to the book of Shannon (1948) [Sha48] as a "sound basis from which to think about primitive issues of information". But additionally it is pointed out that the usage of agent-based models does allow a *more advanced concept* of information as *strategic* information as part of *complex* systems.
6. *Information* can be *send* from one agent *to other* agents. The authors use terms like *behavior, channels, models, kind, flow, allowed* in connection with the term *information*. Furthermore information can happen *simultaneously* or *asynchronously* depending from the kind of *synchronization*.
7. From the point of view of an agent there can be *payoffs* that *accrue to the agents*. To the extend agents can manage the circumstances of payoffs the expected payoffs can trigger the behavior.
8. This can be accompanied by *agent strategies*. To the extend one can define *good outcomes* one can relate strategies to such good outcomes and one can try to optimize such strategies.
9. There can be different *levels of cognition* in an agent accompanied by *mental models* which *inform* the behavior.
10. Because simple rules can create a complex behavior as well as simple behavior can hide complex rules it is *difficult to reconstruct underlying mental models*.
11. The ability *to capture the phenomenon of interest*.

7.2.2 Relation to the DAAI Paradigm

Actor Model [AM]: To a large part what is said by the authors about agents is within the DAAI paradigm located in the *actort model*[AM] part of the theory. And there is nothing said in chapter 7 which can not be stated within a DAAI actor model.

Actor Story [AS]: But there are some terms and considerations which go *beyond a single agent*. This describes the interactions between individual agents and the environment, which can contain other agents too. Because interactions are interpreted within the DAAI paradigm as *changes* translating an actual state in a follow-up state[6] and which induce effects onto more than one agent these phenomena can only be handled in an *actor story*[AS].

Information Hiding: Because actor models are elements of the overall actor story it is possible within the DAAI paradigm to describe such *beyond-agents-effects* within an actor story with all details which are necessary. One can even *hide* the details for a more comfotable communication without to delete or forget them.

Information: The authors are using heavily the term *information*. While they are pointing to the book of Shannon (1948) they state, that the concept of information has to be extended in the context of *agent modeling*. But they do not explain, how such an altered definition should look like. The reviewer has within the DAAI paradigm introduced an agent concept with a cognitive model, which allows definitions of terms like *meaning, ontology, sign, language* and even more. These terms are more or less borrowed from *semiotics*, the general science of symbols.(See e.g. DAAI version 15.06.07, Chapter 3) The phenomena dealt with in the DAAI paradigm are going beyond the Shannon concept of information, which explicitly excluded every kind of meaning!

8 Book Examples

Besides the interesting general methodological considerations of the book there are many elaborated examples, mainly in the chapters 7, p.102-113 and chapters

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[6] even with effects reaching out about more than one state.

8-11. These examples are illuminating and important to understand the general theoretical considerations. But to discuss these in details is beyond this review. The reviewer plans to analyze these examples – or at least some of them – as examples analyzed in the style of the DAAI paradigm. This could be a further 'test' of the DAAI paradigm to cope with adaptive complex systems.

References

[MP07] John H. Miller and Scott E. Page. *Complex Adaptive Systems. Introduction to Computational Models of Social Life*. Princeton University Press, Princeton - Oxford, 1 edition, 2007.

[Sha48] C.E. Shannon. A mathematical theory of communication. *The Bell System Technical Journal*, 27:379–423, 623–656, 1948. July and October 1948.

[Wea58] Warren Weaver. A quarter century in the natural sciences. In *Rockefeller Foundation Annual Report, 1958*, pages 7 – 15. Rockefeller Foundation, 1958. URL: https://assets.rockefellerfoundation.org/app/uploads/20150530122220/Annual-Report-1958.pdf.