Review of Miller & Scott's Book
Complex Adaptive Systems
An Introduction to Computational Models of Social Life
Chapters 1-2,4-5

A Review from the Point of View of the DAAI Paradigm
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Jan 5-14, 2020

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]

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

[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

the *DAAI paradigm*.

Miller & Page begin their journey into complexity with the basic distinction between 'complicated' and 'complex' systems. The basic definitions can be re-written 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. 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:

[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.

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

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):

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

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:

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

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)

Summary Chapter 4: It shows up that all these concepts of chapter 4 can be applied within the DAAI paradigm.

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.

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 interpreta-

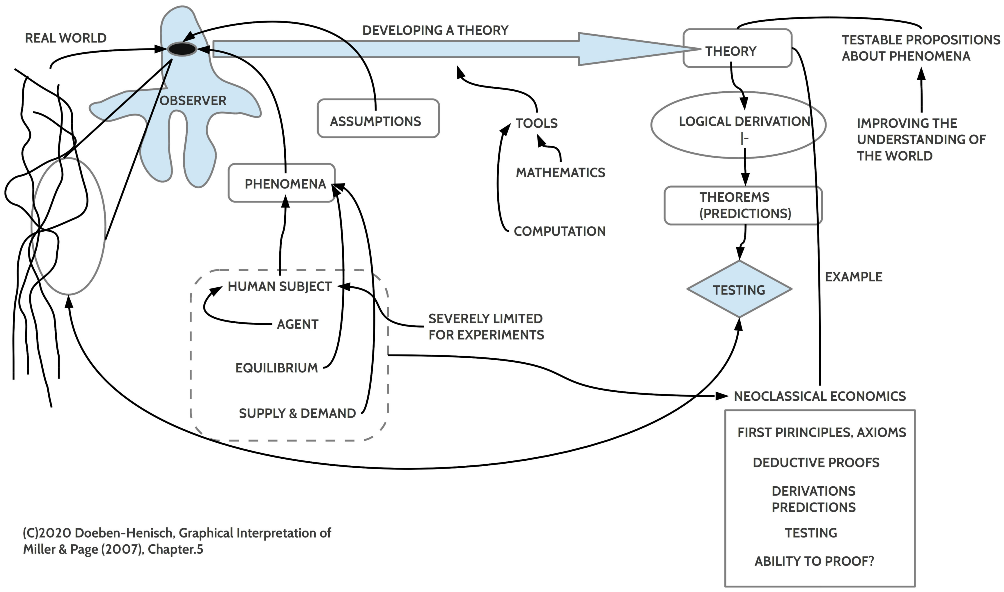

Figure 1: Graphical Interpretation of Miller & Page (2007), Chapter 5

tion. 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.

References

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