The Localization Hypothesis and Machines

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Abstract In a recent article in *Artificial Life*, Chu and Ho suggested that Rosen's central result about the simulability of living systems might be flawed. This argument was later declared "null and void" by Louie. In this article the validity of Louie's objections are examined.

Keywords
(M,R) systems, Robert Rosen, simulability, analytic models, synthetic models

1 Introduction

The field of artificial life is very diverse, with contributions ranging from systems biology to theoretical research into the origin of life to robotics. Yet although artificial life research predominantly uses methodologies from computer science and mathematics, there is also a strong philosophical component in the artificial life research agenda.

This philosophical aspect of the field has been very much connected to the attempt to create living systems in silico. Such an attempt leads to a fundamental question: Given a specific computational system, how do we decide whether or not it is alive? Or alternatively, how do we distinguish between systems that behave like living systems ("lifelike systems") and systems that are truly alive?

As it turned out, this question is not an easy one to answer. Despite many attempts, nobody has yet been able to identify a single set of criteria to demarcate living systems from nonliving systems.

The attempt to create life in silico has so far not been a great success. No examples of computational systems that would, at least at an intuitive level, satisfy even a significant minority of researchers as an example of life have been found. This might be taken as an indication that there is something about life that cannot be captured in computational models. Hence there are two big questions that drive the philosophical quest of artificial life.

- What is life?
- Is artificial life (in the sense of a computational system being alive) possible?

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2 If Living Systems Must Have Uncomputable Models, Then Artificial Life is Impossible

The work of one scientist claims to give definite answers to both of those questions. In his book *Life Itself* [3] Robert Rosen gives a "comprehensive inquiry into the nature, origin and fabrication of life." The central results of this book are (i) a demarcation criterion for living systems and (ii) a proof that whatever qualifies as a living system must have models that are not "simulable." (Note that "simulable" *sensu* Rosen might not directly map to everybody's intuitive understanding of the word, yet it is certainly true that according to Rosen, all computer programs are simulable and have simulable models.) Therefore a central result of Rosen's work is that artificial life, in the above sense, is impossible.

Louie [2] criticized a similar statement we made in [1]:

> Let me reiterate the fact that Rosen did *not* say that artificial life is impossible, only that life is *noncomputable*. [2, Section 5]

Whether or not Louie is correct depends on what one thinks encompasses artificial life. Rosen's results are relevant for *computational* artificial life, but probably not for wet artificial life. Given that the field of artificial life is predominantly (if not exclusively) concerned with computational artificial life and given the context of our statement in [1], we wrongly assumed that it was clear that we only referred to *computational* artificial life.

We would now like to respond to Louie's more substantial objections against the core contributions of [1], namely our argument that Rosen's central results might in fact not be relevant at all.

3 Is Rosen Correct?

In order to arrive at his central result, Rosen constructed a minimal relational model of a cell; this model is usually referred to as the *(M,R) system* (for metabolism-repair system). "Relational" essentially means that the model consists of blocks and arrows connecting the blocks. The justification for assuming that the model is indeed a model of a cell is that it has a certain closure property ("closed with respect to efficient causation"). Rosen's central argument consists then in showing that systems that have this closure property cannot be fully captured by computational models.

The task we undertook in [1] was both to clarify Rosen's central proof and to evaluate its validity; more specifically, we indicated in what sense analytic and synthetic models form categories, and secondly we reconstructed and assessed Rosen's proof while avoiding jargon. This critical assessment uncovered a potential flaw of Rosen's argument but was later declared "null and void" by Louie [2].

We will not repeat the details of our argument from [1] here, but only summarize its overall structure; for details the reader is referred to [1, Section 5].

1. ***Assumption:*** Figure 1 (which is the same as Figure 6 in [1] and Figure 9D.1 in [3]) is a machine.

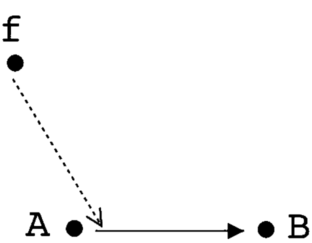

Figure 1. A relational model of a machine. See also Figure 6 in [1].

2. ***Assumption:*** In machines a function (which would correspond to the dotted arrow in Figure 1) is located in an identifiable part of the machine (the *localization hypothesis*; see [3, Section 8G]).
3. All machines are mechanisms, and for all mechanisms it is the case that all models are simulable.
4. All models simulable implies `analytic models = synthetic models`.
5. If `analytic models = synthetic models`, then the system is state-space based [1, Section 2.4.1].
6. If Figure 1 represents a state-space based system, then it is not compatible with the localization hypothesis.
7. ***Conclusion:*** Machines cannot both imply the localization hypothesis and be state-space based.

The conclusion was later declared "null and void" by Louie [2] on the following grounds:

1. The argument in [1] constructs an example of a system that contradicts Rosen's conclusion. Yet Rosen's conclusion was mathematically proven; hence the whole argument is "null and void."
2. The definition of mechanisms in [1] (mechanisms as the class of systems where `analytic models = synthetic models`) is wrong; hence any conclusions drawn from this definition must be "null and void."
3. The discussion by Chu and Ho was based on an incorrect representation of closed systems (i.e., Figure 7 in [1] is wrong).

Let us start with the third point. First of all, even if Figure 7 in [1] were indeed incorrectly reproduced, it would not make any difference to the discussion or conclusion in [1], because the specifics of the figure are never used. Secondly, Louie's criticism is in fact incorrect. The reader can easily convince herself that Figure 7 in [1] is formally identical to Figure 9F.3 in [3].

As to the first point raised by Louie: We think that it represents a misunderstanding of the argument. First of all, we disagree with the strong statement that there cannot be any counter-examples to mathematical proven facts. A counterexample to a mathematical theorem (if correct) is just the same as a proof that the theorem is incorrect. Hence, if a theorem is believed to be proven, but a counterexample exists, then the proof must be wrong. Hence there is no reason to dismiss constructions out of hand on the ground that they contradict a known theorem.

In any case, alleging the use of counterexamples to disprove Rosen's central theorem amounts to a misunderstanding of our argument in [1]. Instead of constructing a counterexample to Rosen's central result, we used one of Rosen's own examples of a machine (in fact, the simplest relational model of a machine) and investigated its properties. Admittedly, our argument is not to be considered a formal mathematical proof, but it is certainly not affected by Louie's first objection.

As to the second objection: While Louie might be correct in pointing out that the definition of a mechanisms in [1] was inaccurate, that inaccuracy would be inconsequential for the argument we made. Let us explain why: Louie complained that we defined a mechanism as equivalent to `analytic models = synthetic models`, while in fact only the implication `mechanism` $\Rightarrow$ `analytic models = synthetic models` is true. Let us, for the sake of the argument, assume he is correct in this criticism. While pointing out the alleged inaccuracy, Louie also grants us the same privilege as Humpty Dumpty claims for himself, namely, that we can choose a word to mean whatever we like, "neither more nor less." We accept this privilege but, in order not to confuse the reader, we will distinguish between R mechanisms (mechanisms defined according to Rosen, i.e., only the implication holds) and CH mechanisms (equivalence holds).

In order to understand the difference between R mechanisms and CH mechanisms in relation to the argument in question in [1], it is useful to review once again the basic chain of implications on which our objection to Rosen relies. This chain is as follows: `machine` ⇒ `mechanism` ⇒ `synthetic = analytic` ⇒ `state − space based` ⇒¬`localization hypothesis`. Another implication is used, namely: `machine` ⇒ `localization hypothesis`.

The reader will immediately see that at no point in the above chain does the `implication analytic = synthetic` ⇒ `mechanism` appear. Hence if the above argument is correct for CH mechanisms, it is so for R mechanisms. Thus, by invoking the Humpty Dumpty privilege, we conclude that Louie's objection is immaterial for our argument in [1].

4 Conclusion

We do not believe that Louie's objections per se force an alteration of our conclusions in [1]. This—of course—does not mean that [1] is beyond all doubt. To the contrary, our claim in [1] has never been to provide a definite argument about Rosen's work, but rather to attempt to present it free from jargon, increase its accessibility, and provide a critical assessment of the central theorem.

We still believe that Rosen's work is of high potential significance for our understanding of life and specifically the relation between life and algorithmic systems. Yet, in order to have any real impact on the way we think about life, Rosen's arguments need to be reevaluated and most of all restated in a language that avoids confusing and unjustified misnomers (such as metabolism and repair for what really are just arrows). Our contribution in [1] was meant as a first step in this direction. Future work will need to address among other things the following questions:

- Which biological systems are clear realizations of (M,R) systems in biology?
- Which aspects of those systems cannot be captured by computational simulation?
- What exactly leads to a failure of the localization hypothesis in organisms?
- How do familiar concepts, such as emergence, relate to Rosen's observations?

References

1. Chu, D., & Ho, W. (2006). A category theoretical argument against the possibility of artificial life. *Artificial Life*, *12*(4), 117–135.

2. Louie, A. (2006). A living system must have noncomputable models. *Artificial Life*, this issue.

3. Rosen, R. (1991). *Life itself.* New York: Columbia University Press.

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