Progress in simulating human geography: Assemblage theory and the practice of multi-agent artificial intelligence modeling

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Abstract
Over the last few years, there has been an explosion of interest in assemblage theory among human geographers. During this same period, a growing number of scholars in the field have utilized computational methodologies to simulate the complex adaptive systems they study. However, very little attention has been paid to the connections between these two developments. This article outlines those connections and argues that more explicitly integrating assemblage theory and computer modeling can encourage a more robust philosophical understanding of both and facilitate progress in scientific research on the ways in which complex socio-material systems form and transform.

Keywords
Assemblage theory, social simulation, multi-agent artificial intelligence modeling, Manuel DeLanda, emergence, ethics

I Introduction
Over the last few years, a growing number of scholars within human geography and related social scientific disciplines have turned to “assemblage theory,” inspired by Deleuze and Guattari (1988) and articulated by Manuel DeLanda (2016, 2006), as a framework for understanding and explaining the socio-material systems they study. Surprisingly, however, most social scientists interested in assemblage theory seem not to have noticed that DeLanda’s own philosophical framing of the theory is informed by and linked to the use of computer modeling and simulation (CMS). This is most explicit in his book Philosophy and Simulation: The Emergence of Synthetic Reason (2011), which is occasionally cited but seldom examined in detail by human geographers. Those who do cite the book rarely comment on his arguments there about the key role of CMS in articulating and applying assemblage theory or about the potential of CMS methodologies for the social sciences in general. This is all the more surprising since DeLanda also alludes to CMS in his earlier A New Philosophy of Society: Assemblage Theory and Complexity (2006) and his later Assemblage Theory (2016), both of which have been

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rigorously engaged by human geographers interested in assemblage theory.

It is also surprising that most scholars interested in using computational tools to address research questions in human geography seem not to have noticed that the successful development and deployment of these techniques lend plausibility to the ontological and causal claims embedded within assemblage theory. Computer simulation techniques, especially agent-based modeling (ABM), have been extensively utilized by human geographers to analyze the causal dynamics and emergent patterns within complex adaptive socio-material systems (e.g., Heppenstall et al., 2011; Manson et al., 2012). In fact, Progress in Human Geography has been the forum within which several of the most enthusiastic calls for a more robust use of ABMs have appeared. The latter have been recommended for research in human geography in particular because of the way in which they “provide a good venue for even more broadly integrative science” (O’Sullivan, 2008, p. 547), “allow for experimentation in virtual worlds” (Miller, 2018, p. 606), offer “an unparalleled tool for modelling human decisions” (Liu et al., 2019, p. 14), and can be “used for explaining social structures and relations and how they might change in the future” (Millington and Wainwright, 2017, p. 78; emphasis in original). This modeling literature occasionally cites DeLanda but does not spell out the relevance of CMS for theorizing assemblages in human-geographic systems.

In this article, I draw attention to this conspicuous—and yet, oddly enough, rarely noticed—lack of engagement with DeLanda’s Philosophy and Simulation by human geographers, both among those interested in the philosophical implications of assemblage theory and among those regularly utilizing CMS methods in their research. I argue that highlighting the connections between assemblage theory and CMS can facilitate a more robust philosophical understanding and practical application of both. Several human geographers interested in assemblage theory have called for more attention to the processes whereby these complex socio-material wholes stabilize and change (Anderson and McFarlane, 2011; Dittmer, 2014; Turker and Murphy, 2019). Here I respond to this call by showing how the integration of CMS into this discourse can promote progress in simulating the conditions under which—and the mechanisms by which—social assemblages form and transform. The value of assemblage theory for the methodological grounding of (and metaphysical reflection on) practices within CMS has been explored elsewhere (Shults, 2020). This article explores the other direction of influence: how can CMS inform the way in which assemblages are theorized in human geography?

I focus primarily on the ability of CMS approaches, especially multi-agent artificial intelligence (MAAI) modeling, to simulate the emergence of macro-level wholes (social assemblages) with properties, capacities, and tendencies that are irreducible to their micro-level parts, and on the implications of the successful use of CMS for human geographers and scholars in related fields interested in assemblage theory. Section 1 introduces and illustrates the appropriation of DeLanda (as well as Deleuze and Guattari) among assemblage geographers, emphasizing the shared concern for explaining the mechanisms of emergence. The significance of the capacity of CMS techniques to simulate emergence for DeLanda’s definition and defense of assemblage theory is the focus of section 2. The third section outlines the potential contribution of recent developments in the practice of MAAI modeling for making progress in simulating human geography. I conclude by briefly exploring some of the ethical and political implications of these integrative efforts.

1. Theorizing assemblages in human geography

Recent years have seen an explosion of interest in (and critical discussion of) assemblage theory among human geographers. It is not hard to understand why. Assemblage thinking has provided scholars with a set of heuristic frameworks and conceptual tools that have helped to dissolve the hegemony of static and essentialist notions in the social sciences and to replace them with a renewed ontological emphasis on relationality, dynamism, and differentiation. The genealogy and usage of the term “assemblage” (the most common translation of the French word agencement in the work of Deleuze and Guattari) is contentious and contested in human geography, and
many scholars prefer formulations developed by or derived from Latour, Foucault, and others (e.g., Allen, 2011; Braun, 2006; Greenhough, 2011; Legg, 2011; Shaw, 2012). In this context, however, I will focus primarily on some of the ways in which the field has engaged and appropriated aspects of the work of Deleuze and Guattari as modified and formalized in DeLanda’s version of assemblage theory.

Following Deleuze and Guattari, DeLanda conceptualizes assemblages as wholes characterized by “relations of exteriority,” which implies that the component parts of an assemblage can be “detached” from the assemblage and “plugged into” other assemblages, and that the “properties” of the component parts cannot explain the properties of the whole because the latter “are the result not of an aggregation of the components’ own properties but of the actual exercise of their capacities” (DeLanda, 2006, pp. 10–11). We will return to the importance of this distinction between properties and capacities (as well as tendencies) in section 2 below. DeLanda also follows the authors of A Thousand Plateaus in defining the concept of assemblage as operating along two concomitant axes: one that describes the intermingling of machinic assemblages of bodies and collective assemblages of enunciation, and one that describes the simultaneous movements of territorialization and deterritorialization.

One of the main differences in DeLanda’s articulation, however, is his emphasis on assemblages as emergent wholes. Deleuze and Guattari did not use this concept often (it was not very popular in the 1970s), but they did use a variety of other closely related terms (e.g., morphogenesis, becoming, production, and individuation). In Philosophy and Simulation, DeLanda asks: in what kinds of concrete emergent wholes can we believe? His answer: “Wholes the identity of which is determined historically by the processes that initiated and sustain the interactions between their parts. The historically contingent identity of these wholes is defined by their emergent properties, capacities, and tendencies” (DeLanda, 2011, p. 3, emphases added). As we will see below, DeLanda finds the concept of emergence in general (and CMS in particular) helpful not only for linking assemblage theory to contemporary debates in science and philosophy, but also for explaining how social wholes are not transcendent to their parts but exist alongside them on the same (immanent) ontological plane (DeLanda, 2016, p. 12).

Human geographers regularly discuss the ontological assumptions of assemblage theory (e.g., Rogers, 2018; Bridge, 2020), but the metaphysical ramifications of the success of CMS methodologies for what Deleuze called the “reversal of Platonism” (2004), the philosophical move that undergirds assemblage thinking, have not been as rigorously explored. Sections 2 and 3 will spell out some of the implications of CMS for understanding and explaining the emergence of new social assemblages within a materialist metaphysics of immanence. In the remainder of this section, I describe some of the ways in which assemblage theory has been appropriated and applied by human geographers. Scholars have discussed the potential (as well as the limitations) of assemblage thinking for engaging a wide variety of topics such as the instability of “oil landscapes” (Haarstad and Wanvik, 2017), the need for “critical data studies” in a world increasingly dominated by computation and big data (Pickren, 2018), and the importance of taking more seriously feminist analyses of social difference, power, and inequality (Kinkaid, 2020a). However, there is no space here for a review of this expansive and expanding literature, and so here I focus on examples of human geographers who have explicitly engaged DeLanda’s work in ways that highlight the relevance of the concept of emergence.

In their article “On Assemblage and Human Geography,” which includes a rigorous engagement with DeLanda as well as Deleuze and Guattari, Anderson et al. (2012a) identified four things that assemblage thinking offers to human geography: “an experimental realism orientated to processes of composition; a theorization of a world of relations and that which exceeds a present set of relations; a rethinking of agency in distributed terms and causality in non-linear, immanent terms; and an orientation to the expressive capacity of assembled orders as they are stabilized and change” (p. 171). Each of these topics is more or less related to the issue of emergence, a link which the authors make explicit: “An assemblage is finite: an emergent effect of

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processes of gathering and dispersion (p. 177). They spell this out in the context of a discussion of agency and causality: “Assemblage operates not just as a concept aimed at understanding how a set of relations emerge and hold together across differences, but as an ethos for thinking the relations between durability and transformation” (p. 180).

The authors do discuss DeLanda’s *Philosophy and Simulation*, and highlight the value of his use of the distinction in that book between properties, capacities, and tendencies in his solution to the “problematic of the stability in form” (2012a, p. 185), but they do not examine the central role of CMS in the solution he exposits in that book. Elsewhere two of these authors point out that the term assemblage “is often used to emphasize emergence, multiplicity and indeterminacy, and connects to a wider redefinition of the socio-spatial in terms of the composition of diverse elements into some form of provisional socio-spatial formation” (Anderson and McFarlane, 2011, p. 124; see also Anderson et al., 2012b; McFarlane and Anderson, 2011). One of the goals of the current article is to show how more detailed attention to DeLanda’s reliance on CMS in his articulation of assemblage theory can render the latter even more useful for human geographers.

Some other human geographers have misinterpreted DeLanda’s version of assemblage theory as utilizing “essentialized” concepts, leading to “fixed” rather than dynamic boundaries, and failing to adequately conceptualize the “manifold mechanisms” of social change (Müller and Schurr, 2016; Turker and Murphy, 2019). These misreadings ignore DeLanda’s explicit claims to the contrary in his philosophical and computational writings (e.g., 2002, 2011), which are not cited by these authors. As DeLanda makes clear throughout *Philosophy and Simulation*, CMS provides distinctive tools that can identify the mechanisms at work in the dynamic and historical processes by which the new properties, capacities, and tendencies of emergent social assemblages are produced. The heterogeneity of the parts and the intricacies of their interactions in the histories of such assemblages render the process of modeling them quite complex. It is precisely here, however, that one finds the greatest opportunities for making progress in simulating human geography.

Incorporating DeLanda’s treatment of CMS into this discourse will not only protect against such misreadings, but also facilitate the outcome for which his critics are calling: the wider use of assemblage theory as an “adaptable template” for studying phenomena such as the emergence, resilience, and sustainability of community economies in a way that emphasizes “relations between heterogeneous actors constituting an assemblage, resources and constraints which flow from an assemblage to its constituent actors, and processes of (de)stabilization” (Turker and Murphy, 2019, p. 17, emphases in original).

One notable exception to the relative lack of attention to DeLanda’s focus on CMS in *Philosophy and Simulation* in the assemblage theory literature is an article on “Geopolitical Assemblages and Complexity” (Dittmer, 2014). In that context, Dittmer mentions several of the unique benefits of CMS technologies highlighted by DeLanda in his 2011 book, including their ability to identify the “tipping points” or thresholds for non-linear change within complex social systems. In his concluding methodological section, however, Dittmer leaves CMS aside and calls for more applications of assemblage theory within “historical analysis” in a way that complements other methods such as “ethnography, interviews and performative research” (2014, 396). I agree that the latter methods ought to be embraced and renewed within human geography, but hope that scholars in the field will pause a little longer to explore the value of CMS as a way of promoting assemblage thinking and fostering policy-oriented research that can incorporate insights gained from all of these other methods.

First, however, it is important to note a potential objection. Ian Buchanan has criticized some human geographers for detaching the concept of *agencement* from its philosophical roots and replacing it with “a synthetic accumulation of readings of readings of Deleuze and Guattari” (Buchanan, 2017, p. 459), and confusing it with concepts proposed by Latour, Foucault and others (Buchanan, 2015). As Buchanan makes clear in his recent book on *Assemblage Theory and Method*, which is quite critical of DeLanda, his interest in returning to the original authors of the concept is not simply about scholarly precision but also, and even primarily, about the potential role that
Deleuze and Guattari’s emphasis on what assemblages do (how they work, what they produce, etc.) could play in the critical analysis and evaluation of policies and politics (Buchanan, 2020). While I share many of Buchanan’s concerns about these issues, in my view the adaptation or bricolage of elements from various conceptualizations of “assemblage” is not inherently problematic, as long as theorists are clear about the genealogy of their claims and the operationalization of their terms. And it is to this task of clarification that we now turn.

2. DeLanda’s assemblage theory and the simulation of emergence

DeLanda’s distinctive conceptualization and articulation of assemblage theory can only be fully understood by taking into account the extent to which he has drawn from both the generative philosophy of Gilles Deleuze and the generative science of CMS. The former has received far more attention (e.g., Shults, 2020, 2014), and so in this context I focus more on the role of the latter in DeLanda’s work. His first book, War in the Age of Intelligent Machines (DeLanda, 1991), which explicitly adopted and adapted language from Deleuze and Guattari’s *A Thousand Plateaus* (1988), also explicitly explored the relevance of developments in CMS for social science. Over the years that followed, DeLanda often returned to the potential epistemological implications of the capacity of computational techniques to create “virtual environments” that could be experimentally explored and analyzed in ways that shed light on the mechanisms by which new synergistic properties of social systems can emerge from the bottom-up interactions of their agents (DeLanda 1995, 1998). Even his books that are explicitly about “assemblage theory” (DeLanda, 2006, 2016) occasionally allude to mathematical state spaces and computer modeling techniques, although the extent to which the latter inform his approach is not as obvious as it becomes in *Philosophy and Simulation* (2011).

In an earlier book on Deleuze, DeLanda had outlined the metaphysical naturalism or “materialism” more or less explicitly articulated in the former’s theory of assemblages (DeLanda, 2002). But how exactly is this related to emergence and what exactly does CMS contribute to this discussion? To frame our answer to these questions, it may be helpful to begin with the debates between proponents of “weak” and “strong” emergence. Advocates of the former typically interpret higher-level emergent properties in a complex system as the result of the organization of causes among (or, equivalently, the form of) their lower-level components. Advocates of the latter who reject supervenience (the claim that there are no differences in emergent properties without matching differences in the organization of lower-level components) make metaphysical room for entities and causal forces that are qualitatively different from and transcendent to the natural world studied within the sciences (Wildman and Shults, 2018). The popularity of this quasi-theological “strong” view of emergence in the 20th century led many social scientists to resist the concept itself and focus instead on reductive explanations.

Today, however, the view that dynamic and immanent interactions within a population can lead to the emergence of new complex wholes (which DeLanda calls “assemblages”) appears to be ascendant. As DeLanda argues in *Philosophy and Simulation*,

Simulations are partly responsible for the restoration of the legitimacy of the concept of emergence because they can stage interactions between virtual entities from which properties, tendencies, and capacities actually emerge. Since this emergence is reproducible in many computers it can be probed and studied by different scientists as if it were a laboratory phenomenon. In other words, simulations can play the role of laboratory experiments in the study of emergence complementing the role of mathematics in deciphering the structure of possibility spaces. And philosophy can be the mechanism through which these insights can be synthesized into an emergent materialist world view that finally does justice to the creative powers of matter and energy (DeLanda 2011, p. 6, emphases added).

Because “virtual” structured possibility spaces are mechanism-independent, topological facts about them (such as attractor spaces that constitute and constrain their tendencies and capacities) can be discovered by studying the nature and number of their degrees of freedom without reference to any “actual” material-
emanate a wide range of states (such as cellular automata, neural nets, and multi-agent modeling) in “virtual worlds.” Below, I will discuss some examples of computational models that are particularly relevant for making progress in simulating human geography. At this stage, however, I want to briefly illustrate the intimate link between DeLanda’s fascination with CMS and the three main tenets of his version of assemblage theory. The latter can be reconstructed in the following way:

- Every assemblage is an individual singularity whose properties are the product of a historical process.
- Every assemblage is actualized in relation to a universal singularity whose real, mechanism-independent, structured possibility space defines the capacities and tendencies of the assemblage.
- Every assemblage is part of a population with distributed variables whose alteration is conditioned by parameters such as (de)territorialization and (de)coding.

What does it mean to say that an assemblage is an individual singularity? This is DeLanda’s way of insisting that an assemblage is “always contingent and not guaranteed by the existence of a necessary set of properties constituting an unchanging essence.” On the contrary, assemblages must be understood as the emergent outcomes of historical processes that produce “unique and singular individuals” (2011, 185). For example, the temperature or density of any assemblage of water molecules is an emergent property of that particular, historically formed individual singularity. The same hold for properties such as the solidarity or legitimacy of an assemblage of persons. We do not need “essences” (such as human nature or a discrete political state) to make sense of either the properties of a social assemblage nor the social assemblage itself. All individual singularities are “irreducible and nondecomposable wholes” and can be explained by “elucidating the mechanisms that produce them at one scale and by showing that emergent entities at that scale can become the component parts of a whole at a larger scale” (2011, 12).

The concept of a universal singularity may initially sound more difficult, but DeLanda is actually referring to a reality that is well understood within the field of CMS: a mechanism-independent, structured possibility space in relation to which every individual singularity is actualized. One can think here of the “state space” of a computational model within which individual simulation runs are (dynamically, historically, and uniquely) executed. While the first tenet above focuses on the properties of an emergent assemblage, the second tenet introduces the concepts of capacities and tendencies. To use DeLanda’s favorite example, a triangular knife blade may have emergent properties (such as sharpness) that the molecules that
compose it do not have. It always has this property as long as its combined metallic atoms are appropriately shaped. However, the knife may also have emergent capacities that are never exercised (e.g., to cut a particular rutabaga) and emergent tendencies that are never manifested (e.g., to melt at a critical temperature). Properties are always actualized while capacities and tendencies may not be. What is the ontological status of these latter two qualities? DeLanda argues that we should think of unexercised capacities and unmanifested tendencies as defining “a concrete space of possibilities with a definite structure” (2011, 17). The possibilities that are opened up to an individual singularity at any given time “are constrained by a distribution of universal singularities, the diagram of the assemblage, which is not actual but virtual” (DeLanda 2006, 40).

The third main tenet of assemblage theory identified above helps to make the value of CMS methodologies for disciplines such as human geography even more explicit. DeLanda argues that “population thinking” enables us to account for the similarities between some assemblages (e.g., the resemblance of members of a species or the isomorphism of political systems) in a way that avoids the need for appeals to transcendent essences or generic categories. Every assemblage is a unique individual singularity but still belongs to a population of assemblages that are more or less similar. This is because processes that lead to assemblages tend to be recurrent, and this “recurrence itself is explained by the fact that the assembly process is governed by universal singularities,” the actualization of which “is always subject to contingent events so what is generated is a population in which variants are distributed in a certain way” (2011, 186; emphases added). Social or human simulation may include “variables” such as individual psychological tendencies or institutional political capacities (Diallo et al., 2019). How can we make sense both of the way in which the members of any population change and of the status of their identity at any given stage of their productive historical process? DeLanda’s answer to this question is to parametrize the concept of assemblage. In the context of CMS methodologies, a “parameter” can specify environmental factors (e.g., demographic density, resource scarcity) that impact the interactions of agents within a complex system. Simulation experiments can then explore the behavior of that system as the relevant parameters are varied.

The value of this philosophically informed use of computational modeling for social scientists interested in applying assemblage theory to analyses of real-world societal challenges should be increasingly clear. In the next section, I introduce and illustrate a particular approach to modeling and simulation that I believe shows particularly strong promise for studying human-geographic systems.

3. Emergent social assemblages in multi-agent artificial intelligence modeling

As noted in the Introduction, several human geographers have already taken advantage of CMS methodologies, especially ABM, in order to analyze the interactions among the heterogeneous parts of the complex human-geographical systems they study. However, the potential fecundity of the link between such approaches and assemblage theory has not yet received significant attention. In the final chapter of Philosophy and Simulation, DeLanda discusses ways in which multi-agent modeling can provide a distinctive way of illuminating the actual mechanisms that generate the emergent properties of social assemblages, such as status and legitimacy. He also explains how they can illuminate the parametric conditions under which the manifestation of their tendencies and the exercise of their capacities (as defined by their structured possibility spaces) are most likely to occur. For example, “rigid social stratification” emerges from the interaction of increased material and status gradients in complex chiefdoms (DeLanda, 2011, 172). Along with this new property comes new capacities and tendencies, such as those related to supernatural beliefs and incest taboos. In 2011, agent architectures that incorporated beliefs, desires, and intentions were in relatively early stages of development, as were techniques for exploring the structured possibility spaces of artificial societies.

A lot has happened in CMS during the decade since DeLanda’s book was published. Of particular relevance for human geography and related disciplines is the development of a method sometimes referred to as multi-agent artificial intelligence...
(MAAI) modeling, which strives to develop simulated agents and virtual worlds that are more cognitively and culturally realistic than traditional ABMs (Diazzo et al., 2019; Gore et al., 2018; Lane, 2013; Lane and Shults, 2020; Shults et al., 2020). Unlike most traditional AI technologies such as machine learning, multi-agent AI simulates artificial societies populated with heterogeneous agents within realistic social networks and parametrized environments. Unlike most game theoretic approaches such as prisoner’s dilemma models, the computational architectures in MAAI typically involve adaptive agents characterized by bounded reasoning whose behaviors and interactions occur within differentiated social networks (informed by disciplines such as evolutionary biology, social psychology, and political sociology). When appropriately calibrated, verified, and validated such models can shed light on the conditions under which—and the mechanisms by which—the variables that compose complex adaptive socio-material systems can be altered. This approach moves beyond correlational observations, providing plausibility to claims about causality in human-geographic systems by “growing” the macro-level structural patterns of interest from the micro-level behaviors and meso-level interactions of simulated agents.

In the remainder of this section, I provide a brief case study meant to illustrate some of the ways in which MAAI can be especially useful for human geographers interested in assemblage theory. To exemplify the potential of CMS, we might have selected one of the models cited above in the Introduction, which were developed explicitly to address topics of relevance in human geography. Or, we might have highlighted the use of other computational techniques that have been used to simulate change within a wide variety of complex socio-material systems, addressing topics such as migration in the wake of climate change (Robinson et al., 2020), sustainability practices in concrete geographic areas (Pedercini et al., 2018), and policy scenarios in spatially-distributed systems (Polhill et al., 2019). However, none of these incorporate cognitively realistic and socially networked agents within a spatio-temporal environment in the same way that MAAI modeling does. The model described below was selected because of the way in which it illustrates the explanatory power of MAAI approaches and lends itself to explicating the three tenets of DeLanda’s version of assemblage theory (identified in bullet points in section 2).

The selected case study is a model of a human-geographic system that simulates the socio-material dynamics and effects of various environmental threats on the behaviors and interactions of agents within the spatio-temporal dimensions of a pluralistic artificial society (Shults et al., 2018b). This model simulated assemblages (or individual singularities) at a variety of scales, including “agents” with psychological, demographic, and religious variables, “ritual clusters” of ideologically similar agents, social “ingroups” tied to religious identity, and each of the distinctive virtual “societies” produced by 150,000 simulation experiments. Each of these assemblages is produced by a historical process (a simulation run) and is part of a population (of agents, clusters, groups, or societies) with distributed variables whose alteration is conditioned by parameters. In this case, parameters included initial levels of religiosity, levels of mortality salience, tolerance or “terror management,” and levels of contagion, social, predation, or natural hazards in the environment. The initial purpose of this model was to simulate the impact of mortality salience on religiosity within a population, but it has been extended to study other phenomena such as the mutual escalation of inter-group violence (Shults et al., 2018a).

The way in which the first and third tenets of assemblage theory (see bullet points above) can be implemented within an artificial society is relatively easy to understand. The second tenet is a bit trickier, but it is precisely DeLanda’a concept of universal singularities (in relation to which every assemblage is actualized) that holds the greatest potential for facilitating philosophical and empirical progress in simulating human geography. The key here is the way in which the real, structured possibility space of a universal singularity defines the capacities and tendencies of an assemblage (or individual singularity). Several scholars within the field have commented on DeLanda’s distinction between properties and capacities in the context of theorizing assemblages (Baker and McGuirk, 2017; Dovey and Ristic,
2017; Haarstad and Wanvik, 2017), but most seem to have missed his discussion of tendencies and failed to see the extent to which all of these are wrapped up within his enthusiasm for computer modeling. As noted above, Dittmer (2014) is an important exception, but even he does not explicitly spell out the way in which DeLanda’s version of assemblage theory is significantly shaped by his engagement with CMS methodologies.

As DeLanda points out, the mathematical analysis of state spaces is typically sufficient to study the tendencies of a system, but capacities are more complicated because they involve a much larger set of possibilities. Because assemblages can exercise their capacities in interaction with a potentially innumerable variety of other assemblages, it is more difficult to study the nature of the universal singularities that structure the possibility spaces associated with capacities. However, “computers can supply the means to explore these other possibility spaces in a rigorous way because the interactions in which capacities are exercised can be staged in a simulation and varied in multiple ways until the singular features of the possibility space are made visible” (DeLanda, 2011, 21).

Because the component parts of the computational architecture are characterized by “relations of exteriority,” the programmed rules of interaction at a micro-level (e.g., agent attitudes and behaviors) can under the right conditions lead to the emergence of new macro-level wholes with qualities irreducible to the component parts. As DeLanda points out elsewhere, assemblage theory provides a way of detailing the “mechanisms of emergence” that link the micro and the macro without associating the latter with “two fixed levels of scale” but rather using these terms “to denote the concrete parts and the resulting emergent whole at any given spatial scale” (DeLanda, 2006, p. 32, emphasis in original).

Let us illustrate this by focusing on the emergence of the “ritual cluster” assemblages within the terror management model briefly introduced above. In the majority of simulation runs within that model, temporarily stable clusters emerged as anxious agents reacted over time to the hazards in their spatial environment and sought out religious in-group members with whom they could engage in anxiolytic ritual behaviors. These socio-material clusters had emergent properties, tendencies, and capacities not shared by the agents that composed them. For example, they had properties such as the average level of anxiety among ritually clustered agents, the tendency to dissolve when the average anxiety of its members reached a critical point, and the capacity to be affected by demographic distributions of agents representing majority and minority religious groups.

The simulation experiments revealed several features of the structured possibility space of the universal singularities that defined the relevant capacities and tendencies of the ritual clusters. For example, smaller ritual clusters were more likely to form when the population has relatively high heterogeneity, and when there are lower probabilities of natural hazards and higher average tolerance levels for out-group members (Shults et al., 2018b, 93). It is important to note that this model was constructed with subject matter experts in the relevant disciplines, who argued about (and specified) the assumptions underlying the cognitive architectures, the social dynamics, and the environmental threats within the simulated social geographical system, all of which are implemented within the code available in the supplemental materials published with the original paper. The model was also face validated by comparing the simulation results to real-world dynamics, including the emergence (and eventual decline) of religious ritual engagement in the wake of the 2011 Christchurch earthquake in New Zealand, and the emergence of macro-level demographic patterns that characterize religious minority and religious conservative groups in the U.S.A. from the micro-level behaviors and interactions of the agents in the model. The theoretical and empirical literature informing the operationalization of key concepts in this model are described elsewhere (Shults, 2015, 2018).

To reiterate, socio-material assemblages such as the “ritual clusters” in the terror management model are individual singularities with new emergent properties, tendencies, and capacities, that interact within simulated space and time. Each simulation run produces “historically” contingent populations of agents (or assemblages with agents as component parts) with distributed variables whose alteration leads to increased (or decreased) anxiety and religiosity spread in the artificial society under different parametric conditions. Each simulation run explores
the universal singularities within the model’s possibility state space. The construction of such models enables human geographers, as well as policy professionals and other stakeholders, to perform simulation experiments to test their hypotheses about the conditions under which—and the mechanisms by which—assemblages stabilize and change.

II Conclusion

I conclude with a brief discussion of the ethical and political relevance of these developments. Human geographers regularly analyze the moral assumptions and implications of the application of assemblage theory within the field (e.g., Burrai et al., 2017; Kinkaid, 2019; Pow, 2014; Rankin, 2008). While some highlight the promise of assemblage thinking for “analyzing and intervening in the emergent politics of socio-material-affective assemblages” (Ghoddousi and Page, 2020, p. 22), others worry that overly simplistic investment in “assemblage-as-ethos” can all too easily have politically regressive effects (Kinkaid, 2020b, p. 481). Given the relevance of the theoretical and empirical efforts of human geographers and the practical concerns of politicians and public policy professionals, it is no surprise that the appropriation of assemblage theory in the former has fueled debates about its potential impact on the latter. Many scholars in the field have addressed ways in which assemblage theory can illuminate the ethical issues—and inform inclusive conversations—around such debates (Briassoulis, 2017; Dalton, 2019; Forney et al., 2018; Gorur, 2011; Palmer and Owens, 2015). Others have explicitly explored the ethics and politics of assemblage thinking within a variety of domains (Anderson et al., 2012b; Greenhough, 2012; Ruddick, 2012).

However, treatments of more abstract questions related to the conditions and criteria for understanding the nature of (and relation between) “the good” and “the right” are less common. Progress in the practice of computer modeling and social simulation has implications for this sort of metaethical issue that ought to be of interest for human geographers and other assemblage theorists (Shults and Wildman, 2019). The successful development and deployment of MAAI (and other) modeling techniques open up new ways of linking policy-oriented moral deliberations in human geography to resources in Deleuze’s philosophical reflections on ethics and politics. That is to say, the ability of computational techniques to elicit the emergence and analyze the alteration of divergent cultural norms within the “flat ontology” of an artificial society provides a point of contact with Deleuze’s philosophical efforts to articulate the conditions for an ethics of pure immanence (2004). There is no space here to unpack Deleuze’s Stoic-inspired ethics (see Shults, 2014, for details). The main point for our current purposes is that CMS approaches can construct and explore wholly immanent socio-material “state spaces” within which we can discover topological facts about the ethical and political capacities and tendencies of networked agents with heterogeneous norms under a diversity of parameterized conditions (Diallo et al., 2020; Shults and Wildman, 2020a). Such tools could make it possible for human geographers to design and execute simulation experiments that tease out the propensities and probabilities of various ethical and political behaviors and interactions in the complex systems whose immanent dynamics they study.

The use of CMS tools could also contribute to debates within critical geography about the political exclusion of feminist and other relational approaches to (and within) digital-social-spatial assemblages (Elwood, 2020) or about hegemonic forces within epistemic geographies of climate change (Mahony and Hulme, 2018). How? Participatory and collaborative methods in the simulation of human-geographic assemblages help to surface ethical presuppositions driving the construction of models and the design of simulation experiments (Shults and Wildman, 2020b). The co-production of MAAI models in transdisciplinary teams of social scientists, computer modelers, and policy stakeholders provides conceptual scaffolding and experimental tools that make it easier for everyone involved to see and critique one another’s ethical assumptions and to explore the political implications of alternative proposals.

These methodologies also have implications for ongoing discussions about “digital geographies” or “virtual geographies.” One popular way of categorizing ways of relating geography and the digital distinguishes between “geographies produced through, produced by, and of the digital” (Ash et al., 2018, p. 27). To this threefold schema, we can add geographies produced in...
the digital. Computational models of the sort described in section 3 produce human-geographic assemblages in artificial societies. These virtual worlds are susceptible to experimentation in ways that would be impossible or unethical in the real world. Such techniques open up new possibilities for fostering wider discussions about the ethical (and ontological) assumptions at work in theorizing assemblages in human geography and other social sciences.

The development of new models of the sort described above is one way of facilitating progress in human geography. Like all methodologies, CMS has its limitations and its use in the simulation of human-geographic systems faces real challenges, including the difficulty of forming the sort of transdisciplinary teams that are usually required for producing such models and finding data for calibrating and validating them (Diallo et al., 2019). However, this approach also offers unique opportunities. It provides human geographers with tools for synthesizing insights across disciplines and analyzing socio-material assemblages in ways that render their efforts even more relevant for public discourse and policy evaluation. It also creates new opportunities for interdisciplinary exploration of the methodological implications of assemblage theory across a wide variety of social sciences (Shults, 2020).

This article has highlighted connections between Manuel DeLanda’s version of assemblage theory and recent advances in CMS, especially in the practice of MAAI modeling. I have argued that more careful attention to these connections will facilitate progress in simulating human-geographic systems in ways that can enhance the philosophical grounding of the relevant fields as well as their capacity to produce policy-oriented scientific insights. DeLanda has suggested that “[p]erhaps one day virtual environments will become the tools we need to track the machinic phylum in search of a better destiny for humanity” (1998, p. 100). The use of social simulation tools such as MAAI to address societal challenges is still relatively new. Nevertheless, their initial deployment has been successful enough to warrant further research to extend and improve their capacity for understanding, explaining, and forecasting changes in the complex human-geographic systems in which we find ourselves striving to adapt.

Declaration of conflicting interests
The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding
The author(s) received no financial support for the research, authorship, and/or publication of this article.

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Supplementary Material
Supplementary material for this article is available online.

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