

Perspective

# Digital Determinism in Popular Culture and Beyond: Motor Variability and Emergence as Sources of Chaos That Constrain Algorithmic Control

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## Abstract

Concerns about digital determinism loom large in popular culture, where advanced predictive systems are frequently portrayed as capable of forecasting, shaping, and controlling individual and societal futures. From *Foundation* and *Minority Report* to *Black Mirror* and *Westworld*, the assumption that human trajectories can be reduced to data points and scores has become a recurring cultural narrative. Similar concerns have recently gained momentum in the academic literature on artificial intelligence in education, employment, healthcare, and talent identification, where algorithmic systems are increasingly used to evaluate individuals, predict future performance, and allocate opportunities. While such systems may influence developmental pathways and create self-fulfilling loops through early classification and differential access to resources, the assumption that human behavior and societal trajectories can be predicted and controlled with sufficient precision remains open to challenge. This perspective article examines whether contemporary visions of digital determinism are compatible with complexity science by drawing upon motor variability, an inherent source of randomness in human movement, and emergence, whereby interactions among individuals give rise to unpredictable system-level properties that cannot be reduced to the behavior of individual agents. We argue that these inherent properties impose fundamental constraints on algorithmic prediction and control. At the same time, we emphasize that algorithms in educational, occupational, and healthcare systems may substantially shape developmental trajectories and life opportunities insofar as individuals and institutions choose to delegate such power to them.

**Keywords:** digital determinism; algorithmic control; motor variability; complexity; emergence



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## 1. Introduction

*“This means that again some Number has impeded the smooth running of the great State machine. Again something that was not foreseen, or forecalculated, happened.”*

—Yevgeny Zamyatin, *We*

*Determinism* generally refers to the view that every event is determined by the combination of prior conditions and the laws governing the system, such that a complete specification of the present state uniquely determines all future states [1,2]. Historically, this idea is exemplified by Laplace’s [3] thought experiment of an all-knowing intelligence (i.e., *Laplace’s Demon*) capable of predicting the entire future of the universe from perfect

knowledge of its present condition. Although the philosophical concept of determinism has been the subject of extensive debate [4], the present article focuses on a more specific contemporary manifestation—*digital determinism*. We use this term to describe the extension of technological determinism to the era of big data and algorithmic decision-making, where data-driven tools and algorithmic systems increasingly determine or overwhelmingly shape human behavior, organizational processes, and social outcomes, leaving less room for human agency, contextual factors, and uncertainty [5,6].

In this vein, the notion that human lives can be quantified, predicted, and ultimately controlled through data and computational infrastructure has become a recurring theme in contemporary culture [7]. Long before the arrival of modern artificial intelligence (AI), science fiction explored the possibility that technologically advanced systems could govern human behavior and direct the course of society. Yevgeny Zamyatin's *We* [8] envisioned a society in which citizens are reduced to numerical identities and subjected to complete rationalization and state control. Aldous Huxley's *Brave New World* [9] portrayed a technologically engineered society in which biological manipulation, psychological conditioning, and predetermined social roles dictate individual destinies. George Orwell's *Nineteen Eighty-Four* [10] depicted a totalitarian regime that maintains power through pervasive surveillance, information manipulation, and the regulation of thought.

Building directly on the idea of predictive control, Isaac Asimov's *Foundation* [11] introduced *psychohistory*, a mathematical framework designed to predict the trajectory of entire civilizations. Philip K. Dick's *Minority Report* [12] envisioned a society in which future actions could be anticipated before they occurred. While there have been limited attempts to challenge such deterministic visions on the grounds of emergence and the nonlinear dynamics of complex systems [13,14], they continue to provoke debate in both popular culture and scientific discourse [15].

More recently, *Black Mirror* sci-fi series repeatedly portrayed algorithms that influence social status, personal relationships, and life opportunities. Similarly, *Westworld* depicts a society governed by a superintelligent system that constructs predictive profiles of individuals and directs their educational, occupational, and social trajectories. Directly invoking the idea of *Laplace's Demon*, *Devs* sci-fi series portrayed a quantum computer capable of reconstructing the past and predicting future human actions with extraordinary precision, thereby challenging conventional notions of human agency and free will.

This recurring narrative of digital determinism has moved beyond fiction and entered contemporary academic discourse surrounding big-data analytics and AI in education, employment, and healthcare. In educational settings, predictive models are increasingly used to estimate academic success, dropout risk, and future achievement, potentially influencing access to scholarships, advanced programs, and other developmental opportunities [16]. In employment, algorithmic screening tools are used to evaluate job applicants and identify candidates deemed most likely to succeed, while in healthcare, predictive systems inform decisions regarding risk assessment, resource allocation, and access to treatment [17,18]. Although these machine learning (ML) tools are typically presented as objective due to their data-driven evaluations, they often learn from historical trends that reflect prior inequalities and institutional practices. As a result, algorithmic classifications may become self-reinforcing when individuals assigned lower scores receive fewer opportunities, resources, or interventions, thereby increasing the likelihood that the original prediction will be confirmed.

Similar concerns have emerged in sport, where ML is increasingly used to evaluate and rank young athletes based on performance, physical, and behavioral indicators. Although often presented as objective tools for detecting athletic potential, these systems remain sensitive to transient developmental advantages and contextual factors that may be only loosely

related to long-term ability, including differences in biological maturation and uneven prior exposure to skill-enriching environments [19]. Nevertheless, their assessments may heavily influence selection and developmental decisions as athletes assigned higher ratings are more likely to gain access to elite coaching, training environments, and competitive opportunities, whereas those assigned lower ratings may be deselected and receive less support for development. Consequently, assessments may become self-fulfilling loops, not because they accurately identify athletic potential, but because they help shape the conditions under which success becomes possible [6]. More broadly, the concern across domains is that classifications established early in life may exert a lasting influence before individuals' abilities, preferences, or potential have fully emerged.

Those risks extend beyond education and talent identification as algorithmic systems may shape behavior by controlling the collection, integration, and dissemination of information about individuals. Since an increasingly diverse aspects of human activity are aggregated into unified reputational profiles, these combined scores may shape decisions regarding loans, insurance coverage, healthcare provision, and criminal justice outcomes, including sentencing and parole [20]. Their influence may be further amplified when evaluations incorporate information about individuals' social networks and affiliations, making people accountable not only for their own actions but also for the behavior and reputations of those with whom they interact. Under such conditions, algorithmic systems function not merely as predictive tools but as mechanisms of social coordination and behavioral governance, shaping incentives, reputational standing, and access to opportunities through the aggregation and control of information [21].

A paradox becomes apparent when the prospect of digital determinism is confronted with *complexity* and *chaos* theory. On the one hand, *motor variability*, *complex systems dynamics*, and *emergence* impose fundamental constraints on the ability to predict individual and collective futures with sufficient accuracy. On the other hand, algorithmic systems may still exert considerable influence over those futures by shaping decisions, opportunities, and the allocation of resources. As a result, it seems that algorithms grow and spread to determine the very outcomes they are otherwise unable to foresee.

This perspective article examines whether the strong deterministic assumption that human and societal futures can be predicted and controlled is compatible with complexity science. The following sections discuss motor variability and emergence as two fundamental sources of uncertainty in living and social systems and consider their implications for digital determinism and governance.

## 2. Motor Variability

Regardless of how experienced, motivated, and well-trained we may be, every time we aim at replicating an action in an identical manner, a certain degree of variation in our motor performance will occur. For many tasks, improving performance implies reducing the variability of our actions. Yet, much to our frustration, repeated attempts to execute identical movements in sport and daily tasks are virtually impossible [22].

To illustrate this problem, consider the free-throw shooting in basketball, which is classified as a fine motor task that is performed in a stable, predictable, and unopposed environment. Since 1954, the distance to the backboard, the height of the basket, and the diameter of the rim have remained unchanged in the National Basketball Association (NBA) [23]. It would therefore be reasonable to assume that in such a setting, improvements would be observed over time, due to higher incentives, increased participation, improved selection, and enhanced training regimes. Yet, analysis of more than 2.6 million free-throw shots during 1969–2019 reveals that the free throw shooting accuracy fluctuated at about 75%, without any steady trend of improvement [24]. An additional intriguing observation

is that across five decades, among thousands of NBA players, only 57 players achieved a career free-throw percentage of more than 85%, with only four exceptional players being able to (slightly) break the 90% barrier.

Though disadvantageous for executing sporting movements, which require accuracy and consistency across multiple repetitions, motor variability is, in general, viewed as an evolutionary advantageous attribute—one that fosters both exploration and learning [25], while enhancing task performance and distribution of physiological strain [26].

Motor variability stems from unpredictable fluctuations and disturbances at a single neuron synapse level, and is further magnified by the coordination of motor neurons and instabilities in the dynamics of neural networks [27]. Thus, motor variability (i.e., motor noise) could be considered the result of fundamental *chaos* within the nervous system [28], with the term chaos implying that small changes in the initial conditions of the elements are magnified, leading to unpredictable changes in the subsequent behavior of the system. From a complexity perspective, this uncertainty is not expected to dissipate at higher levels of biological and social organization. Rather, according to the growing complexity “Matryoshka” principle [29], complex systems are organized as nested hierarchies in which each successive level incorporates the complexity of the levels below while simultaneously giving rise to new interactions and emergent properties. Consequently, uncertainty originating from neuronal machinery may propagate through motor behavior to interpersonal interactions and, ultimately, to the dynamics of larger social systems.

One important notion to consider is that while it may indeed be convenient to detect motor variability in sport, where vast quantities of data regarding observable and measurable actions are available for analysis, motor variability permeates our every action, infusing unpredictable and uncontrollable randomness into even the simplest routine tasks [30]. Driving a car or typing on a cell phone, for example, are susceptible to slight motor fluctuations, that from time to time will inevitably cause unexpected and even undesirable outcomes (such as car incidents or typing errors).

Take for example the highly undesirable yet frequent occurrence of spilling coffee on our desk, keyboard, and documents—a major inconvenience that may extend beyond the affected physical space, affecting our mood and subsequent interactions with colleagues or family members. Spraining one’s ankle during a hike could potentially disrupt our daily routine for weeks to come, affecting our ability to commute, shop, and participate in recreational activities. Consequently, by leveraging the motor variability factor, we argue that it is practically impossible to assert hermetic control over who we interact with and how these interactions unfold. Recognizing even a small degree of unpredictability within our movements implies that some degree of randomness will always be present in the information that we receive and transmit. The impact of this inherent randomness on individuals, and on society as a whole, can be better grasped within the following framework of *emergence*.

### 3. Emergence

Interactions between a system’s different elements have been shown to prompt the emergence of unexpected properties, ones that the elements in isolation do not have. Such emergence is a ubiquitous feature in the world around us, with economies, businesses, ecosystems, and life in general serving as *complex systems* in which the interaction of elements give rise to unpredictable aggregated entities [31].

Emergent social properties are real, as they may have autonomous causal powers [32]. A newly emerged phenomenon can influence the behavior of individuals within a system, referred to as *downward causation*, and in turn, the behavior of the individuals may impact the development of the emergent phenomenon. This creates a chaotic feedback loop,

where emergent properties and individual behavior continuously influence and shape one another.

In chaotic systems (e.g., society), small variations at the component level may have a large impact on the system level [33]. Such variations include the individual's memories, preferences, and relationship networks, all of which can generate tensions, frictions, and perturbations within the system [34]. The inexorable conclusion is that emergent system properties can be neither predicted in full nor explained by a detailed description of the system's components and its initial movements [35].

Let us look at the following example: The conventional perception is that traffic congestion is triggered by an excessive number of vehicles on the road. In other words, with increasing traffic, vehicles affect the driving speed of other vehicles, causing them to slow down. The flow becomes unstable to a point of stop-and-go conditions, typical of traffic jams [36]. However, traffic congestion can often be seen regardless of rush hour, and even without any apparent reason, such as a car accident or roadworks. Indeed, it has been experimentally shown that a traffic-jam state can evolve spontaneously, caused by the enhancement of fluctuations in the multi-particle system, with neither an obstacle nor a bottleneck being an essential component for the formation of congestion [37].

Vehicle density is obviously associated with the emergence of congestion—whereby beneath a certain level of density, severe fluctuations at the element level (e.g., vehicle) will be easily absorbed by the system, with negligible impact on traffic flow. Yet, even in a dense traffic setting, without perturbations caused by interactions between drivers, traffic flow will remain stable. Allegedly isolated and controllable perturbations in traffic flow may include the slow overtaking of trucks, excessively fast reactions to speed changes, judgment errors due to inattentiveness, and queue-jumping. However, in some cases, through interactions, these initial perturbations unpredictably grow in amplitude, change their speed and direction of motion, and cause a serious disturbance in the traffic flow [38].

#### 4. From Motor Noise to Governance Constraints

Combining the motor variability mechanism, which prompts perturbations at the element level (e.g., the driver), with the emergence factor, that causes such perturbations to propagate and evolve at the system level (e.g., traffic), inevitably leads to the conclusion whereby systems that entail large-scale interactions of objects and human movements cannot be fully predicted and controlled. Algorithmic tools mostly operate not on neurons and muscles level but on quantified representations of human behavior and interactions among them. As a result, the uncertainty generated on the element level does not disappear once behavior is translated into data. Rather, it becomes embedded within the behavioral dynamics that algorithms seek to model, remaining an inherent feature of the adaptive systems on which algorithmic predictions are based.

Chaos theory demonstrates that small perturbations can amplify into large and unpredictable consequences through nonlinear dynamics. Complementing this perspective, Lebed's [29] growing complexity principle proposes that uncertainty is propagated across successive levels of biological and social behavior rather than being eliminated as system complexity increases. A further constraint on absolute (i.e., strong) digital determinism arises once algorithmic predictions themselves become incorporated into institutional decision-making. Rather than remaining external observations, they become additional elements within the adaptive social systems they seek to model, influencing—and being influenced by—the interactions among individuals, institutions, and social processes [39].

Consequently, the objects of algorithmic prediction remain adaptive rather than fixed. Individuals modify their behavior, institutions revise practices, and social interactions continuously reshape the conditions under which subsequent predictions are made. This

recursive feedback reflects the same emergent dynamics described above. Just as interactions among individuals generate system-level properties that cannot be reduced to the characteristics of individual agents, algorithmic classifications themselves become additional elements within these interactions [40]. Such dynamics suggest that algorithmic governance cannot be viewed as an exogenous determinant of social outcomes but rather as a participant in their ongoing co-creation through the evolving interactions of individuals, institutions, and culture.

## 5. Conclusions

While eluding the metaphysical discussion of determinism (see [4]), and the perennial question of free will (see [41,42]), this article explored the tension between contemporary visions of strong digital determinism and premises of chaos theory, motor variability, and emergence. While increasingly sophisticated algorithmic systems are often portrayed as capable of predicting, shaping, and controlling human futures, we argue that chaos, motor variability, and emergence collectively impose important constraints on deterministic claims. Taken together these constructs challenge the assumption that future individual and collective outcomes can be predicted with the degree of accuracy required for strong forms of digital determinism.

At the same time, the inability of algorithmic systems to reliably foresee future outcomes does not necessarily limit their capacity to influence them. Through their growing role in classification, selection, reputational assessment, and the allocation of opportunities and resources, algorithms increasingly shape the conditions under which future outcomes unfold. A paradox therefore arises: systems whose predictive capacities are fundamentally constrained may nevertheless exert substantial influence over the very futures they cannot accurately predict.

As notions of digital dystopia and algorithmic control over our lives gain momentum [6,19,20] and in popular culture humans are often being portrayed as merely reacting to exogenously dictated reality, we build on the constructs of motor variability and emergence to argue that individuals not only react to predetermined reality but knowingly and unknowingly shape and co-create it. In this light, human agency remains relevant not despite uncertainty, but because of it. If individual actions can generate perturbations that propagate through social systems in unpredictable ways, then people cannot be reduced to passive recipients of algorithmically determined futures. Rather, they remain active participants in shaping the environments, institutions, and collective outcomes of which they are a part. For this reason, responsible citizenship and ethical judgment will continue to play a central role in shaping social outcomes. While AI-based predictive systems may provide valuable insights and support decision-making, their outputs should be interpreted as probabilistic estimates rather than deterministic forecasts. Accordingly, their use should remain transparent, accountable, and subject to informed human judgment, especially in contexts where they influence decisions with lasting consequences.

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