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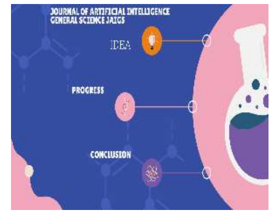

Role of Artificial Intelligence and Big Data in Sustainable Entrepreneurship

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ABSTRACT

There is a pressing necessity to shift our economy, society, and culture to systems and actions that promote ecological sustainability. This radical transformation necessitates an equally radical transformation of resource utilization and decision-making strategies. Sustainable entrepreneurship (SE) is frequently touted as the solution to the triple-bottom-line challenges that businesses encounter; however, there are tangible constraints on its potential. SE is currently in the first phase of implementing technological frontier tools that provide empirical guidance throughout the entrepreneurial decision-making process. The potential for artificial intelligence (AI) to inform decision-making is advanced by Big Data (BD), which also establishes pathways to attain desired outcomes. The interactions between AI, BD, and SE have been generally under-studied thus far. The absence of work that consolidates and synthesizes this literature is the primary focus of this conceptual paper. We propose that AI and BD are capable of rapidly contributing to the continued sustainable development of the weak form, but they also hold significant potential for attaining the strong sustainability ideal. We present two proposals for the integration of AI and BD to inform and facilitate SE. Finally, we outline potential areas for future research.

The core of human cosmology and ethics has always been the definition of his uniqueness. He ceased to be the species situated at the center of the universe, accompanied by the sun and stars, with the arrival of Copernicus and Galileo. He ceased to be the species that was created and specially endowed by God with soul and reason with the arrival of Darwin. With Freud, he ceased to be the species whose behavior could potentially be regulated by the rational mind. He has ceased to be the species that is uniquely capable of complex, intelligent manipulation of his environment as we begin to produce mechanisms that think and learn.

Introduction

Scientific data and empirical observations on anthropogenic changes to our environment have sounded an increasingly urgent alarm about the need to transition to sustainable systems and practices if life on Earth is to continue for the past 50 years (e.g., Berger et al., 2017; Carson, 1962; Dean & McMullen, 2007; Meadows et al., 1972; WCED, 1987). Daily news reports provide evidence of environmental degradation, pollution, and climate change in addition to scientific publications and data. It may appear that we inhabit a planet that is approaching—if not exceeding—its carrying capacity, given that the global population will exceed eight billion individuals in 2022. "Business as usual is not an option for a sustainable future," assert.

An approach known as Sustainable Entrepreneurship (SE) has been implemented by certain enterprises and ventures to transcend the confines of business-as-usual (BAU) and address resource depletion and externalities. SE's objective is to achieve financial benefits through the creative disruption of entrepreneurship, while simultaneously addressing other objectives of social and environmental sustainability (Schaefer et al., 2015). Nevertheless, SE continues to operate within the constraints of the current market failures, which include incomplete/asymmetric information and a variety of externalities, despite its positive intentions. These constraints are embedded within a context of persistent and increasing uncertainty. One of the challenges is that the process of determining a sustainable course necessitates confronting numerous crises that are occurring within a multifaceted system of systems.

An increasing number of publications on this subject, particularly within the past decade, has been indicative of the growing urgency for a transition to sustainability through entrepreneurship. For instance, (Moya-Clemente et al., 2021) conducted a comprehensive bibliometric analysis and reported that 78.6% of papers on the subject of Sustainable Entrepreneurship were published between 2015 and 2019. Nevertheless, it remains challenging to identify a straightforward definition of SE, despite the heightened awareness. This is the case with numerous intricate concepts or subjects, as the lack of unification can result in a conceptual labyrinth. Several domains of what is considered "alternative entrepreneurship," such as environmental, social, and ecological, have been incorporated into SE, further complicating the situation, (Moya-Clemente et al., 202). The most general formulation appears to be that SE is a business that is conducted in a manner that does not undermine the foundations necessary to sustain the business (e.g., Muñoz & Cohen, 2018; Schaefer et al., 2015) and also considers the future impact of conducting the business:

A sustainable business model should be employed to conduct sustainable entrepreneurship, which should not deplete resources but replenish them (e.g., natural resources, human resources, knowledge, and technology foundations). This model should also generate value and material and nonmaterial wealth (i.e., well-being and happiness) for all stakeholders through ethical and just conduct. The embrace of the principle that long-term environmental and social outcomes and impact are equally significant as short-term economic objectives is the foundation of sustainable entrepreneurship and any sustainable business model, (Gutterman, 2018, p. 39–40).

SE is becoming an increasingly prevalent trend, not only in traditional small start-ups but also in all types and dimensions of entrepreneurial endeavors, possibly due to the necessity and urgency of transitioning to sustainable systems. In this context, the term "entrepreneurial venture" is intended to refer to endeavors that are directed toward the creation and realization of entrepreneurial value, and are conducted by a wide variety of actors. This encompasses large corporate entities, government institutions, established Small and Medium-sized Enterprises (SMEs), individuals who are embarking on new ventures, and start-ups that are in the growth phase. The values and morale of entrepreneurs (at all levels) also drive innovation in a sustainable direction, while customers are increasingly demanding accountability from all organizations (Spence et al., 2011).

Simultaneously, the recent surge in the development of Artificial Intelligence (AI) and Big Data (BD)5 has created new opportunities and challenges that businesses and individuals can leverage. Consequently, it is equally important to acknowledge the transformative dynamics that have been introduced by recent accelerations in AI and BD as we advocate for an expanded discourse beyond traditional start-ups. Across a variety of fields and domains, including sustainable agriculture and environmental restoration, healthcare and biotechnology, transport and logistics, smarter cities, and urban planning, these technology stacks are reshaping the social and economic landscape and offering distinctive opportunities for sustainability-driven innovation.

Allen Newell, a pioneering father of the AI field, emphasized that "AI is the study of the mechanisms of intelligence and all supporting technologies" (Allen Newell, 1990 p. 40). Consequently, it is crucial to value the entire AI socio-technology ecosystem, or technology stack. AI is, in fact, supported by a variety of information and communication technologies (ICT), including networking components and communication devices, as well as other enabling (digital) technologies such as the global positioning service (GPS) and mobile technologies, distributed ledgers and computing, the Internet of Things (IoT), and remote sensing/earth observation, among others. Herbert proposed the term "complex information processing" (p. 939), which refers to the systematic generation, manipulation, and transformation of symbols. This convergence of data processing, algorithmic problem-solving, knowledge management, and decision-making is sophisticated. Marvin Minsky, Aaron Sloman, and other scholars (e.g., Bickley & Torgler, 2023; Minsky, 1988, 2000; Minsky et al., 2004; Singh et al., 2004; Sloman, 2000, 2001) contend that cognitive diversity is also necessary for strong AI or AGI (Artificial General Intelligence). This diversity refers to the existence of numerous models or methods of thinking and reasoning about the world and the agents within it. Additionally, their literature emphasizes the advantages of a structured approach (similar to that of Herbert Simon) in the design and development of cognitive circuitry and mechanisms, as well as the integration of procedural elements and contextual factors. Therefore, it is contended that the integration of AI and BD (albeit in distinct manners) is on the brink of enhancing productivity, reducing operational and capital costs, and reducing human error (Akerkar, 2019).

It is becoming increasingly evident that the impact and/or functionality of one technology are exacerbated by the presence of the other when AI and BD are present (i.e., they are interdependent, co-evolving, and/or complementary technologies). BD is the foundation of a significant portion of AI design and development, particularly the more contemporary approaches in machine learning (ML) and deep learning (DL), which are at the core of the most recent advancements in large language models (LLMs, such as GPT-4, Claude 2, and bard). This is intuitive. Nevertheless, the contemporary volume (size of data), velocity (speed of data generation and real-time processing), variety (data from various sources), and veracity (trustworthiness of data/data source) of BD (Laney, 2001; Normandeau, 2013) are frequently insurmountable without the use of modern AI approaches. In other words, the efficacy of the information search and retrieval process is a common reason why ML/DL approaches are frequently used to support numerous BD algorithms and processing pipelines. However, in spite of their similarities, AI and BD are distinct disciplines within the field of computer science, each with its own focus (ontology), knowledge management processes (epistemology), and methodologies for knowledge generation. In other words, the amalgamation of all AI and BD literature as a single entity will result in the loss of conceptual and/or empirical treasures and foundations. In other words, by regarding AI and BD as a conjunction or "AND" statement, rather than a disjunction or "OR" query, we are able to view them as distinct and interrelated fields/entities. Consequently, it is imperative to differentiate between artificial intelligence (AI) and biological design (BD), despite the fact that this symbiotic relationship is worthy of investigation.

Although this paper is conceptual in nature, it is the result of a comprehensive, interdisciplinary literature review. Given this context, it is evident that AI and BD can make a significant contribution to the objectives and pursuits of SE by making incremental modifications to BAU. Furthermore, we observe the potential for AI and BD to jointly establish a path toward strong sustainability (Roome, 2011) and sustainability as flourishing (Schaefer et al., 2015) by realizing early utopian visions (e.g., comprehensive anticipatory design (Fuller, 1971) on Spaceship Earth (Boulding, 1966, 1973). As a result, we investigate two propositions and numerous mechanisms that are associated with the potential for AI and BD to collaborate with SE, thereby enabling improved outcomes from the venture formation stage to a mature organization that delivers on stakeholder returns. Furthermore, we examine the primary obstacles that sustainable enterprises must surmount and the opportunities that can be capitalized on through contextual mapping discussions. These discussions will focus on the actions that decision-makers can take to prepare, position, and gain an advantage in an AI and BD future.

The technology is relatively new, which is likely the reason why there are not many papers on this specific intersection (AI, BD, and SE) at this time. Nevertheless, the analysis is consistent with the existing literature on twin transitions, which refers to the connections between sustainability transitions and digitalization. In general, the resolution of a fundamental conflict for humans, that of resource allocation, could be facilitated by instruments and breakthroughs at the frontier of technology. Books such as Silent Spring (Carson, 1962) and Limits to Development (Meadows et al., 1972) questioned the exploitation of resources and unlimited economic development over fifty years ago. The impossibility of meticulous economic calculation is called into question by the combination of AI and BD. This highlights the potential for a shift to more "social planning" that is based on actual human needs and behavior, as observed or expressed through mass (online) surveillance and instrumentation of the digital economy.

AI and BD can assist in the alignment of incentives that arise from the micro perspective of firms and the macro perspective of the ecosystem, as well as in the integration of (open) data and research from the business and ecological disciplines. The dysconnectivity between the natural environment, industries, and corporations is mitigated by this combination. Therefore, in order to establish a foundation for decisions that are to be made today rather than tomorrow, strategic planning necessitates an understanding of system behavior. In this environment, the ability to make decisions necessitates the management of intricate interrelations within a complex (adaptive) system. For instance, organizations may generate profits by decreasing greenhouse gas emissions within their supply chains (Plambeck, 2013). Nevertheless, sustainable strategies necessitate more than the predictive power to identify and predict supply and demand in order to optimize (or satisfy) the sourcing and design of more effective retailing and manufacturing strategies. To accomplish sustainable operations strategies, they also necessitate the reduction of carbon emissions, the prevention of the use of non-renewable resources, and the minimization of waste, remanufacturing, recycling, disposal, and incineration. Strong AI/BD systems have the potential to facilitate the transition to more robust sustainability measures and to pave the way for SE to actually achieve its objectives.

The current situation necessitates immediate action and innovation, as "the quantity and quality of remaining resources are diminishing as a result of the extensive consumption on a global scale". However, the processes or priorities that are essential for the transition are still being debated. The potential for the integration of AI and BD to deliver all types of sustainability is advanced by the recent simultaneous increase in data availability and digitalization of the physical world. For example, the evaluation and testing of beliefs and hunches, the provision of empirical guidance to every stage of decision-making, and the continuous comparison of inputs against the outcomes achieved. The incorporation of AI and BD can assist in the interpretation and monitoring of the environment, the identification of issues that require attention, the development of plans and strategies, the generation of decisions, and the execution of tactics.

Sustainable Entrepreneurship, Artificial Intelligence, and Big Data

Sustainable Entrepreneurship (SE)

Entrepreneurial activities in pursuit of opportunities should not degrade or act in detriment to the environments (social, economic, and ecological) in which they operate, according to the premise of SE. Ideally, they should contribute to the improvement of society and nature in general, and specifically to the attainment of Sustainable Development Goals (SDGs) (Muñoz & Cohen, 2018). SE consolidates and integrates concepts and methodologies from the research paradigms of social entrepreneurship, eco/environmental entrepreneurship, and institutional entrepreneurship under a shared umbrella. SE has evolved into an umbrella term for these forms of entrepreneurship; however, these are distinct aspects of SE. However, the diversity of thought and approaches could also be viewed as a component of a rich ecosystem from which we may yet observe beneficial emergent convergence, despite the fact that this umbrella-like gathering of concepts makes definitions difficult. For instance, Davies (2013) asserts (citing Dobson, 1996) that "over 300 definitions of sustainability" existed nearly three decades ago (p. 111). Social, ecological entrepreneurship has been incorporated into the definitions of SE, which refer to individual elements or aspects of the "diverse economies" (Gibson-Graham & Dombroski, 2020) as an alternative to strictly profit-driven extraction and exploitation.

In a competitive business environment, sustainable entrepreneurs develop new and superior products, services, techniques, and business models that are successful in the mainstream market and establish market dynamics (at the meso/macro level) of social, societal, and environmental progress (Muñoz & Cohen, 2018). Kalkanci et al. (2019) suggest that an "inclusive innovation" approach to the development of innovations in products/services, processes/business models, and supply-chain management can promote social sustainability in new projects and may be worth exploring in order to close the gap on alignment and collaboration between public (i.e., government and civil societies) and private-sector interests. In the context of the climate change movement, firms are under pressure to modify their practices, processes, and supply chains through internal (e.g., shareholders and employees) and external (e.g., customers, regulators, and legislators) sources. This pressure may have a ripple effect on related firms and industries. Nevertheless, the intricate interactions among networks of various actors in SE (e.g., competitors, suppliers, local government, civil society, and NGOs (Gibb & Adhikary, 2000)) necessitate novel system analysis methods that can more accurately capture the comprehensive picture. In other words, at the micro-, meso-, and macro-levels (Muñoz & Cohen, 2018).

The diverse contexts in which SE has developed emphasize these intricate interactions. The BAU approach frequently entails evaluating whether it is a sound business decision to incorporate social and ecological concerns. Although it may be considered a positive step to adopt more environmentally friendly or socially responsible actions in isolation, these actions are occasionally merely public relations antics or virtue signals and fail to address the systemic issues that are associated with ecological and social issues. A venture is not considered genuinely sustainable if it is only making minor modifications to one aspect of sustainability. Nevertheless, entrepreneurs who are cognizant of this issue can promote sustainable development from a grassroots perspective and assist in the transformation of the system's fundamental structures.

There are at least two routes into SE: traditional entrepreneurship with a sustainable component and sustainability activists who enter entrepreneurship with the intention of altering the system. The reaches of each path may result in various forms of sustainability.

Sustainability: Strong and Weak

The potential at the intersection of SE, AI, and BD can also be viewed in terms of strong and feeble sustainability. Even within this distinction, the definitions are subject to change or variability. One of the initial concepts in determining the distinction between natural and man-made capital is whether capital is substitutable. This formulation " directly applied the savings-investment rule from growth theory with exhaustible resources". It was predicated on the premise that various forms of capital are perfectly interchangeable. Consequently, if a nation exploits all of its natural resources and then allocates the revenue to education and the development of human capital, there would be no net loss.

Nevertheless, the distinction is now made in terms of the orientation of the system through which sustainability is pursued: is it the BAU paradigm or is there a fundamental re-orientation and transformation of the relationship between businesses and humans in relation to nature and society? As Roome (2011, p. 3) elucidates, "weak sustainability is characterized by incremental change, whereas strong sustainability is more radical in nature, establishing a new paradigm that is founded on systems thinking and organizational and social innovation."

The inherent paradox of our needs for ecological conservation or regeneration and our needs for extraction within a market-based economy is succinctly summarized by Torgler et al. (2010):

In order to ensure our own survival and that of future generations, it is imperative that a specific level of environmental quality be preserved. Simultaneously, we are reliant on the exploitation of natural resources from the environment to satisfy the "higher" aspirations of our species, including acquisition, status, comfort, and security, in addition to ensuring our survival. It is a well-known fact that the current activities undertaken in the pursuit of urbanization and development are having a significant and enduring impact on the ecological integrity and quality of the environment (p. 18).

It is possible to achieve weak sustainability by maintaining the business as usual (BAU) with a few minor modifications or by making piecemeal modifications. This method "aims to integrate environmental concerns into the framework established by the structures and systems of business" (Roome, 2011, p. 2). Rather than acting with the intention of guaranteeing the continued existence of future generations, the emphasis is on making incremental adjustments at the margins to "decrease unsustainability" (Schaefer et al., 2015, p. 395). Roome (2011, p. 1) contends that "weak sustainability is insufficient to facilitate the transition to a sustainable future."

In contrast, robust sustainability views business (and human) operations as integral components of the ecological system (Roome, 2011), aiming for transformational rather than incremental progress toward "an aspirational ideal future state" (Schaefer et al., 2015, p. 394). In contrast, robust sustainability endeavors to integrate the company into environmental or socio-ecological systems, ensuring that the production and consumption patterns to which the company contributes are within the planet's capacity to sustain (Roome, 2011, p. 2). This is referred to as "sustainability as flourishing" by Schaefer et al. (2015, p. 395).

Buckminster Fuller envisioned this type of technology-enabled, robust sustainability over 60 years ago, although he did not use the term "sustainability" at the time:

He was adamant that the world's citizens would exist in a manner that was beneficial to all, provided that there was an abundance of precise data regarding the distribution and utilization of global resources, as well as human skills and accumulated knowledge. Fuller's own investigations demonstrated that there was an abundance of nearly every resource if individuals were to utilize their minds for "comprehensive, anticipatory design" in order to "do more with less" (Baldwin, 1990, p. 30).

In fact, Fuller created a device known as the "World Game, an electronically instrumented globe that visitors could use to play the Game. This multiplayer computerized strategy game tasked players with creating scenarios for resource redistribution that would assist humanity in achieving symbiotic coexistence through global resource redistribution and economic optimization.

The World Game continues to be played today and has served as an inspiration for numerous simulation centers. As opposed to a multiplayer game that humans play against humans, we can now generate counterfactuals that are based on AI and BD in order to expand the investigation of the symbiotic relationship between economic mization and resource distribution.

Another visionary from the past century, Kenneth Boulding compared contemporary society's approach to the earth's resources to that of cowboys riding into an open frontier. He viewed the exploitation of resources and the disposal of pollution as exogenous and distinct from the income derived from those resources: "The cowboy economy typifies the frontier attitudes of recklessness and exploitation" (Boulding, 1973, p. 571).

Conversely, a "spaceman economy" (i.e., an economy in which one can observe the grand scheme of Spaceship Earth) regards resources as scarce. In other words, the reservoirs of materials and pollution are finite and cannot take input at an excessive rate while maintaining equilibrium. Then throughput is regarded as a resource that should be minimized rather than optimized (Boulding, 1973, p. 572)." The concept of the GNP (Gross National Income) will be rendered obsolete once the economy of spaceship earth is established, in which humans will maintain a state of equilibrium with their surroundings".

It is extraordinary that both Fuller and Boulding anticipated that once we could perceive the "big picture," we would cease to exploit or extract recklessly, and selfishness would dissipate. The potential to make the "big picture" accessible to all was recognized by these early visionaries; today, AI and BD possess this capability.

SE's promise and ambitions of genuinely sustainable entrepreneurship are realized through the integration of AI and BD, which effectively integrate land, labor, and capital in a manner that does not deplete any of the elements and, in fact, enhances the overall quality of life on spaceship Earth. This was the vision of robust sustainability prior to the existence of the term. The techno-optimism of the early visionaries was occasionally criticized; however, the convergence of AI and BD is bringing us closer to realizing this as a technological reality.

To achieve robust sustainability, one must transform one's values, develop the capacity to conceptualize intricate systems, alter one's outlook and perspective, and adopt a new approach to social justice and equity. This necessitates transformational change at numerous levels, including our perception of cooperation versus competition.

A real-time comprehensive anticipatory design science applied to Spaceship Earth may enable us to determine this balance within the planet's needs and boundaries and may move us closer (and more quickly) to that ideal than humans can on their own. Integrated AI/BD systems may facilitate a strong sustainability balancing of the needs of current and future generations.

Artificial intelligence (AI)

AI is broadly defined as "the investigation of the manner in which digital computers and algorithms solve intricate problems and perform tasks that would typically necessitate (or surpass) the intelligence, reasoning, and prediction power of humans to adjust to evolving circumstances" (Obschonka & Audretsch, 2020, p. 530). This is pertinent to organizations, as they frequently encounter difficulties in adapting to substantial systematic changes. This is due to the fact that established firms can be a reflection of the structure of their environment, as they have invested years of learning and fine-tuning within their current system.

The definition, scope, focus, and funding of AI research and development have undergone significant changes over time, as is the case with any field. Russell and Norvig (2010) have identified and categorized the four primary AI approaches as follows: the cognitive modeling approach (which involves the development of AI based on theories of the human mind, evidence from computer models/simulations, and experimental techniques from psychology), the laws of thought approach (also known as the logistic tradition), the Turing test approach (which involves the creation of AI that performs tasks that humans currently perform at a level that is indistinguishable or exceeds human-level performance), and the rational agent approach (which involves the development of AI that acts/optimizes to achieve the best possible outcome, based on the economic assumption of rationality).

Due to its generality, scalability, mathematical foundations, and readiness for real-world applications (and data), the acting rationally approach has been the dominant approach in AI research. Particularly, the fields of machine learning and deep learning have enabled humans to accomplish remarkable engineering feats. This is true in situations with significant uncertainties regarding current states, observations, and prospective predictions. The early success of knowledge and expert systems was unsuccessful due to the increasing costs of creating (e.g., to extract knowledge from humans effectively) and curating the knowledge base (e.g., software/hardware, utilities, and maintenance costs). In contrast, ML and DL methodologies enable AI to acquire knowledge directly from the data.

AI is a field that frequently addresses problems and duties that humans can solve and perform, but that computers have not yet been able to solve or perform. At times, these are tasks or problems that humans can easily complete (e.g., walking, common-sense reasoning), while at other times they necessitate a significant amount of human skill or effort (e.g., making informed diagnoses from medical imaging). Once AI can solve or perform well on these problems, they will essentially become a more conventional, mundane set of computer applications, presenting less of a challenge to cutting-edge AI researchers and developers in the future. As a result, the field of AI can be viewed as a perpetually changing target, with one aspect influenced by intuition and practice, while the other is propelled by theory and structure.

AI enables the utilization of intricate models that aid in the decision-making process by incorporating the firm and the economic environment/context. AI is, therefore, appropriate for strategizing and planning in both large and small organizations. While unsupervised machine learning models may enhance the exploration of new opportunities (i.e., by assigning AI a goal and mapping the potential paths to achieving that goal), supervised approaches may increase the exploitation of such opportunities (i.e., by maximizing on a pre-defined variable to capture the most value). Therefore, there is merit in transitioning from a single "best" AI method or algorithm to an approach that promotes various methods (e.g., cognitive architectures or ensembles) that are most appropriate for the task, problem, and data at hand.

“The essence of exploitation is the refinement and extension of existing competencies, technologies, and paradigms,” March (1991, p. 85) observed, treating the organization as the unit of analysis. Exploration is fundamentally about experimenting with novel alternatives. Nevertheless, each activity involves some degree of learning. The utility of recent ML developments in solving human problems is elucidated by the accumulation of experience, even in the performance of routine daily tasks, albeit incrementally.

This underscores the critical importance of hierarchical feedback structures in organizational settings (and in general, throughout daily life). For instance, an AI system at the individual level "might search and experiment to discover a new method of producing a product..." which may adopt a longer-term perspective. However, at the organizational level, the system "might then exploit this new innovation for profit" with a short- to medium-term perspective. This may allow the organization as a whole to derive more benefits from both approaches (i.e., "ambidexterity"20), especially when the outcome is as ill-defined and ambiguous as "ensure sustainable production."

Big Data (BD)

The discipline of BD is concerned with the contemporary issue of (and solutions to) the ever-increasing volume, velocity, variety, and veracity of data, as well as the increasingly personal, individual instrumentation and surveillance of our daily behaviors. "Big Data is a logical outcome of the significant role that digital technology has played in our lives, as the volume of data is increasing at an unprecedented rate." Nevertheless, BD's "paradigmatic" influences on science extend beyond the mere accumulation of large amounts of data. It undermines the traditional, rigorous control zones of science, necessitating a reevaluation of the procedural aspects of research. BD subsequently challenges the integrity of data collection, collation, curation, and provenance, as well as the credibility or trust we place in the science that deploys it.

The demand for innovative solutions to critical computational tasks, including data mining, storage, and administration, presents new challenges to academia, practitioners, and policymakers as the multidimensionality and scale of BD continue to expand. Technology does not exist in a vacuum, nor does any single digital technology exist in a vacuum, independent of other co-evolving established/foundational or emerging technologies. Rather, it is embedded within a complex system (economic, socio-political, natural) that naturally responds to the mechanisms and influence of technology. The literature has devoted significant attention to grey areas, including data privacy, protection (requirements and liability), and the regulatory environment (which is constantly evolving in anticipation and response to the increasing prevalence of BD) as additional significant barriers to the diffusion of BD (Niebel et al., 2019). Another challenging obstacle to surmount is developing and administering intangible resources, such as knowledge and human resources (skills, talent). This is especially true for small and medium-sized enterprises (SMEs), which are more constrained by resources (economic, social, and ICT).

BD has also garnered significant attention in the business literature. Niebel et al. (2019) propose that BD also interacts with the organizational innovation process itself, asserting that BD analytics is a pertinent determinant for the probability of a firm becoming a product innovator and for predicting the market success of product innovations. BD has also examined the correlation between entrepreneurship news coverage and regional entrepreneurial activity (von Bloh et al., 2019). The authors assert that news coverage catalyzes the development and creation of regional ventures, indicating that entrepreneurship does not operate in a vacuum; external influences can and will alter the environment.

The BD Value Chain is an emerging conceptualization that is an extension of/addition to the Data Value Chain. This perspective views BD as the collection of all BD activities, which AI could potentially assist in one, multiple, or all activities, as well as all of their interactions (similar to an ecosystem/complex systems approach). This is beneficial for comprehending the BD landscape and actors as a whole, as well as for identifying prospective areas for firm specialization/consulting and the functions that more generalist firms must develop. Additionally, delineate three primary applications of BD analytics in the business and management literature, which are undoubtedly pertinent to SE ventures: descriptive/diagnostic analyses (i.e., what potential patterns and trends are embedded in historical data that provide insights into cause-and-effect relationships and how can these be leveraged to enhance existing operations?), prediction (i.e., what event/behavior is most likely to occur in the future based on current and historical facts?), and prescription (i.e., what actions should we take and why?).

Combining AI and BD

AI and BD are in a symbiotic relationship, specifically a mutualism (i.e., a co-evolution or co-existence that is mutually beneficial). AI, particularly ML and DL, is significantly dependent on data availability, as larger specifications (in theory, more accurate to advance predictive power) typically necessitate larger sample sizes (i.e., more data). Additionally, BD is becoming more dependent on AI algorithms and systems, particularly ML and DL, to facilitate and expedite progress along critical stages of the BD Value Chain. Data is generated on a massive scale in the daily operations of businesses and in the lives of individuals. As a result of the widespread use of computers in economic transactions, the growth of Big Data is inevitable. Therefore, it is logical to contemplate them in conjunction (with the caveat that they are still distinct entities).

In this context, we will refer to the integration of AI and BD as Big Data Analytics and related Technologies (BDAT) from this point forward. Upon combining these two elements, it becomes evident that BDAT is somewhat similar to Herb Simon's (1995) concept of "complex information processing" (p. 939), as it echoes a similar integration of a variety of analytical components.

BDAT systems are pivotal in the pursuit of sustainable business practices. Their combined capabilities in predictive modeling, data management, and analysis present novel and innovative opportunities for identifying and implementing sustainable practices. These technologies facilitate developing innovative solutions consistent with SE's objectives, efficient resource management, and a more profound comprehension of intricate ecological issues. AI's predictive analytics can predict ecological impacts and identify sustainable alternatives, while BD's comprehensive data analysis can reveal patterns and insights that facilitate informed decision-making. This combination of entrepreneurship and technology improves organizational efficiency and directs businesses toward ecologically responsible and economically viable practices.

The integration of AI and BD within SE represents a technological advancement and a fundamental transition toward the potential for increased efficiency and optimization in business practices. These technologies allow businesses to optimize resource utilization, reduce waste, and expedite operations—all essential components of sustainable entrepreneurship. AI reduces the likelihood of human error and allocates human resources to more strategic, sustainability-oriented initiatives by automating routine tasks. BD's capacity to manage large volumes of data facilitates the creation of more precise, data-driven decisions, the reduction of superfluous expenditures, and the prioritization of resource-efficient strategies. BDAT collaborates to enable entrepreneurs to not only accomplish their business goals but also to pursue a socially responsible and ecologically sustainable path.

For instance, numerous organizations find it advantageous to implement BDAT-enabled methodologies for the examination of extensive, "open" social media datasets. In addition to altering how we share, retain, and present knowledge and information to others, online mediums such as social media enable individuals to connect and collaborate in novel ways. In their 2013 study, Kosinski et al. demonstrate that a variety of highly sensitive personal attributes, including sexual orientation, ethnicity, religious and political beliefs, personality traits, intelligence, happiness, use of addictive substances, parental separation, age, and gender, can be automatically and accurately predicted using easily accessible digital records of behavior (Facebook Likes). Such functions are applicable in the fields of advertising and marketing. Sentiment from text is increasingly employed in (socio)econometric quantitative analyses of individuals, groups, and society (Algaba et al., 2020; Andrejevic; 2011; Nowzohour & Stracca, 2020) This information can be utilized to segment consumer groups further.

BDAT can also be employed to advance SE in a similar manner. For instance, Obschonka et al. (2020) have employed BD derived from Twitter, Facebook, and LinkedIn to investigate the regionality of personality and its influence on entrepreneurial activities. It is a descriptive endeavor that is employed to map regional entrepreneurship partially. Management scholars have also investigated various aspects, including the role of prediction as an input to decision-making, as an instrument to generate high returns on investment, and as a method to comprehend the implications for business strategy (Agrawal et al., 2018). Nevertheless, there has been a lack of emphasis on how BDAT can assist companies and managers in the planning, measurement, site selection, forecasting, innovation, and development of products and services in a manner that is ecologically and/or socially sustainable.

Role of AI and BD in Sustainable Entrepreneurship

Organizations fulfill critical psychological and social requirements (Simon, 1977). Leadership must make urgent, concerted, and genuine efforts to establish organizational objectives and facilitate sustainable advancements in response to climate change. Simultaneously, the capacity and complexity of AI and BD tools and approaches are becoming more valuable in collecting, analyzing, and managing information to facilitate the understanding of intricate processes and inform decision-making. Although the use case for the weak form of sustainability (incremental adjustments to BAU) is immediately apparent and feasible, the AI and BD frontier offers genuine potential for the stronger form of sustainability (transformation).

The practice of entrepreneurship can be enhanced by the analogous transfer learning of theory, concepts, and methods used in AI and BD analytics, to obtain a more robust and design-focused science. For instance, (Zhang and Van Burg, 2019) propose design principles that are implemented during the development of genetic algorithms. The acquisition of intuition guided by a problem-solving style can be facilitated by advanced BDAT systems, which can influence managers' habits of attention. It has the potential to draw attention to issues and solutions that are less immediate or imperative, but that are sustainable in the long term. This sensitivity to the future has the potential to institutionalize attention and can enhance managerial intuition (Simon, 1987). Ultimately, the system's direction is determined by knowledge (Simon, 1977). Similarly, the literature and management practices that have endeavored to comprehend the unpredictable and persistent/persistent behaviors and decision-making of entrepreneurs have a wealth of information to contribute to developing more creative, insightful, and lasting impacts of BDAT by concentrating on the goals and objectives of sustainable entrepreneurs. This cross-fertilization of concepts can revitalize research programs that are either sluggish to progress, exhausted, or otherwise mature.

One of the problems with utilizing BDAT to balance out or determine the costs of externalities is that if we reduce costs and benefits to a single common denominator, it may (by default) be a monetary price, thereby commodifying nature and potentially leading to deleterious incentives. As Torgler et al. (2010) note, "economic efficiency is not a guarantee of other forms of efficiency or justice, and the outcomes may vary, despite the promise of market-based instruments" (p. 25). We can integrate alternative forms of efficiency and synthesize multiple stakeholder inputs with BDAT to achieve beneficial outcomes for other stakeholders that are not solely based on monetary or market values.

Carpenter et al. (2009) underscore the significance of concentrating on regulating ecosystem services, investigating the impact of drivers such as human feedback and biodiversity. For instance, Charles (2009, p. 807) posits that "the next significant force for behavioral change may be technology that brings consumers face-to-face with their energy consumption." This is because it not only allows users to comprehend the true impact of their actions and behaviors on the environment but also compares their consumption to that of others in their area or peer group, which contributes to the evolution of values and norms. This could also be implemented in knowledge systems through smart meters and continuous feedback to assist entrepreneurs in making minute-by-minute decisions regarding their bottom line in the context of ethical and sustainable supply chain management. For instance, Strandhagen et al. (2017) define Logistics 4.0 as the potential of this capacity for real-time information and insights, which could encourage the development of "new business models."

According to Moya-Clemente et al. (2021, p. 316), "a research problem was identified that has not been solved": "there is no index that measures sustainable entrepreneurship. This could be a very interesting line of research." BDAT is in an ideal position to assist in developing and providing such an index at the frontier of sustainable systems transformation. Industry-verified marks of approbation, or stop-light (green, yellow, red) indicators of sustainability for a wide range of products, from investment portfolios to packaged goods, may become more widely recognized and verifiable. The development of new metrics and indicators will allow organizations to monitor the progress of sustainability measures and strategy beyond current methods by utilizing novel combinations and recombinations of various data sources and nebulous, imprecise data query methods. Consequently, businesses are instrumental in the implementation of observational systems and the monitoring of performance.

One method of identifying individuals' revealed preferences in terms of increased sustainability performance, or a combination of ecosystem services, is to observe consumer choice with respect to companies. This is achieved through the effective maintenance of such flows and ecosystem services by institutions, incentives, and regulations. BDAT can be utilized to enhance the IoT and remote monitoring technologies of ecosystem services, thereby facilitating ecologically sustainable human development. The necessity of such monitoring is evident in the evaluation of trends and the drawing of conclusions regarding the relationships between social-ecological variables (Carpenter et al., 2009). Our awareness of the genesis of pandemics may be increased through improved monitoring and analysis of ecosystem practices, which could divert human decision-making from a quasi-brinkmanship interaction with the planet's carrying capacity, sustainability, and biodiversity. AI and BD are critical to the sustainability transition, as they have significant implications for the collection, storage, and processing of information. They are essential for determining the direction, transportation method, and the transition's current status.

Decision-making in complex problem spaces is frequently a component of entrepreneurship, and in such environments, it is necessary to act on imperfect information that may vary in many ways. For instance, its social range, genesis, scope, any discrepancies in decision-making processes and procedures, its consequences, and its context. To characterize our volatile, uncertain, complex, and ambiguous world, acronyms such as VUCA have been created. Even before the COVID-19 pandemic, uncertainty and unpredictability were already prevalent in contemporary life. Conversely, disruption, opportunity, and exposure are all components of the same pandemic. The fundamental issue is that the interpolation of historical data no longer enables a one-to-one prediction of the future. The complex and swiftly changing conditions necessitate the integration of more current contextual factors into forecasting models in disruptive times. Nevertheless, our models become more intricate and demanding as technological advancements enable us to prioritize accuracy over efficiency.

In a world that is becoming more complex, competitive, and uncertain, the capacity to perceive, respond to, and alter business plans, processes, and procedures is essential for survival. To achieve this, organizations, regardless of their age, should strategically position themselves in the market by utilizing portfolios of assets and resources that have been historically derived. This concept is also referred to as the resource-based view of the firm. An less well-developed area in the literature is the potential interaction between AI/BD-informed decision-making and the resource-based view of the firm and natural environment. It is worth further investigation. In various domains, including online dating (i.e., in a two-way market), restaurant/movie/music recommendation systems, targeted advertising (e.g., combining user preferences such as privacy, personal interests, and advertiser preferences such as target audience), and educational learning, research has recently investigated the utility of multi-stakeholder recommendation systems

(Milano et al., 2021). For instance, their potential application to dynamic SE problems, such as options analysis/selection in multi-stakeholder projects or sustainable procurement and sourcing (i.e., matching buyers and sellers based on mutually beneficial and agreed-upon contract characteristics), could be intriguing.

SE's ultimate objective is to ensure the continuation of existence. The decision regarding "how" to achieve this (i.e., the continuance of life) becomes political and contentious due to human decision-making and biases.

Conclusion

We are approaching the point at which we can envision realizing Buckminster Fuller's vision to "make the world work, for 100% of humanity, in the shortest possible time, through spontaneous cooperation, without ecological offense or the disadvantage of anyone"37. By leveraging the capacity of AI and BD to access real-time data, resource stocks, and fluxes, we can envision this ideal outcome as a reality. In the past, what appeared to be techno-optimism could be our (very near) future. The question is: Will humans cooperate when technology (BDAT and its successors) can genuinely make strong SE possible?

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