Matthew A. Alighchi

Professor Erik Ringle

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The Environmental Need of Computers: The Effects of Computer Science, Game Theory, and Artificial Intelligence in Sustainability

As we keep progressing towards the future, the sustainability crisis looms closer to our consciousness. Yet, there is very little work to capitalize the exponential growth of computers for sustainability. The intersection between computer science and sustainability, computational sustainability, has been overlooked for far too long, even though computers are one of the best methods to solve the hardest of the sustainability issues. Two subfields, game theory and artificial intelligence, in particular offer great support for sustainability. Game theory not only illuminates sustainability strategies for businesses and government agencies but also human behavior and reward optimization. Artificial intelligence not only generates results for copious, menial tasks, but also tracks natural phenomena on a much larger scale than humans can. While the benefits are substantial, there are still environmental consequences to using computers, such as pollution, lithium mining, and non-biodegradable waste. However, computational sustainability offers too many benefits to be overlooked as traditional thinking is becoming less efficient.

Even though computer science is growing more than ever, computational sustainability has not seen such a boom. In fact, computational sustainability has been largely ignored. Most researchers, like Kyu Koh, focus more on general education and practice rather than specialization and interdisciplinary by trying to find new ways to engage children in computer science to diversify the field. By creating inventive ways to introduce coding to primary school students, they sought to invigorate students desire for programming, as the world moves more towards the digital age. While the study has proven effective, it does not directly address computational sustainability (Koh et al. 1-6). Koh does not introduce any interdisciplinary actions in his study; similar to how almost all schools in the United States. Without properly applying computer science to other fields, especially ones pertaining to the environment, students will have a harder time making those connections, or refuse to notice them. Therefore, rather than providing new information and studies, many environmental computer scientists spread awareness of computational sustainability instead. Some researchers, like Michela Milano from the Institute of Electrical and Electronics Engineers (IEEE), provide many case studies in which computation has already helped tremendously in the sustainability crisis. Studies such as Chung Sung's dynamic game (a game in which neither of the participants' moves are known by the other until they are performed) demonstrate the full effect of computers and how they benefit sustainability. Other studies, such as Iranian researchers being able to produce drought forecast with ninety percent accuracy, demonstrate the extent of computer science's ability to help us understand nature. Milano concludes by actively campaign for more interdisciplinary focus

between computer science and environmentalism (Milano et al.). However, a glaring issue is the lack of case studies that are available. Many computer scientists, and even environmentalists, refuse to acknowledge the necessity of computer science for sustainability and other fields, so they largely remain segmented from other disciplines. While far and few, the case studies give a sense of scope of the capabilities of what computers can do, but Elon Eaton, while emphasizes the importance of computational sustainability like Milano, he also illuminates a larger focus on artificial intelligence (Eaton, Gomes, and Williams). Artificial intelligence is incredibly important to sustainability, because of the difficulty of observing nature on a large scale. Furthermore, like what the Iranian researchers discovered, it can offer extremely accurate predictions of natural disasters, thus allowing us to properly brace for them. As more researchers unveil case studies, there is an increasing trend to two major focuses in computational sustainability: artificial intelligence and game theory. While neither is more valid than the other, they both offer solutions to different problems.

The more supported method, however, is game theory. Game theory is the study of competitive and cooperative settings through mathematics and computer science. While it seems to hold little relevance for sustainability, it can actually help companies, and other agencies, create sustainable business tactics. As Sung explains in his book, much of the sustainability crisis is from company competition and their desire to seek as much short-term profit as possible. However, many companies model their tactics as games in order to achieve the most

profit (*Exploring Computational Sustainability*, 1-5). Therefore, if companies utilize games that consider sustainability and not just profit, their tactics will shift toward sustainable outcomes. Sung demonstrates this in a separate study to show how companies who harvest sustainable resources can be modeled through a dynamic game involving planning period, harvest efforts, and discount values, and illuminates more sustainable behavior when planning period is expanded (*Dynamic Sustainability Games*). The study discovered that companies with a greater planning horizon have more sustainable behavior while those with a shorter horizon, and/or more concentrated on discount values, have a significantly less sustainable harvest method. Sung's game illuminates the discrepancy of corporate desires to that of sustainability, but also attempts to find a balance. The issue that created the biggest discrepancy between the two was planning period. If left alone, companies tend to have a shorter focus on their environmental impact, however games can force them to not only acknowledge it, but also take it into account for their businesses. However, a major part of sustainability is the illegal actions caused by poachers and other criminals. Therefore, another researcher, Fei Fang, expands the application of game theory to not only companies, but also environmental protection. Many government and non-government agencies utilize game theory to simulate criminal behavior and prediction. The games provide extensive analysis to properly allocate funding to prevent such behavior (Fang 1-6). Even though it is not a completely accurate prediction, it still offers more insight and behavior analysis that would have been ignored. While game theory is helpful in companies and

government facilities, it can also reveal information on sustainability on a personal level. In one of their studies, Yan Liu and Tong Chen create a game in which they demonstrate how sustainable behavior is more prevalent if it produces positive reputation and conforms to their habituation. By providing positive reinforcement for sustainable behavior, they emphasized the human condition that confirmation creates more positive results than if they were left to their own devices (Liu and Chen). People do not like going out of their way to create sustainable habits, but if there are positive incentives to do so, then their behavior will change. From all of the applications of game theory, they all converge to a singular purpose; the desire to find the best outcome. Whether it be the dichotomy between companies and sustainability or preventing illegal activity, game theory illuminates the outcomes and tactics that lead toward sustainability. On almost every level of society, game theory enlightens new understanding and methods of approaching sustainability that is otherwise impossible to discover without it.

The other major subdivision of computational sustainability is artificial intelligence. While most will simply apply artificial intelligence to robots, it can actually be applied to many of the issues of sustainability. As AI magazine explains, the majority of the world that would benefit from sustainability the most are often uneducated and developing countries. A large fear with uneducated countries is the increase of human error, which many of these countries cannot afford. However, artificial intelligence does not require human input, thus it eliminates this fear and provides extensive details to help these countries (AI Magazine). Without the need to worry

about the current state of the education of the country, leaders can focus on better education and other activities to benefit the future. By providing extensive details, artificial intelligence can eliminate the fear of human error, help educate the population at a better rate, and let countries become sustainable. Furthermore, With the help of artificial intelligence, new and better information is more readily available to not only developing countries, but to the world, and on a much larger scale. Anthony Farnsworth demonstrates this by utilizing artificial intelligence in weather radars to track bird migrations. Bird migrations are very complex phenomena that are impossible to track through human observation, but artificial intelligence can easily record these behaviors (Farnsworth). While bird migrations are not directly related to sustainability, the study is still important to computational sustainability, because not only does this demonstrate the potential of artificial intelligence for sustainability, but it also exemplifies the potential to collect data on a global scale. Data that can range from human behavior to complex natural events. Elon Eaton further elaborates the potential of artificial intelligence by providing several case studies from researchers utilizing artificial intelligence for their research and explaining the need for artificial intelligence for the sustainability crisis (Eaton). Artificial intelligence is incredibly beneficial to retrieving data that humans never could. While game theory provided us with solutions and tactics, artificial intelligence presents the raw data that is necessary to understand and improve the world. That is not to say the two are exclusive from each other. Much like computer science and sustainability, game theory and artificial intelligence are often more linked than separated. Many of the studies pertaining to game theory previously mentioned had to

utilize artificial intelligence in some way. They function the best when paired together, and if they are, they achieve phenomenal results. However, that is not to say that they do not have their faults. With all the possibilities of artificial intelligence and game theory, it can be deceptively simple to solve global problems.

Artificial intelligence and game theory both suffer in their ability to be applicable to the real world. For the majority of artificial intelligence's life, it had not had an applicable purpose. Whether it be the insufficient hardware or the inability of scientists to create effective code, artificial intelligence largely remained science fiction. Even in its current state, artificial intelligence still struggles to get proper data. With these circumstance, Andreas Krause, however, argues that researchers like Eaton and Farnsworth have a far too large scope. She argues that computers can only handle so much, so to produce the most efficient result, the scope needs to be broader so that less variables will be present, thus making it less error prone (Krause). As Krause alludes to in her study, like any solution, computer science has its faults. In its current state, computers cannot handle too much variability. As more variables are introduced into a program, at some point its performance will decrease so much that it will be functionally useless; a phenomenon known as the curse of dimensionality. Therefore, computers cannot accurately simulate the real world as the variables and conditions are almost infinite. This phenomenon is not just exclusive to artificial intelligence, but all of computer science, including game theory. Furthermore, computer programs are often dictated by either a single person or a

group of people, thus it may not represent the interests of the entire world. This raises many ethical questions regarding artificial intelligence, because the idea of computers dictating people's lives is very questionable, and many people would rather that not be the case. Regardless of limitations and ethicality, computers still have a negative impact on the environment. Brett Robinson conducted a study to determine the amount of waste produced by electronics and their effects on the world, especially developing country. He found that the world produces between twenty to twenty-five million tons of electronic waste, or E-waste per year, with the biggest contributors being Europe, Australia, and the United States. The effects of E-waste are detrimental to the environment, and specifically harm developing countries as they lack proper recycling techniques. The effects are so drastic that Robinson claims could be contaminating global agriculture (Robinson). The full extent of the consequences of computers has yet to be explored, but should not be ignored. Unless people work to make computers themselves sustainable, there will still be a sustainability crisis in some form. However, in order to develop a more environmental world, computers are necessary to guide us to a better and more sustainable path than the one we're heading toward right now.

Computers are not only a vital part of our daily tasks, but for the entire world. Game theory and artificial intelligence have proven to be not only useful for gathering data, but also combating a lot of sustainability issues. With the help of game theory and artificial intelligence, the sustainability crisis can be solved at a much faster rate than previously thought.

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