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The Interdisciplinary Aspects of Computing

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The Interdisciplinary Aspects of Computing

Abstract
The role of computing has aided humankind for over thousands of years, helping them with calculating and crunching large numbers with ease. Although it has been around for millenniums, the advancement we had in these past few decades has been significantly greater than the past century. Intel 4004 was leading the technology revolution, creating the first ever single chip microprocessor containing 2300 transistors and producing 60,000 instructions per second. Consequently, the computing power exponentially grew to achieve a performance rate of over four million times the speed of the original microprocessor. The advancement of computing has allowed us to solve all different types of problems in various fields. With the development of computation power, pure scientists, doctors, economists, engineers, and even musicians can use the power of computation to solve problems they would never have been able to solve before. The advancement of computing gives birth to several new fields all under the name of Interdisciplinary computing. Interdisciplinary computing is the foundation for solving all sorts of problems faced in different types of fields.

The role of computing has aided humankind for over thousands of years, helping them with calculating and crunching large numbers with ease. Although it has been around for millenniums, the advancement we had in these past few decades has been significantly greater than the past century. Intel 4004 was leading the technology revolution, creating the first ever single chip microprocessor containing 2300 transistors and producing 60,000 instructions per second. Consequently, the computing power exponentially grew to achieve a performance rate of over four million times the speed of the original microprocessor. The advancement of computing has allowed us to solve all different types of problems in various fields. With the development of computation power, pure scientists, doctors, economists, engineers, and even musicians can use the power of computation to solve problems they would never have been able to solve before. The advancement of computing gives birth to several new fields all under the name of Interdisciplinary computing. Interdisciplinary computing is the foundation for solving all sorts of problems faced in different types of fields.

The most critical interdisciplinary field today, making breakthroughs and solving problems in all different kinds of other fields, would be Data Science. What is Data Science and how is it interdisciplinary? It is a broad and subjective topic that institutions and experts spark several different definitions for Data Science. However, there is one definition where institutions and experts would agree is best. It comes from David Blei, Professor of Computer Science and Professor of Statistics at Columbia University, and Padhraic Smyth, Professor of Statistics at the University of California, Irvine. Blei and Smyth continued explaining, as Data Science is the “child” of Statistics and Computer Science, it inherits both of their technique and thinking. It grows and learns to be its individual, and separate field, merging the best from both sides of the field, refocused to solving a new problem in the modern day of scientific data analysis: “Our perspective is that data science is the child of statistics and computer science. While it has inherited some of their methods and thinking, it also seeks to blend them, refocus them, and develop them to address the context and needs of modern scientific data analysis" (Blei and Smyth 2017). However, what are these methods which Data Science inherited from Statistics and Computer Science? An Article written by Jeannette M. Wing, the Director of the Data Science Institute at Columbia University explains that from Computer Science, Data Science inherits its computational foundation, and its ability to compute and generate a huge amount of data. It also inherits the algorithmic design and analysis aspect of Computer Science to solve problems efficiently and accurately. From Statistics, Data Science inherits its method of designing and building experiments and statistical model. This is used to evaluate, quantify the uncertainty, predict trends and generate the data from the experiments and model (Wing 2018).

Another set of quality Data Science inherited from Statistics would be the capability to infer information and facts through the data of any field of study (Blei and Smyth 2017). Especially with today's power of computation, different fields have produced a large amount of data like never before, and Data Science can help solve problems in these diverse fields. Data Science is a gateway to allow computing to bring integration into more than one field at a time. A great example of the product of this interdisciplinary interaction is the field of Bioinformatics. Bioinformatics is the interdisciplinary science that makes use of the traits of Data Science, but only focuses on biological data, to make predictions and solve problems in biology: "Bioinformatics is an interdisciplinary field that develops and applies computational methods to analyze large collections of biological data, such as genetic sequences, cell populations or protein samples, to make new predictions or discover new biology. The computational methods used include analytical methods, mathematical, and simulation" (Pranavathiyani 2017). The research area where bioinformatics has been making breakthroughs and discoveries is in cancer research. Cancer is categorized as a genetic disease where cells stop following the normal chronological phase of the cell cycle where they divide. Instead, they uncontrollably start dividing, and chromosomes of cancer cells will have large pieces missing, or it would not be in order (Chowdhary 2016). Therefore, rather than just focusing on that particular gene, with the rise of biological data from laboratory and patient records, scientists would be able to make use of bioinformatic techniques. With this, scientists have been developing new intuitions into the genetics of cancer. Few of the things these bioinformatic techniques have accomplished in cancer research are the discovery of the connection between gene expressions and disease pattern and describing a typical pattern in different cancers. These are useful information to help us understand how cancer might occur and the whole structure of the disease (Hanauer 2007).

Another field which integrated with Data Science that made a huge impact, this time for a more profitable approach, rather than a scientific approach is the field of Finance. Two Sigma, a $51 billion hedge fund company, founded by David Siegel an MIT computer scientist and John Overdeck a Stanford University math and statistics alumni, is a great example to use (Two Sigma About). Two Sigma makes use of Data Science technique such as collecting and computing data and incorporates it with their knowledge of finance to create complex trading models to predict the stock market: "We combine massive amounts of data, world-class computing power, and financial expertise to develop sophisticated trading models. Moreover, we use technology in an effort to constantly refine our investment process and our insights into how the markets will behave" (Two Sigma About). Although the specific method the hedge fund company Two Sigma uses data science to predict stocks is a company kept secret, Computer Science researchers all around the globe have been researching and finding new insights on this specific topic. One of them being Nikola Milosevic, a Computer Science research associate from the University of Manchester. He published an article to share his insights and results through his experiment of using a data science technique called Machine Learning to predict long-term stock price movement (Milosevic 2016). Machine Learning, according to Dr. Yoshua Bengio, a Professor of Computer Science and the Head of the Machine Learning Laboratory from the Universite de Montreal, is a subset of artificial intelligence, which uses data science technique like observing data, which is gathered by interacting with the world in order to provide knowledge to software. What Machine learning does then is to allow the software to use its newly gained knowledge to generalize on trends, connections, and new ideas: “Machine learning research is part of research on artificial intelligence, seeking to provide knowledge to computers through data, observations and interacting with the world. That acquired knowledge allows computers to correctly generalize to new settings” (Faggella). Therefore, what computer science researcher Nikola Milosevic is essentially doing in the experiment is first gathering data, in this case, different stock prices of companies from 2012 to 2015. He then creates a Machine learning software using these data and uses Machine learning algorithms which teaches the software to spot patterns and predict whether the stock prices of the company will either go up or down. With this, he was able to predict whether a company will have a 10% increase in stock value throughout one year or not. The final results of his experiment achieved an accuracy of 76.5% which will lead to a profit (Milosevic 2016).

Robotics is the next interdisciplinary field which companies have also turned that into a multi-million-dollar industry. It is also being used to solve numerous types of problems biologically and physically. Robotics is an example of the interdisciplinary integrative field that consists of computer science, mechanical engineering, and electrical engineering to engineer robots (Félix 2014). To gain a better understanding of robotics, we need to understand the definition of robot, according to the Robot Institute of America: “A robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks” (Muthe). Therefore, during collaboration, the mechanical engineers are in charge of the design and mechanical system of the robots making sure it moves functions well. The computer scientists are responsible for programming the robots and are constructing its brain. Finally, the electrical engineers are in charge of the electric circuits in the robot which allows the mechanical side to interact with the computer science side. Robots have already aided humans with solving a huge amount of problems, and the possibilities of problems it could resolve are countless. The very first machine that fits the definition was built during the 1960s also known as Shakey the robot. Shakey was constructed by the SRI International, initially known as the Stanford Research Institute in Silicon Valley to help navigate through a complex environment (Simon 2018). Although Shakey is not the most advanced robot we have in the history of robots, being awkward, slow, and jiggly, it is arguably the most notable. Shakey paved the way for the revolutionary and interdisciplinary field of robotics, allowing robotics researchers, engineers, and computer scientists to continue the development (Simon 2018). It is also the foundation of robotics research and solving robotics problem today and in the future. However, what is the future of robotics and what are robotics researchers trying to accomplish? According to Dr. Minoru Asada, a Professor at the Osaka University of Adaptive Machine Systems at School of Engineering, and the Director of the Division of Cognitive Neuroscience Robotics, the ultimate goal for robotics is to expand its interdisciplinary field and integrate the field of Artificial Intelligence and Machine Learning to allow robots to be independent in completing its task by interacting with the real world: “An ultimate goal of robotics and AI is to build an autonomous agent that behaves adequately to accomplish a given task through interactions with its environment. (Asada 1996)” As for the motivation towards this goal, robots are reprogrammable machines designed for a task, and it will be impossible for computer programmers to program a robot that vacuums with specific instructions as every household has a different layout. With the help of Machine learning, this will then allow robots to gained knowledge based on interacting with the world (Faggella). Going back to the vacuum robots, it will give robots the ability to teach itself and learn about the layout of the household. Perfecting this will be revolutionary and incredibly useful to all of humankind as it gives us the capability to solving countless problems like traffic through self-driving robot vehicles.

Another interdisciplinary field that has been on the rise, especially after the increase in human and machine interaction through our smartphones or laptops, is the field of Computational Linguistics. Computational linguistics is the interdisciplinary field that bridges computer science and linguistics. It looks at written and spoken language from a computational perspective. Linguistics is the study of language, and to an extent, the human language is a representation of the human mind. Therefore, learning the language from a computational perspective gives us insights into thinking and intelligence. As language is also our most essential medium of communication, computers that are linguistically competent would tremendously improve the human-computer interaction and experience (Schubert 2014). So what type of problems are computer scientists and linguists trying to solve in this interdisciplinary field? According to Dr. Lenhart Schubert, professor of computer science at the University of Rochester, as well as a member of the Center for Language Sciences, the problems are split into two sides: a theoretical side and a practical side (Schubert 2014). As for the theoretical side, one of the questions researchers are asking is: “How does language processing and learning occur in the brain?” This question then brings along researchers from Neuroscience to collaborate along with Computational Linguistics researcher. Their attempt to answer this question is by gathering neuroscience data and feeding it to a neurocomputational model, essentially a computer model of the human brain. Through the model, they then try to figure out how precisely the brain processes information and language (Arbib 2013). Understanding how the brain learns and develop, especially in languages is crucial as any insights on how humans can process or learn a language better would be revolutionary. As for the practical side, the things Computational Linguistics researcher are working on a more extensive but at the same time, much more straightforward but all with the goal to help aid human with language as the medium. Some of the leading areas are machine translation, question answering, text summarization, and most importantly creating computer software that is a good as a human in dialogue and gaining language and knowledge from a text, for example, Apple’s Siri, Amazon’s Alexa (Schubert 2014).

The kinds of fields Computer Science is interacting with does not have to be limited within the pure sciences, mathematics, and social sciences. The numerous fields under humanities could also be significantly impacted by the advancement and integration of Computer Science. One of them being music. Computing has become an integral part of music, as it helps enrich the field in multiple ways. According to an article by the University of Massachusetts Lowell, through the experience of their professors and students, they believe there are two extremes in the applications of the interdisciplinary field of computing and music. One is exceptionally low-level in the sense that it is more practical and applies more to the musician; while the other is high-level in which it is much more sophisticated and applies more to the actual music and sound (Heines 2011). One great example of a low-level application of computing and music is by Dr. Kia Ng a computer science and music professor from the University of Leeds and the director and co-founder of the Interdisciplinary Center for Scientific Research in Music. He invented a new way of improving a musician's technique by using a motion sensor computer. It captures the gesture and posture of the musician as they play and compares it with the ideal performance. This motion sensor computer is vital as it helps musicians on all calibers. For beginners it helps them with getting a good posture early on in their career, and for the more experienced musicians it can help them make minor changes in their playing style: "If a student develops a bad posture early on, this can be potentially very damaging to their career and our system can help teachers to identify problems easily. Similarly, the system enables experienced musicians to make small changes in gesture and posture that can improve the sound they make. (Ng 2009)" As for the high-level applications of computing and music, an excellent example for it would be the invention of the Musical Instrument Digital Interface better known as MIDI. MIDI is a computer software that allows the user to edit all aspects of the music. It also acts as a brain controlling all the different instrumental device connected to it (Gibson). Consequently, this interface made by computer programmers revolutionized music production. It made producing music accessible to anyone that has a computer, allowing aspiring artists and producers to have a head start.

As much computing power, we already have, there are still limits on what we can do with our "classical" or "traditional" computers — limits such as not being able to factor large numbers for starters. It is proven to be impossible for classical computers ever to compute the factors of a huge number, which shows how much computational power we still lack (Chu 2016). Fortunately, physicists, engineers, and computer scientists have joined together in recent years, aiming to create a “supercomputer” on a whole other level of speed and accuracy. This joint effort resulted in an entirely new interdisciplinary field known as “Quantum Computing,” and the “supercomputer” these physicists, engineers, and computer scientist dreamed of, is now known as the “Quantum Computer.” With this amount of speed and accuracy through quantum computing, researchers from all different types of fields could potentially solve problems at a tiny fraction of the time, what otherwise the classical computer would have taken (Microsoft “*What is quantum computing*”).

So, what is quantum computing and how is it much faster than classical computers? Quantum computing is the interdisciplinary field where quantum mechanics (a subfield of physics) meets computer science. It operates by using the laws of quantum mechanics to process information and data. Therefore, it does not work like the classical computer which uses bits to store data in a single binary value of 1 or 0. Instead, it uses quantum bits or qubits for short, which like the classical bits, also stores data. However, instead of just storing the data as ones or zeros, the qubit uses the quantum mechanics concepts of “superposition” and “entanglement” to store its data (“Quantum computing 101” 2018). Superposition is the concept which gives quantum systems the ability to exist at different states all at the same time. For example, a penny in the quantum world would be able to be faced up and down at the same time (*What Is Superposition?*). While Entanglement is the concept which gives the quantum systems the ability to be linked to each other creating a perfect unison, therefore, no matter what happens to one, the same thing will happen to the other one, even if they are incredibly far apart. This concept is what Albert Einstein described as "spooky action at a distance (Atkinson 2015)." The qubit takes advantage of superposition to hold the value of 1 and 0 at the same time. It also takes advantage of entanglement to allow multiple qubits to act in unison, computing a large number of options concurrently (Atkinson 2015). This is the reason why quantum computers have so much more power and speed compared to its classical counterpart (Microsoft "*What is quantum computing*"). Quantum computing has enabled researchers to start tackling new problems we never thought could be solved ("Quantum computing 101" 2018). This interdisciplinary field of quantum physics and computer science will be the foundation for solving the next wave of interdisciplinary problems.

Interdisciplinary computing is the foundation for solving all sorts of problems faced in different types of fields. The advancement of computing in the past decades allowed different researchers from diverse fields such as mathematics, physics, biology, and engineering all the way to linguistics, and music to come and collaborate. These researchers took advantage of the computing power we have today to calculate the vast amount of data produced in their respective fields. Computing gives them the ability to tackle further the countless problems they would never have thought could be solved while continuing to gain new insights into their field.

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