Decision Support System for Radiation Oncology

(Technical Paper)

Impact of Technology on Biology and Physiology

(STS Paper)

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Introduction

Medical devices have increased the average life expectancy from 47 years to 77 years ("Health Technologies—Greatest Engineering Achievements of the Twentieth Century," n.d.). Artificial intelligence is an area of computer science which has improved quality of life by "utilizing computing to mimic the way … data is interpreted but at a scale not possible by human capability" (Spizzirri & Fitzpatrick, n.d.). Integration of artificial intelligence in medic is a developing subfiles in medical technology that aims to reduce the cost, time, and medical error involved in patient treatment (Ishak & Siraj, n.d.). With the same objective of improving overall quality of life, the purpose of the capstone project set forth in this proposal is to improve radiation oncology treatment planning using data-driven artificial intelligence.

Although such advancements appear to have a positive outlook, there are factors that need to be considered as technological progress continues to be made (Unger, 2014). The use of science and technology, specifically biotechnology, as means for violence and terrorism has been in practice since fourteen centuries before the current era. Biotechnology is arguably the deadliest weapon ever produced: if not properly defined and understood, the consequences of exploited biotechnology could cause permanent and irreversible destruction (Barras & Greub, 2014). The current definition of bioweapons encapsulates the impact of biotechnology as a weapon at a large scale, but there is less clarity in the definition in smaller scales and indirect forms. Due to scholarly age of the term "bioterrorism," and the ambiguity in potentially smaller, indirect forms of terrorism that may qualify as bioterrorism, the goal of biotechnology and bioweapon investigation is to review the definition of bioterrorism in the second proposed project.

Technical Topic (Capstone)

Radiation therapy, also known as radiotherapy, is a form of cancer treatment that uses high doses of radiation to kill cancer cells and shrink tumors ("Radiation Therapy for Cancer," 2015). There are two main types of radiation therapy, external and internal beam. Determining the most effective radiation therapy depends on a variety of factors, including, but not limited to, the type of cancer, the size of the tumor, the tumor's location in the body, how close the tumor is to normal tissues that are sensitive to radiation, and patient's general health and medical history. Depending on the combination of such factors, every patient requires a treatment plan tailored to the individual's diagnosis.

Current oncology treatment planning methods include a dosimetrist, who uses his or her knowledge and expertise to generate a plan of radiation dose distributions in collaboration with a medical physicist and radiation oncologist ("What is a Medical Dosimetrist?," n.d.). While designing treatment plans, there are dose-limiting structures that need to be carefully studied, which vary for each case. The primary drawback of the current radiation planning method is the potential for human error while transferring information to different specialists (Weidlich & Weidlich, n.d.). Research that aims to reduce the prevalence of cancer and identify new cancer treatments are being heavily funded, providing more opportunities for innovation in oncology treatment planning. The National Cancer Institute (NCI) has been collecting data and producing statistics through their Surveillance, Epidemiology, and End Results (SEER) Program. Using its cancer registry, SEER supports research in quality of cancer care, documents differences by variables such as race and ethnicity, gender, geography, demonstrates the effectiveness of public health interventions, and guides the translation of research into health policy and practice

(*Surveillance, Epidemiology, and End Results (SEER)*, 2018). Although the information that results from the SEER Program has been critical in tracking the Nations' progress against cancer and providing insight on cancer trends, no action has been taken to perform extensive research using data analysis on oncology treatment plans. Using data analysis for treatment plans would greatly improve the efficiency and accuracy of oncology treatments, as research indicates "the prevention of errors is most effective when data transfer processes [are] automated and operational decision [are] based on logical or learned evaluations by [a] system" (Weidlich & Weidlich, n.d.).

The purpose of this proposed technical project is to leverage artificial intelligence, big data, and analytics to personalize medical treatment and develop a decision support system for radiation therapy treatment. The artificial intelligence algorithm will be trained and developed using the Oncospace database, which is a SQL database constructed by the University of Virginia in collaboration with Johns Hopkins University (Bowers et al., 2015) ("Oncospace Abstract: Big Data and Opportunities for Oncology," n.d.). The Oncospace database contains data useful for treatment planning, decision support, and research, which includes but is not limited to data on imaging, segmentations, radiation therapy dosimetry, and patient outcomes. Some of the tools and resources that will be used are CSS, HTML, JavaScript, MATLAB, Python, and a secure SQL server. Once a working prototype of the support system is developed, the prediction of segmentation, patient dosimetry, and patient outcomes will be predicted. The overarching goals of this project are to develop an interactive tool to allow oncologists to determine the best treatment plan, and to test the effectiveness of the tool. The development of the interactive tool will involve using a machine learning algorithm trained by data gathered in the Oncospace

database, and incorporating an interface which displays visuals treatment trends and potential outcomes. The effectiveness of the tool will be evaluated in two ways: collecting feedback from oncologists who will be given a demonstration of the software, and by testing the developed code for speed, accuracy, and bugs. Throughout this entire process, Dr. William T. Watkins will act as an advisor.

The amount of information needed when designing treatment plans, especially for oncology patients, has continued to grow (Abernethy et al., 2010). With the technological field rapidly expanding, current methods of determining oncology treatment plans may no longer be the most effective, perhaps becoming outdated. Developing a decision support system integrated with artificial intelligence for radiation oncology will allow doctors to make more informed treatment decisions for their patients by expanding the amount of past data that they can use beyond just the patients that they have personally treated in the past. The added visualization of trends will further allow them to make quicker decisions, thus improving the efficiency of the treatment process. Clinical decision support systems have been shown to be effective in a variety of fields, such as diagnosis and drug dosing (Hunt, Haynes, Hanna, & Smith, 1998). By applying this approach to radiation oncology, the novel system will improve the accuracy and efficiency of radiation treatment for future patients.

STS Topic

Currently, bioterrorism is defined as terrorism which involves the application of biological weapons or microbes use by terrorists as an act of terror (Danciu, 2011). Biological weapons are defined as the means or devices which produce a biological agent release generating harmful or lethal pathogens (Danciu, 2011). Although the general consensus opposes the

possession and use of biological weapons, sixteen countries are suspected of having biological weapons programs, including the United States. A well-known example of modern biological warfare is the use of Anthrax in World War I. Anthrax is a spore-forming bacterium which can cause a rare but serious illness ("Anthrax—Symptoms and causes," n.d.). According to the Centers for Disease Control and Prevention, there is evidence that the Germans infected livestock traded to the Allied Nations with anthrax (A History of Anthrax, 2019). More recently, Anthrax was used in letters as a form of bioterrorism against America one week after the September 11, 2001 terrorist attacks. The total cost of Anthrax decontamination efforts after the Anthrax Letter Attacks was estimated to be $320 million USD (Schmitt & Zacchia, 2012). Biological weapon development is a global concern because of its potential to affect multiple factors which impact humanity and society. With ~~Because~~ the weaponization of technology is one of the less recognized ramifications of technology and innovation which continues to improve, it is important to analyze the gravity of its effect and address the issue.

A science, technology, and society (STS) framework that will be considered in relation to bioweapons and bioterrorism is technological fix. Technological fixes are defined as "the use of technology to respond to certain types of human political, legal, organizational, or other social purposes" (Newberry, n.d.). Bioweapons are developed for the purpose of protecting the people and resources of those who possess them against an enemy in times of war and have arguably succeeded in this purpose. One of the criticisms of technological fixes are their tendency to mask the symptoms of complex social problems without addressing their causes or true costs, "technological fixes do not get to the heart of the problem… they create new problems as they solve old ones" (Newberry, n.d.). Although bioweapons are effective in their purpose, they

arguably fail to address the root of the issues which stem from social injustice, therefore straining relationships among social groups. These successes and shortcomings of bioweapons as a technological fix will be further reviewed in the proposed STS paper.

Another STS framework that will be considered is the politics behind a technology. It is easy to see how bioweapons have affected politics, but the way in which it came to have political influence is unclear. Langdon Winner proposes two possibilities for how technologies gain political influence: inherently political or deterministically political (Winner, 1980). One drawback of the political technology framework is that it can be unclear which category a technology falls under. To address the lack of clarity in the definition, the definition of bioterrorism will be analyzed, and a recommendation to modify or elaborate on the definition maybe be proposed based on research findings.

Research Question and Methods

The primary topics to be addressed through the analysis of biotechnology, bioweapons, and bioterrorism is whether the current definition of bioterrorism is sufficient, and whether there are forms of bioterrorism that have yet to be identified and accepted by the scientific community. Having a clear definition of bioterrorism and understanding of the technologies around it will reduce misunderstandings and minimize risk and expenses (Lab, n.d.). Analysis of bioterrorism and biotechnology as bioweapons will be conducted through documentary research and discourse analysis. In order to outline a more holistic definition of bioterrorism, the current understanding of bioweapons and bioterrorism will be reevaluated. This reevaluation will involve the review and comparison of multiple definitions and examples of what is currently considered bioterrorism. Some preliminary research defines bioterrorism as

"type of terrorism that involves the use of biological weapons / pathogens, by terrorists, in carrying out specific acts of terror," and "the intentional release of organisms that can cause sickness or death" (Danciu, 2011) (Evans, Kleinman, & Pagano, n.d.). Acts of terror similar to those currently classified as bioterrorism will be analyzed to see if they might classify as bioterrorism, or what differentiates an act from bioterrorism. The impact of bioweapons on society will also be evaluated, along with its future implications. Using the information gathered, an improved understanding of bioterrorism will be defined.

As biotechnology has continued to flourish, it has become more and more imperative to have a solid understand biotechnology, especially within the context of terrorism, as its potential for exploitation continues to rise. It is important for the scientific community to understand biotechnology and bioterrorism so that scientists are conscious of the ramifications of innovative technology and can determine if the development of a particular technology is ethical. Individuals within society should also be aware of biotechnology and bioterrorism, for they have the knowledge and power to influence the technological field to their collective benefit. Upon completion of analysis, a more comprehensive definition of bioterrorism will be proposed if the research and evaluation provide sufficient basis to modify the current definition. Ideally, a concrete definition will allow for better regulations on biotechnology to limit the potential of bioweapons.

Conclusion

The result of the project involving the application of artificial intelligence in radiation oncology treatment planning will include a medical image viewer with the incorporation of an image over lay capability. Integration of a radiation treatment-planning algorithm, which

computes the most effective and viable treatment plans, will also be a part of the final deliverable. The implementation of artificial intelligence in medical diagnosis treatment procedures will result in reduced costs, time, and error in medical diagnosis and treatment.

The term “bioterrorism” will be clarified in this STS research, and either the definition will be expanded upon or a new term which focuses on how technology effects physiology will be proposed. The objective of analyze the word “bioterrorism” is to clarify what is classifies as bioterrorism and to encourage discussion about the potential of technology to effect human physiology.

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