CREATING HEALTHCARE EQUITY THROUGH SAFER SCHEDULING ALGORITHM PRACTICES

A Research Paper submitted to the Department of Engineering and Society
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Systems Engineering

By

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March 30, 2023

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.

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MAKING INFUSION CARE EFFICIENT AND EQUITABLE

In the past decade, oncology programs across the country have expressed challenges in optimizing infusion center workflow, leading to the formation of the Infusion Efficiency Workgroup by the National Comprehensive Cancer Network in 2015 (Sugalski et al., 2019, p. 458). The University of Virginia (UVA) Health System encompasses four different infusion centers in the Greater Charlottesville area, and these centers serve many residents within central and southern Virginia. Due to increased demand, supply chain considerations due to lasting COVID implications, and continual short staffing, this technical project is designed to provide the UVA Infusion Center leadership team with consulting services dedicated towards creating a more strategic plan and efficient use of their main infusion center, the UVA Infusion Center in the Emily Couric Cancer Center. As a healthcare institution, the infusion center aims to serve as many patients as possible while maintaining safe conditions for both the patient and nurse, but the leadership team, and consequently the consulting team, are concurrently motivated by revenue and profit maximization, as the infusion center serves as one of the top revenue generating entities within the hospital.

The UVA Infusion Center has already made changes to their operations within the past two years, specifically funneling optimal scheduling of appointments through a popular infusion center scheduling software, iQueue. Scheduling is commonly seen as the first leverage point in these optimization problems, but much of this software is prone to creating racial healthcare disparities through their algorithms. Thus, in a tightly coupled fashion, this science, technology, and society (STS) paper looks to analyze how current data collection practices, confounding data relationships, and other communication structures can identify how the introduction of these new software affects existing racial disparities. Using an Actor Network Theory approach adapted

from Bruno Latour, this paper will look at the integral relationships between actors (Latour, 1984, p. 277). Consequently, these findings can evaluate the social impacts of scheduling software, like the one introduced in the UVA Infusion Center, and if the heightened efficiency comes with a tradeoff of racial equity. On an even broader scale, these findings can highlight the importance of understanding and communicating the logic behind any algorithm, which can prove very beneficial as the world turns towards an artificial intelligence and algorithm era.

In the short term, the findings of this paper will look to evaluate system changes that result in fairer algorithms, while also not sacrificing a positive patient experience. Outlined changes will influence work practice for practitioners, hospital leadership, and software engineers, but patients should experience little change to their appointment flow. In the long term, considerations should be made to codify algorithm standards for both engineers and corporations alike. In America, all people are supposed to have equal rights, and it is important that this does not waver, but rather only improves as more algorithms are adopted. This paper focuses on appointment scheduling and risk modeling, but the application can extend to general healthcare and other large-scale systems.

ALGORITHMIC AND HEALTHCARE FACTORS AFFECTING RACIAL INEQUITY

The efficiency of infusion care has increased through the introduction of advanced scheduling tools and standardized infusion practices. However, these new tools and existing healthcare practices allow racial inequity to remain. Ruha Benjamin, an African American Studies professor at Princeton University, (2016, p. 2227) has characterized modern technologies as “one of the most effective conduits for reproducing racial inequality.” In this, she implies that racial inequity will continue due to the combination of existing racial inequity and new

technology. Thus, it is important to examine the mechanics of how new technology can introduce bias and recognize current healthcare practices that fuel existing inequity.

CURRENT ALGORITHM CENTERED INVESTIGATIONS

IRS Racial Disparity for Taxes

Over the past year, the world has seen computer searches, salesperson' calls and emails, and promotional videos be replaced by large language model algorithms and artificial intelligence "deep fake" technology that can manifest itself as any character one could imagine (Metz, 2023, D1). This use of algorithms and artificial intelligence is only projected to increase soon. Their application includes many facets of healthcare, but these algorithms are also used in economics, logistics, and legal areas. While much of the healthcare studies are either academic or theoretical, the economic and tax system showcases a current event where advanced algorithms are amplifying race inequality. According to Jim Tankersley at *The New York Times*, the Internal Revenue Service (IRS) audits Black Americans three times more than other taxpayers, but this phenomenon is due to bias computing algorithms rather than bias from specific human groups within the IRS (Tankersley, 2023, p. A18). Additionally, it seems that human factors contribute to the bias seen by these algorithms. Like many bias systems, the IRS claims to be unbiased since the organization does not collect any explicit racial information. Confounding variables such as tax credits and return complexity, which are indirectly linked to race, are hypothesized as some reasons for such a discrepancy, but the IRS does not publicize its process, making concrete evidence hard to come by (Tankersley, 2023, p. A18). Lack of understanding from algorithm users and lack of visibility for external validators results in a dangerous environment where racial bias can survive undetected.

California Health System Probe

Research findings and internal findings from the IRS have already prompted advisory committees to advance racial equity. Meanwhile, healthcare systems are primed to be the next system that examines these algorithms with policy and legal ramifications rather than just theoretical or academic use. In California, the attorney general has requested data from over 30 hospitals to evaluate the equity of the current algorithms being used. According to Attorney General Rob Bonta (2022), he believes "Government Code section 11135, Health & Safety Code section 1317, Civil Code section 51 et seq., and Business & Professions Code section 17200 et seq., as well as related federal laws" could all possibly be in conflict with the current state of algorithm use in California. California historically serves as a trailblazing state for American policy and could push similar investigations in other states. Gabrielle Canon (2021), a writer with experience at *USAToday* and *The Guardian*, even claims that much of the current presidential administration led by Joe Biden is modeled after Californian policies and uses the state as a guide for national policy. Thus, healthcare equity and its relationship with new-age algorithms is very much on the precipice of being a national issue. However, to fix such an issue, it is important to first understand where such biases arise in the healthcare system.

ALGORITHM IMPLICIT BIAS AND HUMAN EXPLICIT BIAS

Bias Introduced by Confounding Variables and Poor Training Data

In many cases, scheduling algorithms and other artificial intelligence technology introduce bias through a lack of critical thinking rather than intentional biased design. Algorithms tend to optimize for a specific objective function based on a variety of predictive variables, and bias can occur when these predictive variables are related to a socio-demographic identity like race. In the context of patient scheduling, common confounding variables include

the probability of a patient to arrive and success ratios. Samorani et al. (2021) exposes differing "no show" rates in racial groups as one factor creating bias in the objective function of these scheduling programs, and ultimately creating longer waits and a worse patient experience for the minority racial groups with lower show probabilities (p. 2827). For example, many outpatient clinics experience patients who do not show up, and thus the clinics will overbook some scheduled slots. However, the patient experience greatly decreases in the case that both patients show up, and biased algorithms create an unfair reality where these patients tend to be minorities most of the time. It is also important to acknowledge that these racial biases can even begin in the primary care stage, and thus any further bias in infusion stages further perpetuates bias. Research from Ziad Obermeyer (2019), a distinguished public health professor, shows that black patients are assigned a lower risk score when testing for serious health conditions because the objective function is based on health cost rather than need, which is shown in Figure 1 (p. 447).

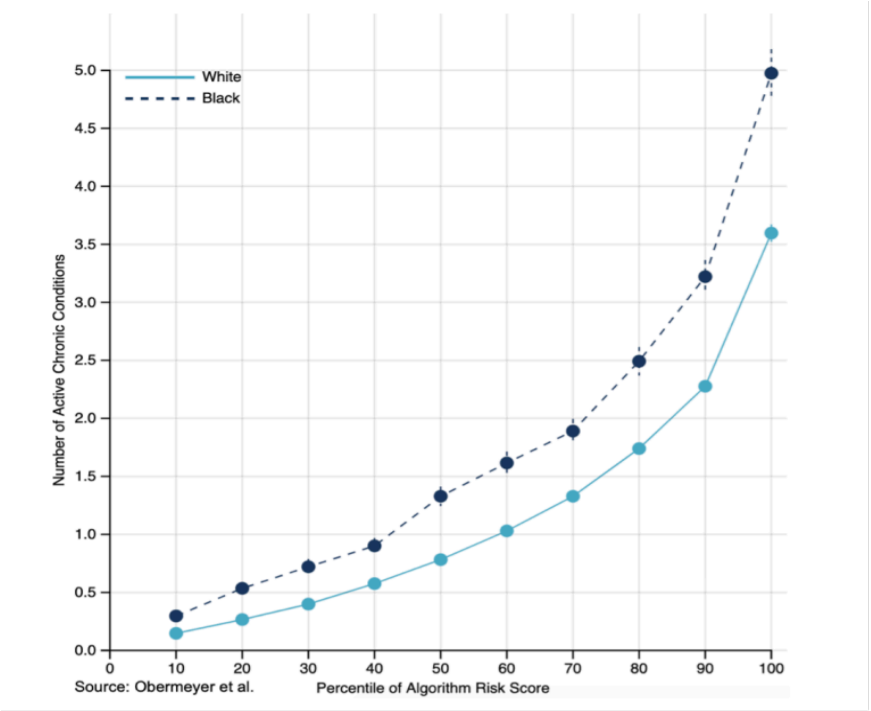

Figure 1: Algorithm risk score by race. This figure depicts the bias given to white individuals versus black individuals when basing the objective function on cost rather than care needed. (Obermeyer et. al., 2019, p. 449)

A variety of external factors ultimately decrease the health cost of black patients even though their need is on par with that of white patients. Thus, the chosen objective function for any algorithm must be free from correlation with any protected identities like race, religion, and so on. It is also important to consider the reliability of the training data and human conditions.

Extension of Lingering Implicit and Explicit Bias by Humans

Healthcare inequity was still prevalent before the introduction of these newer algorithms. Specifically in oncology programs, racial minorities felt like they received worse treatment due to a variety of issues. Explicit bias of practitioners is the true reason in some cases, but other studies show a lack of education and understanding as the driving force behind the perceived inequity. Academic research, mostly qualitative assessments, exposed racial disparities from improper symptom diagnosis and reporting for chemotherapy infusions (Robertson-Jones et al., 2018, p. 94). These clinic infractions fuel poor algorithms through poor data, as well as priming minority patients with an already poor experience. Studies from Stanford have shown pairing minority patients with minority physicians creates a more comfortable experience for the patient and informative encounter for the physician (Alsan et al, 2018, p. 23). While this is not always possible, it is an important factor for providers to consider practicing, while concurrently stressing continued diversity training for practitioners and in nursing schools. In addition to healthcare professionals, the software engineers behind the algorithms also bear responsibility for any unintentional bias created by their software.

DATA COLLECTION AND STORAGE ISSUES

Collection Affecting Patient Experience

Better data to ensure better algorithms seems like a straightforward solution to correcting some of the bias introduced by algorithms. However, increased data collection can ultimately

worsen the patient experience, which is the highest priority for all healthcare practices. Cruz (2020) concedes that data collection and analysis can theoretically inform local providers about their patient population and specific needs, but also showcases the practice of data collection can worsen the patient experience and add difficulty to the practitioner's duties (pp. 5-9). Instead, patient appointments become longer, and their comfortability can take a toll based on the questioning, all while the perceived benefits only come to fruition in validation studies rather than algorithm creation. Additionally, hard coding demographic inputs into algorithms does not necessarily affect the outcome as one would think. In some cases, this may fix a biased objective function for one identity like race but may miss another identity like religion or gender. Thus, the root issue of healthcare bias is still ignored. Building off prior information, it is evident that healthcare systems and infusion centers should stress improvements to the accuracy and completeness of existing data collection rather than adding new data points that would require added collection and questionnaire time to patient appointments.

Storage Practices Lead to Dangerous Ease of Use

Considering the worsened patient experience from increased data collection, another method to create better algorithms includes the use of data collected across a range of healthcare domains. For instance, a unified electronic health record database allows for one clinic (or software engineer) to capture data from many different appointments without as much duplication. However, data requires context to be fully understood and data transparency without limits, especially within healthcare, is dangerous. According to two Danish researchers, Wadmann and Hoeyer, "It also creates challenges of opacity, as it becomes increasingly difficult for users to grasp how the data sourcing occurs unless specific effort is made to create transparency" (Wadmann & Hoeyer, 2018, p. 2-3). Thus, increasing automated connections

without true understanding or background knowledge of the data can create even more harmful algorithms than first expected. The healthcare realm, rich with patient protected information, requires extreme caution, especially when sourcing software algorithm work to outside software engineering firms.

RETHINKING THE USE OF ALGORITHMS IN HEALTHCARE WITH ADDED COMMUNICATION

Both the root problem of racial inequity due to algorithms and the underlying problems with data-heavy solutions occur due to a lack of communication and context to accompany the data. Technical perspectives see increased data sources and computing capability as the linchpin for success, but the better solutions rely within the human-centered areas of communication and increased context. As the use of algorithms increases, so too must the human wisdom within the leadership spheres of healthcare.

AN ACTOR-NETWORK THEORY APPROACH

Current Network Shortcomings

To best understand this problem, the entities and their relationships are mapped using Actor Network Theory (ANT). Actor Network Theory, according to Latour (1984), applies sociology to technology through associations rather than strictly hierarchical social ties (p. 277). There are a wide variety of human actors, ranging from patients to nurses to internal data scientists to external software companies and the leadership within both the healthcare system and algorithm company. However, racial bias can covertly enter the system because non-human actors, scheduling algorithms and electronic health records, serve as the main communication link between the hospital and external environment. This creates a lack of critical thinking and context within the main negotiation space, as seen below in Figure 2 on page 10. Additionally,

there also seems to be an overestimation of trust that should be attributed to such software firms. In a hectic environment where nurse burnout is a large factor, health system leadership are easily influenced by efficient workdays and earlier clock out times for their staff. However, internal

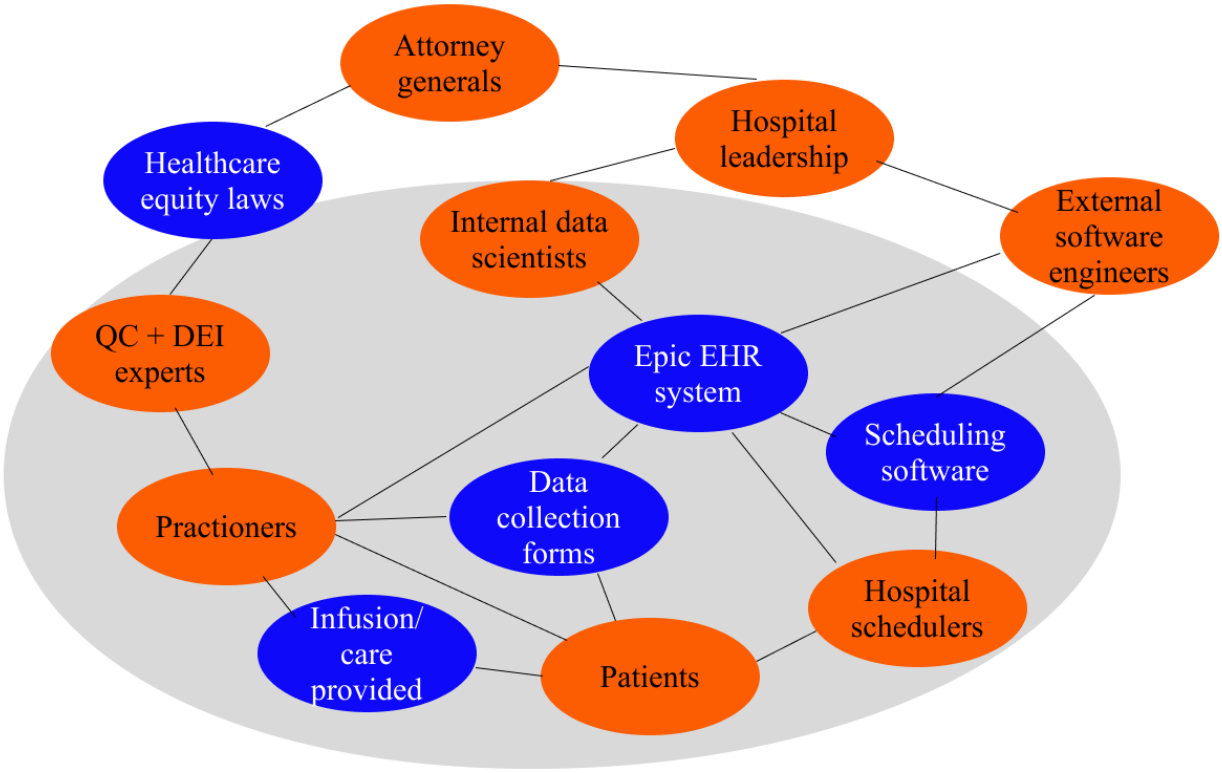

Figure 2: Current system actor-network. This figure depicts the actor-network of the current healthcare system. The orange indicates human actors, the blue indicates non-human factors, and the gray is the local network. The main shortcoming is the global network communicates mainly through a non-human actor to connect to the local network. (Created by Zavacky (2022) with Figma.com)

validation is sometimes lacking from an equity perspective. This project will complete its anticipated aim of understanding racial bias in scheduling algorithms and recommending better solutions by focusing on the perceived breakdown in the point of passage between the local hospital network and global network in this system.

New Network and Negotiation Space

One of the most important aspects of any network is the negotiation space. Law and Callon (1988) argued that negotiation space, and ultimately a project, can fail due to an unclear or unreliable communication liaison between a local and global network (p. 292). In this scenario, the negotiation is far too often an automated process between human and non-human or even non-human to non-human relationship. Any proposed solution should limit the amount of the latter of these interactions and instead favor human to human interactions, especially within the negotiation space. The goal is to ultimately change the communication point and resulting behavior of the actor-network, which is shown below in Figure 3. The result could very well include more work and meetings but should create more equitable processes in the end.

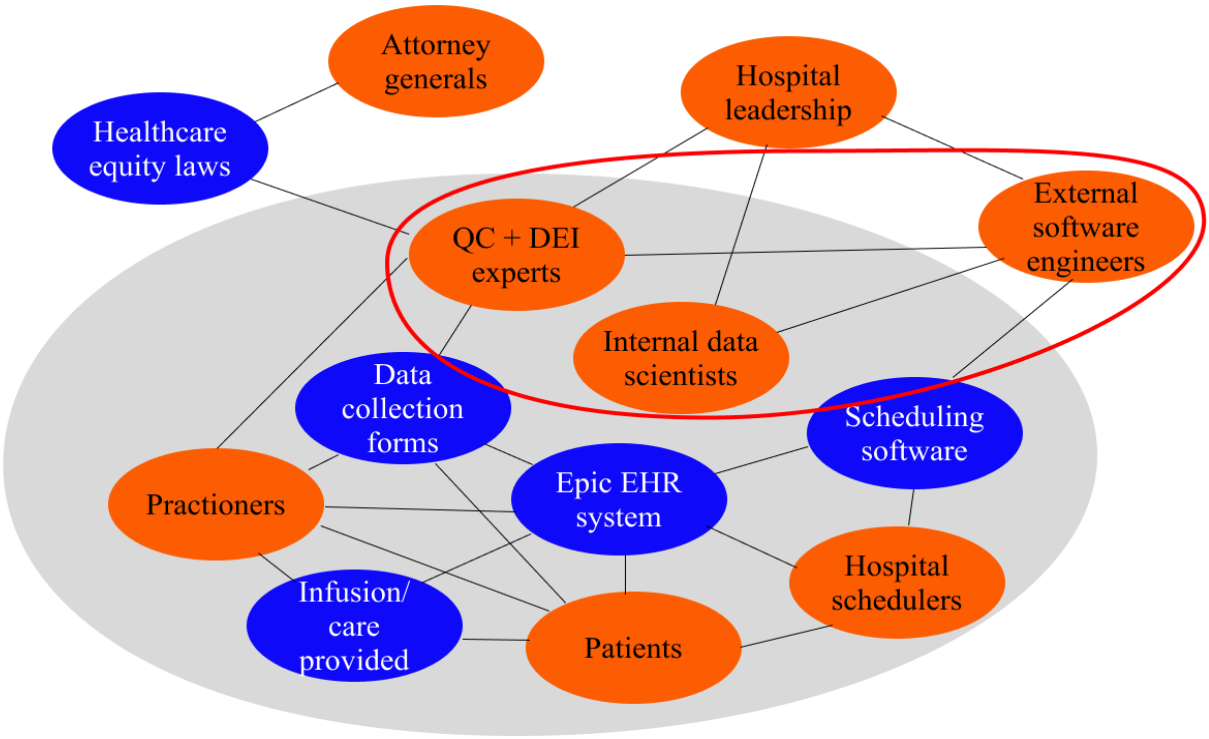

Figure 3: Idealized system actor-network. This figure depicts the actor-network of the ideal healthcare system. The orange indicates human actors, the blue indicates non-human factors, and the gray is the local network. The main change, circled in red, is the global network communicates mainly through knowledgeable human actors to connect to the local network. (Created by Zavacky (2022) with Figma.com)

ENHANCED COMMUNICATION AND DATA FLOW

Connecting Practitioner to Software Engineer

From direct observations and stakeholder meetings for the technical project, it is apparent that there is a disconnect between practitioner and software engineer. In some cases, there is even a disconnect between healthcare leadership and software engineers due to the automated data collection process included in many scheduling algorithms. This software is often outsourced due to better technical experience outside the immediate healthcare field and a lack of resources to complete such a project within the healthcare system itself. Thus, the software engineers have the incentive to advertise the efficiency improvements or cost-saving implications of their algorithm, but there would be little reason on their end to expose unintentional bias or wrong objective function to the healthcare system (Obermeyer et. al., 2019, p. 447). However, creating a more constant and closer connection between practitioner and software engineer will allow the software engineer to better understand the actual workflow, and thus be better equipped at designing a software free of compounding variables in the first place. Conversely, practitioners with a better understanding of algorithm intent can better balance increased data accuracy and documentation for certain stages of their process without overloading the patient with questions. The healthcare system should also dedicate both a technical lead and diversity lead to each outsourced algorithm project. The technical lead, most likely a data analyst or systems engineer, could validate the algorithm logic better than practitioners or leadership, acting as an unbiased judge of the outsourced project. The diversity lead, possibly a very experienced nurse or research nurse, could evaluate any possible confounding that goes above the expertise of an ordinary practitioner or software engineer.

Meanwhile, healthcare leadership should still be present in this process to ensure the overall health system's needs are still met.

Owning Data from Collection to Algorithm Ingestion

Additionally, healthcare systems collect a large amount of data, but the accuracy of this data can be questionable. Based on technical project observations, practitioners opt for their personal documentation methods rather than the outlined methods, which can create discrepancies in the data. Poor data accuracy leads to poor algorithm results, which can manifest in forms of racial bias. Additionally, excess data being fed into a model without proper context or oversight increases the chances of dangerous confounding variables (Samorani et al., 2021, p 2827). Thus, close regulation of the data entry process is integral within the hospital setting. Physical tool improvements, such as linked scanners or measurement devices, should be a focus when regulating the data entry process. These upgraded physical tools will better automate the data collection process, which will increase data reliability and keep patient appointment time safe from added collection time. The same regulation should also extend to algorithm data access. Any addition of new data should require a formal agreement or meeting to ensure patient safety and equity. This meeting will also give the proposed technical and diversity lead to evaluate the logic and possible confounding of an introduction of new data.

SETTING THE STANDARD FOR SAFE ALGORITHM USE

In conclusion, process changes from initial collection to final algorithm creation to continual validation are needed to ensure healthcare equity for all races. However, it is important to remember that healthcare is only one aspect of people's lives. As mentioned earlier, algorithms are being used in the economic and legal systems. The hope is that the general framework described in this paper can be extended to these other large-scale systems, ultimately

creating a more equitable America. While certain process improvement mechanics may vary from field to field, the intent and underlying reasoning behind changes can be applied to any space in which newer algorithms are employed. As technology continues to progress into an age with more advanced algorithms and artificial intelligence, the scrutiny and examination of those employing and creating the algorithms must also increase. It is the responsibility of both software and systems engineers to evaluate these tools both during and after the creation stage. Additionally, the physical tools used to collect the data for such algorithms must also be a focal point for organizations employing this new technology. Healthcare systems and infusion centers save people's lives. Introducing scheduling algorithms and risk algorithms are meant to maximize these lifesaving capabilities for as many people as possible. However, these algorithms only work in conjunction with human wisdom rather than in place of human wisdom. Safe optimization algorithms are born from optimized communication environments.

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