A User Interface Informing Medical Staff on Continuous Indoor Environmental Quality to Support Patient Care and Airborne Disease Mitigation

(Technical Paper)

To Parachute or Perish: A Dive into the Ethical Implications of Parachute Researching

(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

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The Effect of COVID-19 on Indoor Life

December 31, 2019 changed the world forever, as this was the day the novel coronavirus disease (COVID-19) was first reported in Wuhan, China. As threatening as COVID-19 is, it has been shown to be much more dangerous inside buildings (Allen & Marr, 2020). This is a grave problem in places with at-risk people, crowds, significant movement, as well as COVID-19 patients such as hospitals. For businesses and hospitals, returning to indoor spaces can be hard to achieve given the difficulties of air filtration. Air filtration systems promote a safe environment, but it could become very costly to renovate old buildings to improve indoor environmental quality (Balgeman et al., n.d.). These systems are already economically strained because of months of lockdowns, and it could be too expensive for these groups to upgrade their systems. Being able to model these buildings to understand what areas have poor air quality is an important aspect of targeting renovations. Also understanding what organizations need to return to an in-person environment and how to fund these renovations needs to be addressed.

In order to address these problems, this project can be split up into two aspects, a technical topic and an STS topic. The technical topic of this project is to develop a solution to model and visualize through a user interface (UI) the air quality of different buildings, specifically hospitals. This will help us understand which rooms need to upgrade ventilation and the capacity of people each room could be able to have. The STS aspect of this project is to discuss the conflicts surrounding the improvement of indoor air quality between the consumers and adopters. This paper hypothesizes that the people who will benefit from improved air quality and the people who will invest in improving air quality have conflicting interests that will need to be balanced in systems that improve air quality. The anticipated deliverables of this technical work will be a software package? and user interface that could tell a building or hospital what rooms might be susceptible for spreading COVID-19. The STS work ideally will help understand how to solve the future conflict between the consumers and adopters.

Technical Topic: Developing a Solution to Display Air Quality in a Building to Minimize Virus Spread

Our lives have changed drastically since the pandemic started. It's rare for you to see any friends standing less than six feet away at a park or field. Inside environments need to innovate to better protect people from contracting the virus in order to move back to a more normal indoor lifestyle. This has led to more attention being directed towards indoor air quality and its impact on COVID-19 spread (Allen & Marr, 2020). Small businesses and restaurants aren't quite sure how good their ventilation is or how to improve it (Ossola, n.d.). To better understand the potential problems and solutions to implementing safe indoor spaces, our Capstone team wants to design a user interface (UI) that hospitals and buildings could use to inform workers about indoor air quality in different spaces. This ideally will help hospitals and buildings optimize their indoor air quality. To be able to implement this, the project has been divided into two main sections: (1) understanding what data to gather and (2) gathering and displaying the data.

Gathering and communicating information about air quality is very difficult because it is hard to understand how different indoor environments affect virus spread. There are a lot of different factors that can affect the virus spread, and modeling all of them together is even more difficult (Morris et al., 2020). For example, in indoor air in temperate or cold climates, relative humidity values are low, and the droplets will evaporate rapidly to much smaller sizes (Science, 2020). Finding a solution that can work in any of these different environments is a top priority it ideally can work universally. The main consequence if this is not fixed is that it will be very difficult to move back into indoor environments. “Airborne spread of virus between rooms” will keep people from moving back to a more normal life (Balgeman et al., n.d.) plus hospitals and businesses will have a difficult time being sure they have a safe environment.

To understand what data to gather, the capstone team will do a literature review and interviews to get a user perspective to understand what will be useful to them. It was important to find and create models that could be applied to COVID-19 before creating the UI. One way to do this is to use an existing model called the Wells-Riley equation to model poorly ventilated environments (Rudnick & Milton, 2003). This likely will work for COVID-19 as well. Another possible model to use was developed by Morris (2020). Figure 1 illustrates an application of this model. This helps the capstone team understand how particles spread in indoor environments and what metrics could help improve these environments. To understand what data would be useful to users in this UI, there is no better reference than the users themselves. Hospital workers, doctors, nurses, and businesses are the main people that will be targeted to interview. This will help us gain better insight into what they would find beneficial to use and how it could hopefully make their lives easier and safer. It will also give us insight into what information could potentially be useful for them and how to implement a process they would actually want to use.

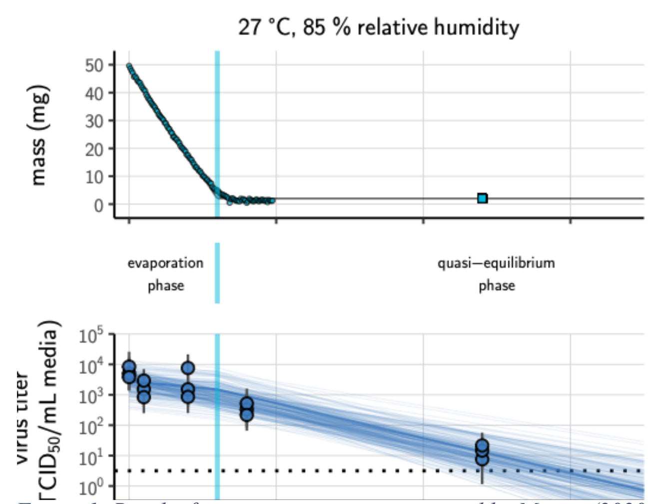

Figure 1: Results from using equation generated by Morris (2020) in a room with 27 degrees Celsius and 85% humidity

The second part of the project is to gather and display data to visualize potential risk problems in a building. To gather the data in each environment, Figure 2 shows sensors made by Awair and a visualization which can be help determine air quality in an environment. This tries to show how close each area is to the ideal inside environment. The ideal inside room in a building would be a room with laminar flow where the air being breathed is constantly fresh or filtered air (Balgeman et al., n.d.). This would be able to completely eliminate COVID-19 from the room. This will be almost impossible to achieve, but there are many techniques that can be used to create airflows that are close to laminar. The two things that can be improved are ventilation and filtration (Ossola, n.d.). Ventilation is making a higher air change rate while filtration is removing airborne particles. To do this for new construction, including a sufficient number of air outlets (Balgeman et al., n.d.) can help filter out the air. For existing structures, upgrading outlets in HVAC systems or replacing outlet covers with new ones that produce laminar flow would both benefit breathability. The specific UI design and recommendations will become clearer as the project develops.

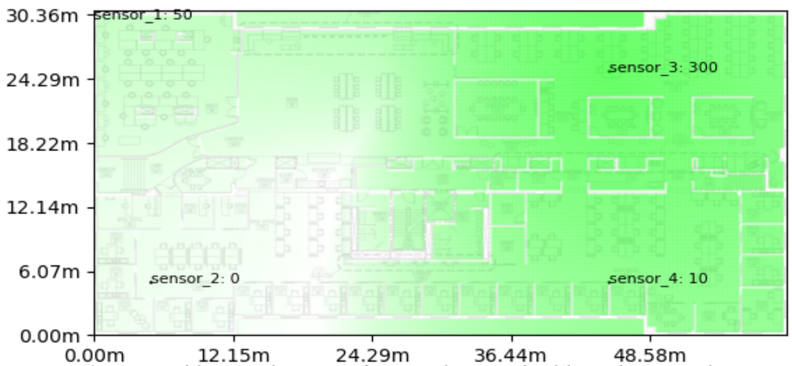

Figure 2: A possible visualization of air quality in a building shown in the Living Link Lab in Olsson Hall at the University of Virginia.

STS Topic: Conflicts Surrounding the Improvement of Indoor Air Quality Between the Consumers and Adopters

This section hypothesizes that the implementation of these new measures could create a conflicting dynamic between both the consumers (people who occupy the spaces) and the adopters (the people who will invest in the air quality improvements). The consumers include workers and consumers who will be inside of these buildings; these are the people that need to be in a safe environment. On the other hand, the adopters are a wide range of groups that need to coordinate, and include organizations such as businesses and building management. This research uses an actor-network and a TOC framework that is supported by the theory of controversies described in “Diving in Magma” (Venturini, 2010) to predict and hypothesize that these two groups of people will be in conflict and how to find a solution.

The difference in perspective between adopters and consumers will put them in conflict that will cause a controversy according to Venturini. He describes a controversy as “situations where actors disagree” (261). The paper discusses how different actors described in actor network theory have conflict and tension that create a controversy when these tensions cannot be ignored anymore. This likely will happen to consumers and adopters of better air quality measures. Businesses that need to go back to normal in-office environments to be able to start making money again might not have the necessary air quality or air filtration systems (Ossola, n.d.). The consumers in general want to be in a safe environment and older buildings might have trouble implementing this without significant renovations. The consequences of not solving this controversy will be detrimental for public health as most likely spaces will not be safe for citizens and customers to interact in.

To solve this problem, government regulators will need to play a large role in funding or incentivizing businesses to improve their ventilation or filtration. Right now the government is "not supporting small businesses to assess their ventilation and get air cleaners" and no state or federal government has suggested requiring a rating system for ventilation required in building codes (Ossola, n.d., n.p.). This poses a challenge but could be partially be solved by understanding what businesses need the most assistance. Many businesses have started moving permanently to remote work (Loten, 2020). Identifying the businesses that are least likely to continue with? remote work would be an important first step to help solve this controversy as this will greatly decrease the financial cost. Another possible way to decrease the cost would be by identifying businesses that can open windows or adjust building conditions (CDC, 2020). These have both been shown to be very effective ways to mitigate COVID-19 spread. The final deliverable could be an economically reasonable way to identify vulnerable businesses that would need government funding to upgrade their ventilation and filtration systems.

Conclusion

The anticipated deliverables of this technical work would be a software and user interface that could tell a building or hospital what rooms might be susceptible for spreading COVID-19. This could lead to possible recommendations for what to upgrade to improve their environmental air quality. The STS deliverables include identify vulnerable businesses that would need government funding to upgrade their ventilation and filtration systems.

If these deliverables are successfully implemented, it will help hospitals and businesses to manage COVID-19 exposure and help life return to normal. It will also improve the air quality which would help keep citizens safe from other airborne viruses in the future.

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