A BREATH OF FRESH AIR: TOWARDS OPTIMAL INDOOR AIR QUALITY

INVESTIGATING INTERVENTION STRATEGIES FOR ENHANCING OCCUPANTS AWARENESS, COMFORT AND HEALTH

SUBMITTED IN PARTIAL FULFILLMENT FOR THE DEGREE OF MASTER OF SCIENCE

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ABSTRACT

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KEYWORDS

Human-Building interaction, Indoor air quality, Living Lab, Data physicalization, Smart buildings, User-centered design.

1 INTRODUCTION

Globally, it is estimated that people spend approximately 90% of their time indoors [3, 5] and breath 11.000 liters of air per day [1]. Suboptimal indoor air quality (IAQ) conditions affect building occupants' experiences of comfort and insufficient ventilation in indoor spaces is proven to play significant roles in occupants' well-being, health and cognitive functions [2, 7].

The research into the influence of Indoor Environmental Quality (IEQ) [4] on occupants', including acoustic, thermal and visual conditions, is gaining more attention espicially the field of indoor ventilation. One core aspect of air quality is its invisibility to occupants [6], polluted air is not easily detected by smell or sight. Additionally, mechanical ventilation systems in buildings operate discreetly, contributing to occupants' perceived lack of control since these systems are typically automated and cannot be directly regulated or controlled by occupants themselves.

This thesis focuses on understanding occupants' needs through in-the-wild studies measuring indoor air quality in specific spaces (e.g. meeting rooms) and arprototyping various persuasive technologies and data physicalization devices to visualize indoor air quality and evaluating their effectiveness with the overall goal of gathering insights into occupants' comfort levels and helping them to take preventive action against poor indoor air quality. This creates an interplay between occupants' health and comfort, architecture and built environments, and computing technologies.

Researching occupants' subjective needs, experiences, and behavior, coupled with a human-centric design approach, has the potential to improve occupants' well-being and create indoor environments with good indoor air quality. Furthermore, it provides valuable insights to faculty staff in making decisions in setting up ventilation systems, arranging indoor spaces, and informing architecture and interior design studios on making decisions about structuring spaces and integrating computing technologies within built environments.

While research on defining comfort within indoor buildings, gathering and analyzing sensory indoor climate data, and the effects of poor air quality are prevalent, there is a gap in understanding occupants' behavior and their subjective needs, along with limited research on how design solutions visualize environmental data and computing installations can empower occupants, particularly within the field of physically visualizing data to convey IAQ to building occupants in real-time.
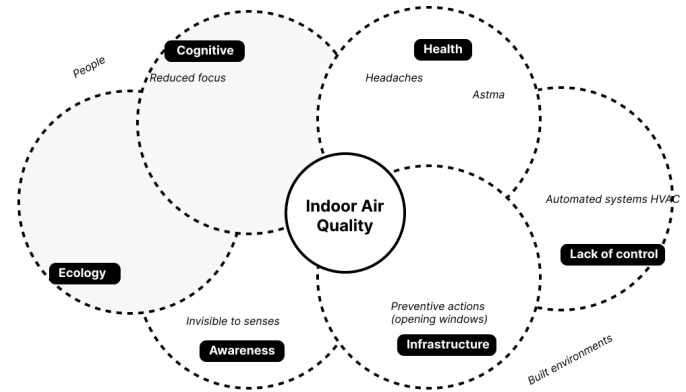

Figure 1: Complexity diagram providing an overview of the effects of Indoor Air Quality and needs of occupants

1.1 Research questions

In order to research intervention strategies for improving indoor air quality, the following main research question is formulated:

RQ: How can real-time sensory measurements and future predictions of air quality be physically visualised in specific indoor spaces integrating both environmental information and elements that increase awareness among occupants facilitating their adoption of preventive measures against poor air quality?

To effectively answer this main research question, this research is guided by the following supporting sub-questions that also serve as objectives to delineate the necessary knowledge:

- **SRQ1:** *How can environmental information related to air quality, such as pollutant concentrations and ventilation rates, be incorporated into the visual representations?*
- **SRQ2:** *How do different types of physical visualizations impact occupants' understanding of air quality and their willingness to adopt preventive measures?*
- **SRQ3:** *How do occupants' perceptions and behaviors regarding indoor air quality change over time, from pre to post-installation of the physical representation of poor air quality?*

2 RELATED WORK

Write about your related work here. Make clear to which key papers you will compare your eventual results. This can be done from the perspective of methods used, the task at hand and the addressed domain.

3 METHODOLOGY

Write about your methodology here. Focus on your own contribution. Indicate exactly how you will assess your work in terms of evaluation.

4 RESULTS

Write about your results here. Good captions to tables and/or figures are key.

5 DISCUSSION

Write your discussion here. Do not forget to use sub-sections. Normally, the discussion starts with comparing your results to other studies as precisely as possible. The limitations should be reflected upon in terms such as reproducibility, scalability, generalizability, reliability and validity. It is also important to mention ethical concerns.

6 CONCLUSION

Write your conclusion here. Be sure that the relation between the research gap and your contribution is clear. Be honest about how limitations in the study qualify the answer on the research question.

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Appendix A   ACKNOWLEDGEMENTS

My sincere gratitude to all the participants who generously contributed to this study by dedicating their time to respond to the surveys and questionnaires voluntarily, as well as those who willingly tested and interacted with the prototype. Special appreciation goes to everyone who supported me in data analysis, provided hardware for the prototypes, and reviewed and tested the code for the hardware devices.

A thank you to supervisor, Dr. H. Seiied Alavi (University of Amsterdam), for his invaluable guidance, though-provoking questions, and overall assistance throughout the project and Dr. Shruti Rao (University of Amsterdam) for her constructive feedback and suggestions, which further expanded this research. Also, my sincere appreciation to all the reviewers of this research for their insightful comments and contributions.

Appendix B   ETHICAL CONSIDERATIONS

Before user studies were conducted, an application to the Ethics Committee for Information Sciences (ECIS) [1] about the methodology of this research, how data is being gathered and stored was made. Advice from the committee is still pending.

Prior to conducting the questionnaire survey and evaluation procedure, a domain expert from the Informatics Institute at the University of Amsterdam reviewed the methodologies involved. All individuals participating in the survey and evaluation process were obliged to confirm their voluntary involvement by carefully reading and signing a letter of consent, with the assurance that they retained the right to withdraw from participation at any point without the need for explanation. To uphold confidentiality and privacy, survey participation occurred anonymously, and all evaluation data underwent anonymization following the conclusion of the evaluation sessions.

Interacting with occupants within the building and interacting with participants of the usability tests of the prototype adhered to the the principles outlined in the UvA code of conduct [2].

Appendix C   DATA STORAGE AND ARCHIVAL

Take some parts of the ethical application to describe data storage and archival of the devices etc.

Appendix D   SOURCE CODE

In the spirit of open research, to support reproducibility and enable future work in this problem space the datasets, research notebooks, and prototypes in this work are publicly available on a GitHub organization with the working title 'viszlab' [3] using the MIT License. Several code repositories for different parts of the research can be accessed. The readme.md of the repository described the contents and how to perform the technical set-up:

(1) **Prototype**. Code and models for the physical prototype.
https://github.com/viszlab/prototype
(2) **Datasets**. Code and models for the physical prototype.
https://github.com/viszlab/prototype

A one-page website was created for shareability of this research. It's an online website which gives an overview of the research, allows for viewing the source coded of the prototype and allows for downloading of this paper. A live version is deployed on:

(1) **One-pager**. Code and models for the physical prototype.
https://viszlab.github.io/

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[1]https://ivi.uva.nl/research/ethical-code/ethical-code.html
[2]https://www.uva.nl/en/about-the-uva/policy-and-regulations/
[3]https://github.com/viszlab

Appendix E FLOORPLAN AND LAB SET-UP

A diagram indicating where the sensors where installed. This shows the lab set-up in the two meeting rooms.
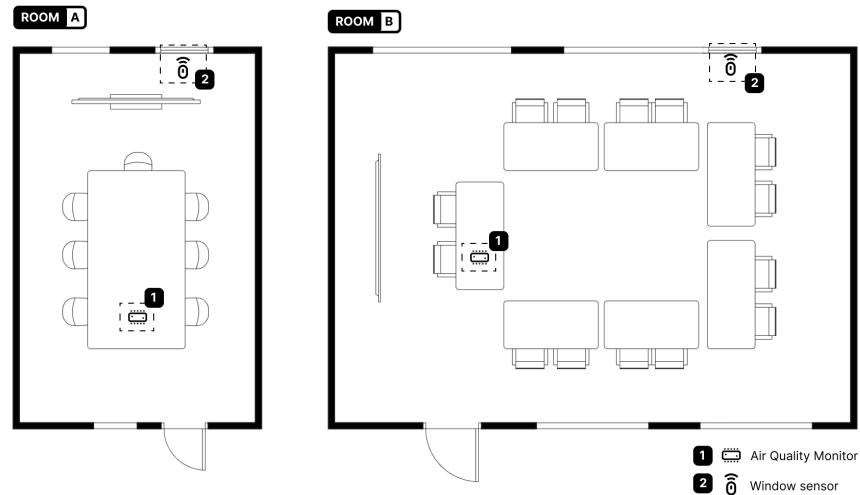

Figure 2: Diagram of the floorplan with sensors installed

Appendix F IOT ARCHITECTURE OF THE PROTOTYPE

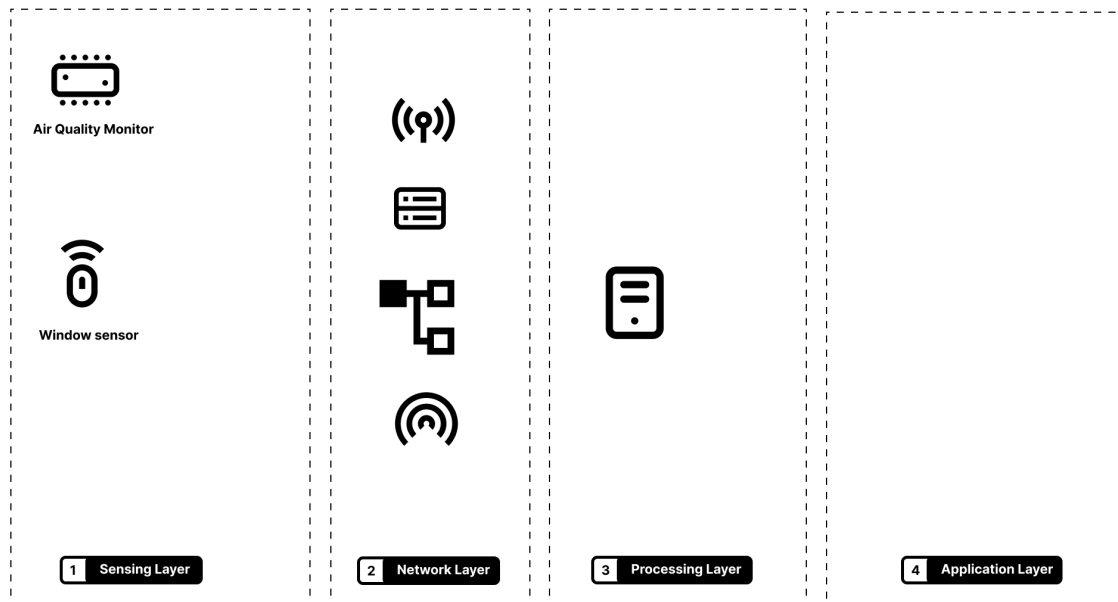System diagram which shows the IoT architecture of the prototype.

Figure 3: System diagram that shows the technical set-up of the prototype

Appendix G   MEETING ROOM IMPRESSIONS

Figure 4: System diagram that shows the

Figure 5: System diagram that shows the

Appendix H   PROTOTYPE IMPRESSIONS

(a) first

(b) second

(c) third

(d) fourth

Figure 6: caption

Figure 7: System diagram that shows the