NEED TO DO[[1]](#footnote-1)

Tool for measuring welfare parameters(May 2025)

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*Abstract*— This paper discusses change traceability in Building Information Modeling (BIM) using Augmented Reality(AR). BIM refers to a 3D model of a building that includes details such as materials, placement, and other critical data. However, BIM as a modeling tool was not designed initially to keep track of and compare changes across different versions within AR. Therefore, this study bridges this gap by finding ways to allow better traceability within BIM in an AR environment. It focuses on methods for comparing different BIM versions and appropriate visualization of these changes for the user. To realize this, a head-mounted display called Xreal Light was used for the AR-based visualization of BIM models. Using Industry Foundation Classes (IFC) the application was implemented in Unity, which allows an interactive and immersive experience, and thus makes it easier to realize changes between different BIM versions. The results of the research were mixed. The participants found that the AR application features, like color coding and decision cards, were beneficial for understanding the changes and informing stakeholders who are not deeply involved in the project. But they also stated that BIM software offers more advanced features like filters and clash detection.

*Index Terms*— Augmented Reality, Building Information Modeling, Industry Foundation Classes, Traceability

# INTRODUCTION (NEED TO DO)

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n today's workplace, employee well-being is becoming a significant part of productivity and job satisfaction. Stress is one of the leading causes of work discomfort and can have negative impacts on physical and mental health. Therefore, the ability to measure and monitor stress-related physiological parameters effectively plays a critical role in creating a healthier workplace.

This thesis focuses on the development of a portable and miniaturized stress measurement device using physiological sensors interfaced with an Arduino Nano ESP32. With the inclusion of a MAX30102 optical heart rate sensor and a Grove - GSR Sensor for skin conductivity measurement, the device can capture real-time biometric readings of stress levels. Such physiological signals provide valuable feedback on an individual's stress response and allow for constant monitoring of well-being during work activity.

The aim of this project is to create and implement a system that not only collects data but also presents it in a useful format through a dedicated application. The application will enable users to real-time heart rate and and skin conductance data. The hardware and software in this project are designed to provide a simple tool for measuring workplace well-being.

To achieve this, the research first explored relevant sensor technologies used to measure stress. This is followed by developing a system architecture that would ensure seamless communication between the sensors and Arduino and data processing and visualization in the app.

By providing a low-cost and user-friendly solution to stress monitoring, the project aims to be a contributor to the new wave of workplace well-being technology and a foundation for more data-based solutions for managing stress.

# Related work (NEED TO DO)

## Traceable design rationale in Augmented Reality

In recent years, the integration of BIM in AR has shown great potential in improving the visualization of architectural projects, however, the challenge of tracing the changes within these projects receives little attention. Previous studies, such as the research done by Ceyssens et al. (2020) [2], have highlighted the lack of tools supporting this traceability. It showcases the ability of decision cards, highlights, pinpointing annotations to specific locations and visually comparing new or removed parts to allow stakeholders to trace the evolution of a design. The participants of the study found the highlighting of removed and added objects useful and would like to see such highlights for more changes. The study did note that highlights would not scale well with a large number of changes and that highlighting is not effective for non-visual changes. This paper aims to build on these results for tracking the changes in different versions of BIM models.

## Decision rationale using decision cards

Decision documentation plays a critical role in traceability throughout the design process. Studies have shown that a tool that documents and externalizes the design rationale is important to do this efficiently. Research by Lopez et al. [3] indicated that making a design more rationale makes it more acceptable and easier to understand for stakeholders from different backgrounds. To document a design rationale, they tested a tool called a decision card. The research explores how designers use the decision card to document their design decisions and how the decision cards help when presenting to team members. Results showed that the decision cards are effective, user-friendly tools for documenting and externalizing design rationale. A lab study showed that practitioners not involved in the design process were able to easily understand the structure of the decision cards. This indicates that the tool can be used to effectively communicate with stakeholders outside the project. The study does note that a disadvantage of the decision cards is the time spent to document all the information of the decisions. In this paper about traceability of changes in BIM, the decision card is used to simplify tracking changes throughout the life cycle of a BIM model and to make it easier to explain why these changes were made to stakeholders who are not as closely involved in the project.

## Application of AR/VR in construction project management

The use of AR and Virtual Reality (VR) is increasing across various industries like education, healthcare and entertainment. Even though the construction industry is traditionally slower in digitizing, AR and VR are becoming a tool to enhance communication and collaboration in a project’s lifecycle [4].

The article written by Albahbah et al. [4] investigates the knowledge that exists about using VR and AR for construction project management. Several studies indicated that AR and VR have several benefits within architecture, engineering and construction industries. Areas such as cost and time management, defect management, safety management and training within project management have been proven to be significantly better using these technologies.

Communication and data acquisition are an important part of a successful project. Several studies have explored the use of AR to improve the collection of information and communication amongst shareholders. The findings suggest that AR can enhance on-site decision-making, collaboration with various stakeholders and safety management through improved information retrieval and field communication. It has been successfully used in applications like building inspections, construction progress monitoring and defect management. These studies demonstrate the potential of AR and VR to improve visualization, collaboration and project execution. Building on these benefits of AR, this study investigates the use of AR in combination with BIM for the traceability of changes and their potential to improve project outcomes.

# Methods and materials (STARTED BUT NOT FINISHED)

## Arduino Nano ESP32

The stress measuring device is powered by an Arduino Nano ESP32 which is based on the ESP32-S3 System on Chip. The main reason for using this microcontroller instead of other Arduino microcontrollers is the presence of Bluetooth and Wifi. In this project the Bluetooth is used to wirelessly transmit the sensor data to a smartphone that runs software to present and visualize the stress level and the measurements. Other criteria for choosing this microcontroller include:

* Compact size
* Low power consumption
* Dual-core processor for real-time processing of sensor readings
* I2C interface, used by MAX30102 and MAX30205 for communication

Because it is so compact and energy efficient it is ideal to use in a portable device.

## MAX30102

The MAX30102 is an optical biosensor that measures the subjects heart rate and blood oxygen level(SpO2) and uses the I2C interface for communication with the microcontroller. Because it is a small sensor with a low power need, it is optimal to use in wearable/mobile devices.

The sensor includes LEDs, photodetectors and low-noise electronics capable of ambient light rejection. Although it contains ambient light rejection, it is still advised to limit the ambient light interference to get the most accurate result. The LEDs consists out of a red LED and an IR LED which are used to extract heart rate and SpO2 using signal processing.

Heart Rate Variability (HRV), derived from heart rate measurements, is a strong indicator of stress level. Which makes this sensor a vital inclusion in the stress measurement. Its compact design and low-power make it optimal for continuous monitoring of the heart rate.

## GSR Sensor

The Galvanic Skin Response (GSR) sensor measure the skin conductance, which varies with sweat activity. Because this is connected to the nervous system it is a good indicator for stress level.

It works by placing two electrodes on the skin (usually fingers) and applying a small amount of voltage. The difference in conductance gets measured. A higher conductance indicates a higher sweat level which can be the result of a higher stress level.

## MAX30205

The MAX30205 is a body temperature sensor. This sensor has a high accuracy with a precision of ±0.1°C. This sensor, just like the MAX30102, uses the I2C interface for communication with the microcontroller.

Change in body temperature can be linked to stress response. The MAX30205 works alongside the HRV to improve the stress analysis. Combing temperature, HRV and GSR results in a comprehensive stress analysis.

# User study (NEED TO DO)

In the user study, the participants tested the efficiency of the AR application and used their experience with 3D modeling software to compare the AR application and the software. Before starting the study, the participants were guided through a demo version to introduce the features and lower the initial learning curve. The study was divided into two phases: tasks during the study and a post-study survey. During the study, the participants were asked to document changes and provide a reason for these changes. Adding to this, they were asked to measure the distance between walls in different versions. After completing the tasks, participants were asked about their experience using the AR application. These questions evaluated the ease of use, the confidence in capturing and understanding the changes, the benefits of spatial awareness and their overall preference between AR and 3D modeling software. Using quantitative data from rating scales, the overall effectiveness of the AR tool was assessed. The follow-up questions, such as asking for an explanation of a score or what features should be integrated into the software, offered a perspective on the strengths and weaknesses of the tool.

# Result

For the user study participants from different fields were asked to perform tasks using the AR application. After the tasks were performed, their opinion about the application was asked. 2 participants came from architecture, 2 from project management and 1 from BIM drafting. They were around 23-26 years old, as BIM is a relatively new upcoming technology.

The user study showed that in comparison to the familiarity with AR, the familiarity with 3D modeling was high with an average rating of 4,6 (5 being the highest). Opinions about the usability of the AR applications were mixed. The clear visualization and spatial context of the changes and the small learning curve of finding the information were beneficial certainly to explain it to people who are not following the project closely, but participants stated that BIM offered more advanced features such as filters and clashes. The AR application would benefit from making a UI that cannot have as many pop-up windows open at the same time. Adding filters that can filter on a specific modification, or object or can filter per job (ex. filter for plumber only shows the pipes) would make the AR application more user-friendly.

The confidence in capturing all changes was very high with an average score of 4,2 out of 5. A feature like the color coding and removal of other objects when a certain change is clicked puts the focus on the changed object. This in combination with a description of the changes in plain text makes the change easy to find and understand. Following a participant, the downside of using plain text to describe a change is that this has to be well documented throughout the process. Adding keywords of the change (removed, added, …) at the back of each object in the list combined with in number on the object itself corresponding with the number in the changes list would result in an even higher confidence level.

With an average score of 4 out of 5, the user study indicates that AR for tracking changes would be beneficial. Certainly for bigger real-world projects if they are looked at per room. For smaller projects, it would be too time-consuming to track all the changes. A participant stated that orienting in a larger building can be too difficult to orient and have too many changes. A solution for these drawbacks can be using a small map for orientation within a bigger building and using lists of changes per room. Another drawback of using the AR glasses Xreal Light is that light can interfere with the display and can make the AR display lag, making the visualization less clear. A positive of using AR is that the possibility to track the changes on site is less confusing and prevents overlooking small details. AR in combination with the added features of this research would help to explain the process to stakeholders that are not directly involved with the making of the project.

# Discussion (NEED TO DO)

Just like research [2], this research shows that participants appreciated the decision cards and highlights of the object within a BIM model. The use of plain text within the decision cards helps with explaining the decisions that were made. Similar to findings in research [4], this study indicates that AR could be a useful tool within the construction industry. The study did show that participants forgot about the buttons that were on the phone’s UI. Making that the list was activated by such a button, it was overlooked easily. A suggestion for future applications is to put the buttons in the view of the user to lower the learning curve of the application.

A significant limitation of this study is the small user study size, comprising only 5 participants, all under the age of 27. This demographic may not fully represent the broader range of users, particularly older professionals, who might experience a steeper learning curve with AR applications.

# Conclusion (NEED TO DO)

Based on the results of the user study, the use of AR applications to trace changes within BIM models shows significant potential. Although the participants were more familiar with 3D modeling software they stated that AR, combined with more advanced features such as filters, show considerable benefits. The spatial awareness and the ease of change explanations and their visualization make it an effective tool for communicating with all stakeholders, even if they are not deeply involved in the project. The high confidence in the AR application's ability to track changes suggests its potential as a valuable tool in the construction industry, especially with future enhancements like keyword integration and improved object-linking mechanisms. For future research, it is recommended to integrate more advanced features, such as filtering and clash detection, while maintaining or improving a user-friendly interface minimizing the learning curve. Another recommendation is researching how orienting in a bigger building can be made easier, for example by using a mini-map.

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