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Design and Development of an XR Assistance System for Industrial Workers

vorgelegt von
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Saarbrücken, Tag. Monat Jahr

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Zusammenfassung

Kurze Zusammenfassung des Inhaltes in deutscher Sprache, der Umfang beträgt zwischen einer halben und einer ganzen DIN A4-Seite.

Orientieren Sie sich bei der Aufteilung bzw. dem Inhalt Ihrer Zusammenfassung an Kent Becks Artikel: `http://plg.uwaterloo.ca/~migod/research/beckOOPSLA.html`.

We have seen that computer programming is an art,
because it applies accumulated knowledge to the world,
because it requires skill and ingenuity, and especially
because it produces objects of beauty.

Danksagung

Hier können Sie Personen danken, die zum Erfolg der Arbeit beigetragen haben, beispielsweise Ihren Betreuern in der Firma, Ihren Professoren/Dozenten an der htw saar, Freunden, Familie usw.

Contents

1 Introduction

In modern industrial environments, ensuring the safety and well-being of workers is an increasingly complex challenge. This is due to the rise in automation of factories, which has led to workers being exposed to a range of risks from moving parts to robots. Traditional safety measures like warning signs, floor markings, and standard training provide a necessary foundation, but they are not always sufficient. In many cases, these static systems fail to reach workers at the right moment, especially when attention is focused elsewhere or hazards change rapidly. These systems require real-time adaptation and individualization.

To protect workers more effectively, safety solutions must become adaptive, personalized, and accessible. They must understand the individual context of the worker: how they move, where they are in the environment, and when they may be at risk, whether from poor posture, fatigue, or close proximity to danger zones.

Advances in extended reality (XR) and wearable technology, such as full-body haptic suits and immersive head-mounted displays, are opening new avenues for real-time assistance and feedback systems. These technologies are no longer confined to research labs or entertainment industries but are being increasingly considered for applications in healthcare, rehabilitation, training, and industrial safety. In this context, integrating real-time physiological and spatial data with immersive and haptic feedback presents a promising opportunity to enhance worker safety in hazardous zones.

Based on the identified challenges and objectives, this thesis investigates the following research questions:

1. **RQ1:** How effectively can physiological and postural data from the Teslasuit be used to detect unsafe posture in real time?
2. **RQ2:** What latency thresholds are acceptable for haptic and visual feedback in XR-based industrial safety systems?
3. **RQ3:** How can spatial data from XR devices be aligned with sensor data from wearables to create a reliable danger zone alert system?
4. **RQ4:** How do users perceive the comfort, usability, and intrusiveness of an XR-based safety assistance system during typical industrial tasks?

This thesis explores how such a system could be designed and deployed. Specifically, it proposes an XR-based assistance framework that helps workers stay safe by making risk visible, posture perceptible, and hazards tangible. By integrating real-time motion, biometric, and positional data, the system aims to provide immediate, personalized support without disrupting the workflow or overwhelming the user. Rather than replacing human judgment, it enhances situational awareness and supports safer, more ergonomic behavior in industrial settings.

2 Motivation

Modern industrial environments are increasingly characterized by high levels of automation, dynamic workflows, and close interaction between human workers and complex machinery. While these developments have improved efficiency, they have also introduced new safety challenges. Workers are required to perform physically demanding tasks in proximity to moving parts, robotic systems, and other potential hazards. In such conditions, it is hard for workers to maintain constant situational awareness, leading to an increased risk of accidents and injuries.

Returning to the typical workstation on an assembly line, an XR based assistance system utilizing information about it's environment Traditional safety measures—such as fixed signage, floor markings, or general training programs provide an essential baseline but are inherently limited. They rely on the worker's ability to notice and process external warnings while engaged in their primary tasks. This static approach does not account for the worker's individual posture, or the evolving state of their environment. As a result, critical risks may go unnoticed until it is too late.

There is a clear need for safety systems that are adaptive, personalized, and context-aware. Such systems must continuously monitor the worker's physical state and spatial position, detect unsafe situations as they emerge, and deliver warnings through intuitive, non-disruptive channels. Advances in Extended Reality (XR) and wearable technologies offer a unique opportunity to meet these requirements. Head-mounted displays can overlay hazard information directly into the user's field of view, while full-body haptic suits can provide spatially localized alerts that are instantly understood without diverting visual attention.

The XR-based assistance framework proposed in this thesis addresses these needs by combining immersive visualization with real-time haptic feedback, powered by continuous analysis of physiological and positional data. Unlike existing solutions, it adapts its feedback to the worker's specific context, enabling timely interventions without distracting the worker. In doing so, it has the potential to reduce the risk of acute injuries, prevent the development of musculoskeletal disorders, and improve overall situational awareness in industrial environments.

The urgency for such a solution is amplified by current industry trends: increasing automation, a growing focus on occupational health, and the wider availability of high-performance, affordable XR and wearable devices. Now is the right time to explore how these technologies can be integrated into practical safety systems that protect workers without compromising efficiency.

3 Theoretical Background

This chapter outlines the conceptual and scientific foundations relevant to the development of an XR-based assistance system for industrial workers. It introduces key technologies, principles of ergonomics, human-machine interaction modalities, and architectural tools that enable real-time support in complex environments.

3.1 Extended Reality in Industrial Contexts

Extended Reality (XR) technologies are increasingly being explored beyond their origins in gaming and entertainment. In recent years, they have shown significant promise for applications in healthcare, education, training, and particularly in industrial environments [**palmarini2018ar**, **portman2022xrsurvey**]. These immersive systems offer novel ways to visualize information, monitor surroundings, and interact with complex machinery or digital twins in real time.

In industrial settings, XR can bridge the gap between human workers and automated systems by enhancing spatial awareness, reducing cognitive load, and supporting ergonomically sound behavior [**makransky2019vrlearning**, **nee2012ar**]. By embedding visualizations directly into the user's perceptual field and supplementing them with spatially anchored cues or haptic feedback, XR opens new pathways for context-sensitive assistance. This is especially relevant in environments that involve repetitive tasks, heavy machinery, or dynamic hazards—scenarios in which traditional safety protocols may fall short [**palmarini2018ar**].

This section introduces the conceptual foundations of XR, outlines its most common industrial applications, and discusses the key challenges and opportunities associated with deploying XR systems in real-world industrial settings.

3.1.1 Definition and Taxonomy

Extended Reality (XR) is an umbrella term encompassing a spectrum of technologies that combine or replace real-world perception with computer-generated input. The conceptual foundation for this spectrum was introduced by Milgram and Kishino in their seminal work on Mixed Reality visual displays [**milgram1994taxonomy**].

At the core of their model lies the *Reality–Virtuality Continuum*, which represents a scale between the completely real environment and the fully virtual environment. Technologies within this continuum can be classified as follows:

- **Real Environment (RE):** The physical world, unmediated by digital augmentation.
- **Augmented Reality (AR):** Systems that overlay virtual elements onto the real world while maintaining real-time interaction and correct spatial registration. Examples include visual annotations or digital twins of industrial machinery displayed through XR headsets.
- **Mixed Reality (MR):** A broader concept encompassing AR, but also allowing for deeper integration where virtual and real elements interact and are spatially and temporally consistent. In MR, digital and physical objects can influence each other.

- **Augmented Virtuality (AV):** Mostly virtual environments that incorporate some real-world data—such as sensor streams or camera feeds.
- **Virtual Reality (VR):** Fully immersive digital environments with little or no real-world input.

XR, as used in this thesis, refers to the entire continuum and highlights systems that combine immersive visualization (e.g., via head-mounted displays) with real-world input data (e.g., motion capture, spatial localization, physiological sensors). This definition is especially relevant in safety-critical industrial contexts, where virtual feedback must accurately reflect physical risks and user behavior in real time.

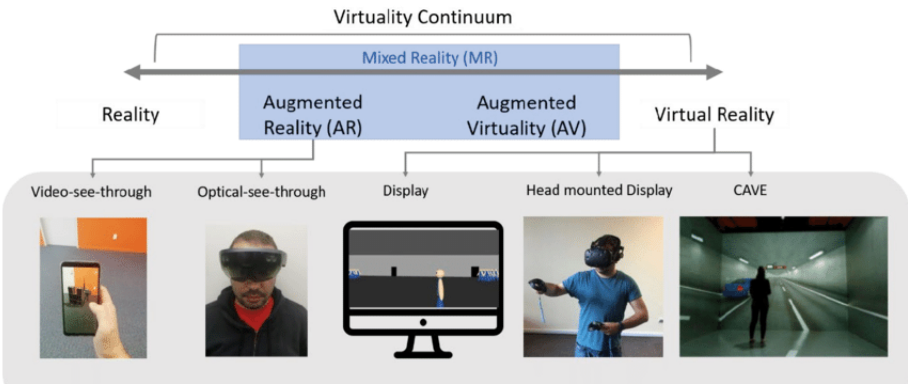

Figure 3.1: The Reality–Virtuality Continuum, adapted from Milgram and Kishino [**milgram1994taxonomy**].

3.1.2 Applications of XR in Industry

3.2 Human Factors and Ergonomics

3.2.1 Rapid Upper Limb Assessment (RULA)

As Posture Assessment Method, this thesis utilizes the Rapid Upper Limb Assessment (RULA) to evaluate the ergonomic risk associated with a worker's posture. RULA is a survey method designed to assess biomechanical and postural loading on the upper limbs [**MCATAMNEY199391**]. It is particularly useful in environments where workers perform repetitive tasks or maintain static postures for extended periods. Due too limiting factors of the Teslasuit, a limited version of RULA is used excluding loads carried and arm support. The assessment involves scoring various body segments, including the upper arms, lower arms, wrists and neck based on their angles and positions. Each segment is assigned a score based on its deviation from neutral posture, with higher scores indicating greater ergonomic risk. The scores are then combined to produce an overall RULA score, which categorizes the risk level and suggests the urgency of intervention. The RULA method is widely used in occupational health inform ergonomic interventions aimed at improving workplace safety and comfort.

subsectionRapid Entire Body Assessment (REBA) REBA is another ergonomic assessment tool that evaluates the entire body. It functions similarly to RULA in the sense that it scores body segments based on their positions and movements.[**chiasson2012comparison**] However, REBA is more comprehensive and as such more complex than RULA, making it less suitable for real-time applications. Additionally factoring in the lower body would require the to wear the entire Teslasuit which is counterproductive to the goal of creating a system that is easy to use and as unobtrusive as possible. Therefore, REBA is not used in this thesis.

3.2.2 Muscoloskeletal Disorders (MSDs)in industry

"Musculoskeletal disorders include a wide range of inflammatory and degenerative conditions affecting the muscles, tendons, ligaments, joints, peripheral nerves, and supporting blood vessels. These include syndromes such as tendon inflammations and related conditions, nerve compression disorders, and osteoarthrosis, as well as less well standardized conditions such as myalgia, low back pain and other regional pain syndromes not attributable to known pathology. Body regions most commonly involved are the low back, neck, shoulder, forearm, and hand." [**punnett2004wrmsd**] MSDs are the largest category of work related illnesses the united states, nordic countries and japan. Whereas in Industries such as for example heavy and light manufacturing the frequency of MSDs is three to for times higher than in other industries [**punnett2004wrmsd**]. Some of the features frequently cited as risk factors for MSDs are repetitive motion, high pace of work and non-neutral postures [**punnett2004wrmsd**]; these are all features that can be found in modern industrial environments. Highlighting both the economic and human cost of MSDs, as well as the relevance of the problem in modern industrial environments.

3.2.3 Need for Real-Time Monitoring

Traditional ergonomic assessments, such as RULA or REBA, are typically applied asonetime observational surveys during workplace evaluations. While these methodshave proven valuable for identifying high-risk tasks, workers' postures, physical loads, and environmental conditions fluctuate dynamically during a shift. A snapshot analysis cannot capture the variation of these factors, leading to potential underestimation of risk exposure.

Recent advances in wearable sensing and extended reality systems make it feasible to move beyond periodic ergonomic audits towards continuous, real-time monitoring. Wearable inertial measurement units, haptic suits, and vision-based tracking can provide ongoing streams of biomechanical data, enabling posture recognition and ergonomic risk scoring on the fly [**syberfeldt2016vrar**, **portman2022xrsurvey**]. When integrated into XR environments, such systems allow adaptive feedback that alerts workers before musculoskeletal strain develops or before entering hazardous areas.

Real-time monitoring therefore represents a paradigm shift: from retrospective identification of risk to proactive prevention. By continuously processing physiological and spatial data with ergonomic models such as RULA and REBA, XR-based systems can provide immediate, context-sensitive feedback without interrupting workflow. This capability is particularly important in dynamic industrial settings where human workers operate in close proximity to machines and robots, and where static safety protocols are insufficient to ensure long-term health and safety.

3.3 Wearable Technologies for Assistance

Wearable technologies have gained increasing relevance in industrial contexts as tools for safety, monitoring, and human-machine interaction. By continuously capturing biometric, postural, or spatial data, they enable real-time assistance and adaptive feedback. This section highlights the most relevant classes of wearables for industrial safety systems, with a particular focus on the Teslasuit and the Meta Quest 3, which form the hardware basis of this framework.

3.3.1 Overview of Industrial Wearables

Industrial wearables span a broad spectrum of devices, including smartwatches, exoskeletons, head-mounted displays (HMDs), and full-body sensor systems. These devices are designed to augment workers' capabilities by monitoring physiological signals, capturing motion, or overlaying digital information on thephysical workspace. Applications include fatigue detection, posture monitoring, safety training, and real-time hazard warnings [**de2019industrialwearables**, **syberfeldt2016vrar**]. Wearables are increasingly integrated into industrial IoT infrastructures, allowing their data streams to be combined with machine sensors and environmental data for context-aware decision support [**portman2022xrsurvey**].

3.3.2 The Teslasuit

The Teslasuit is a full-body wearable that integrates motion capture, haptic feedback, and biometric sensing. Its motion capture system is based on inertial measurement units (IMUs), enabling tracking of joint angles and postures in real time. The haptic system uses electrostimulation to deliver localized cues to the body, which can be employed to warn workers about unsafe postures or proximity to hazardous zones [**teslasuitwhitepaper**]. Additionally, the biometric module allows monitoring of heart rate, stress, and other physiological parameters, offering insights into fatigue and workload. While powerful, the Teslasuit is limited by the precision of its IMUs and cannot directly capture external load or arm support, which affects the accuracy of ergonomic risk assessment.

3.3.3 The Meta Quest 3

The Meta Quest 3 is a commercially available mixed reality headset that provides inside-out tracking, hand tracking, and high-resolution stereoscopic displays. Its passthrough capabilities allow seamless blending of digital content into the real environment, making it suitable for industrial XR applications [**metaquest2023**]. In safety contexts, the headset can overlay warnings, display digital twins, and visualize danger zones directly in the worker's field of view. Compared to previous generations, the Quest 3 offers improved spatial mapping and computational performance, enabling low-latency integration with external data sources such as wearables. This makes it an accessible and practical platform for deploying industrial XR assistance systems.

3.4 Haptic Feedback and Multimodal Warning Systems

3.4.1 Perception of Haptic Stimuli

3.4.2 Design Principles for Effective Feedback

3.4.3 Visual vs. Haptic Alerts

3.4.4 Cognitive Load and Safety Feedback

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3.5.2 Spatial Consistency with Teslasuit Data

3.6 Multisensor Integration and Synchronization

3.6.1 Challenges in Multimodal Systems

3.6.2 LabStreamingLayer (LSL)

-explain why LSL is used (low-latency, open-source, widely adopted in research, easy integration with Unity, easy to use with multiple data streams, supports wide range of devices)

3.6.3 Integration of MQTT and Environment Data

3.7 Related Work

3.7.1 XR in Industrial Safety

3.7.2 RULA in Industrial Applications

4 Concept

4.1 Introduction

This chapter presents the conceptual design of an XR-based assistance system aimed at enhancing the safety and ergonomics of industrial workers. Building on the theoretical foundations outlined in Chapter 3, it details the system requirements, architectural framework, posture analysis and hazard detection concepts, feedback modalities, interaction design, and evaluation criteria. The goal is to provide a comprehensive framework that addresses the identified challenges by utilizing the capabilities of wearable technologies and XR environments. This conceptual framework serves as a foundation for the subsequent implementation and evaluation phases of the project.

4.2 System Requirements and Constraints

The XR-based assistance system's design is guided by a set of functional and non-functional requirements, as well as hardware and software constraints. These requirements ensure that the system effectively addresses the needs of industrial workers while adhering to practical limitations.

4.2.1 Functional Requirements

In order to give appropriate feedback on the users posture and the surrounding hazards the system needs to achieve a multitude of functional requirements. Accurate real-time posture tracking is essential for effective application of ergonomic assessment models like RULA. Due to the Teslasuit's use of accelerometers the system also needs to be able to calibrate the sensors to minimize the effect of drift over time. In addition the system needs to correctly place the user in the XR environment and align the real-world coordinates with the XR coordinates. This is necessary to accurately assess the users proximity to hazard zones. For the system to be accesible to workers it also needs to provide a user-friendly interface which allows easy calibration and minimal interaction during tasks. The system also needs to be able to integrate with existing industrial systems like GAIA to leverage existing infrastructure and data. In order to be able to properly analyze the data the system also needs to log relevant data for later assessment. Finally the system needs to provide haptic and visual feedback to alert workers of unsafe postures and hazards in their environment.

4.2.2 Non-functional Requirements

To fulfill its functional requirements the system also needs to meet several non-functional requirements. The system must operate with low latency to ensure timely feedback. It should be reliable, minimizing false positives and ensuring consistent performance in industrial environments. The system should be intuitive and require minimal training for workers to use effectively. Additionally, the system should be non-intrusive, allowing workers to perform their tasks without significant disruption. The system should also be scalable to accommodate different industrial settings and adaptable to various tasks and environments.

4.2.3 Hardware and Software Constraints

The design of the XR-based assistance system is influenced by several hardware and software constraints. Most notably the teslasuit introduces several limitations. In order to transmit data from the teslasuit a software provided by the manufacturer is required. sadly this software only runs on windows which means a device running windows is required for the system. Due to this limitation the software also needs to be distributed between the Meta Quest 3 and a windows PC. Due to the Teslasuit using IMUs for motion tracking the posture detection is subject to drift over time and will need to be calibnrated occasionally. Additionally there is no way for the Teslasuit to detect whether a body part is resting on a surface which rules out certain aspects of ergonomic assessment models like RULA. The battery life of the Teslasuit and Meta Quest 3 also limits the duration of use before recharging is necessary. The comfort of wearing the XR headset for extended periods is another consideration, as discomfort could affect worker compliance. Finally, maintaining a stable wireless connection between the wearable devices and the processing unit is crucial for real-time data transmission and feedback.

4.3 Interaction Design

The interaction design is focused on ensuring that the system requires minimal input from the user, while still providing accruate and effective feedback. The system is designed to be as non-intrusive as possible, allowing workers to focus on their tasks without being overwhelmed by alerts or notifications. Aside from the initial setup and calibration, the system operates without additional user input aside from periodic recalibration of the Teslasuit. The user interface is designed to be intuitive and easy to navigate, allowing users to autonomously setup and adjust the system as needed.

4.3.1 Avoiding Information Overload

An important aspect of the interaction design is avoiding information overload. There are several strategies implemented to achieve this. Firstly the system categorizes alerts into low, medium, and high priority levels. Low priority alerts are subtle and non-intrusive by triggering only localized low intensity haptic feedback. Medium priority alerts are more noticeable by triggering higher intensity haptic feed and visual cues in case of proximity to hazard zones. High priority alerts are designed to be as intrusive as necessary to ensure immediate attention, employing strong haptic feedback and prominent visual warnings. When multiple alerts occur simultaneously the system prioritizes them based on severity, ensuring that the most critical information is communicated first. Additionally the system employs adaptive alert frequency, reducing the frequency of alerts during periods of low risk to prevent alert fatigue. Personalization options allow users to adjust the intensity and type of feedback according to their preferences, further enhancing usability. Finally an option to temporarily ignore alerts is provided, allowing users to focus on critical tasks without being distracted by non-urgent notifications this option can also be activated by removing the Meta Quest 3.

4.3.2 Safety-Critical Design Considerations

There are several safety-critical design considerations that need to be considered. Firstly the system needs to offer the user to define zones where no visual alerts should be shown in order to avoid obstructing the vision of critical components such as warning lights or signs. The system also needs to handle sensor failures gracefully by providing default feedback in case of lost tracking or sensor errors. Additionally the system needs to minimize false positives to avoid alert fatigue and ensure that users remain responsive to alerts.

4.4 Framework Architecture

Due to the software limitations the Framework is distributed between the Meta Quest 3 and a windows PC which will handle the data and most of the computation. Which has the advantage of allowing the use of more powerful hardware for data processing. Due to this the Meta Quest 3 will primarily handle XR rendering and user interaction resulting in lower latency and higher frame rates. The Windows PC will handle data acquisition from the Teslasuit, posture analysis, hazard detection, and integration with industrial systems like GAIA. The two devices will communicate via Unity's native networking capabilities. This architecture allows for efficient distribution of tasks while leveraging the strengths of each device.

4.4.1 Hardware Components

The XR-based assistance system requires serveral hardware components to function effectively. First and foremost the XR-based assistance system requires an XR headset to provide the spatial tracking and visual feedback. The Meta Quest 3 is chosen for its low cost, standalone capabilities, spatial tracking features and widespread adoption. The Teslasuit is used for posture tracking and biometric data collection due to its comprehensive sensor suite and haptic feedback capabilities. A Windows PC is necessary to run the Teslasuit software and handle data processing tasks that exceed the capabilities of the Meta Quest 3. Additionally the system will integrate with existing industrial systems like GAIA to leverage existing infrastructure and data. Optionally additional sensors like smart watches can be integrated to provide supplementary biometric data.

4.4.2 Communication Protocols

The system employs several communication protocols to ensure efficient and reliable data transmission between components. LabStreamingLayer is used for low-latency synchronized collection of all sensor data streams, including posture and biometric data from the Teslasuit. MQTT is utilized for lightweight messaging and integration with industrial systems like GAIA, allowing for efficient data exchange and command execution. Unity's native networking capabilities facilitate communication between the Meta Quest 3 and the Windows PC, ensuring seamless interaction and data flow between the two devices.

4.5 Posture Analysis Concept

The posture analysis component of the XR-based assistance system is designed to monitor and assess the ergonomic risk of the user's posture in real-time. This is achieved through the use of the Teslasuit's IMU sensors to capture angle data for the bodyparts which is then trasnformed into joint angles to be analyzed using a simplified version of the Rapid Upper Limb Assessment (RULA) model. the angles will be continuosly sampled and assessed to provide timely feedback to the user.

4.5.1 Ergonomic Assessment Model

To assess the ergonomic risk of the user's posture the System uses a simplified version of RULA where limbs and the torso will be scored individually to apply localized feedback. The ergonomic risk will also be aggregated into an overall score to provide a general overview of the user's posture. The ergonomic assessment will be performed at regular intervals to provide timely feedback without overwhelming the user. For the purpose of providing feedback to the user the ergonomic risk levels are mapped into three categories:

- Low Risk: No action needed
- Medium Risk: Subtle corrective feedback (haptic, visual)
- High Risk: Strong alert to prompt immediate correction

Additionally the scores will be continuously logged for later analysis and statistics.

4.5.2 RULA Scoring Adaptation

The scores are determined based on the RULA scoring system as described by McAtamney and Corlett [**mcatamney1993rula**]. However due to the limitations of the Teslasuit's IMU-based tracking system some adaptations are necessary. The RULA scoring system is divided into two sections with respectively 4 and 3 subcategories corresponding to different body parts. The first section (A) evaluates the upper arm, lower arm, wrist, and wrist twist, while the second section (B) assesses the neck, trunk, and legs. Each body part is assigned a score based on its position and movement, which are then combined to produce an overall risk score. Addtionally muscle use and force/load scores are added to the overall score of both categories. The force score is disregarded in this implementation due to the lack of force sensors in the Teslasuit. The wrist twist, wrist position and leg score is also disregarded due to missing sensors needed to determine these scores. To account for the lack of these scores they will be assumed to be in a neutral position and assigned the lowest possible score. This means that the overall ergonomic risk may be underestimated, especially in tasks that involve significant wrist movement or leg strain. However, this adaptation allows for an ergonomic assessment using the available data from the Teslasuit and The Meta Quest 3. Additionally to avoid overwhelming the user with constant feedback, as is one of the stated goals of this system, the assessment should slightly underestimate the risk in some cases rather than overestimate it and cause alert fatigue.

4.6 Hazard Detection Concept

The Hazards are defined as a cubical or spherical volume in the XR environment it's position and size can be defined by the user during setup. The current Hazard Level is determined by a preset rule which can use data from a predefined LSL stream. Each hazard zone can be individually and manually adjusted if the environment changes. The system continuosly monitors the position of the user and their limbs, using the Meta Quest 3 and the Teslasuit, in order to determine their proximity to the defined hazard zones. If the user enters a hazard zone or comes within a predefined distance of it, the system triggers an alert through haptic and/or visual feedback. The hazard detection is performed in real-time to ensure timely alerts and enhance worker safety.

4.7 Feedback Modalities

The system employs both haptic and visual feedback to communicate with the users.

The haptic feedback will be delivered in form of local cues for posture correction and hazard proximity with intensity scaling depending on urgency. This localized approach ensures that the user can intuitively understand which part of their body requires attention, enhancing the effectiveness of the feedback. Haptic feedback is prioritized due to its ability to provide immediate cues that contribute little to cognitive load except for immediate or high hazard scenarios.

Visual feedback will be provided through the XR headset, utilizing non-intrusive overlays and indicators to alert users of hazards and ergonomic issues. The visual feedback is designed to complement the haptic cues, providing additional context without overwhelming the user. Visual feedback will primarily be used for hazard alerts, leveraging the XR environment's capabilities to highlight danger zones and provide spatial awareness. While also providing subtle visual cues for posture correction on longer or repeated poor posture. The visual feedback is designed to be minimalisitc and will be color coded to indicate the severity of the alert.

4.8 Evaluation Criteria

In order to evaluate the effectiveness of the conceptual design, several criteria are established. These criteria focus on the system's ability to meet functional and non-functional requirements, as well as its overall usability and integration capabilities. These criteria include:

- Posture Detection Accuracy: The system should accurately detect and assess user posture, with a target accuracy of within 5 degrees for joint angles.
- Hazard Detection Reliability: The system should reliably detect proximity to hazard zones, with a low rate of false positives and negatives.
- Latency: The system should operate with low latency, ideally below 200ms, to ensure timely feedback.
- User Experience: The system should be user-friendly, requiring minimal training and allowing for easy calibration and adjustment.
- Integration: The system should seamlessly integrate with existing industrial systems like GAIA, leveraging existing infrastructure and data.

4.9 Summary and Transition

Research Questions Addressed: -Posture monitoring accuracy -Hazard detection reliability -Latency thresholds -Spatial alignment

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Kolophon

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