Institute for Lightweight Design
Department Sports Equipment and Technology

INSTRUMENTATION PROJECT REPORT

Topic: Smart Posture Monitoring and Feedback System

Supervised by:

Prof. Dr.-Ing Stephan Odenwald

Mr. Christoph Warnat

Submitted By: (Group 1)	**Mtr.No.**
Prajjwal Garag	812210
Sushant Shetty	812096
Pratik Dhulap	807759
Ankit Wala	807436
Akash Deshpande	805445

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1. Introduction:

The act of lifting boxes, a common task in various workplace settings, may appear straightforward but poses significant risks to musculoskeletal health when performed with improper angles and postures. To address this, our task involves to measure the Back, Back arch, Femoral (Knee) and Arm angle during lifting tasks, enabling real-time analysis and feedback for safer lifting techniques. This ensures that workers adopt safe lifting techniques is not only vital for their long-term well-being but also for reducing the incidence of occupational injuries and associated costs.

According to the European risk observatory report (2010), 24.7% of the European workers complains of backache, 22.8% of muscular pains and 45.5% reports working in painful or tiring postures [1]. To reduce workload and consequently the drop out of workers due to these complaints, companies adapt the work place, provide tools and/or give training.

1.1 Importance of Proper Angles and Postures in Box Lifting:

The human spine, a complex structure composed of vertebrae, intervertebral discs, muscles, and ligaments, is designed to support the body's weight and enable mobility. When lifting tasks are executed with incorrect posture or at improper angles, the mechanical loads placed on the spine increase substantially, particularly in the lumbar region. Over time, such improper techniques can lead to cumulative low back load (CLBL), a key factor associated with low back pain (LBP), as highlighted in recent research.

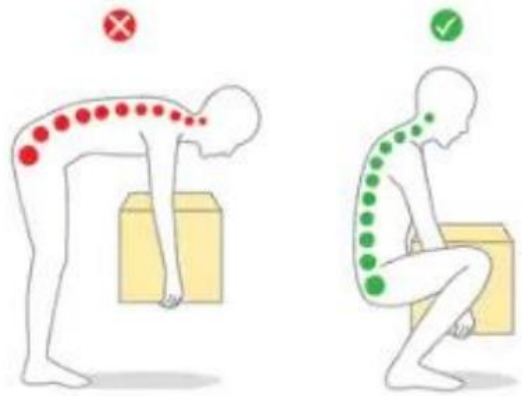

Figure 1: Effect on the Back bone due to incorrect box lifting

Figure 2: Wrong body posture vs Correct body posture for lifting
Source: Blender

1.2 Potential Problems Arising from Improper Lifting:

The problems stemming from poor lifting posture can range from minor discomfort to severe and debilitating conditions, categorized as follows:

a) Severe Risks:

- Herniated Discs: Excessive pressure on the intervertebral discs caused by bending incorrectly or twisting while lifting can lead to disc herniation, where the soft inner material of the disc protrudes, compressing nearby nerves.
- Spinal Fractures: In extreme cases, improper lifting of heavy loads can lead to fractures in the vertebrae, causing acute pain and requiring immediate medical intervention.

b) Moderate Risks:

- Chronic Low Back Pain (LBP): Repeated exposure to poor lifting practices contributes to cumulative stress on the lumbar spine, a primary cause of chronic LBP.
- Facet Joint Strain: Incorrect posture can strain the small joints located between the vertebrae, leading to inflammation and stiffness.

c) Low Risks:

- Muscle Strains: Overexertion of the lower back muscles due to poor alignment can cause strains, leading to short-term pain and discomfort.
- Fatigue: Inefficient movement patterns increase energy expenditure, leading to quicker fatigue and reduced productivity.

1.3 Affected Bones and Spine Regions:

The lumbar spine (lower back) bears the brunt of the load during lifting tasks. Improper techniques can:

- Exert undue stress on the lumbar vertebrae (L1 to L5), leading to degeneration and instability.
- Overload the sacroiliac joints, which connect the spine to the pelvis, causing localized pain and dysfunction.
- Impact the thoracic spine if the worker compensates by arching the upper back during lifting, resulting in strain.

By understanding the biomechanical impact of improper lifting, workplaces can adopt preventive measures such as ergonomic training and real-time feedback systems. This report focuses on the development of a measurement system that uses accelerometers to monitor the shoulder angle during lifting tasks, providing actionable insights to ensure safe and healthy movement patterns.

2. Best Practices from prior art of lifting:

The research conducted on ergonomics for proper box lifting techniques identified several critical factors essential for ensuring safe and efficient lifting practices. Key findings emphasized the importance of maintaining proper posture, joint alignment, and minimizing strain on the musculoskeletal system during manual material handling tasks. Figure.3 illustrates key guidelines derived from established ergonomics standards for Manual Material Handling. These guidelines provide a reference for achieving optimal postures and minimizing the risk of injuries during lifting activities.

Figure.3. illustrates the proper posture for lifting, designed to minimize the risk of injury. To ensure safe lifting practices, the knees should be bent, and the back should remain as straight as possible, avoiding excessive bending

Figure 3: Proper lifting of box (Guidelines for Manual Material Handling) [2]

or arching. The box should be held close to the body to reduce strain on the spine and muscles. Additionally, the arms should not be overextended during lifting, as this can increase the risk of musculoskeletal injuries.

Further research referred to Table.1 which provides a range of body angles ideal for maintaining a comfortable and safe posture. These guidelines specify joint angle ranges for the back and hips, ensuring proper alignment to minimize discomfort and reduce the risk of injury. These ergonomic principles were incorporated into the suite design in Table.2.

Postures	Comfortable	Non-comfortable	To avoid
Back			
Rotation left	$<-15°$	$-15°$–$<-30°$	$>-30°$
Rotation right	$<15°$	$15°$–$<30°$	$>30°$
Flexion	$<30°$	$30°$–$<45°$	$>45°$
Extention	$<-10°$	$-10°$–$<-20°$	$>-20°$
Lateral flexion left	$<-10°$	$-10°$–$<-20°$	$>-20°$
Lateral flexion right	$<10°$	$10°$–$<20°$	$>20°$
Hips			
Flexion	<70	$70°$–$<100°$	$>100°$

Table 1: Body angle analysis [3]

2.1 Importance of Ergonomics Tracking Devices in the Workplace:

The working environment, especially in manual labour industries, demands continuous monitoring to ensure employee safety. Manual tracking, such as observing and recording worker actions, is inefficient and prone to human error. Ergonomics tracking devices provide a more accurate, automated solution by using sensors to monitor body movements, lifting tasks, and posture in real-time. These devices eliminate subjective errors, enable consistent risk assessment, and support evidence-based interventions like optimizing work height and reducing load mass. By automating risk evaluation, ergonomics tracking devices enhance workplace safety, prevent musculoskeletal disorders, and reduce economic costs associated with injuries.[4]

3. Approach and Implementation:

3.1 Development of Body Suit and selection of Sensor:

Figure 6: Placement of sensors on upper body suit

Figure 5: Placement of sensor on the lower body suit

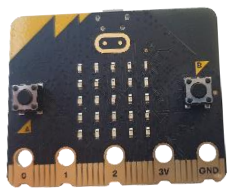

Figure 4: Generic Micro bit used in the project

3.1.1 Placement and Integration of Micro:bits:

This project utilizes a total of seven Micro:bit devices strategically placed (stitched) at critical points determined through extensive research from journals and prior art. Two sensors are positioned on the arms near the shoulders to monitor arm movement, while two are placed near the knees, aligned parallel to the movement of the knee joint hinge, to accurately track leg dynamics. Additionally, one sensor is placed on the upper back and another on the lower back to capture posture and spinal alignment. These placements are carefully selected to ensure comprehensive tracking of body movements.

The sensors collect real-time acceleration data and transmit it over a shared radio frequency to a receiver Micro:bit. The receiver acts as a central hub, aggregating incoming data from all sensors and parsing it for subsequent processing in a Python environment on a connected computer. This setup facilitates efficient data acquisition and ensures that critical motion data is continuously fed into the processing pipeline. Furthermore, the receiver Micro:bit plays a vital role in the feedback loop, as it is capable of sending signals to the sensor nodes to provide corrective feedback, a mechanism elaborated upon later in the report. This configuration ensures seamless data flow and enables real-time posture analysis and correction.

3.1.2 Selection Criterion for the Sensor:

The Micro:bit Figure.4 is a versatile microcontroller platform that integrates a 3-axis MEMS (Microelectromechanical Systems) accelerometer, making it highly suitable for applications such as motion tracking, posture monitoring, and IoT systems [5]. Its compact size, wireless communication capabilities, and ease of programming in Python allow for rapid prototyping and seamless integration into various use cases. The onboard accelerometer operates using capacitive sensing, where microscopic silicon structures within the chip detect changes in capacitance caused by acceleration forces. These signals are then processed through ADC (Analog-to-Digital Conversion) to produce digital data, enabling real-time analysis of motion and orientation.

In this application, the Micro:bit's accelerometer achieves a sampling rate of approximately 33 Hz, determined by the 30 ms delay in the sender code [6]. This rate is well-suited for monitoring human motion, as typical postural and movement frequencies remain below 10 Hz. The accelerometer, often the STMicroelectronics LIS3DH or a similar variant, operates within a sensitivity range of ±2 g (configurable up to ±8 g), with a resolution of approximately 1 mg/digit at ±2 g. This level of sensitivity ensures precise measurements of small accelerations, which are critical for posture correction and motion tracking.

The response bandwidth of the accelerometer spans from 0.5 Hz to 1.6 kHz, making it capable of capturing a wide range of motion dynamics while effectively filtering out high-frequency noise. Additionally, the device exhibits a nonlinearity of less than ±0.5% of the full-scale range, ensuring reliable and consistent performance even during complex movements. These features enable accurate tracking of posture changes and detailed motion analysis, making the Micro:bit an efficient tool for real-time monitoring applications[7].

3.2 Angels to be measured and sensors placements on body:

Referring to Table 1, the solution integrates four key body angles into the ergonomic suit: arm angle, back angle, knee angle, and back arch angle. These angles were systematically classified into three risk zones low, moderate, and high, based on their potential ergonomic risk, as depicted in Table 2.

- Arm Angle: Tracks arm movement and elevation, essential for identifying overreaching or prolonged strain during lifting tasks.
- Back Angle: Monitors the forward or backward tilt of the torso, crucial for assessing improper bending postures.
- Knee Angle: Measures knee flexion to detect whether proper bending techniques are followed.
- Back Arch Angle: Calculated as the difference between the lower back angle and upper back angle, this measures spinal curvature, critical for assessing the load on the lumbar spine.

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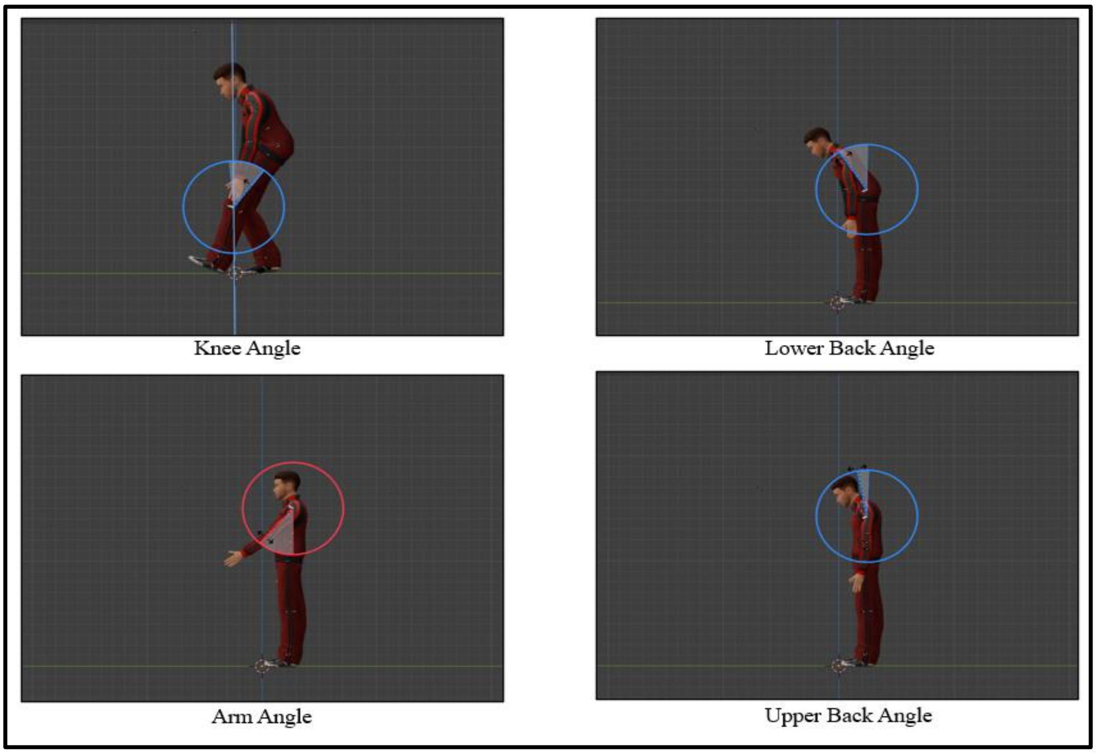

Figure 7: Illustration of four angle which is being measured
Source: Blender

The figure.7 above illustrates how each angle is measured in relation to the body's posture and movement. These measurements provide a clear understanding of the body's biomechanics during work tasks

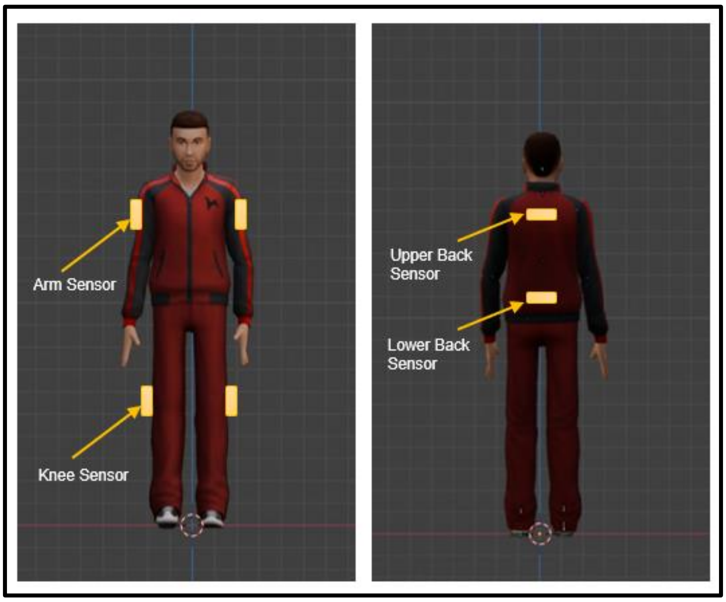

Figure 8: Sensor Placement on body
Source: Blender

Figure.8 shows the placement of six sensors for ergonomic tracking: two on the arms, two on the back, and two on the knees. The arm sensors monitor arm movement to prevent overextension, back sensors measure spinal alignment to avoid strain, and knee sensors help track posture and detect whether the person is bending or not. These six sensors are essential for accurately tracking critical body angles during lifting, enabling precise risk analysis and promoting safe working practices.

3.3 Project Flowchart:

Figure 9: Flowchart encompassing the entire flow of the application to measure body posture

The flowchart in Figure.9 outlines the process PostureAware our system uses with the help of Micro:bit sensors to monitor posture by measuring angles for body parts like the back, knee, and arm. The program initializes serial communication and GUI, collects raw data, applies filtering for stability, calculates angles, and classifies posture states into risk levels (No Risk, Low, Moderate, High). For high-risk postures, feedback is sent to the user via the Microbit. The GUI updates in real-time to display angles, posture states, and connection status.

3.4 Data Processing and User Interface:

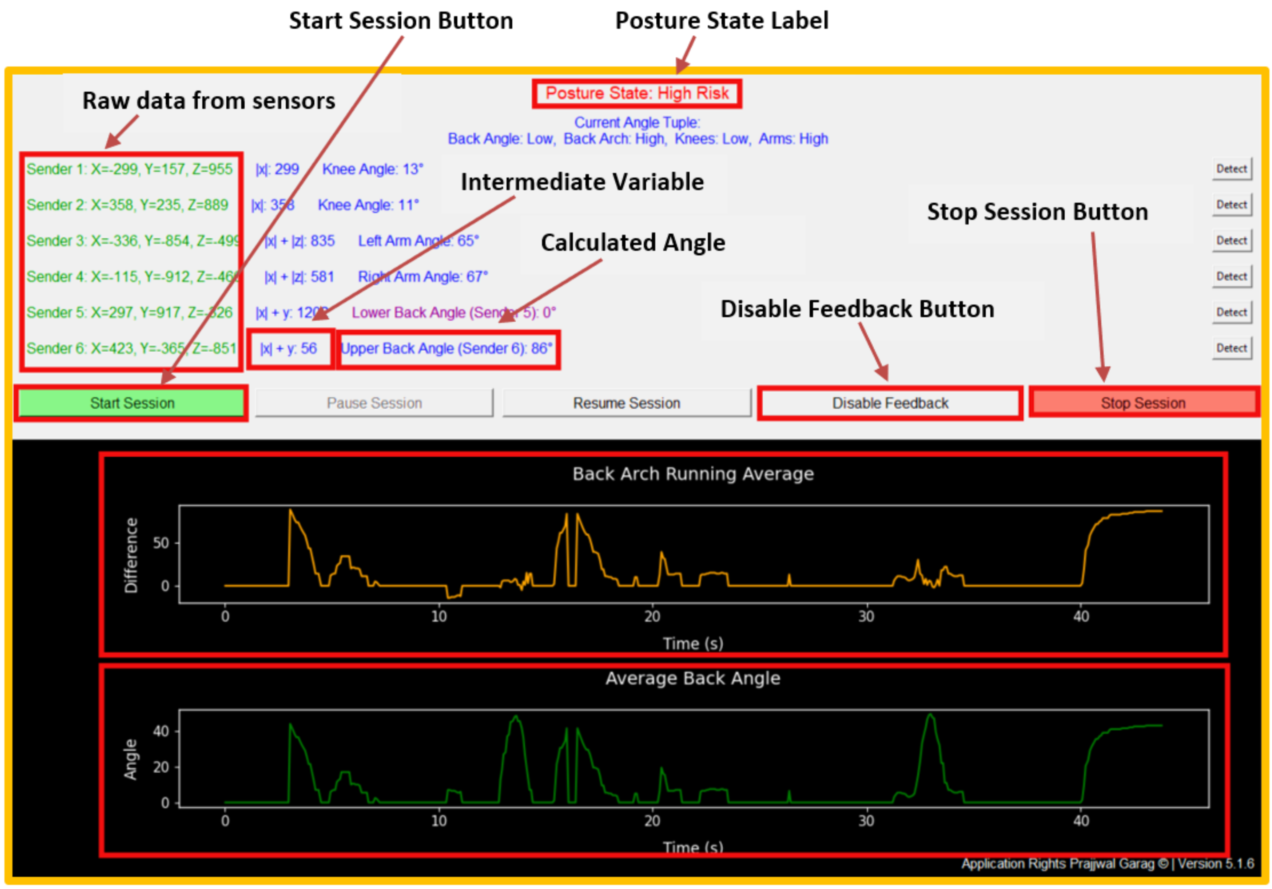

Figure 10: Posture Monitoring GUI with Real-Time Data and Risk Feedback

The GUI is named PostureAware and is designed to monitor and assess posture using real-time data from multiple sensors, it transmits data using radio frequencies. At the top, the "Posture State" section highlights the current risk level of the user's posture, such as "High Risk," enabling unsafe postures to be easily identified. Below this, the "Current Angle Metrics" display critical joint angles such as knee, back, and arm angles, with highlighted boxes like "Upper Back Angle °" for quick review. To the left, sensor readings labelled as "Sender 1" through "Sender 6" provide raw data (X, Y, Z coordinates) for individual body parts, aiding in pinpointing specific areas of concern. On the right, "Detect" buttons allow manual detection or reinitialization of sensors to ensure accurate performance and reliability.

At the bottom, session control buttons provide functionality to start, pause, resume, disable feedback, or stop monitoring sessions, offering flexibility in session management. The GUI also includes two graphical representations: the "Back Arch Running Average Chart," which tracks posture deviations over time, and the "Average Back Angle Chart," which monitors overall back angle trends during the session. Additionally, ownership and version information, such as "Version 5.1.6," is displayed for documentation, version control and reference purpose.

3.5 Data flow for calculation of Angle:

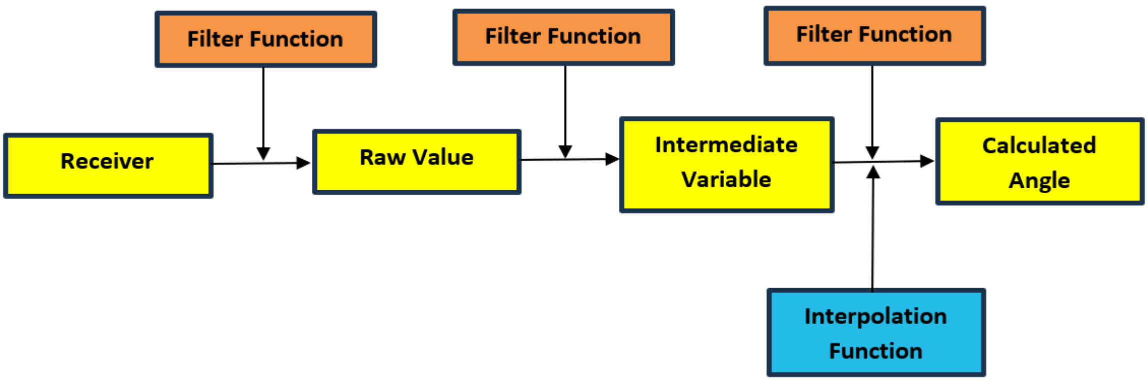

Figure 11: Data Processing Flow: From Sensor Input to Calculated Angles

The flowchart illustrates the process of data manipulation in the program as the receiver collects data from sensors and body angles are calculated.

1. **Receiver**: The data from the sensors is received by this component on a radio frequency.
2. **Filter Function**: The received raw data undergoes filtering to remove noise and improve accuracy. This step is repeated multiple times as the data progresses.
   - **Raw Value**: The initial filtered data, still in its raw form.
   - **Intermediate Variable**: This value is calculated from Raw data by fixing the plane perpendicular to which measurement takes place (discussed further in next section).
3. **Interpolation Function**: This function processes the intermediate variable to calculate missing or intermediate data points, enhancing the precision of the result.
4. **Calculated Angle**: After passing through the final filtering stage and interpolation, we get the computed the angles.

This flow ensures the raw sensor data is refined, interpreted, and transformed into accurate angle measurements.

3.6 Calculation of Intermediate Variable:

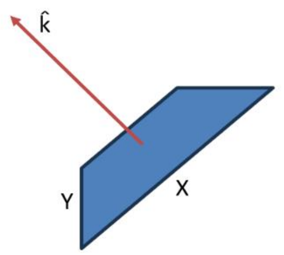

Figure 13: Calculating Perpendicular Acceleration Along $\hat{k}$ for Accurate Angle Measurements Relative to Body Surface

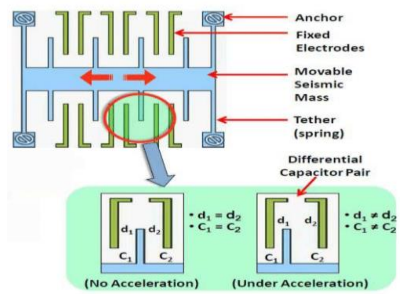

Figure 12: Working principle of accelerometer
Source: makeagif.com

The sensors output raw acceleration data in cm/s², with values ranging from 0 to 981 for each axis (x, y, z). However, when the sensor is placed on a body, it lies in a plane where the acceleration values are distributed across all three axes (x, y, z), making the readings impure or mixed.

To address this, an intermediate parameter is calculated. This involves fixing a plane orthogonal to the surface of the body where angle is to be calculated and measuring acceleration perpendicular to this plane along the $\hat{k}$ vector. This allows for obtaining readings that are aligned perpendicular to the body's surface rather than to the standard coordinate planes (xy, yz, and xz). Using this approach, angles can be measured with respect to planes that are not aligned with the global coordinate system, enhancing the accuracy and relevance of the measurements.

3.7 Working of Filter:

```
def low_pass_filter(new_value, previous_value, alpha):  6 usages
    return alpha * new_value + (1 - alpha) * previous_value
```

Figure 14: Low-pass filter function

The low_pass_filter function implements a simple yet effective low-pass filter, which smoothens signals by passing low-frequency components while reducing high-frequency fluctuations. It computes a weighted average of the most recent input (new value) and the previous filtered value (previous value), using a smoothing factor alpha (between 0 and 1).

Filtered_value = (alpha) x (**New_value)** + (1 - alpha) x (**Previous_value)**

1. Role of alpha:
   - High alpha (close to 1): The filter reacts quickly to changes in the input, offering less smoothing.
   - Low alpha (close to 0): The filter prioritizes historical data, leading to stronger smoothing but slower responsiveness.
2. Recursive Behaviour: The current filtered value becomes the input (previous_value) for the next step.

This approach ensures a gradual transition in the signal, making it suitable for applications such as noise reduction in sensor data, trend analysis, and signal smoothing. It balances responsiveness and stability based on the chosen alpha value.

3.8 Interpolation Function:

```
value = int(x_value)
ranges = [
    (0,   14,   0,  0),
    (15,  100,  10, 0),
    (100, 380,  20, 10),
    (380, 420,  30, 20),
    (420, 590,  40, 30),
    (590, 670,  50, 40),
    (670, 820,  60, 50),
    (820, 880,  70, 60),
    (880, 970,  80, 70),
    (970, 1000, 90, 80),
]
```

Figure 15: Interpolation Function

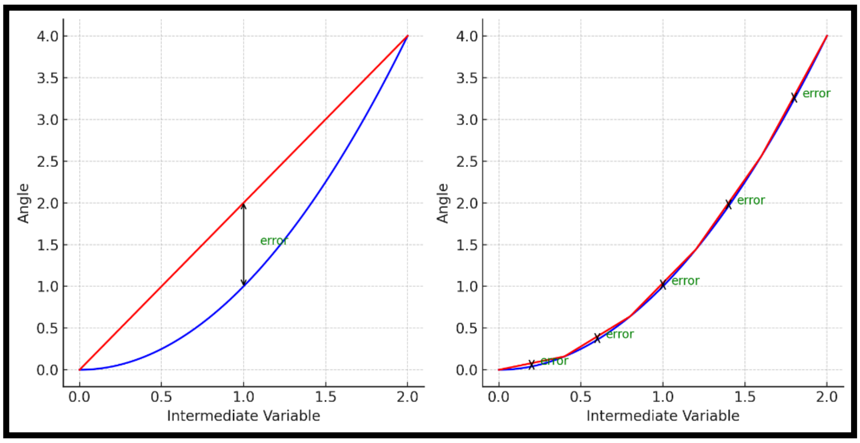

Figure 16: Reduction of approximation error due to improve interpolation function, red graph indicates interpolation function and blue graph indicates actual variation.

The interpolation function is used to map the intermediate variable to the calculated angle. This is necessary because the relationship between the intermediate variable and the calculated angle is non-linear.

If the mapping were done using only the extreme values (e.g., 0 and 90 degrees), it would result in significant errors, as evident in the graphs. To minimize this error, additional intermediate values are provided based on experimentally collected data through physical measurements. The interpolation function works by interpolating between these experimentally determined values.

The first image displays the code snippet defining the ranges of intermediate variable values and their corresponding angles. This data serves as the basis for the interpolation function there are 3 such functions in the code for Back, Arm and Femoral (knee) inclination angles.

The graphs demonstrate the impact of using this interpolation:

1. **Left Graph**: Without proper interpolation, the error between the calculated and actual angles is substantial.
2. **Right Graph**: By incorporating intermediate values and applying interpolation, the error is significantly reduced, leading to more accurate angle calculations.

This approach ensures that the calculated angles closely follow the actual physical measurements, improving the overall accuracy of the system.

3.9 Multiple cases of Body Movement:

The classification of risk zones and corresponding angle ranges were determined based on Table.1 and validated through multiple practical iterations performed while wearing the suit. This iterative process ensured that the suit accurately identified ergonomic risks and provided reliable data for minimizing work-related injuries.

Body Angle	Low Risk	Moderate Risk	High Risk
Back Angle	< 30°	30° - 60°	> 60°
Back Arch Angle	< 10°	10° - 40°	> 40°
Knee Angle	< 20°	20° - 35°	> 35°
Arm Angle	< 30°	30° - 50°	> 50°

Table 2: Risk Zone of Body angle while lifting the weight

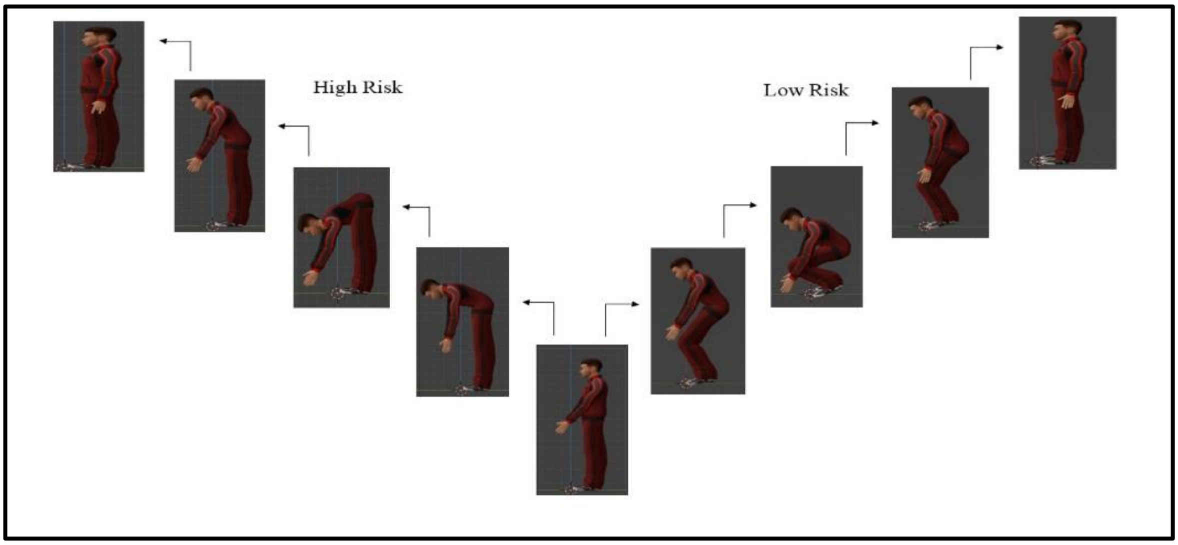

Figure 17: High risk and Low risk process flow
Source: Blender

Figure.17 compares two weightlifting scenarios: a low-risk case with proper posture and alignment, and a high-risk case with poor posture, highlighting the importance of monitoring body angles to prevent injuries.

The four body angles: arm angle, back angle, knee angle, and back arch angle, were categorized into three distinct risk zones: low, moderate, and high. By combining these risk classifications for each angle, a total of 81 unique cases were derived in Table.3 (3 risk zones for each of the 4 angles: 3 × 3 × 3 × 3 = 81).

Back Angle	Back Arch Angle	Knee Angle	Arm Angle	Risk Level
Low	Low	Low	Low	No Risk
Low	Moderate	Low	Low	Low Risk
Low	Moderate	Moderate	Low	Low Risk
Low	Moderate	High	Low	Low Risk
Moderate	Low	High	Low	Low Risk
Moderate	Low	Low	Low	Low Risk
Low	Low	Low	High	Low Risk
Low	Moderate	Low	High	Low Risk
Moderate	High	Moderate	Low	Low Risk
Low	Low	Moderate	Low	Low Risk
Low	Moderate	Low	Moderate	Low Risk
Low	Moderate	High	Moderate	Low Risk
Moderate	Low	Moderate	Moderate	Low Risk
Moderate	Low	High	Moderate	Low Risk
Moderate	Moderate	Moderate	Moderate	Low Risk
Moderate	Moderate	High	Moderate	Low Risk
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Low	Low	High	Moderate	Low Risk
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Moderate	High	Low	Low	Moderate Risk
High	Low	Low	Low	Moderate Risk
High	Low	Moderate	Low	Moderate Risk
High	High	Moderate	Low	Moderate Risk
Low	High	High	Low	Moderate Risk
Moderate	High	High	Low	Moderate Risk
High	Low	High	Low	Moderate Risk
Low	Moderate	Moderate	Moderate	Moderate Risk
Moderate	Low	Low	Moderate	Moderate Risk

Back Angle	Back Arch Angle	Knee Angle	Arm Angle	Risk Level
Low	High	Moderate	Moderate	Moderate Risk
High	Low	Moderate	Moderate	Moderate Risk
High	Low	High	Moderate	Moderate Risk
Moderate	Moderate	Moderate	High	High Risk
Moderate	Moderate	Low	High	High Risk
Low	High	Low	High	High Risk
Low	High	Moderate	High	High Risk
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Low	High	Low	Moderate	High Risk
High	Low	Low	Moderate	High Risk
High	High	Low	Moderate	High Risk
High	High	Moderate	Moderate	HIgh Risk
Low	High	High	Moderate	High Risk
Moderate	High	High	Moderate	High Risk
High	Moderate	High	Moderate	High Risk
High	High	High	Moderate	High Risk
Moderate	Low	Low	High	HighRisk
Moderate	Moderate	Moderate	Low	HighRisk

Table 3: 81 unique Cases derived from four angles and 3 risk zones

This categorization ensures a comprehensive assessment of ergonomic risks by accounting for every possible combination of the angles and their associated risk levels. It allows for a detailed analysis of various postural scenarios and their potential impact on the worker's musculoskeletal health. This systematic approach provides a robust framework for identifying high-risk combinations, enabling targeted interventions to reduce injuries and optimize workplace ergonomics.

3.10 Feedback Loop:

The feedback loop in this system provides real-time corrective actions by creating a subtle nudge for the user to adjust their posture after prolonged time in moderate or high-risk positions. The receiver Micro:bit continuously analyses data from multiple sender Micro:bits placed on the body. When moderate-risk posture persists for over 10 seconds or high-risk posture for 5 seconds, the receiver triggers a feedback mechanism.

This mechanism sends a "BUZZ" command to the sender Micro:bits, which generate an audible alert (440 Hz buzz for 500 milliseconds) and activate onboard LEDs as visual feedback. The aim is to encourage the user to correct their posture, reducing the risk of strain or long-term ergonomic issues.

For user flexibility, the feedback loop can be disabled if needed. However, to maintain safety, authorization for disabling the feedback is assigned to a higher authority, ensuring a balance between user comfort and workplace health standards.

4. Results and Conclusion:

4.1 Graphical Results:

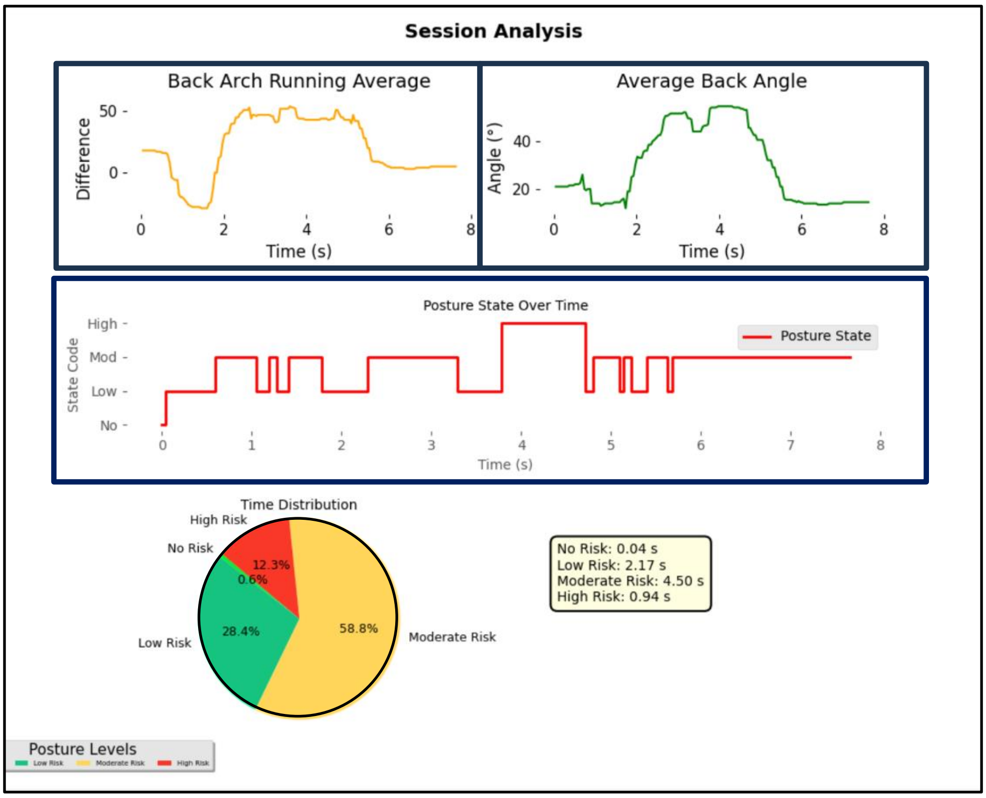

Figure 18: Session Analysis Window

Once the "Stop Session" button is pressed, the recording halts, and various graphs are displayed to analyse the session data as shown in Figure 18. The Back Arch Running Average and Average Back Angle plots, available in the live view, are shown again to review the recorded trends. Additionally, a Posture State Over Time graph is plotted, providing insights into the worker's risk states during different activities. This graph is particularly useful for identifying high-risk activities that occur throughout a worker's shift.

The analysis also includes a pie chart that visually represents the percentage of time spent in each posture state, ranging from "No Risk" to "High Risk." Beside the pie chart, a box displays the exact time spent in each posture state, providing detailed metrics. Together, these visualizations enable a comprehensive understanding of posture dynamics and can guide interventions to improve workplace ergonomics and reduce high-risk activities.

4.2 Conclusion:

The Posture Aware system represents in our opinion a groundbreaking solution to address ergonomic risks associated with improper lifting techniques. By leveraging seven strategically placed Micro:bit sensors, the system continuously monitors critical body angles, including back, back arch, knee, and arm angles. Real-time data is transmitted to a Python environment, where angles are classified into risk zones ranging from "No Risk" to "High Risk." The integrated feedback loop provides auditory and visual cues, nudging users toward better posture when they remain in moderate or high-risk positions for extended periods.

This project demonstrates the potential to minimize musculoskeletal disorders, reduce workplace injuries, and enhance productivity through preventive ergonomic measures. The combination of real-time monitoring, data visualization, and corrective feedback fosters a safer working environment, aligning with modern occupational health standards. The graphical results, including posture trends and time distribution across risk zones, enable targeted interventions to address high-risk activities.

5. Future Scope:

1. Integration with Advanced Sensors: Incorporate additional sensors, such as gyroscopes or EMG sensors, for enhanced motion and muscle activity analysis.
2. AI-Driven Risk Assessment: Use machine learning algorithms to predict potential injuries based on historical data, enabling proactive ergonomic planning.
3. Cloud Integration: Implement cloud-based storage and analysis for centralized monitoring across multiple workers in real-time.
4. Mobile Application Support: Extend functionality to mobile devices, allowing supervisors to access worker posture data and risk assessments remotely.
5. Industrial Adoption: Adapt the system for various industries, including manufacturing, logistics, and healthcare, with customizable thresholds for different job roles.

6. Reference:

1. Schneider, E., & Irastorza, X. (2010). Work-related musculoskeletal disorders in the EU. *European Agency for Safety and Health at Work, Luxembourg: Publications Office of the European Union*.

2. *Ergonomic-Guidelines-for-Manual-Material*, https://www.cdc.gov/niosh/media/pdfs/Ergonomic-Guidelines-for-Manual-Material-Handling_2007-131.pdf

3. Hermien Matthys, Willy Bohets, Veerle Hermans, *Effectiveness of Specific Lifting Techniques and Tools on Workload in a Lifting Situation – A Case Study: Volume I: Healthcare Ergonomics*, https://www.researchgate.net/publication/326903553

4. P Paul FM Kuijer, Jos HAM Verbeek, Bart Visser, Leo AM Elders, Nico Van Roden, Marion ER Van den Wittenboer, Marian Lebbink, Alex Burdorf, Carel TJ Hulshof1, *An Evidence-Based Multidisciplinary Practice Guideline to Reduce the Workload due to Lifting for Preventing Work-Related Low Back Pain* https://doi.org/10.1186/2052-4374-26-16.

5. Micro:bit Official Documentation, Micro:bit Educational Foundation, 2024.

6. R. Lee, "Sampling Rates for Human Motion Monitoring," IEEE Sensors Journal, vol. 19, no. 7, pp. 2100-2105, 2023.

7. STMicroelectronics LIS3DH Datasheet, STMicroelectronics, 2023.