**traceReal-time Stabilization and 3D Reconstruction of Hand Gestures and Finger Movement Traces Using LED-Equipped Gloves**



***RISK MITIGATION, MONITORING, AND MANAGEMENT (RMMM) PLAN***

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# 1.0 Introduction

The RMMM Plan outlines the approach to identifying, managing, and mitigating risks associated with the Adaptive HCI – 3D Gesture Tracking Project. The purpose is to ensure that risks are proactively managed to minimize their impact on project execution and overall success.

## 1.1 Scope and intent of RMMM activities

The focus of the RMMM plan is to address risks associated with the real-time stabilization, image processing, and gesture smoothing in this project. The primary objectives are to:

* Proactively identify potential risks that may impact the project.
* Outline a mitigation strategy to prevent risks from escalating.
* Define monitoring activities to track risk status.
* Provide contingency plans to manage risks should they occur.

## 1.2 Risk Management Organizational Role

The project team has collective responsibility for risk management. The following roles have been assigned:

* **Soham Naik**: Image Processing Lead – responsible for managing risks related to image pre-processing, feature extraction, and privacy filtering.
* **Deniz K. Acikbas**: Front-End Mobile App Lead – responsible for risks related to user interaction, hardware integration, and camera feed.
* **Alan Raj**: 3D Visualization Lead – responsible for risks related to 3D path reconstruction.
* **Zaynab Mourtada**: Machine Learning Lead – responsible for risks related to machine learning smoothing algorithms.

# 2.0 Project Risks

## 2.1 Risk Table

|  | **Risk Table** | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| Risk | Description | Probability | Impact severity | Impact | Mitigation Plan | Contingency Plan |
| R1 | Technical requirements outside team experience | Low | Med | Potential design failures or issues with hardware/software integration | Early planning and requirement gathering to identify skill gaps early on | Seek external help, such as consultants or additional resources with relevant expertise |
| R2 | Inconsistent LED tracking due to ambient lighting | Med | High | Difficulty in accurately tracking LED movements, leading to incorrect data | Test under different lighting conditions; enhance image processing techniques (denoising, threshold) | Adjust LED brightness or use more advanced sensors to compensate for poor lighting conditions |
| R3 | Real-time processing performance limitations | Med | High | Slow response times may affect gesture tracking accuracy and user experience | Optimize code for performance; prioritize hardware capabilities in app development | Simplify features to reduce computational load or upgrade to more powerful hardware if possible |
| R4 | Privacy filtering failure | Low | High | Failure to remove irrelevant data could lead to privacy concerns and data leakage | Implement robust filtering algorithms and conduct regular privacy testing | Roll back feature until security improvements are made |
| R5 | Misalignment between image processing and machine learning | Med | Med | Data processed by image processing module may not be compatible with the ML module | Define strict data formats for communication between modules | Add a real-time debugging layer between the two modules to catch and adjust data discrepancies |
| R6 | Insufficient training data for machine learning | Med | Med | Machine learning models might not perform well due to insufficient or poor-quality data | Collect/Create diverse data sets early, including various lighting and movement scenarios | Supplement with synthetic data generation or manual labeling to expand dataset |
| R7 | Hardware failure or incompatibility | Low | High | Smartphone cameras may not function as expected, causing system interruptions | Conduct extensive hardware testing during initial phases | Use backup hardware or simulate inputs to keep development on track |
| R8 | Changes in hardware specifications during development | Med | High | Significant changes may force redesigns, delaying the project | Continuous monitoring of hardware compatibility with the app | Work with minimal specs to keep the app functional with basic hardware; plan updates accordingly |
| R9 | Data loss or corruption during frame capture | Low | Med | Loss of critical gesture data during frame capture could reduce tracking accuracy | Implement data validation checks and automatic re-capture protocols | Allow re-capture or redundant data logging to mitigate data loss |
| R10 | Unclear or delayed requirements from stakeholders | Med | Med | Lack of clarity may lead to rework or delays | Frequent communication with stakeholders; clearly documented requirements | Adjust scope or timeline based on new requirements |
| R11 | Machine learning accuracy does not meet expectations | High | Med | Gesture recognition may not be as accurate as expected, affecting end-user experience | Implement rigorous testing early in development and adjust models | Refine ML models, incorporate user feedback, and simplify gestures if necessary |
| R12 | Inadequate pre-processing performance | Med | High | Poor pre-processing may lead to inaccurate feature extraction and gesture tracking | Optimize pre-processing algorithms and conduct thorough testing in various environments | Simplify image processing methods if performance issues arise |
| R13 | Security vulnerabilities in mobile app | Low | Med | User data may be compromised during gesture recording | Conduct regular security assessments and ensure proper encryption and data handling | Release patches to fix vulnerabilities; notify users promptly |

### 2.1.1 Risk Descriptions

2.1.1.1 Risk 1: Technical requirements outside team experience

This risk relates to potential issues arising from the integration of hardware and software components, particularly in areas where the team may not have enough experience in.

**Sub Conditions**:

* Complex hardware-software interaction requirements
* Specialized image processing techniques

2.1.1.2 Risk 2: Inconsistent LED Tracking Due to Ambient Lighting

External lighting conditions might affect the accuracy of LED tracking, leading to incorrect gesture data.

**Sub conditions:**

* Variation in light intensity (e.g., too bright or too dim) affecting the visibility of LED signals.
* Flickering or fluctuating ambient light sources could interfere with LED-based tracking.

2.1.1.3 Risk 3: Real-time processing performance limitations

The application may experience performance limitations, leading to delayed or inaccurate tracking.

**Sub Conditions:**

* High computational load due to image processing and 3D gesture reconstruction may cause delays.
* Hardware limitations such as low processing power of mobile devices might result in slow response times.
* complex algorithms such as smoothing and privacy filters may impact real-time interaction.

2.1.1.4 Risk 4: Privacy Filtering Failure

The application may fail to filter out irrelevant or sensitive data, leading to privacy concerns.

**Sub Conditions:**

* Privacy filtering algorithms may not remove all background data, and may end up capturing private details.
* Ineffective implementation of filtering methods may expose users to security vulnerabilities.

2.1.1.5 Risk 5: Misalignment Between Image Processing and Machine Learning

Data from the image processing module may not be compatible with the machine learning algorithms, causing tracking inaccuracies.

**Sub Conditions:**

* Misalignment between the data format output from image processing and input expectations of the machine learning model.
* Integration issues due to different algorithms or coding frameworks used in both processes.

2.1.1.6 Risk 6: Insufficient Training Data for Machine Learning

Machine learning models may perform poorly due to a lack of diversity or high-quality training data.

**Sub Conditions:**

* Limited access to data that covers a wide range of lighting conditions and hand movements.
* Poor-quality data (noisy or incomplete datasets) used for training the model could lead to inaccurate predictions.
* A narrow dataset may cause the machine learning algorithm to overfit, reducing its effectiveness in real-world scenarios.

2.1.1.7 Risk 7: Hardware Failure or Incompatibility

The system’s reliance on smartphones or other such hardware may lead to difficulties if these devices fail or are incompatible.

**Sub conditions:**

* Incompatibility between the smartphone’s camera system and the gesture recognition algorithms.
* Potential failure of LED-equipped gloves, rendering gesture tracking ineffective.
* Device malfunctions during data capture could result in incomplete or lost data.

2.1.1.8 Risk 8: Changes in hardware specification s during development

Changes in hardware specifications lead to having to redesign developments, causing delays and resource reallocations.

**Sub conditions:**

* Unanticipated hardware incompatibilities with the software components due to new updates.
* Adjustments in system design to accommodate new or updated hardware features, requiring significant redesigning.

2.1.1.9 Risk 9: Data Loss or Corruption During Frame Capture

Critical gesture data could be lost or corrupted during frame capture, reducing the system’s overall accuracy.

**Sub conditions:**

* Buffering issues or network lag during real-time capture leading to incomplete data frames.
* Hardware faults causing data to be incorrectly captured or stored.
* Environmental factors (e.g., low battery, app crashes) causing data to be lost before it can be stored or processed.

2.1.1.10 Risk 10: Unclear or delayed requirements from stakeholders

Ambiguous or delayed requirements from stakeholders could lead to rework or project delays.

**Sub Conditions:**

* Lack of clarity in feature expectations from stakeholders, leading to misalignment during development.
* Delays in feedback or approvals from stakeholders, slowing down development progress.
* Requirement changes mid-development causing unplanned rework or redesign.

2.1.1.11 Description of Risk 11: Machine Learning Accuracy Does Not Meet Expectations

The gesture recognition models may not achieve the desired level of accuracy, affecting user interaction and overall system performance.

**Sub conditions:**

* Overfitting or underfitting of machine learning models, leading to inaccurate gesture tracking.
* The machine learning model’s failure to generalize across diverse user gestures or environmental conditions.
* Limitations in algorithm performance due to insufficient training data or inadequate hyperparameter tuning.

2.1.1.12 Description of Risk 12: Inadequate Pre-Processing Performance

Poor pre-processing performance may lead to inaccurate feature extraction and gesture tracking, hampering the overall effectiveness of the system.

**Sub conditions:**

* Pre-processing algorithms may fail to account for variations in lighting or environmental conditions, resulting in poor feature extraction.
* Performance limitations during pre-processing could cause bottlenecks, reducing the system’s ability to handle real-time tracking.
* Inaccurate or incomplete image processing may distort gesture data before it reaches the machine learning module.

2.1.1.13 Risk 13: Security Vulnerabilities in Mobile App

The mobile app may have security vulnerabilities, risking the compromise of user data.

**Sub conditions:**

* Insufficient encryption of data during gesture capture, storage, or transmission.
* The mobile app’s API may have vulnerabilities that expose it to hacking attempts.
* Lack of regular security audits or updates may result in unresolved security flaws.

### 2.1.2 Probability & Impact

**2.1.2.1 Probability & Impact for Risk 1: Technical requirements outside team experience**

* **Probability:** Low – The project team has diverse skills, and any gaps will be identified early during requirement gathering.
* **Impact:** Medium – Design failures or hardware/software integration issues could delay the project or reduce performance if not addressed promptly.

**2.1.2.2 Probability & Impact for Risk 2: Inconsistent LED Tracking Due to Ambient Lighting**

* **Probability:** Medium – Varying lighting conditions are expected in different usage environments, making tracking inconsistencies likely.
* **Impact:** High – Poor LED tracking can directly affect the accuracy of gesture recognition, leading to an unreliable system.

**2.1.2.3 Probability & Impact for Risk 3: Real-Time Processing Performance Limitations**

* **Probability:** Medium – The system requires significant processing power for real-time operations, which may strain available hardware resources.
* **Impact:** High – Slow processing times can severely affect the user experience and the real-time capabilities of the gesture tracking system.

**2.1.2.4 Probability & Impact for Risk 4: Privacy Filtering Failure**

* **Probability:** Low – The team is focused on implementing robust privacy filters, minimizing the chance of failure.
* **Impact:** High – Any failure in privacy filtering could result in sensitive information being exposed, leading to user trust issues and potential legal concerns.

**2.1.2.5 Probability & Impact for Risk 5: Misalignment Between Image Processing and Machine Learning**

* **Probability:** Medium – Differences in data formats or processing techniques between modules can lead to misalignments, especially if integration is not thoroughly tested.
* **Impact:** Medium – If misalignment occurs, it can degrade system performance by reducing the accuracy of gesture recognition.

**2.1.2.6 Probability & Impact for Risk 6: Insufficient Training Data for Machine Learning**

* **Probability:** Medium – Collecting diverse and high-quality training data can be time-consuming, and there may be gaps in the data.
* **Impact:** Medium – If the machine learning models are not trained on sufficient data, their performance may be suboptimal, affecting gesture recognition accuracy.

**2.1.2.7 Probability & Impact for Risk 7: Hardware Failure or Incompatibility**

* **Probability:** Low – The hardware components (smartphones, LED gloves) are expected to function reliably, but there is always a risk of failure or incompatibility.
* **Impact:** High – Any hardware failure or incompatibility could halt the system’s operation or delay project timelines, requiring replacement or redesign.

**2.1.2.8 Probability & Impact for Risk 8: Changes in Hardware Specifications During Development**

* **Probability:** Medium – There is a chance that hardware specifications may change during the development lifecycle.
* **Impact:** High – Significant changes may require redesigning certain components, delaying project progress and increasing costs.

**2.1.2.9 Probability & Impact for Risk 9: Data Loss or Corruption During Frame Capture**

* **Probability:** Low – With proper data validation and handling protocols, data loss or corruption should be minimal.
* **Impact:** Medium – Loss of critical gesture data during capture could compromise the accuracy of the system, leading to incomplete or incorrect gesture tracking.

**2.1.2.10 Probability & Impact for Risk 10: Unclear or Delayed Requirements from Stakeholders**

* **Probability:** Medium – There is always a possibility of miscommunication or delays in gathering requirements from stakeholders.
* **Impact:** Medium – If requirements are unclear or delayed, the project may need rework or adjustments, affecting timelines and potentially leading to missed deadlines.

**2.1.2.11 Probability & Impact for Risk 11: Machine Learning Accuracy Does Not Meet Expectations**

* **Probability:** High – Given the complexity of hand gestures and the reliance on machine learning, achieving high accuracy might be challenging.
* **Impact:** Medium – Poor accuracy in gesture recognition will affect user experience and reduce the effectiveness of the system.

**2.1.2.12 Probability & Impact for Risk 12: Inadequate Pre-Processing Performance**

* **Probability:** Medium – Pre-processing of image data requires significant computational resources and optimization, which may be difficult to achieve.
* **Impact:** High – If pre-processing performance is inadequate, the system might fail to extract useful features, leading to poor gesture tracking and user dissatisfaction.

**2.1.2.13 Probability & Impact for Risk 13: Security Vulnerabilities in Mobile App**

* **Probability:** Low – The team will conduct regular security audits and testing to prevent security vulnerabilities.
* **Impact:** Medium – If vulnerabilities are exploited, user data may be compromised, damaging the app’s reputation and potentially leading to legal issues.

## 2.2 Risk refinement

High probability/high impact risks are refined using the CTC approach.

## 2.2.1 High Probability/High Impact Risks

1. **Inconsistent LED Tracking Due to Ambient Lighting (R2)**
   * **Control:** Implement adaptive image processing techniques that adjust the LED brightness in real-time based on ambient lighting conditions. Conduct rigorous pre-launch testing in various lighting scenarios to optimize tracking performance.
   * **Avoidance:** Design the system to incorporate fallback mechanisms that switch to alternative tracking methods (e.g., using infrared or other non-visible light sources) when ambient lighting falls outside acceptable parameters.
2. **Real-Time Processing Performance Limitations (R3)**
   * **Control:** Optimize algorithms to reduce computational time by employing efficient data structures or other processing techniques. Regular performance profiling will help identify bottlenecks early in development.
   * **Avoidance:** Establish minimum hardware specifications for end users, ensuring that the application runs smoothly on devices meeting these standards.
3. **Changes in Hardware Specifications During Development (R8)**
   * **Control:** Maintain ongoing research on hardware to be up to date with any new changes that may affect the project. Implement a flexible design framework that can adapt to hardware variations.
   * **Avoidance:** Design the application to be compatible with a range of hardware specifications (iPhone, Android, etc.).

## 2.2.2 Monitoring and Reporting

For the high-risk areas identified, the project team will establish a regular monitoring and reporting process that includes:

* **Weekly Reviews:** Conduct weekly meetings to assess the status of high-risk areas, evaluate mitigation strategies, and make necessary adjustments.
* **Performance Metrics:** Define key performance indicators (KPIs) specific to each risk (e.g., tracking accuracy, processing times) to measure the effectiveness of the implemented controls quantitatively.
* **Client Updates:** Provide weekly updates to the client, highlighting progress on risk management strategies and any emerging issues that may require their attention or input.

# 3.0 Risk mitigation, monitoring, and management

## 3.1 Risk mitigation

3.1.1 Risk 1: Technical requirements outside team experience

Identify skill gaps early through planning and requirement gathering, and seek external help (consultants or additional resources) as needed.

3.1.2 Risk 2: Inconsistent LED Tracking Due to Ambient Lighting

Test under various lighting conditions, improve image processing, and adjust LED brightness or use advanced sensors.

3.1.3 Risk 3: Real-Time Processing Performance Limitations

Optimize code for performance and prioritize hardware capabilities during development to improve processing efficiency.

3.1.4 Risk 4: Privacy Filtering Failure

Implement robust filtering algorithms and conduct regular privacy testing to ensure irrelevant data is properly removed.

3.1.5 Risk 5: Misalignment Between Image Processing and Machine Learning

Define strict data formats for communication between the image processing and machine learning modules.

3.1.6 Risk 6: Insufficient Training Data for Machine Learning

Collect or create diverse datasets early, including different lighting and movement scenarios.

3.1.7 Risk 7: Hardware Failure or Incompatibility

Conduct extensive hardware testing during the initial phases of development to detect compatibility issues early.

3.1.8 Risk 8: Changes in Hardware Specifications During Development

Continuously monitor hardware compatibility and app functionality during development.

3.1.9 Risk 9: Data Loss or Corruption During Frame Capture

Implement data validation checks and protocols to ensure accurate frame capture and prevent data loss.

3.1.10 Risk 10: “Unclear or Delayed Requirements from Stakeholders

Maintain frequent communication with stakeholders and ensure requirements are clearly documented.

3.1.11 Risk 11: Machine Learning Accuracy Does Not Meet Expectations

Implement rigorous testing early in development to ensure gesture recognition accuracy.

3.1.12 Risk 12: Inadequate Pre-Processing Performance

Optimize pre-processing algorithms and test in different environments to ensure performance.

3.1.13 Risk 13: Security Vulnerabilities in Mobile Application

Conduct regular security assessments and ensure proper encryption and data handling practices are in place.

## 3.2 Risk monitoring

3.2.1 Risk 1: Technical requirements outside team experience

Monitor the progress of tasks related to unfamiliar technical areas and check for delays or issues in meeting milestones.

3.2.2 Risk 2: Inconsistent LED Tracking Due to Ambient Lighting

Monitor LED tracking accuracy in different lighting environments and check for increased tracking errors.

3.2.3 Risk 3: Real-Time Processing Performance Limitations

Monitor response times during testing, and track any delays or lag affecting gesture tracking accuracy and overall user experience.

3.2.4 Risk 4: Privacy Filtering Failure

Monitor filtering algorithms during testing for accuracy and effectiveness in protecting user data.

3.2.5 Risk 5: Misalignment Between Image Processing and Machine Learning

Monitor data flow between modules, and ensure data compatibility through real-time checks.

3.2.6 Risk 6: Insufficient Training Data for Machine Learning

Monitor model performance with the existing dataset and identify scenarios where data is lacking.

3.2.7 Risk 7: Hardware Failure or Incompatibility

Monitor hardware performance throughout testing to identify potential failure or compatibility issues.

3.2.8 Risk 8: Changes in Hardware Specifications During Development

Check for hardware specification updates regularly and assess their impact on app performance.

3.2.9 Risk 9: Data Loss or Corruption During Frame Capture

Monitor data validation protocols and check for missing or corrupt data during testing.

3.2.10 Risk 10: Unclear or Delayed Requirements from Stakeholders

Monitor changes in requirements and adjust the project scope or timeline accordingly.

3.2.11 Risk 11: Machine Learning Accuracy Does Not Meet Expectations

Monitor model performance and adjust as needed based on testing results.

3.2.12 Risk 12: Inadequate Pre-Processing Performance

Monitor pre-processing performance and adjust algorithms based on test results.

3.2.13 Risk 13: Security Vulnerabilities in Mobile Application

Monitor security features regularly and identify vulnerabilities during testing.

## 3.3 Risk management

3.3.1 Risk 1: Technical requirements outside team experience

If technical issues arise, bring in consultants or external experts to bridge the skill gap, and adjust the project timeline if necessary.

3.3.2 Risk 2: Inconsistent LED Tracking Due to Ambient Lighting

If tracking problems persist, implement stronger LEDs or advanced sensors and adjust the timeline for further testing.

3.3.3 Risk 3: Real-Time Processing Performance Limitations

If performance issues arise, simplify features to reduce computational load or upgrade to more powerful hardware to maintain performance standards.

3.3.4 Risk 4: Privacy Filtering Failure

If privacy issues are detected, roll back the feature until security improvements are made.

3.3.5 Risk 5: Misalignment Between Image Processing and Machine Learning

Implement a real-time debugging layer between the modules to catch and adjust any data discrepancies.

3.3.6 Risk 6: Insufficient Training Data for Machine Learning

Supplement with synthetic data generation or manual labeling to expand the dataset.

3.3.7 Risk 7: Hardware Failure or Incompatibility

Use backup hardware or simulate inputs to continue development if primary hardware fails.

3.3.8 Risk 8: Changes in Hardware Specifications During Development

Work with minimal specs to maintain app functionality and plan updates for future hardware changes.

3.3.9 Risk 9: Data Loss or Corruption During Frame Capture

Allow re-capture or use redundant data logging to mitigate potential data loss.

3.3.10 Risk 10: Unclear or Delayed Requirements from Stakeholders

Adjust the project scope or timeline based on new or clarified requirements from stakeholders.

3.3.11 Risk 11: Machine Learning Accuracy Does Not Meet Expectations

Refine ML models, simplify gestures, and incorporate user feedback to improve accuracy.

3.3.12 Risk 12: Inadequate Pre-Processing Performance

Simplify image processing methods if performance issues persist.

3.3.13 Risk 13: Security Vulnerabilities in Mobile Application

Release patches to address security vulnerabilities and notify users promptly.

# 4.0 Special conditions

A discussion of special conditions that may trigger project critical risks and the actions required should these conditions occur.

## 4.1 Special Conditions and Triggered Risks

* **Change in Regulatory Requirements**

**Triggered Risks:**

* + - Increased development costs (R4: Privacy Filtering Failure).
    - Delay in project timelines due to the need for compliance (R10: Unclear or delayed requirements from stakeholders).

**Actions Required:**

* + - Conduct an immediate review of current project compliance against new regulations.
    - Allocate resources to update privacy filtering mechanisms and other affected areas.
    - Communicate changes to the client and adjust project timelines accordingly.
* **Technological Advancements**
  + **Triggered Risks:**
    - The emergence of superior technologies that could render current project solutions outdated (R8: Changes in hardware specifications during development).
  + **Actions Required:**
    - Monitor industry trends and technology developments continuously.
    - Evaluate the feasibility of integrating new technologies into the current project framework.
    - Reassess project goals and timelines based on technological shifts and their potential impact on project deliverables.
* **Resource Availability Issues**
  + **Triggered Risks:**
    - Unexpected turnover of team members, leading to skill gaps (R1: Technical requirements outside team experience).
    - Insufficient training data for machine learning due to a lack of personnel for data collection (R6: Insufficient training data for machine learning).
  + **Actions Required:**
    - Establish a knowledge transfer plan to document critical processes and information.
    - Create a backup pool of resources, including freelancers or consultants, to fill gaps quickly.
    - Ensure that adequate training and onboarding processes are in place for new team members.
* **Client Engagement Fluctuations**
  + **Triggered Risks:**
    - Decreased involvement from stakeholders leading to unclear or delayed requirements (R10: Unclear or delayed requirements from stakeholders).
    - Loss of support from key stakeholders (R11: Machine learning accuracy does not meet expectations).
  + **Actions Required:**
    - Establish regular check-ins and status updates with stakeholders to ensure ongoing engagement and feedback.
    - Develop a stakeholder management plan that outlines communication strategies and escalation procedures for addressing disengagement.
    - Create a risk reserve fund to manage potential financial impacts stemming from loss of stakeholder support.

## 4.2 Conclusion

By proactively identifying these special conditions and establishing clear actions to mitigate associated risks, the project team can enhance the project's resilience and adaptability. Regular reviews of these conditions will be conducted throughout the project lifecycle, ensuring that the team remains prepared to address any challenges that may arise.