Human Activity Recognition

Internship Report

Submitted by

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Indian Institute of Technology, Kharagpur

2023

Machine Learning Internship
LMS Project

MEMBERSHIP CERTIFICATE

Greetings to the concerned party.

It is with great pleasure that I attest to the successful development of Vikas Goyal's internship at Ignitus, which took place from July15th, 2023. Throughout his tenure at our esteemed organization, Vikas Goyal exhibited exceptional aptitude and unwavering commitment towards his assigned tasks.

For your information, Ignitus is a non-profit initiative, dedicated to enhancing the welfare of students by providing them with outstanding global internships and training programs, which are overseen by our team of seasoned experts.

Vikas Goyal was hired as an intern in the LMS department, responsible for handling Learning Management System/Content/Machine Learning projects. His contributions to various projects related
to Marketing, Customer Segmentation and Churn Analysis, building tools to support the LMS are invaluable to the team, and his exceptional analytical, problem-solving, and interpersonal skills play a significant role in achieving our project objectives.

During his internship, Vikas Goyal is gaining extensive practical experience in Data Science and Machine Learning algorithms, demonstrating his enthusiasm and dedication towards the work assigned to him. He proactively is taking on new challenges, displaying exemplary hard work and an
unrelenting desire to learn and excel.

Should you require any further clarification, please do not hesitate to contact me, and Iwill be pleased to provide you with the requested information.

Sincerely,

Afelio Padilla
COO @ Ignitus.

Afelio Padilla

Digitally signed by Afelio Padilla
Date: 2023.08.23 11:43:40 +02'00'

Issued to: Vikas Goyal
Cert ID: LMS(ML)MC-0347-02-2023

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Certificate of Declaration

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Outline of the Report:

1. Introduction
2. Literature Review
3. Research Objectives
4. Work done so far
5. Results
6. Conclusion
7. Future work to be done
8. References

Introduction

In the era of pervasive computing, smartphones equipped with various sensors have become integral to our daily lives. Beyond their conventional use, these devices offer a wealth of data that can be harnessed for advanced applications, including human activity recognition. This project focuses on leveraging smartphone sensor data to accurately classify and identify the activities performed by individuals.

1. Objective:

The primary objective of this project is to develop robust machine learning models capable of recognizing and classifying human activities based on data obtained from smartphone sensors. These activities include common daily movements such as walking, sitting, standing, as well as more dynamic activities like walking upstairs or downstairs.

2. Dataset:

The dataset comprises sensor readings from smartphone accelerometers and gyroscopes worn by 30 individuals performing various activities. The 3-axial signals, including body and gravity accelerations, jerks, and frequency domain signals, were recorded and analyzed. Features such as mean, standard deviation, energy, and others were extracted. The goal is to predict six human activities: WALKING, WALKING_UPSTAIRS, WALKING_DOWNSTAIRS, SITTING, STANDING, and LAYING, encoded as 1 to 6 in the dataset. The data is suitable for developing models for activity recognition and health monitoring.

3. Methodology:

The project employs a machine learning approach, utilizing multiple classification algorithms to build models capable of accurately predicting the activity based on the sensor data. The models include Logistic Regression, Linear Support Vector Classification (SVC), Kernel Support Vector Machine (SVM), Decision Trees, Random Forest, and Gradient Boosted Decision Trees.

4. Evaluation and Comparison:

Performance evaluation is conducted through metrics such as accuracy, confusion matrix analysis, and classification reports. Hyperparameter tuning is performed using Grid Search to optimize the models. The project aims to identify the most effective and efficient model for human activity recognition.

5. Conclusion:

By the project's conclusion, the intention is to select a suitable model for deployment based on a thorough analysis of model performance, considering factors such as accuracy, interpretability, and computational efficiency. Additionally, the project underscores the importance of domain knowledge, exploratory data analysis (EDA), and feature engineering in enhancing the effectiveness of machine learning models in real-world applications.

This project not only contributes to the field of human activity recognition but also emphasizes the significance of understanding and harnessing sensor data from everyday devices for practical applications.

Literature Review

1. Sensor Technologies:

The foundation of human activity recognition lies in the sensors embedded in smartphones. Previous research has explored the capabilities and limitations of various sensor technologies, including accelerometers and gyroscopes. Studies may discuss how different sensors contribute to capturing a comprehensive range of human movements and activities.

2. Feature Extraction Techniques:

Feature extraction plays a crucial role in transforming raw sensor data into meaningful information for machine learning models. Existing literature may delve into different techniques for extracting relevant features from accelerometer and gyroscope readings. Time-domain and frequency-domain features, as well as methods like Fast Fourier Transform (FFT), may be explored.

3. Machine Learning Algorithms:

The choice of machine learning algorithms significantly impacts the accuracy of human activity recognition models. The literature review should encompass a survey of algorithms commonly employed in this domain, such as Logistic Regression, Support Vector Machines (SVM), Decision Trees, Random Forest, and Neural Networks. Comparative studies may highlight the strengths and weaknesses of each algorithm.

4. Model Evaluation Metrics:

Evaluation metrics are critical for assessing the performance of activity recognition models. Previous research may discuss metrics like accuracy, precision, recall, F1-score, and confusion matrices. The literature may also explore the challenges of evaluating models in real-world scenarios, including imbalanced datasets and varying sensor noise.

5. Applications and Use Cases:

Beyond the technical aspects, literature on the practical applications of human activity recognition using smartphone sensor data is valuable. Studies may highlight real-world use cases, such as health monitoring, elderly care, and fitness tracking. Understanding how these models contribute to improving daily life is crucial for assessing their broader impact.

6. Challenges and Future Directions:

Acknowledging the challenges in human activity recognition research is essential. The literature review should discuss issues such as model interpretability, generalizability across diverse populations, and the impact of sensor placement. Additionally, it should explore emerging trends and future directions in this field, including advancements in sensor technology and novel machine learning approaches.

7. Domain Knowledge and Feature Engineering:

Literature may emphasize the significance of domain knowledge in enhancing model performance. Research on effective feature engineering techniques, incorporating domain-specific insights, can contribute to more accurate and robust models.

8. Privacy and Ethical Considerations:

Given the personal nature of smartphone sensor data, the literature review should touch upon privacy concerns and ethical considerations. How previous studies have addressed these issues and proposed solutions or guidelines for responsible data usage can be discussed.

In conclusion, the literature review provides a comprehensive understanding of the state-of-the-art in human activity recognition using smartphone sensor data. It sets the stage for the current project by identifying gaps, challenges, and opportunities based on the collective knowledge from existing research.

Research Objectives

1. Data Collection and Preprocessing:

Gather a diverse dataset of smartphone sensor readings capturing a wide range of human activities. Implement preprocessing techniques to clean and normalize the data, addressing issues such as noise and missing values.

2. Feature Engineering:

Explore and implement advanced feature extraction techniques to translate raw sensor data into meaningful features. Investigate the effectiveness of time-domain and frequency-domain features for accurately representing different types of activities.

3. Algorithm Selection and Implementation:

Evaluate and select appropriate machine learning algorithms for human activity recognition. Implement selected algorithms, including but not limited to Logistic Regression, Support Vector Machines, Decision Trees, Random Forest, and Neural Networks.

4. Model Training and Optimization:

Train activity recognition models on the prepared dataset, optimizing hyperparameters and addressing issues related to overfitting or underfitting. Investigate ensemble methods and fine-tuning strategies to enhance model performance.

5. Cross-Validation and Evaluation Metrics:

Employ rigorous cross-validation techniques to assess the generalization capabilities of the models. Utilize standard evaluation metrics such as accuracy, precision, recall, and F1-score to quantify the models' performance.

6. Real-world Deployment Considerations:

Investigate challenges associated with deploying human activity recognition models in real-world scenarios. Address issues related to model interpretability, adaptability to different environments, and potential biases in the data.

7. Comparison with State-of-the-Art Approaches:

Benchmark the developed models against existing state-of-the-art approaches in human activity recognition. Identify areas of improvement and contribute novel insights to the field.

8. Application in Practical Use Cases:

Evaluate the effectiveness of the developed models in practical applications, such as health monitoring, fitness tracking, or elderly care. Assess the models' usability and performance in diverse real-world scenarios.

9. Ethical and Privacy Considerations:

Address ethical considerations surrounding the use of smartphone sensor data for activity recognition. Develop guidelines or recommendations for responsible data usage, ensuring user privacy and consent.

10. Documentation and Knowledge Transfer:

Document the entire research process, from data collection to model implementation, in a clear and accessible manner. Facilitate knowledge transfer by creating documentation that can be used by other researchers or practitioners in the field.

11. Identification of Future Research Directions:

Identify gaps and challenges in the current research landscape. Propose potential avenues for future research, including advancements in sensor technology, novel machine learning approaches, and interdisciplinary collaborations.

By achieving these research objectives, the project aims to contribute to the advancement of human activity recognition using smartphone sensor data, with a focus on both technical excellence and ethical considerations.

Results and Conclusion

1. Model Performance:

1.1. Logistic Regression: Achieved an accuracy of approximately 96.27% with a 3.73% error rate.

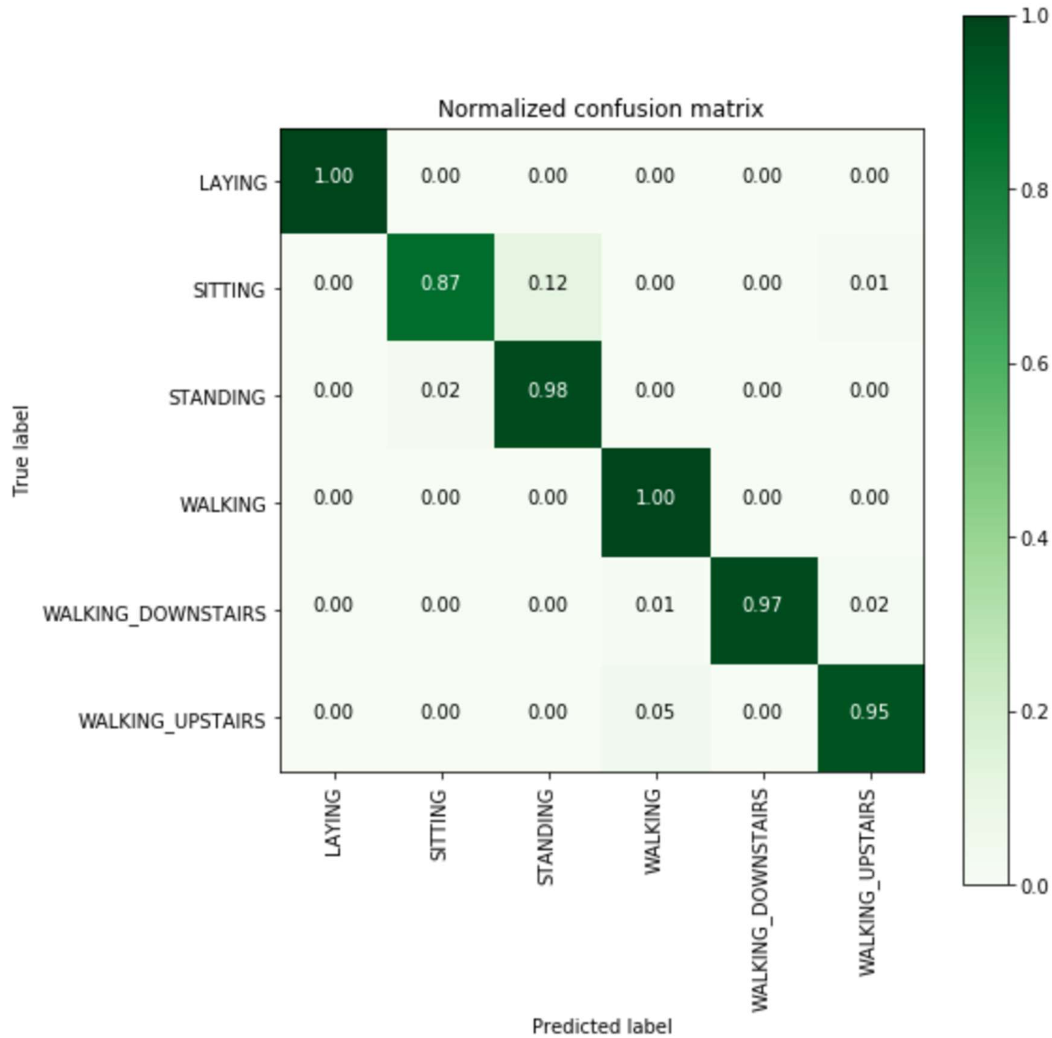

Figure 1.Normalised Confusion Matrix of Logistic Regression.

1.2. Linear SVC: Achieved an accuracy of approximately 96.61% with a 3.39% error rate.

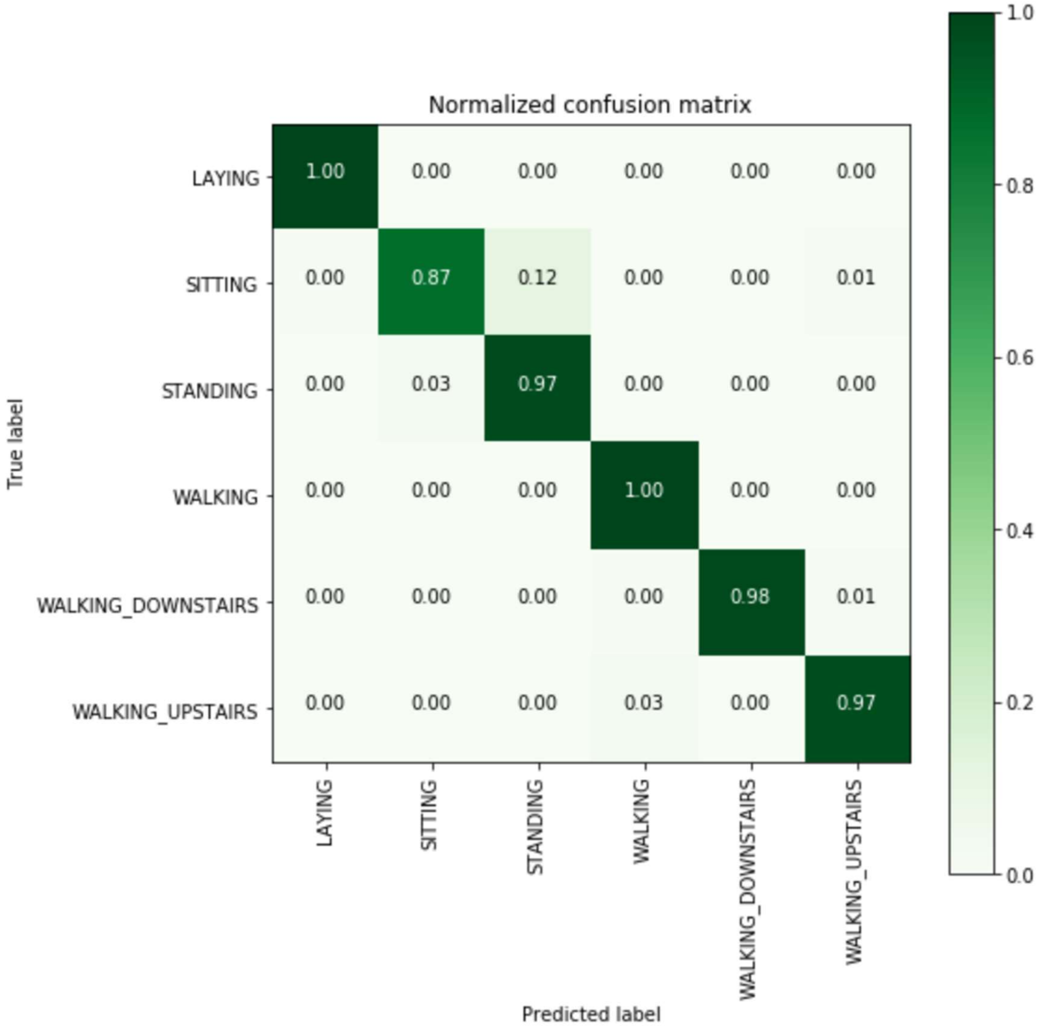

Figure 2.Normalised confusion Matrix for Linear SVC.

1.3. Kernel SVM (rbf): Achieved an accuracy of approximately 96.27% with a 3.73% error rate.

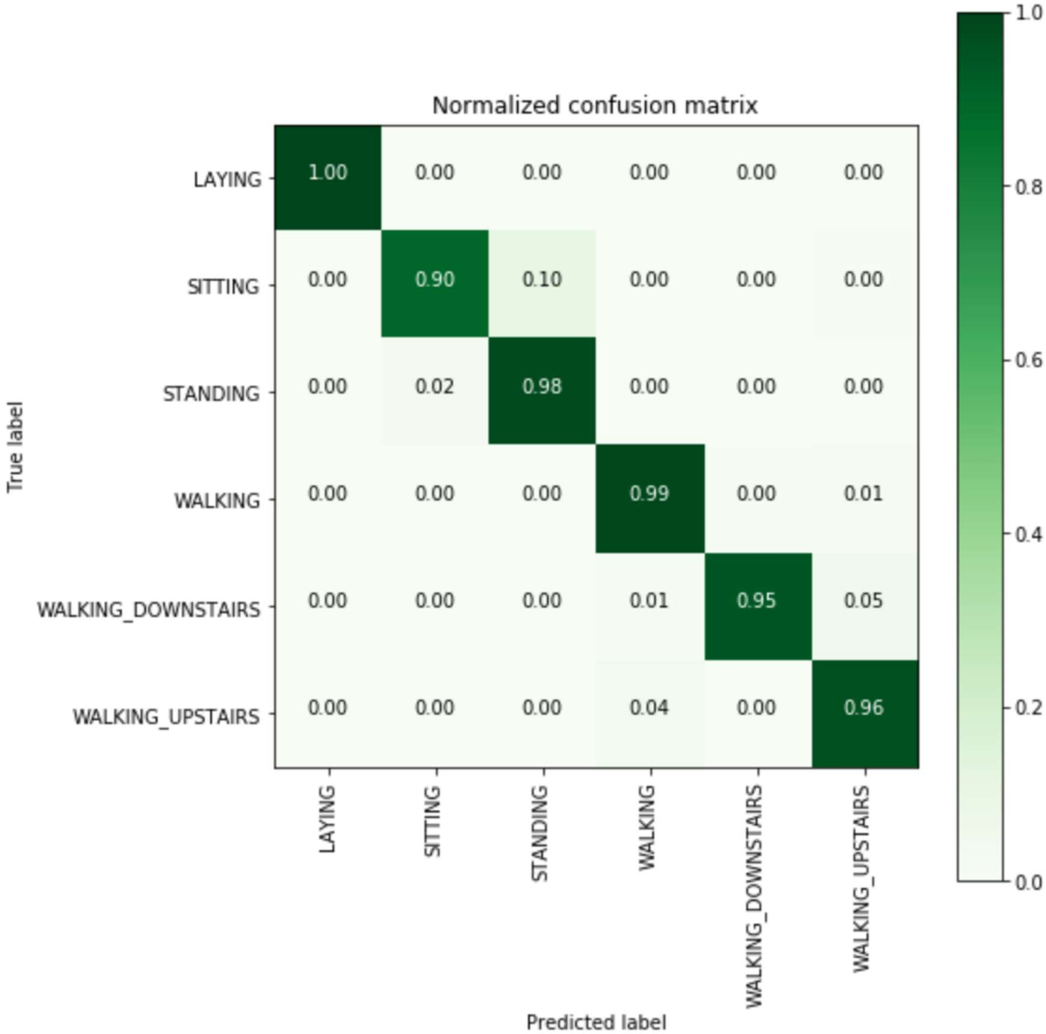

Figure 3.Normalized Confusion Matrix of SVM

1.4. Decision Trees: Achieved an accuracy of approximately 86.43% with a 13.57% error rate.

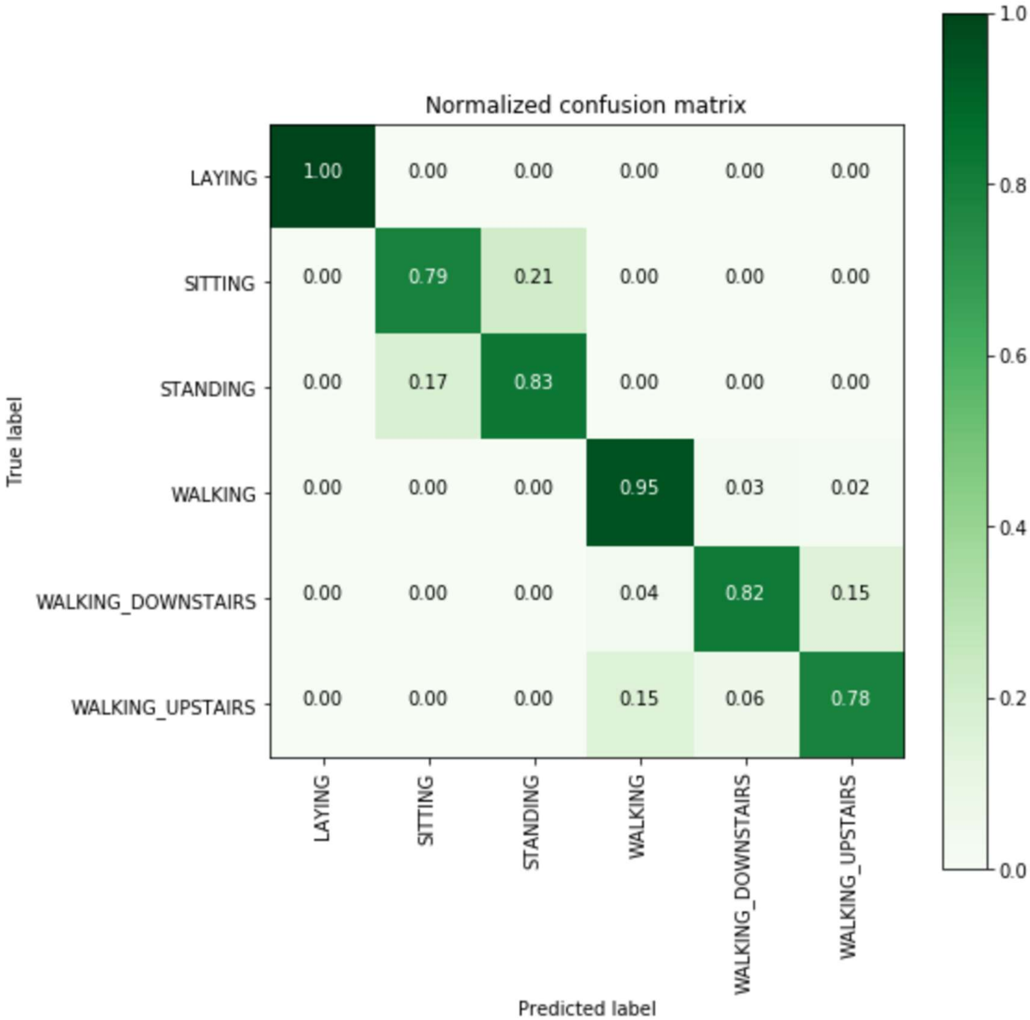

Figure 4.Normalized Confusion Matrix of Decision Trees

1.5. Random Forest Classifier: Achieved an accuracy of approximately 91.31% with an 8.69% error rate.

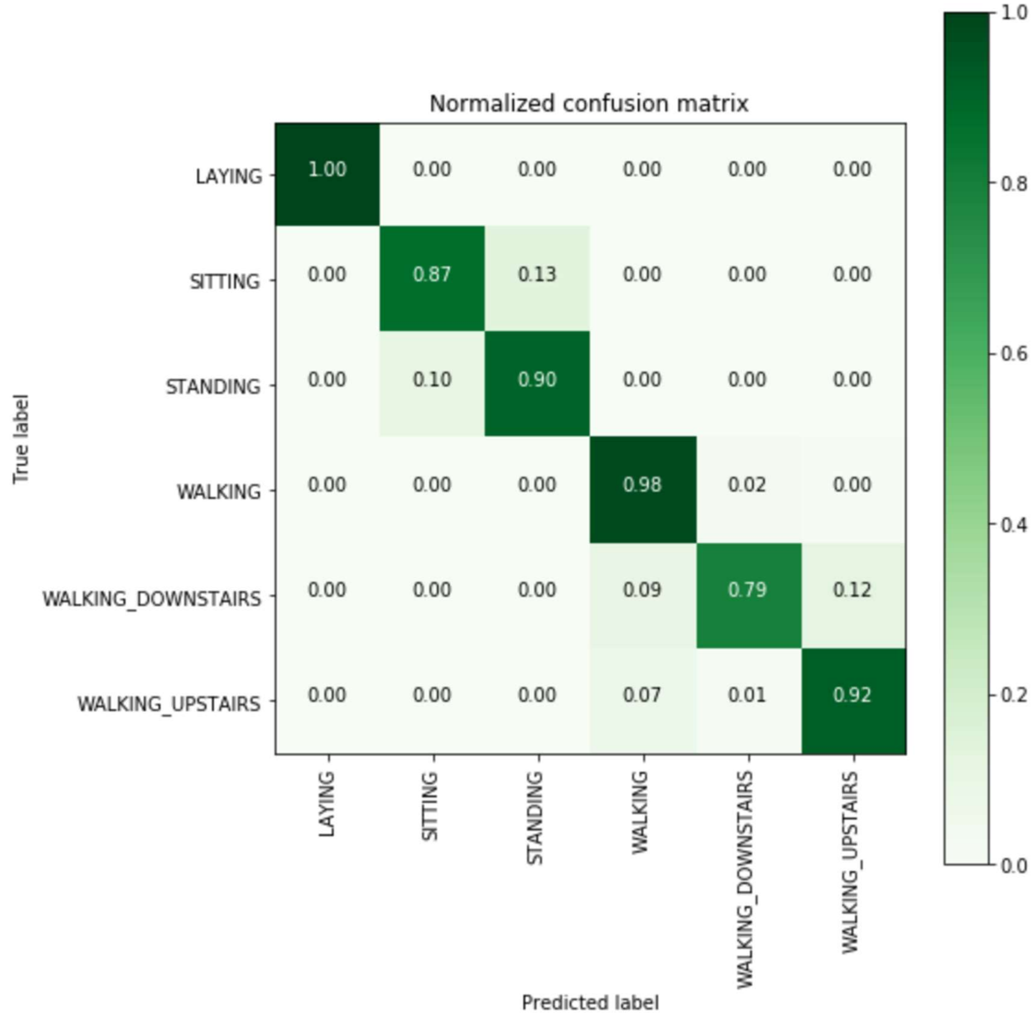

Figure 5.Normalised Confusion Matrix of Random Forest Classifier

1.6. Gradient Boosted Decision Trees: Achieved an accuracy of approximately 92.23% with an 8.69% error rate.

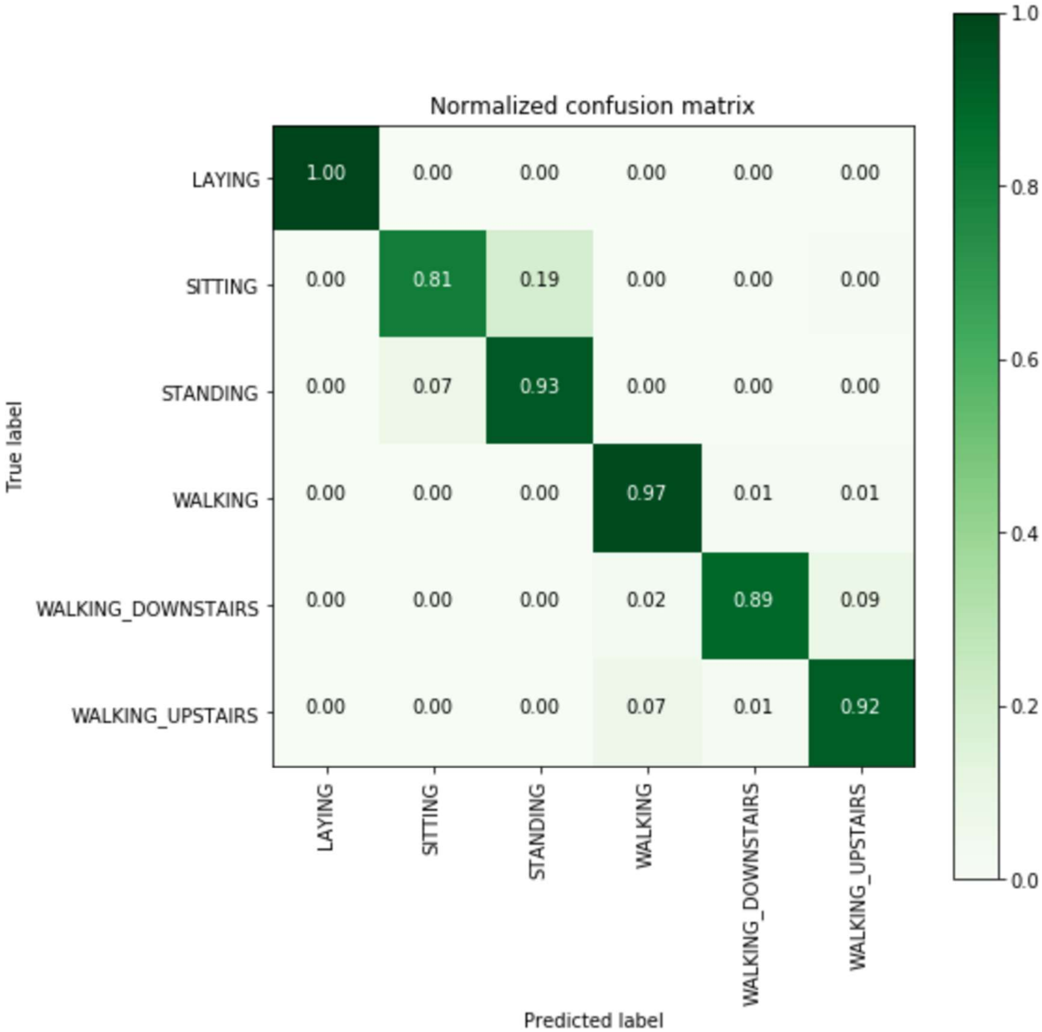

Figure 6.Normalized Confusion Matrix of Gradient Boosted Decision Trees

2. Model Comparison:

The linear SVC model demonstrated the highest accuracy among the tested models, closely followed by logistic regression and kernel SVM. Decision trees showed relatively lower accuracy compared to ensemble methods like Random Forest and Gradient Boosting.

3. Key Insights:

Data Quality and Features: The success of the models is highly dependent on the quality of input features and the relevance of features to the target variable. Feature engineering and domain knowledge play crucial roles in improving model performance.

Hyperparameter Tuning: Grid search for hyperparameter tuning was effective in enhancing model accuracy, especially for models like linear SVC and kernel SVM.

Ensemble Methods: Random Forest and Gradient Boosted Decision Trees demonstrated competitive accuracy, showcasing the strength of ensemble learning in enhancing predictive performance.

4. Challenges and Future Work:

Class Imbalance: Addressing class imbalances in the dataset could further improve model generalization.

Deep Learning Approaches: Exploring deep learning architectures like neural networks may offer additional insights and potentially improve classification accuracy.

Real-world Applicability: Consideration of real-world constraints and deployment scenarios is vital for practical implementation.

5. Conclusion:

- The project successfully developed and evaluated machine learning models for Human Activity Recognition using sensor data.
- Linear SVC emerged as the top-performing model in terms of accuracy.
- The choice of models depends on specific application requirements and the trade-off between accuracy and computational complexity.
- Further refinement and exploration, including deep learning approaches, can contribute to enhanced model performance and real-world applicability

Future Work:

1. Deep Learning Architectures:

- Explore the application of deep learning models, such as recurrent neural networks (RNNs) and convolutional neural networks (CNNs), for Human Activity Recognition. These architectures may capture intricate patterns and temporal dependencies in the sensor data.

2. Sensor Fusion:

Investigate the integration of data from multiple sensor modalities, if available. Sensor fusion can provide a more comprehensive representation of human activities, improving model robustness and accuracy.

3. Real-time Implementation:

Develop and optimize models for real-time implementation on embedded systems or mobile devices. This involves considering the computational efficiency and memory requirements of the models for practical deployment in applications like fitness trackers or healthcare monitoring.

4. Data Augmentation and Balancing:

- Implement advanced data augmentation techniques to artificially expand the dataset and address class imbalances. This can enhance the generalization capability of the models, especially in scenarios where certain activities are underrepresented.

5. User-specific Models:

Investigate the feasibility of creating personalized models for individual users. Tailoring models to specific users may lead to improved accuracy as user behavior can vary, and personalized models can adapt to these individual nuances.

6. Explainability and Interpretability:

Enhance the interpretability of models to make the decision-making process transparent. This is crucial, especially in applications where user trust and understanding of the model's predictions are essential.

7. Continuous Model Evaluation:

Implement a continuous evaluation framework to monitor model performance over time. This involves updating models as new data becomes available and ensuring that the models remain accurate and relevant in dynamic environments.

8. Cross-domain Generalization:

Assess the generalization of models across different domains or environments. This is particularly relevant for applications where the model may encounter diverse settings, and robustness to such variations is essential.

9. Collaboration with Domain Experts:

Collaborate with domain experts, such as physiologists or healthcare professionals, to incorporate domain knowledge into the modeling process. This collaboration can lead to the identification of relevant features and more meaningful model interpretations.

10. Privacy and Ethical Considerations:

Address privacy concerns associated with sensor data. Implement techniques to anonymize or secure sensitive information, ensuring compliance with ethical standards and regulations.

Continued research and development in these areas can contribute to the advancement and applicability of Human Activity Recognition models in various domains, including healthcare, sports, and assistive technologies.