Real-time fall detection and emergency alert system for elderly individuals

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ABSTRACT

Falls among the elderly pose a major health concern, often leading to loss of independence, fear of falling, and significant hospitalization costs. Over the past two decades, medical institutions and researchers have conducted extensive studies on falls, resulting in the development of various scientific solutions and commercial products. Traditional fall detection systems utilize different sensing methods to identify falls after they occur. However, recent research has shifted towards fall prevention, focusing on predicting falls before they happen. Despite advancements, early fall prediction systems are still primarily limited to clinical investigations, and existing studies lack a standardized classification framework. This study aims to bridge this gap by providing a comprehensive overview of falls in the elderly and proposing a generic classification of fall-related systems based on sensor deployment. Using this classification, an in-depth study covering both fall detection and prevention methods has been carried out, including various data processing techniques. The primary objective of this research is to improve the understanding of fall-related systems among medical technologists in public health, thereby aiding in the development of more effective fall-prevention strategies. By integrating advanced sensing technologies and data analysis techniques, this study seeks to enhance the accuracy and reliability of fall detection and prevention methods, ultimately reducing the impact of falls on the elderly population.

Keyword Fall Detection, Emergency Alert System, Elderly Care, Real-Time Monitoring, Health Safety, Machine Learning, Computer Vision, Deep Learning, Internet of Things (IoT)

1. INTRODUCTION

Falls are a significant health concern for elderly individuals, often leading to severe consequences such as loss of independence, fear, and increased hospitalization costs. Over the past two decades, extensive research has been conducted on fall detection and prevention, resulting in various fall management technologies. Traditional detection methods rely on wearable and environmental sensors; however, the absence of a standardized classification makes direct comparison challenging. This project introduces a structured classification of fall-related systems, covering both detection and prevention based on sensor deployment. By providing a comprehensive framework, this study aims to assist public health technologists in understanding fall prevention technologies, ultimately improving elderly care and reducing fall-related risks. The framework categorizes existing methods into sensor-based and vision-based approaches, ensuring better adaptability and efficiency in real-world applications. Additionally, it highlights key advancements in fall management, including AI-driven analytics and IoT integration, which enhance real-time monitoring and emergency response. This structured approach helps bridge the gap between research and practical implementation, fostering innovation in elderly healthcare solutions.

2. LITERATURE REVIEW

1. Paper Name: Detection of Human Falls on Furniture Using Scene Analysis Based on Deep Learning and Activity Characteristics.
Author Name: Weidong Min1, Member, IEEE, Hao Cui1, Hong Rao1, Zhixun Li1 and Leiyue Yao.
Description: One major study area in caring for vulnerable people, such as elderly people at home and patients in hospital facilities, is automatic human fall detection. Several approaches to tackling the problem have been offered throughout the last decade. However, existing systems mainly focus on recognizing humans and are ineffective in complex situations, particularly when it comes to falls on furniture. This work presents a new method for human fall detection on furniture based on scene analysis, deep learning, and activity characteristics to address this issue. To detect humans and furniture, the suggested method uses a deep learning algorithm called R-CNN to analyze the scene. Meanwhile, the human-furniture space relationship is identified.

2. Paper Name: A high reliability wearable device for elderly fall detection
Author Name: P. Pierleoni, A. Belli, L. Palma, M. Pellegrini, L. Pernini and S. Valenti.
Description: Falls are common among the elderly and necessitate prompt assistance. We offer a fall detection system based on an inertial unit containing a triaxial accelerometer, gyroscope, and magnetometer, as well as effective data fusion and fall detection algorithms in this study. The developed orientation filter offers the correct orientation of the subject in terms of yaw, pitch, and roll angles starting with the raw data. Volunteers underwent simulated falls, simulated falls with recovery, and activities of daily living to test the system according to experimental protocols. The unit is able to accomplish fall detection performance that is superior to that of similar systems proposed in the literature by placing our wearable sensor on the subject's waist. The accuracy, sensitivity, and specificity of the results obtained using widely used protocols are superior to those obtained using other methodologies proposed in the literature.

3. Paper Name: Human fall detection with smartphones
Author Name: L. N. V. Colo´n,Y.DeLaHoz and M. Labrador
Description: One in every three adults over the age of 65, according to the CDC (Centers for Disease Control and Prevention), will fall. Twenty to thirty percent of these persons suffer fractures, lose their independence, and even die [1]. Fall detection is a hot topic in study, with thegoal of using pervasive computing to improve people's lives. This study describes a method for detecting falls using data from a smartphone. It uses the smartphone's built-in sensors (accelerometer, gyroscope) to determine where the phone is in the user's body (chest, pocket, holster, etc.) and to look for recognized fall patterns. A brief overview of fall detection systems is presented, as well as the many types of sensors now in use. The proposed approach is thoroughly explained and described. Finally, known performance metrics are used to evaluate the system. The suggested algorithm for fall detection yielded a total accuracy of 81.3. Texting, with a 95.8 fall detection accuracy, jeans' side pocket, with an 87.5 accuracy, and shirt chest pocket, with an 83.3 accuracy, were the top three sites to detect a fall.

4. Paper Name: Machine Learning in Video Surveillance for Fall Detection.
Author Name: Lesya Anishchenko.
Description: The current research looks at how surveillance camera data processing can be used to identify falls using deep learning and transfer learning approaches. An open dataset acquired by the National Center for Scientific Research's Laboratory of Electronics and Imaging in ChalonsurSaone was utilized as a dataset. The CNN AlexNet architecture, which was employed as a starting point for the classifier, was modified to overcome the problem of fall

detection. A dataset of 30 records including a single fall occurrence each was used to evaluate the proposed approach. For the known and unknown classifier surrounding conditions, we attained Cohen's kappa of 0.93 and 0.60, respectively, for fall – non-fall classification.

5. Paper Name: Supervised Machine Learning-based Fall Detection.
Author Name: Meo Vincent C. Caya; Glenn V. Magwili; Denver L. Agulto; Russell John Laranang; Louisse Kayle G. Palomo.
Description: Falls are a critical public health issue, and the number of proposed fall detection systems has risen dramatically in recent years. Using a wearable accelerometer device attached to the subject's waist, a supervised machine learning-based fall detection system was built in this study. Fifteen participants conducted a standardised set of movements, including 10 falling activities and 10 non-falling activities, that were constructed by duplicating the scenarios in the FARSEEING Fall Repository, resulting in a dataset of 900 samples. Supervised Learning is implemented utilising two training sets: (1) 80% of all simulated fall and non-fall activities, and (2) 10 real-world fall signals from the FARSEEING Fall Repository added to the 80% of all simulated fall and non-fall activities.

6. Paper Name: FissureNet: A Deep Learning Approach For Pulmonary Fissure Detection in CTImages.
Author Name: Sarah E. Gerard, Taylor J. Patton, Gary E. Christensen
Description: The detection of pulmonary fissures in computed tomography (CT) is essential for automatic lobar segmentation. The bulk of fissure detection approaches rely on low-level, handcrafted feature descriptors with a limited spatial range. The design of such feature detectors is often focused on normal fissure morphology, resulting in limited sensitivity to weak and aberrant fissures found in clinical datasets. Furthermore, local features often have limited specificity, as the various textures in the lung can be mistaken for the fissure if the global context is ignored. For simultaneous feature extraction and classification, we present a supervised discriminative learning system. FissureNet, the suggested framework, is a coarse-to-fine convolutional neural network cascade. The coarse-to-fine technique overcomes the difficulties of training a network to segment a thin structure that only accounts for a small percentage of the image voxels. FissureNet was tested on 3706 patients who had 3DCT scans of their inspiration and expiration from the COPDGene clinical study and 20 subjects who had 4DCT scans from a lung cancer clinical trial. FissureNet outperformed a deep learning system based on the U-Net architecture and a Hessian-based fissure detection method on both datasets in terms of area under the precisionrecall curve (PR-AUC).

7. Paper Name: Machine Learning-based Fall Characteristics Monitoring System for Strategic Plan of Falls Prevention.
Author Name: Chia-Yeh Hsieh1 , Wan-Ting Shi1 , Hsiang-Yun Huang1 , KaiChun Liu1 , Steen J. Hsu2 and Chia-Tai Chan1.
Description: The likelihood of falling increases with age and physical fragility. Because falls are unavoidable and unexpected events, fall characteristics tracking is essential for developing a strategy plan for preventing falls. Typical clinical recording methods, on the other hand, have problems with objective and continuous assessment. A fall characteristic monitoring system is presented in this work to assist healthcare experts in determining the causes of falls in order to develop fall prevention measures. The system includes a high-accuracy fall event recognition algorithm as well as fall direction identification. In this experiment, eight males are selected and requested to do the seven categories of falls and six types of ADL. Motion acceleration is measured using a 128 Hz sample rate using a waist-mounted tri-axial accelerometer. The hierarchical fall event detection algorithm's sensitivity, specificity, precision, negative predictive value, and accuracy are 99.83 percent, 98.44 percent, 98.67 percent, 98.44, and 99.19 percent, respectively. Furthermore, employing fall direction identification, the total average performances of sensitivity, precision, and accuracy are 98.52 percent, 97.49 percent, and 97.34 percent, respectively. The findings showed that the proposed method met the requirements of the fall characteristics monitoring system.

8. Paper Name: A Machine Learning Approach to Falling Detection and Avoidance for Biped Robots.
Author Name: Jeong-Jung Kim1, Yeoun-Jae Kim2, and Ju-Jang Lee3.

Description: The ability of biped robots to resist falling is an essential research area for their application in human environments. In this research, we present a machine learning strategy for biped robots to recognise and prevent falling. The machine learning algorithm Support Vector Machine (SVM) is used to determine the robot's falling state based on the torso's acceleration and the robot's centre of pressure value. When a fall is detected, the reaction module generates a gait that extends the robot's supporting polygon areas. The paper's key contribution is the identification of falling biped robots using sensor data and a machine learning system without using explicit robot dynamic parameters or a specified threshold value.

9. Paper Name: Falling Detection System based on Machine Learning.
Author Name: Mai Nadi1,3, Nashwa El-Bendary2,3, Aboul Ella Hassanien1,3, Tai-hoon Kim4.
Description: Because falling is the most common problem that elderly people confront around the world, this research presents a Machine Learning-based fall detection system (ML). A collection of films showing falling movements was used in the proposed system by breaking each video into numerous shots, which were then turned into gray-level images. The foreground is first recognised in order to detect moving objects in movies, after which noise and shadow are removed in order to detect the moving object. Finally, in order to detect the presence of falling, a number of variables, such as aspect ratio and falling angle, are retrieved and a number of classifiers are applied. The suggested falling detection strategy based on Linear Discriminant Analysis (LDA) classification algorithm outperformed both support vector machines (SVMs) and Knearest neighbour (KNN) classification algorithms in 10-fold cross validation.

10. Paper Name: Low-Dose Lung CT Image Restoration Using Adaptive Prior Features From Full-Dose Training Database.
Author Name: Yuanke Zhang, Member, IEEE, Junyan Rong, Hongbing Lu.
Description: Low-dose computed tomography (LdCT) imaging can benefit from the valuable structure features seen in full-dose computed tomography (FdCT) scans. However, the inability to adaptively capture local characteristics of interested structures in the LdCT image may result in poor detail/texture preservation in the LdCT image. The goal of this study is to investigate a novel prior knowledge retrieval and representation paradigm dubbed adaptive prior features assisted restoration algorithm for better lowdose lung CT image restoration by adaptively capturing local features from FdCT scans. The development of an offline training database and an online patchsearch technique that is coupled with principal component analysis is the novelty (PCA). The offline training database, in particular, is made up of 3-D patch samples taken from full-dose lung scans. As training samples for online patch-search, 3-D patches having a structure comparable to the noisy target patch are initially selected from the database. The training samples are then subjected to PCA to adaptively extract their local previous main features. The noise of the target patch may be efficiently reduced and the detailed texture kept by applying principal features to deconstruct the noisy target patch using an adaptive coefficient shrinkage technique for inverse transformation.

3. MOTIVATION

Falls, especially among the elderly or individuals with medical conditions, pose significant health risks and can lead to severe consequences if immediate medical attention is not received. Common repercussions include fractures, particularly hip fractures, which can cause long-term immobility, and head injuries that may increase the risk of strokes. Repeated falls can result in a loss of independence, making individuals reliant on caregivers, and in extreme cases, falls can be fatal. The growing threat of falls significantly impacts health and quality of life, especially for older adults, as they are the ninth leading cause of death in the United States. Additionally, the physical and psychological effects, such as the fear of falling, further contribute to reduced mobility and independenc

4. OBJECTIVE

- **Detect Falls Accurately** – Utilize advanced sensors and machine learning algorithms to detect falls with high accuracy while minimizing false alarms.
- **Provide Instant Alerts** – Automatically send emergency alerts to caregivers, family members, or medical personnel when a fall is detected.
- **Ensure Real-Time Monitoring** – Enable continuous monitoring of elderly individuals to provide timely assistance in case of an emergency.
- **Enhance Independence** – Support elderly individuals in maintaining their independence by ensuring immediate help is available when needed.
- **Integrate with Wearable and Smart Devices** – Develop a system that can be integrated with smartwatches, mobile applications, or IoT-based healthcare solutions for seamless operation.
- **Improve Response Time** – Reduce the time taken for medical assistance by providing precise location and health status information during an emergency.

5. PROBLEM STATEMENT

As the global population ages, the safety and well-being of elderly individuals, particularly those living alone or at a higher risk of falls, has become increasingly important. Falls are a leading cause of injury and death among older adults, often resulting in severe health complications if not addressed quickly. This project aims to develop a machine learning-based fall detection system that monitors and identifies falls in real-time, sending instant alerts to caregivers or family members. By using a logistic regression model, the system analyzes body movements through live video input, such as from a laptop camera or CCTV setup, to detect potential falls. This approach allows for efficient and accurate fall detection, helping to provide immediate assistance and preventing further harm. The system's automated notification feature ensures that caregivers are alerted via SMS, reducing the time it takes for help to arrive and significantly improving the safety of elderly individuals who may not be able to seek assistance on their own.

The system is designed to be scalable, suitable for use in various environments like homes, hospitals, and assisted living facilities. It can integrate with CCTV cameras in healthcare settings to continuously monitor without infringing on privacy. Future developments of this system could include incorporating IoT devices like wearable sensors or smart home technologies to further enhance fall detection. Additionally, cloud storage and remote monitoring would allow caregivers to access real-time data from anywhere, and predictive analytics could be used to assess fall risks based on individual behaviors. By combining artificial intelligence with healthcare, this project has the potential to revolutionize eldercare, offering both immediate aid and long-term safety, thus improving the quality of life for aging populations and helping them maintain their independence

6. METHODOLOGY

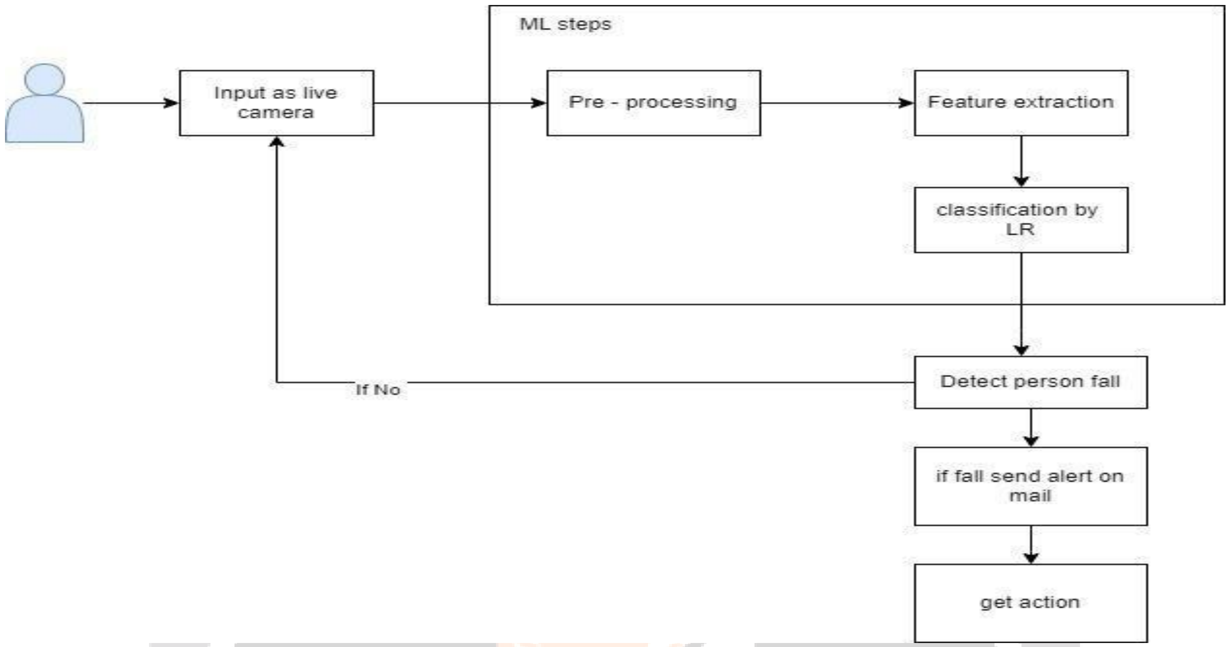

Chart -1: System Architecture

Hardware Requirements:

- Processor: Intel Core i5 (8th Gen, 2.6 GHz) or equivalent
- Hard Disk: 150 GB (Min)
- RAM: 8 GB (Min)

Software Requirements:

- Operating System: Windows 10 (64-bit)
- Python Version: Python 3.7 or above
- Coding Language: Python
- Database: SQLite
- GUI Library: Tkinter
- IDE: Spyder, PyCharm
- Development Environment: Anaconda Navigator
- Web Server: None (Local processing)
- Machine Learning Libraries: TensorFlow, Keras, Scikit-learn, Tinker

7. PROJECT SCHEDULE

Project task set:

Major Tasks in the Project stages are:
Task 1: Correctness
Task 2: Availability
Task 3: Integrity

Task network:

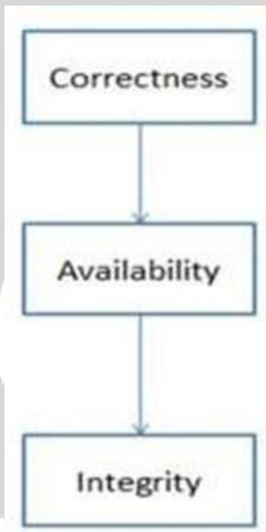

Chart -2: Task Network

8. DATA FLOW DIAGRAMS

A Data Flow Diagram (DFD) visually represents the flow of data within a system, mapping out processes, data storage, and external entities that interact with the system. It typically consists of four main elements: processes, data stores, data flows, and external entities. Processes represent activities or functions where data is manipulated. Data flows illustrate the pathways that data follows within the system, Data stores represent places where data is held, such as databases or files, External entities are objects outside the system boundary, such as users, other applications.

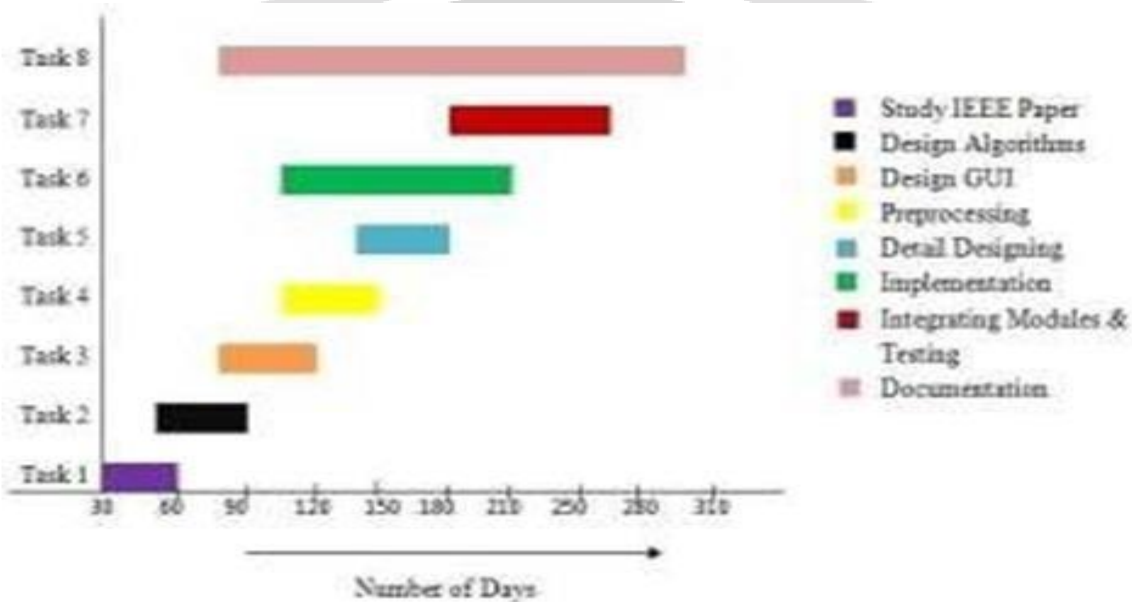

Chart - 3: Gantt chart of projet

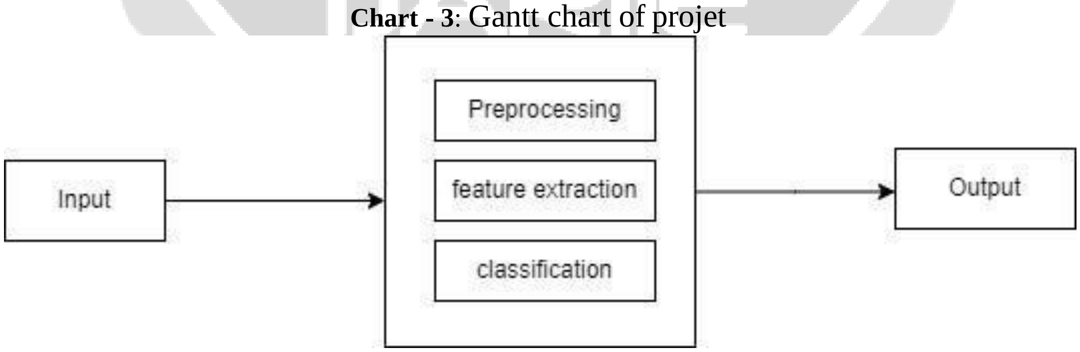

Chart – 4.1: Data Flow Diagram Level-0

Chart – 4.2: Data Flow Diagram Level-1

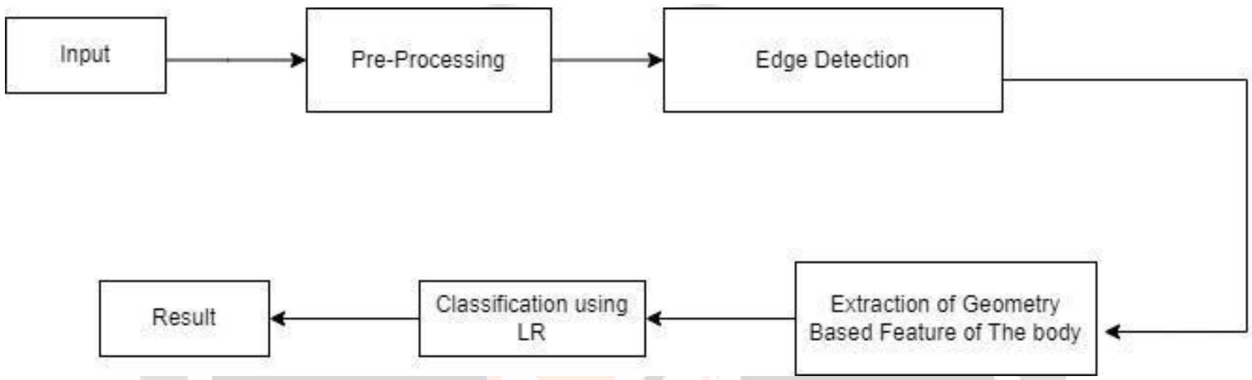

Chart – 4.3: Data Flow Diagram Level-2

4. CONCLUSIONS

Sign language bridges the communication gap between deaf-mute individuals and others. The proposed system introduces a method for real-time conversion of sign language into speech, enabling seamless two-way communication. By eliminating the need for a human translator, this system serves as the voice of the deaf-mute person, making interactions more natural and efficient. This project is a step toward empowering specially challenged individuals, enhancing accessibility and independence. Future advancements can focus on improving user-friendliness, efficiency, and portability. Expanding compatibility to recognize a wider range of static and dynamic signs will make the system more effective. Additionally, integrating this technology into mobile devices using built-in cameras can provide greater accessibility and convenience. Such developments will make sign language recognition more practical and widely available, helping to bridge communication barriers in everyday life. This innovation contributes to an inclusive society where everyone can communicate effortlessly.

5. Algorithm Details

Logistic Regression Algorithm:

Input: Training dataset with features (X) and labels (Y).

Output: Predicted probabilities or binary classification (placed/not placed).

1. Initialize weights and bias values.

2. Compute the linear combination of features: Z=XW+bZ = XW + bZ=XW+b.

3. Apply the sigmoid activation function: σ(Z)=11+e−Z\sigma(Z) = \frac{1}{1 + e^{-Z}}σ(Z)=1+e−Z1 to map values to probabilities.

4. Determine the class labels based on a threshold (e.g., 0.5):

   o If σ(Z)≥0.5\sigma(Z) \geq 0.5σ(Z)≥0.5, predict placement.

   o Otherwise, predict no placement.

5. Optimize weights using gradient descent to minimize the logistic loss function:

   o L=−1n∑i=1n[yilog(y^i)+(1−yi)log(1−y^i)]L = -\frac{1}{n} \sum_{i=1}^{n} [y_i \log(\hat{y}_i) + (1 - y_i) \log(1 - \hat{y}_i)]L=−n1∑i=1n[yilog(y^i)+(1−yi)log(1−y^i)].

6. Iterate until the model converges or a specified number of iterations is reached.

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