Forecasting and Decision-Making System for Military Resource Allotment

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ABSTRACT
Every country is in some sort of rivalry with its neighboring countries. Military forces safeguarded people's lives day in and out. The forces are being placed in many zones near the hotspots of the border areas to fight off enemies. These zones are critical and challenging in many ways, which put the militia's life at risk. The main goal of this research is to save the militia's life. This paper proposes an Environment Condition-based Resource Allocation in Military (ECRAM), which helps in decision-making and in providing a report to aid the militia in a war zone. This ECRAM Model analyzes many factors like climatic condition, resource availability, and health status of the militants at the base station. It was implemented by comparing different machine learning approaches to analyze the appropriate one for the proposed model. Results show that the accuracy of prediction and decision-making with the random forest algorithm has outperformed with an accuracy of 94.4 percent.

Keywords: *Forecasting, Machine learning, Military, Spatial Analysis.*

1. INTRODUCTION

Military operation includes planning military armed forces and forecasting demand for required resources. This is one of the vital steps to help effective decision-making in saving the lives of the militants [1]. Health and food supplies are the most critical requirements to keep them safe and strong during adverse conditions. The commander has to take up quick and efficient decisions to help with the needs of his battalion [2]. Data is the most important and critical component that can facilitate effective decision-making. In this proposed Environment Condition-based Resource Allocation in Military (ECRAM) model, machine learning and spatial analysis are used as a key approach to optimize and improve efficiency. Machine learning provides the system the capability to automatically learn and make decisions [3]. Spatial analysis of geographic information helps in locating militant's geo points and visualized information [2]. The identification of such properties and soldier's health care provides the strength to associate results with real-time data. Ongoing developments in spatial statistics and modern geographic information systems have greatly improved the ability to undertake geospatial studies. Some of the tools in the spatial analysis also make data easier to represent and understand visually [4]. For example, simply mapping data over a study area can provide powerful insight for users (military authorities in the field) without requiring advanced statistical knowledge.

The geospatial and methodological development environment has evolved in the last few years. The sources and forms of available geospatial data are growing rapidly. The Flow of information from a host of sensors has grown in recent years to the point that many observations can be geo-referenced. Data storage and handling change what, how, and when to collect data on individuals and their environments.

This research work proposes a spatial visualization approach that supports the efficient use of militia resource information and medical conditions in war zones. The base of this work was on considering the weightage of a soldier (as a resource) to calculate the workload distribution. Machine learning algorithms were used in the proposed ECRAM model to improve decision-making in critical scenarios [5]. The decision-making depends on various factors like climatic conditions and resource availability. These factors can be related indirectly as a major reason to affect the decision making as the health of a soldier can also reflect in his performance. It becomes an important criterion to be considered for research.

The work also extended to visualize the data in real-time. Example: Wearable electrochemical sensor placed on militants captures the toxicity in the air, which means in that particular time the geo points captured and highlights there is a possible chance of bomb blast and the commander should send necessary medical aid to help those soldiers in that location. The work also implements various machine learning algorithms for comparative analysis.

2. DATA AND COMMUNICATION OF ARMED FORCES

Armed forces are the organized troops working for the country's political interest [4]. These armed forces are remotely controlled by the higher commands selected by the ruling bodies of the country. The army personnel is deployed at critical locations like country borders, forests, and mountains. These forces work in challenging environments like high altitudes and ever-changing climatic conditions, risking the life of militia [6]. The soldiers might have been held captive or could have experienced any threat or resource crunch at any point in time. In such cases, the commander should plan the resources effectively and distribute them accordingly. Data mining techniques are used by the commander to forecast unforeseen circumstances and help them get prepared for any situations in real-time [7]. However, with the implementation of the Machine Learning model, the whole process of reporting the resource status manually and the risks/ problems in communication can be bypassed automatically by the prediction algorithm. In fact, the continuous monitoring of the vital signs of the resources (diesel, oil, gases, medicines, food, and supplements) can be maintained and allocated accordingly in every base station.

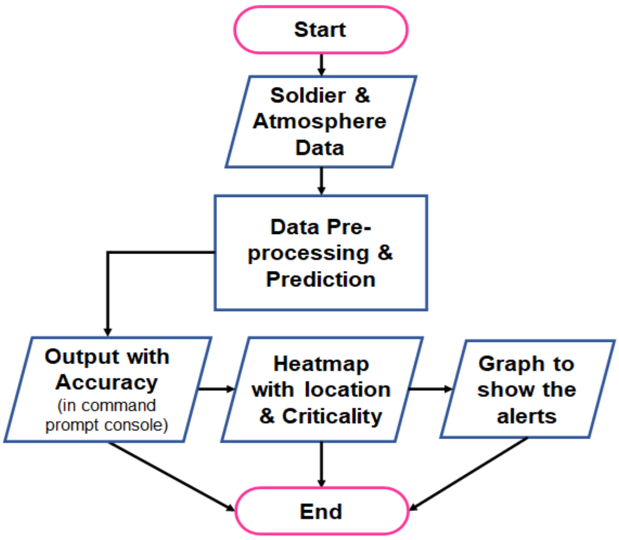

Figure 1 Data collection and processing in the military environment.

As shown in Figure 1, data pre-processing is important for successful analysis; it makes the data more manageable for the data mining process. In data mining, pre-processing is an important function as it transforms data into a more understandable form [8]. The pre-processed data is in a flexible format, so easier to analyze and hence improves the data quality. Another advantage of data modification is that it will be more suitable or fit for a specified data mining technique [7]. Data pre-processing techniques normally clean, integrate, transform or reduce the size of data [9]. Fixing the attribute weightage is one of the critical activities. Higher weight is assigned to more important features and going to very low weight based on how less important the feature is [6]. These Weights are sometimes assigned to the resources having the relative importance of features. For example, the relevancy calculated based on weighted Euclidean distance is captured from the base station and visualized in a heat map for alerting the general in case of any uncertainties.

3. CHALLENGES AND NEEDS OF RESEARCH

Sensor data collected from the military personnel and base station points in real-time helps to constantly monitor the environment and the health status of a person [7]. The research aims at providing the base station with information superiority about the army personnel's health and resource management. Hereby, analyze the militants' location and resource availability plotting their health and base station points with colors such as red (High), orange (Moderate), and green (Good), indicating the intensity of trouble. This allows the control room to navigate and coordinate with the troop [10]. The main issue with these communications is that the signals can be lost due to harsh weather, fog, high altitudes, etc. Such cases can prove fatal to the army personnel to stay at those high altitudes and harsh weather conditions. This work proposes to monitor both Weather conditions of the army personnel location using sensor devices and constantly feed this information to a machine learning model [11]. This ECRAM model will then analyze the given data and predict the exact situation and show it on the heatmap, drawing a graph on time vs. the current status of the resource information. The authorities can use the framework for effective deployment and to know about the ideal condition of their troop at a particular point in time [12]. This uses a Random forest algorithm to accurately analyze the data and predicts the militant's condition. It furthermore tests the atmospheric parameters that affect an individual militant and analyses the resource usability and maintenance.

4. PROPOSED SYSTEM

In this section, an ECRAM model is proposed that can collect the data to the central stations from the environment for better decision-making. Figure 2 shows the proposed ECRAM Model that can improve decision-making. The system collects the data from sensor devices to record climate, explosive gases, the soldier's body temperature, pulse, and other biological data. The data is aggregated and forwarded to the centralized stations. It is analyzed to collect accurate conditions of climate change and soldier's health details. Finally, the system can be used to alarm or alert the higher officials to take on the time necessary decisions. It is to value soldiers' life by providing medical service and necessary resources, In case of any sudden attacks or threats. By predicting the situation, prior soldiers are alerted accordingly, which leads to better management of resources and saving the country. It is crucial to take care of the army people because they are the reason for people to have a safe and happy life.

Pre-processing refers to the transformation applied to data before applying it to the algorithm. Data Preprocessing is used to convert the raw data into a useful data set. When the data is obtained from different sensors, it is collected in raw format, which is not ready for analysis, so the data has to be processed to be in a proper form.

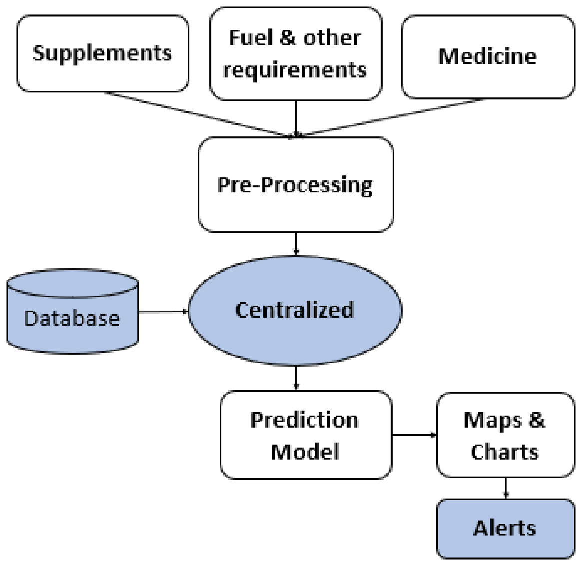

Figure 2 System flow diagram

Some specified machine learning models need data in a specific format. Another aspect is that data sets should be in a form where more than one Machine Learning algorithm is executed in one data set. One of the best out of them is considered.

Machine learning is the development of computer systems that can learn and adapt without explicit instruction, using algorithms and mathematical models to analyze and draw from data patterns. Supervised learning is the task of extracting data or deriving performance from labeled training data [13]. It examines the data and provides results that could be used for mapping models.

Unsupervised learning is an AI system where you do not have to administer the system [13]. Rather, possible to enable the model to take a shot on its own to find data. It mostly manages the unlabeled information.

5. IMPLEMENTATION OF PROPOSED MODEL

The proposed ECRAM Model was implemented and analyzed using python. Figure 3 shows the workflow of the proposed ECRAM Model using python. The real-time implementation of the proposed system is challenging because of the cost and challenging conditions involved in the research. To prove the claims of the research, data was generated using a simulation in different virtual scenarios. The environment was designed based on a case study of shared borders between India and its neighbors [14] [15].

Table 1. Data description of selected attributes

Attribute	Description
Id	Unique identification number given for militants
Time	Realtime monitoring of the personnel
StaID	ID of the base station
Pulse	Realtime pulse rate of the militant
Temperature	Realtime time body temperature
Lat	Soldiers Geopoint
Long	Soldiers Geopoint
PM2.3	Fine particulate matter of size less than 2.5mm, is an air pollutant that is a concern for people's health when levels in air are high
PM10	Particulate matter in the air
SO2	Sulphur Dioxide Gas released as the results from the burning of either sulfur or materials containing sulfur
NO2	High reactive gas that results due to explosion (All explosion will emit some toxic Nitrogen)
CO	Carbon Dioxide - metastable at atmospheric pressure but is a powerful explosive.
Status	Health status of the militants
Sound	Sound frequency in the surrounding

The collected data were further processed using different machine learning approaches by considering the challenging climate and difficult life in such an environment.

In the proposed ECRAM, soldier weight calculation was done using Fuzzy Logic. The equation for fuzzifier is given below:

$$\mu A'(x) = \{1,\ if\ x = x*\quad 0,\ Otherwise \qquad (1)$$

Membership function μA(x) equals the degree to which x is an element of set A. This degree, a value between 0 and 1, represents the degree of membership, also called membership value, of element x in set A.

DE fuzzifier:

A= {(x,μ A(x):x ϵ X)} (2)

Here, μA(x)is called the membership function of A.

Table 2. Parameters involved in resource allocation

Site Difficulty Level
Infrastructure
Food/Shelter
Access to resources
Risk Zone
Minimum time to get backup
Working Hours

Table 3. Input Membership functions

Whether
Good
Average
Bad

Table 4. Site Difficulty Level

Site Difficulty Level
Low
Medium
High

Multiple external factors as shown in Table 2, Table 3 and Table 4, influences the soldiers weight value. Fuzzy logic uses nine fuzzy rules to calculate weight values as shown in Table 5. These values make a difference in decision-making, as the calculation is considered in such critical environments.

The work further compares the existing classifiers for the generated data. This helped to learn the best classifier applicable for the proposed ECRAM model.

5.1. Data Description

The research on the proposed ECRAM Model was analyzed using the data from [16]. The selected attributes and their description for the used data are presented in Table 1.

5.2. Classifiers used in the Implementation

Four different classifiers were experimented to find the best suit for the proposed ECRAM Model. The classifiers used for the research are given below:

Table 5. Output

Soldier Weight Value	
High	1
Medium	0.75
Low	0.5

5.2.1. Decision Tree Classifier

A decision tree is a finite branching structure that has internal nodes with a decision rule [17] [18]. In the decision tree, each node shows a feature, and the proceeding link shows a decision rule. There is a set of leaves, each containing some information that is used for final decision making. A classification rule is specified by the whole path, from the root to the leaf. Decision Trees can handle continuous and discrete data effectively [19].

5.2.2. SVM Classifier

SVM (Support Vector Machine) is a type of supervised learning approach. It has the capability to select its own support vectors [20]. SVM minimizes the empirical error and maximizes the geometric region and is one of the widely used classification tools [21].

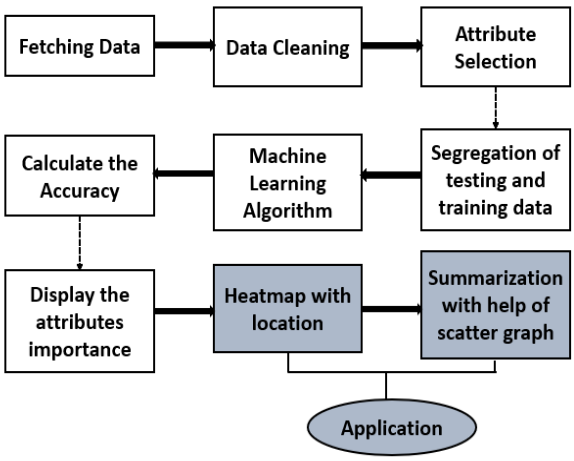

Figure 3 Workflow of the proposed ECRAM Model

5.2.3. Gaussian NV Classifier

A gaussian naive Bayesian data classification model was proposed in [22-26]. It is basically used for classifying unknown continuous data with a large amount of non-prior information. The naive Bayes classifier assumes all the features are independent of each other.

Even if the features depend on each other or upon the existence of the other features. It's specifically used when the features have continuous values.

5.2.4. Random Forest

A random forest is a type of classification algorithm constructed with many decision trees randomly selected from a set of possible trees [27]. Random forest is an integrated form of decision tree algorithm and has better generalization ability [28-34]. Each individual tree has an equal chance. It can be efficiently generated by a random tree, and the combination of large sets of random trees leads to the design of accurate models. Random forests have different benefits like reducing risk, reducing the training time required, and providing high-level accuracy in large databases.

5.3. Real-time implementation requirements

Real-time implementation of such a model can be achieved by the following system requirements.

5.3.1. Wireless Sensor Networks [35]

WSNs consist of a large number of small sensor nodes. There are different types of sensors available like temperature sensor, humidity sensor, impact sensor, electrochemical sensor, and others. Due to these variant sensors that are available, WSNs play a major role in military application multiple parameter monitoring, information gathering, detection, and smart logistics support in an unknown deployed area. Capabilities of real-time transmission play an important role in military operations.

5.3.2. Fog paradigm [36]

The fog paradigm helps in overcoming the challenge in cloud storage which is storing and processing data from all regions within data centers which cannot be effective in terms of response time and other factors that are important for mission-critical applications. A multi-sensor geo-fog model helps to address these limitations and is recommended for the defense field as it is a mission-critical application.

5.3.3. Application Server

The real-time implementation becomes possible by providing an interface for the users. As per the requirement of the model, the users are going to be the decision-makers for the soldiers, especially the higher commanding officers. The interface can be designed and developed as an application visualizing the current status and alerts. Further, the application can be enhanced with multiple features to facilitate multiple features.

6. RESULT ANALYSIS

The analysis shows which machine learning algorithm has the highest accuracy and is suitable for this ECRAM Model, and thorough analysis, it is identified that the Random Forest algorithm has the highest accuracy, 94.44% when compared to the algorithms applied on the ECRAM Model (refer to Figure 4). The accuracy percentage was obtained based on the correct predictions for the test data. It can be calculated by dividing the number of correct predictions by the number of total predictions. The data is split into training and testing data in the Golden Ratio of 70:30. Now the training data is fed into machine learning models.

A third subset of data also used to evaluate the model during building is called the validation set. A typical format of train-test-validation format of data would be: 60% of the data is used for training, 20% for validation, and 20% for testing. A shuffling process is also done before splitting the data to ensure the split should contain a perfect representation of data.

The classification prediction has four types of outcomes: true positive, true negative, false positive false negative. When the predicted observation of a class actually belongs to that class, then it is called a true positive. True negative prediction is; correctly predict the negative class. False positives occur when you incorrectly predict the positive class. False negatives are when you predict a negative observation, but it belongs to the class. These four outcomes are used to plot a confusion matrix [37-41]. The confusion, a type of binary classification, is a kind of table layout that includes actual values and models predicted values and compares them. After the model is trained with the data, test/validate the model by using a metric called accuracy (How efficient is the model).

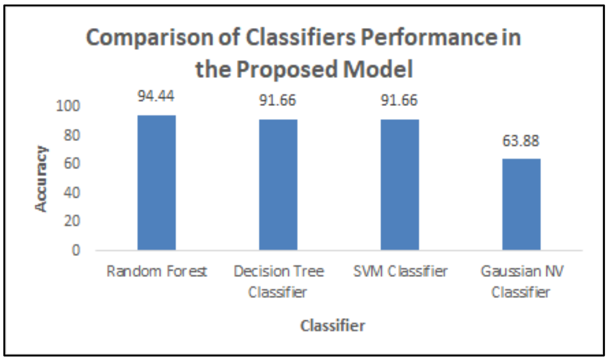

Figure 4 Comparison of the classifier with ECRAM Model.

Based on the implementation of four models, the results were taken for the new data and presented in Figure 4. It shows the performance of all four classifiers being experimented with the ECRAM Model. The graph is drawn between accuracy and the classifiers. As per the experiment, Random Forest classification algorithm has the highest accuracy with respect to the proposed ECRAM model.

The study also shows the importance of relative variables in the given environment, as shown in Figure 5. It can be marked out that Pm 10 and Pm 2.5 had higher concerts in the environment based on the count of the death causes.

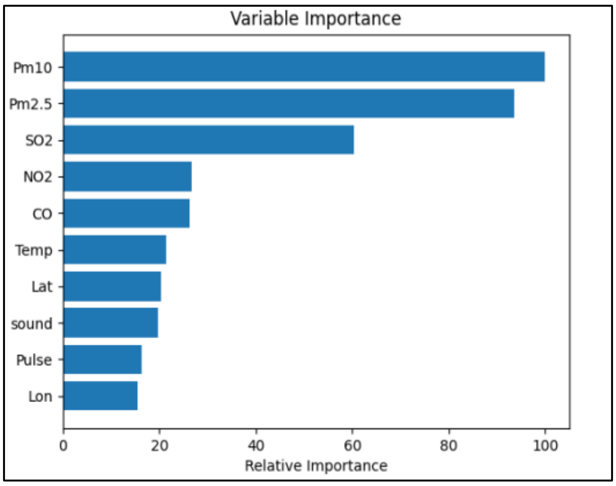

Figure 5 Critical Parameters

As a part of the research an application window was built to demonstrate the user visualization of the data and alert generation based on the data feed. Figure 6 shows the heatmap generated with the alerts for the dataset used in the research.

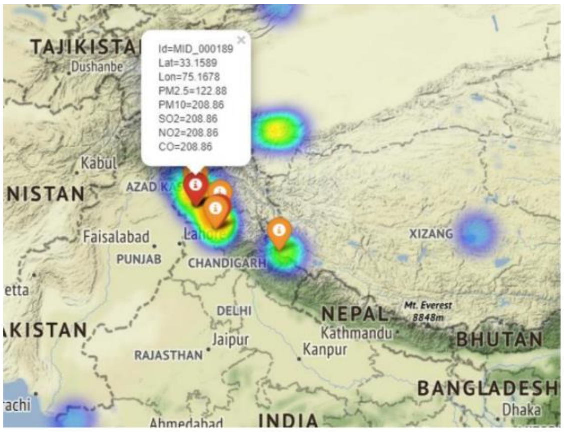

Figure 6 Heatmap with alerts generation for the application window.

7. CONCLUSION

Making appropriate decisions in terms of resource allocation is a crucial task for military authorities. These decisions are risked on life while sending help to the military personnel. Manual systems of such have been enhanced with the help of decision support systems implemented on data collected by sensors in the field. The proposed Environment Condition-based Resource Allocation in Military (ECRAM) model helps the commander to take quick decisions in handling any uncertainties. Results show the accuracy of the model is around 94.4% for the random forest classifier, which can be improved further by using large amounts of data for the training. This result can also be enhanced by cleaning the data more precisely and including an authentication system in place.

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