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Recent Trends Of Machine Learning In Soil Classification: A Review

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ABSTRACT:*Soil classification has been the matter of interesting research in the field of engineering. The engineers need to have some primary information about the type and structure of the soil. Earlier methods of soil classification included standard penetration test (SPT), cone penetration test (CPT), pressure meter test (PMT), and vane shear test (VST). The initial methods were time consuming and required presence of an expert for accurate results. In India, major 9 types of soils could be found which includes Alluvial soil, Forest soil, Red soil , Black / regur soil Saline soil, Arid / desert soil, Peaty / marshy soil, Sub-mountain soil, Laterite soil, Snowfields. With the development of machine learning methods as a part of Artificial Intelligence (AI), many techniques have been progressively developed to automate the soil classification process. The developed techniques include Decision Trees (DT), k-Nearest Networks (k-NN), Artificial Neural Networks (ANN) and Support Vector Machines (SVM). Machine learning is used to classify soils based on various detectable features such as soil moisture content, soil nutrients, soil structure, soil quality, soil pH, and soil texture. A huge amount of literature is available for soil classification methods using the machine learning methods. These methods have been discussed in this paper in brief.*

KEYWORDS:*Soil classification, Machine Learning, k-NN,ANN, SVM.*

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I. INTRODUCTION

In a number of engineering problems, such as geo technics, petroleum engineering, etc., the conventional techniques to identify soil could be inadequate, majorly due to a continuous requirement of an expert for efficient classification.In this paper the approaches developed and tested for automating the classification procedure of soils are discussed. In most of the approaches a segmentation algorithm has been first applied to segment the measured signals from the collected. Then, the useful features of these segments are extracted using efficient extraction algorithms. Based on the measured data and extracted features from the collected samples, some selected classifiers dedicated to assign classes to these segments are built; these classifiers may positively employ DT, kNN, ANNs and SVM. The classical methodology used for classifying sub-surface soil employed using measured data from Cone Penetration Testing (CPT) and satisfactory results were obtained. In previous classification methods such as CPT, there is a requirement of a domain expert to observe the magnitude and the trends of segmented signals in addition to any a priori information that might be available.In this paper the proposed approaches for automating this classification procedure using image processing are also discussed. There are methods available such as segmentation algorithm from which the salient features of the observed segments can be extracted using boundary energy method. Based on the measured data and extracted features from the collected data of soil, dedicated classifiers assign classes to these observed segments. They employ DT, kNN, ANNs and SVM. In these first features extraction methods of image processing is applied to extract the features of soil sample images. Then database of sample images will be prepared and classification of soil will be done using SVM algorithm.

ANNs are statistical learning algorithms, inspired by properties of the biological neural networks of the brain. ANNs are employed for a wide variety of tasks, ranging from relatively simple classification problems to much complex problems such as speech recognition and computer vision [1]. ANNs are actualized as an arrangement of interconnected handling establishments, called nodes or hubs, which are practically similar to organic neurons. The associations between various hubs have numerical qualities, called weights, and by fluctuating these qualities efficiently, the system is at last ready to genuinely precise the coveted capacity.

K-Nearest Neighbor (KNN) is another supervised machine learning technique used for classification purpose. This strategy is known for its straightforwardness and generally fast. It considers the k closest cases { } from a case (x) and chooses which is the most regular class in the set { }. The most rehashed class is thought to be the class of that occurrence (x). KNN framework embraces a separation metric with a specific end goal to decide closest occasion. Different separation measurements can be received including Euclidean which is utilized here as it gives the best outcomes.
The Support Vector Machine is a propelled learning machine for two-gather grouping issues. The vector machine adroitly actualizes mapping input vectors to a high measurement highlight space utilizing nonlinear mapping, after which a direct choice surface is developed. SVM is a hypothetically unrivaled machine learning system with incredible outcomes in order of high dimensional datasets and has been discovered aggressive with the best machine learning calculations.

II. SOIL CLASSIFIACTION REVIEW

Development of soil science began with the founding of modern taxonomy of soil, which makes the soil classification and soil science research to become the most classic and basic research category. With the advancement of soil resource mobilization States since the mid-20th century, countries on the basis of their geographical distribution of natural soil use and soil management needs, has formed a plurality of soil classification system which consisted of naming rules that were not consistent, resulting in exchange of scientific aspects of soil processes at the international level, and the lack of common benchmark. Problems begin to arise with the same name, different soil between the so-called different names or different classification systems. In recent years many authors and researchers have engaged in the study of soil survey and soil classification [2]. Soil classification refers to the modern understanding of soil genetic processes on the basis of the different soil classification and naming system. In the mid-20th century to the late half century, the main objective of national soil survey is to identify soil types and their distribution, the main results of the survey are compiled and drawn soil profile blog to complete soil map.In 1883 soil scientist Dokuchaev Russia first proposed the soil zonal doctrine, laid the theoretical foundation of modern soil classification occurred. The core idea of soil genesis taxonomy is that soil classification and naming of the process of formation and iconic characteristics of soil under the influence of climate, biology, topography, parent material, time 5 Dacheng soil factors, so that people identify the different types of soil, nature[3]. Based on soil classification, all major countries in the world have established their own soil classification system based on surface soil sampling survey. Although these classifications are based on the same theoretical basis, but they differ from one another due to the different countries and regions in which the different climatic zones, with the type of soil resources and per capita funding.The amount of different sources, different levels of economic and technological development, using the principles of classification, naming, ground survey methods and sampling volume varies; the final form of the classification system is also different [4].Soil classification system adopted by most countries is described as hierarchical classification (hierarchal system) systems, from high to low, with each level having its own definition of affiliation between the different levels. The soil classification grade classes, and subclasses, for the expression of earth or soil during soil factors form the most significant difference among different soils. The most important feature in advanced classification of different soil types is based on morphological characteristics (morphological feature) which is the difference of the soil structure, mainly refers to the soil type, number, thickness, and material composition of horizons relationship status. As the soil is classified lower level, for the expression of different soil types soil during soil profile physicochemical difference caused traits, such as texture, clay minerals, ion-exchanged with soil temperature change [5].In US 6 Soil classification system is hierarchical classification system containing soil order 12, subclass 64, 325 soil types, more than 470 subtypes 2, a number of more than 19 000 and Tu-based soil, wherein the soil order for defining a main soil soil conditions; subclass used to distinguish differences in the soil order to process the soil; soil within soil type table daya gang difference, the substance for different soil processes lead to differences in the soil; soil types and the expression profile characteristics subclasses; Tu table daya texture class, clay minerals, ion-exchanged with soil temperature difference; soil classification and recognition based mainly expressed the local soil species[6] .Canada is using hierarchical classification system 5, does not have a subclass, the soil order for the soil type, soil order a total of 10, 31 and several subclasses soil types, soil series [7] .Russia released in 1977, soil classification system is 4 grade classification, does not have a soil classes and subclasses, directly to the establishment of 71 soil types, 194 subclasses and several soil genus and species of soil; in 1997, newly released soil classification system changed to 8 grade classification, advanced classification on soil types and increases the soil dry soil orders, a lower classification under the soil types and soil with the addition of variants. Germany (West Germany) using a 5-level classification system, has four Domon (Bodenabteilungen, similar soil order division basis), 21 soil level (Bodenklassen, similar division basis subclass), 56 soil types, 220 and several subclasses soil species[8] . Presence and expression of national soil types were different classification systems meaning some differences, resulting in relevant research results have been difficult to communicate and share. To facilitate comparison of different types of soil classification system, international soil science community has been trying different soil classification systems integration. Among various national soil classification systems there exists a big difference in the hierarchy, and the connotation of the border at all levels, and this difference began forming methods and procedures used during ground surveys. There are reasons that different classification systems difficult to integrate and associate countries[9].In soil classification, soil characteristics and soil-forming process form the main basis for classification. In many countries, soil classification system, is also an important basis for classification. If different classification systems differ in their function finds will lead to different degrees of reliance on the occurrence of soil processes and functions, will also be difficult to integrate or associate with one another on the classification, for example, it is difficult to distinguish between a major pedogenesis for soil classification system based on the same classification is necessary to take into account the soil-forming process should take into account the part of the production function of soil classification system to merge or associate[10].In the fields of agriculture, environment and other studies which involves soil processes, the one purpose of the soil survey is to understand the function of different parts of the soil characteristics, the large number of soil types, soil function ,expression characteristics, making in addition to soil taxonomy.In order to facilitate the exchange and sharing of research results of national soil, in 1988 by the FAO - UNESCO Organization (FAO-UNESCO) soil scientists in several countries completed the 1: 5,000,000 scale soil map of the world compilation containing two World Soil classification, a classification soil containing 28 groups, secondary classification legend soil containing 153 units. Because the map information, this classification is widely used in research related to climate and environmental change [11].

III. SOILS OF INDIA

In the soil map of the India, the Indian soil groups have involved 14, are as follows: Alluvial soil, Forest soil, Red soil, Black / regur soil Saline soil, Arid / desert soil, Peaty / marshy soil, Sub-mountain soil, Laterite soil, Snowfields [12][13].

Table 1.Soils of India and Favorable Crops [12].

Soil	State in which soil is present	Favorable crop
Alluvial	Gujarat, Punjab, Haryana, UP, Bihar, Jharkhand	Sugarcane, Cotton, Wheat, Jute.
Black soil	Madhya Pradesh, Gujarat, Andhra Pradesh, Maharashtra, Tamil Nadu.	Cotton, sugarcane, tobacco, wheat, Rice.
Red	Orissa, Chhattisgarh	Wheat, Rice, Cotton, Sugarcane, and pulses.
Laterite	Karnataka, Tamil Nadu, Madhya Pradesh, Assam,Kerala.	Cashewnuts, tea, coffee, rubber
Arid and Dessert	Western Rajasthan, North Gujarat, and Southern Punjab	Barley, Cotton, Millets, Maize and pulses

IV. TRADITIONAL METHODS OF SOIL CLASSIFICATION

Traditional methods of soil classification involved in-situ investigation and laboratory testing.

In situ investigation work generally included drilling and sampling, in situ testing, and groundwater investigation.Four major in situ tests include Standard Penetration Test (SPT), Cone Penetration Test (CPT), Pressure Meter Test (PMT), and Vane Shear Test (VST).

SPT is a simple method, suitable for many soil types. SPT strategy comprises of a standard thick-walled sampler pushed into ground utilizing rehashed blows of a standard sledge, towards the base of a borehole and estimating the number (i.e., SPT N-esteem) of blow checks to propel the sampler to a vertical separation of 300 mm after an underlying seating drive of 150 mm. This strategy gives soil tests to soil order and research center tests.The results (SPT N-values) provided by SPT are, however, highly operator-dependent and are highly variable [14] [15].

CPT strategy for soil distinguishing includes pushing a tube shaped steel test into the ground at a consistent rate and estimating the protection from the infiltration. This strategy gives three estimations: cone tip obstruction, sleeve grinding, and pore water weight. CPT has picked up prevalence around the globe since it gives quick outcomes and is generally administrator autonomous and in addition CPT gives close consistent estimations. Be that as it may, CPT experiences a few burdens as it isn't appropriate for rock and stone stores [16] [17] [18] [19].

In the technique for PMT, we bore a long round and hollow test into encompassing ground radially to gauge the measure of volume of liquid and weight required to expand the test. The estimations got from this procedure along these lines give the connection between the weight and the disfigurement of soils. This strategy has a solid hypothetical foundation and can give an entire stress– strain bend. The strategy of PMT based investigation is, in any case, moderately confused, and it is very tedious and costly [20] [21].

VST method of soil identification includes insertion of vane into the soil and then rotating this four blade vane into the soil about the vertical axis by the application of a constant torque. The shear strength and in situ sensitivity of the soil (usually clay) is calculated using the residual values of torque and the measured peak. This procedure is relatively simple and appropriate way to estimate the undrained shears strength for stability investigation of embankment, footing, and excavation in soft clay [22].

The above steps all are regarded as in-situ investigation. After the completion of in situ investigation work, the collected soil samples are further tested in laboratory. In laboratory, index properties such as moisture content, specific gravity, unit weight, particle size distribution, Atterberg limits, and moisture–density relationship are measured. Different tests led incorporate quality and solidness tests (e.g., unconfined pressure test, coordinate shear test, and triaxial tests), penetrability tests (e.g., consistent head test and falling head test), and solidification tests (e.g., oedometer test). Research center tests by and large outcome in more exact estimations than those got from in situ tests, however they are generally additional tedious and costly than in situ tests.

V. MACHINE LEARNING METHODS

Machine learning is a part of AI (Artificial Intelligence) ,in the field of research which implies statistical techniques to enable the computers the ability to learn with the data without the need for explicit programmingpresented.Machine learning is utilized to prepare machines the ability of dealing with the information all the more proficiently. Now and again in the wake of survey the information, we can't decipher the example or concentrate data from the information. Machine learning is an effective method for application in the field of analytics of data to predict the result of the system using some models and algorithms. There are several applications for Machine Learning (ML), the most significant of which is image classification [16] [23] [24][25].Image classification using ML refers to the process of labeling a wide set of images into a number of predefined categories, decided by the user's requirement. The classification system developed needs to be trained using the predefined patterns from the training database, to classify the set of images. The classification system, after being trained, then successfully compares the test image with the training database and classifies the detected object or feature into a proper category or class. The necessity of image classification arises with the need for effective means of searching and classifying the rapidly increasing the number of collections of digital images. With the advancement of image classification research procedures, many advance techniques for classification such as ANN [26] [27], DT [28] [29], SVM [29] [30] Fuzzy classification [31] [32] and kNN [55][56][57][58][59][60] have been developed.

The major steps included in the successful image classification includes,

(i). Selection of suitable sensor data
(ii). Selection of a suitable classification system and training samples
(iii). Image pre-processing
(iv). Feature Extraction and Selection
(v). Selection of suitable classification method
(vi). Post classification processing
(vii). Accuracy assessment or evaluation of classification performance

VI. MACHINE LEARNING BASED SOIL CLASSIFICATION APPROACHES

In, soil classification the systematic characterization of soil systems in dealt, this characterization is based on thedistinguishing characteristics as well as criteria that dictate choices in use.This type of classification is a dynamic subject, which ranges from the system structure, to class definition, and finally field applications. These methods can be approached from the perspective of soil as a resource like the engineers who classify soil according to the engineering properties of the soil.Present day building arrangement frameworks are intended to permit a simple change from field perceptions to fundamental expectations of soil designing properties and practices [33] [34] [35] [36].

The challenge of automating the process of CPT was achieved by using a new algorithm called CONCC (CONstraint Clustering and Classification) [16] which included segmentation and classification of the recorded signals while maintaining the constraint of contiguity for automatic classification of soil segments. The found segments from CONCC were then classified using three ML methods: DT, ANNs and SVM [16].

Application of ML in Soil classification to landslide susceptibility mapping using GIS has been studied in [37]. Land slide susceptibility is a difficult and nonlinear problem, because of which it has been one of the hot topics in the international landslide literature. In this research the author compared the prediction performances of approaches such as DT, SVM and Adaptive Neuro-Fuzzy Inference System (ANFIS) in Penang Hill area, Malaysia for landslide susceptibility mapping. For this study, the researchers identified 113 landslide locations using the digitally collected aerial photographs and manually conducted field surveys .The collected images of these locations were combined in the system and a total of 15 maps showing landslide susceptibility were produced using DT, SVM and ANFIS based models. These resulting maps were validated with the landslide locations. To employ DT, SVM and ANFIS models for landslide susceptibility prediction, three main stages were applied such as landslide inventory, susceptibility analyses, and validation. Receiver Operating Characteristics (ROC) was employed to verify the prediction performances of these maps [37].

ML for agricultural land soil classification using the Naye Bayes Data mining technique [24] which is a fast and incremental classifier with an ability to deal with attributes either continuous or discrete, and shows excellent performance in solving real life complex issues. The benchmark was built up by the yield of NayeBaye Data mining Technique and after that the information grouping was imitated utilizing WEKA information mining programming to decide whether any gain could be extended in either efficient or elucidation of the dirt informational collection. The utilization of the information to WEKA information mining programming necessitated that some preprocessing be embraced on the dirt information.The trials directed amid this investigation [24] examined that few singularities contained inside the dataset to oversee their adequacy when contrasted and regular factual procedures. The horticulture soil profiles that were utilized in this examination were chosen for culmination and for straightforwardness characterization of soils.

Studies to investigate the efficiency of various available classifies have been conducted [38] [39]. However, these studies have mostly employed pixel-based approaches.When utilizing machine learning classifiers, there exists factors that significantly influence the order exactness and proficiency. These elements included picture division, highlight determination, preparing test choice, and tuning parameter setting [40]. While the first three factors have been investigated in many previous studies [41], few studies have investigated the effects of the setting of tuning parameters [39].

VI. APPLICATION OF SVM, k-NN and ANN IN SOIL CLASSIFICATION

Application of machine learning techniques such as SVM, k-NN and ANN in soil properties identification and soil type classification based on known values of particular chemical and physical properties in sampled profiles has been an important paradigm of research. Various modeling procedures, known as predictive soil mapping, are specially developed to estimate spatial distribution of soil variables. These techniques use different algorithms and filters are developed to acquire and process the colored images of the soil samples. These developed algorithms are used to extract different features like color, texture, etc. Different soil types like red, black, clay, alluvial, etc. are considered. The accuracy of a supervised classification method is dependent to a large extent on the training data used.

The other way to deal with the gauge of soil factors is more centered on direct estimate of estimations of inconclusive soil parameters, in light of estimated or open estimations of some different parameters. The improvement of quick and shoddy microchips has brought about a developing utilization of modern factual and machine learning strategies, for example, ANN or SVM, in a wide assortment of natural sciences. SVM has demonstrated critical focal points over ANN, particularly in soil matric possibilities.There are numerous precedents of regulated learning strategies utilized in farming, particularly in exactness horticulture. The grouping assignment in recognizing weeds and yields by their ghastly legitimacies, with the end goal of exact herbicide utilize, could lessen the info costs and furthermore moderate the ecological effect. [42].

SVM has applications in soil classification and identification [43]. Many characteristics of soil can be identified using SVM such as moisture content detection [44] [45] [46], soil nutrients [48], soil structure [49], soil quality [47], soil pH [50] [51][52][53], soil texture[54].

In [43], the Logistic Regression and Linear Support Vector Machines have been compared on soil samples of which particular and chemical and physical properties are known. Logistic Regression acted as a method for choice for data sets with enough training examples per each class. However, it has been found by the author that when the training samples per class is much smaller, Linear SVM had a clear advantage over the other methods. In the relapse assignments, the outcomes acquired recommended that direct techniques were not sufficiently skilled to appraise the physical properties utilizing the officially estimated properties. Nonetheless, the nonlinear SVM can appraise the estimation of clay and physical sand adequately well in this examination.

For soil moisture identification in [45], SVM model is utilized for estimation in the 10 locales of Lower Colorado River Basin (LCRB) in the western United States. The proposed SVM demonstrate is prepared on 5 years of information and two models are created to assess the quality of SVM displaying in evaluating soil dampness. In this investigation, the prepared model demonstrated acceptable outcomes, and the evaluations are in great understanding with the desired results. The got results from the SVM displaying are contrasted and the evaluations acquired from feed forward ANN and Multivariate Linear Regression demonstrate (MLR); and it was seen in this investigation that SVM performs better for soil dampness estimation over ANN and MLR models.

Soil quality is the limit of soil to manage plant, have organic capacity and creature generation, to keep up or improve water and air quality and to help human wellbeing and home. The paper [50] shows that SVM - based characterization is possible and dependable for soil quality evaluation. The investigation was directed in the rural zone of Taiyuan city. The SHM– SVM model, when applied to 140 soil samples gathered from Taiyuan

city, demonstrated an exactness of 98.5417%., The general objective of this examination [50] was to build up a SVM-based arrangement display that consolidated soil substantial metal pollution and soil ripeness information together in one model to all the more likely survey urban soil quality.
Soil pH is utilized to depict the level of sharpness or basicity which influences supplement accessibility and at last plant development. The pH in soils is a critical concerning some portion of the soil health. pH is a term that is utilized to portray the level of acidity or basicity. Soil causticity or alkalinity straightforwardly influences plant development. The strategy for soil pH distinguishing proof can be depicted as when light hits the samples, a portion of the wavelengths are ingested and some are reflected, contingent upon the materials in the protest. Nonetheless, soil is a piece of a question and computerized photo of this protest (soil) was taken through a camera, it got wavelengths as the fundamental variable. Many researchers have used the RGB values obtained from the image to measure the pH value of the soil [48][51][52].
An application of kNN for soil classification is based on the same theoretical basis as of SVM; some chemical and physical properties need to be identified through the smart algorithms of machine learning. These applications have been discussed in [59][61][62][63][64]. In [61], the data mining techniques are applied to predict the yield of the farmland. The soil datasets are analyzed using Naïve Bayes and KNN methods to identify soil and predict the yield of the crops. The reason for such investigation is critical for high return cultivating is to decide the relative capacity of a dirt to supply trim supplements amid a specific developing season, to decide the requirements, and for diagnosing issues, for example, over the top saltiness or alkalinity. This system was tested successfully by the author and the future advancements showed a possibility of collecting data directly from the server.
Soil colour can be used to describe attributes of the soil such as mineral content , organic matter as discussed in [62]. While the authors in [59] has developed a techniques to detect soil damage using kNN technique of machine learning. Soil contamination prediction was done using two prediction models , support vector regression (SVR) and k-nearest neighbor regression method (KNNR) in [63].
Land cover classification for the remote sensing images, particularly the Sentinel-2 Multispectral Imager (MSI) was carried in [64], and the classification results ranging from 90% to 95% were achieved.
The applications of ANN for soil classification have been discussed in [65][66][67][68][69][70]. In [70], ANN has been utilized for the expectation of soil profile to limit time and cost before the boring and exhausting errands. Five principles ANN models were developed in view of the dirt information of 1909 boreholes from 417 destinations. As a piece of this study, ANN is found to have the satisfactory capacity to anticipate the dirt arrangement and soil parameters. The need in exactness in some anticipated information which was when contrasted and the dirt profile acquired from real boreholes is because of irregularity of directions and profundity. Texture based characterization of Indian soils utilizing ANN has been done in [65]. The nearby paired examples on red green and blue channels of data images were connected and after that GLCM lattice was utilized decided from which homogeneity, complexity, relationship and vitality highlights are taken from each channel and after that feed to fake neural system by linking them. ANN has been prepared and tried on entire dataset. In [67], multilayer perceptron fake neural systems (ANNs) were created to outline units utilizing computerized rise show (DEM) traits. A few ideal ANNs were created in light of various info information and concealed units. The methodology utilized test and approval territories to figure the exactness of added and extrapolated information. The outcomes demonstrated that the framework and level of soil order utilized directly affected the exactness of the outcomes.

VII.CONCLUSION

Soil classification is one of the main concerns in the field of engineering. Some knowledge about the type of soil is necessary before staring any construction work. There existed some traditional methods for this purpose but now they are fastly replaced by the image processing methods employing techniques such as ANN, Decision trees, SVM's. Each method has its own relevance of application. In this paper we studied about the traditional methods of soil classification standard penetration test (SPT), cone penetration test (CPT), pressure meter test (PMT), and vane shear test (VST). Machine learning techniques have boosted the process of soil classification by a great extent. There exist various machine learning based soil classification approaches which have also been discussed here. SVM is one of the most commonly used machine learning algorithm to classify soil.

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