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Analysis of Colour Vision Deficiency Using Machine Learning

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Abstract – *Generally, colour blindness is a name given to the condition where individuals have problems discriminating different colours. It is not defect of eye, but a defect of the brain and its total misleading term because people with colour blindness are not blind. Proposed System have analyzed the color vision deficiency dataset in order to know the features. In these various techniques are used to generate and visualize the dataset and to get most significant attribute in this condition.*

Key Words: BayesNet, Colour Blindness, colour vision deficiency (CVD), J48, JRip, MultiClass Classifier, Naïve Bayes, OneR, RandomForest, RandomTree, REPTree, SMO, Weka.

1.INTRODUCTION

The methods of teaching computers to learn and act like humans and to upgrade their learning over time in autonomous fashion by providing them data and information in the form of real word interactions and observations is known as Machine Learning. The Defined algorithms of machine learning are Supervised Learning, Unsupervised Learning and Reinforcement Learning, where supervised learning divides into two methods where first one is Classification which contains Support Vector Machines (SVM), Discriminant Analysis, Naïve Bayes, Nearest Neighbour techniques. On the other side Regression supports Linear Regression, SVR, GPR and Decision Tree techniques. While in Unsupervised learning method there is clustering which contains K-Means, Neural Networks, Gaussian Mixture. Colour vision deficiency also called as colour blindness depicts a group of conditions that affect the perception of colour. Most common type of colour vision deficiency is Red-green colour vision defects and other colour blindness types are separated in different categories are blue-yellow colour blindness and much rarer complete colour blindness. Colour blindness are of two types as artificial colour blindness like one who is colour blinded due to accidental damage and second one is natural like one who is colour blinded by birth that is inherited from parents. Some of the symptoms of colour blinded people are inability to distinguish between shades of the same or similar colour as this happens most with red, green, blue and yellow colour, other is trouble seeing colour and brightness of colour in the usual way.

2. LITERATURE REVIEW

Alessandro Bruno et al[1] have showcased the difference between human visual system behavior between normal visual system and vision-deficient visual system with the help of doing eye-tracking of human fixations in the first three seconds of observation of colour images and building real fixation point maps. They have also worked and contributed on techniques that detect the difference between human visual system regarding colour blindness by real fixation maps among people with colour vision deficiency and without colour vision deficiencies, another is they have served a method that improves the specific colour regions of the image with the help of CIE L*a*b* colour mapping. At last they have also provided the dataset of experimental sessions under the name of EToCVD (Eye Tracking of Colour Vision Deficiencies).[1]

Ahmed E. Salih et al[2] explained how patients are suffering from CVD or colour blindness and how they cannot differentiate between colours. Here it is also discussed that the most common form of colour blindness is Red-Green which is the result of missing red or green photoreceptor cones and since there is no medicine or cure for this disease. So, the main aim of this is the products and methods that have been developed to aid CVD or colour blinded patients are discussed and these technologies include work on gene therapy, tinted glasses, lenses, optoelectronic glasses. Among this the most widely used by CVD patients is tinted glass.[2]

Dudy Suparyadi et al[3] have explained based on the method for conventional test for colour blindness testing through microcontroller systems for more accurate results. Here the whole test is explained as a collection of stacked pictorial cards and coloured spots which is usually used to diagnose red-green deficiency. The result of this test can distinguish between normal vision and colour blindness. Through a series of different tests from electronic testing and testing the use of application programs the system which works well is the system with micro controller and through the results of other tests comparing the Ichihara method with conventional test tools showed that the Arduino based Ichihara method of colour blindness testing works well.[3]

Raju Shrestha et al[4] explained about the daltonization algorithm which tries to upgrade and modify colours in image in order to increase colours and contrast to overcome the missing features for colour vision deficiency. This method is based on generalization of colour vision deficiency models

and types. Thus, a spectral colour vision deficiency imaging system based on methodology can be used for acquiring CVD images in real-time conditions. The system can be built for specific people according to the type of CVD they are facing and how sensitive it is and this can be built using off the shell camera systems and it is further extended with an in-built daltonization method.[4]

Jamie R. Nuñez[5] proposed colourmaps for the most accurate perception of scientific data along with many viewers. Along with this a python module is developed named cmaputil to create CVD optimized colourmaps. Through this anyone can design their own CVD optimized colourmaps.[5]

Ila Venkata et al[6] proposed in this research paper that colour blindness caused due to inheritance is a lifelong challenge as it limits the prospects for certain jobs. The defect is usually for red-green colour and majorly homozygous develops colour vision defects. The author also proposed that if both the parents have colour vision defects with particular blood group, and very myopic or hypermetropic then there is a good chance that their child will also possess colour blindness. Screening test for congenital colour vision deficiencies should be made mandatory foe children as there is injury risk.[6]

Reiner Eschbach[7] have discussed about the different algorithms which are developed to simulate the effect of CVD, but actually do they work efficiently for the colour deficient observer. Do they see things normally? This paper questions some of the underlying assumptions of the algorithms. At what age the person actually realize that they are colour blind? Deducing from the algorithms ideally it should occur in early life at some point during the first few years of school. Under what situations is the eye act as main driver in vision and under what situations our brain plays major role.[7]

D B Yandikaputri et al[8] presents how colour blinded people see and explore open space. This research investigated the spatial experience in presence of two respondents one having protanomaly and other was the interviewee and the results concluded that how the colours used in the area are still inadequate to support their deficiency. But they are still able to recognize the objects and navigate themselves with the help of contrast and shadows.[8]

Abdulhaq Suliman et al[9] have proposed to find the prevalence of CVD between dentists and dental students and to evaluate its effect on shade matching ability. A test was conducted on 319 dentists and dental students in the College of Dentistry at Ajman University, Ajman, UAE. They were examined with Ishihara test to find the prevalence of CVD. After that the participants with CVD were tested for shade matching ability and then they were compared to participants with normal colour vision with same gender. Results concluded that 8 out of 143 males and 0 out of 176 females had CVD. Finally, it was concluded that males showed higher prevalence then females in CVD and CVD had no significant effect on shade matching ability.[9]

Abdel-Rahman Badawy et al[10] demonstrates the potential of the dyed contact lenses in wavelength filtering and colour vision deficiency management. Abdel-Rahman Badawy et al invented contact lenses with colour filtering for colour blinded people. They have used rhodamine derivative in commercial contact lenses to filter the wavelengths of range of (≈545–575 nm). The lens was fabricated by submerging them in Atto 565 dye for 30 s and the concentration level of the dye can be used to control accurately provide a high level of customization of the process. A survey was conducted which verified that dye tinted contact lenses can be used to slightly improve the colour perception of both people who are affected by colour vision deficiency and who are not affected. The major drawback of the system was that the dye diffusion in PBS and this diffusion can be controlled using covalent bonding to contact lens polymer backbone and incubation in hydrophobic preservation materials or oils.[10]

Huei-Yung Lin et al[11] have explained people with Colour Vision Deficiency cannot observe the colourful world due to damage of colour reception nerves. Huei-Yung Lin et al presented an approach to enhance the the image in order to assist the colour blind people. An algorithm for re colouring the image based on eigenvector processing is proposed for robust colour separation under colour deficiency transformation. The eigenvector is distorted by an angel the λ, Y-B, R-G colour space. Compared to the existing technique the results of natural images with CVD simulation work very well.[11]

Basaeir Y Ahmed et al[12] have discussed new methods by using data visualization principles. As colour blindness is a subject of colours , so data visualization can contribute to this subject for providing specific mechanisms for correction of colours. The results are based on Ishihara's data sets which is used to measure the degree of colour blindness. In this paper two methods have been discussed namely Colour recognition for people with partial colour blindness and Colour analysis method to treat full colour blindness.[12]

Omursal GOZKAYA et al[13] presented a 25-year-old person being treated for medical problem known as Gyrate Atrophy (GA) intricated by epiretinal tissue, foveoschisis and ONHD by applying selected technologies such as fundus fluorescein angiography (FFA), optical coherence tomography (OCT), fundus autofluorescence (FAF). A young person suffered from advanced night blindness and visual damage till six years. A while ago he went through cataract surgery for both eyes for period of 3 months. Former segment examination unveiled about the existence of bilateral intraocular lens in the mid-peripheral zone. The upraised levels of plasma ornithine also confirmed the diagnosis. As a result of possible complications and biomicroscopic examination with the multimodal imaging techs should be executed precisely to track down issues regarding gyrate atrophy.[13]

Noemi Szell et al[14] presented couple of hypotheses that explains the pathosystem of disease called Myopia-26. Female-limited premature high myopia which is a rare monogenic disarrangement outlined by serious short sightedness beginning in tender age and make progress to blindness potentially by the midlife introduced as Myopia-26. However, the X-linked location of the mutated ARR3 gene strangely disturbs women only, whereas males being

symptom-free carriers. As long ago, this sickness has been noticed only in Asian communities and has not lost during in-depth analysis in terms of collateral symptoms or pathogenesis.[14]

Ahmed E. Salih et al[15] observed that the patients who are facing ocular disorder from different shades of specific colours are often not taken into consideration for such crucial profession (i.e., military, police) and cannot distinguish colours in public places or media (e.g., watching Television). In this research paper the author researched on the several technologies that are used to enhance CVD patient's colour perception. The products and methodologies that are being developed for the CVD patients. These technological methods include modern efforts on gene therapy, lenses, tinted glasses, optoelectronic glasses and advanced features developed on cellular devices and computers. These wearables and glasses are developed by certain organizations such as Enchroma that are the most extensively used by CVD patients.[15]

Shinji Matsuba et al[16] have discussed to predict age related macular degeneration (AMD). Shinji Matsuba et al made a system which is a combination of a deep convolutional neural network (DCNN), a machine-learning algorithm, with Optos and an ultra-wide-field fundus imaging system. The foremost method used to measure the diagnostic accuracy of DCNN is that to amplify about 364 photographic pictures (AMD: 137) and the section down the curve as well as sensibility and preciseness were analyzed also. Additionally, in order to match the diagnostic capabilities between DCNN and six opthalmologists, around 84 sheets been prepared and each of them contained 50% of normal and wet-AMD data. Furthermore, accurate answer rate, specificity, sensibility and respond time calculated and concluded that a fusion of DCNN with Optos photographs was not better than a medical examination; On the other hand, exudative AMD can be identified with the help of high level of accuracy and the developed system was believed beneficial for screening and telemedicine.[16]

3. METHODOLOGY

Machine Learning Techniques:

J48 - This is one of the types of decision tree algorithm. It is an algorithm which is used to generate a decision tree which is generated by C4.5, it is also known as statistical classifier. J48 is the implementation of algorithm ID3 which is developed by Weka project team. [17]

Decision Tree - A decision tree is particular type of probability tree which allow you to create a decision for the process. For example, if you want to decide between manufacturing product A or product B, or investing in choice 1, choice 2, or choice 3. Trees are a magnificent way to handle the types of complex decisions, which always involve different factors and usually involve some degree of uncertainty. It can be drawn by hand; software is rarely used as the trees can become complex very quickly. [18]

Naive Bayes – It is an algorithm which is used for classification. It uses a simple implementation of Bayes theorem. For each class the prior probability is calculated from the training data and assumed to be self-sufficient with everyone. It is an unrealistic assumption because we look for the variables to be interrelated and dependent, however using this assumption we make the probabilities fast and easy to calculate our data. And also, this unrealistic assumption, Naive Bayes has been shown to be a very efficient classification algorithm. Naive Bayes calculates the posterior probability for every class and makes a prognostication for the class with the high probability. It also supports both binary classification and multi-class classification problems. [19]

REPTree - It is also one of the types of decision tree algorithm and It is fast decision tree learner. It builds a decision, reduces error pruning, forms regression tree using information gain. [20]

Below are the various Machine Learning algorithms which are defined to check the efficiency of the dataset.

Cross Validation - A technique which is evaluated on standard basis, and a systematic way of running repeated percentage splits is known as Cross Validation. This method divides a dataset into 10 pieces by default then hold out each piece in turn for testing and train on the remaining 9 together. This gives 10 evaluation results, which are averaged and presented. Anyone can increase or decrease the number of folds. [21]

RMS Error - The differences between values predicted by a model and the values which are actually observed during testing, is known as RMS Error. It is also known as the root-mean square deviation, RMSD. [22]

Kappa statistic - Chance-corrected measure of agreement between the classifications and the true classes is known as Kappa Statistic. It is calculated by taking the agreement expected by change away from the observed agreement and dividing by the maximum possible agreement. A value greater than 0 means that your classifier is working fine. [22]

Percentage Split - It is one of the test options used while classifier applies its algorithm on the data. Generally, default value is 66%, anyone can increase or decrease the value but decreasing the value below 50% is of no use. [23]

Attribute - Attribute is a term in dataset on which anyone can apply classifiers to get the result.

Correctly Classified Instances - Sum of true positive (TP) and true negative (TN) is known as correctly classified instances. [24]

Classifier - Classifier is a discrete valued function or a hypothesis used to assign class labels or particular data points. It is used after the learning process to classify new records by giving them the best target attribute. [25]

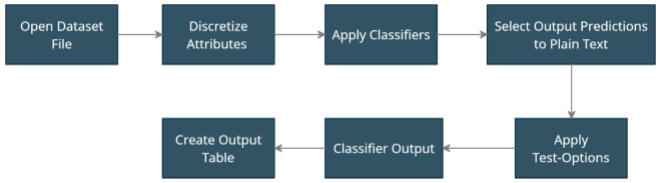

Fig -1: Process Flow

Test options - For both, training and testing, user need data. These options are used for us to inform Weka how to proceed about the test data user will be using.

We have applied several machine learning techniques to analyze dataset - "National Health Interview Survey (NHIS)" for 'Vision and Eye Health Surveillance' which was surveyed by 'National Center for Health Statistics' for around 87,500 persons annually in year 2014.This dataset is summarized by available combinations of age group, category, gender, and risk factor. [26]

In this paper seven attributes have been shortlisted from the dataset and discretized them in Weka tool. The seven attributes are Category, Question, Response, Age, Gender, RiskFactor, RiskFactorResponse after doing this we applied some of the classifiers and test options like cross-validation and percentage split on all of the 7 attributes, and got desired result from 2 attributes which are Category and Question which are in the following table.

SR.NO	Attribute	Classifier	Test Options	Correctly Classified Instances (%)	RMS Error
1.	Category	Logistic,AttributeSelectedClassifier. Bagging, MultiClassClassifier, MultiClassClassifierUpdateable, FilteredClassifier, JRip, OneR, PART, J48, RandomTree, REPTree	Cross Validation (10)	100	0
			Percentage Split (66%)	100	0
2.	Category	MultilayerPerception	Cross Validation (10)	100	0.0006
			Percentage Split (66%)	100	0.0008
3.	Category	SimpleLogistic, LMT	Cross Validation (10)	100	0.0117
			Percentage Split (66%)	100	0.0105
4.	Category	SMO	Cross Validation (10)	100	0.2722
			Percentage Split (66%)	100	0.2722
5.	Category	ClassificationViaRegression	Cross Validation (10)	100	0.0002
			Percentage Split (66%)	100	0.0002
6.	Category	IterativeClassifierOptimizer, LogitBoost	Cross Validation (10)	100	0.0013
			Percentage Split (66%)	100	0.0014
7.	Category	RandomCommitee	Cross Validation (10)	100	0.0026
			Percentage Split (66%)	100	0.003
8.	Category	DecisionTable	Cross Validation (10)	100	0.0044
			Percentage Split (66%)	100	0.0064
9.	Category	HoeffdingTree	Cross Validation (10)	100	0.0027
			Percentage Split (66%)	100	0.0009
10.	Category	RandomForest	Cross Validation (10)	100	0.0015
			Percentage Split (66%)	100	0.0027
11.	Question	BayesNet	Cross Validation (10)	100	0.0037
			Percentage Split (66%)	100	0.0044
12.	Question	NaiveBayes, NaiveBayesUpdateable, HoeffidingTree	Cross Validation (10)	100	0.005
			Percentage Split (66%)	100	0.0059
13.	Question	Logistic, AttributeSelectedClassifier, Bagging, FilteredClassifier, MultiClassClassifier, MultiClassClassifierUpdateable, JRip, PART, J48, REPTree	Cross Validation (10)	100	0
			Percentage Split (66%)	100	0
14.	Question	SimpleLogistic, LMT	Cross Validation (10)	100	0.0084
			Percentage Split (66%)	100	0.007
15.	Question	SMO	Cross Validation (10)	100	0.3103
			Percentage Split (66%)	100	0.3103
16.	Question	ClassificationViaRegression	Cross Validation (10)	100	0.0012
			Percentage Split (66%)	100	0.0044
17.	Question	IterativeClassifierOptimizer, LogitBoost	Cross Validation (10)	100	0.0005
			Percentage Split (66%)	100	0.0004
18.	Question	RandomCommittee	Cross Validation (10)	100	0.0033
			Percentage Split (66%)	100	0.0023
19.	Question	DecisionTable	Cross Validation (10)	100	0.0119
			Percentage Split (66%)	100	0.0164
20.	Question	RandomForest	Cross Validation (10)	100	0.002
			Percentage Split (66%)	100	0.0044

Table -1: Machine Learning Classifier's result

By applying steps mentioned in flowchart on both attributes and applying well known classifiers such as J48 and RepTree and applying test-options such as Cross validation and percentage split we got correctly classified instances as 100%, kappa statistic value as 1%. By applying NaiveBayes, AdaBoostM1, RandomizableFilteredClassifier, DecisionStump, OneR, etc on both the attributes we got some of the results which were in the range of 89% to 99%. By applying same classifiers and test options on the other attributes we got results which were above 65% and below 80% but were not the desired results so that were not included in this result set.

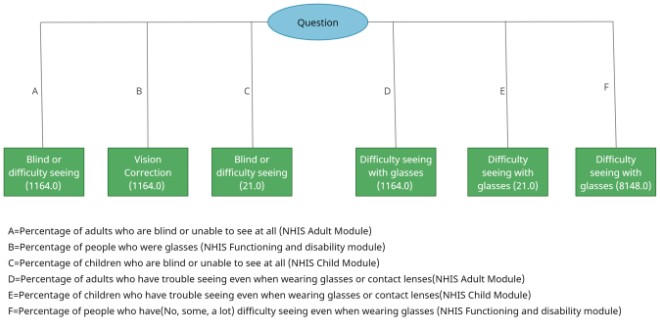

Fig -2: Visualization Tree of J48 Classifier

The data of colour blindness is generated by tree in which the main attributes are parents and child. This tree depicts the probability of having colour blindness to child. Our attributes/variables for the dataset of colour blindness are as follows: Gender: Male (normal), female (normal), male (colour blinded), female (colour blinded), male (carrier genetic), female (carrier genetic). And the attributes which are inherited practically from the parents are son, daughter, daughter (carrier genetic), son (colour blinded), daughter (colour blinded).[27]

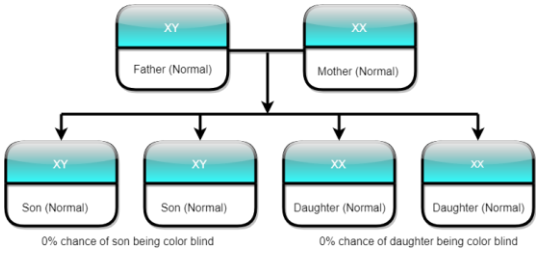

Fig -3: Father (Normal) & Mother (Normal)

Now, if male is normal and female is also normal then the result of son having colour blindness is 0%, Result of daughter having colour blindness is 0%, result of daughter (carrier genetic) having colour blindness is 0%, result of son (colour blinded) having colour blindness is 0%, result of daughter (colour blinded) having colour blindness is 0%.

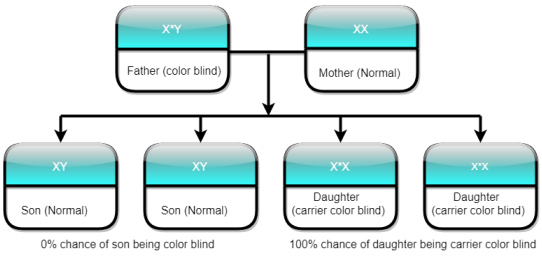

Fig -4: Father (Colour Blind) & Mother (Normal)

Now second instance, if male is colour blinded and the female is normal then the result of son having colour blindness is 0%, result of daughter having colour blindness is 0%, result of daughter (carrier genetic) having colour blindness is 100%, result of son (colour blinded) having colour blindness is 0%, result of daughter (colour blinded) having colour blindness is 0%.

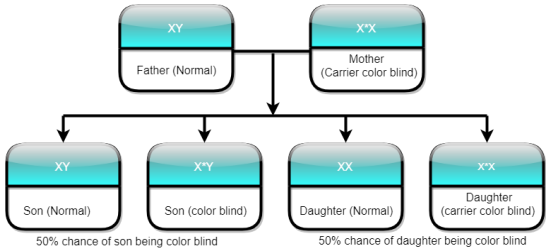

Fig -5: Father (Normal) & Mother (Carrier Colour Blindness)

Now taking the third instance if male is normal and the female is carrier genetic then the result of son having colour blindness is 50%, result of daughter having colour blindness is 50%, result of daughter (carrier genetic) having colour blindness is 50%, result of son (colour blinded) having colour blindness is 50%, result of daughter (colour blinded) having colour blindness is 0%.

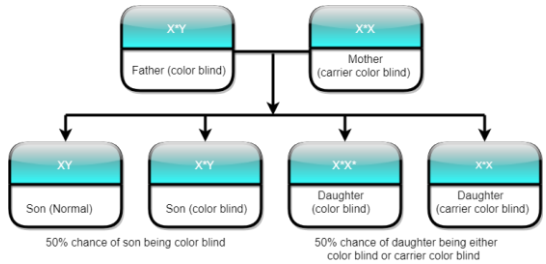

Fig -6: Father (Colour Blind) & Mother (Carrier Colour Blindness)

Now taking fourth instance if male is colour blinded and the female is carrier genetic then the result of son having colour blindness is 50%, result of daughter having colour blindness is 0%, result of daughter (carrier genetic) having colour blindness is 50%, result of son (colour blinded) having colour blindness is 50%, result of daughter (colour blinded) having colour blindness is 50%.

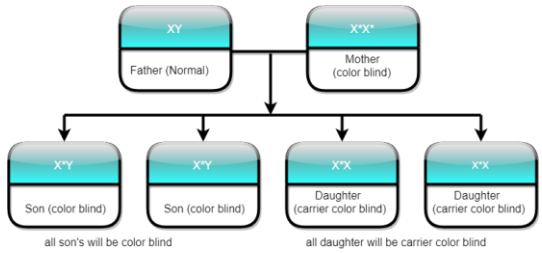

Fig -7: Father (Normal) & Mother (Colour Blind)

Now taking the fifth instance if male is normal and the female is colour blinded then the result of son having colour blindness is 0%, result of daughter having colour blindness is 0%, result of daughter (carrier genetic) having colour blindness is 100%, result of son (colour blinded) having colour blindness is 100%, result of daughter (colour blinded) having colour blindness is 0%.

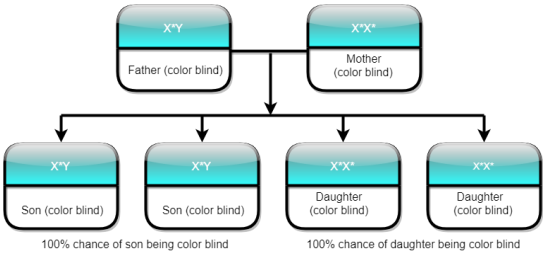

Fig -8: Father (Colour Blind) & Mother (Colour Blind)

Now taking the sixth instance if male is colour blinded and the female is also colour blinded then the result of son having colour blindness is 0%, result of daughter having colour blindness is 0%, result of daughter (carrier genetic) having colour blindness is 0%, result of son (colour blinded) having colour blindness is 100%, result of daughter (colour blinded) having colour blindness is 100%.

3. DISCUSSION

By Applying machine learning techniques and its advantages on dataset of color blindness and its attributes, many things can be judged and final results are obtained based on that. Initially colour blindness was mentioned as the shortage in colour perception was caused by dis colouration of liquid medium of the eyeball called aqueous humor. Later on, it was found that there are three types of cone cells and each type has a different sensitivity to light wavelengths which differs in different types of colour blindness as one type of cone perceives blue light, another perceives green and the third perceives red light and this red, green, blue cone all work together allowing to see the whole spectrum of colours. It has been observed in past that when there was only red-green colour blindness, the most common type of colour blindness, that scientist have imagined gene therapy as a way to correct this common type of colour blindness. In past some of the experiments which were done on glasses through which basic type of colour blindness issues can be

solved. In this current phase right now with the help of analysis the dataset has been analyzed for colour vision deficiency and a method is created to analyze attributes and to corelate them. Some of the future works which are upcoming or which can be applied in this are colour blindness may soon be treatable with a single injection as the tests and studies are ongoing on animals and soon to be tried with humans next, also trials are going on as an experimental gene therapy improved the vision of some of the humans who have complete colour blindness who can only see black, white and gray scale colours, there could be various gene editing techniques like CRISPR which can be developed through that anybody can retain/restore vision in patient who are having inherited blindness or can repair DNA at its source which could stop or reverse disease in their tracks rather than just treating symptoms like the vast drugs and medicines are designed to do. In future more experiments are to be done with colour blindness glasses which are made with certain minerals to absorb and filter out some of the wavelengths between different colour blindness and which can be applied with different types of colour blindness and makes easy for the patients who are suffering from colour blindness.

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