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Pattern Recognition in Eye Movement Validation

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Abstract:- Pattern recognition of eye movements on web pages are often studied by recording the eye movements using eye tracker , that scans the eye sand produces visual patterns made by the pattern direction, which are created by the eye. These are mostly of target pattern sand non-target patterns. Here, we present an approach that make use of the quantitative data recorded from the eye tracker and applied classification algorithm to understand the correlation between patterns and be able to predict the eye movement behavior of users. Result shows significant relationship between the eye gaze components combined with other physiological attributes. External measures contribute to feasible positive predictions without conforming to unduly flawless output when learning from standardized machines.

Keywords:- Pattern recognition, Eye tracking, Eye movements, Skin conductance's, Pupil eccentricity,

I. INTRODUCTION

In order to fully comprehend the reasoning behind studying eye movements, some basic facts about the human vision need to be understood. This introductory section provides short description on important characteristics and terms of human vision through what we call Eye tracking. In eye tracking, human sight has a visual field of about 120 degrees, encompassing three degrees of visual acuity: foveal, parafoveal, and peripheral vision [8]. Primarily, visual data are taken in through the outside world through the foveal that provides the largest visual acuity [8]. The head and eyes are focused on objects of interest through movement to a desired position. The eye movement has two states: Saccade , which is the fastest movement of which the human body is capable and take only about 30 milliseconds, centering on contents within the foveal area. The Fixation,this occurs when the saccade movement stops and permits the eye to acquire contents, which are viewed. During a saccadic activity, the human sight is partially blind. The world is perceived visually through fixations and the brain virtually integrates the visual images that are acquired through successive fixations. Eye tracking is capable of showing which parts of user interfaces are visible to users and which parts seem to be invisible just by observing users and gathering qualitative data and analysing their gaze plots and other quantitative data. By using a remote, digital eye tracker, we can record the length of each fixation, the distance to the eye, the changes in pupil size, and information about other useful data within accuracy of half a degree. In other to determine the validity of the eye movement on web stimulus, the task are designed in such a way as to induce cognitive workload through vision, while the algorithm provides the features and components to be applied to:

- classification algorithm that analyse the eye movement behaviour of users, using the quantitative data exported from the eye tracker.
- with this knowledge, we can improve the usability and usefulness of webpages and other software applications throughpattern recognition.

II. RELATEDWORK

Most work on pattern recognition are mostly through understanding scanpaths in eye movements during pattern perception [12] by learning and recognising patterns which were marginally visible and require fixation directly on feature to which they wished to attend. This is mostly based on fixed scanpath specific to subject and pattern. Also, other pattern recognition includes using stimulus matrix containing target patterns of elements that match certain pattern and non-targets of elements. This is based on computer aided design task produced by the evaluators. The mean number of fixations is evaluated as a function of number of target elements [6].

Eye movement strategies are also conducted in facial perception [1] where recordings were made of the eye fixations of subjects in a task involving black and white photographs of faces. The eye movement were recorded using a corneal reflection technique, it is noted that each of the subject showed an individual fixation strategy for the tasks and recordings was made of which facial features these subjects preferred and the sequential pattern of their eye movements. Viewing conditions of marginal visibility and also force subjects to fixate directly each feature to which they wished to attend [12] and reveal sequence of processing. Internal subject's eyes can also scan over pattern following repeatedly at initial viewing, on a fixed scanpath. An eye movement also is observed to follow the same scan path when presented with the same vision for a second time. There is also the need to extend traditional psychophysical methods to include the analysis of patterns in eye movement [1] and also comparing subjects' verbalisations with their eye movements [7], where most results

Fig.: User interaction with web pages on an eye tracker

showed that stimulated think-aloudisvalidandreliableinusability,througheyemovementvalidation.This provides a valid account of what people attended to when completing a task, there is a low risk of introducing fabrications, where the validity is unaffected by task complexity. More so, face alignment is normally conducted using eye positions or eye movement behaviour by applying an accurate eye localisation algorithm for accurate face recognition. An automatic technique is then used for eye detection. The performance of the eye detection algorithm can also be validated using certain database [15] [14] [9].

Sometimes users eye movement is affected by their emotion response to stimulus, this is the specific area of web usability that is often a challenge. To understand user interaction and perception, eye tracking is normally used with physiological measures. In this paper the Skin conductance response SCR was also applied as part of the parameters to determine the accuracy of the predictive models. The Skin conductance is normally the measure of the electrical conductance of the skin as a result of sweat cause by specific emotions, in this case, emotion cause by interaction web stimulus. In web usability, common sense approach has been applied on elements and attributes of webpages [10], to determine where certain elements are to be placed with the help of eye positions obtained during performance of a task [11].

Different applications can be applied to the eye tracking measurement to collect eye gaze data in real-time and perform different calibrations. Other applications that can be used with the eye tracker sensor include custom written software for analysis, gaze dependent applications and eye control applications. The quantitative eye movement data obtained can be validated and improvedusing classification algorithm for pattern recognition.

In most study, the basic theme of is that eye-movement data reflect the cognitive processes that occur in a particular giventask. The early period of basic work on eye movement research was conducted by training eye-movement patterns to improvereading and other vision enable task [13][2][5][16]. There are a number of advantages of recording eye movements this includesthe capability of controlling stimulus presentations as a function of eye location, computer scoring of eye-movement data ratherthan the manual scoring, improving greater accuracy by identifying the location of the fixation, which can be obtained by using the computer in the calibration process [4][16][12].

III. EXPERIMENTALMETHODOLOGY

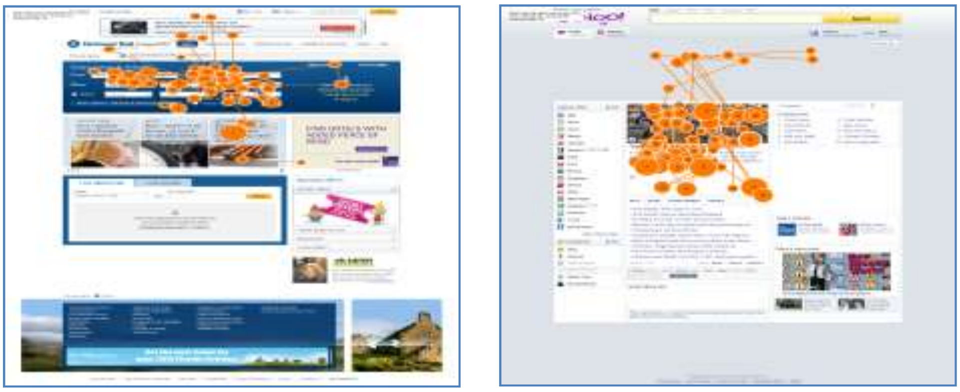
The experimental setup is based on the normal approach applied in every usability study that involves the use of eye tracker. The experiment was conducted with approval from the University of Manchester Senate Committee on the Ethics of Research on Human Beings, with reference number CS77. The users are asked to sit in front of the eye tracker and interact with webpages that contains both dynamic and static contents (Figure 1). Their free hand is place on two electrodes to also collect their SCR. The eye movement of the users are then recorded by the eye tracker sensor and exported to a system.

A.Task

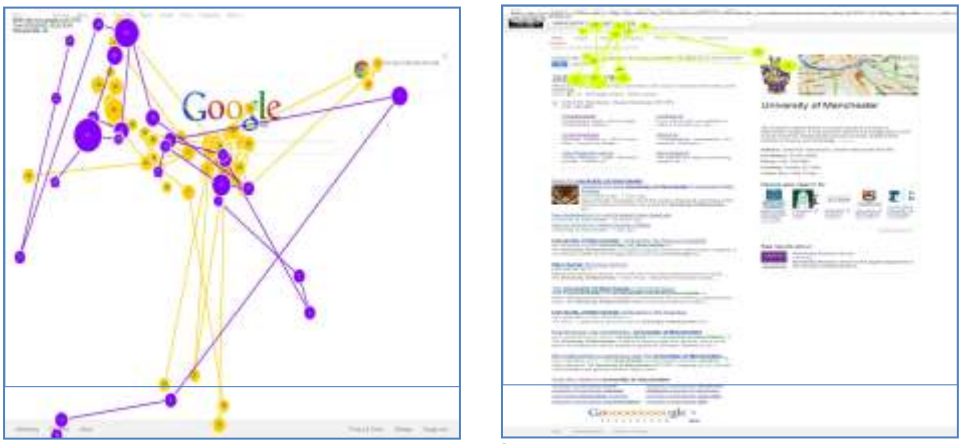
The users were asked to search for certain locations, such the position of an institution, search the route of a train from one location to another. This involves interaction with complex interfaces on these webpages and determining their cognitive abilities when in contact with the video and picture content of the pages. The intellectual task will allow the predictive models to test the patterns of their eye movement behaviour and eye scoring by the eye tracker.

B.Stimulus

The Web stimulus is presented and uses the contents of webpages as stimuli, this includes the interfaces and dynamic contents. The subject is presented with a standard Internet browser at a predefined start page, and is free to browse the Internet in any way. The Web stimulus (Figure 2) is used as a comprehensive tool for web usability to measure task conducted from the eye movement of the participants in task completion and attention and also to study their fixation patterns by collecting their eye movement data for the models.



(a) Fixation points on National Rail Enquiry page. **(b)Subject's gaze plot on Yahoo page.**



(b) The Gaze plot visualizes the scan path of a user **(d) Gaze plot on Google page**

Fig.2: Gaze plot with fixation points on web pages from the study

C. Eye Filter and Validity

To sort binocular data and filter out bad data, the validity and eye filter is used. The eye tracker to each gaze data that is recorded, both to the right and left eye, assigns a validity code respectively. This is basically a good indication of how certain the system sensor is of recording the correct data. The validity codes are translated by the validity filter and records which eye are accurately found, the settings are termed fixed, probable and uncertain as describe in the table below.

Left Validity	Right Validity	Accuracy
2	2	uncertain
4	0	Fixed
0	4	Fixed
3	1	Probable
1	3	Probable
4	4	uncertain
0	0	Fixed

TABLE I: Table showing score of eye accuracy according to the eye tracker

The eye filter bases gaze analysis on both eyes separately. This is generally more accurate, and more stable over long time and across changes in light conditions. The eye tracker studies, records each eye individually and determine the difference in behaviour between the two eyes. For this study, we are only interested in the eyes found, which are fixed, probable or uncertain.

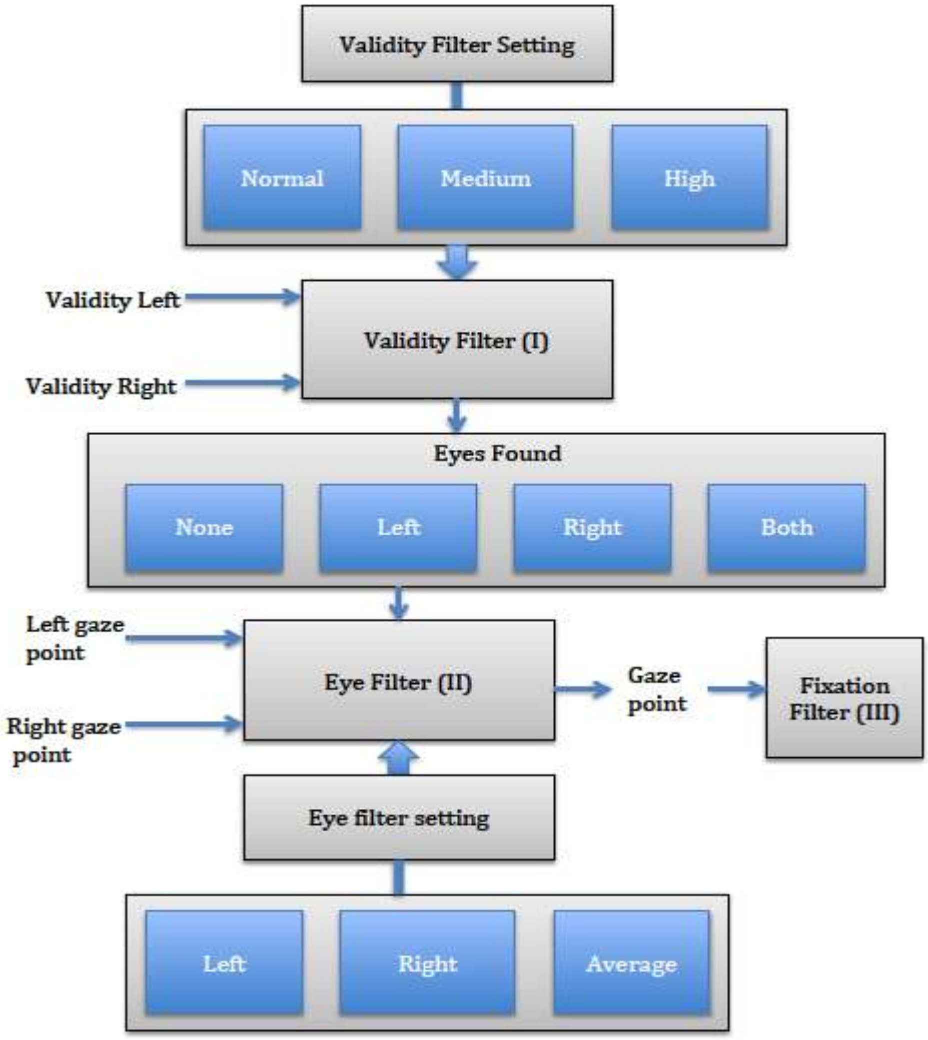


Fig 3: Validity and eye filter algorithm

To determine the predictive ability of the algorithms applied, more eye parameters, such as the Pupil eccentricity (PE), Pupil Ovality (PO), Pupil Roundness (PR) and the Circularity Index of the pupil (PCI) are added to the eye movement parameters of the eye tracker. These are briefly discussed below:

- Pupil Roundness: This the stake equality coefficient between the outlined pupil and a reference fitted circular region C, has equal area with the pupil ranging between 0 to 1 and a perfect circle that is equal to 1.

$$PR = \frac{2|P \cap C|}{[|P| + |C|]}$$

- Pupil ovalness: This is the dice similarity coefficient between the outlined pupil and a reference fitted elliptical region E, and equal area with the pupil, ranging from 0 to 1 and a perfect ellipse equal to 1 [14].

$$PO = \frac{2|P \cap E|}{[|P| + E]}$$

- Pupil eccentricity: The parameter pupil eccentricity here is associated with every pupil. It can be thought of as a measure of how much the roundness of the pupil deviates from a circle during interaction. Circles or ellipses can model the inner and outer boundaries of an iris in the image of an eye (Figure 4). The eccentricity of an ellipse is determined according to:

$$PE = e \equiv \sqrt{1 - \frac{b^2}{a^2}}$$

where b = inner boundary measure, a = outer boundary measure of the fitted elliptical region of the eye [14].

- Circularity index measure: In addition to the PO, PR, PE, and measures, PR and PO were used together to calculate the pupil circularity index measure (Figure 4. This was computed as the geometric distance between PR and PO [14].

$$PCI = ((1 - PR)_2 + (1 - PO)_2)^{0.5}$$

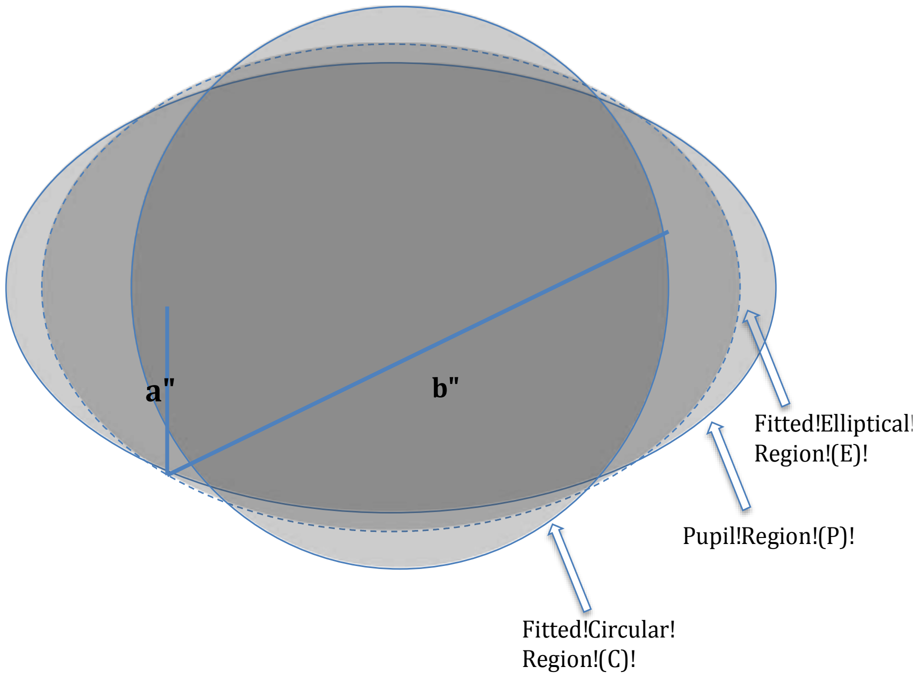


Fig.4: Pupil shape Measures

D. J48:

The J48 model decides the target value of a test sample based on various components values of the available dataset. The model is a decision tress in which the internal nodes denote the various attributes that are individually different, the terminal nodes tell us or classifies the dependent variable.

In this paper, the predicted attribute are the gaze points that "fixed" and those that are "probable" (dependent variable). The class such as "uncertain" and "partial" are assigned if the machine predictions are uncertain to the evaluator. These attributes depends upon, the gaze points of both the x and y coordinates, camera point on both sides and the pupil changes in pupil size on both eyes of the dataset.

E. Bootstrap aggregating (bagging(BA)):

The model is simple meta algorithm of averaging technique that improves the stability and accuracy of learning algorithms used in classification and regression. It is used here because it helps reduce variance and avoid over fitting [3].

F. Support Vector Machine (SVM):

This also used here because of its capability in handling regression problem like the dataset obtained from the study, applied as a supervised learning associated with learning algorithms that analyse data and recognise patterns used in the classification and regression analysis. The model takes a set of the input data and predict for each input, which forms the output. It employs all attributes of the eye movement data in the study.

G. Naive Baiyes (BN):

Here the baye's theorem is employed with independence assumptions, assuming the presence or absence of a particular feature, such as the gaze point or changes in pupil size is unrelated to the presence or absence of any other feature, given the class variable. It considers all the features of the eye movement data to contribute independently to the probability that a particular eye-tracking component is either due to eye been fixed, probable or uncertain, regardless of the presence of absence of all other components. The algorithm finds patterns in the dataset that predicts the eye movement from unstructured sources like the eye tracker sensor. The WEKA software is used in implementing the algorithms.

These algorithms are applied to the datasets (both training and test sets), to determine and compare the performance of each individual algorithm in terms of predicting the validity of the eye movement fixations using the cogency of the both eyes, which are classified as "fixed", when both eyes are detected, "probable" when only one of the eye is confirmed and "uncertain" if both eyes are not detected. The basic features used here are briefly illustrated in Table I. The final performance of the classification algorithms is assessed by the eye tracker parameters and those introduced as additional features. This can be done with or without the prior knowledge of the stimuli.

H. Performance Measurements

The primary interest of these intelligent algorithms is the capability of predicting the class of previously unseen datasets. The original data exported from the eye tracker are divided into both the training and test set. The purpose is to have samples ready for testing that has never been applied on the system during the training stage. This technique allows for training and testing on various dataset samples and precludes the need to test on unknown eye movement behaviour whose features are uncertain.

I. Analysis

A custom sort In-place algorithm was designed for data reprocessing The In-place algorithm sort and partition in action both the components and large list of data. The eye validity here is the pivot attribute (Figure 5), where the primary sorting commences with the element Pupil Right (PR), Gaze Point X and Y (GPX and GPY) and Pupil Left (RL), these are of high priority and due to the fact that the sensor measure depends on the eye position (gaze points).

The Camera position Left (CL), Camera Position Right (CR), Distance of camera from the eye on the left side (DL) and Distance of Camera from the eye on the right side (DR) which are of lesser precedence are then located. The in-place algorithm partitions the percentage of the array of the present priority between indexes left and right, inclusively, moving all array of the attribute of lesser priority to the pivot-attribute, in this case, validity of the eye as measured from the eye tracker sensor. The iteration is performed in the following order:

Algorithm 1.1*Custom sort In-place process*

subarray=right_attr−left_attr+1
function*partition(array,left_attr,right_attr,pivotIndex*
pivotValue=array[pivotIndex
swaparray[pivotIndexandarray[right_attr]
storeIndex:=left
for
*i=left_attr****to****rightattr−1*
lef_tattr<i<right_attr
if*array[i]<=pivotValue*
swaparray[i]andarray[storeIndex]
storeIndex:=storeIndex+1
swaparray[storeIndex]andarray[right_attr]
return*storeIndex*

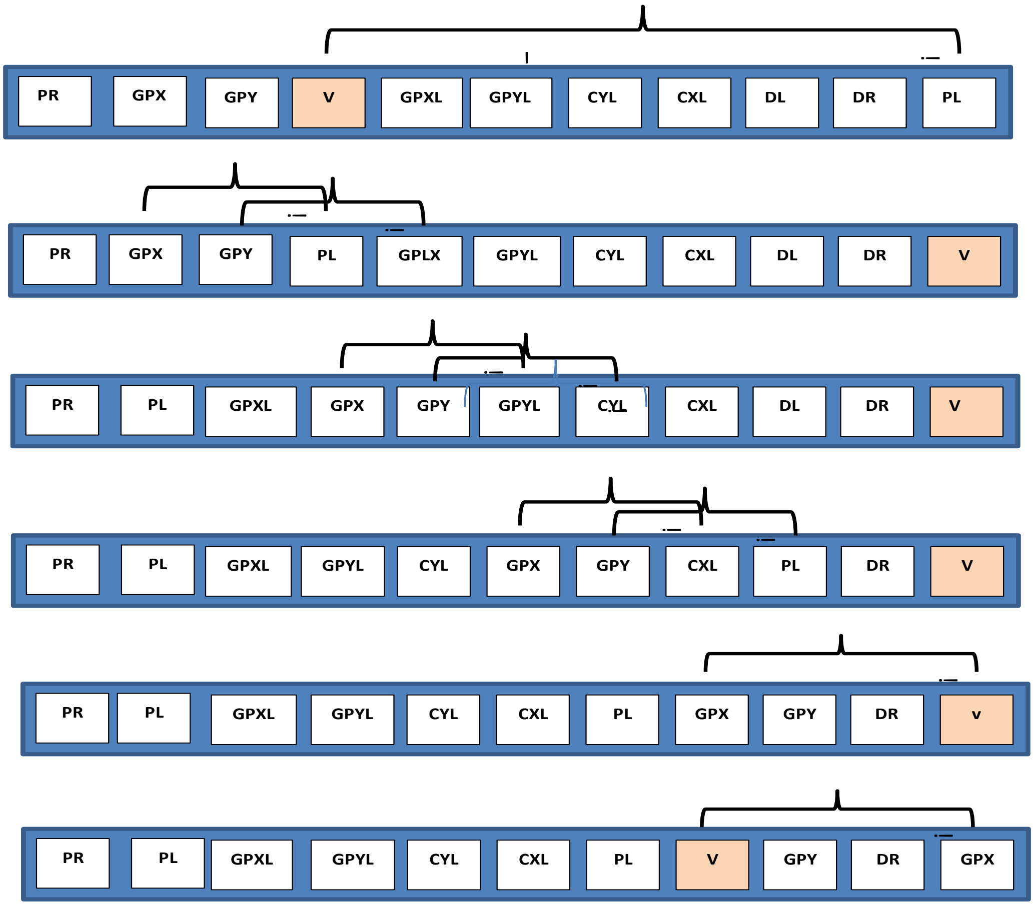


Fig.5:In-place sortingalgorithm

For the average of both eyes, a 3min instances was separately applied with the subjects SCR, to test the model with additionalparameters from their emotion response during a session. The performance of the predictive model and confusion matrix isshown in Table IV and TableV of the next page.

IV. RESULT

There exist a positive correlation between the measure of distance of the eye tracker sensor from the right eye to the gaze point measures on the left eye. From the result for a subject, the features are normally distributed (Figure 6).

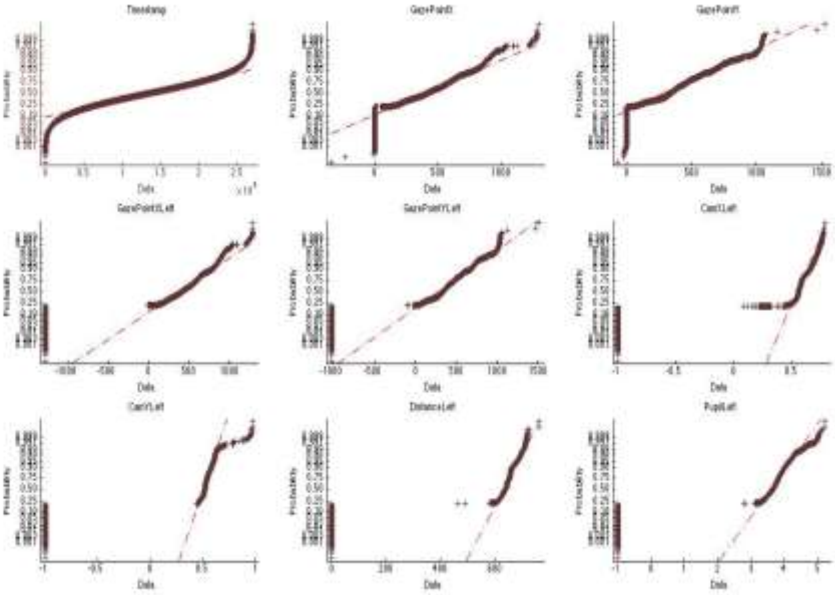


Fig. 6: Normally distributed features of eye movement

Most of the features contributing to the authentic predictive of the baiyesian model, are both the gaze point by the right eye on the X-coordinate and the distance of the sensor from the eye on the right side (this is the horizontal location of the right pupil in the camera image).

The Bagging model indicates that the measure of the right pupil and the gaze point in the X-ordinate are of most precedence. This implies that the gaze point and pupil changes are common factors to the validity code that leads to indicating the system's confidence in whether it has correctly identified which eye is left or right for a specific sample. As stated previously, the validity is 0 if the eye is found and 4 if the eye cannot be found.

Model	BN	SVM	BA	J48
Accuracy	99.7	99.9	99.8	100

TABLE II: Performance of models

		Validity right		Validity left	
		Predicted			
		Fixed	Probable	Fixed	Probable
#P1		8685	0	2269	4
		5	2347	3	8767
#P2		14764	40	14650	6
		52	886	0	2019
#P3	Actual	1823	52	2019	0
		40	14210	6	14662
#P4		3135	4	2846	5
		0	10365	0	9705
#P5		10554	0	2944	6
		4	2957	0	10565
#P6		2375	5	2232	4
		0	17637	0	17780

TABLE III: Confusion matrix result with class for each eye

The confusion matrix in Table III shows the predicted and actual values of the fixed and probable gaze points from both the left and right eye. All model performed well with accuracy close to 100% (Table II).

Model	B	SV	B	J
Accurac	6	74	7	7

TABLE IV: Performance of models with subjects SCR

	Predicted			
	Probabl	Uncert	Fixed	Par
actual	9	12	3	0
	7	68	6	0
	4	3	32	5
	4	3	32	5
	0	1	3	1

TABLE V: Confusion matrix

V. CONCLUSION

The paper discusses the validity in the eye movement behaviour with a novel approach of analysing or studying each eye individually to see the difference in behaviour between the two eyes using classification algorithm that predicts whether fixations form either eye is fixed (both eyes detected) or probable (one of both eyes detected).

A method that uses classification algorithm for pattern recognition was proposed for detecting eye movement's validity. The baiyesian model, the Bootstrap aggregating, Support Vector Machine and the J48 model were compared after preprocessing for pattern recognition of the validity of eye movements.

The result showed that there is significant relationship between the eye gaze components, with the the gaze points, distance of camera from the eyes and horizontal location of the right pupil in the camera image, as predicted by the baiyesian and bagging model and are of high importance in eye movement behaviour to these models. In a case where either eye is a suitable setting is when the test subject on a study has high gaze accuracy on one eye and a low accuracy on the other eye. The data from the dominant eye is used for the analysis.

To understand and determine the overall accuracy of the intelligent models, the SCR response of participants was used as an additional parameter. This covers the affect feature of the subject that initiate slight changes in eye movement behaviour such as eye dilation. The Bagging model also performed better in this case, as shown in the Receiver operating characteristics graph in Figure 7. This also supports the fact that using physiological measures with eye tracking can authentically interpret quantitative methods of conducting usability studies, without seeming overtly perfect.

There are different algorithms for fixation definition that has been proposed and are available among researchers and evaluators. The fixation filter applied is based on the eye trackers, which is used to group gaze data into several meaningful fixations. In part, the purpose of the study is to understand eye movement behaviour in terms of the eye validity as detected from the eye tracker. The validity code indicates the system's confidence in whether it has correctly identified and differentiated both eyes. It also filters remove data points, which are incorrect.

Since classifications algorithms learns better from natural data acquisition, from the result it is obvious that external measures contributes to feasible positive predictions without conforming to unduly flawless output, when learning from standardized machines. Further research would be to develop a custom algorithm that defines the fixation points in terms of the system's accuracy in predicting gaze positions on visual stimuli.

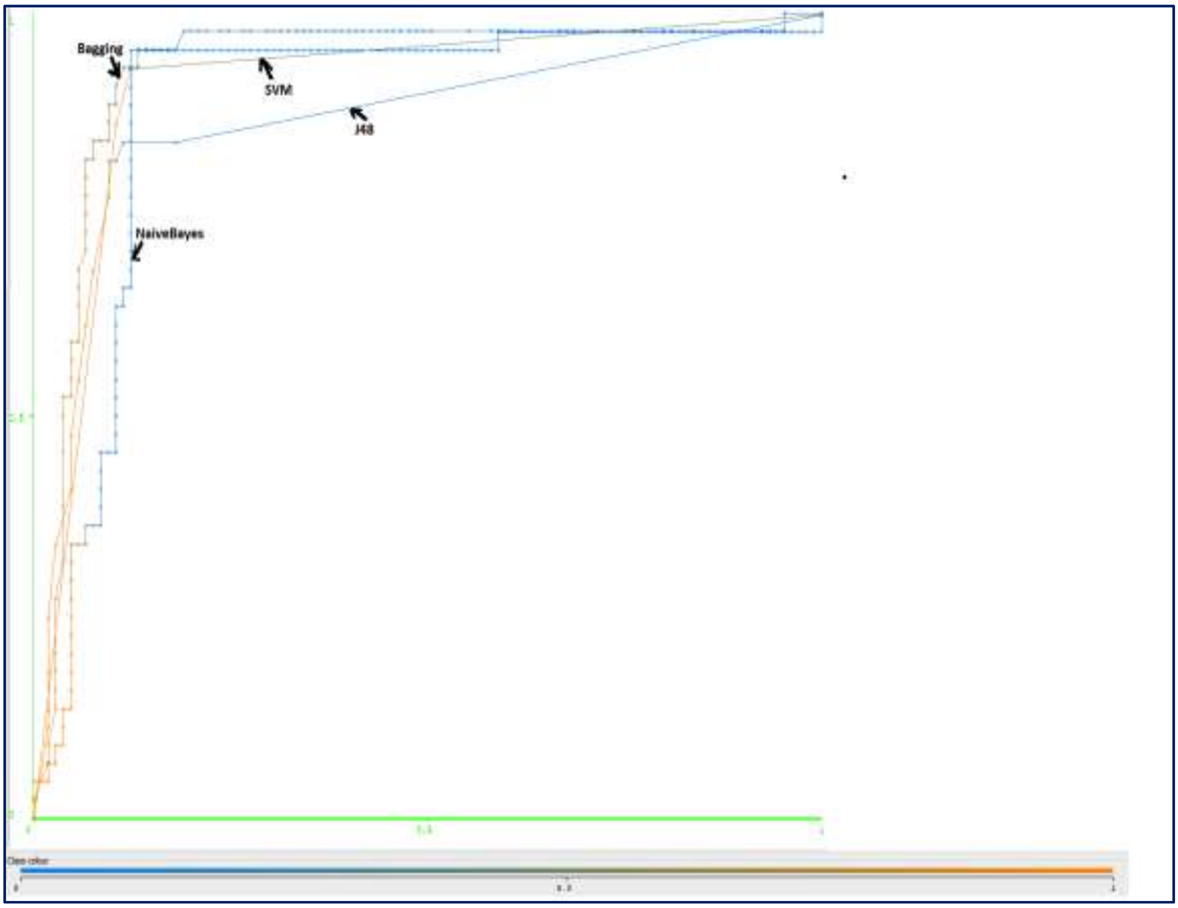


Fig. 7: ROC shows diagnostics with Bagging having high performance

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