



# Medical Diagnosis of Cerebral Palsy Rehabilitation Using Eye Images in Machine Learning Techniques

P. Illavarason<sup>1</sup> · J. Arokia Renjit<sup>2</sup> · P. Mohan Kumar<sup>3</sup>

Received: 2 April 2019 / Accepted: 26 June 2019 / Published online: 9 July 2019  
© Springer Science+Business Media, LLC, part of Springer Nature 2019

## Abstract

Cerebral Palsy (CP) is a non progressive neurological disorders commonly associated with a spectrum of developmental disabilities such as strabismus (misalignment of eye). The Eye image are captured through camera, this make the quick diagnosis and examination the periodical assessment for CP kids. By capturing the Eye Movement of 40 children with CP (aged 3–11 years) with relatively mild motor-impairment and also we have analyzed the performance of CP children periodically. Nowadays, Bio-Medical image processing and Machine learning Classification algorithm used for detection and diagnosis the certain diseases and plays the important tool to decrease the risk of any diseases. This work presents a computational methodology to automatically diagnose the Improvement of CP children and performance can be evaluated. The alternate medical evaluation techniques have shown their potential for the treatment and diagnosis of disease like strabismus and nystagmus for CP kids. The proposed method is used to measure and quantify the performance improvement by classify the abnormal eye condition of CP kids and these results attained by machine learning method. The results show the best classification accuracy of 94.17% calculated from Neural Network Classifier. Specificity Rate were absorbed as 0.9800 and Sensitivity Rate were absorbed as 0.9165 respectively. The proposed method for non-invasive and automatic detection of abnormalities in CP kids and evaluates the performance improvement more accurately.

**Keywords** CP kids · Image processing techniques · Classification · Machine learning techniques · Improvement analyzed

## Introduction

Cerebral Palsy (CP) describes as a neurological disorder is mainly due to the non progressive brain injury or the abnormalities develops while in kids brain is under development.

This appears in early childhood development. CP Caused due to genetic disorder, some infections during pregnancy time, medical problems and accidents that appear in mother during pregnancy, premature babies, poor blood flow to brain [1, 2]. This can be controlled while taking certain precautions during pregnancy time and this might decrease the risk of CP. Since there is no cure for CP; however, proper rehabilitation therapy, visual therapy treatments, medications etc., may help many individual CP Kids. This considers the best approach for CP Rehabilitation. Rehabilitation interventions should be considered for CP kids and need to become an vital part of the standard treatment in Effective Way and which can be assessed rigorously for each and every individual.

The Importance of the proposed research in the context of current status, According to World Health Organization (WHO) estimation, In India, is around 3 per1000 live births suffer from CP kids. For World, the estimated incidence is around 7.5 per 1000 live births. Currently 17 million people in the world diagnosed with CP. Majority of CP Kids are affected by Visual Dysfunction. Visual therapy is non surgical method to improve the specific

---

This article is part of the Topical Collection on *Image & Signal Processing*

---

✉ P. Illavarason  
illavarason.p@gmail.com

J. Arokia Renjit  
arokiarenjit@jeppiaarcollege.org

P. Mohan Kumar  
mohankumarmohan@gmail.com

<sup>1</sup> Faculty of Information and Communication Engineering, CEG, Anna University, Chennai, India

<sup>2</sup> Department of CSE, Jeppiaar Engineering College, Chennai, India

<sup>3</sup> Department of IT, Jeppiaar Engineering College, Chennai, India

visual dysfunction useful in treatment of strabismus and nystagmus in CP kids. Automated Visual therapy simultaneously improves low Vision, Eye Blinks and Eye Ball Rotations [3, 4].

There are no Computational techniques is available for monitoring the Improvement of CP children at the Rehabilitation Center. Based on several literature surveys, Manual therapy process has no input over the severity levels of the CP children. Also, no Standard Techniques are available for Visual therapy. The effectiveness of Visual therapy is employed with comparison groups, since there is availability of expertise is limited. So, there is high risk that the scientifically unproven techniques adopted for visual therapy may cause severe damage to the retina, which may worsen the condition of CP children. So, research work aims at identification of Visual therapy techniques and verifying it scientifically and then adopting this technique in computational methodology which can be used for assess the CP children and also measuring the improvements of the CP Children using this computational methodology by periodically.

Visually Evoked Potential (VEP) Device is costly for evaluating the condition of CP kid for every time [5, 6]. Instead of VEP, this method is economic and alternate solution for

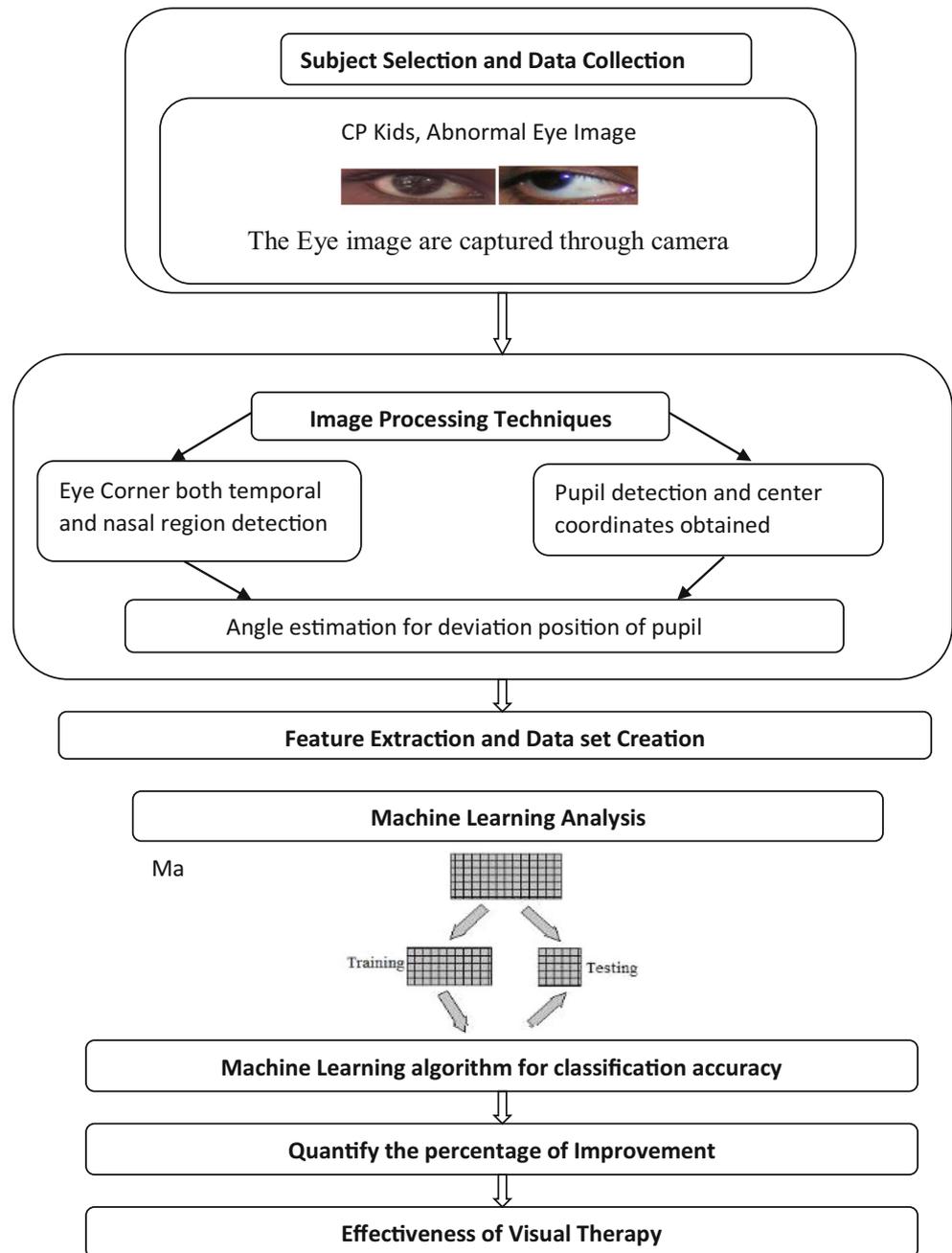
evaluating the effectiveness of Vision affected CP kids by visual therapy [7, 8].

The Eye image is captured through camera, which makes the quick diagnosis and examination the periodical assessment of CP kids. By capturing the Eye Movement of 40 children with CP (aged 3–11 years) with relatively mild motor-impairment and also we have analyzed the performance of CP children periodically. Nowadays, Bio-Medical Image processing and Machine Learning Classification Algorithm used to detection and diagnose the certain diseases also it used as an important tool to decrease the risk of any diseases. This approach is computational methodology to automatically diagnosis the Improvement of CP children and performance metrics can be evaluated. The improvement analyzed for CP kids were maintained and recorded the outcome results for the periodical month of initial, 6th and 12th month. The proposed method is used to measure and quantify the performance improvement by detecting the abnormal eye of CP kids and the results attained by machine learning method. In this context, Image processing techniques are being recommended as a performance evaluation tool in children with CP. Each of these processes is suggesting method for developing a more systematic understanding of

**Table 1** Literature review - In different applications, the image processing and machine learning techniques applied and summarized some potential work done for disease diagnosis

S.no	Applications	Reference author name	Image processing techniques	Machine learning techniques	No of samples	Classification accuracy
1	Diabetic Detection and prediction	Lin ma et al. [9]	<ul style="list-style-type: none"> <li>• CHT</li> <li>• Gabor filter and 2-Dimension discrete wavelet transform</li> </ul>	Support Vector Machine	292	90%
2	Gender Prediction using Iris Image	V.Thomas etal, A. Bansal etal, S. Azilah et al. [10–12].	<ul style="list-style-type: none"> <li>• Circular Hough Transform</li> <li>• Daugman's rubber sheet normalization,</li> <li>• Principle Component analysis</li> </ul>	Neural Network-Feed forward.	80	85.68%
3	Tumor Detection in Iris	Helwan et al. [13].	<ul style="list-style-type: none"> <li>• Canny Edge detection,</li> <li>• Circular Hough Transform</li> </ul>	Modified back propagation algorithm utilizing parameter as adaptive learning.	100	70%
4	Diabetic Mellitus diagnosis	Piyush Samant et al. [14].	<ul style="list-style-type: none"> <li>• Iris texture analysis from different region of interest</li> </ul>	Random Forest	338	89.63%
5	Diagnosis of kidney diseases	Hussein et al. [15]	<ul style="list-style-type: none"> <li>• CHT</li> <li>• Gabor filter and 2-Dimension discrete wavelet transform.</li> </ul>	Artificial Neuro-fuzzy interference system	340	93%
6	Alimentary Canal diseases and nerve disorder diseases	L. Ma et al.	<ul style="list-style-type: none"> <li>• Feature extracted and classified by Texture method.</li> </ul>	Support Vector Machine Classification	429	85.4%
7	Healthcare information	D. Hareva et al. [16]	<ul style="list-style-type: none"> <li>• Texture analysis of Iris from various region of interest</li> </ul>	Artificial neural Network	32	90.95%

**Fig. 1** Architecture of summarized methodology

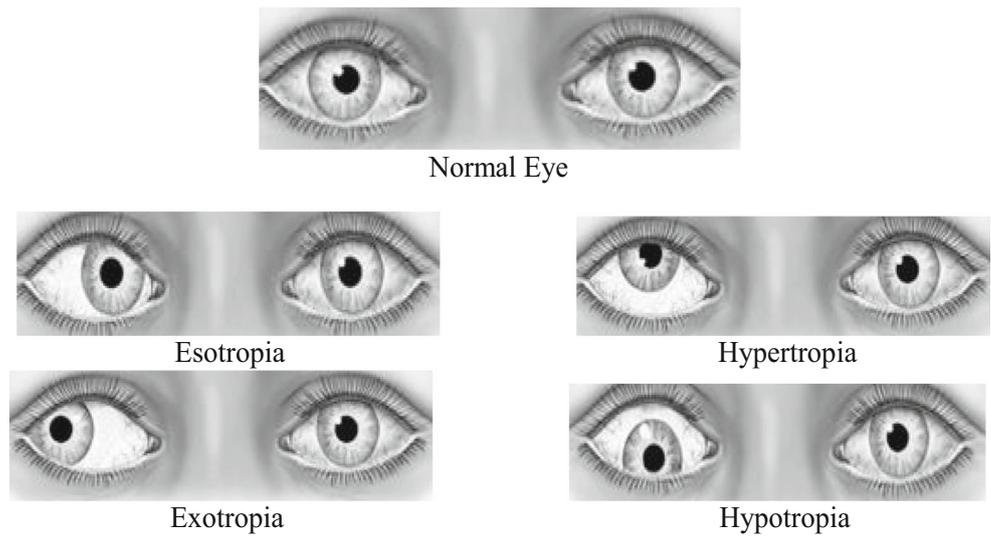


**Table 2** Detailed characteristics of children with CP (subject selection)

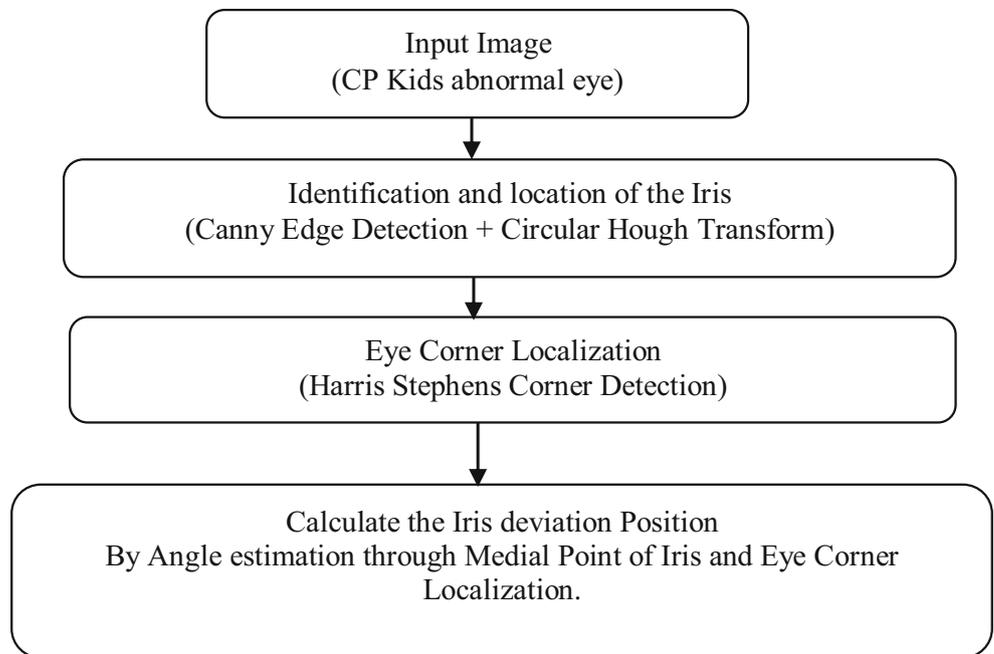
Cerebral palsy children	Total CP children	Age range between
Vision affected CP Children	40	3 to 11 years
Boys	25	3–10 years.
Girls	15	4–11 years.
Strabismus	32	3–10 years.
Visual field loss	2	9–11 years.
Oculomotor Dysfunction	5	4–10 years.
Visual Acuity	1	6–9 years.

Oculomotor abnormalities. So this Computational methodology to automatically diagnosis the Improvement for CP Kids and performance can be evaluated. This solves the solution of long-outstanding problems in the visual and ocular research. As the result, the Rehabilitation therapist and Vision Expertise can use this computational report to guiding the CP kids in Rehabilitation Center. Table 1 demonstrated the Literature Review - In different applications, the image processing and machine learning techniques applied and summarized some potential work done for disease diagnosis.

**Fig. 2** Overall illustration of oculomotor abnormalities of strabismus condition for children with CP



**Fig. 3** Block schematic of image processing techniques

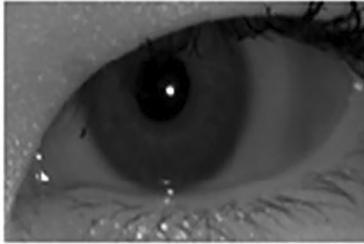
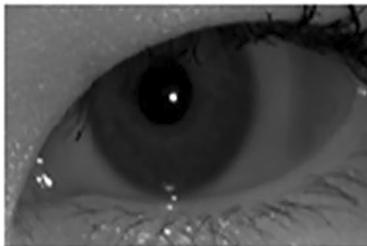
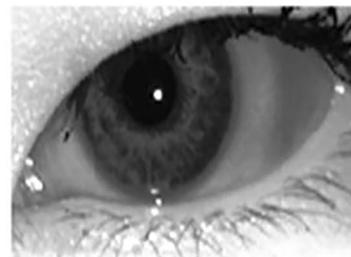


**Table 3** Image acquisition process

Total image	120 (For the periodical month of initial, 6th and 12th month) for the 40 CP patients.
Observations	Images captured under low lighting environments without flash. Several reflections and obstructions can be observed.
Acquisition device	Canon EOS 5d Camera
File format	JPEG
Resolution	640 × 480 pixels

**The highlights of the proposed system**

This paper proposes a novel segmentation method for eye images. The Proposed method detect the eye corner localization and identification of the location of the Iris to estimate the center coordinates of Iris achieved by using different image processing algorithms and angular movement measurement was investigated. To further enhance this estimate the angular movement for the abnormal eyes and analyze the performance improvement achievement by Visual Therapy Method used for CP

**Selected Image(Initial)****Enhanced Image(Initial)****Selected Image(6th Month)****Enhanced Image(6th Month)****Selected Image(12th Month)****Enhanced Image(12th Month)**

**Fig. 4** Input image selection process

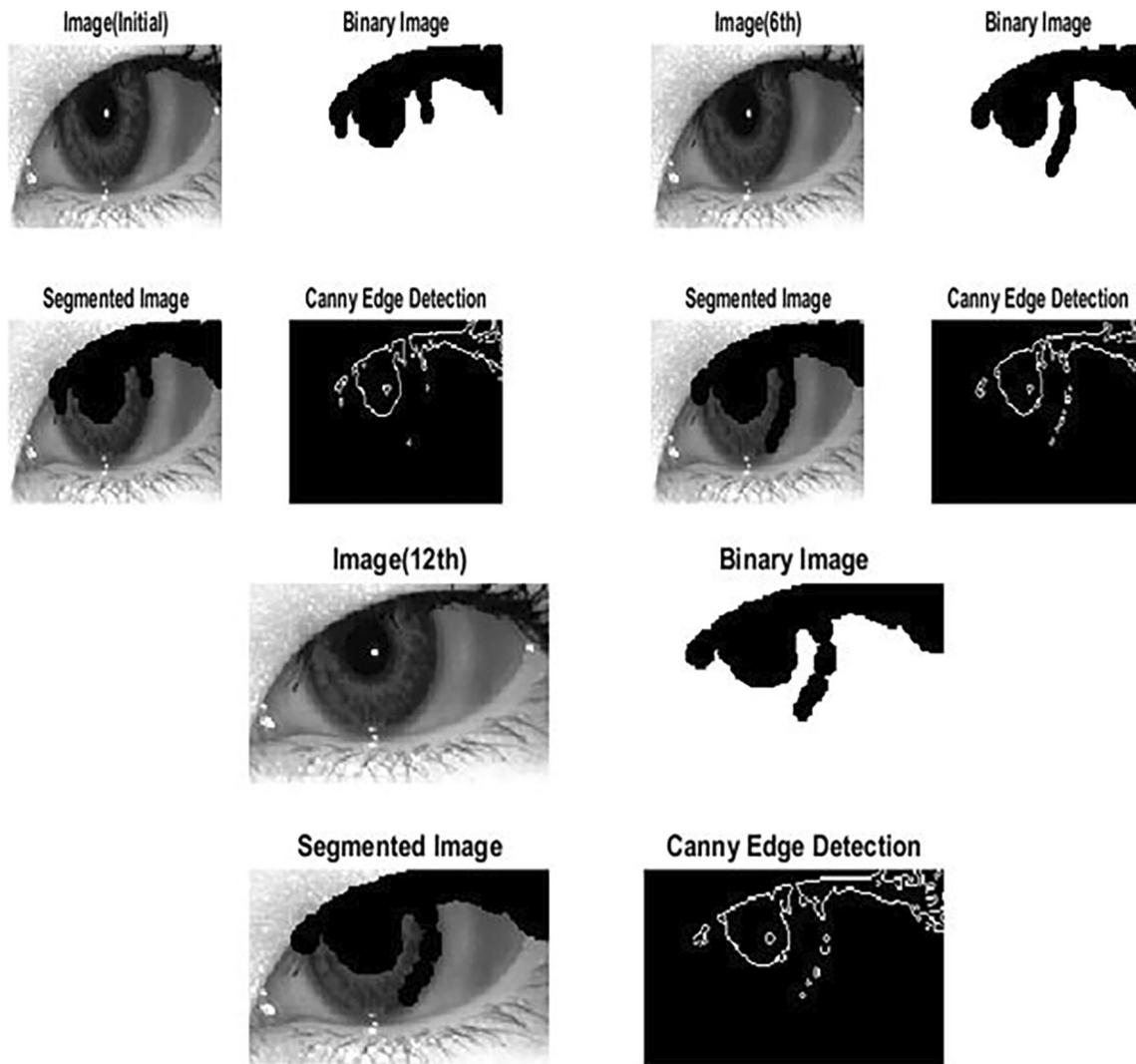
**Fig. 5** Preprocessing-enhancement techniques process

rehabilitation. In this context, Image processing techniques are being recommended as a performance evaluation tool in children with CP. Each of these processes is suggesting method for developing a more systematic understanding of Oculomotor abnormalities [17, 18]. The result reported using several performance measurement metrics reveals that the first step and also yields the better performance. The periodically improvement assessment made by capturing the Eye image through camera, in which where the eye position of CP kids were recorded for the period of 1st, 6th, and 12th. The difference in the periodical assessment in which improvement of CP kids were analyzed by comparing the results for making the prediction of how long the child may take to show the significant improvement by evaluating the visual therapy techniques. Based on the

report generation, compare the 1st, 6th, and 12th data, the brain neuron activity were assessed. Figure 1 illustrates the Architecture of Summarized Methodology.

### Implications for rehabilitation

- Categorization of CP kids eye images into any one of 4 abnormal categories using Machine Learning Classification Algorithm.
- Improvement assessment in CP kids by analyzing eye features using Image Processing Techniques.
- Analyzing the number of kids improved from each category and improvement percentage to determine the Effectiveness of Vision Therapy method.



**Fig. 6** Edge detection results of initial, 6th and 12th month

- Effectiveness of Vision Therapy method determination by periodically assessing the eye features of CP kids

## Materials and methodology

### Subject selection and data collection

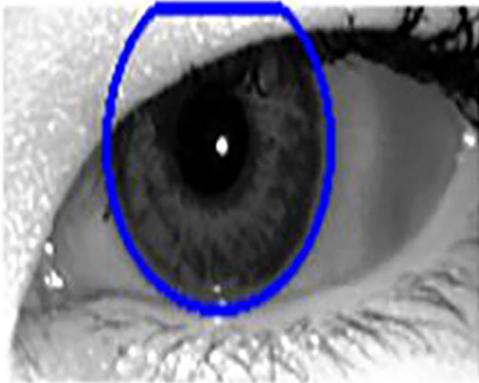
A total of 40 (120 abnormal eye image of CP patients) participants were analysed in the present study. The protocol followed for the data acquisition was approved by NIEPMD under the guidance of Dr. Vijayalakshmy investigated the visual components of CP Children. Forty kids with CP age range of (3–11 years) are subjected in this study though they are several categories of CP children. The improvement analyzed for CP kids were maintained and recorded for the periodical month of initial, 6th and 12th month. so, total of 120 (40\*3)

abnormal eye image of CP patients subjects were investigated in the present study. These studies include the participant of potential visual symptoms and performance deficit frequently reported in CP children. The CP children visual ability includes Thirty two children with strabismus, two children with visual field loss, five children with Oculomotor Dysfunction, one visual acuity due to dry eyes. The CP children characteristics are represented in Table 2. In this present study, obtained the angular movement estimated of abnormal eye in CP children. The CP children eye image captured by high resolution camera and also performed the implementation by using these high resolution camera images.

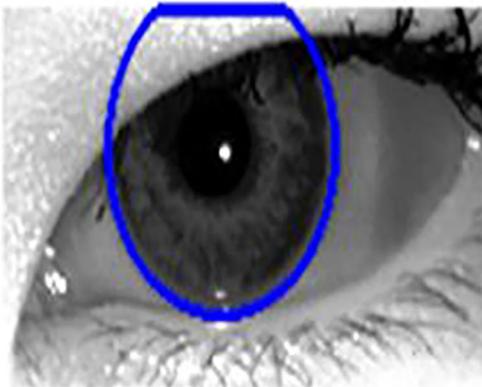
### Proposed image processing methodology

The defect in the eye of CP Kids or the Oculomotor abnormalities are due to damage to the parts of brain that control movement, balance and posture. So this brain damage causes

### Iris Image(Initial)



### Iris Image(6th)



### Iris Image(12th)

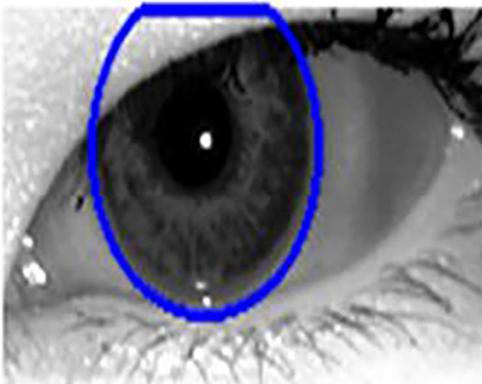


Fig. 7 Iris detected

stiffness in the eye muscles causing oculomotor abnormalities [19, 20]. The improvement in brain neuron activity improves the visual function of CP kids, which is achieved by visual therapy given in Rehabilitation Center. So, the improvement in brain activity can be assessed by assessing the eye features of CP Kids. Figure 2 represent the Overall Illustration of

### Corner Harris Image(Initial)



### Corner Harris Image(6th)

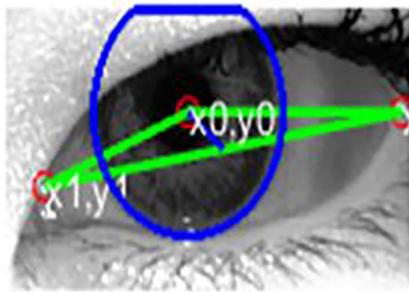


### Corner Harris Image(12th)

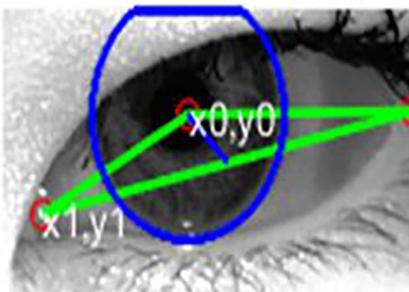


Fig. 8 Harris and Stephans corner detected

### Features of Image(Initial)



### Features of Image(6th)



### Features of Image(12th)

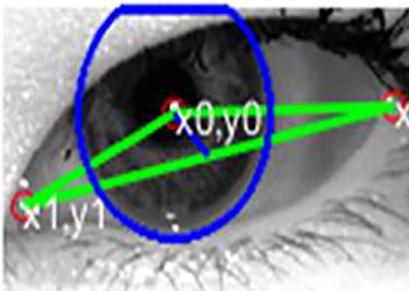


Fig. 9 Angle of deviation

Oculomotor Abnormalities of Strabismus Condition for Children with CP.

This article reports the data about incidence and kind of visual problems in CP kids. The Ocular Motility issues is most common problem to develop the Strabismus (Exotropia and Esotropia Mainly) these are the major Ocular disorder these were discussed briefly among the various associated Visual Problem of CP kids. The Major of the Visual Functional Assessment of CP kids which were assessed in Rehabilitation Center, activities of CP kids are performed in rehabilitation center and found the good response from item given to the CP kids. The Quantitative assessment of oculomotor abnormalities, Classifying and detect the directional movement of eyes from center position. To develop the algorithm for statistical approach and Performance Evaluating vision stimulation therapy process and Oculomotor function brings the diagnosis and treatment of brain disorder.

Representation of Oculomotor Abnormalities of Strabismus Condition for Children with CP which includes the,

- Esotropia-In this condition, where eyeball turned towards in direction.
- Exotropia, In these condition, where eyeball turned towards out direction.
- Hypotropia, In these condition, where eyeball turned towards down direction.
- Hypertropia, where In these condition, where eyeball turned towards up direction.

These are all considering the most common Visual challenges for Kid with CP.

The proposed area segments the eye image into Iris and eye corner by using the different image processing algorithms as well as estimate the angular movement of Iris for the abnormal eyes.

The Fig. 3 represent the Block Schematic of Image Processing Techniques. The Proposed Approach can be divided into following Modules,

- a) Iris Detection,
- b) Eye Corner Localization,
- c) Angle estimation through Medial Point of Iris and Eye Corner Localization,

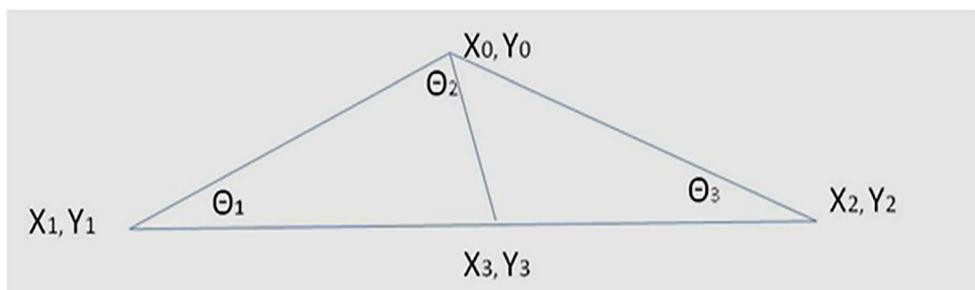


Fig. 10 Diagrammatic representation of angle of deviation

**Table 4** Feature extraction and data set creation

CP kids	Category	Periodical month	Iris center point	Eye corner point temporal region		Eye corner point nasal region		Angular estimation			Distance between eye corner temporal and Iris center	Distance between eye corner nasal and Iris center	Distance between eye corner temporal and eye corner nasal side	D4-Distance between Iris center and midpoint of eye corner points	
				X0	Y0	X1	Y1	X2	Y2	Θ1					Θ2
1	Hypertropia	Initial	68	30	15	51	147	30	57.00	79	133.66	0.37	0	0.15	0.99
		6th Month	68	30	15	58	150	29	59.94	82.00	138.07	0.48	0.01	0.21	0.87
		12th Month	63	30	8	56	143	28	60.83	80.025	137.8731	0.44	0.02	0.20	0.84
2	Hypertropia	Initial	73	38	6	61	148	42	70.83	75.10659	143.2655	0.33	0.05	0.13	0.85
		6th Month	68	38	7	60	147	37	64.84	79.00633	141.8767	0.34	0.01	0.16	0.7
		12th Month	70	33	9	57	150	37	65.55	80.09994	142.4114	0.37	0.04	0.14	0.69
3	Hypertropia	Initial	73	38	1	51	137	45	73.16	64.38167	136.1323	0.17	0.10	0.04	0.78
		6th Month	73	40	8	58	147	52	67.44	74.96666	139.1294	0.27	0.16	0.04	0.54
		12th Month	75	43	3	67	150	40	75.89	75.05998	149.459	0.32	0.03	0.18	0.53
4	Hypotropia	Initial	80	48	5	62	148	47	76.29	68.00735	143.7846	0.18	0.01	0.10	1.34
		6th Month	83	53	2	63	148	52	81.61	65.00	146.48	0.12	0.01	0.07	0.46
		12th Month	73	38	4	71	150	58	76.48529	79.55501	146.5776	0.44	0.25	0.08	0.37
5	Hypertropia	Initial	68	43	6	41	149	63	62.03225	83.43261	144.6824	0.03	0.24	0.15	0.65
		6th Month	75	45	11	39	148	62	64.28063	74.95332	138.9172	0.09	0.22	0.16	0.37
		12th Month	80	40	3	38	150	55	77.02597	71.58911	147.9797	0.02	0.21	0.11	0.36
6	Hypertropia	Initial	70	40	6	47	150	53	64.38167	81.04937	144.1249	0.10	0.16	0.04	0.73
		6th Month	68	38	1	47	148	50	67.60178	80.89499	147.0306	0.13	0.14	0.02	0.64
		12th Month	70	40	9	48	150	54	61.52235	81.21576	141.1276	0.13	0.17	0.04	0.62
7	Hypotropia	Initial	90	53	3	44	147	63	87.46428	57.87055	145.2481	0.10	0.17	0.13	0.75
		6th Month	73	48	12	43	146	62	61.20457	74.33034	135.3403	0.08	0.18	0.14	0.6
		12th Month	73	48	5	50	140	70	68.02941	70.5195	136.4734	0.02	0.31	0.14	0.38
8	Hypotropia	Initial	75	48	7	59	144	46	68.88396	69.02898	137.6154	0.16	0.09	0.09	0.23
		6th Month	73	45	1	55	150	30	72.69113	78.44743	151.0828	0.13	0.19	0.16	0.2
		12th Month	75	48	10	44	148	51	65.12296	73.06162	138.1774	0.06	0.04	0.05	0.18
9	Hypotropia	Initial	80	48	3	32	143	60	78.64477	64.13267	142.7725	0.20	0.18	0.19	0.49
		6th Month	83	50	5	40	149	64	78.63841	67.46851	145.9863	0.12	0.20	0.16	0.36
		12th Month	83	40	2	40	150	54	81	68.44706	148.6607	0	0.20	0.09	0.32
10	Hypertropia	Initial	68	33	1	56	142	57	70.83784	77.7946	141.0035	0.33	0.31	0.07	1.19
		6th Month	68	38	4	43	148	57	64.19502	82.2253	144.679	0.07	0.23	0.09	0.72
		12th Month	78	40	2	29	146	66	76.79193	72.8011	148.6775	0.14	0.36	0.25	0.43
11	Esotropia	Initial	58	35	10	53	150	35	51.26402	92	141.1524	0.35	0	0.12	1.32
		6th Month	55	35	6	53	146	43	52.20153	91.35097	140.3567	0.35	0.08	0.071	1.23
		12th Month	55	33	7	52	147	43	51.62364	92.54188	140.289	0.37	0.10	0.06	1.19
12	Exotropia	Initial	58	45	1	42	142	51	57.07889	84.21401	141.2869	0.05	0.07	0.06	0.81
		6th Month	60	40	1	48	142	55	59.5399	83.36066	141.1737	0.13	0.18	0.04	0.68
		12th Month	78	38	1	29	143	67	77.52419	71.17584	146.9966	0.11	0.41	0.26	0.58
13	Exotropia	Initial	60	33	1	57	150	40	63.69458	90.27181	149.9667	0.38	0.07	0.11	1.1
		6th Month	60	40	3	60	150	44	60.40695	90.08885	147.8682	0.33	0.04	0.10	1.02
		12th Month	63	38	3	46	150	43	60.53098	87.14356	147.0306	0.13	0.05	0.02	0.75
14	Esotropia	Initial	75	40	11	59	150	37	66.76077	75.05998	140.7302	0.28	0.03	0.15	0.49
		6th Month	78	40	6	62	145	37	75.28612	67.06713	141.2303	0.29	0.04	0.17	0.49
		12th Month	78	40	8	60	147	28	72.8011	70.03571	142.6359	0.27	0.17	0.22	0.2

**Table 4** (continued)

CP kids	Category	Periodical month	Iris center point		Eye corner point temporal region		Eye corner point nasal region		Angular estimation			Distance between eye corner temporal and Iris center		Distance between eye corner temporal and eye corner nasal side		D4-Distance between Iris center and midpoint of eye corner points	
			X0	Y0	X1	Y1	X2	Y2	Θ1	Θ2	Θ3	D1	D2	D3	D4		
15	Esotropia	Initial	63	35	6	56	148	43	60.74537	85.37564	142.5938	0.35	0.09	0.09	1.12		
		6th Month	58	35	1	58	150	40	61.46544	92.13577	150.0833	0.38	0.05	0.12	1.12		
		12th Month	65	33	2	60	150	45	68.54196	85.84288	148.7582	0.40	0.14	0.10	1.01		
16	Esotropia	Initial	53	35	9	72	145	46	57.48913	92.65528	138.463	0.69	0.11	0.18	1.7		
		6th Month	48	40	7	65	144	50	48.02083	96.51943	137.8187	0.54	0.10	0.10	1.63		
		12th Month	70	35	1	60	147	42	73.38937	77.31753	147.1054	0.34	0.09	0.12	0.82		
17	Exotropia	Initial	70	45	8	49	142	61	62.1289	73.75636	134.5362	0.06	0.21	0.08	0.74		
		6th Month	68	40	6	42	150	59	62.03225	84.17244	145	0.03	0.22	0.11	0.73		
		12th Month	78	35	1	40	146	58	77.16217	71.7844	146.113	0.06	0.32	0.12	0.56		
18	Exotropia	Initial	58	38	1	44	142	53	57.31492	85.32878	141.2869	0.10	0.17	0.06	0.86		
		6th Month	63	45	9	42	140	50	54.08327	77.16217	131.244	0.05	0.06	0.06	0.58		
		12th Month	80	40	1	33	147	65	79.30952	71.51224	149.4657	0.08	0.35	0.21	0.54		
19	Esotropia	Initial	55	35	8	56	135	45	51.47815	80.62258	127.4755	0.42	0.12	0.08	1.13		
		6th Month	70	38	1	75	148	44	78.29432	78.23043	150.2332	0.49	0.07	0.20	1.1		
		12th Month	65	38	5	62	148	46	64.62198	83.38465	143.8923	0.38	0.09	0.11	0.99		
20	Esotropia	Initial	63	33	10	52	146	32	56.30275	83.00602	137.4627	0.34	0.01	0.14	0.87		
		6th Month	65	45	11	72	130	34	60.37384	65.9242	124.92	0.46	0.16	0.30	0.62		
		12th Month	68	43	7	71	150	28	67.1193	83.36066	149.3251	0.43	0.18	0.29	0.49		
21	Esotropia	Initial	83	35	4	49	137	50	80.23092	56.04463	133.0038	0.17	0.26	0.02	1.05		
		6th Month	88	38	3	51	150	55	85.98837	64.28841	147.0544	0.15	0.26	0.02	0.96		
		12th Month	85	30	2	48	141	44	84.92938	57.72348	139.0575	0.21	0.24	0.02	0.95		
22	Esotropia	Initial	100	48	5	47	145	70	95.00526	50.08992	141.8767	0.01	0.45	0.16	1.36		
		6th Month	73	40	4	48	147	65	69.46222	78.1089	144.0069	0.11	0.32	0.11	0.83		
		12th Month	75	40	10	47	146	64	65.37584	74.94665	137.0584	0.10	0.32	0.12	0.79		
23	Hypertropia	Initial	85	40	1	39	135	57	84.00595	52.81098	135.2036	0.01	0.32	0.13	0.94		
		6th Month	83	43	1	37	132	57	82.21922	50.96077	132.5179	0.07	0.27	0.15	0.85		
		12th Month	80	40	1	33	137	61	79.30952	60.74537	138.8524	0.08	0.35	0.20	0.65		
24	Hypertropia	Initial	88	35	10	50	144	42	79.42921	56.4358	134.2386	0.18	0.12	0.05	0.9		
		6th Month	90	40	4	55	146	45	87.29834	56.22277	142.3517	0.17	0.08	0.07	0.78		
		12th Month	75	40	9	67	150	36	71.30919	75.10659	144.3676	0.38	0.05	0.21	0.62		
25	Esotropia	Initial	100	40	1	38	141	48	99.0202	41.7732	140.3567	0.02	0.19	0.07	1.71		
		6th Month	108	38	1	43	148	46	107.1168	40.79216	147.0306	0.04	0.19	0.02	1.46		
		12th Month	83	35	5	49	147	48	79.24645	65.30697	142.0035	0.17	0.20	0.007	0.76		
26	Hypertropia	Initial	93	28	1	41	137	44	92.91394	46.8188	136.0331	0.14	0.34	0.02	1.45		
		6th Month	93	30	1	43	134	45	92.91394	43.65776	133.015	0.14	0.35	0.01	1.4		
		12th Month	78	38	1	32	139	58	77.23341	64.19502	140.4279	0.07	0.18	0.31	0.53		
27	Esotropia	Initial	80	38	4	49	140	48	76.79193	60.82763	136.0037	0.14	0.16	0.00	0.89		
		6th Month	70	35	3	47	139	51	68.06614	70.83078	136.0588	0.17	0.22	0.02	0.7		
		12th Month	70	33	3	46	144	55	68.24954	77.20104	141.2869	0.19	0.28	0.06	0.66		
28	Esotropia	Initial	90	33	7	38	145	54	83.15047	58.87274	138.9244	0.06	0.36	0.11	0.96		
		6th Month	85	38	1	33	139	58	84.14868	57.58472	140.2462	0.05	0.35	0.17	0.84		
		12th Month	78	40	5	36	140	65	73.10951	66.85058	138.0797	0.05	0.38	0.21	0.59		

**Table 4** (continued)

CP kids	Category	Periodical month	Iris center point		Eye corner point temporal region		Eye corner point nasal region		Angular estimation			Distance between eye corner temporal and Iris center		Distance between eye corner temporal and eye corner nasal side		D4-Distance between Iris center and midpoint of eye corner points	
			X0	Y0	X1	Y1	X2	Y2	Θ1	Θ2	Θ3	D1	D2	D3	D4		
29	Esotropia	Initial	83	33	5	55	138	36	81.0432	55.08176	134.3503	0.27	0.05	0.14	0.92		
		6th Month	85	38	5	61	141	38	83.24062	56	137.9311	0.27	0	0.16	0.85		
30	Esotropia	Initial	83	35	1	58	140	39	85.16455	57.14018	140.2926	0.27	0.07	0.13	0.83		
		6th Month	90	33	1	47	145	46	90.09439	56.51548	144.0035	0.15	0.23	0.00	1.18		
31	Hypertropia	Initial	90	33	1	48	142	47	90.25519	53.85165	141.0035	0.16	0.26	0.00	1.09		
		6th Month	78	40	1	55	146	56	78.44743	69.857	145.0034	0.19	0.23	0.00	0.81		
32	Hypertropia	Initial	75	35	1	33	150	54	74.02702	77.36924	150.4726	0.02	0.24	0.14	0.47		
		6th Month	78	30	1	29	150	49	77.00649	74.46476	150.3363	0.01	0.25	0.13	0.43		
33	Hypertropia	Initial	78	33	4	32	150	47	74.00676	73.34848	146.7685	0.01	0.19	0.10	0.33		
		6th Month	78	35	2	51	148	50	77.66595	71.58911	146.0034	0.20	0.21	0.00	0.79		
34	Hypertropia	Initial	75	35	2	49	148	49	74.33034	74.33034	146	0.18	0.18	0	0.7		
		6th Month	75	35	1	32	148	52	74.06079	74.95332	148.3543	0.04	0.24	0.13	0.35		
35	Hypertropia	Initial	80	35	2	40	148	52	78.16009	70.0928	146.4923	0.06	0.29	0.08	0.6		
		6th Month	80	35	6	39	148	53	74.10803	70.34202	142.6885	0.05	0.25	0.09	0.57		
36	Hypertropia	Initial	78	38	5	39	150	58	73.00685	74.72617	146.2395	0.01	0.27	0.13	0.53		
		6th Month	75	30	1	38	143	57	74.43118	73.1642	143.2655	0.10	0.37	0.13	0.89		
37	Hypertropia	Initial	75	33	4	47	142	52	72.36712	69.64194	138.0906	0.19	0.27	0.03	0.88		
		6th Month	80	30	4	44	147	50	77.27872	69.92138	143.1258	0.18	0.29	0.04	0.83		
38	Hypertropia	Initial	70	35	1	63	150	43	74.46476	80.399	150.3363	0.38	0.09	0.13	0.96		
		6th Month	70	33	3	59	147	44	71.86793	77.78175	144.7791	0.37	0.14	0.10	0.94		
39	Hypertropia	Initial	80	35	10	58	148	43	73.68175	68.46897	138.8128	0.31	0.11	0.10	0.78		
		6th Month	75	28	4	58	147	51	77.07788	75.58439	143.1712	0.39	0.30	0.04	1.33		
40	Hypertropia	Initial	75	30	3	59	145	53	77.62087	73.68175	142.1267	0.38	0.31	0.04	1.3		
		6th Month	73	30	5	49	145	51	70.60453	75	140.0143	0.27	0.28	0.01	1		
41	Hypertropia	Initial	70	30	9	62	146	29	68.88396	76.00658	140.9184	0.48	0.01	0.23	0.86		
		6th Month	68	38	3	70	142	30	72.44998	74.43118	144.6409	0.45	0.10	0.28	0.78		
42	Hypertropia	Initial	68	35	6	68	142	31	70.23532	74.10803	140.9433	0.48	0.05	0.26	0.64		
		6th Month	75	33	4	55	147	39	74.33034	72.24957	143.8923	0.30	0.08	0.11	0.7		
43	Hypertropia	Initial	75	38	3	61	147	40	75.58439	72.02777	145.5232	0.30	0.02	0.14	0.63		
		6th Month	73	35	2	58	150	33	74.63243	77.02597	150.0966	0.31	0.02	0.16	0.55		
44	Hypertropia	Initial	75	35	9	59	136	42	70.2282	61.40033	128.1327	0.34	0.11	0.13	0.79		
		6th Month	75	30	8	53	134	37	70.83784	59.4138	127.0118	0.33	0.11	0.12	0.78		
45	Hypertropia	Initial	73	43	2	64	140	50	74.04053	67.36468	138.7083	0.28	0.10	0.10	0.71		
		6th Month	75	35	1	55	150	34	76.65507	75.00667	150.4726	0.26	0.01	0.14	0.63		
46	Hypertropia	Initial	73	35	1	54	150	40	74.46476	77.16217	149.6563	0.25	0.06	0.09	0.61		
		6th Month	73	38	1	63	149	38	76.2168	76	150.0966	0.33	0	0.16	0.48		

**Table 5** Accuracies of three different classifiers

Classification accuracy			
SVM	RF	NN	No of features extracted
86.67%	73.33%	94.17%	39 Features

**Table 6** Specificity, sensitivity, precision and F1 score of classifier performance against extracted features

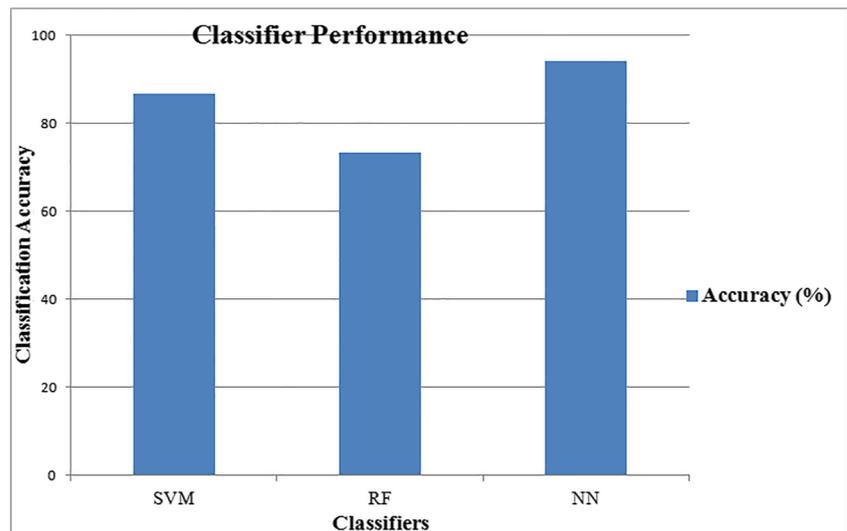
Performance metrics Classifiers	Specificity	Sensitivity	Precision	F1 Score
SVM	0.9564	0.8233	0.8659	0.8389
RF	0.9101	0.7392	0.7318	0.7322
NN	0.9800	0.9165	0.9480	0.9303

## Image acquisition

The algorithm has been implemented in real-time using Canon EOS 5d Camera resolution of  $640 \times 480$  pixels. After image acquisition, eye portion is cropped. Image Acquisition Process described in Table 3. Input Image process illustrated in Fig. 4.

## Pre-processing step

The Pre-processing step achieved by converting the input image into gray scale and resize the input image by pixel brightness transformation techniques by this intensity level is raised [21–23]. Pre-Processing Image Enhancement Techniques Process results shown in Fig. 5.

**Fig. 11** Classifier performance**Table 7** Sample size and accuracy for existing methods compared with proposed methods

Applications	Reference author name	No of Samples	Classification Accuracy
Diabetic Detection and prediction	Lin ma et al. [9]	292	90%
Gender Prediction using Iris Image	V.Thomas etal, A. Bansal etal, S. Azilah et al. [10–12].	80	85.68%
Tumor Detection in Iris	Helwan et al. [13].	100	70%
Diabetic Mellitus diagnosis	Piyush Samant et al. [14].	338	89.63%
Diagnosis of kidney diseases	Hussein et al. [15]	340	93%
Alimentary Canal diseases and nerve disorder diseases	L. Ma et al.	429	85.4%
Healthcare information	D. Hareva et al. [16]	32	90.95%
CP Kids Improvement Analysed	Proposed Method	120	94.17%

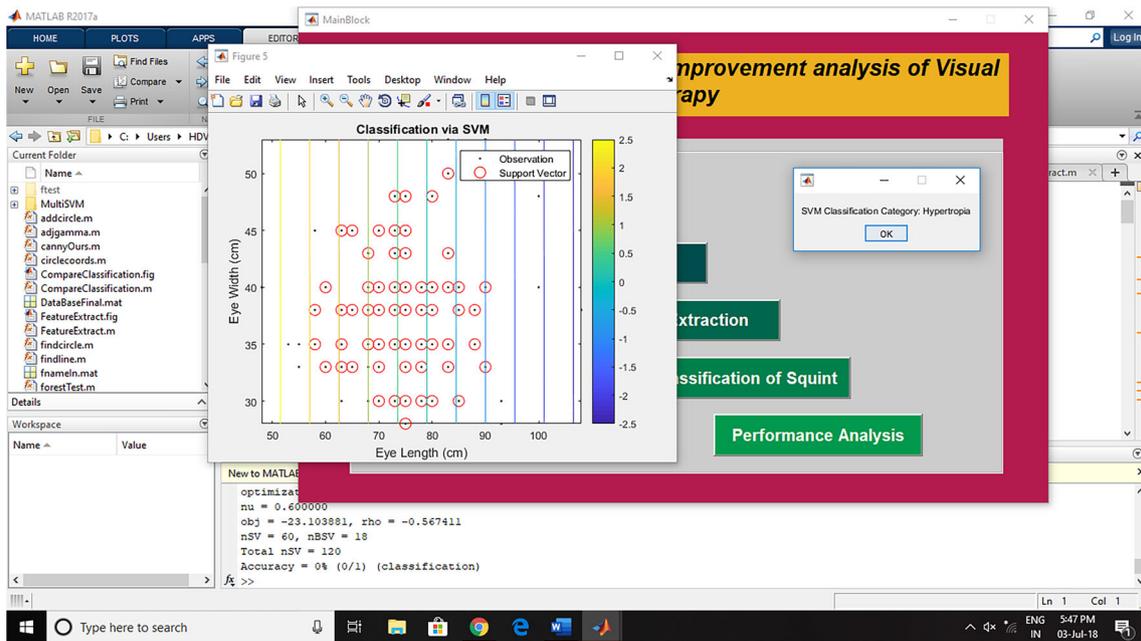


Fig. 12 SVM classification results

**Canny edge detection algorithm**

The Canny Edge Detection is used to detect the Iris boundaries from the observed Eye image. These algorithm runs in

five basic steps. They are as follows, the First Step is Smoothing, Second Step is Finding Gradients, the Third step is Non-Maximum Suppression the Fourth step is Double Thresholding and Final and Fifth step is Edge tracking by hysteresis.

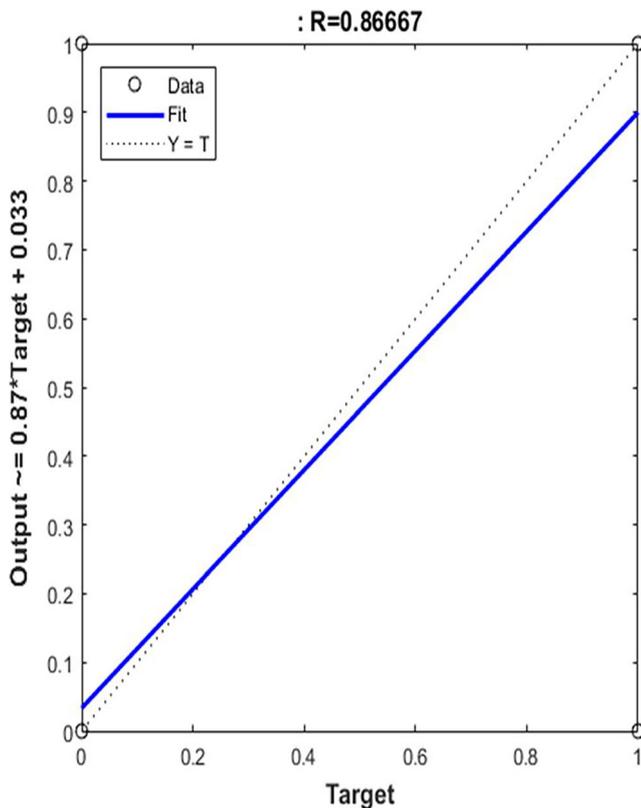


Fig. 13 SVM regression state

**Smoothing** Smoothed the Image by applying the Gaussian filter. The main aim of the smoothing is to remove the unwanted noise information area from the blur image [24].

**Finding gradients** This step is used to approximate the gradient of both axis directions separately by utilizing the kernels. The gradient magnitude is determined by Mathematical Euclidean calculation and it is measured by applying the Pythagoras law, appeared in Eq. 1. The Edge Strength is improved by using the Mathematical Manhattan distance measure as appeared in Eq. 2. The Euclidean distance is used to measure and test the image for strengthen the edges.

$$G = \sqrt{G_x^2 + G_y^2} \tag{1}$$

$$G = G_x + G_y \tag{2}$$

Where:  $G_x$  and  $G_y$  represent the magnitude gradient in the both axis (X axis and Y axis) directions respectively. In the event that the most of the edges are commonly broad and do not show the accurately where the edges are. To make it possible is determine the direction of edge determined by Eq. 3.

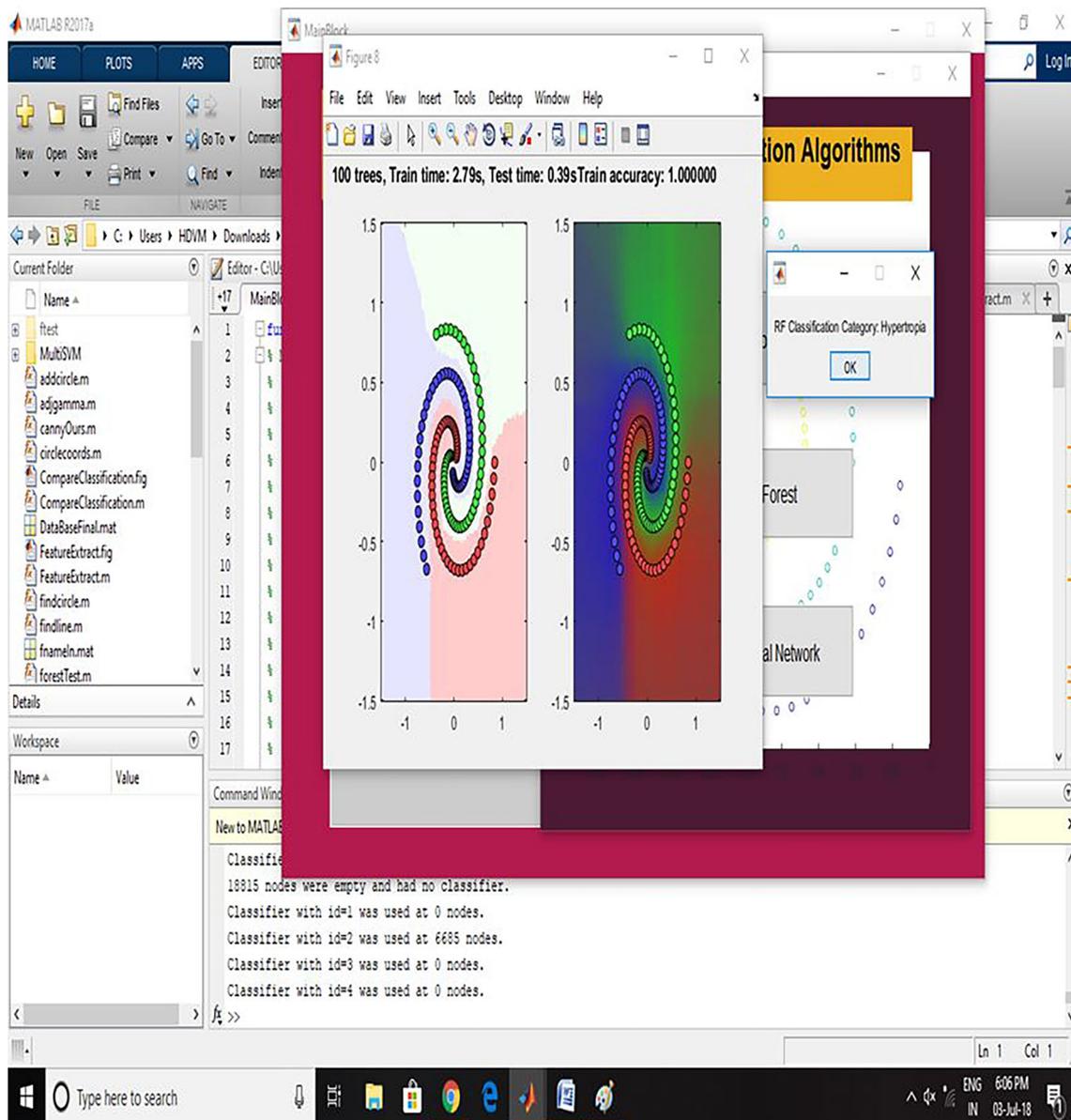


Fig. 14 RF classification results

$$\text{Where } C = \arctangent\left(\frac{G_x}{G_y}\right) \quad (3)$$

**Non maximum suppressions** This Step is used to convert the blurred edge in the image to the sharp edge by magnitude gradient. This is accomplished by saving all neighbourhood pixel maxima in the gradient image, and eliminates the rest of the part.

**Double thresholding** This Step is achieved after the non maximum suppression by edge pixels staying apart with their quality pixel by pixel.

**Edge tracking by hysteresis** The strong edges are deciphered as certain edge and can promptly be incorporated into the

last edge eye image. The strong edge will only be due to true edge in the original image. Due to true edges the weak edges formed are considerably more prone to be associated straightforwardly to strong edges. Canny operator is used in finding Iris region which gives accurate values of boundaries. The results of canny edge detection algorithm are shown in Fig. 6.

### Circular hough transform

The Final Iris location is detected by using Circular Hough transforms [25, 26]. The Standard of the Circular Hough Transform is a specific kind of calculation used to look for a parameter space of round about the shapes in the image [27]. Then convert into recognizing the circle

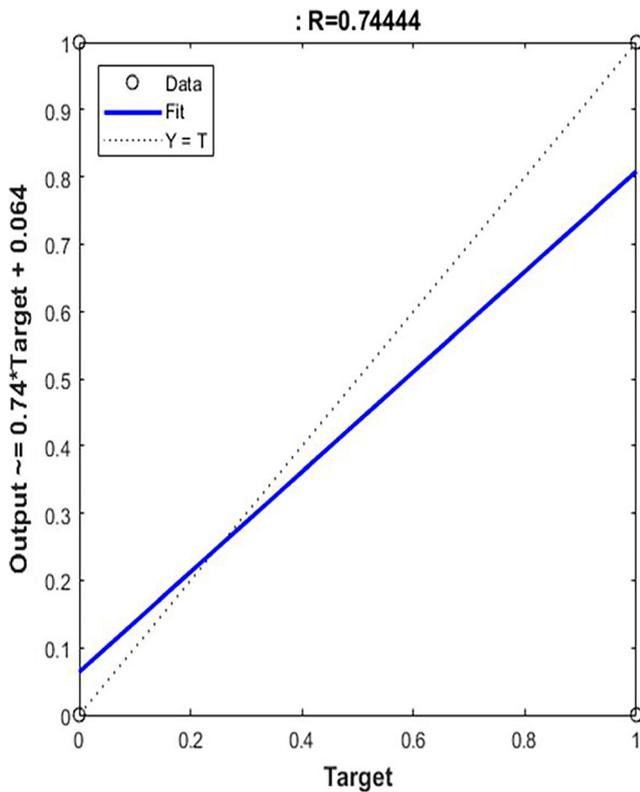


Fig. 15 RF regression state

parameters given by the center coordinates ‘a’ and ‘b’ and the circle radius ‘r’ displayed in the circle condition in Eq. 4.

$$r^2 = (x-a)^2 + (y-b)^2 \tag{4}$$

The fundamental preferred standpoint of the Hough Transform Techniques is its resistance to the holes in include limit depictions and it is relatively unaffected by image noise [22, 23].

In experiments, our created datasets obtained from CP patients. For performing the canny edge detection and CHT. To find out the radius of a circle range is set as the 20–100 and the peak is set to 1. Finally the Iris boundaries are localized by this method. The Iris detection by using canny edge detection and CHT is shown in a Fig. 7. It is marked in Blue Circle.

The proposed algorithm was implemented on these created datasets, using Intel core i7 3.40 GHz processor with 4GB DDR3 RAM.

### Eye corner detection

The eye corner is modeled by a simple feature vector that generates by the upper and lower eyelids [27–29].

We consider

$$\{Ci\}_{i=1}^n Ci^{j=1} = (xi, yi)$$

the set of eye-corners candidates.

Harris Pixel Weight H(Pc): Considering that all candidates were generated according to the Harris and Stephens method. This score is given in Eq. 5:

$$H = [M] - K tr(M)^2 \tag{5}$$

[M] denotes the matrix determinant, tr(M) denotes traces of a matrix and M is the Hessian matrix from a blurred version of the original data:

Finally, the eye corners are localized by Harris and Stephens corner detection method.

To Evaluate this hypothesis by using the Eqs. 6 and 7 by Harris and Stephens Corner Detection,

$$D_{cor} = [H] - k.trace(H)^2 \tag{6}$$

Where | | and trace denotes the matrix determinant and trace respectively, K is the algorithm parameter, H is the Harris matrix, (Gx and Gy are the image derivatives in the x and y direction).

$$H = \sum(x,y) W(x,y) \begin{bmatrix} G_x G_x & G_x G_y \\ G_x G_y & G_y G_y \end{bmatrix} \tag{7}$$

Corners in the image with respect to the local maxima in this response map.

The Proposed Method has shown the overall performance in terms of robustness and accuracy and simple in implementation. Figure 8 represent the results of Harris and Stephens corner detection method.

### Angle deviation position estimation

Triangle is formed by connecting three points (Eye Corner points and Pupil Center points) using Line function.

The Eye Corner points are connected to create a reference axis and then the Iris center is connected with corner points to estimate the various angles.

To further enhance this measure the angle deviation position for the abnormal eyes, analyze the performance improvement achievement by Visual Therapy Method used for CP rehabilitation. Finally Angular movement estimated through Medial Point of Iris and Eye Corner Localization. The Results shown in Fig. 9 and diagrammatic represented in Fig. 10.

### Feature extraction

Depending on the CP patient eye condition of individual, eye image were observed for the periodical month of initial, 6th and 12th month were recorded. Total (13\*3) 39 features were extracted to quantify the improvement and effectiveness of visual therapy techniques. These features were based on Eye

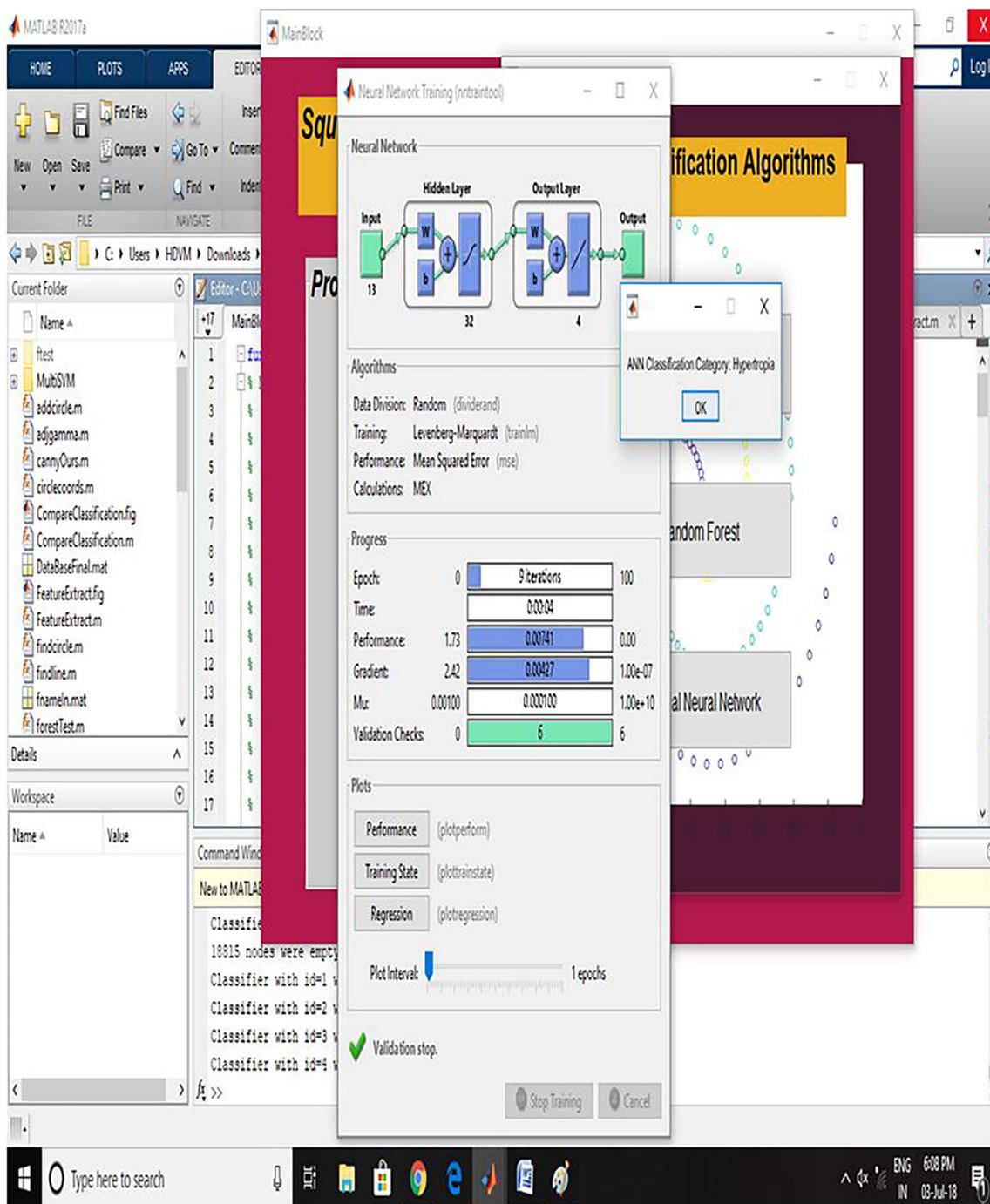


Fig. 16 NN classification results

corner and Iris Center. The Table 4 represent the Feature extraction of Eye Image of CP patients and Data sets are created.

The following features from eye images are extracted and dataset's are created.

- D1-Distance between eye corner temporal and Iris center
- D2-Distance between eye corner nasal and Iris center
- D3-Distance between eye corner temporal and eye corner nasal side

- X0, Y0- Iris center point Coordinates,
- X1, Y1- Eye corner point temporal region,
- X2, Y2- Eye corner point nasal region,
- D4-Distance between Iris center and midpoint of eye corner points (i.e., Central axis of eye position).
- $\theta_1$ - Angle Inclined between D1 and D3,
- $\theta_2$ - Angle Inclined between D1 and D2,
- $\theta_3$ - Angle Inclined between D2 and D3.

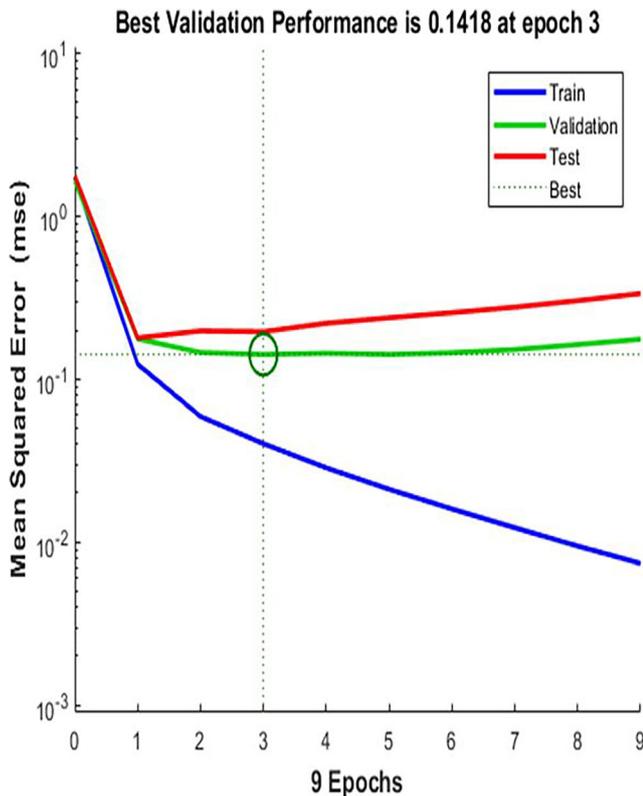


Fig. 17 NN performance analysis

In general,

The Improvement analyzed based upon the values of D1, D2, D3 and D4 and  $\theta_1$ ,  $\theta_2$  and  $\theta_3$  respectively.

Since we have the four categories of abnormalities, in each category the features are analyzed. This is because to classify and detect the category of abnormalities eye Image is useful to provide the proper treatment of CP Kids by Physicians.

In **Category 1-Exotropia-Condition**, D1 values will increase when compare to the initial data, vice versa, the D2 value will decrease when compare to the initial data, the value of D3 remains varies in every periodical month.

The value of D4 will decrease when compare to the initial data value.

The D4 value plays the essential role this states that the Improvement in CP kids.

All the  $\theta$  values (i.e.,  $\theta_1$ ,  $\theta_2$  and  $\theta_3$ ) differs when compare to the initial data values.

In **Category 2-Esotropia-Condition**, D1 values will decreases when compare to the initial data, vice versa, the D2 value will increase when compare to the initial data, the value of D3 remains varies in every periodical month.

the value of D4 will decrease when compare to the initial data value.

The D4 value plays the essential role this states that the Improvement in CP kids.

All the  $\theta$  values (i.e.,  $\theta_1$ ,  $\theta_2$  and  $\theta_3$ ) differs when compare to the initial data values.

In **Category 3-Hypertropia Condition**, D1, D2 and D3 remains varies in every periodical month. The value of D4 will decrease when compare to the initial data value.

The D4 value plays the essential role this states that the Improvement in CP kids.

All the  $\theta$  values (i.e.,  $\theta_1$ ,  $\theta_2$  and  $\theta_3$ ) differs when compare to the initial data values.

In **Category 4-Hypotropia Condition**, D1, D2 and D3 remains varies in every periodical month. The value of D4 will decrease when compare to the initial data value.

The D4 value plays the essential role this states that the Improvement in CP kids.

All the  $\theta$  values (i.e.,  $\theta_1$ ,  $\theta_2$  and  $\theta_3$ ) differs when compare to the initial data values.

### Classification - machine learning algorithm for classification accuracy

The Three Classification algorithms named as, Support Vector Machine (SVM), Random Forest (RF) and Neural Network (NN) have been used to determine more accurate approach for the classification of eye image datasets. We have collected the image dataset that consists of Initial, 6th month, 12th month eye images. Using the chosen classification algorithm, the system has been trained and then testing phase starts.

Training data is 40 samples is features of  $40 \times 3 \times 13$ , label  $40 \times 3$  is spited to Train, Test and Validate in Learning Process as 70,15,15% respectively. These all  $40 \times 3 \times 13$  features are given to classification algorithm and we got  $40 \times 3$  labels as output. From these the Overall Performance is obtained. Three classifier algorithms are trained using the observed eye features and then applied these features on the testing phase data to predict the correct classes. Hereafter the performance metric is evaluated with includes the parameters of Accuracy, Sensitivity and Specificity.

This method automatically quantifies the percentage of improvement obtained and effectiveness of visual therapy. The quantification process is based upon the features extracted from the eye images based on the D1, D2, D3, and D4 and  $\theta_1$ ,  $\theta_2$  and  $\theta_3$  values respectively.

Sensitivity or True Positive Rate (TPR) is defined as the ratio of correctly identified the CP kids abnormalities and Improvement in the eye. (1-Specificity) False Positive Rate (FPR) is another characteristic of classifier which is defined as the ratio of CP kids, incorrectly recognised the abnormalities of eye. Sensitivity and specificity both are most essential parameters for Performance metrics calculation of any classifier.

Where,

Confusion Matix,

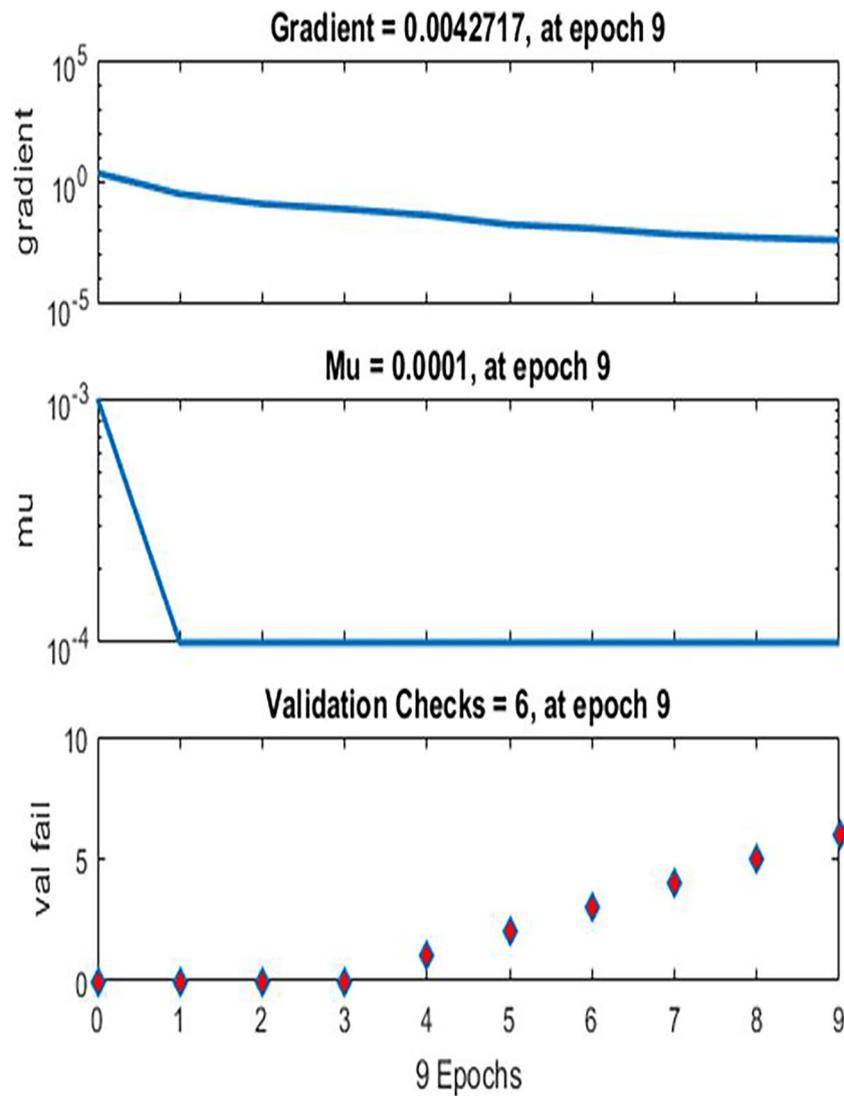


Fig. 18 NN training state analysis

	Predicted Class	
Actual Class	TP	FN
	FP	TN

Where Confusion Matrix is a techniques to analyze the performance matrix of classification algorithms (SVM, RF and NN) and also it gives the better idea.

$$\text{Sensitivity (or) Recall(or) True Positive Rate} = \frac{TP}{TP + FN}$$

$$\text{Precision} = \frac{TP}{TP + FP}$$

$$\text{Specificity (or) True Negative Rate} = \frac{TN}{TN + FP}$$

$$\text{False Positive Rate} = (1 - \text{Specificity}) = \frac{FP}{FP + TN}$$

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}$$

$$\text{F1 Score} = 2 * \frac{\text{Precision} * \text{Recall}}{\text{Precision} + \text{Recall}}$$

### Experimental results

The Classifier accuracies is attained for three different classifiers. Table 5 shows the Accuracies of three different classifiers. Best classification accuracies have been calculated by feature extraction method as 86.67%, 73.33%, 94.17%, by SVM, RF and NN classifiers respectively. Table 6 shows specificity, sensitivity, precision and F1 Score of classifier performance against extracted features. Maximum sensitivity and specificity have been found as 0.9165 and 0.9800 for feature selection method for using

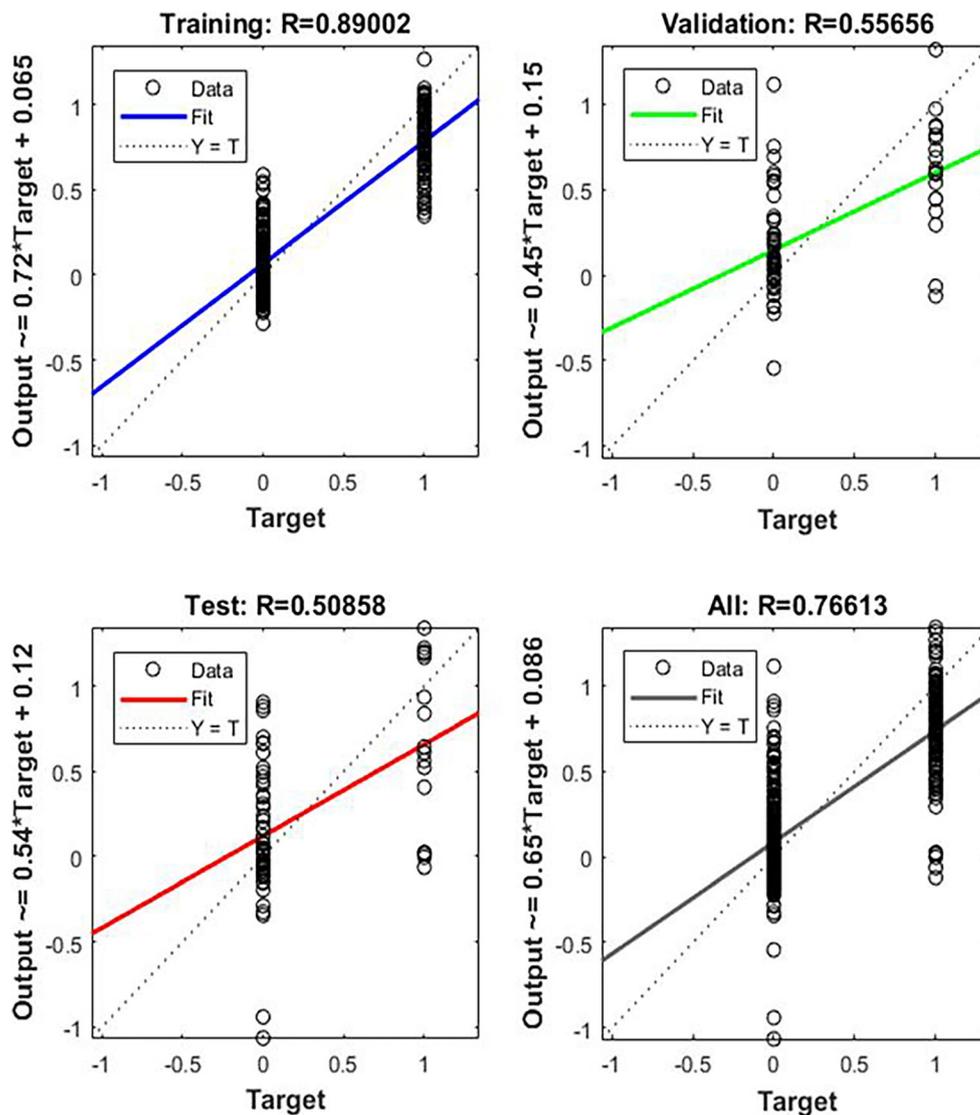


Fig. 19 NN Regression Analysis

NN classifier. Figure 11 shows the Classifier Accuracy Performance.

**Discussion**

In the current research new technique has been formulated to develop an computational approach for improvement analysis of CP patient for Rehabilitation. The results indicate that NN classifier attained the overall diagnosed the Improvement performance of CP kids using this computational methodology.

Table 7 sample size and accuracy for existing methods compared with proposed methods. Figure 12 represent the SVM Classification Results, Fig. 13 represent the SVM

Regression State. Figure 14 illustrate the RF Classification Results, Fig. 15 illustrate the RF Regression State and finally Fig. 16 represent the NN Classification Results, Fig. 17 represents the NN Performance Analysis, Fig. 18 represent the NN Training State Analysis, Fig. 19 represents the NN Regression Analysis and Fig. 20 represents the NN Regression State.

**Area under the curve (AUC) analysis**

AUC is to find out performance evaluation metrics of the three different classifier. Figures 21, 22 and 23 illustrate the ROC (Receiver Operating Characteristics) curve between FPR and TPR of three different classifier.

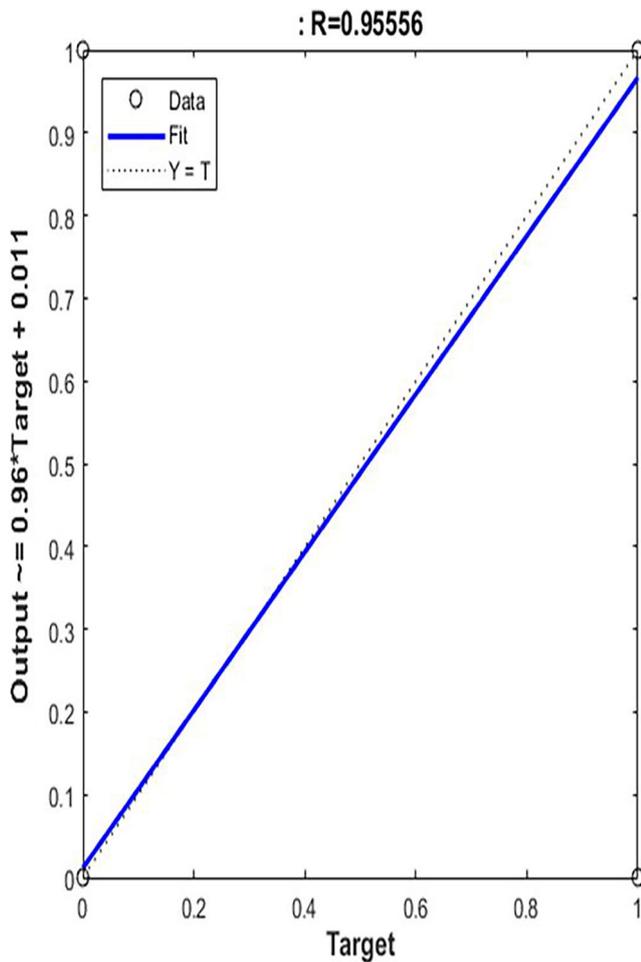


Fig. 20 NN regression state

**Improvement analysis**

By Applying Mathematical Time and Data Analysis formula given in Eq. 8,

$$\text{Improvement Achieved} = \frac{\text{new data} - \text{old data}}{\text{old data}} * 100 \quad (8)$$

In order to quantify the percentage of improvement, based on D4 values (distance between Iris Center and Eye Center) only. Because after visual therapy the Iris Position tend to reaches the central axis of the eye, from these improvement analysed through periodical assessment.

Where, D4 is Distance between Iris center and midpoint of eye corner points.

From these Improvement attainment can be found out for each CP kids.

Here baseline is Initial month D4 value, after visual treatment D4 values are noted, from these can able to quantify the percentage of Improvement [30] is given in Eq. 9.

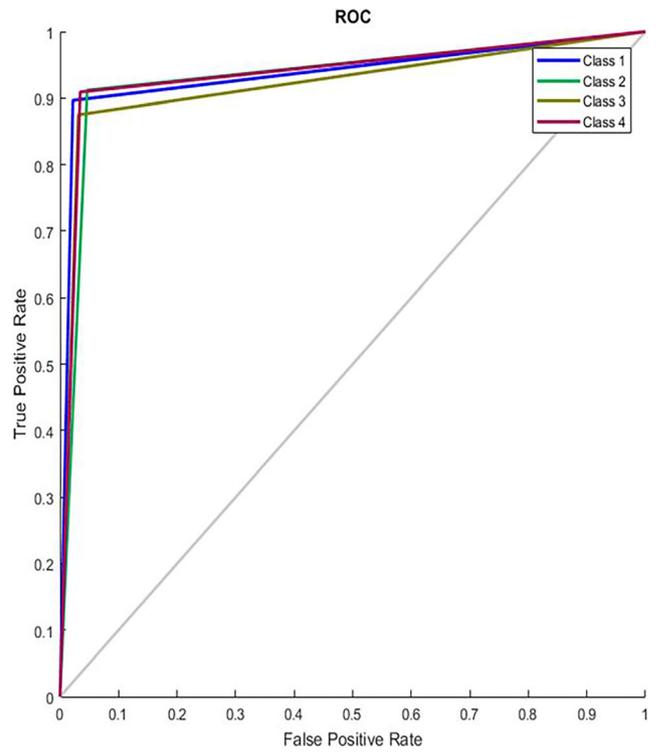


Fig. 21 ROC of SVM

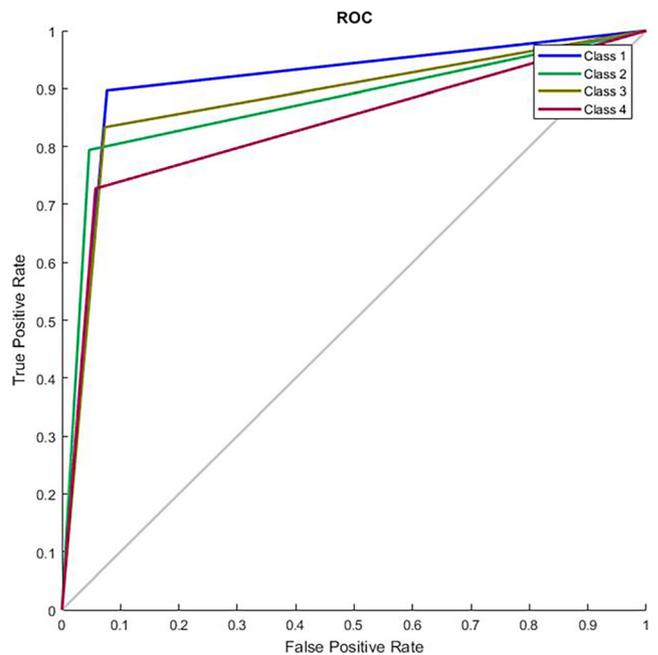


Fig. 22 ROC of RF

So, Improvement Achieved

$$= \frac{\text{Baseline Value} - \text{After Treatment Value}}{\text{Baseline Value}} * 100 \quad (9)$$

**Table 8** CP kids improvement achievement

CP Kids	Category	D4 values (mm)			Improvement achieved (%)
		Initial	6th Month	12th Month	
1	Hypertropia	0.99	0.87	0.84	15.15
2	Hypertropia	0.85	0.70	0.69	18.82
3	Hypertropia	0.78	0.54	0.53	32.05
4	Hypotropia	1.34	0.46	0.37	72.38
5	Hypertropia	0.65	0.37	0.36	44.61
6	Hypertropia	0.73	0.64	0.62	15.06
7	Hypotropia	0.75	0.60	0.38	49.33
8	Hypotropia	0.23	0.20	0.18	21.73
9	Hypotropia	0.49	0.36	0.32	34.69
10	Hypertropia	1.19	0.72	0.43	63.86
11	Esotropia	1.32	1.23	1.19	9.84
12	Exotropia	0.81	0.68	0.58	28.39
13	Exotropia	1.10	1.02	0.75	31.81
14	Esotropia	0.49	0.49	0.20	59.18
15	Esotropia	1.12	1.12	1.01	9.82
16	Esotropia	1.70	1.63	0.82	51.76
17	Exotropia	0.74	0.73	0.56	24.32
18	Exotropia	0.86	0.58	0.54	37.2
19	Esotropia	1.13	1.10	0.99	12.38
20	Esotropia	0.87	0.62	0.49	43.67
21	Esotropia	1.05	0.96	0.95	9.52
22	Esotropia	1.36	0.83	0.79	41.91
23	Hypertropia	0.94	0.85	0.65	30.85
24	Hypertropia	0.90	0.78	0.62	31.11
25	Esotropia	1.71	1.46	0.76	55.55
26	Hypertropia	1.45	1.40	0.53	63.44
27	Esotropia	0.89	0.70	0.66	25.84
28	Esotropia	0.96	0.84	0.59	38.54
29	Esotropia	0.92	0.85	0.83	9.78
30	Esotropia	1.18	1.09	0.81	31.35
31	Hypertropia	0.47	0.43	0.33	29.78
32	Hypertropia	0.79	0.70	0.35	55.69
33	Hypertropia	0.60	0.57	0.53	11.66
34	Hypertropia	0.89	0.88	0.83	6.74
35	Hypertropia	0.96	0.94	0.78	18.75
36	Hypertropia	1.33	1.30	1.00	24.81
37	Hypertropia	0.86	0.78	0.64	25.58
38	Hypertropia	0.70	0.63	0.55	21.42
39	Hypertropia	0.79	0.78	0.71	10.12
40	Hypertropia	0.63	0.61	0.48	23.8

Table 8 comprises the CP kids Improvement Achievement.

Finally, therapy center effectiveness can be measured it shown in Table 9.

Where, Therapy Center Effectiveness

$$= \frac{\text{No of Improved person}}{\text{Total no of person}} * 100$$

**Table 9** Therapy center effectiveness

Improvement achieved (grade)	No of kids	Therapy center effectiveness
Less than 15% achieved by	10kids	25% of kids show as low improvement in rehabilitation center.
In range 16–30% achieved by	12 kids	30% of kids show as average improvement in rehabilitation center.
In range 30–50% achieved by	11 kids	27.5% of kids show as good improvement in rehabilitation center.
Above 50% achieved by	7 kids	17.5% of kids show as best improvement in rehabilitation center.

Figure 24, Represents the CP Kids Improvement analysed through Therapy Center Effectiveness.

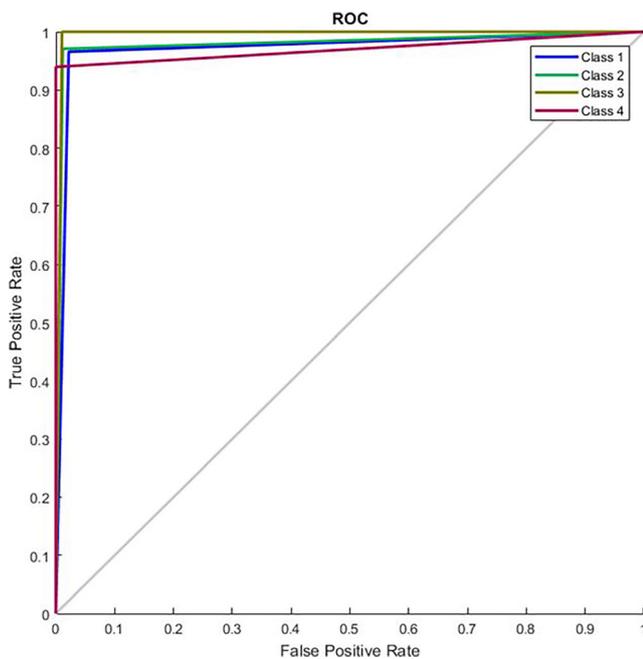
### Conclusion

The proposed novel approach which is precise, relatively simple for measuring various conditions of visual issues in CP kids and also evaluating the effectiveness of performance improvement achievement of CP kids by utilizing the visual therapy method and this solves the solution of long-outstanding problems in the visual and ocular research. This can be considered as alternate techniques where various Image Processing Techniques are used for visual therapy techniques can be opt for such CP Kids. The Nystagmus and Strabismus condition are common vision issues for CP kid this might improves by visual therapy techniques and evaluate the effectiveness of improvement by examined through periodically. So these

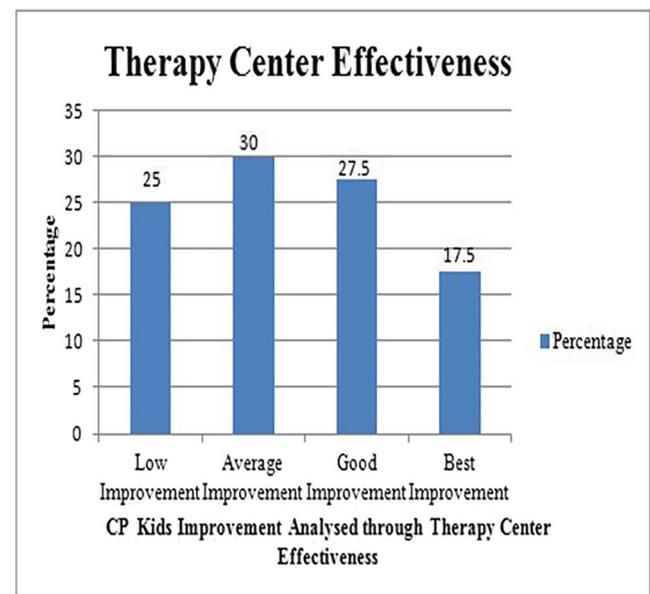
techniques serve as the quantitative biomarker for CP kids. The proposed novel algorithm for Improvement Achievement for vision affected CP children. Investigated the algorithm by using MATLAB and obtained the results using different image processing techniques. The Proposed image processing techniques have proven good performance in terms of robustness and accuracy and very easy to implementation. This Approach shows the considerable potential of this method to become an easy to use, modern tool with widespread application in basic and clinical research or in diagnostic testing.

The improvement assessment of CP kids by analyzing the Eye features periodically. Finally, the Improvement of CP kids analyzed by comparing the results of Initial, 6th month and 12th month, from this improvement of brain neuron activity were assessed and report was generated.

As the Results, the Doctors can use this report to train the CP kids in the Rehabilitation Process in diagnostic testing. The Effectiveness of Visual therapy method determination



**Fig. 23** ROC of NN



**Fig. 24** Therapy center effectiveness

by periodically assessing the eye features of CP kids and calculating the number of kids improved through therapy over a period. This approach assesses the improvement in CP kids by using the Eye Image which overcomes the burden of VEP (Visually Evoked Potential) test.

This research can be used in any rehabilitation centers to assess the improvement in CP kids by recording and analyzing the eye features over a period of time. The number of CP kids improved over a period of time can be assessed using this application to determine the effectiveness of therapy given in the rehabilitation center. This Experimental results show that investigation of eye features can be used to assess improvement of CP kids and hence this approach can be used to avoid VEP test to assess improvement.

**Funding** This Project was funded by DST-SERB (Department of Science and Technology-Science and Engineering Research Board) through the Fund Grant Number (EMR/2017/000073).

### Compliance with ethical standards

**Conflict of interest** None.

**Research involving human participants** The authors would like to thank the participants from Dr. Durgabai Deshmukh General Hospital and Research center, Iswari Prasad Dattatreya Special School (Andhra Mahila Sabha) Adyar, Chennai, for helping us with the data collection process and also author thank Dr. Vijayalakshmy J, Dept. of Medical Science and Rehabilitation from NIEPMD (National Institute for Empowerment of person with multiple disabilities), Govt. of India, Muttukadu, at Chennai, for Investigated the several case studies and Visual Problems in CP kid.

**Informed consent & ethical approval** This study has been approved by the Ethics Committee of the NIEPMD. All participants provided informed consent for participation in the study.

### References

- Elmshawy, A. A., Ismael, A., Elbehairy, H., Kalifa, N. M., Fathy, M. A., and Ahmed, A. M., Visual impairments in children with cerebral palsy. *Int. J. Acad. Res.* 2(5):67–71, 2010.
- Vijayakumar, K., and Arun, C., Automated risk identification using NLP in cloud based development environments. *J. Ambient. Intell. Humaniz. Comput.*, 2017. <https://doi.org/10.1007/s12652-017-0503-7>.
- Chen, Y.-L., Chen, C.-L., Chang, W. F. I., Wong, M.-K., Tung, F.-T., and Kuo, T.-S., The development of a biofeedback training system for cognitive rehabilitation in cerebral palsy. In: *IEEE/EMBS Oct. 30 - Nov. 2, Chicago, IL, USA*, 1997.
- Vijayakumar, K., and Arun, C., Continuous security assessment of cloud based applications using distributed hashing algorithm in SDLC. *Clust. Comput.*, 2017. <https://doi.org/10.1007/s10586-017-1176-x>.
- Al-Sadik, F. N. A., Visual evoked potential in children with spastic cerebral palsy. *Med. j. Babylon.* 9(2):379–384, 2012.
- Illavarason, P., Arokia Renjit, J., and Mohan Kumar, P., Clinical evaluation of functional vision assessment by utilizing the visual evoked potential device for cerebral palsy rehabilitation. *Procedia Comput. Sci.* 132:128–140, 2018. <https://doi.org/10.1016/j.procs.2018.05.174>.
- Illavarason, P., Arokia Renjith, J., and Mohan Kumar, P., Performance evaluation of visual therapy method used for cerebral palsy rehabilitation. *J. Med. Imag. Health. In.* 8(9):1804–1818(15), 2018.
- Vijayakumar, K., and Arun, C., Analysis and selection of risk assessment frameworks for cloud based enterprise applications. In: *Special Issue on Biomed Research India - Artificial Intelligent Techniques for Bio-Medical Signal Processing*, 2017, 1–8.
- Heydari, M., Teimouri, M., Heshmati, Z., and Alavinia, M., Comparison of various classification algorithms in the diagnosis of type 2 diabetes in Iran. *Int. J. Diabetes. Dev. C.* 36:167–173, 2015. <https://doi.org/10.1007/s13410-015-0374-4>.
- Thomas, V., Chawla, N. V., Bowyer, K. W., and Flynn, P. J., Learning to predict gender from iris images. In: *Proceedings of First IEEE International Conference on Biometrics: Theory, Applications and Systems*, 2007, 1–5.
- Bansal, A., Agarwal, R., and Sharma, R. K., Predicting gender using Iris images. *Res. J. Recent Sci.* 3(4):20–26, 2014.
- Azilah, S., and Paper, F., Identification of vagina and pelvis from iris region using artificial neural network. *Teknologi* 76(7):91–95, 2015.
- Helwan, A., ITDS: Iris tumor detection system using image processing techniques. *Int. J. Sci. Eng. Res.* 5:76–80, 2014.
- Samant, P., and Agarwal, R., Diagnosis of diabetes using computer methods: Soft computing methods for diabetes detection using Iris. *International Journal of Medical, Health, Biomedical, Bioengineering and Pharmaceutical Engineering* 11(2):63–68, 2017.
- Husseina, S. E., Hassanb, O. A., and Granat, M. H., Assessment of the potential iridology for diagnosing kidney disease using wavelet analysis and neural networks. *Biomed. Signal. Process. Control.* 8(6):534–541, 2013.
- Hareva, D., Lukas, S., and Suharta, N., The smart device for healthcare service: Iris diagnosis application. In: *Eleventh International Conference on ICT and Knowledge Engineering*, 2013, 1–6.
- Ego, C., De Xivry, J. J. O., Nassogne, M.-C., Yuksel, D., and Lefevre, P., Spontaneous improvement in oculomotor function of children with cerebral palsy. *Res. Dev. Disabil.* 30:630–644, 2015. Elsevier.
- Illavarason, P., and Arokia Renjit, J., Cerebral palsy rehabilitation - effectiveness of visual stimulation method by analyzing the quantitative assessment of oculomotor abnormalities. *Int. J. Biomed. Eng. Technol.*, 2018 (in press).
- Lee, K.-R., Chang, W.-D., Kim, S., and Im, C.-H., Real-time 'eye-writing' recognition using electrooculogram (EOG). *IEEE Trans. Neural. Syst. Rehabil. Eng.* 25:1–1, 2016. <https://doi.org/10.1109/TNSRE.2016.2542524>.
- Kumar, D., Dutta, A., Das, A., and Lahiri, U., SmartEye: Developing a novel eye tracking system for quantitative assessment of oculomotor abnormalities. *IEEE Trans. Neural. Syst. Rehabil. Eng.* 24(10):1051–1059, 2016. <https://doi.org/10.1109/TNSRE.2016.2518222>.
- Bozomitu, R. G., Pasarica, A., Cehan, V., Rotariu, C., and Coca, E., Eye pupil detection using the least squares technique. In: *IEEE International Spring Seminar on Electronics Technology (ISSE)*, 2016. 978-1-5090-1389-0/16/\$31.00.2016.
- Shasmi, M., Saad, P. B., Ibrahim, S. B., and Kenari, A. R., Fast algorithm for Iris localization using Daugman circular Integro differential operator. *International Conference of Soft Computing and Pattern Recognition*, 2009. 978-0-7695-3879-2/09.
- Zhu, D., Moore, S. T., and Raphan, T., Robust pupil center detection using a curvature algorithm. *Comput. Methods Prog. Biomed.* 59(3):145–157, 1999.

24. Ionescu, C., Fosalau, C., Petrisor, D., and Zet, C., A pupil Centre detection algorithm based on eye color pixels differences. In: *The 5th IEEE International Conference on E-Health and Bioengineering-EHB 2015*, 2015. 978-1-4673-7545-0/15.
25. Li, J., Li, S., Chen, T., and Liu, Y., A geometry-appearance based pupil detection method for near-infrared head-mounted cameras. *IEEE Access*. 6:23242–23252, 2018. <https://doi.org/10.1109/ACCESS.2018>.
26. Sardar, M., Mitra, S., and Uma Shankar, B., Iris localization using rough entropy and CSA: A soft computing approach. *Appl. Soft Comput.* 67:61–69, 2018.
27. Alkassar, S., Woo, W. L., Dlay, S. S., and Chambers, J., Robust sclera recognition system with novel sclera segmentation and validation techniques. *IEEE Trans. Syst. Man Cybern. Syst.* 47:2168–2216, 2016. <https://doi.org/10.1109/TSMC.2015.2505649>.
28. Liu, P., Guo, J.-M., Tseng, S.-H., Wong, K. S., Lee, J.-D., Yao, C.-C., and Zhu, D., Ocular recognition for blinking eyes. *IEEE Trans Image Process* 26(10):5070–5081, 2017. <https://doi.org/10.1109/TIP.2017.2713041>.
29. Levinshtein, A., Phung, E., and Aarabi, P., Hybrid eye center localization using cascaded regression and hand-crafted model fitting. *Image Vis. Comput.* 71:17–24, 2018.
30. Vickers, A. J., The use of percentage change from baseline as an outcome in a controlled trial is statistically inefficient: A simulation study. *BMC Med. Res. Methodol.*, 2001. <https://doi.org/10.1186/1471-2288-1-6>.

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.