Autism Detection using Computer Vision

Najeed Ahmed Khan†, M. Ajmal Sawand††, Maryam Qadeer†††, Anum Owais†††, Sarah Junaid†††, Phunparah Shahnawaz†††

†Computer Science & SE department NED University of Engg. & Technology, Karachi, Pakistan.
††Sukkur Institute of Business Administration, Sukkur, Pakistan.
†††Depart. of Bio-Medical Engineering, NED University of Engg. & Technology, Karachi, Pakistan.

Abstract
Autism is a mental developmental disorder that manifests itself in young children in the form of difficulty behaving socially, in using language, communication and understanding of abstract, emotional concepts.
Computer vision is an emerging filed contributing from high level security surveillance to people health micro level disease identification. This paper proposes a framework based on computer vision technique to identify early stage autism in the autistic children. The rapid reactions of autistic and non- autistic (normal) children are analysed from the recorded videos of the children while participating activities assigned to them. Body response time, eye movement response time and humero-radial angles are computed to figure out their body symmetries. Results demonstrated that the proposed framework is an efficient and user friendly tool to diagnosis autism in autistic children.
Key-words:
Autism; Spatio-temporal sensitivity; Body symmetry; Humero-radial angles; Autistic; Echolalia.

1. Introduction

Autism is also referred to as ASD (Autism Spectrum Disorders). The autism spectrum condition refers conditions of autistic people cause them certain difficulties. Autism is a complex developmental disability, resulting of neurological disorder. According to the experts [1], autism commonly begins before the age of 3 and lasts throughout a person's life. Conventional methods for ASD diagnosis generally start when clinical results of such people are comprehensively evaluated and compared with the criteria in the Statistical Manual of Mental Disorders to confirm if a person has ASD. However, computer vision based methods may provide immediate and accurate results to identify ASD in patients if present.

There is no single known cause of autism, although the studies guide to some abnormalities in essential genetic components. One of the major issues of autistic people is lack of ability with non-verbal communication. They often miss to catch signals in proper time during communication with normal people. They interact differently compared to the normal people and have been observed to take least interest in initiating conversation with people around them.

People with ASD have impaired social understanding and reduced reactions to others' emotions, which may be interpreted as lack of empathetic concern. They often shows difficulties in disengagement and change of attention [12]

Early detection of autism in people can provide proper medication and guide them proper exercises.

According to the report published in 2016 [2], every one child from 68 children can have some form of autism symptoms. Here we discuss few significant abnormalities in the autistic children compare to the normal ones.

Physical Contact

A number of autistic children do not like cuddling or being touched like other children do, but some may hug a relative like the mother, father, siblings, and feel great.

A. Repetitive behaviours

ASD patients are more likely to be comfortable and adaptable with their routine. Going through the motions again and again is very much part of their lives. To others, these repetitive behaviours may seem very strange. In contrast, people without autism are much more adaptable to changes in procedures.

B. A child with autism develops differently

While a child with autism may not develop at a well-balanced rate than a child without autism. Their cognitive skills may develop faster than social and language skills. Also, their language skills may develop rapidly while their motor skills don't. They may not be able to catch a ball like other children, but could have a much larger vocabulary but the social skills of an ASD patient will not develop at the same pace as others'.

C. Physical tics and stimming

It is common for people with autism to have tics. These are usually physical movements that can be jerky. Some tics can be quite complicated and can go on for a very long

Manuscript received April 5, 2017
Manuscript revised April 20, 2017

time. Some people with autism may be able to control when they happen, while others may not.

2. Literature Review

Videos can play progressively important role to identify autism in children. This requires a detailed frame-by-frame analysis using computer vision techniques to process the videos. Computer vision has already been used in medical imaging, where patients data is recorded in the form of images e.g. MRI images [2, 3], blood slides [4] etc. Using image processing techniques diseases are identified. The use of videos can play a vital role to identify autism in children at early stage. Early identification ASD in children can change rest of the whole life of the child. Studies suggested that early

diagnosis autism can recover such children to the point where longer they are considered autistic [5]. According to Shattuck et.al in [] in US the average age of ASD diagnosis 5 years.

Jordan Hashemi et. al. [6, 7] proposed low-cost computer vision tools to measure and identify autistic signs in children (if exist) based on Autism Observation Scale for Infants (AOSI). They developed algorithms to measure responses to general ASD risk assessment tasks and activities by assessing visual attention, facial features tracking. They showed their outcome results in comparison with the domain experts and non-experts. They demonstrated that their proposed computer vision tools are efficient to capture critical autistic behavioral observations.

Researchers at Duke University [8], from multiple disciplines are investigating and also using computer vision processes to make early diagnosis of autism in children. They aim to develop an app for parents to use at home which will help them to identifying any autism signs in the children. Although the entire mystery of what causes autism has not been solved yet. On the basis of emerging science and parents reporting what specific treatment have improved (or in some cases recovered) their children, there are now some strong clues regarding the prevention and treatment of autism [10, 11].

3. Materials & Methods

This paper studies about this world-changing technique, and what it entails. In the proposed framework an application has been developed from which extensive frame-by-frame video observation and analysis of a child can be done to identify automatically the autistic suffered children behaviour. Figure 1, illustrates the step by step division of the framework to show the process.

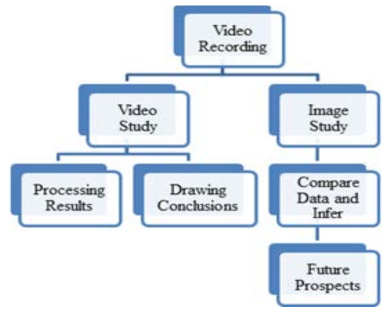


Fig. 1 Procedural structure of the project and data flow diagram

In the proposed framework visual tracking is used to evaluate how well the regular kids and autistic kids track the moving object. Following measures are used to attain the observation and analysis the autistic suffered children behavior.

A. TIME LAPSE

Since the idea of the proposed framework had stemmed from Rubinstein's work [9], the term time-lapse come out of it. Time lapse photography can be described as a method in which the frame rates (the frequency at which film frames are captured) is not the same as the viewing rate. In fact, the frequency at which the frames are viewed is much lower. So when the video is played at normal speed, time appears to be moving faster and thus lapsing. It is well known that a frame (image) is simply a unit of video and video is essentially a series of such frames one after the other and then playing them together sequentially in a defined time slot. Films that are shown in the cinema have been filmed at 24 frames-per-second, and television shows, sitcoms usually have a frame-rate of 24 or 25 frames-per-second. Playing them back at the same rate, it then appears that things are happening in so-called real time.

B. VIDEO MAGNIFICATION

Video magnification is a term that is contrary to time lapse; where time lapse consists of elapsed time and so essentially skipping time. In video magnification the time is essentially slowing down in order to observe the motion that is taking place in a very small section of time. The purpose of observation is to find small motions in a video and magnify them. We used motion estimation [14] because it is helpful to track tiny motion of the object (body), most of the time gives high accuracy when the child moves their head quickly or some time slowly.

Rubinstein's method [9], not only magnifies the motions, but also displays them in an indicative manner. The videos are treated same as trajectories or translations of pixel intensities in a certain reference frame. This would mean that put very simply, the translation from one frame to the next of the pixels is computed and then the video re-rendered. However, such a simplistic approach will result in artefactual transitions between amplified and unamplified pixels within a single structure.

4. Data Collection

On- Site Equipment setting

Handling the camera and observing equipment along with managing little children proved quite a handful task.

To record the video of the children activities assigned them, a camera fixed at a height so that the movements of directed children was recorded appropriately. The activities conducted in the assistance of an attendant while the camera filmed the proceedings. The videos were recorded 25fps standard rate films shows at cinema. Esposito et al. [15] compiled videos only at 8 frame per seconds (fps) and were annotated manually frame-by-frame using EWMN.

Subject Selection

It was difficult to discover the willing participants for the study. To select the desired autistic and non-autistic people it was decided that the data group is taken from the aged between 3 to 8 year olds comprising of both male and female children. These group children comparatively easily agreed to take part in the study. These children are chosen from different school and from our acquaintance with the consent of their parents. The autistic children in the dataset were with varying levels of severity of autism. Table-1 shows the statistic of participants with arbitrary names in the study. The letter C indicates children from the Centre of Autism, M and P indicate regular students for whom we were able to acquire permission for videography (the letters merely a way of identification), and A indicates children from a school, two of whom were known to have a hyperactive tendency. From the 11 boys, 4 were autistic with varying levels of severity, one had been diagnosed as hyperactive, and the rest were not labelled as autistic to the best of their paediatricians' and parents' knowledge.

Table1: Brief detail of the children took part in the study.

Participant	Gender	Status	Age (years)
C1	Male	Autistic	5
C2	Male	Autistic	8
C3	Male	Autistic	4
C5	Male	Autistic	5
M1	Female	Non- Autistic	6
M2	Female	Non- Autistic	3
M3	Female	Non- Autistic	5
M4	Female	Non- Autistic	9
P1	Male	Non- Autistic	6
P2	Male	Non- Autistic	3
P3	Female	Non- Autistic	2.5
A1	Male	Non- Autistic	3
A2	Female	Non- Autistic	3.2
A3	Male	Non- Autistic	4.5
A4	Female	Non- Autistic	3
A5	Male	Non- Autistic	4
A6	Male	Non- Autistic	3.7
A7	Male	Non- Autistic	4.7

Data Collection

To record the directed motions of the children following test were conducted from the children:

- Test for disengagement of attention
- Test for visual tracking
- Test for ball playing activity to judge the sharing interest
- Test for 2D pose estimation

5. Experiments, Results & Discussion

I. Test for Disengagement of Attention.

To conduct the disengagement of attention test, a performer (attendant) asked to shake a noisy object near the right ear of the child, continuing to shake it for a reasonable length of time to react the child. Then the performer asked to bring the noisy object to the eye level of the child, and take it across the child's line of sight between the eyes. Finally, a second noisy object was used to create noise at the right side, opposite to where the child's attention was focused. Figures 2 and 3 show the activity perform for the disengagement of Attention test. Time span by each child for each activity was recorded, shown in Table 2. In the Table 2, Tp indicates time span to perceive the rattling object. Tr indicates time span to react to the shaking object. The recording Time span have been broken down into two spans, Tp1, Tp2 and Tr1, Tr2 respectively for time taken to perceive and to react for the child to respond to the noisy object shaken to one side and other side. The reason was that many children perceived the object but wouldn't look at it due to one or more reasons.

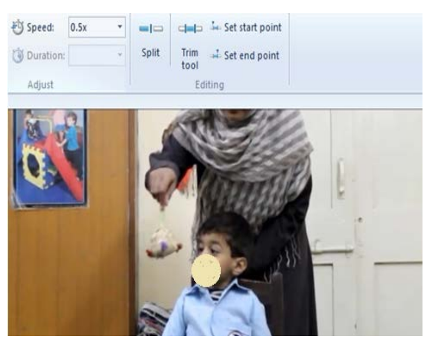


Fig. 2 The ability to engage in the first distracting object

It is observed that the reasons may range from shyness as the simplest to a symptom of ASD on the other end.

Soon as the child shows signs of having registered the presence of the noisy object, by an indication of narrowing eyes, or a sudden stillness followed by movement to react (read: move towards the object to see it) to it, is the duration of Tp1.

Fig. 3 The ability to disengage from the first object and engage in the second.

To compute the time spans, Windows Movie Maker was used, where we could effectively slow down the video and play it frame-by-frame in order to get the accurate timestamps.

Table3: Disengagement of Attention.

Participants	***Age years***	***Tp1 sec***	***Tr1 sec***	***Tp2 sec***	***Tr2 sec***
C1	5	2.06	3	N/A	N/A
C2	8	N/A	N/A	N/A	N/A
C3	4	0.2	0.84	1.66	N/A
C4	5	N/A	N/A	N/A	N/A
M1	6	0.4	0.07	0.93	0.5
M2	3	0.1	0.47	2.03	0.3
M3	5	1	0.77	2	0.73
M4	9	1	0.27	0.5	0.27
P1	6	0.3	0.24	1.03	0.37
P2	3	1.3	0.14	2.34	0.3
P3	2.5	N/A	0.2	1.1	1.27
A1	3	2.03	0.3	1.84	1.4
A2	3.2	2.13	0.9	N/A	N/A
A3	4.5	1	1.2	0.4	0.8
A4	3	0.83	1.24	N/A	N/A
A5	4	1.97	1.87	1.44	0.73
A6	3.7	N/A	0.27	1.24	1.06
A7	4.7	1.53	2.53	N/A	N/A

Table3: Total time taken in reacting to the two objects respectively

Participant	***(Total Time1)/2 (seconds)***	***(Total Time2)/2 (seconds)***
C1	2.53	0
C2	0	0
C3	0.52	0
C4	0	0
M1	0.24	0.72
M2	0.29	1.42
M3	0.89	1.37
M4	0.64	0.39
P1	0.27	0.7
P2	0.72	1.54
P3	0.1	1.19
A1	1.47	1.62
A2	1.72	0
A3	1.1	0.6
A4	1.04	0
A5	1.92	1.09
A6	0.19	1.15
A7	2.53	0

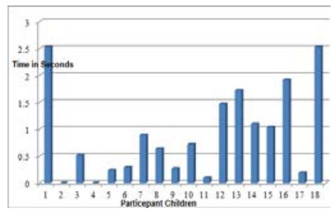
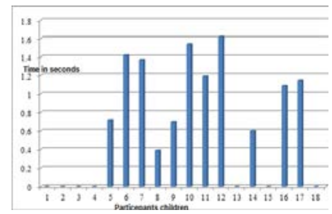


Fig. 4 (a). Bar graph of time taken to respond to the first object against the number of children.



(b) Bar graph of time taken to respond to the second object against the number of children.

In figure 4 (a) graph explains that the behaviour of (first four) autistic and rest of the normal children; First child have taken so long a time to respond to the object where the second and fourth were involved in their own world didn't pay any attention to what was being waved, shows typical autistic behaviour. Of the rest of the 14 children, 9 falls comfortably inside the normal response time, children 13, 16 and 18 exhibited shy behaviour and were deliberately avoid looking at the object.

In figure 4 (a) graph explains, the autistic children showed no response. The first child was too hung on the first object to pay us any attention. The second child looked unseeing. Soon he resumed his habitual flapping of the arms making incoherent sounds with his mouth as babies are often wont to do. He was shaking one of his legs in continuous motion too, and was blissfully unaware of the fact that we sought his attention.

Similarly the third and fourth child was this attention seeking individual, who made the first grab for the toy and when we wouldn't give it to him, he turned his face away towards the attendant in a gesture of non-compliance. We were failing to get any response from them. It was clear that we or activity were too boring for them.

Of the rest of the children (not labelled as autistic to the best of our knowledge), we can see that the trend falls comfortably within 1.6 seconds, showing that the greater values for time period which occurred with the first object may have been anomalies only, and not characteristic behaviour worthy of worry.

We compared the disengagement and engagement times for the boys verses girls. In figure 5 graph shows the girls have a shorter reaction time generally than the boys except for at one position. This trend shows that boys have a longer reaction time compared to girls. This also correlates to the reality of how boys are more prone to autism than girls.

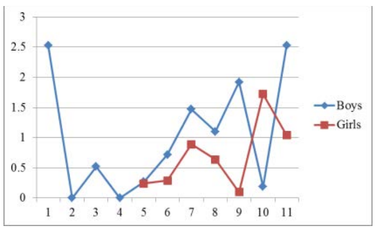


Fig.5 Comparison of engagement/ disengagement times between boys and girls.

II. Test for Visual Tracking

For visual tracking, the number of disruptions indicates the number of breaks/ distractions during visual tracking, while Ts is the Time Sustained, or the continuous time period during which they gazed at or followed the object. The letters N/A (Not Applicable) indicate the scenarios where the children were perfectly aware of the scenario and that they were to track the object moving along their line of vision. These children had zero disruptions to their gazing/ tracking, and thus the field Ts was inapplicable to them. The measurements of visual tracking for the autistic and regular children are given in Table 4.

In the table, the first four children afflicted with autism, disinclined to gaze at the object. As it requires attention and concentration to track its progress in the air which the autistic children could not delivered.

Fig. 4 Activity for visual tracking

Table 4: measurements of visual tracking for the autistic and regular children

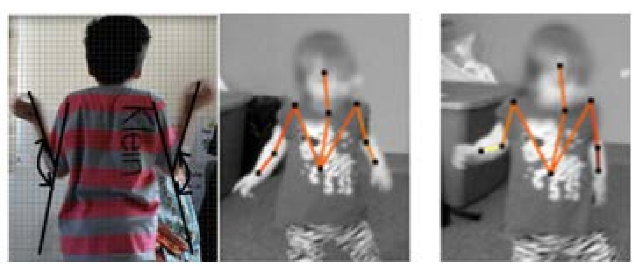
Participant	***Number of Disruptions (arbitrary units)***	***Ts (seconds)***
C1	0	N/A
C2	N/A	1.13
C3	N/A	N/A
C4	N/A	1.1
M1	0	N/A
M2	0	N/A
M3	0	N/A
M4	0	N/A
P1	0	N/A
P2	1	0.9
P3	0	N/A
A1	1	4.33
A2	1	N/A
A3	0	N/A
A4	0	N/A
A5	2	0.97, 0.9
A6	1	0.87
A7	N/A	0.53, 0.94

III. Test for 2-D pose (Digital image)

To compute the symmetry of the body from the digital images, rather than use of markers as used by Hashemi et. al. [6, 7] or employ the gait lab, we used image processing technique in

the proposed framework.

The processing software read the image file and then superimposes a grid or closes knit mesh upon the digital image of the 2D pose of the children and then computed symmetry. Using the upper arm (humerus) as the base line, a protractor is used to measure the deviation of the lower limb from the line in a regular standing position (rather than involved in some activity which would have discredited the results). Since the regular anatomical position requires arms falling straight down (albeit with palms facing forward), we measure the angle of the arm moving outwards. The measurements of deviation angles along with the difference symmetry for the autistic and regular children are given in Table 6.



(a) (b) (c)

Fig. 5 (a).Measure the deviation angle for an autistic child's regular pose. (b, c) The symmetry ascertained using markers [Hashemi et. al.]

Fig. 6 Measur the deviation angle for non-labelled child's regular pose.

Table5: The deviation angles for the autistic and regular children.

Participant	*Deviation Angle R*	*Deviation Angle L*	*Difference (Symmetry)*
	(degrees)	*(degrees)*	*(degrees)*
C1	97	76	21
C2	144	150	6
C3	45	30	15
C4	140	120	20
M1	5	5	0
M2	3	3	0
M3	2	2	0
M4	10	10	0
P1	5	3	2
P2	20	50	30
P3	0	0	0
A1	0	0	0
A2	0	10	10
A3	0	0	0
A4	0	5	5
A5	0	7	7
A6	10	10	0
A7	0	0	0

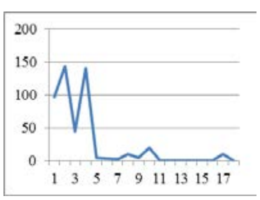
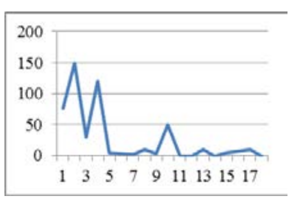


Fig.6(a) Line plot showing the deviation angles for the right arm.



(b). Line plot showing the deviation angles for the left arm.

Aside from child C2, the children C1, C3, and C4 all had high deviation angles characteristic of children with autism. This is clearly visible from the plots in figure 5 (a) and (b), none of the other normal children have high deviation angles. In fact, we attribute the anomaly with C3's results to a less severe manifestation of autism to his body pose.

IV. Test for Ball Playing Activity

For the third test, the ball playing activity, the children asked to stand up and a ball rolled out to them. Observations and conclusion for this test were recorded after observing the activity on screen. Results are given in Table 6.

Fig. 7 Ball playing Activity

6. Conclusion

The proposed framework is simple and easy to use. It is powerful breakthrough, as it makes the diagnosis of ASD approachable for the patient without getting clinical expensive tests. Telemedicine is already progressing at greater rate and becoming useful and familiar to more and more individuals over the world, the consultant and their team may not even be from the same nation as the child's, yet can give a satisfactory answer if they follow through. From the output results, the children with the odd results have been pointed out at each stage of analysis and processing and these are the ones to look out for and keep an eye over in case of further development as the clinician sees fit. The proposed approach is an aid to the diagnosis of autism and not the solution to diagnosis in itself. The existing computer vision tools e.g. Hashemi et. al. [6] are still not self-sufficient, mostly because autism is not a simplistic disorder characterised by some specific symptoms. In fact, it is a syndrome which may manifest itself differently.

Acknowledgment

We acknowledged the support provided by the Dar ul Sukun Karachi, Pakistan. They originated as a shelter home for the abandoned children with disabilities founded in 1969 by a Dutch nun, Sr. Gertrude Lemmens. They helped to record the information of autistic children.

We also acknowledged the support provided by Centre for Autism Karachi, Pakistan. This is one of the pioneering training centres of Pakistan for the Parents and children

with Autism. They arranged meeting for us with the parents of the autistic children.

Participant	Gender	Age (years)	Ball Playing Activity
C1	M	5	Stares at ball, stands when prompted. >3s to notice, holds ball, lost again in 2.23s.
C2	M	8	Directly looks at ball for 0.9s in all, grabs upon prompting and gives away in 3.9s.
C3	M	4	Continues grabbing for first object, glances at ball as part of surroundings.
C4	M	5	N/A. Playing with first object, refuses to look away from it.
M1	F	6	Caught the ball on the first try, looked forward to it and engaged right away.
M2	F	3	same as above.
M3	F	5	same as above.
M4	F	9	same as above.
P1	M	6	Perfect ball playing, engaged right away.
P2	M	3	Tried catching the ball and looked to the camera.
P3	F	2.5	Caught the ball, looked at attendant and engaged right away.
A1	M	3	Perfect ball playing, engaged right away.
A2	F	3.2	Perfect ball playing, engaged right away.
A3	M	4.5	Was not interested in playing ball, continued sitting with an occasional glance to ball.
A4	F	3	Responded well and quick to ball play.
A5	M	4	Half-heartedly engaged in the form of two foot prods to kick the ball away.
A6	M	3.7	Shy but responded well.
A7	M	4.7	Slightly slower than peers in engaging but responded well.

Table6: showing Results for Ball Playing Activity

REFERENCES

[1] C. Nordqvist. “What is Autism: Causes and Research”. Available: http://www.medicalnewstoday.com/info/autism/. [accessed on 30 March 2017].

[2] Community Report on Autism 2016 - CDC, National Center on Birth Defects and Developmental Disabilities, Division of Congenital and Developmental Disorders, 2016.

[3] K. A. Najeed, Z. Shehnila, K. Shabeen, S. Sehrish, “A Method for Tumour Detection on Brain MRI Image by implementing SVM”, International Journal of Computer Science and Information Security (IJCSIS), ISI, ISSN: 1947-5500, pp. 154-160 Vol. 14 No. 8 AUG 2016

[4] K. A. Najeed, P. Hassan, A. Arsalan, S. Aysha, “Unsupervised Identification of Malaria Parasites using Computer Vision”, Pakistan Journal of Pharmaceutical Sciences (PJPS), ISI, ISSN:1011-601x, Vol.30, No.1, January 2017. pp 223-228

[5] “8 Basic Early Autism Signs in children”, http://peptalkbox.com/8-basic-early-autism-signs-in-children. 2012, [accessed on 31 March 2017].

[6] J. Hashemi et.al, “Computer Vision Tools for Low-Cost and Noninvasive Measurement of Autism-Related Behaviors in Infants,” Autism Research and Treatment, vol. 2014, 2014. doi:10.1155/2014/935686.

[7] J. Hashemi, M. Tepper, V. S. Thiago, "A computer vision approach for the assessment of autism-related behavioral markers," IEEE International Conference on Development and Learning and Epigenetic Robotics (ICDL), San Diego, CA, pp. 1-7, 2012.

[8] Computer vision enables researchers to screen earlier for autism, Heidi Hoopes, 2013. http://newatlas.com/computer-vision-early-screening-autism/32217/. [accessed on 30 March 2017].

[9] M. Rubinstein. (Filmed November, 2014). “See Invisible Motion, Hear SilentSounds”. https://www.ted.com/talks/michael_rubinstein_see_invisible_motion_hear_silent_sounds_cool_creepy_we_can_t_decide. [accessed on 20 Feb 2017].

[10] Maureen McDonnell, RN, What Can Be Done to Prevent Autism Now? March, 2010. http://www.ageofautism.com/2010/03/what-can-be-done-to-prevent-autism-now.html. [accessed on 20 Jan 2017].

[11] M. Fuchs, T. Chen, O. Wang, R. Raskar, R. Seidel, “Real-time temporal shaping of high-speed video streams”. Computers & Graphics, pp. 575-584, 2010.

[12] R. Landry , S. Bryson, “Impaired disengagement of attention in young children with autism.” Journal of Child Psychol. Psychiatry, vol. 45, no. 6, pp. 1115–22, 2004.

[13] P. T. Shattuck, M. Durkin, M. Maenner, C. Newschaffer, D. S. Mandell, L. Wiggins, L.-C. C. Lee, C. Rice, E. Giarelli, R. Kirby, J. Baio, J. PintoMartin, and C. Cuniff, “Timing of identification among children with an autism spectrum disorder: findings from a population-based surveillance study.” JAACAP, vol. 48, no. 5, pp. 474–483, May 2009.

[14] M. Tepper and G. Sapiro, “Decoupled coarse-to-fine matching and nonlinear regularization for efficient motion estimation,” in proceeding of 19th IEEE International Conference on Image Processing Orlando, USA, 2012.

[15] G. Esposito, P. Venuti, F. Apicella, and F. Muratori, “Analysis of unsupported gait in toddlers with autism,” Brain Dev., vol. 33, No. 5, pp. 367–373, 2011.