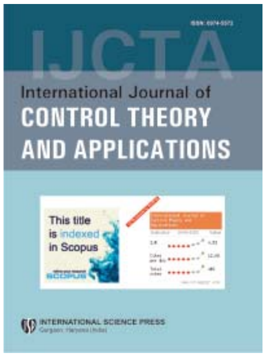

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Adaptive System to Support Context Awareness a Study with Gesture Recognition

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Abstract: Differently abled students suffer normally in effective gesture expression of mathematical notations in the classrooms especially for signs with different meanings. We developed a learning environment called Context Aware Gesture Recognition System(CAGR) to assist physically disabled students for overcoming this problem in the context of understanding sign language dialogue, a set of sign with different meanings. This system has the ability to capture user gesture inputs with the help of Microsoft Kinect device and to manage gesture interaction between students and teachers. It will also detect, extract gestures and recognize the context of gestures shown by the user and finally display the respective text in the screen. Thus this assists physically disabled students to have an effective dialogue between them and teachers for better cognition. This paper presents CAGR and describes activities in which we evaluated the efficacy and compared its potential benefits with different type of users. Our results show that the CAGR is effective in assisting physically challenged students to perform effective dialogue through this context aware gesture recognition mechanism.

Keywrods: *Gesture recognition, Context awareness, Learning technology, differently abled learners, kinect depth sensor.*

1. INTRODUCTION

The concept “ubiquitous computing” was proposed by Mark Weiser[42] in his research on Human-Computer Interaction(HCI). Human-Computer-Interaction technology has seen significant changes over the years which range from text-based User Interface relies heavily on the keyboard and mice as an input device. The desire to provide a more natural interaction between humans and machines has brought about the wide focus on gesture recognition. Gestures have long been considered the most natural form of interaction among humans and it is defined as a motion of the body that contains information [25]. It involves the physical movement of the head, hands, arms, face or body with the aim of conveying semantic information to the system. Gestures can be used as a tool for learning and interaction among users[19]. The main requirement for supporting gesture recognition is the tracking technology used for obtaining the input data. The tracking technology generally falls into two major categories: *Glove based* approaches and *Webcam based* approaches. Former approach is to instrument the hand with a glove which is equipped with a number of sensors to provide input to the computer about position of the hand, hand orientation, and fingers using magnetic or inertial tracking devices and the latter uses Camera(s) at a fixed location or on a mobile platform in the environment and are used for capturing the input image usually at a frame rate of 30 HZ or more. The role of Context awareness in gesture aims to make the system more human-centric[12].

With the commercial success of systems like glove based, web cam based and Microsoft Kinect[45], attention has been drawn to the potential of using gesture-based technology in the classroom communication [9]. Communication is foremost important in interactive Teaching-Learning process. Spoken language and written words in communication will provide rich access to learning resources. Students with speech impairment and hearing impairment will use sign language as their mode of communication to the listeners. The World Federation of Deaf (WFD) recognises that approximately 80% of sign language people do not receive any basic education, especially in developing countries. Differently abled Students greatly vary in abilities. In addition to difficulty in communicating with others, these students also struggle to make the listeners to understand their sign language. Researchers are exploring the role of gestures in participatory art, simulations, training, physical education, science math education, music education and special education to students. The investigation of the researchers also includes the usage of multi-user gestural interactions and cooperative gestures, to increase the sense of teamwork among the differently abled students. Playfulness, equity of participation, learning and collaborative creativity were also studied in [28][37].The study reveals that, Students showed higher performance when using a gestural interface, in their study [41]. Gesture based technology provides support for differently abled students. Understanding the sign language and its context in a class room by a teacher and responding to them will enable the learners to understand the concepts quickly and effectively. Gesture recognition software can provide valuable and engaging opportunities for students to practice their signing[14]. The context of using sign should be understood by the system to have efficient communication. Kinect has shown that it is well suited for sign language recognition[21] and supporters of using Kinect in education suggest that the active component of learning provided by these devices will increase the academic and social performance of students[20].

The role and advantages of using gesture based technology in teaching-learning and context awareness and inability of differently abled students to make express the listeners sign language context, motivated us to design a Context Aware Gesture Recognition (CA-GR) system for differently abled learners. CA-GR recognizes users and understands their intentions using a “natural” user interface consisting of gestures. To implement this, the skeletal tracking ability as well as both the depth map and color image of the Kinect sensor are utilized to capture the image. CA-GR utilizes Gaussian mixture model (GMM), a back ground subtraction algorithm to remove the background of the captured image and to find the exact gesture. Context awareness is modelling through relevance and metadata concepts. Teaching potential, performance and technical evaluation of this system in classroom environment shows positive results.

This paper is organized as follows: Section 2 gives a brief overview of background of gesture recognition and context awareness. Section 3: objective of the work is briefed. Section 4: discusses the description of CAGR. Evalution and Conclusions are given in Section 5.

2. BACKGROUND

The Gallaudet Research Institute indicates that the median reading comprehension score of 17 and 18 year old deaf students is equivalent to the level of fourth-grade hearing students [38]. Nowadays, computational resources are more and more common in the area of education, aiming at stimulating and improving learning in both children and adults [2]. Information Communication Technology(ICT) helps the students to communicate and learn more effectively. There are several benefits in using ICT not only for the students but for teachers and parents as well [3]. Many research papers have been published on the methods of utilizing ICT to overcome the difficulties of differently-abled students. These students mostly lack in communicational and behavioural skills and slow in understanding in what is being taught in the classroom. According to the analysis done by British Educational Communications and Technology Agency [3], it is found that ICT can be used to support the learning of students with special educational needs. The technology can help these students to overcome many of their communicational difficulties. This analysis has covered several areas including communication aids, software and web accessibility, teacher training and support and connecting learning communities. As mentioned by C. S. Lanyi et ai, 'Cheese Factory' is a serious game [22] designed for teaching percentages, factions and decimals to these students. In that game, it is expected to match the given shape with the shapes in bottom of the interface to produce a full 'cheese'. There were several speed levels and difficulty levels in that game to make it scalable for any student with special educational needs. Further, the user interfaces are simple, colours are matched with overall interface, and instructions are clear [22]. Hancock, Parton and their research team [32][33] developed a physical world hyperlinking teaching system using RFID-tagged toys to teach American Sign Language to deaf preschoolers. An initial set of 500 real-world objects with RFID tags were constructed to initiate instructional contents, such as a video of an individual signing that object's word, as well as several pictures of the object. Deaf preschoolers could not only practice their words, but also encourage their hearing parents to learn to sign as well. Several suggestions have been made in the literature on how to accommodate the difficulties experienced by deaf and hard of hearing students in inquiry-based science activities [44]. Easterbrooks and Stephenson [8] suggested the addition of visual prompts, graphic organizers, and lower-level reading materials in the use of scaffolding. Physical manipulation of objects, combination of simplified text and explanations with animation, practice material on vocabulary and graphical representation of contents are effective means to accommodate as suggested in [6], [23].

[43] "Komputer Saya", a courseware for multimedia was designed especially for the slow learners. KomputerSaya system integrates multimedia tool for the differently abled students courseware for effective understanding. PRAISE [27] reports on a classroom practice that focuses on the effectiveness of peer review in drawing picture education for hard-of-hearing students. As revealed by analysis in [3] the differently abled students should be motivated by accessing the same curriculum by using other access devices to use the computers. According to the research "Preparing special education frontline professionals for a new teaching experience" [36], Learning content used, Student – teacher communication, pedagogy used are the vital factor in using ICT for special education. If the technology is used to support the acquisition of traditional skills, it will be a waste of time and technology. Therefore, both theoreticians and practitioners have to think in a different, innovative way to apply the technological advancement into the real context. Glove based gesture recognition and Webcam based recognition are technological advancement in gesture recognition. Merits and demerits of Glove based and gesture based is shown in table 1. Huei[40] developed a system based on Windowed template matching focuses on recognizing a continuous flow of signs in American Sign Language (ASL) based on Data glove. Hand glove based ASL recognition using pseudo 2-D HMM , a Kalman filter and hand blob analysis was proposed by Nguyen and Shuichi[43]. Ouhyoung[39] designed a primitive signer dependent system for Taiwanese Lexical vocabulary, which uses Data glove to solve the problem of end point detection. Loeding and Sarkar[24] developed a system using Iterated Conditional Modes (ICM) to extract parts of signs in most occurrences,from videos. A radial basis function Artificial Neural Network (*k*-means) for gesture classification was proposed in the Human alternative and augmentative communication (HAAC) developed by Ghosh and Ari [11]. Back propagation neural network for recognition of gestures from a set of segmented hand images in videos was suggested by MacLean James[16]. [7] proposes a virtual class room for creating and displaying resources, materials for Deaf people in sign language. The virtual class room supports the implied scripted collaborative task of teaching the people through interactive videos and photos displaying sign language. This system aims to provide communication among deaf students and Instructors through the visual interfaces that makes it easier for deaf students to join the virtual classrooms and enhances communication between their instructors and their colleagues.

Table 1
Glove Based Vs Webcam Based Approaches

	Glove based approach	*Webcam based approach*
Merits	Easier to collect hand configuration and movement with this approach	More natural way of HCI as it requires no physical contact with any devices.
Demerits	Quite expensive and cumbersome; hampered by the load of cables attached to the user	The problem of occlusion; The camera view is always limited as there are always parts of the user's body that are not visible.

[26] Proposes Vision based Hand gesture Recognition system that recognizes hand gesture in midair and displays the recognized character along with corresponding sound. Our literature survey also finds that many researchers address the use of sign language [30][35][39] in communication for differently abled students using glove based and webcam based approaches. The demerits of Glove based and Webcam based approaches are taken care by the Microsoft Kinect Depth Sensor[45]. [1] gesture based paint application using Kinect Sensor can be used to teach Microsoft Paint™ to school kids where the kids can move their hands in the air to draw shapes or tap in the air to pick up tools from the toolbox. However, the current experiments and developments with Kinect are also in basic level. Kinect technology will be a powerful interactive educational tool[15], if it comes with more educational software for teachers. As stated in cited manuals and in works such as Poggi's [34], the same gesture can have different meanings and the meaning of that gesture has to be taken care by the system. For a system to be able to gather different meanings from a same gesture depending on the context it should be able to analyze gesture at different time scales and get real-time information. Several context aware education applications were designed with the intention to support the Teaching-Learning environment. Context aware System to learn Japanese expressions and attributes was suggested by Ogata and Yano [31]. Location based context aware system with audio in an art exhibition was suggested by Jamescon[17][47]. Context awareness in museum guide was applied by Zancanaro etal [46]. Ouhyoung[39] designed a primitive signer dependent system for Taiwanese Lexical vocabulary, which uses Data glove to solve the problem of end point detection. A haptic feedback system that allows people with visual impairments to get more feedback with fine degrees of touch proposed in [10]. In such context aware Teaching-Learning applications [4][5][18] learners are the primary beneficiaries. Context Aware Gesture Recognition addresses the need of teachers to understand the sign and the context of the sign language used by differently abled students in a classroom.

3. OBJECTIVE

The objective of this study is to explore the combination of Context Aware and Gesture Recognition technology in the class-room to automatically convert student and instructors Gesture to text. The objective will bridge the communication gap between normal and differently abled pupils in both directions and also recognize the context of communication. Our specific objectives are to:

1. Identify the issues regarding the use of CAGR as a standard classroom tool in capturing sign languages and converting into corresponding text,
2. Explore the effects of CAGR on Teachers` cognition of dialogue with physically disabled students.
3. Iinvestigate the potential benefits of CAGR for instructors, normal and differently abled students.

We believe that the framework and strategies of this study could be applied to include any Gesture Recognition engine that others may wish to employ.

4. DESCRIPTION OF CA-GR

In this section, we present our Context Aware Gesture Recognition system (CA-GR). The architecture of the CA-GR, implemented in Microsoft C#, is shown in Fig. 1. Various stages are involved in the development of this Context Aware Gesture Recognition system. Foremost stage is the ability of the system to capture users gesture with Kinect sensor and our graphical user interface manages gesture interaction between students and teachers. The engine of the system controls the modules used to detect and extract gesture. Those modules recognize the context of the gesture shown by the user and activate the visual display module to display the relevant data to the receiver. There exists a gesture database to store all the gesture data. The workflow of the proposed system is shown in the following Fig. 2.

4.1. Kinect Sensor

This section discusses the role of kinect sensor. The most important aspect of developing a CAGR system is to detect the user hand gesture from human skeleton. According to Microsoft, the Kinect sensor shown in Fig. 3 is composed of a RGB camera,3D Depth Sensor, Multi-array microphone and Motorized tilt. RGB camera provides images with an 8-bit VGA resolution of 640 x 480 pixels at 30 frames per second (fps). Image in Ambient light can be also be captured using 3D depth sensor. Combination of this RGB and 3D depth sensor provides the system with accurate image data.

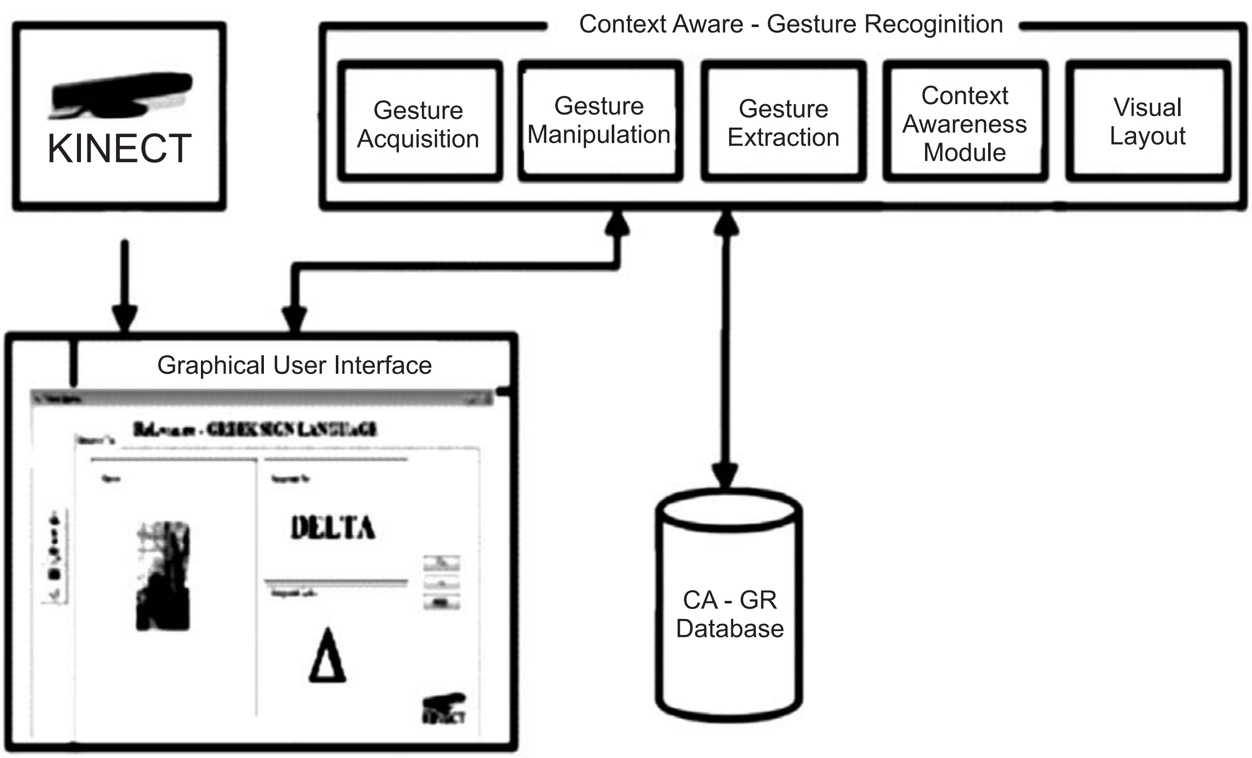

Figure 1: Context Aware Gesture Recognition Architecture

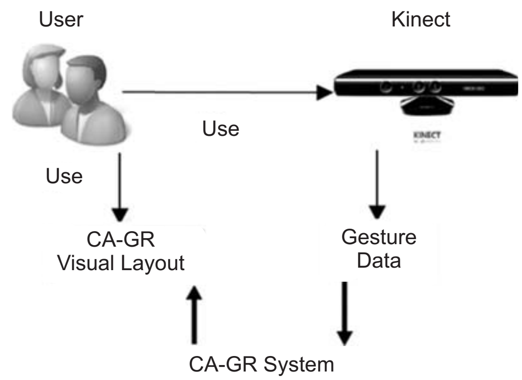

Figure 2: Context Aware-Gesture Recognition Workflow

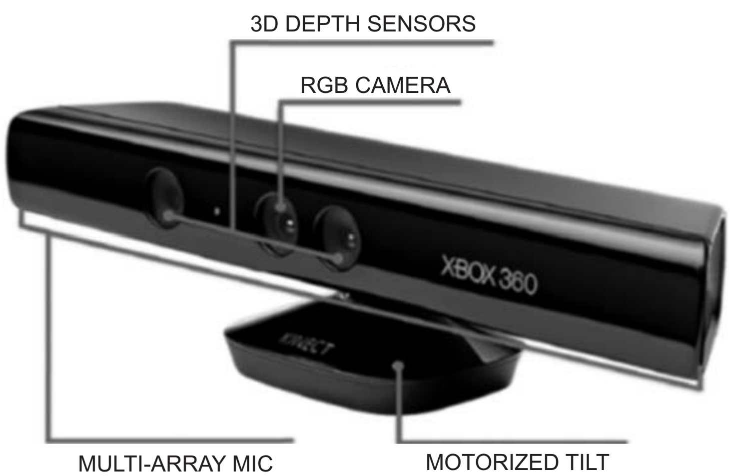

Figure 3: Kinect Sensor

The purpose of Multi-array mic is to implement voice command to the system. With the help of tilt motor, sensor position can be changed on both vertical and horizontal axes.

4.1.1. Requirements for Application Development with Kinect

Figure 4: Application Development

Installing Kinect for Windows SDK is necessary to develop any Kinect-enabled application. Fig. 4 shows the communication of Kinect sensor with an application. Natural User Interface (NUI) library in the Kinect[29] [45] SDK provides the tools and the Application Programming Interface (APIs) needed for high-level access such as color , depth images, motor control, audio capabilities, and skeletal tracking features. One can collect the complete information of the position of the user body's twenty joints in the camera from the skeleton data. Fig. 5 shows the skeleton [48]tracking capability of kinect sensor. Various functions required to control kinect sensor are specified in *Microsoft.Kinect* namespace which requires *Microsoft.Kinect.dll* assembly. Instance of Kinectsensor class helps the developer's routine to perform various commands in an application.

4.2. Graphical User Interface

This section briefly describes the layout of CA-GR system. Fig. 6 displays the Context aware Gesture Recognition (CA-GR) Graphical User Interface. It has the following features:

1. **Kinect on/off :** Starts the CA-CR engine to recognize gesture, hand gesture push is used to on / off the kinect.
2. **CA-GR toolbox:** Provides user roles and feedback for the system.
3. **Screen Display :** Displays context of the CA-GR.
4. **Gesture captured Layout :** Displays captured gesture from the kinect sensor.
5. **Recognized Text :** Ddisplays recognized Layout text for the captured gesture.
6. **Recognized Symbol Layout :** Displays recognized symbol for the captured gesture.

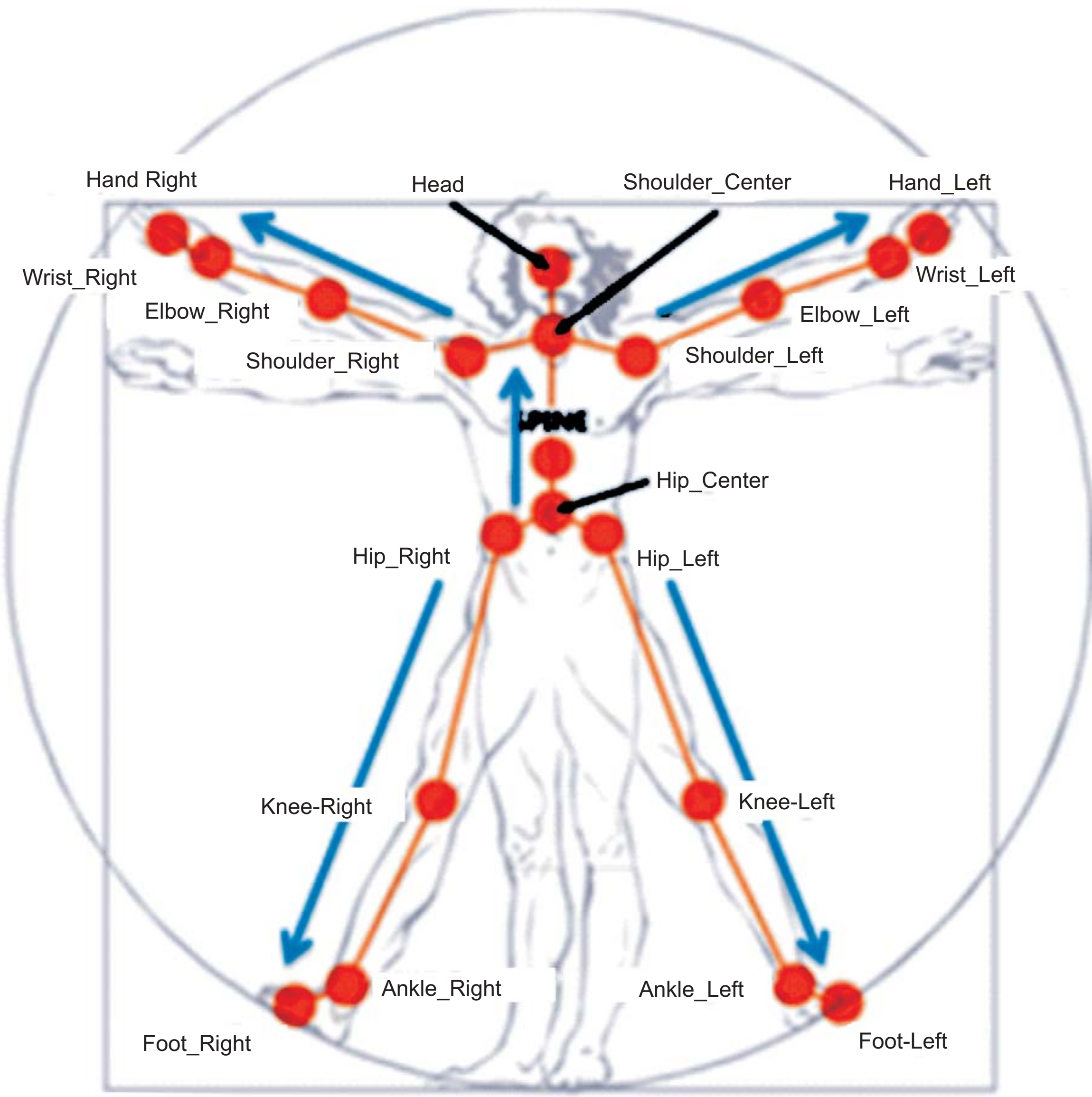

Figure 5: Kinect Sensor Skelton tracking joint (Courtesy: Microsoft)

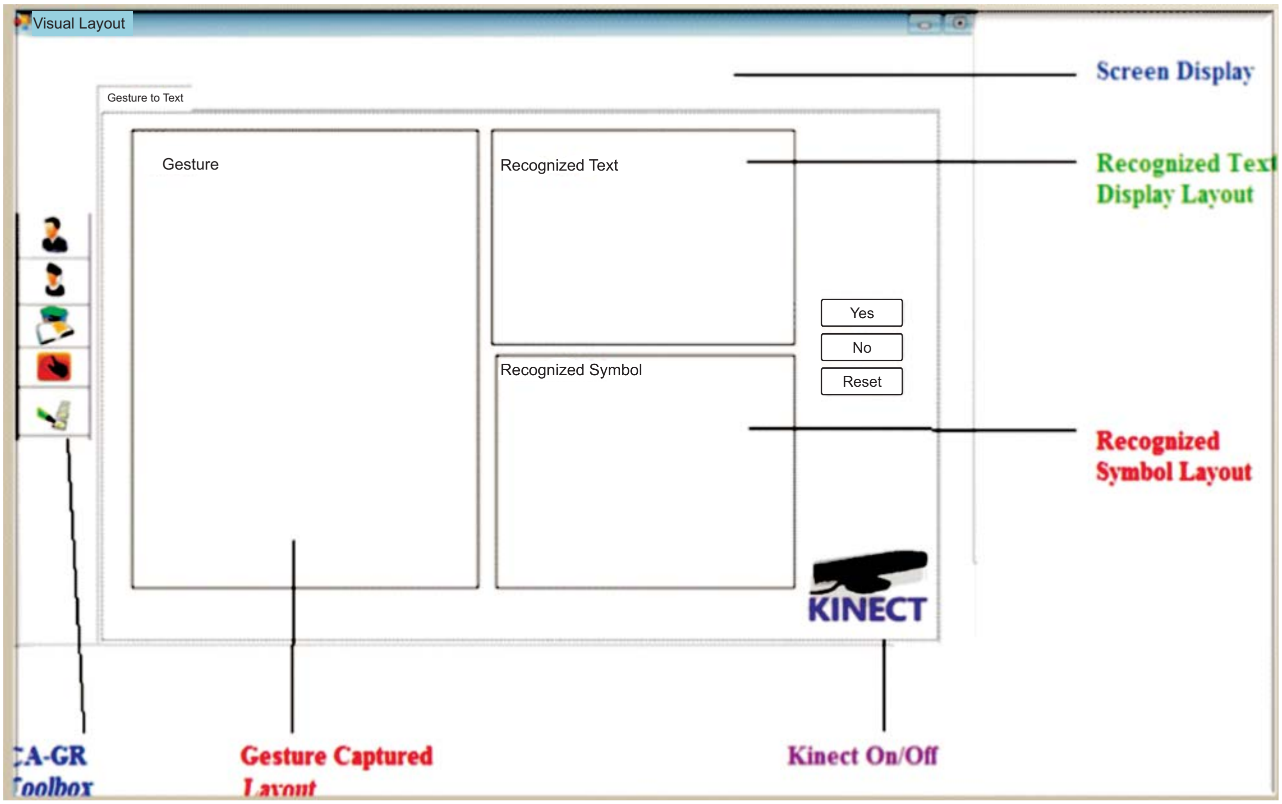

Figure 6: CA-GR GUI

4.2.1. CA-GR Users and roles

1. **Administrator:** The main role of administrator is to manage and administrate the roles and the tasks of various users to the proposed paradigm. The administrator gives the permission and revokes the given permission from the users.
2. **Teachers:** Teacher can use the system to recognize the gestures shown by the students. Teacher incorporates new gesture to gesture database and also provides the system with course material for learning, quizzes and assignments.
3. **Students :** Differently abled students can use the system as a mode of communication to the normal Pupils. Different sign languages such as American Sign Language alphabets and Greek sign language alphabets can be used by the students to communicate with the teachers. The Sign language expressed by the students will be recognized by the system and the relevant context will be communicated to the teachers.

4.3. Gesture Acquisition

This section describes the gesture acquisition procedure. The first step is to obtain the image from the camera. Kinect can capture image using depth information by projecting an infrared dots pattern and its subsequent capture by an infrared and RGB camera. Hand detection can be carried out either on depth images only or by fusing the RGB and depth information. This is done by enabling through coding the *ColorStream* component of the Kinect which provides the RGB video stream; the *DepthStream* which provides the 3D representation of the image in front of the sensor. Gesture acquired is shown in the Fig. 7.

Figure 7: Acquired gesture

4.4. Gesture Manipulation

This section describes the methods used in gesture manipulation. To improve the raw image, image color conversion, image rescaling and background elimination is preferred. This module improves the raw image by performing the above process.

4.4.1. Image Grayscale

When someone operates the system, the person's gesture is acquired as a raw image. The raw image is barely recognizable due to low color contrast, and thus using the predefined library functions of Kinect SDK the whole image frame (Fig. 8) will be converted into a matrix in uint8 gray scale.

Figure 8: Gesture in Grayscale

4.4.2. Image Rescaling

Figure 9: Rescaled gesture

The gesture can be resolved by adjusting the scale factor. The sensitive range of the system covers upto 1 metre from the minimum range of the kinect. When the user operates the Kinect properly, this minimum depth should reach some point at the user's gesture. Since the hand gesture is in the sensitive range, it is in gray scale, other that grayscale or image maximum of maximum of depth, are not visible. Fig. 9 shows the rescaled gesture.

4.4.3. Background elimination

The white background and the body are not necessary for extraction. A digital-negative operation on the image to make the image should be performed more optimal for subsequent steps. The shadows around the hand and the body, are due to the positional disparity between the RGB camera and the depth sensor, will affect the recognition performance, so one should eliminate them. Based on the previous step, the shadow at this point will be white, while the background will be black. The gray part is the hand, which is in the sensitive range. The system deploys Gaussian mixture model (GMM) , which is background subtraction algorithm to remove the background of the gesture. Fig. 10 Shows the background eliminated gesture.

Figure 10: Gesture without Background

4.5. Extraction

This section explains the procedure of gesture extraction. To perform extraction, one should process the image further. The top point of the palm of the hand, should be captured and the pixels which represent the depth up to 24 units from that point should be kept to convert the pixels into white. Otherwise, they will be eliminated. Finally image for recognition (Fig. 11) will be extracted.

4.6. Context Awareness

This section describes the context awareness in CA-GR system. One should do a few basic steps before going to the depth of the gesture recognition methodology. The first is to determine the context where the application, needs to be listened.

Figure 11: Gesture for Recognition

The CA - GR system makes use of Alphabet, numerical and Greek Alphabet Symbol Context to recognize the user gesture and convert them into corresponding text. The Usage of Greek symbols for alphabet and numbers are identical. So the chances of clear conveyance of messages are bleak as it may create some complexity in the meaning. In this situation the context of gesture becomes challenge. Considering this, A differently-abled student wants to express the notation "delta" in a mathematical classroom; the symbol for delta is 'Δ' and 'δ' which has different usage context, but the gesture for the notation will be the same for both cases as shown in the Fig. 12.

Figure 12: Delta Gesture notation

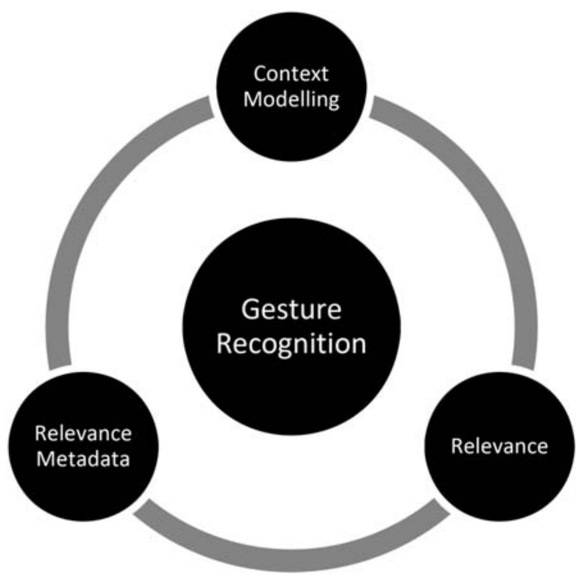

Figure 13: Gesture Context Methodology

Without the benefit of the context surrounding, meaning of that gesture will be less understood by the system. There has to be context understanding of the gesture in order to comprehend the intended meaning. In our system to determine the Context we use Context Modelling, relevance and relevance metadata. The methodology to recognize the context of the gesture is shown in the Fig. 13.

4.6.1. Context Modelling

Generally speaking, the precise definition is obtained by means of a context model, additionally permitting the appliance designer to specify the constraints to all the potential contexts associated with its application. Moreover, a context model ought to even be ready to model the association between every context and relevancy for that context.

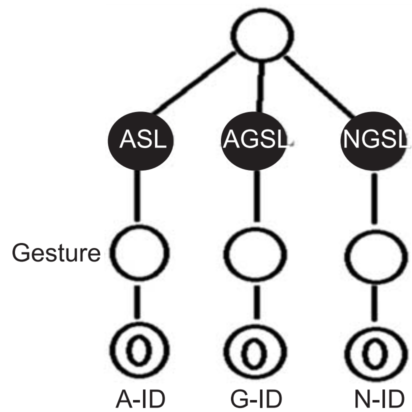

Figure 14: Gesture Context Modelling-GCM

As modelled in [13], the Fig. 14 shows Gesture Context Model compatible with the domain and the gesture contexts envisaged. In a GCM, dimensions are represented by black nodes while value is represented by white nodes. An edge (*b,w*), where *b* is a black node and *w* is a white node. Edge(*b*, *w*) represents relationship between a dimension and value (i.e., the context-model allows the association of the value *w* to the dimension *b*), while an edge (*w, b*) represents the specification of a sub-dimension, *i.e*., whenever a dimension assumes the value *w*, it is possible to specify further the context by assigning values to the sub-dimension *b*. *Parameters* represented in Fig. 14 as nodes with a double border will be used as identifier. Parameters may also be associated to dimensions especially in those situations where we have a large number of values for a given dimension and we do not want to elicit all of them.

4.6.2. Relevance

"Relevance" is significant in any context aware system. Relevance of the context depends on any one or all of the following; Time, Person, location and object. User interaction with the system will have a purpose to get most relevant and appropriate data. In a GCM, we specify relevance as set of rules or conditions or statements for the dimensions, we implicitly identify a point in the multidimensional space representing the possible contexts *i.e.*, we *instantiate* a context. All the combinations of dimension-value assignments are not necessarily meaningful or even coherent. In order to prevent certain combinations of values from being present at the same time in a context, the *GCM* provides constraints of the form $!(a_1, \ldots, a_n)$, whose semantics is to restrict the contemporary presence of the values $a_1, \ldots a_n$ in a context. In the *GCM* model a valid context (*i.e*., compatible with the context-model) is a combination C of the dimension-values such that:

1. Each black node corresponds to one child white node (C),
2. C does not contain two values *w*,*w*_ such that *not*(*w*,*w*_) is in the *GCM*,
3. If node belongs to C , then all the ancestor node also belongs to C.

The relevance for the gesture shown by the student in Fig. 12 is identified by the context "mathematical" hence the relevance for the symbol is identified.

4.6.3. Relevance Metadata

Gesture relevance metadata defines the gesture-independent vocabulary used to build a context model. The gesture vocabulary is constituted by a set of enumeration expressing the high-level constraints common to the gesture dimension;

Table 2
Relevance Conditions

Condition	*Explanation*
Condition (1)	Ensures that all the assignments dimension-value are unambiguous.
Condition (2)	Ensures that all the forbidden combinations of values do not appear in the same context
Condition (3)	States that whenever we assign a value to a sub-dimension, the values for the corresponding super-dimensions are deterministically assigned according to the structure of the context model.

In other words, the gesture context vocabulary provides the means for representing the gesture and the meanings of the context-model. The full specification of the gesture context-vocabulary is explained as follows:

"ASL" context that handles actions related to a American sign language alphabet gesture information (Fig. 15*a*);

"AGSL" context that handles actions related to a greek sign language alphabet gesture information (Fig. 15*b*);

"NGSL" context that handles action related to greek sign language numeric gesture information. (Fig. 15*c*);

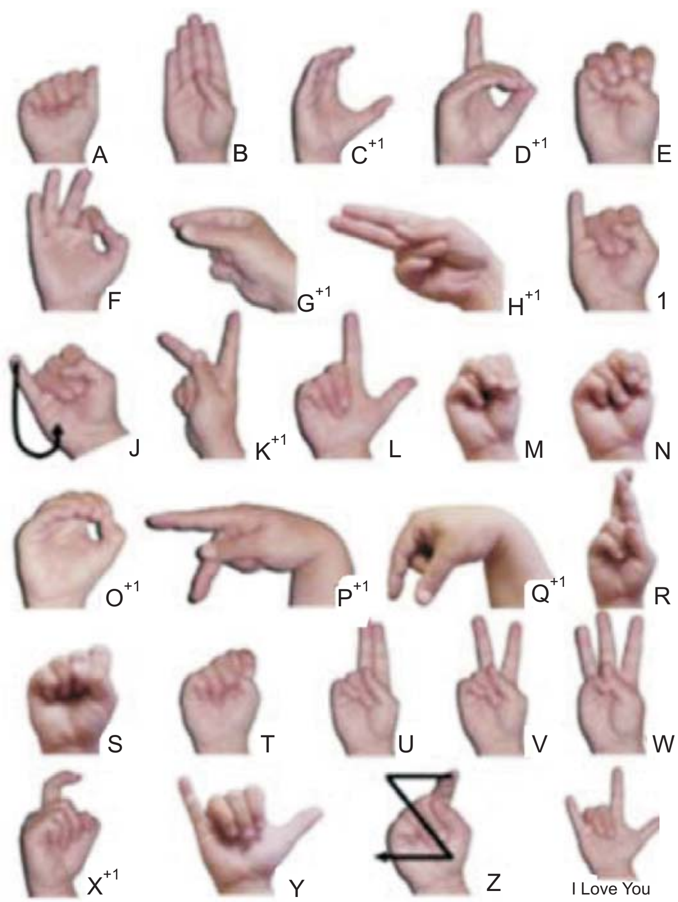

Figure 15: (*a*) American Sign Language

As shown in the following Fig. 16, Context modelling, relevance and relevance metadata were utilised to make the system as Context Aware Gesture Recognition system.

Figure 15: (*b*)

Figure 15: (*c*)

Figure 15: (*b*) and (*c*) Greek Sign Language-Alphabet and Numeric

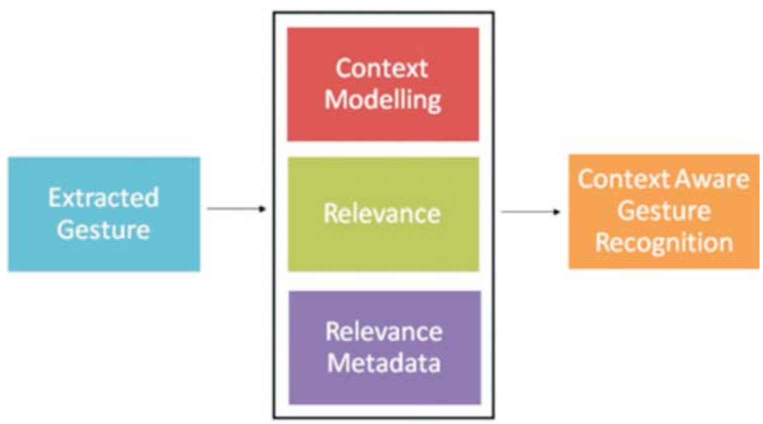

Figure 16: Context Aware Gesture Recognition System

To recognize the gesture shown by the student in Fig. 12, the system understands the relevance by the scenario subject "mathematics" and chooses NGSL context. Differentiation between the 'Δ' and 'δ' gesture is understood with the help of the relevance of the gesture context "NSL" and relevance metadata. Fig. 17 illustrates the recognition.

4.7. Visual layout Module

This section describes the visual layout of CA-GR. Visual layout is a simple and effective means of helping the users of the system. Visual layout in CA-GR will use images, gestures and displays the written textual information, which will act as a reference point beyond normal spoken communication and it will enhances the ability of learning. CA-GR performs a visual layout with well-designed templates to generate the visual message from those gestures and audio which corresponds the respective gesture and this module represents only the concepts but not the logical meaning. This module is responsible for bridging the gap between sign language users and spoken language users in a classroom environment. This layout will also support the slow learners and beneficial to students who are predominantly visual learners. The context of the gesture recognised in Context aware module is compared with the predefined gesture database to display corresponding image, text and audio user in the screen of CA-GR (Fig. 18).

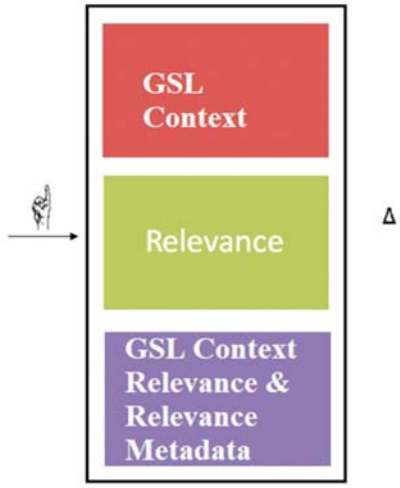

Figure 17: Output of the gesture

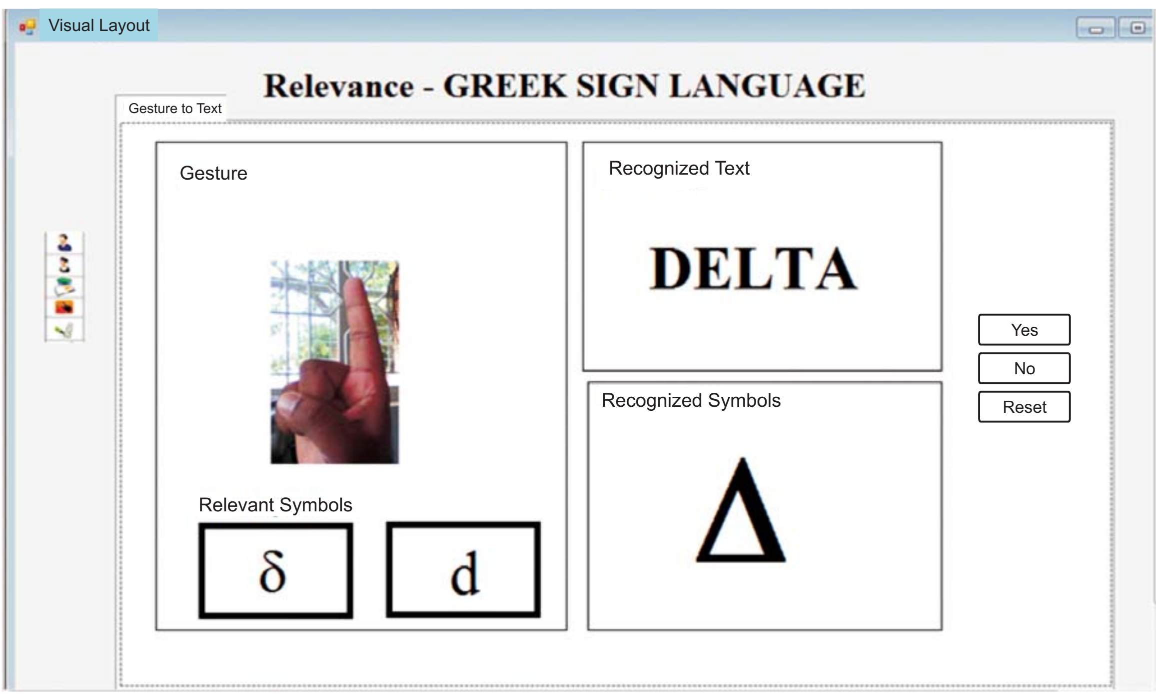

Figure 18: Visual Layout

5. EVALUATION

The CA-GR systems was evaluated during two phases of in-class testing during mathematics lecture course at A.Veeriyar vandayar Memorial Sri Pushpam College (Autonomous) , Poondi ,Thanjavur, to explore gesture recognition capabilities and respective context in Teaching-Learning. We used a case study methodology incorporating cognitive walk-throughs with normal students, students with disabilities, and instructors, to evaluate the potential benefits of CAGR , technical implementation of CA-GR with sign language recognition and conversion accuracies with different contexts. Prior to evaluation of the system, instructors were trained to operate the system and provided initial best practices for improved GR accuracy.

5.1. Phase 1 Initial Evaluation with CA-GR System

In the first phase of the evaluation, the teachers rated the system using the questionnaire shown in Table 3. The teachers were told to bear in mind that the system was aimed at recognizing gestures in teaching students having disability. The responses to the questionnaire were measured on a five–point Likert scale ranging from 1-5 Likert scale with interval 1, which means ’very bad’, ’bad’, ’average’, ’good’, ’very good’, respectively. Additionally the experts were asked to rate the system from 0 (minimum) to 10 (maximum); there was also an open question to write comments or remarks. The results of the questionnaire are summarized in Table 4. It can be observed, that the satisfaction with technical aspects is high, as well as the perceived didactic potential.

Observation from the questionnaire suggests that the CA-GR is considered good-looking and satisfactory. The teachers also consider that the system succeeds in making students understand the teaching concepts easily. Although the results are very positive, in the open question the teachers also point out desirable improvements. One of them is to make the system in regional vernacular interface. Also, although they consider the CA-GR attractive, they suggest to create new gestures to make transitions smoother. From the interactions of the experts with the system we completed an objective evaluation of the application considering the Gesture Question success rate (GQSR). This is the percentage of successfully completed questions: system questions some gesture – user answers with respective gesture – system provides appropriate feedback about the answer. We achieved 96.56% correctly for the interaction by different experts.

Table 3
Questionnaire Employed for the Evaluation of the System by Teachers

	Technical quality
TQ01	Interaction of the system
TQ02	Accessibility of the system
TQ03	Support of the system in recognizing gesture
TQ04	Reliability of the system in recognizing gesture
TQ05	Performance of the system
TQ06	Ability of the system to understand various gestures of sign language
TQ07	Whether CA-GR is attractive?
TQ08	Whether CA-GR reacts to gesture in a consistent way?
TQ09	Whether CA-GR complements the activities without distracting or interfering with them
TQ10	Whether CA-GR provides adequate verbal and non-verbal feedback?
TQ11	Whether CA-GR supports completely context awareness for the sign language?
	Teaching potential
TP01	Do the system fulfils the Learning objective of making students to learn
TP02	Do the contents covered in the activities are relevant for this objective
TP03	Do the design of the activities was adequate for students with disability
TP04	Do the activities support participative learning of students?
TP05	Does the gesture feedback by the system improves learning of students
TP06	Does the system encourage continued learning after feedback

Table 4
Results of the Evaluation of the System by Experts

Question Number	*Minimum and Maximum Likert Scale*	*Average*	*Standard Deviation*
TQ01	3/5	4.17	0.69
TQ02	¾	3.67	0.47
TQ03	4/5	4.83	0.37
TQ04	5/5	5.00	0.00
TQ05	4/5	4.67	0.47
TQ06	4/5	4.83	0.37
TQ07	4/5	4.83	0.37
TQ08	4/5	4.50	0.50
TQ09	4/5	4.83	0.37
TQ10	4/5	4.67	0.47
TQ11	3/5	4.50	0.76
TP01	5/5	5.00	0.00
TP02	4/5	4.67	0.47
TP03	4/5	4.83	0.37
TP04	5/5	5.00	0.00
TP05	4/5	4.67	0.47
TP06	4/5	4.83	0.37

5.2. Phase 2 Evaluation of Student Class Performance in a Mathematical Course

To evaluate the effectiveness and the performance on our CA-GR, we have conducted a classroom study in a mathematical class at A.Veeriyar vandayar Memorial Sri Pushpam College (Autonomous), Poondi. In this experimental class a combination of normal students and differently abled students were taught with mathematical symbols.

5.2.1. Method

The study lasted one week in the classroom for a total of five classroom periods. After three classroom periods, the effectiveness of the system was assessed by the questionnaire analysis.

5.2.2. Measurements

To measure the students' improvement towards CA-GR System, we conducted a questionnaire analysis. Then each person gave a score to four aspects: (1) effectiveness , (2) convenience, (3) usefulness, and (4) understanding. Students were asked to answer questions using a 1-5 Likert scale with interval 1, which means ’very bad’, ’bad’, ’average’, ’good’, ’very good’, respectively.

5.2.3. Results

Overall, the students replied highly positive to the questionnaire items as shown in Fig. 19. The reliability test (Cronbach's Alpha) shows high scores for effectiveness, convenience, usefulness and understanding.

5.3. Issues for CA-GR implementation in classroom

However, in order to make the system function, optimally, the following limitations have been identified:

1. The system recognizes the hand gesture of only one person at a time.
2. The gesture needs to be identified should be within a specific depth range (~70cm)
3. There should be no obstacle between the camera and the gesture to be recognized.
4. The palm and forearm should be clear and close for effective context awareness
5. The two hands should be spread apart, and gesture for hands should not be mismatched

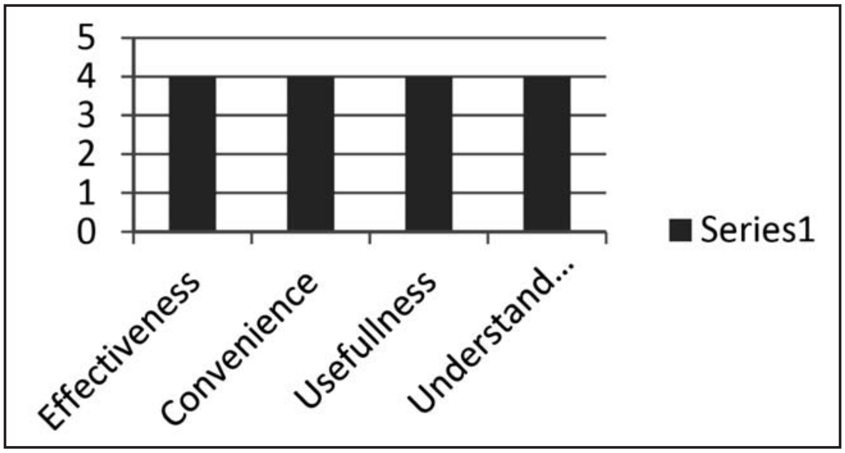

Figure 19: Students Performance Evaluation

6. CONCLUSION

In classroom environment, communication has to be interactive for efficient and effective understanding of concepts. Although there are benefits to tangible interaction, there might be situation for the less need of tangible devices and the more mode of interaction. One such interaction is sign language interaction. Sign language is the basic alternative communication mode between deaf people and normal pupils. Understanding the sign language communication needs some expertise, but the system that we proposed doesn't need any expertise, the system recognizes the gesture as well as the context of the sign language.

The presence of an easy to use and customizable user interface in CA-GR will ensure that teachers who are using the system for the first time will not face any difficulties. Our system enables both students and faculty to be become more interactive and enhances the confidence of differently-abled students, which in turn will make them more competitive just like any normal students. Teachers' who have no prior knowledge of any sign languages will face an overwhelming task when it comes to teaching differently abled students particularly speaking and hearing impairment. The proposed system enables them to convey their teachings in an effective manner which is easily understood by differently abled students. Our system easily fixes the issue of understanding the context of the gesture to the communicators and provides students with contextual learning. Demerits of wearable and web cam based devices in sign language recognition are taken care by our system which uses Kinect sensor. Its user groups also recognize the need for more educational and teaching applications. Applications might be free or commercial. From a technical point of view, there is a vast scope in future for research and implementation in this very field. The upcoming years could witness a combinatorial explosion of different methodologies, such as using several gestures in parallel or independent coupled with context awareness.

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