THE HONG KONG POLYTECHNIC UNIVERSITY

RESEARCH DEGREE PROPOSAL

(To be typewritten by the Applicant)

Note: Please note that the information given in this form will only be used for processing this application.

1. **Name of Proposed Chief Supervisor (if applicable):**

Prof. Kenneth Fong

2. **Project Title:**

The use of machine learning (ML) algorithms to quantity multi-modal means for argumentative and alternative communication (AAC) in daily activities for people with Cerebral Palsy

3. **Project Objectives: (Purpose of proposed investigation)**

1. To interpret big data on the verbal mean through speech recognition and non-verbal means through body gestures, movements, and facial expressions on real-life communication for people with Cerebral Palsy of different ages, types, and severities.
2. To develop a machine learning (ML) algorithm for the use of argumentative and alternative communication (AAC) in basic activities of daily living (BADL) for people with Cerebral Palsy.

4. **Scope and Background of Research:**
(Please identify key issues/problems to be addressed)

Cerebral Palsy (CP) is a severe neurological condition when a brain injury occurs due to a lack of oxygen in delivery, early birth, or contracting certain diseases during pregnancy. This condition primarily affects their four limbs, body posture, and coordination or even triggers severe symptoms, including vision, speech problems, walking, unstable hand movements, and learning disabilities. It is not a perfect treatment to recover the full functionalities of their body [11]. According to the statistic report of CP global population is approximately 20 million people, and the newborn rate of CP is avenged 1.8 out of 1000 in developed countries and 2.8 out of 1000 in developing countries [14]. There are four systems to use for the functional classification of CP: GMFCS, MACS, CFCS, and EDACS. GMFCS has five levels of describing voluntary movement and the use of aid for motion to revise the age of 2-18; MACS is five levels of evaluation of the functions of the upper limbs and is used for the age of 4-18; CFCS is five levels of assessment the communication with other people or their family; EDACS is determined whether sallow food and drink in safety. however, this evaluation procedure is needed to classified by the medical staff, including doctor, OT, PT, and ST in case by case. The research has exploited the five machine learning techniques to classify the CP cases in Jordan's electric health record system, including K-Star, Multilayer Perceptron, Native Bayes, Random Tree, and Support Vector Machine [1].

The research report has found that about one-third of CP is non-verbal or has varying speech barriers. Still, people can communicate their needs and feelings and connect with others [15]. Therefore, it is a crucial life skill. People with CP and other speech disorders also have complex communication needs (CCN) and may experience difficulties and challenges communicating with others [12].

Augmentative and Alternative Communication (AAC) can augment and leverage existing communication skills for many non-verbal patients. In the technological era before, AAC was performed by these speech therapists in the form of traditional face-to-face therapy involving sign language and gestures. It uses physical communication cards and activities as an alternative method of communication [15]. But with the technological advancements in AAC it can enhance communication and therapy for people with speech and language impairments through technological advances in digital devices that are more advanced and user-friendly today. Many AI-based mobile/iPad AAC applications have matured over the past five years. These applications make AAC technology accessible to millions of patients worldwide. Due to technological advancements and computing requirements at lower cost, it is possible to generate voice through IT devices for communication [4]. The markerless motion capturing system is a crucial computer vision feature for recognising the human motion pattern, which uses the movement capturing camera and plots the 3D skeleton model on the screen, for example, Kinect device or high definitions digital camera—increasing the image quality that is using the HSV colour space, instead of the RGB model. It can reduce the brightness noise and accurately analyse this movement behaviour in the video recording. Therefore, several research studies have measured voice, hand gestures, and facial expressions using machine learning techniques to train these kinds of data when it has annotated labelling in this dataset [7].

The occupation therapist has exploited the video sports game when they need to use therapeutic gesture detection by wearing electromyography and inertial sensors with CP patients. There have been uses of random forest classifications to select the most discriminative, person-specific features during the calibration and classification process. Then, the therapists can use this subset of features to train a support vector machine for their body gestures [2]. The IntellWheel project is driven by an intelligent wheelchair using facial expressions and a brain-computer interface by people with CP. It is based on proper signal preprocessing of Hjorth parameters and is used in several classified data mining algorithms such as Naive Bayes, Neural Networks, and Support Vector Machines [3]. The artificial speaking system is based on capturing information from gestures through flexible sensors and MEMS accelerometers. Each motion has a specific meaning, which is used in everyday communication. The artificial voice is generated using hand movements through an artificial neural network [7]. The LIVOX app has applied the NLP and neural network to organise the vocabulary card for communication between people with speech disorders and their interlocutors, especially CP children. At the same time, they have to join social and educational activities daily [12]. The intelligent wheelchair system has exploited the MediaPipe framework with gesture recognition to control the wheelchair movement and special functions of people with Cerebral Palsy [10].

There have transformed the literature review and research gap in the table, which is shown below:

literature review
research gap identifier - table 1 details the selected studies

Study	Type of patient samples	Type of investigation technology / human postural detection system	Measurement items	machine learning technique /types	Content of measurement	Context of measurement/environment criteria/national	Primary results	Results interpretation	Limitations criteria
A. Macintosh et. al. 2021 [2]	Nineteen young people with CP, MACS I-II with no medical treatment within three months or constraint-based movement therapy within six months.	EMG and inertial sensor, commercial video game Dashy Square and custom controller for recording the movement and command in the game	real-time gestural recognition identifies therapeutic activity for game feedback and control	random forest and support vector machine	The procedure uses features intended to be sensitive to signs of CP and leverages directional statistics to characterise muscle activity around the forearm	4-week home-based intervention in France and Canada.	Components exposed to signs of CP significantly contributed to classification and correlated to wrist extension improvement.	variety of the gestures in CP people and demonstrating a new gesture controller to facilitate home-based therapy gaming	- Lack of sample data collection and no poor hand function participants had included - Complexity of system configuration environment needs to fine-tune the activity threshold weekly. By researcher - No implementation of

									deep learning methods is increasing more accurate predication, e.g. CNN - need to classify the target gesture in three classes by participants clearly and collect more testing data.
B. M. Faria et. al. 2012 [3]	30 CP people with GMFCS IV-V and all use of a wheelchair were 28 years old, with 73% males and 27% females. Of their school level, 36% have an elementary school, 27% have a middle school, 27% have a high	BCI device with EEG signal and central nervous system, Intelligent Wheelchair system	measurement of facial expressions is: smile; left smirk; right smirk; blink the eyes; blink the left eye; blink the right eye; furrow; clench; eyebrows and normal	Naive Bayes, neural network, K-Nearest Neighbour, Linear Discriminant Analysis and support vector machine	These facial expressions are interpreted in some movement directions, e.g. forward; back; left; right; left spin and right spin.	The indoor environment of the cerebral palsy center in Belgium	the preprocessing and variable selection methods were effective, enabling to improve the results of a commercial BCI product by 57%	the developed system has performed a circuit in a simulated environment using just facial expressions and thoughts.	- No implementation of deep learning methods is increasing more accurate predication, e.g. CNN with LSTM - No consideration of

	school, and only 10% have a bachelor's degree. The dominant hand was divided as 50% for the left, 33% for the right hand, and 17% did not answer								- filtering the abnormal facial expressions for CP people - small sample data collection and no system testing for outdoor environment
Ikeda et. al. 2020 [7]	One participant for athetosis type CP, a 20-year-old male	voice recognition technique for MFCC	measurement of Japanese vowels	SVM, Linear Discriminant Analysis	interpretation of five English vowels, e.g. a, I, m, e, o	rehabilitation center for Japan	The results were compared with those for conventional communication aid tools such as transparent communication boards.	The time required for communication using our proposed method was shorter than that required using traditional communication tools.	- tiny data collection and only focus on Japanese - the participant's head movement has been recognised by OT instead of deep learning methods. E.g. CNN

Neamtu et. al. 2019 [12]	special for people with speech disorders	Android mobile platform	finger touching area on the screen	NLP, Neural Network	selected the vocabulary card on the touchscreen	No specific venue for using this mobile app	The LIVOX app has applied AI algorithms to organise the vocabulary card for communication between people with speech disorders and their interlocutors	This enables people with disabilities, especially children, to participate in daily social and educational activities.	- No emotional speech and speak English and Spanish - Only have English system interface and single input method - touch screen
Huda et. al. 2022 [10]	No specific for people with cerebral palsy	Webcam system with MediaPipe framework	measurement of several hand gestures, e.g., the tip of the single index finger, open and closed hand	2D CNN	interpretation of four driving directions, open and close power	indoor environment in Bangladesh	developing a prototype of an advanced algorithm for gesture recognition and decision-making for a control system for intelligent wheelchair users	The MediaPipe framework with gesture recognition is a greater emphasis on users' flexibility by requiring less hand movement	- No invitation of any CP people for the system testing - No filter abnormal muscle tone.

The research gap findings have been demonstrated in three bullet points below:

- Lack of sample data collection for people with cerebral palsy and only focus on the non-Chinese language environment
- The existing AAC systems are only entirely dependent on users' input, not considering the real-time presence to prompt some relevant wording or sentences on the screen when they can choose very quickly
- No implementation of the machine learning techniques to filter some abnormal facial expressions, e.g. involuntary facial grimaces

Hypothesis

- To compare with using the AAC System for people with speech disorders' responding time when the system depended on their input or provided some keywords based on real-time presence.
- To compare with using the computer or tablet methods, more accuracy rates of selecting the system items when using their head movement to pronounce one out of four vowels or using their hand gesture to pronounce one out of four vowels.

5. Research Methodology:

1. To interpret the big data of multitype gestures and voice data for people with CP

- Development of new mobile apps for AAC System and need to input some personal information when a new user is registered, e.g. year of birth, CP type, MAC address of this mobile device and GFMCS level
- Provide the system interface with self-defined specific gestures, head and body movements or pronouncing English vowels when switching the selected item in the system interface and confirming the item chosen.
- Collecting these kinds of data to upload them on the private cloud server and building up the personal profile when the gesture recognition rate is ≥ 80 or recording them for the first time.

According to the poor four limb function control of people with cerebral palsy whose having classified each GMFCS level, they can only do some joint or simple body movements, facial expressions, and gestures in different types of CP with severity levels. There has elaborated in the table which is shown below:

Severity	CP Type	Facial expressions and gestures	pronouncing English vowels
GMFCS III-V	Athetoid and spastic	Shirk head and nod, blinking both eyes or continuously opening the mouth at least 3s.	Focusing on the four English vowels 'a', 'i', 'o', 'u', their speech is inconsistent if they investigated monosyllabic words instead of vowels.
GMFCS III-V	Athetoid and spastic	Turn the head in left and right, tilt the head in left and right.	
GMFCS I-III	Ataxic and spastic	Open and close with a single hand at least 3s continuously	
GMFCS I-II	Ataxic and mixed	Some single hand signals, e.g. good, bad, ok and no, etc., within at least 3s continuously	

The development of multi-type gesture and voice-recognizing big data systems for people with cerebral palsy is based on machine learning methods to facilitate their control of computers and mobile devices through AAC tools in daily life and achieve barrier-free communication in work and study environments. The system will decide to use specific body posture, head movement and sound frequency according to the severity levels of disability of the CP patient to control the direction of mouse movement and clicking behaviours. They have poor control of involuntary movements and voice, and their limb function and face

muscle control abilities are also different. Comparing ordinary people and similar symptoms cases is impossible in this case when these datasets represent the system output. Therefore, data training compares the system's posture and audio frequency stored individually rather than with other people. When the system can keep a large amount of data of the same type, the generated data trains the ML model, which can easily recognise their body movements and audio frequency and accurately predict the meaning expressed.

This ML system will be developed based on supervised learning. A machine learning model of a deep learning architecture "transformer" will be adopted, mainly used to train large language models and process them in parallel according to the input sequence. However, it must be calculated in a time series sequence, e.g., RNN and LSTM. When the time distance is farther, the possibility of practical occurrence is lower, so it is not very helpful for people with cerebral palsy to speed up text input. The existing AAC systems have applied the traditional NLP technique to propose related words in the candidate list when users can choose them and help speed up their typing. Still, the policy of output word processing is based on users' typing history or selection frequency according to the time series instead of focusing on the contents and feedback generated. So, their interlocutor must focus more on waiting for the users' input feedback [6]. In this research proposal, the aim is to provide some feedback related to the interlocutor's content simultaneously, so the crucial part is focused on which wording is the most important and assigned the top scores of weight; the weight score of other words have listed out of ascending order, such as the local attention mechanism is use the wording elements for input sequence and focus on dependencies closed to the sequences beginning or close. This model is good for the contents-specific decision because it can make the weight score of these elements dynamic. This multimodal architecture consists of three main components: an encoder, which converts webcam image and sound-to-text input into a vector representation; a decoder, which generates text output from the vector representation; and an attention mechanism which allows encoding. The encoder and decoder focus on the relevant parts of the input and output. In this case, the system should use KOSMOS-2 to describe the image's content and the positioning of each detail, using the GPT4 technology to generate the next sentence prediction and retrieve the user's past text communication records for reference [17]. Therefore, they can significantly improve daily communication skills.

This research proposal will collect pixel-based video frame data on the gestures, facial expressions and voice pronunciation of people with cerebral palsy, and these data will include video clips, real-time audio and video streams. As the muscle tone of people with cerebral palsy is poor, it is unstable to control their movement and facial expression. Their gestures may be made differently than every time. Thus, the system can only choose the most straightforward head movement and one-hand movement to express the command to control the computer. For example, palm open or collapse means the mouse's left or right click. In addition, it needs to eliminate some involuntary movement of the system users instead of relying on static images and existing gesture training models to judge their intentions. First, the system will exploit the Vision Transformer (ViT) model, divide the image into multiple patches and input into the attention model's encoder module. It maps a series of image blocks to semantic labels as an image classification method. It differs from CNN in its self-attention mechanism and its ability to achieve early aggregation of global information. In addition, the ViT model uses a tokeniser to convert a feature map into a series of tokens, which are then fed into a transformer, which applies an attention mechanism to generate a series of output tokens. Then, the output class labels are passed through the multi-layer perceptron head to obtain the final class prediction. Second, it used the Haar cascade algorithm (HCA) to recognise various gestures and head movements of each user's video clips or real-time video streaming when they can self-defined their gesture or facial expressions and build the training models [8].

To ensure the system can prevent making wrong decisions, users must concentrate on the webcam when they make certain gestures and facial expressions for at least 3 seconds to confirm their choices every time. First, there is a need to build up a training model for the system. When the CP patient has done each gesture or facial expression to record the video around ten times during the initialisation step, their pose coordination values and duration time frame are extracted to store in the database. By default, there have been 60 images within the video of one second; each clip should contain around five to ten seconds. If the duration is shorter, the gesture may be uncertain. Oppositely, they should lose patience and feel tired.

simple block diagram for the multitype gesture system
initialisation step:
For the recording video times: 1 to 10 and input the type of gesture or facial expression
Recording video → extracted the number of images in a video frame(1) → each frame cut off the small image patch of fixed-size → input to the linear projection of flattened patches and labelled these data

patches to position embedding (2) → output to the transformer encoder and using the MLP classification → finding targeting class in the image, hand or face → using the HCA to extract the gesture or facial expression features by the pixels of image → stored the values of coordinates and image index in database.

(1) Assume that the video duration is 6 seconds and contains 360 images total, because the system is needed to ensure their gesture or facial expression is correct, the extracted sequences of images should only focus between 3 and 5 seconds. The number of image locations has contained 180 to 300 to store in the array.
(2) Let i=image index, i=180(input image[i]→cut off the nine small patches and store in matrix form with labelling the position embedding between 1-9 …… i=300 → transformer encoder (Norm → multi-head attention + Norm → MLP)
End for

Second, real-time video [assume that the cycle of video duration is 6 seconds and extract the image index between 180 and 300 to store in the array; it is a testing dataset]
Set i=image index
Set training_datamodel[x,y,i] = fetching the record in database
Set testing_datamodel[x,y,i]

For i=180 to 300 // first 1 or 2 seconds, the user may have some abnormal movement when they do their specific gesture or facial expression, so the system should ignore them
x,y = extract the image[i] of 2d coordination values in transformer encoder for using HAC
set testing_datamodel[x,y,i]
end for
SVMModel(training_datamodel, testing_datamodel, testing_size=3)
Print accuracy rates

If accuracy rates > 80 ok : failed

As the training dataset is small, it's only focused on individuals instead of comparing with all system users, so the SVM is appropriate in this case. This proposed system is needed a high accuracy rate in the small dataset because people with cerebral palsy control their IT device during gestures or facial expressions.
Experiment design
For the initialisation step, each user needed to record the same video clip and their pronunciation of these vowels when they have chosen around ten times for each body gesture or facial expression and their voice.

1) In the workflow of this program, the system interface has provided self-defined movement directions for their own. It is a base sample data, and the system setting of recognition similarity rate should be reasonable around 80% when it is triggered by the moving direction by them. Suppose the dataset has grown up for using these users frequently. In that case, the system should automatically increase the similarity rate by 90% and estimate their movement features more accurately than they want.
2) using the real-time webcam system, records the participant‘s action to store in a private cloud server and extract their movement features to analyse in our Python or Microsoft app system, which is the training model in the database, using supervised learning techniques.

2. proposing a new system design for AAC System
- capturing their interlocutor's voice to use the voice-to-text techniques for prompting on the screen, and using NLP techniques to provide at most eight relevant sentences for their choosing; or capturing the real-time environment object for using object classification to identify this object what is it and provide at most six appropriate wording or sentences for their choosing. While they have selected the sentence item, the system should speak it out.
- the system should automatically store their communication history and e-mail data in a web database. At the same time, they have input the first sentence on the screen, and the system can use text mining with a self-attention algorithm to estimate what they need to talk about in the following sentence.

Participant‘s invitation
- invitation of 10 people with Cerebral Palsy and non-verbal or speech disorders who have trained the speech therapy in Hong Kong special schools and handicapped workshops; aged between 6 – 19 years old, e.g. JFKC, SAHK etc
- invitation of 10 people with Cerebral Palsy and non-verbal or speech disorders who have trained the

speech therapy in CN cornerstone association; aged between 6 – 19 years old

Reference

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6. Project Significance and Value:

In this project, the machine learning algorithm with argumentative and alternative communication systems will be developed for the next-generation communication tool for people with cerebral palsy. It will collect real-time data on their body gestures, facial expressions and voice frequency when this system can interpret the cursor movement control, select the responding sentence appropriately or the specific system commands for using ML techniques. It is an innovative input method for them and reduces the frequency of typing errors for using their limbs. We hope the computer can know what they want to say or even estimate what they must do next. It can enhance their self-confidence in communication, learning, and working, contribute to their ability for society, decrease the financial burden for the social welfare system and reduce the high stress of caring responsibility their caregiver for the long term. So, this project is necessary and worth doing. We believe it can turn a new page in the research field of computer science, rehabilitation science and assistive technology.

7. Details of Any External Collaboration:

N/A

In these circumstances, are there likely to be any complications associated with the publication of your thesis? Give details.

N/A

8. Declaration of the Applicant

I wish to register for a research degree on the basis of the proposal given in this Form (GSB/1A).

I understand that, during the period of my registration with the University, I may not be a candidate for any other degree or award.

I understand that, except with the specific permission of the Research Committee, I must prepare and defend my thesis in English. (You are required to seek permission if another language, which is considered more appropriate to the subject, is to be used in the presentation of the thesis. Please submit the justification together with this application.)

I undertake to abide by the general regulations of the University.

Signature 張世豪 Date 25 August 2023

Name Cheung Sai Ho

During the application period
After completing Sections 1 to 8, the applicant should upload this form to the eAdmission system at www.polyu.edu.hk/admission.

After admission
RPg students should submit this form to the General Office of the Department after completing Sections 1 to 8.

For internal use only. Applicants should leave Sections 9 and 10 blank.

9. Endorsement by the Proposed Chief Supervisor

9a. Research Ethics/ Safety Approval

[For ethics approval, Chief Supervisor / Temporary Chief Supervisor please read the Ethical Clearance for Research or Teaching Projects or Investigations Involving Human Subjects, which are available at Section V of the Handbook for Projects and Grants at https://www.polyu.edu.hk/ro/staff/handbooks/HD_PG.pdf, and make sure that ethics approval is obtained if your project involves human subjects. For safety approval, please read the policy and procedures for safety approval available at the Health, Safety & Environment Office Homepage. Please attach the approval letter where appropriate.]

I confirm that approval:

	* has been Obtained	* is not required	* will be obtained before the start of the project
Human Research Ethics	☐	☐	☐
Animal Research Ethics	☐	☐	☐
Biological Safety	☐	☐	☐
Ionizing Radiation Safety	☐	☐	☐
Non-ionizing Radiation Safety	☐	☐	☐
Chemical Safety	☐	☐	☐

(* Please tick as appropriate)

9b. Research Facilities and Space

☐ I confirm, to the best of my knowledge, that adequate facilities and space are available to enable the student to conduct and complete the research programme in an efficient and safe manner.

☐ I would like to request the following additional research facilities and/or space to enable the student to conduct and complete the research programme in an efficient and safe manner:

Research Facilities	
Space (Other than the regular space provided by the Department for RPg students)	

Signature _____ Department/School RS

(^ Chief Supervisor / Temporary Chief Supervisor)

Name Prof. Kenneth Fong Date _____

(^ Chief Supervisor / Temporary Chief Supervisor)

(^ Please delete as appropriate)

10. Recommendation of Head of Affiliated Department in the University

☐ I support this application and understand, on the basis of the Chief Supervisor's endorsement, that adequate research facilities and space are available to enable the student to conduct and complete the research programme in an efficient and safe manner.

☐ I support this application and agree to provide the additional research facilities and/or space, as requested by the Chief Supervisor in section 9b above, to enable the student to conduct and complete the research programme in an efficient and safe manner.

Signature _____ Date _____
(Head of Department/Dean of School)

~ The completed form should be kept by the General Office of the Department. ~