Playing Games via Personalized Gestural Interaction

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***Abstract*—Motivation is a key element in the learning process, and using games for this goal is an undeniably attractive option. However, individuals with motor disabilities are still finding themselves excluded from many game-based school approaches. This paper presents a solution developed for people with motor and speech impairments that includes a game-based approach to contribute in this context. Based on a methodology in which gestures and their meanings are created and configured by users and their caregivers, we developed a Computer Vision system named PGCA that employs machine learning techniques to create personalized gestural interaction as an Assistive Technology resource for communication purposes. This personalized gestural interaction enabled disabled people to interact with the PGCA system and play a game using their remaining functional movements. Results from experiments carried out with the target audience indicate that the structure used in the developed system can be expanded to create new games, with different purposes, including to educational context.**

***Index Terms*—Assistive Technology, Gestural Interaction, Machine Learning, Games, Education.**

I. Introduction

Games can be supportive resources in the school environment, as they represent a motivating activity that can reinforce concepts and support teaching standards [1]. Furthermore, in the educational context, using games as a teaching-learning strategy offers the student the opportunity to develop several skills and learning in an interdisciplinary scenario [2].

Computer games are an undeniably attractive alternative for students. However, for some people with motor disabilities, using traditional devices is not possible, needing support from Assistive Technology to play. These players demand alternative means to interact with computer systems or games, so gesture-based games can be a way to make this interaction feasible.

A gesture is a non-verbal communication performed with hand, finger, head, face, or other body parts. Interaction based on gesture recognition has the potential to consider particularities and capacities of each user when performing movements, being considered "natural" and even intuitive because humans learn to use gestures since childhood [3].

Computer Vision systems can benefit from recognizing users' remaining functional motions as an alternative interaction design approach without contact with a physical device. In recent years, gesture-based games have been increasingly used in education, and positive effects have been reported [4].

Investigating personalized gestural interaction, we have developed a Computer Vision system named PGCA (Personal Gesture Communication Assistant). The system is based on a methodology to support Augmentative and Alternative Communication (AAC) [5] [24], named MyPGI (Methodology to yield Personalized Gestural Interaction), in which gestures and their meanings are created and configured by users and their caregivers. Based on MyPGI, PGCA was conceived to recognize movement patterns for gestural interaction captured by a low-cost camera. A game-based approach has been included to motivate the execution of personalized gestures used for AAC, helping in training both the users and the system. The positive results observed in experiments carried out with students with motor and speech impairments, reported in [6], encourage using the same system to generate other games for this target audience, including those aimed at the teaching-learning context.

To contribute in this direction, this paper presents a game developed for this target audience, examples from its practical use in real setting, and the proposal to use the PGCA system structure to create other games with different purposes.

II. Related Work

Motivation and engagement occur in games designed for different purposes; however, for people with motor difficulties, this may be only possible when adequate Assistive Technology resources support them.

The PGCA system was created to support AAC. Still, the personalized gestural interaction enabled by this system can be used in the educational context through communication boards with different themes or even with educational games.

Games have been proposed to users with motor impairments. Foletto et al. [8] present a serious game to help rehabilitation and therapy for Parkinson's disease patients. Lopez et al. [9] proposed GNomon, a framework that provides specific functionalities for creating accessible digital games for children with severe motor disabilities, interacting with electronic devices via a single switch only. Jiang et al. [10], [11], in turn, converted a gesture-based interface designed for people without disabilities into an interface usable by individuals with motor impairments.

These and other initiatives have explored more opportunities for inclusion in the school environment and also for rehabilitation. However, has not to our knowledge been previously investigated games supporting personalized gestural interaction, therefore reducing the audience they are able to reach. Enabling people who have motor difficulties to interact with a game is not "just playing a game" (which is fun and provides learning benefits) but a matter of inclusion into social life [25].

III. Personal Gesture Communication Assistant

Our approach was designed to explore low-cost and adaptable alternatives, considering needs and challenges reported by teachers and family members of people with motor disabilities. The PGCA system captures movements performed in front of a webcam and represents them as Optical Flow-based Motion History Image (OF-MHI). Motion History Image (MHI) converts the 3D space-time information from a video sequence into a single 2D intensity image [14], including information of time and space and reflecting movements order. Lucas Kanade's optical flow (OF) [15] was used to aggregate velocity information to MHI.

Using Machine Learning techniques, two classifiers were evaluated to recognize gestures: one based on Support Vector Machine (SVM-based classifier) and other based on Convolutional Neural Network (CNN-based classifier). The SVM-based classifier uses the "one-versus-all" method to address problems of multiple classes, and the feature descriptor Histogram of Oriented Gradient (HOG). The CNN-based classifier employs transfer learning using the TensorFlow [17] Inception V3 [18], trained initially on ImageNet dataset [19], retraining Inception's final layer with new categories according to labels and gestures generated by users.

The system was explored in an experiment with three students (people with cerebral palsy, students from inclusive schools or special education, aged between 18 and 38) with motor limitations, accompanied by their teachers or caregivers. The tasks performed were: i. creating the dataset by capturing gestures for training the system; ii. training and evaluating the system; iii. using the system to recognize gestures; iv. using gestures to play a game, whose goal is to move a turtle until it reaches the sea; v. using the system to select options in a communication board. Finally, participant professionals evaluated the system usability. Students were able to use the system and also play the game. Both classifiers presented satisfactory results as the average accuracy for datasets generated by three students was close to or greater than 0.9.

Fig. 1 shows screens of the developed system, constructed based on results from different evaluation steps conducted [24]: (A) the Caregiver Area, where datasets are created and the system is trained to gesture recognition; (B) User area where gesture recognition is used for communication, interaction with communication boards[1] and customizing functionalities; and (C) Communication boards area where the caregiver can generate customized boards using images.

IV. Personalized Gestures for Playing a Game

When evaluating the PGCA system with students with motor and speech impairments (mostly caused by cerebral palsy),

[1]Images from ARASAAC [20]. Research approved by an Ethics Committee

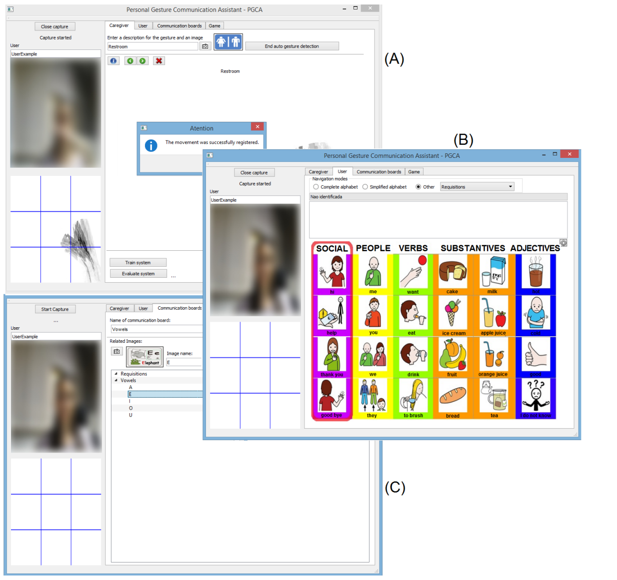

Fig. 1. (A) Caregiver Area; (B) User Area; (C) Communication boards Area.

we observed that some students were not motivated to perform ordinary tasks [24]. Therefore, a gesture interactive game-based approach was designed to motivate the students. The Game Area was included to allow analyzing in a standardized way the system accuracy on gesture recognition and the effort required for each user to reach the same goal by using the gestures each one is capable of (or prefer) performing.

Using gestures, users must avoid obstacles in the sand (shells or crabs) and lead the turtle to the sea (upper region of the screen). As some students use (or can perform) only two gestures for interaction (as Yes and No), the game was designed to be playable with only two different gestures. For the game, a turtle can be moved to four directions, but the game's goal was designed to be achieved by exploring only two directions. Passing through any obstacles does not prevent the turtle from moving, only presents a different feedback via sound and image. Due to the inherent difficulties of the target audience in performing movements, and also because they are not used to interacting with computers, there are no scores or time constraints of any kind. The game has been designed mainly to encourage users to perform repeated gestures, not to compete with each other or with a computer.

Fig. 2 (A) shows the Game Area and the turtle initial state positioned on the beach. Fig. 2 (B) shows the turtle state change during gameplay when the upward motion was recognized and caused the turtle to encounter the crab obstacle. The green border indicates that a gesture has been completed and recognized by the system. Fig. 2 (C) shows the screen presented to the user when the goal was achieved, i.e., the turtle reached the sea. The Game Area is available for use after system training had been performed for creating the personalized dataset. Images selected for the game are free and open for reuse [21] [22] [23].

At the top of the Game Area, selection lists with gestures

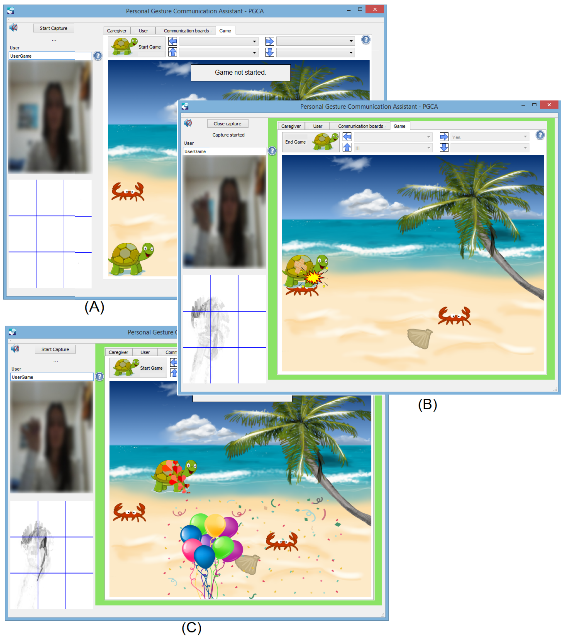

Fig. 2. (A) Game home screen; (B) Example of a playing session. (C) Screen presented to the user when the turtle reaches the sea.

(used to train the system) related to the up, down, right, and left scroll movements are available. To start the game, the system capture must be enabled. When activating the "Start Game" button, the turtle is positioned in the lower-left corner of the screen (Fig. 2 - A). Each change in turtle status gives a distinctive sound. A "Jump" sound is played when a gesture associated with some movement is recognized. After completing the game, an "Applause" sound is played.

In the upper left corner of the screen, there is a "Speaker" icon, which, when activated, enables a speech synthesizer to reproduce all messages presented textually by the system, aiming to facilitate the understanding by non-literate users. Furthermore, the system has buttons characterized by the "?" icon related to the help function that presents a message to the user explaining the objectives and interaction form with the area in use.

V. Opening possibilities

Considering the perceived positive acceptance by the students in the carried experiment (students showed engagement and interest), we realized that the approach used to execute triggers via the PGCA system could be used to design other games with different purposes, including educational ones.

For example, a simple board game, widely used by students in early grades (such as the first year), in which dice is used to move cars on a race track, encouraging students to perform simple sum operations from the results presented by the dice, and to assess the ability to interpret short texts. For this context, one gesture could be used to activate the dice, and the result of the dice must be added up so that the user knows how many movements must be made with the car. One gesture can make the car move one space forward, and another gesture can make the car move one space back. As long as the user does not perform all the movements indicated by the sum of the dice, the system can notify that the task has not yet been completed. When the car stops in a featured region, the system should show details regarding what action should be taken. Afterward, the user can continue moving the car until reaching a space that does not refer to a featured region. The results obtained by players can be associated with some gamification concepts, such as time or number of gestures ranking to achieve the game goal. Fig. 3 presents a low fidelity prototype. Students would throw the dice and move the cars on the track using their personalized gestures.

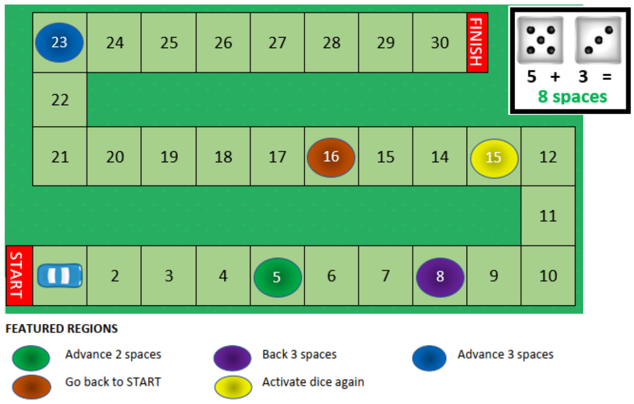

Fig. 3. A prototype of a digital board race track. Gestural interaction can move the car, roll the dice, and to consult details of feature regions.

Another example is the word search puzzles (Fig. 4): one or more gestures can be used to scroll through the available letters (e.g., scrolling letters from left to right and top to bottom) and another gesture could be used to select or deselect a letter. After completing the selection of all the letters that make up the words, the game is completed. These examples are simple but illustrate the potential of enabling interaction using a limited set of gestures. Games can help the user calibrate and improve the precision of their gestures, which are used to communicate and interact with other software and systems.

FIND THE HIDDEN WORDS

F	D	F	A	P	T	T	J	E	R
G	B	C	A	N	P	O	J	L	R
P	Z	I	C	D	E	H	X	Z	M
D	N	Z	P	A	N	Z	H	Z	M
T	E	R	U	T	C	I	P	U	C
P	P	G	Y	V	I	B	M	P	G
L	A	Y	B	U	L	A	E	J	Q
H	A	S	S	D	K	I	U	K	W
M	O	K	T	C	Q	I	V	M	V
E	R	A	S	E	R	H	Y	R	I

PAINT – PENCIL – PICTURE – PASTE – PUZZLE – ERASER

Fig. 4. An example of a word search puzzle, used in student literacy.

VI. Discussion

Results from experiments carried out with students with motor and speech impairments using PGCA system [5] suggested that it is possible and feasible using personalized gestural interaction to enable AAC and also to play a game [6]. Due to the particularities of each student's disability, the effort required by each player to achieve the game goal can vary significantly. Therefore, this diversity must be considered when designing a game for this target audience, mainly because players' expectations could be frustrated if the game demands too complex or difficult goals to achieve through gestural interaction.

Based on the perception of the researcher who carried out the experiment and the accompanying teacher, students were happy to reach the game's objective. Some students smiled, others performed movements that indicated animation or excitement. Further evaluations with different instruments are necessary to obtain more precise results regarding the participants emotional states and reactions. Further studies are also needed to investigate whether this excitement influence the precision of the gestures they perform.

For students who can only perform two different gestures, the possibilities of interacting with a game are quite limited. However, designing games that explore different types of stimuli and offers different interaction possibilities is a good way to start reducing barriers for their autonomous playing, making playing possible.

VII. Conclusion

This paper presented a solution developed for people with motor and speech impairments that includes a game-based approach. Using a Computer Vision system (PGCA) that enables personalized gestural interaction, students with motor and speech impairments could interact with a game using their remaining functional movements. Results from experiments carried out with the target audience indicate the feasibility of the developed system and the possibility of expanding the implemented structure to create new games, with different purposes, including to educational context. Playing games via personalized gestural interaction can, besides including players with motor and speech impairments, be usefull to encourage the use of few gestures to interact with other systems.

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