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WatchControl: A Control for Interactive Movie Using Continuous Gesture Recognition in Smartwatches

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Abstract: This work proposes the development of a method to allow the use of smartwatch as a control for interactive movies using continuous recognition of gestures in smartwatches. We developed two prototypes to interact with interactive movies. The first one uses gesture recognition on the smartwatch screen. Thus, we created a set of gestures composed of straight lines that represent the actions in the interactive movie. In this prototype, the recognition of gestures is performed by the algorithm of continuous recognition of gestures. In this way, a gesture can be recognized before the user finalizes, and the action is sent quickly to the movie. The second prototype uses a touch of pressure in the smartwatch to control the film. As a study case, we have conducted our user study with the movie “Black Mirror: Bandersnatch”, with usability and experience evaluation. A result has shown that the gestures proposed in the method are intuitive and that it has the potential to be used pleasantly and satisfactorily by the users. For 90% of the participants, the use of the smartwatch is more practical and easy to control Netflix compared to the remote control.

Keywords: wearable computing, smartwatch, interactive movie, continuous gesture recognition, controller

1. Introduction

On-demand streaming services such as Netflix, Youtube, Amazon Video and Hulu have been around for some time, however in recent years they have gained more space and are present in the lives of several people and on different devices [12]. These services contribute to 55% of Internet traffic [7].

Netflix is a subscription service that provides movies and series via streaming present in several countries with millions of users [19], [21]. You can run it on a variety of devices, such as Smart TVs, computers, smartphones, Chromecast, and more.

Recently Netflix has released its first interactive adult film “Black Mirror: Bandersnatch”, the story shows a programmer trying to create an interactive game.

An interactive film allows the user to interact at different times and choose the story and even the end of the film, this can provide different experiences according to the choice and preferences of each user, so the story of the film is not linear [17].

This movie can be run on devices such as Smart TVs and PCs, for example and controlled by their respective input devices: remote control, keyboard and mouse.

Considering that the smartwatch is a wearable device that gets stuck to the user’s pulse, it can be used to facilitate people’s daily lives [14], [16]. In this way, it becomes interesting to use it to control the movie “Black Mirror: Bandersnatch”, because the user

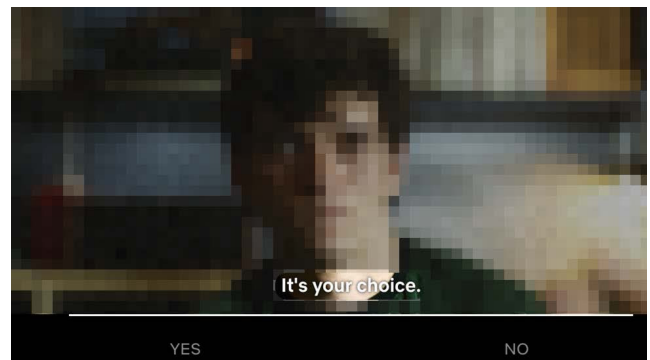


Fig. 1 Viewer Choice Screen (Adapted Sample from Bandersnatch movie).

can control the course of the movie without using a keyboard or control, using only a device in the format of a clock.

Therefore, the objective of this work is to control the interactive films through gestures using a smartwatch as a control mechanism. To do this, you will need to: define a set of gestures and their respective actions in the movie, establish communication between the smartwatch and the device that runs the movie, and finally perform the actions performed on the smartwatch in the movie.

We present in this work the results of interaction research with interactive films using smartwatches with continuous gesture recognition, conducting a case study with the film “Black Mirror: Bandersnatch”. **Figure 1** presents a screen sample of the film, which presents the user with two options, and he can choose one of them.

The prototypes presented in Section 3 allow the user to make

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This paper is an extended version of our works published in COMPSAC 2019 [8] and COMPSAC 2018 [16].

this choice.

The next sections present relevant content for the understanding of the research developed, the next section exposes the related works, in sequence we will show the prototypes for smartwatches and their functionalities, soon after will be approached the results and, finally, the final considerations.

2. Related Work

The work developed by Zhu et al. [26] presents a deep neural network based on bidirectional LSTM that can recognize the gestures movements of the wrist and fingers of the users, the results show that the system has the potential to use a smartwatch as a remote control. The work of Gkourmelos et al. [5] proposed a method that allows controlling robots using a smartwatch as a control mechanism.

Ens et al. [4] developed a prototype that allows the user to control the smartwatch by turning a ring on the index finger. The prototype combines the use of a ring with a depth camera used on the user's head.

Alanwar et al. [2] have created a device for selection and control of IoT devices. The interaction is performed only by pointing to the device and performing gestures. Smartwatches need to be equipped with inertial and ultra-wideband (UWB) sensors. The accuracy of choice for the device was 84% and the gesture recognition was 97%.

In the research developed by Speier et al. [20] a prototype was developed to control a music player, in this way, a bracelet was developed to be worn on the users' wrist and the results of this work show that users prefer gestures that slide to touch gestures.

Luna et al. [13], developed a method that allows the control of Smart TVs using gestures made by the pulse of a person using a smartwatch. With the focus on device development, the work proposed by Volkinburg and Washington [23] developed a wearable controller for gesture recognition using polyvinylidene fluoride (PVDF), the controller is attached to a comprehension glove used on the user's forearm.

Ike et al. [9] proposed a gesture interaction technique that shows the user the appropriate gestures to perform the actions available in the TV content navigation interface with natural and intuitive gestures, the interaction is performed with movements of the fingers, hand or wrist.

The work of Seetharamu et al. [22] uses a smartwatch with personalized gestures to control a Web browser on a TV, the method allows the user to define personalized gestures to control the TV, to perform the interaction the user needs to make hand gestures.

In the work of Yeo et al. [24] a method was developed that allows the interaction with smartwatches with continuous pressure taps and turns without the need to modify the smartwatches and they conducted experiments with good results in seven different applications. Yoon et al. [25] have proposed a method that uses a light sensor to allow a multitouch input on unmodified smartwatches. Nakasu et al. [15] have developed an interface that allows the user to control digital products without touching the screens or keyboards by using a wearable sensor on a wristband that recognizes the change in the user's arm posture. Gong et al. [6] proposed a method that allows continuous one-handed in-

teraction on smartwatches for freeform interaction.

Research of Ahn et al. [1] presented a technique of multi-touch interaction sensitive to pressure in a bracelet, by using the bracelet for interaction. The technique allows interaction without occlusion of the screen. Oakley and Lee [18] have developed a hardware prototype that allows a multi-touch interaction using the edges of the sensor, thus leaving the screen free. Darbar et al. [3] has developed a method that extends the smartwatch's interaction space to the sides of the device by utilizing four pressure sensors allowing users to enter different pressure levels that can be used for two-way navigation (zoom, scroll and rotation). Jiang et al. [10] Introducing the development of a wristband for detecting eight air gestures and four surface gestures at two different strength levels, the article demonstrates the potential of wrist devices for precise hand gesture recognition applications.

A method that allows to control platform games using a smartwatch was proposed by Nascimento et al. [16]. In their approach a continuous gesture recognition was used to manipulate a Mario character. Although, a result showed that users adapt well to the method and that the algorithm of the continuous recognition of gestures is efficient in a smartwatch, the method was unable to provide a full experience demanded by platform games. Those games generally require many continuous or even simultaneous button presses, and the method is unable to provide it, since it is limited to a single interaction at same time.

Although many prototypes are designed to carry out interactions on smartwatches, researchers have developed extra hardware to conduct their approaches. Besides, these works neither address using continuous gesture recognition in smartwatches nor use them as a mechanism for interacting with interactive films. Therefore, this work uses an unmodified smartwatch to control interactive movies. This work extends our previous work [16] in which we created a control for interactive films using smartwatches with continuous gesture recognition.

In this work, we are presenting two methods to interact with non-linear movies using smartwatches, which requires the user to decide during the movie. The first method provides interaction via basic swipe gestures, while the second one offers interaction via pressure touch on the watch bezel edge. To validate our methods, we performed a user study with our prototypes and we also compared them with a regular remote controller.

3. Prototypes for Smartwatch

3.1 Continuous Gesture Recognition

We use the algorithm of continuous recognition of gestures proposed by Kristensson and Denby [11]. This algorithm is able to predict partial gestures, that is, one can recognize a gesture before it is finalized, in this way, it is possible to perform the action quickly.

For this, it uses a technique that considers a gesture as a model and divides it into several segments. In this way, each model is represented by a set of segments that increasingly describes the partial parts of the model [11]. **Figure 2**, illustrates this technique.

As can be seen in Fig. 2, a model is a set of segments, that is, a gesture is considered as a set of small gestures. In this way,

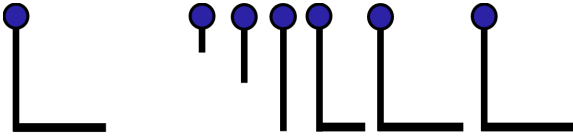


Fig. 2 Full model to the left and segments of the gesture to the right (Adapted from Ref. [11]).

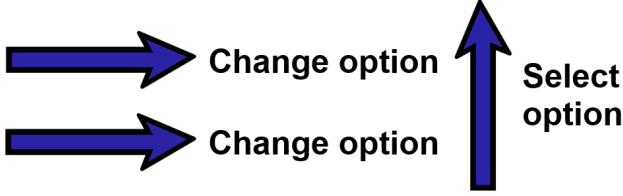


Fig. 3 Set of gestures and their respective actions in the interactive film Bandersnatch.

it is possible to recognize a gesture without having to perform it completely.

A model can be considered to be a vector of ordered points in relation to time, that is, a vector of ordered points relative to the way the movement is to be produced, a gesture is segmented in several parts and in increasing movements. A model represented by w is a pair (l, S) , where l is the model description and S is a set of segments that describes the complete model. Equation (1), describes a complete model ordered in relation to time T [11].

$$S = [s_1, s_2, \dots, s_n]^T \quad (1)$$

As the gesture is executed, the system calculates the probability of being a gesture of the set. The algorithm works with gestures that are executed more frequently, that is, it seeks to find patterns, because, normally, there are gestures that are more repeated than others.

Let $\Omega = \omega_k$ the set of models and the input vector I with i points $[i_1, i_2, \dots, i_i]$.

For each new point in the index i , the posterior probability is calculated for each set $\omega_j \in \Omega$ using the Bayes rule, as shown in Eq. (2):

$$P(\omega_j | I_i) = \frac{P(\omega_j)P(I_i | \omega_j)}{\sum_k P(\omega_k)P(I_i | \omega_k)} \quad (2)$$

Where $P(\omega_j)$ is the prior probability, and $P(I_i | \omega_j)$ is the probability and the denominator is the exclusion term.

3.2 Prototype for Interaction with Screen Gestures

We created a set of gestures that allows the user to interact with the Bandersnatch interactive movie, when performing one of these gestures the action that it represents is performed in the movie. The actions are: select option and choose option, **Fig. 3** exposes the gestures and their respective actions in the interactive film.

The linear gestures of the set were generated from the reduced equation of the line, represented in the equation below. Where x and y are the points belonging to the line, m the angular coefficient and c the linear coefficient.

$$y = mx + c \quad (3)$$

We have developed a prototype that interacts with the Bandersnatch interactive movie. Using this prototype, the user can

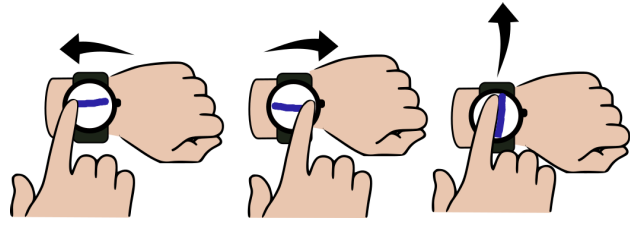


Fig. 4 Illustration of a user performing the actions of selecting the option from the left, selecting the option from the right and choosing the option selected in the prototype of gesture interaction on the screen.

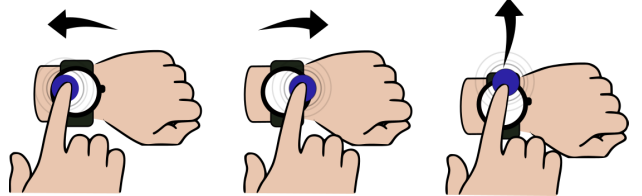


Fig. 5 Illustration of a user performing the actions of selecting the option from the left, selecting the option from the right and choosing the option selected in the prototype of interaction by pressure touch.

change and select options of interaction of the film by performing one of the gestures shown in **Fig. 3** on the prototype screen. The Prototype was developed for the Android Wear system, **Fig. 4** illustrates a user's actions by selecting and choosing options in a smartwatch.

Considering that when using the algorithm of continuous recognition of gestures, the recognition is continuous, a gesture can be recognized before being finalized by the user. In this way, the prototype was designed to send the action to the film when the user makes a gesture with at least 2 cm (160 pixels) and with the minimum recognition accuracy of 70%, these values were obtained empirically by trial and error. These minimum gesture lengths are equivalent to half of the screen and resolution, which are 4 cm and 320 pixels, respectively.

3.3 Prototype for Pressure Touch Interaction

We also developed a prototype that allows the user to interact with the Bandersnatch interactive movie by applying a touch of pressure to the smartwatch. In this way, pressing the smartwatch left or right will activate the command left and right respectively, and pressing the smartwatch up will select the selected option.

Figure 5 illustrates the actions described above being carried out in a smartwatch by the user.

Using the accelerometer it is possible to identify the change in the position of the smartwatch, because it is possible to obtain the values of its location with the axes x, y e z . In this way, it is possible to identify the slope of the smartwatch when the user puts pressure on it.

However, the values obtained from the accelerometer and the gyroscope are constantly changing, so it was necessary to establish a threshold to determine if the change in values really represents a user action.

Therefore, it is constantly checked whether the change in values is small or if the pre-set threshold has been exceeded. In our tests we identified that the threshold varies according to the gesture. Firstly, gestures for selecting a left option, a threshold was defined as one positive point in a x -axis. Second, gestures for

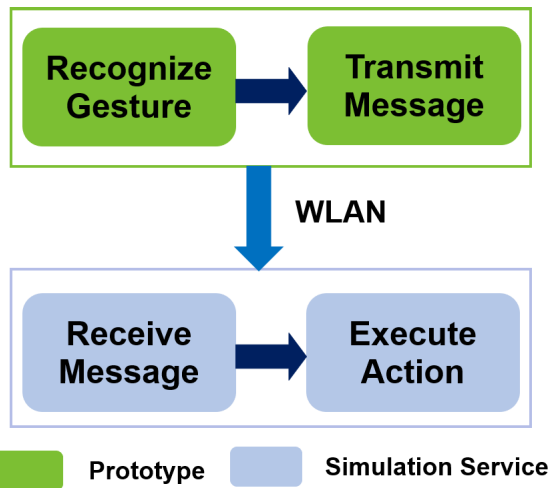


Fig. 6 Steps to perform the action in the interactive movie after a gesture is performed.

selecting a right option, a threshold was defined as 1.3 negative points in the axis- x . Finally, gestures for confirming a selected option, a threshold was defined as 1.3 negative points in the y -axis.

3.4 Communication between Prototype and Movie

The Bandersnatch interactive movie is played on a computer with an Intel Core i7-5500U 2.40 GHz processor, 8 GB of RAM and an NVIDIA GeForce 830 M graphics card.

Considering the prototype interaction of gestures on the screen, when the user makes a gesture, the first step is to recognize the gesture using the algorithm of continuous gesture recognition, then identify the action that it represents and it is sent to the interactive movie player. For the pressure touch prototype, the first step is to define which axis the user is pressing on the smartwatch, in sequence identifies the action that it represents and is also sent to the interactive movie player. These steps are shown in **Fig. 6**.

The prototypes communicate with the simulation service using a WLAN network. Only a code represented by an integer is sent over the network, thus reducing any possible delay in communication.

To perform the action in the interactive movie, we simulate the actions of moving the cursor and clicking the mouse on the computer.

In this way, there is an active simulation service that is responsible for receiving the messages and performing their respective actions in the interactive movie. Whenever this service receives a message, it identifies the action related to the received code and executes it. For the actions of changing between the options, the mouse cursor is positioned on top of the option, and to select an option the action performed is the mouse click.

4. User Study

The experiment was conducted with 10 volunteers, aged between 26 and 54 years, 5 males and 5 females. Among them, 3 are from the area of computing. None of the participants have a smartwatch.

About smartwatches, one volunteer claimed to have regular ex-

perience and the others said they had little or no experience. During the experiment all participants used the smartwatch in their left hand.

In order to validate the method, the prototypes were installed in the smartwatch *Motorola Moto 360*.

Before starting the experiment, some training sessions were held for users to gain experience. After training, the experiment was performed for data collection. The set of gestures shown in Fig. 3 was exposed to the participants and they were able to observe it during the whole experiment. We also explained and demonstrated to the participants the actions in the pressure touch prototype, as shown in Fig. 5.

Participants were able to choose which hand to use the smartwatch. For the on-screen gesture interaction prototype, participants used the smartwatch in the position they felt most comfortable.

As for the pressure-touch prototype, so that it was not necessary to set a trigger for prototype activation or perform calibration, users used the smartwatch with their hands resting on a table.

4.1 Usability and Experience Test

First the usability test was carried out and then the user experience test. In the usability test, we verified the efficiency and effectiveness of the method. The experience test explored the users' perception of the developed method.

We applied a questionnaire to the participants of the experiment to evaluate the usability and experience of the method and the prototypes developed. The questions were answered by the participants using the Likert scale. The affirmations applied to the participants were:

- (1) The proposed method is intuitive.
- (2) The gestures proposed for using the method are intuitive.
- (3) The proposed method is easy to use, i.e. it was easy to control the film in the first few minutes using the prototype.
- (4) You felt familiar with the prototype in the first few minutes of use.
- (5) The actions performed on the prototype are sent correctly to the movie.
- (6) The actions performed on the prototype are executed quickly in the movie.
- (7) It is nice to control the film with the proposed method.
- (8) I would use this method to control interactive movies in my everyday life.

To verify the experience and usability with respect to the prototype of pressure touch interaction in the smartwatch, the experiment participants answered the following statements using also using the Likert scale.

- (1) The actions to be performed on the prototype are intuitive.
- (2) It was easy to use the prototype in the first few minutes of use.
- (3) You felt familiar with the prototype in the first few minutes of use.
- (4) The actions performed on the prototype are sent correctly to the movie.
- (5) The actions performed on the prototype are executed quickly

in the movie.

- (6) It is nice to control the film with the proposed method.
- (7) I would use this method to control interactive movies in my everyday life.

The next section will discuss the results of the user study, as well as the usability and experience test.

5. Results and Discussion

It can be seen in Fig. 7, and Fig. 8 that the responses of the participants to the prototype of gesture interaction on the screen and to the pressure touch prototype are similar and that the method can be considered efficient. However, it can also be observed that in general the prototype of gesture interaction on the screen has a better evaluation.

5.1 Screen Gesture Interaction

Prototypes developed were used in an experiment with users

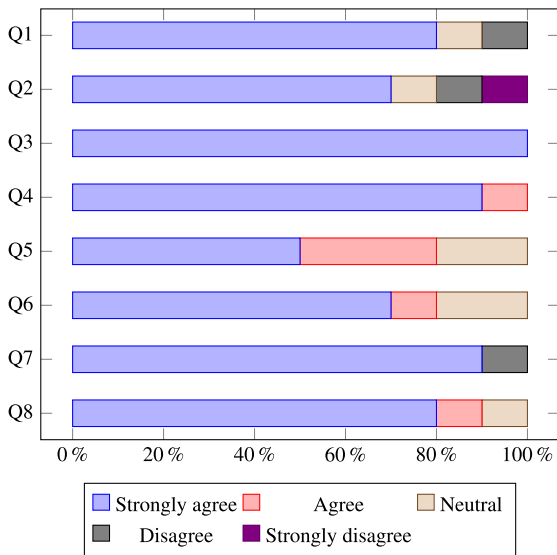


Fig. 7 Responses from the experiment participants to the usability and experience questionnaire for the on-screen gesture interaction prototype.

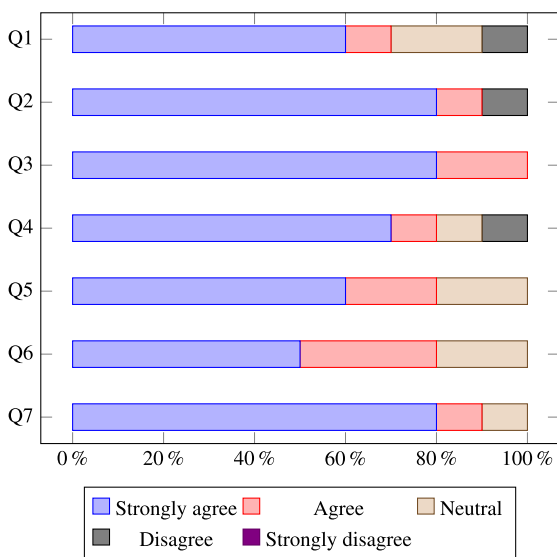


Fig. 8 Responses from the experiment to the usability and experience questionnaire of the pressure touch interaction prototype.

with a usability test and experience with the purpose of validating the proposed method, as well as, the prototype. Figure 7 shows the responses of the experiment participants to the usability and experience test statements for the on-screen gesture interaction prototype.

Looking at Fig. 7 it is possible to see that 80% of users said they fully agree that the proposed method is intuitive, 10% said they agree, and another 10% claimed to be neutral. 90% of participants stated that they fully agree that the proposed gestures are intuitive. In relation to the proposed gestures are intuitive, 90% of users said they fully agree.

The participants' responses to item 3 show that learning was easy, since all stated that they fully agreed that it was easy to use the method proposed in the first minutes of use. The answers to question 4, however, show that participants felt quickly familiar with the prototype because 50% stated that they fully agreed and 30% stated that they felt they were familiar with the first few minutes of use.

All participants stated that the actions performed on the prototype are performed quickly in the film, as can be seen in item 5 of Fig. 7, therefore, all the participants marked the option I strongly agree or agree.

70% of the participants stated that it would be nice to use the proposed method, since 80% of the participants said they would use the method proposed in everyday life, as can be seen in item 8 of Fig. 7.

It can be observed according to the response of the participants that the method developed has the potential to be used in the daily life of the people, the method and the gestures proposed are intuitive. It is also observed that the response time is satisfactory and that the prototype has the potential to be pleasant when used in the daily routine.

It is possible to verify that the method developed has potential to be used to control non-linear movies. In Fig. 7, it is possible to view that most participants ticked the option I fully agree or agree to all the statements

5.2 Pressure Touch Interaction

Responses of the participants to the usability and experience test for the prototype that uses the touch of pressure in the smart-watch can be observed in Fig. 8.

In item 1 of Fig. 8 it is noted that 90% of users said they fully agree or agree that the actions to be performed on the prototype to control the film are intuitive.

Checking the answers of item 2 and item 3, it is observed that the proposed method is easy to use and that users felt familiar in the first minutes of using the prototype.

Participants' responses to item 4 show that the actions are sent correctly to the film because 70% stated that they fully agree and 10% agree. In addition, 90% of users stated that they fully agree that actions are performed quickly on the film, as can be seen in item 5 of Fig. 8.

Analyzing the answers to item 6, it is possible to identify that the method developed has the potential to please the users and be used in daily life, since 90% of users marked the option agree or strongly agree to this statement. There are also indications that

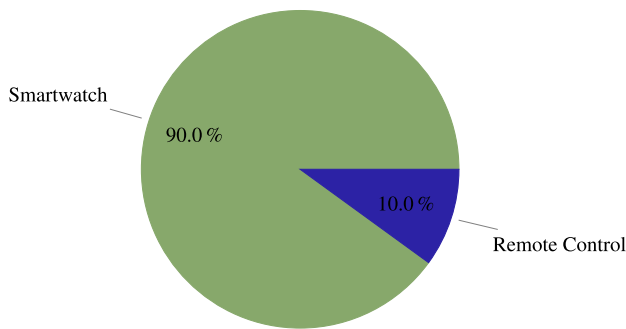


Fig. 9 Preference of users for using smartwatch or remote control.

the method can be used in people's daily lives, since 70% of the participants stated that they agree or strongly agree with the affirmative of number 7.

5.3 Comparison between smartwatch and remote control

Regarding the users' preference for controlling non-linear movies using the smartwatch or the remote control, we can observe that in Fig. 9, 90% of the participants found it better to control the method using the smartwatch.

It can be observed according to the response of the participants that the developed method has the potential to be used in the daily life of the people, the proposed gestures are intuitive. It is also observed that the response time is satisfactory and that the prototype has the potential to be pleasant when using it.

Despite being a new proposal, users showed enthusiasm when using this new form of interaction, as the smartwatch is a device that is on the user's wrist, in addition, this new approach allows interaction without the user having to look at the smartwatch therefore uses simple, intuitive and easy to memorize commands.

It was also verified that the average time for the user to perform gestures on the smartwatch is equivalent to the time used to find and press a button on the remote control, this indicates a good experience for users with the developed method.

6. Final Considerations

This work proposes the development of a method to control interactive films using a smartwatch with continuous gesture recognition and performs a case study with the film "Black Mirror: Bandersnatch". In this way, we present two prototypes in this work to interact with interactive films using a smartwatch as a control, the first one uses gesture recognition on the screen of the smartwatch and the second uses pressure touch on the smartwatch to control the movie.

Thus, to control the Bandersnatch interactive film, the user performs the gestures shown in Fig. 3 in the prototype of gesture interaction on the screen or apply pressure on the smartwatch in the prototype for interaction using touch of pressure, as was shown in Fig. 5. In the prototype of gesture interaction on the screen, gesture recognition is performed using the algorithm of continuous gesture recognition. In the pressure-touch interaction prototype, the accelerometer data is captured and changes in values are observed according to a pre-set threshold. In both prototypes, after the recognition of the gestures, its respective action is sent by the WLAN network to the simulation platform that is responsible

for simulating the actions of moving the cursor and clicking the mouse according to the gestures performed by the user.

The results of the experiment and the usability and experience test show that the method developed is pleasant to use, has easy learning and is intuitive, so the method has the potential to be used by everyday users to control interactive movies using smartwatches with recognition of gestures in an efficient and effective way.

It is important to emphasize that the usability test and experiments showed that for 90% of the participants the smartwatch is more practical and easy to control Netflix.

Existing applications have buttons with pre-programmed functions and this mimics the remote control function. This method uses only simple gestures based on geometric shapes or touches of pressure on the screen as a form of interaction, thus allowing the user to control the interactive film without having to look at the smartwatch, facilitating its use.

The next step of this research will be with screens of different sizes and people with hands and fingers of different sizes to identify the minimum gesture size, as well as the minimum recognition accuracy to send an action to the film. In sequence, the method will be tested in other interactive films. Soon after, a method will be developed that allows the user to control interactive films by moving the wrist. Afterwards, it is proposed to develop a technique that sends feedback to the user through sounds or vibration when the user changes or selects an option.

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