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Smart Tablet Monitoring by a Real-Time Head Movement and Eye Gestures Recognition System

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Abstract: Different research works are studying to integrate new ways of interaction with mobiles devices such as smartphone and tablets to provide a natural and easy mode of communication to people. In this paper we proposed a new system to monitoring tablets through head motions and eye-gaze gestures recognition. This system is able to open browser application with simples motions by the head and the eyes. For the face detection we used a viola and jones technique, and for the eyes detection and tracking we used Haar classifier to the detection part and the template matching for tracking. We develop this system on android based tablet. Through the front-facing camera the system capture a real-time streaming video on which we implemented the detection and recognition module. We tested the system on 10 persons and the experiment results shows that this system is robust and it is invariant for the lightness and the moving state of the user. We introduce also in this system, a module to estimate point of regard on the tablet's screen based only on the front-facing camera. As known the tablets resources are limited, in consequence the response time of our system is not satisfied for the real time condition. That is why we apply the cloud computing to solve this problem.

Keywords: Eye tracking, gaze gestures, head movements, human-machine interface, android tablet, cloud computing

1. INTRODUCTION

Mobiles phones and tablets have become an important part of our daily life. The number of user increases continuity and it exceed to cover more than one billion on 2014. Today, these mobile devices are more advanced, thinner and smarter. The HCI on this device is one of things that are known a big evolution: from small screen and big physical keyboard to a bigger touchscreen with virtual keyboard. This evolution aim to user their phone easier and actions require few item to select. The touchscreen has changed the way of communication with mobile devices because it is natural and easy to use. However, mobile devices are designed to use on perfect conditions where people sit in front of their devices and this is not what happen in reality. People use their devices in different environments and contexts: on driving in the car, on cooking in the kitchen, on practicing sports, etc. That is why the current mobile interface and the use of touch way of interaction has many limits and can't be useful all the time. Many research works focus on this topic and try to develop a mobile interface that is can be adapted to different scenarios and facilities the usage.

When we look into the way of communication with the mobile device we find that is based on the touch way, but in fact that is based mainly on the use of the eyes: we look on the icon then we press on it and this is so normal: when we speak to someone we look at him. And this is the same rule in our communication with mobile devices. The eye is our first channel to discover the exterior environment. That is why many of research work introduced the use of eye tracking to interact with computer. This technology is more natural and intuitive than the traditional ways of interaction. And for the same reason, we find this technology introduced in the mobile device. But with these devices, the challenge to implement these technologies is more difficult. In fact, using the mobile device in many variant conditions and let the scenario of use is very unpredictable; the lighting conditions, the head pose, the distance between the user and the device, etc. We propose to introduce the usage of the eye to manipulate tablet devices. Our system is based on the tablets front-facing camera and it does not require any additional peripheries.

In this paper, we will present the previous research works that are interested to this topic then we presented the architecture of our proposed system. We detailed then each part of face and eyes detection and head and gaze gesture recognition. We will present the experiments results of testing our system on 5 volunteers and finally

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we will expose the applying of the cloud computing part on the system.

2. Related work

Only few research works are interested by monitoring mobile devices by using eye tracking.

N. Iqbal, H. Lee and S. Y. Lee [1] proposed a new system for mobile devices based on eye- gaze estimation without any physical contact. This system is user independent and head/device invariant and does not require additional peripheries. In fact, it is based on geometric algorithm that defines the relation between the device and the user's cornea by estimating the position of the corneas center. This system is aim also to reduce errors of glint image position. The authors present a binocular algorithm that determines the point of gaze by estimating the angle between the optical and the visual axes with only one point of calibration.

V. Vaitukaitis and A. Bulling [2] present an eye gesture recognition system for mobile devices using only on the front-facing camera of the device. On an android-based smartphone, the authors present a real-time prototype that is able to recognize four different eyes gestures.

H.Drewes, A. De Luca and A. Schmidt [17] present a gaze tracking system for mobile phone. This system aim to monitoring applications on mobile devices. For this purpose, the author compared 2 methods: eye gaze interaction based on dwell-time method and gaze gesture. This system mainly by using gaze gesture aims to resolve the problems of lighting and the outdoor use and the calibration.

E.Miluzzo, T. Wang and A. T. Campbell [3] present their system EyePhone, an eye tracking system implemented on Nokia N810. This system is aim to control the phone with only the eye gesture through the phones font facing camera. This system tracks the eye and detects the gaze on the phones display and it can also detect the eyes blinks. The blink is considered like an order to activate the target application.

This system makes the phone independent of any physical touch by the user.

E.Wood and A. Bulling [4] proposed a model-based approach for binocular gaze estimation designed for unmodified tablet: EyeTab. This system based on real-time gaze estimation algorithms that can detect gaze direction and estimate the point of regard on the screen.

C.Pino and I. Kavasidis [5] describes a non-intrusive eye tracking system for mobile devices using the front facing camera. The user can interact with his device by using spontaneously his gaze. The authors are based on the Haar classiffier it identify the eye in the images and the CAMSHIFT to find and track the eyes movements and users gaze.

3. System Architecture

Our system is aim to provide to the tablets user a process to control it device by using their head and eyes. To achieve this purpose, we designed our system like shows the flowchart in the Figure1. Our system is composed by different modules which one of it has a specific function. To satisfy the real-time constraint, the basically input of the system is a live video capturing by the front-facing camera of the tablet. A face detection module is responsible for detecting users face. Once this function is achieved a face tracker subsystem is charged to track the face in all his movement. In consequence, the motion due by the face can be recognized and execute the correspondent action. In the same time, eyes regions of interest are extracted from the face detected. The Eyes ROI are the based image from which we can localize the pupils' positions. A gaze tracker module is responsible for the pursuit of pupils' positions. Once we obtained these positions, a gaze gesture module recognizes the gaze's motion and so the corresponded action is lanced.

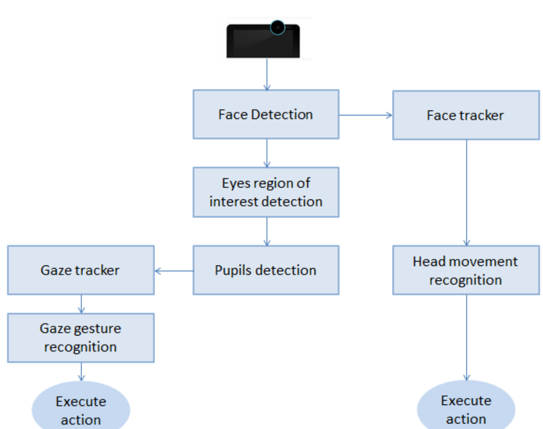

Figure 1. System architecture

A. Face detection

The face detection is the first step on our system. In fact, it is consider of one of the most popular research domains. Many research's works are interested on this topic. P. Viola and M. J. Jones [6] is proposed an approach to detect faces. In fact, the viola and Jones algorithm is consider as the best approach to detect faces: the recognition percentage is about and it is 15 times rapid than others approaches. The rapidity of this technique and the non-requirement of a lot material resources help us to introduce this technique on the tablet while maintaining the real-time constrain.

B. Eye tracking

Once the face is localized, an eyes detection module is used to detect and track the eyes. In fact, in the eye tracking previous works there are many different approaches and methods applied that can be divided on intrusive and non-intrusive type. In this paper we will focus on the second type because we will use just the tablet based on its own camera.

V.Vaitukaitis and A.Bulling [2] describe their prototype eye gesture recognition system for hand-held portable devices. That does not need any external material and it utilizes image processing and computer vision algorithms to track eyes from a video recorded by the devices camera. First, the system detects the face of the user by a face detector. Then it detects eyes by an eye detector. This prototype was applied on two devices: a laptop and a smartphone and five persons took part this evaluation. This system realised a near real-time gesture recognition with accuracy of 60.

H. Al- Rahayed and M. Faezipour [7] proposed a system of eye tracking which uses the circular Hough Transform to detect iris and then calculates the coordinates of the eyes centers. This system improve the task of eye detection by minimize the time required for CPU processing. This minimization is performed by investigating the minimum of video frame rate. In the case of law speed, 2 frames per second are enough to detect all eyes movements and the CPU improvement is 1500.

W. Tunhua, B. Baogang , Z. Changle, L. Shaozi and L. Kunhui [9] proposed a system of a real-time eye tracking that uses differents algorithms such us Adaboost, optical flow and Camshaft. This algorithm is based on 4 steps:

First, it standardized the light condition and the camera was placed in front of user. Second, it localized the nostril tracking point. Third, it used algorithms of camshift and Lucas-Kanade optical flow to track face and nostrils. The gradient Hough circle transform is used to localize pupils. Finally, the nostrils and pupils coordinates are used to calculate velocity and trajectory of eye motion. The experiment results show the robustness of this method.

C. Chan, S. Oe and C. Lint [10] developed an eye-tracking system by quad-PTZ camera. This system is able to capture the image of the user and calculate the coordinates of eyes center. The eye motions can be calculated with the ratio with 86-96The experiment result shows a very successful eye detection gaze even in the case of changing the posture.

Z. Zhang and J. Zhang [11] present a new Driver fatigue detection based on Unscented Kalman filter and eye tracking. It detect _rstly users face by using Haar algorithme because it prove this efficiency even in the change condition and input data, like different lighting condition, variable head position, having or not glasses, etc.

Once it detects users face, it detects the eyes by using the projection technique and Unscented Kalman filter in the same time. It has a 99.5In the last step, the system detects driver fatigue if the eyes blink over 5 consecutive times, by using the vertical projection matching. The experimental study shows robustness of this system which applied under realistic conditions.

A. M. Bagci, R. Ansari, A. Khokhar and E. Cetin [12] present an eye tracking algorithm based on Markov models and using skin color detection algorithm and geometrical features of users face. The system initializes automatically facial feature and track eyes with successful rates under variable lighting condition and different head motions.

S. Amamag, R. S. Kumaran and J. N. Gowdy [13] developed a system that track eyes center in real time by using a Bayesian classifier and an unsupervised clustering stage. The system is indifferent with variable light condition and head position Experimental results which applied in a real time environment prove that this algorithm is efficient and beneficial even in different conditions.

X. Liu, F. Xu and K. Fujimura [8] study the problem of the effects of the variable light condition on the eye detection. They present a system which uses IO light and methods of appearance-based object recognition to combine images. In this way, the system can track eyes in bad light condition that cause not bright pupils. To detect and track eyes, this method use a support vector machine (SVM). The experimental results show that this algorithm is robust and not only in different light condition but also for drivers wearing sunglasses.

In our system and like shows Figure 2 the eye tracking system consists of three parts. The first one is the eyes detection; it has to find the eye location. Once its founded we reduce the region on interest to have the iris zone. When we look at the human eyes closely we find that the pupil is the darkest zone then it surrounding. In order to track the eyes, we use the template matching method that can using the comparison between the template image and the source image in which we expect to find a match with the template image.

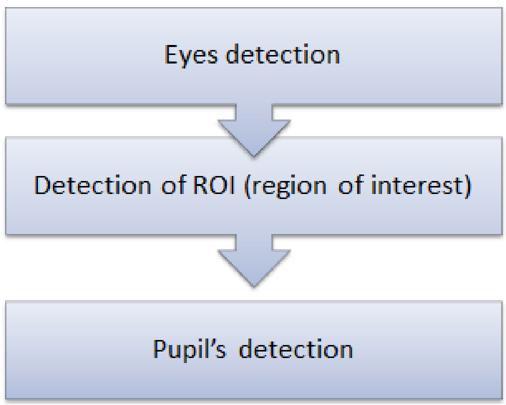

Figure 2. Eye tracking stapes

C. Gaze movement detection

We define the gaze movement as the motion of the eyes pupil. As those movements are so variant and different, the number of command and action provides by gaze movement can be increased. That not limited on a screen size mainly on tablet and mobile devices on general that have a small screen in comparison with computers ones. And for this reason, eye gesture does not require any calibration and the distance between the eye and the device have any impacts on the result. Monitoring tablet through gaze gesture does not be sensible to different conditions and context where the user is integrated (moving or not, close to the device screen or far). Additionally, the use of the gaze motion helps to make the difference between the natural eyes movement and the intentional motion dedicated for specific commands. These observations are the reason why gaze gestures are worth to be examined in more detail. Once the eyes are tracking, a gaze movement detection module analyzes the sequence of the eye gaze position. It first takes the initial position in the first frame then it compares it in the next frame. The movements recognized by this system are: up, down, right and left

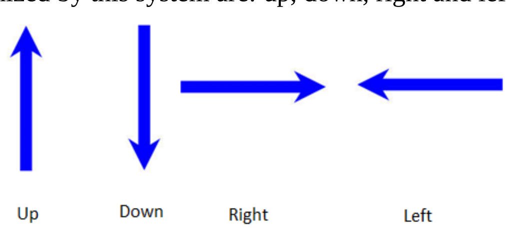

Figure 3. movements recognized by our system

D. Application based head and eye-gaze motion

Monitoring the tablet by eye detection technology is an intuitive way that does not require a much effort from the user neither a specific learning. With a simple motion of the head and the gaze we can execute actions. And the variety of these motions opens horizons to adapt each motion for the most correspondent application. In our system we realize a gaze gesture recognition system that aims to open applications on an android tablet like navigator, calendar, etc. And to make the difference between the intentional eyes motion and the gesture that we mean by it an order, we add to our system the head gesture recognition module. If the user moves his head in the right way, the system is ready to take the order by using the eye-gaze movement.

4. REALISATION AND EVALUATION

We implemented this system on an android tablet. We conducted a study on 10 persons. We put them on different conditions of use that can emulate the 3 different context of use:

- different light conditions
- the user is moving or sitting
- having or not glasses

So we have 8 different scenarios tested like shows table1:

TABLE I. DIFFERENT SCENARIOS TESTED

Lightness	Having glasses	User's position
Good	Yes	Moving
		Sitting
	No	Moving
		Sitting
Bad	Yes	Moving
		Sitting
	No	Moving
		Sitting

For each user we tested the recognition rate for eye gesture and head. The experiment results were presented on the following tables:

TABLE II. TABLE TEST WITH SCENARIO 1

Volunteer persons	Eye gesture recognition	Head gesture recognition
P1	Yes	Yes
P2	No	Yes
P3	Yes	Yes
P4	No	Yes
P5	Yes	Yes
P6	No	Yes
P7	Yes	No
P8	No	Yes
P9	Yes	Yes
P10	Yes	No

TABLE III. TABLE TEST WITH SCENARIO 2

Volunteer persons	Eye gesture recognition	Head gesture recognition
P1	Yes	Yes
P2	Yes	Yes
P3	Yes	Yes
P4	Yes	Yes
P5	Yes	Yes
P6	Yes	Yes
P7	Yes	Yes
P8	No	Yes
P9	Yes	Yes
P10	Yes	Yes

TABLE IV. TABLE TEST WITH SCENARIO 3

Volunteer persons	Eye gesture recognition	Head gesture recognition
P1	Yes	Yes
P2	Yes	Yes
P3	Yes	Yes
P4	Yes	Yes
P5	Yes	Yes
P6	No	No
P7	Yes	Yes
P8	Yes	Yes
P9	Yes	Yes
P10	No	

TABLE V. TABLE TEST WITH SCENARIO 4

Volunteer persons	Eye gesture recognition	Head gesture recognition
P1	Yes	Yes
P2	Yes	Yes
P3	Yes	Yes
P4	Yes	Yes
P5	Yes	Yes
P6	Yes	Yes
P7	Yes	Yes
P8	Yes	Yes
P9	Yes	Yes
P10	Yes	Yes

TABLE VI. TABLE TEST WITH SCENARIO 5

Volunteer persons	Eye gesture recognition	Head gesture recognition
P1	Yes	Yes
P2	Yes	Yes
P3	No	Yes
P4	Yes	Yes
P5	Yes	Yes
P6	No	Yes
P7	No	No
P8	Yes	Yes
P9	No	Yes
P10	Yes	Yes

TABLE VII. TABLE TEST WITH SCENARIO 6

Volunteer persons	Eye gesture recognition	Head gesture recognition
P1	Yes	Yes
P2	Yes	Yes
P3	Yes	Yes
P4	Yes	Yes
P5	Yes	Yes
P6	Yes	Yes
P7	No	No
P8	Yes	Yes
P9	No	Yes
P10	Yes	Yes

TABLE VIII. TABLE TEST WITH SCENARIO 7

Volunteer persons	Eye gesture recognition	Head gesture recognition
P1	Yes	Yes
P2	Yes	Yes
P3	Yes	Yes
P4	Yes	Yes
P5	Yes	Yes
P6	No	Yes
P7	Yes	Yes
P8	Yes	Yes
P9	No	Yes
P10	Yes	Yes

TABLE IX. TABLE TEST WITH SCENARIO 8

Volunteer persons	Eye gesture recognition	Head gesture recognition
P1	Yes	Yes
P2	Yes	Yes
P3	Yes	Yes
P4	Yes	Yes
P5	Yes	Yes
P6	Yes	Yes
P7	Yes	Yes
P8	No	Yes
P9	Yes	Yes
P10	Yes	Yes

The experiments results show that the percentage of recognition is very high. However, we note that having glasses and the non-perfect lightness condition have a negative impact on the results; more the light condition is bad more the recognition rates decrease.

5. GAZE ESTIMATION

A. Related works

In the previous section we proposed a system to monitoring tablet through the eye gaze movement. With a simple eye motion we lance a command. But this method is limited in the term of actions that we can do it. So, few movements that we can do it with eyes and as consequence there are few commands that we can lanced. In this section we proposed another module that complete our system and open the door to a novel mode of communication with tablet through eye gaze.

In fact, many previous works are interested to estimation user's gaze on screen for many reasons such as education, marketing, psychology studies, etc…

Y.T. Lin et al. [13] present a real-time gaze localization system, that use a traditional webcam with a low resolution. This system is able to estimate gaze position without any additional equipment.

The authors use an IL luminance filtering method to decrease the light change effect on eye detection from frames captured by low-resolution webcam. They employ the Fourier Descriptor to specify the features of the eyes and the Support Vector machine (SVM) to localize the gaze position.

Although this system demands a low computational it is characterized by realizing a high performance shown in the experiment results..

M. Pouke et al. [14] proposed a gaze-tracking system gaze tracking with non-physical gesture recognition on tablet based on 3D virtual space. The main idea of this system that provides to users a way to select objects with the gaze and manipulate it by hand gesture. This system doesn't need any physical contact so it is independent of peripheries like keyboard or mouse.

The authors tested their system on 13 subjects and applied a scenario test and compare it with the touch screen method. They measured completion times for the both cases.

The experiments results show that the method based on touch gesture is faster than the non-touch one. In spite of this result the users find the eye-gaze tracking interested but it need more stability for generate it on mobile devices.

Y. Ebisawa, and K. Fukumoto [15] present a gaze detection system based on pupil-corneal reflection method. This system is independent of head movement.

This system is based on two optical systems: a near infrared light attached to the webcam. The eyes centers are detected by identifying the difference between the bright and the dark images. In the same time the infrared light generates the corneal reflection. The authors define the relation between vector from the glint and the pupil (r) and the angle between the light of sight and the line that passed the eye center (θ). The equation is defined as $\theta = k\,|r|$ where k is a constant.

For the stage of calibration, the authors tested 3 methods: the user look around the screen randomly without any target, the one-point calibration method and the two-point calibration.

The experiment results show that these methods increase the success rate of gaze detection and the average error is less than 1 tested on 7 different head positions.

Y. Fu et al. [16] proposed a gaze tracking system applied on a low-resolution camera. As known the low quality of an image decrease the performance of any eye detection system and to combat this constraint, the

authors uses the cornel reflection vector based on local image reconstruction using 2D bilinear interpolation.
The experiment results prove the feasibility of developing a system of gaze tracking although the low-resolution of camera.

B. Proposed system

To improve the performance of our system we develop another module to locate the point of regard in the tablet screen. The architecture of this module have the same three first steps: face detection, extraction the eyes regions of interest and the pupils detection like show figure 4. The final step is the estimation of the gaze.

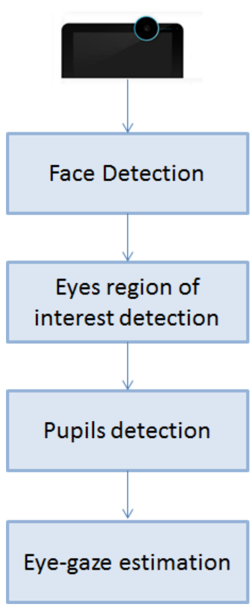

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Figure 4. Architecture of a gaze estimation module

The tablet is equipped with the front-facing camera that it doesn't have a high resolution. This constraint has a negative effect on the gaze estimation. So, we divide the screen on 8 zones and we try to estimate in any zone the gaze location is (figure 5).
For the calibration, we tested the algorithm in the way that we fixed the position of user and tablet to have constant parameters like shows figure 6.
In this case we fixed the distance between user and tablet and in the same time the angle of camera for the user.
In the first time we initiate the point of regard by proposing to user to look at the four corners of the tablet as targets. And in the second time, we proposed for user to look at every zone of the tablet to test our system.

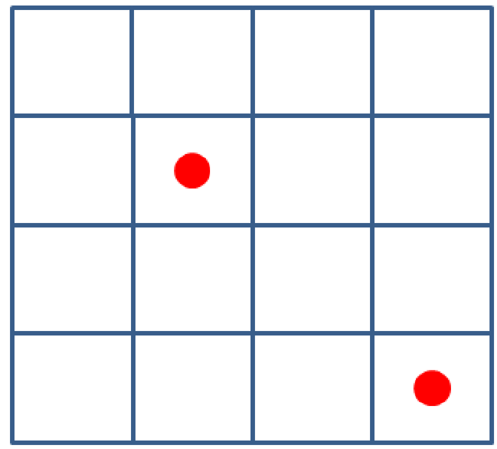

Figure 5. Screen zones

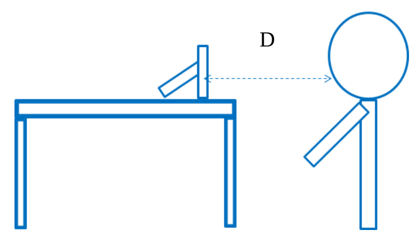

Figure 6. State of the user relative to the tablet

D: Distance between the user and the tablet

6. Cloud Computing

As it is known the mobile devices resources are characterized by the low battery life, constraint storage and low processing power. That is posing a problem to execute many applications that need important computing resources as well as real time applications.
This problem is solved by using the cloud computing. In the case of mobile devices, we use the term of mobile cloud computing. It based on the same concept of cloud computing. Applications demand computing resources and software are presented for users as a service.
In fact, when we testes out system we find that his time response is not really satisfied the real time condition. So we have try to apply the mobile cloud computing solution to migrate the calculate part of the system on the cloud (Figure 7). In fact the mobile cloud computing help the mobile application to be executed in the portable devices in the perfect condition in spite the limited resources. The Implementing of the cloud computation for this system is designed in the way that is being transparent for the user.

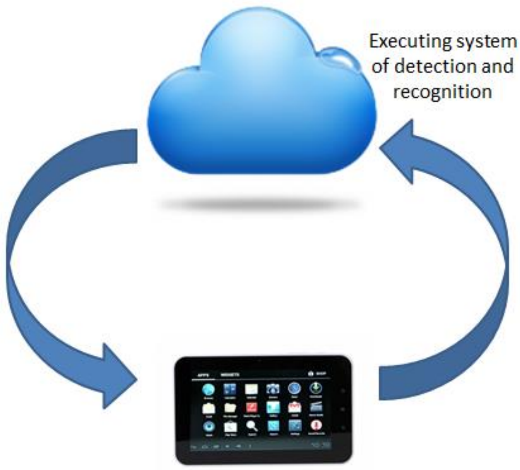

Figure 7. Deployment of our system in the cloud

7. CONCLUSION AND FUTURE WORK

In this paper we presented a head and a gaze gesture recognition system to monitoring tablets. This way of communication is very intuitive and natural. People need to control their device in this manner because it is fast and doesn't need any experience.

This system is implemented on an android tablet and it provides the possibility to control tablet with simple head and eye movement.

The Experiment result proves that our system is robust in the perfect condition. Having glasses, bad lightness and moving state of the user have a negative effect on the success rate of recognition.

We developed also another module to estimate the point of regard of user on the tablet screen. This system is based on the front-facing camera that it has a low-resolution. This constraint has a negative effect on the result so we try to fix the distance between the user and the tablet to develop the calibration step.

This system require to be real time, but the video and image processing and the recognition steps need much computing resources that let the processing of the algorithm very low. For this reason, we use of cloud computing in the way that all processing steps are being executed in the cloud out of the tablet. The use of the cloud help us to have a response time of execution satisfied the real-time constraint.

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