A Survey of Applications for Deaf-Mute People Based on IoT and Cloud Computing Services

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***Abstract*— In the world there are more than 400 million people with disabilities associated with speech and hearing, which represents more than 6% of the population worldwide, these people have various problems to be able to integrate into routine activities, as well as to access work sources. This research presents a compilation on technological developments based on IoT devices, as well as cloud computing services dedicated to helping people deaf and mute in their integration into society and the use of information technologies to closing the gap with people who do not have some type of disability. Among the most important investigations are those that use neural networks applied to video to interpret movements of people who use sign language, and in this way be able to generate the translation of text and speech, on the other hand, the outstanding investigations in IoT can interpret the movements of sign language for translate to text and voice using smartphones and other electronic devices. This paper includes a proposal focused on an evolutionary system to resolving some of the vulnerabilities that sign language translation systems present.**

Keywords*— *Cloud computing, Deaf-mute people, Internet of Things, Sing Language, Communication.

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I. Introduction

In the world there are currently more than 400 million people who have hearing and speech limitations. Of these disabilities there are different ranges on the perception of sounds, as well as the emission of words, being the most common conditions of these genetic inheritance, problems in childbirth, infections, as well as the use of medications and exposure with loud noise sources that damage the ear. People with this type of disability often experience situations of social exclusion [1]. Any type of these limitations generates a series of problems that endanger this sector of the population, as well as living with restrictions in society in access to services and sources of work decreasing their quality of life.

Traditionally, people with speech and hearing disabilities can communicate using sign language to be able to communicate in different environments. Sign language has the characteristic of taking elements in the expression of facial movements, through the hands, as well as the expression of written language [2]. According to the Federation of Deaf People (WFD) there are more than 300 sign languages [3]. An important characteristic of sign languages is that evolve with respect to the local needs of each region and each country in the world. Of the different types of sign language families, the following stand out [4]:

- British family
- Spanish French family
- German family
- Swedish-Finnish family
- Indo-Pakistani family
- Kenyan family
- Arab family

Due to the evolution of sign languages tend to have wide differences, since the evolutionary conditions to which these have been subjected [5] [6].

Currently, among the technologies that stand out to solve the communication problem is the Internet of Things (IoT), which is a process that allows connecting everyday physical elements to the Internet, to control household objects, medical devices, driving systems, city signage among others [7]. The architecture of IoT devices can be visualized in Figure 1.

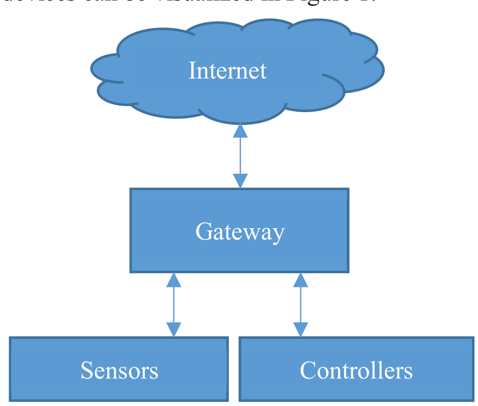

Figure 1. IoT Architecture

The first layer of the IoT architecture is related to the Internet users, the second layer include the network layer which has to do with routers for internet connection, finally the perception layer is related to devices such as sensors, actuators, and controllers. Among the most relevant hardware platforms

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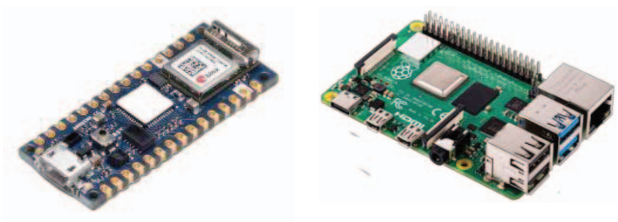
that are related to the IoT is Arduino and Raspberry [8], Figure 2, due to the ability integrate with different types of devices [9]-[10]. These platforms allow the incorporation of sensors for the reading of various variables, as well as internet connection to access the database, and data processing algorithms.



a) Arduino   b) Raspberry

Figure 2. Most-used IoT devices

The architecture of cloud computing allows different applications on information acquisition, the information that enters the servers is used to be stored and processed. Cloud services allow to partially replace desktop applications, since there are a lot of developments, ranging from word processors, video, and image applications, as well as advanced software based on neural networks for pattern recognition. One of the characteristics of cloud computing is that the terminals must be constantly connected to the internet but give the advantage that it is not necessary to acquire specialized hardware, as well as the acquisition of expensive software licenses. Therefore, it is aimed at meeting specific needs. This concept has a specific architecture, which is shown in Figure 3.

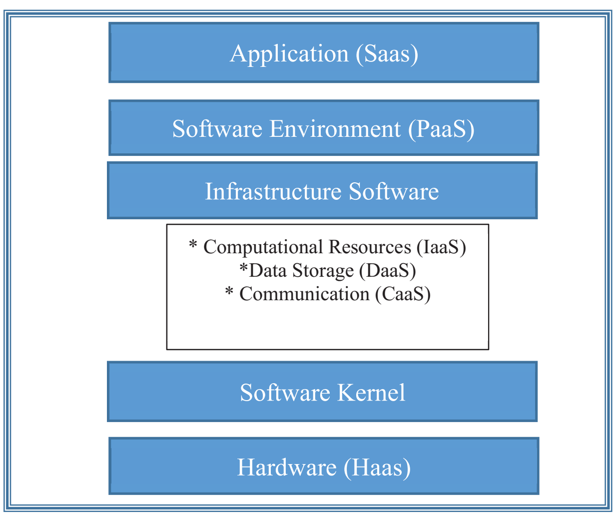


Figure 3. Cloud computing architecture

Figure 3 presents the architecture of cloud computing which includes models' software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS). All cloud computing models include a rigorous security scheme because their violation generates problems of data loss, as well as misuse of these [11]. Both cloud services and IoT devices present solutions to solve problems related to communication with deaf-mute people. The following section includes information on computational developments that use IoT and cloud computing for the interpretation of different sign languages, as well as other uses aimed at solving hearing problems.

II. State of the Art

Currently, various models based on IoT, and cloud services have been developed to help people with hearing and speech disabilities to perform better in their work environments, as well as to better establish contact in society. The following investigations present solutions for people with hearing and speech disabilities through IoT devices and cloud computing services for the translation of different sign languages, as well as tools that help to carry out various types of activities.

A. IoT models for deaf-mute people

The IoT devices have great processing capabilities, as well as data acquisition that can be transmitted over the internet, which gives them the advantage of solving communication problems. IoT-based models for communicating for the hearing impaired are widespread [12]-[18] because these allow sign translation applications using smartphones and electronic gloves. On the other hand, voice recognition and sound emission by means of gloves allows signal-based communication [19]-[23] to generate two-way communication between people with disabilities and without hearing impairment. In general, IoT models allow sign interpretation using sensors [24]-[26].

Among the platforms most used for sign language interpretation are open architectures such as Arduino [27]-[30], while Raspberry platform [31]-[35] occupies an important participation for the translation of the language of signs. Among the outstanding works in the use of platforms such as Raspberry is the work of Jain et al. [36], the authors developed a home sound recognition system for deaf and hard of hearing users, this system consists of a microphone and a screen as well as the listing of devices used in a home. The system is capable of emitting vibration alerts to help people with hearing disabilities to move around their homes. In Vasanth et al. [37] was developed a device based on Raspberry Pi to transmit voice in real time, the information was sent to the Google API to convert it into text and then display it on an LCD screen in addition to amplifying the voice through a speaker, the work is oriented for people with moderate deafness, as well as blind people who need to perform in work environments, but the device is dependent on stable Internet connections.

Because today home automation applications are voice-based creating a gap for deaf and mute, research such as Sathya et al. [38] they developed gloves for the use of home automation functions. In Lee and Lee [39] was proposed an intelligent sign language interpretation system that uses a portable device that incorporates pressure sensors, flexible sensors, as well as a three-axis inertial motion sensor to detect the gestures that represent the American alphabet. Once a gesture is made it is transmitted to a mobile device via Bluetooth to an Android application as well in the form of a text message, on the other hand, there is an application to convert voice to text.

In Kumar et al. [40] was conducted a study on IoT devices on their application different areas exposing the advantages of portability and data processing. In Hasan [41] developed a deaf-mute Electronic Assistant System (DMEAS) employed a Thalmic Labs Myo bracelet and a smartphone to read electromyography signals from the disabled person's forearm muscles through non-invasive surface-mounted electrodes (sEMGs) to send data directly to the smartphone via Bluetooth, the mobile application is responsible for interpreting the movements as words. A work on multimodal interfaces was presented in Moustakas et al. [42] as a game application which serves as a recreational educational tool with haptic functions with audio and video projection, incorporating computer vision, as well as sign language analysis and speech recognition.

The use of CNN (convolutional neural networks) is highly widespread in IoT devices as can be seen in Jeyasheeli and Indumathi [43] employed an automated sign language identification system, by connecting different sensors to gloves to perform gestures, movements are processed by a CNN. The work of Siddineni [44] refers a research study in the domain of sign language recognition on communication difficulties with people with hearing and speech disabilities. In Trivedi et al. [45] was developed a system for hand gesture recognition, with the ability to interpret the numbers from 0 to 9 and the American Sign Language alphabet, the system processes gestures to recognize the number with the help of a CNN. The research of Wasfi and Zeebaree [46] is based on a review of recent studies in the field of division of recognition systems into continuous and isolated, and the algorithms used in both methods such as the method based on recurrent neural network (RNN), CNN, and convolutional neural network three-dimensional (3D-CNN) for sign language recognition.

Devices such as gloves or computer vision analysis on the gestures that are generated with the hands can be seen with the work of Nanda et al. [47] was employed parameters measured by the flexible sensor and the accelerometer data is transmitted to a microcontroller. The microcontroller analyzes the data received from the sensors to send the respective s gesture analysis wirelessly via Bluetooth to an Android app. The development of an electronic application using Raspberry with machine learning was developed in [48], the development base focuses on gesture recognition using computer vision, the system recognizes the posture of the hand and the gesture it executes to detect the spelling that represents the fingers of a hand.

An important application of motion analysis can be observed in [49], the authors developed a device called Deaf Vibe, this device converts the voice inputs of normal people into a tactile vibro output into Morse, in the first instance the voice message is converted to voice, later in Morse code signals which are equal to those used in a table that is stored in the device. Through the signals it is possible to activate vibration motors that are placed in the position of the fingers of the hand, this motors are in a portable glove, for a deaf person through a glove perceive the vibration emitted by the motors and it is possible for him to interpret the message, it is also possible for the deaf-mute to use his fingers to achieve communication in Morse, the signals are converted into text using a text-to-speech synthesizer. Several sign translation investigations are based on the use of mobile applications, as in the work of Rehman [50], it shows a system to register the ALC gestures created by the user, using a processing unit whose function is to capture information from the available sensors, as well as a unit in charge of classifying the alphabet that is being expressed the system could translate signs into text using the Sign to Speech mobile app.

In Baba and Bala [51] created an electronic talking glove for signal interpretation that makes it easier for deaf-mute people to converse with normal people, voice translation messages appear on an LCD screen. Patil et al. [52] developed an independent interpreter through transference learning for American Sign Language (ASL) based on digital spelling using Raspberry Pi, in addition to presenting an interface for the development of two-way communication recognizing letters and numbers with 95% efficiency.

The proposals that use IoT devices previously presented have the advantage of adapting various electronic devices to offer a range of solutions that adapt to the needs of disabled people, allowing them to incorporate themselves with certain advantages in their routine activities. It is important to point out that most of the proposals are based on static models that are based on a translation of signs to text and voice or from voice and text to sign language, but no clear effort is shown to propose systems that allow incorporating new information to their knowledge bases.

B. Cloud Computing models for deaf-mute people

Cloud computing technology allows the development of various models for the implementation of translation applications and the ability to communicate people with speech and hearing disabilities. Among the investigations that stand out with the use of cloud computing is in [53], where authors evaluated the current automatic speech recognition (ASR) with voices of deaf and hard of hearing users (DHH) speakers. The authors reported that ASR systems have improved over the years and are able to achieve word error rates (WER) around 5-6% with the help of machine learning algorithms found in the cloud, employ special vocabulary, and assess the importance of improvement when using DHH speech. In the research of Xia et al. [54] proposed a system with the ability to interpret sign language for patients, so that the doctor can generate a more accurate diagnosis. The system employs MobileNet-YOLOv3 for the recognition of signs, it presents a 90% accuracy. This system depends on a constant internet connection. Vinoth and Nirmala [55] evaluate the advantages of the e-learning process for people in higher education with disabilities in Chennai, concluding that students acquire the skills necessary for their development. Da Rosa Tavares and Victoria [56] proposes a system of Apollo SignSound, for deaf people in a smart home environment, giving priority to safety with the detection of environmental risks through neural networks, this work is aimed at Brazilian Sign Language (LIBRAS in Portuguese), notifications are observed on a smartphone, it collects ambient sounds and notifies the deaf user, with an accuracy of 73%, and a 90% approval with 5 people evaluated.

A combination of cloud computing and IoT can be seen in Patil and Prajapat [57] was developed an advanced communication system for deaf people through an IoT device which is based on a Raspberry Pi board with Embedded Linux. A non-disabled person from the Raspberry Pi through a speech-to-text module, while the deaf person views the text through

Wi-Fi, Bluetooth, or cloud server communication. A mobile-based framework for deaf Arabs to communicate is presented in [58]. The framework employs cloud computing for higher complexity processing, which makes it possible to obtain Arabic language in text. In this work the authors developed an avatar to display Egyptian Arabic Sign Language on the deaf person's mobile phone. Oliveira Neto and Kofuji [59] present an approach that combines IoT and cloud computing to create a digital application focused on offering help on the context of an urban space, locating the points to which a deaf-mute need to move. The tools available for smart cities are available to perform common actions such as parking automatically [60], which benefits people with disabilities.

ProSign+ [61] is an experimental platform in charge of converting voice to sign language, the main base is the connection to a cloud service, which is accessible to any entity to provide inclusive access to information and services for deaf people. A paper dealing with the combination of different techniques is in Tanwar et al. [62], present privacy-preserving sign language recognition (P2SLR) which works under a scheme in the cloud infrastructure, protecting the user's visual information to the cloud service provider (CSP). The P2SLR system is based on a probabilistic image encryption scheme arranged in blocks and in combination of a fractional order chaotic system (FOCS) with singular value decomposition (SVD) to obfuscate the visual information that is presented in video frames.

Numerous investigations have been carried out for the interpretation of sign language with the use of cloud computing, as can be seen in the works of [63]-[66] due to the flexibility of generating systems with the ability to perform shape recognition. These works show the extensive use of frameworks based on cloud services for the identification of sign languages, to achieve high levels of interaction with deaf-mute people.

The development of a multimodal framework for isolated sign language recognition (SLR) using sensors is presented in Kumar et al. [67], in this proposal, Microsoft Kinect and Leap motion sensors are used to capture the positions of the fingers and palm. The Leap Motion sensor stays under hands while the Kinect sits in front of the signer to capture horizontal and vertical finger movement during gestures. Meanwhile, in Akin-Ponnle [68] was presented a Machine Language Algorithm method, to use holistic CNN to recognize digits shown by human hands by an interpreter. CAPTCHA services are highly required to verify that Internet services are used by people and not by robots. Proposals such as [69] use a cloud-based service using animated hand gestures to represent a sequence of characters that a hearing or speech impaired person can recognize. An architecture proposal of Cloud Robotics can be seen in [70], this technology uses hand tracking technology and bio-inspired robotic arms which are printed in 3D, allowing remote communication for deafblind people using a tactile sign language to allow develop their activities in a more natural way.

An analysis by image is presented in [71] executed a comparison between an architecture that recognizes the elements of mute person sign language using image processing and a CNN. On the other hand, a second architecture based on a visual recognizer that uses a cloud service to recognize gestures is used. The accuracy obtained by the CNN model is 98%, while the second model called Watson which runs in the cloud, obtained 97% accuracy. The use of CNN is highly extended for the recognition of sign language [72]-[73] due to its high effectiveness in recognizing gestures, for this reason in works such as [74] was developed a study in which use technology of automatic machine learning (AutoML) to recognize ASL using Google Cloud Platform (GCP). In general, the software detects people in motion. The proposed model presents a 99.5% precision, on the other hand this system can run in Android environments. Cloud computing-based solutions generally rely on computer vision and artificial intelligence (AI) techniques to perform sign language to speech or text translation tasks.

III. Discussion

According to the information analyzed, it is possible to observe that there is a large amount of research that takes different approaches when looking for sign language translation, when using IoT and cloud computing devices.

Due to the wide spectrum of solutions that can be applied with IoT it is possible to classify the different applications by the type of output these produce.

- Translation of text and voice into sign language through images or avatars.
- Translation of sign language to text and speech.

Among the most common proposals can be observed the use of voice-to-text and text-to-speech translators, those with greater complexity can display images related to sign language, as well as the use of vibration systems to alert users when a conversation or risk situation may arise. The use of communication networks allows to establish the sending of data with various equipment, through Wi-Fi, Bluetooth, as well as internet connection for data processing.

With the versatility offered by open hardware platforms such as Arduino and Raspberry it is possible to implement different technological solutions among which stand out.

- Development of electronic gloves.
- Deploying speakers with microphones.
- Development of electronic solutions in combination with mobile devices.

Of the previous implementations, the ones that present the most complexity, are those that allow to capture movements through mobile devices in combination with the sensors controlled by the IoT to reduce the degree of invasion presented by using this type of devices with deaf-mute people.

Table 1 shows the most important work on supporting people with hearing and speech disabilities.

TABLE I. RELEVANT IOT AND CLOUD COMPUTING WORKS FOR SING LANGUAGE RECOGNITION

Author	Main techniques	Contributions
Vasanth et al. [37]	Raspberry device with Google API connection	Real-time voice transmission to convert it to text and then

		display it on an LCD screen and speech synthesis
Hasan [41]	Myo bracelet for reading electromyography signals	Interpretation of electromyography signals of the forearm muscles with non-invasive sensors to send the data directly to the smartphone
Baba and Bala [51]	Electronic talking glove	Signal interpretation that facilitates the passage of voice translation messages appear on an LCD screen.
Hasdak et al. [49]	DeafVibe IoT Device Vibration motors for a finger glove	Converts the voice inputs of normal people into a vibro tactile output into Morse code, the voice message is converted first into text and then into equivalent Morse code signals
Da Rosa Tavares and Victoria Barbosa [56]	IoT with home automation Neural networks	Detection of environmental risks using neural networks with an accuracy of 73%
Tanwar et al. [62]	Probabilistic system Chaotic system SVD for image obfuscation	Block-based probabilistic image encryption scheme with FOCS SVD to obfuscate visual information in video frames.
Akin-Ponnle [68]	Machine Language Algorithm CNN holistic	Recognizes digits displayed by human hands by an interpreter
Shumilov [69]	Cloud-based CAPTCHA service	Use animated hand gestures to display a sequence of characters for deaf-mute people
Gullapalli et al. [71]	CNN Networks Cloud-based Watson model	Comparative study between neural networks and cloud services for sign language recognition

As can be seen in Table 1, IoT-based proposals have the versatility to implement devices such as LCD screens, speakers, [51] as well as being associated with neural networks [56]. An important part is that the sensors applied to deaf-mute people can interpret the signs that are being made [49], although this model has the limitation of learning new gestures. On the other hand, with the current development of cloud services allow combining the acquisition of information from IoT devices, as well as smartphones, to develop the translation of the gestures made by a deaf-mute person to be able to establish communication with other people. One of the biggest advantages of sign language translation models is that allow CNN and other powerful AI algorithms to be applied to classify the movements of individuals without a secondary device receiving the processing load [68], [71].

Table 2 shows the main applications for sign language using IoT devices, where it is possible to visualize the use of devices based on electronic gloves, speakers, with the use of hybrid systems for the use of sensors that interpret hand movements or muscle movement, as well as the use of mobile devices that implement AI techniques for gesture recognition.

TABLE II. IoT SOLUTIONS FOR SING LANGUAGE INTERPRETATION

Device	Advantage	Disadvantage
Glove-based	Allow establish with precision the push-ups that are performed with hands to interpret the movements	Are intrusive with the people who must employ them. Are not easy to transport.
Based on speakers and microphones	Allow display sound messages, as well as visualize the response of the interlocutors on LCD screens	Require a higher energy consumption. These must be in acoustic noise-free environments.
Hybrid systems with sensors and connection with mobile devices	Allow combining the precision of sensors such as flexors, accelerometers among others. Use of smartphones for advanced motion detection.	Generally depend on a stable internet connection

Cloud computing services oriented to the translation of sign language are generally designed to the processing of digital images in real time for the interpretation of signs, allowing the devices that are used to be less invasive with the end user.

One of the main disadvantages that can arise when using cloud computing service is that the internet connection must be constant, which is difficult because the connection to Wi-Fi networks is not always guaranteed, therefore, it is necessary to use telephony services to communicate data through 4G or 5G networks.

It is possible to notice that so many proposals oriented to the use of IoT, cloud computing or the combination of the two perspectives, the conversation that can be held between the disabled person with other people is usually with a 1 to 1 relationship, but generally these are not 1-to-many or many-to-many communications are considered, due to the complexity that occurs in this type of conversation. On the other hand, the communication that is established in a complex environment must contemplate a reduction of the noise that exists in the communication channel, which in most of the investigations presented has not been taken into consideration.

IV. PROPOSED MODEL

Models oriented to sign language translation are generally based on the interpretation of movements by sensors or with the interpretation of movements captured by video, usually limiting the solutions to static models that do not allow learning new signs. In this proposal it is chosen to use a video sign mapping software to establish the movements that have been made and then perform an interpretation by voice and text, the analysis of movements would be executed in a cloud service so that the result is reflected in a PC / Mobile Device. The voice capture of other actors with the conversation of the deaf-mute is processed by a Gaussian filter and SVD for the noise elimination, then the information is sent to the cloud service and returned in the form of signs that the deaf-mute can understand. With the inclusion of a learning matrix that allows the model to learn gestures that the user needs or wishes to incorporate is proposed.

Figure 4 shows a device that is responsible for monitoring the movements of a person through a camcorder that is mounted on a mobile device or a PC to generate the interpretation of the movements, in this way, the translation on the sign language is generated, in communication with an IoT device with the function of monitoring stress levels to determine the mood of the deaf-mute person and thus generate feedback to reduce the level of stress or anxiety in the disabled person. When stress events are detected, the system tells users that they must verify if any message in the conversation is not being understood, to resume a fluid conversation.

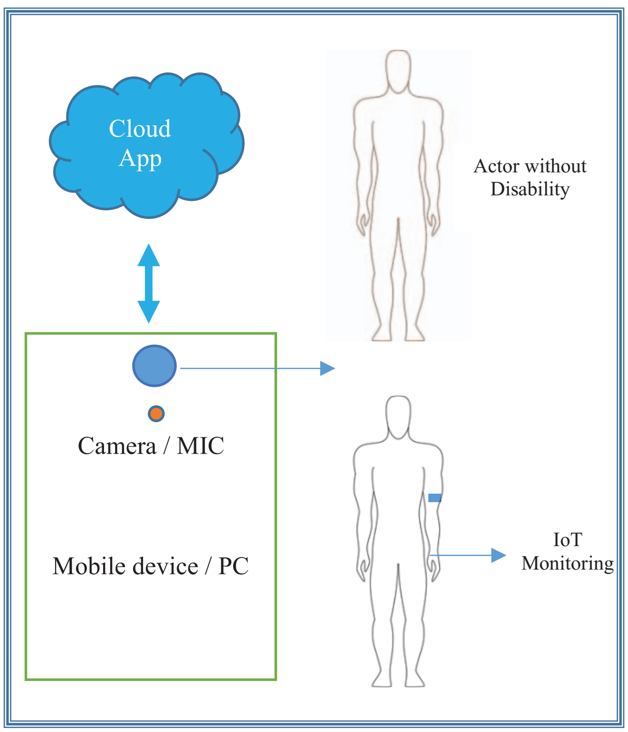


Figure 4. Sign Language Translation Proposal

The advantage of incorporating the learning of signs in the proposed system allows the use of language to be natural, since languages are constantly evolving, as well as presenting new options to the user that allow them to reduce their stress levels. In Figure 5 the learning memory of the system is shown for the generation of the learning of new gestures, validating that the inputs are consistent, and that data do not conflict with the inputs previously defined.

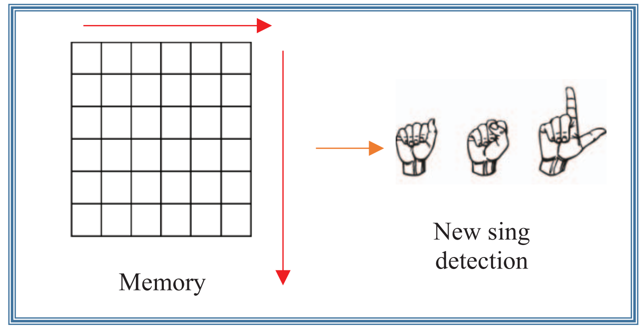


Figure 5. Memory evolutive

The translation proposal includes a quick response mechanism for the identification of different voice frequencies, to identify if there is more than one speaker in the communication, and thus indicate to the person with hearing impairment that there is more than one actor in the conversation.

V. Conclusions

IoT devices, as well as cloud computing services, provide a series of tools capable of opening the possibilities of communication to deaf-mute people, because take advantage of the potential of data transmission networks to send the results of translation of a language into sign language.

The most widely used hardware platforms for conversion of sign language to text and speech and vice versa is Raspberry, these devices work with its own operating system for information control, use of sensors, the ability to use advanced graphical interfaces and communication with smartphone. Due to the use of sensors and other devices, IoT devices can distribute the workload to devices such as smartphones and cloud services.

With cloud computing the possibilities of using frameworks and recognition networks, are technically unlimited, as well as the possibility of implement AI techniques (CNN, AA, among others), because any software can run and only obtain the necessary information, although internet connection is necessary in a stable way.

In this work, a proposal was presented for a system that combines the potential of cloud-based systems for the interpretation of sign language with the function of learning new gestures, in combination with an IoT device to establish a point of balance in communication to detect the level of stress and anxiety present in communication.

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