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Hardware and architecture: Human computer interaction and it's role in modern computer science

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Abstract
Hardware architecture is the identification of a system's physical components and their interrelationships in engineering. Hardware differs from software in that it is a physical representation of electronic and electromechanical components that contains both information and software. The internal electrical interfaces between the system's components or subsystems, as well as the interface between the system and its external environment, are the focus of hardware architecture. Human-computer interaction lies at the heart of Hardware architecture's goals. Human Computer Interaction or HCI started with giant machines in which punch cards were used to maintain loops of interaction then came more easier use computers which could be installed in homes and had keyboard and mouse to got with it. Folders and desktop were introduced and later the Operating system came and then access to the internet and with this HCI design shifted from how to accomplish tasks to encouraging interaction between people. Touchscreens are also a biproduct of HCI and are now a staple of most devices to the point that now it is becoming a relic of the past and new methods are being looked into to include a variety of people. The purpose is to delve into the process of development used for HCI and look in the methods that can improve HCI through different fields like connecting the brain, Augmented/Virtual Reality, Speech recognition etc. In conclusion the significance and implication of these fields is endless for example: AR and VR can be used in motion tracking image rendering and image merging which can be used for investigative purposes, connecting to the brain could possibly increase the capacity of the brain, speech recognition for better security and implementation of speech recognition in noisy environments would very useful too.

Keywords: Hardware and architecture, Human computer, modern computer science

1. Introduction

Human-computer interaction (HCI) is the study of the interaction between people and computers. Such interaction is mainly done at the user interface. The design of interactive computing systems for human usage is one of the key concerns of professional practitioners in the subject of HCI. As a result, one of the primary goals of HCI designers is to make computers more usable and responsive to the needs of their users. HCI designers are meant to construct systems that minimise the barrier between the human's cognitive model of what users wish to do and the computer's knowledge of the users' task in order to provide the best possible interface within given limits.

The user interface, which includes both hardware and software, is where users and computers interact. Interaction design is the process of creating interactive products to assist people in their daily and professional life. Because HCI is concerned with the interaction of a human and a computer, building a user interface necessitates understanding on both sides. On the one side, information about communication theory, graphic disciplines, social sciences, cognitive psychology, etc. are needed; Techniques in computer graphics, operating systems, programming languages, and so on, on the other hand. The field of HCI does not only mean the quality of interactions, it has also spread to other fields such as the focus on the concept of multimodality rather than unimodality such as VR and AR, intelligent adaptive interfaces and active interfaces.

This paper intends provide general concepts of HCI systems and explore its different fields as mentioned above and the methods through which it has progressed and how those different fields can be progressed further. The next section will go over how HCI products are created. The next section will look at how HCI has progressed by looking at the approaches, difficulties and solutions for building specific HCI interfaces like Brain Computer Interfaces and Speech Recognition in order to advance the field of HCI as a whole. The final sections discuss HCI applications and the field's future directions.

2. Process of designing a HCI product

2.1 Conditions of HCI product design

1. Functionality and Usability

A system is defined by its functionality but can only be valued when it's possible to be efficiently used by the user. Hence the essential conditions to consider while creating an HCI system are functionality and usability. Even if a system is capable of performing a complex task, it is worthless if it cannot be used effectively by people, and if it is simple to use but unable to finish the task owing to limitations in hardware or software, the machine is useless [1]. When the functionality and usability of a system are properly balanced, the system's true efficacy is reached [2]. That said what makes a HCI design good is mostly subjective and context dependent for example, an aircraft part designing tool should provide high precisions in view and design of the parts while a graphics editing software may not need such a precision. The technology that is available may also influence how different types of HCI are built for the same objective. Using instructions, menus, graphical user interfaces (GUIs) or virtual reality to access computer functions is one example.

2. Hardware and Software architecture

Examining the platform capabilities and limits is an important step in the usability engineering lifecycle [3]. The platform capabilities are employed to suit the needs of users, however they are limited by the architecture of the computer/device. The restrictions, likewise, are the outcome of the architectural organisation of the device's components.

Because of the limits connected with the device architecture, software built for usage on a certain machine/platform benefits from the capabilities of the computer/devices but may be constrained in having some intended features. As a result, human-computer interaction (HCI) must also identify and/or construct interaction modality to supplement the restrictions while adhering to the machine's architectural design. On the restricted platform, such approaches may enable and support users to execute their use cases (tasks/functions) effectively and efficiently.

Because of the wide range of uses and applications of computers and specialised devices for specific tasks, such as biomechanical and biomedical equipment, the interaction designer must also research the context of the tasks. Furthermore, instead of focusing just on hardware performance, embedded systems and smart devices should be viewed as opportunities in the design of HCI, allowing user interface/interaction designers to quickly and systematically absorb user interaction modalities in devices.

The purpose of HCI design should be to improve the usability of the designed product, whether the interaction is with the hardware element of the computer (machine or device) or the software [4]. In order for the user to accept the product, it is also necessary to give an intuitive and natural interaction experience [5].

3. Useful vs. Usable

Usability can often be compensated through trainings and technical supports when an engineered product is useful but not usable, but when the user's motor capability prevents them from operating a product that is perceived to be useful (e.g., due to disability), supplementing the user's physical limitation through additional accessories can be critical. A user may, for example, be unable to control his or her fingers as usual as a result of a stroke. As a result of their weak motor skills in the hands and fingers, such people will struggle with interactions that may require keyboard use and typing. As a result, consider using assistive typing or a typing assistance to improve the user's performance [6]. Another example is in the video game industry more games are now being equipped with facilities to accommodate special-abled people such as changing the display colours of the User Interface for colour-blind people and visual cues of sounds for deaf people.

The characteristics of a product should be designed with the human needs in mind so that it is usable but at the same time the product should be able to complete the task it is intended for efficiently so that it can be useful this can mean compromising on some of the constraints a person can have. This does not apply only to special-abled people it is more so that some products cannot be acquired due to different reasons or some products cannot be used on a system due to that system being outdated. This is a common dilemma in the video game industry where developers have to balance between designing higher quality games which can only be run on the newest consoles which limits the number of people who have access to them or reducing the quality or functions of the product so that it can work on older models too but this has risks as the game might still malfunction since it is being run on an older console. These malfunctions occur because even though the product can be used on both newer and older version models it is still designed with the newer model as a basis due to different reasons such as the quality of the product and in cases to market the newer model and entice people to purchase the newer model to run the product.

Usability is not a one-dimensional quality feature of an engineered product; rather, it is made up of multiple components that might occasionally clash; as a result, interaction designers must balance the various quality criteria. It is critical to investigate and comprehend human wants as well as ability in order to trade-off between crucial usability qualities and/or design usable products. As a result, it's critical to comprehend the physical, cognitive, perceptual, personality, and cultural diversity among the users for whom the product is designed [6].

4. Usability attributes

The usability attributes can be used to objectively measure interaction design based on the user's motor capabilities, psychological makeup, perceptual and cognitive model, as well as their experience and expectations.

Perceptual and cognitive model of the user: Aligning the design and architecture of engineered products with the user's perceptual and cognition model (or mental model) would make it easier for the user to interact; and the more a user engages with and uses the product, the more he or she learns and understands it. The user experience would be enhanced by a product that is simple to comprehend and learn [7].

Psychological makeup of the user Even if users are able to physically contact with an engineered product, this does not mean they want to use it. The reasons why users dislike or are apprehensive about a product, why they are not inspired to use it or drawn to it, and why they are not eager to use it are not always related to the product's utility. Even persons who enjoy using computers may have very diverse tastes for how they interact with the computer when utilising a certain application [6]. The psychological makeup consists of satisfaction, attractiveness, attitude and motivations [8].

Motor capability of user: Motor capability refers to the physical orientation of a user. The user's capacity to operate the apparatus is determined by his or her motor capabilities. This encourages the user to gain a better grasp of the engineered product they're dealing with [9]. As a result, it is beneficial to comprehend and model the user's competence as well as their limitation. The operability of the product and the efficacy of the user in accomplishing a task are the key aspects examined from the motor capability dimension from the standpoint of the engineered product.

2.2 Design Steps and Methodologies

Since its inception, a number of approaches have emerged that explain the techniques for human-computer interaction. A few design techniques are shown below [10].

1. **Activity theory:** This is a human-computer interaction (HCI) method that outlines the framework in which human-computer interactions occur. Reasoning, analytical tools and interaction designs are all provided by activity theory.
2. **User-centred design:** It puts users at the centre of the design process, allowing them to collaborate with designers and technical experts [11].
3. **User interface design principles:** The seven principles of interface design are tolerance, simplicity, visibility, affordance, consistency, structure and feedback.
4. **Value sensitive design:** This method is used to build technology and consists of three different sorts of studies: conceptual, empirical and technical.

- Conceptual investigations are aimed at gaining a better grasp of the values of technology-savvy investors.
- Empirical investigations are qualitative or quantitative design research studies that demonstrate the designer's comprehension of the values of the target audience.
- In both conceptual and empirical studies, technical investigations include the application of technologies and designs.

5. **Participatory design:** All stakeholders are included in the design process via a participatory design method, ensuring that the finished outcome fits their needs. Software design, architecture, landscape architecture, product design, sustainability, graphic design, planning, urban design, and even medicine all employ this style. Participatory design is not a style, but rather an emphasis on the design processes and methods. It is viewed as a means of reducing designers' design accountability and origins [12].

Profiling the user is vital now that a multidimensional perspective of HCI has been gained, such as the mental, psychological, and physical dimensions, because people can have their own capabilities and restrictions. Setting goals to be reached in the creation of the interaction modality and in alignment of the users' profile is the next stage to eventually generating a finished product once the user profile has been determined.

The user and platform are two of the building blocks that need due consideration to meet the goals of HCI and the task is the third block.

After determining measurements to include, the following iterative design steps are performed:

1. Design the user interface
2. Test
3. Analise results
4. Repeat

The iterative design process is repeated until a sensible, user-friendly interface is created [11, 12].

2.3 Display design

This is the final step in the development process. Displays are man-made artefacts that aid in the perception of relevant system variables and the subsequent processing of that data. The task that a display is intended to support must be defined before it can be developed (e.g., navigating, controlling, decision making, learning, entertaining, etc.). A user or operator must be able to interpret whatever data a system generates and shows; as a result, data must be shown in accordance with principles that promote perception, situation awareness, and understanding [13].

1. Perceptual principles

1. **Make displays legible or audible:** The readability of a display is essential for creating a useable display. If the characters or objects on the screen aren't discernible, the operator won't be able to use them efficiently.
2. **Avoid imposing absolute judgement boundaries on yourself:** Asking the user to determine the degree of a variable based on a single sensory variable is not a good idea (e.g. colour, size, loudness). These sensory factors might have a wide range of levels.
3. **Processing from the top down:** Signals are most likely seen and interpreted in accordance with what a user has already experienced. If a signal is delivered in a way that the user does not expect, extra physical evidence of that signal may be required to ensure that it is correctly comprehended.
4. **Increased redundancy:** It is more likely that a signal will be appropriately understood if it is provided multiple times. As redundancy does not imply repetition, this can be accomplished by delivering the signal in different physical forms (e.g., colour and shape, voice and print, etc.). Because colour and location are redundant, a traffic light is a good example of redundancy.
5. **Similarity causes confusion:** Use discriminable elements. Signals that appear to be the same will almost certainly be mixed up. Signals are comparable when the ratio of similar features to distinct features is high [14].

2. Mental model principles

6. **Principle of pictorial realism:** A display should resemble the variable it depicts (e.g., the high temperature on a thermometer shown as a higher vertical level). If many elements are present, they can be adjusted to appear as they would in the depicted environment.
7. **Principle of the moving part:** Moving pieces should follow a pattern and direction that is consistent with the user's mental image of how the system works. An altimeter's moving part, for example, should travel upward as altitude rises [14].

3. Principles based on attention

8. **Minimizing information access cost or interaction cost:** There is a cost in time or effort when the user's attention is moved from one spot to another to get vital

information. A display design should reduce this expense by placing commonly used sources in the most convenient location. However, in order to save money, adequate legibility should not be disregarded.

9. **The notion of proximity compatibility:** For the accomplishment of one job, divided attention between two sources of information may be required. These sources must be cognitively integrated and described as being in close mental proximity to one another. Access to information should be inexpensive, which can be accomplished in a variety of ways. (e.g., proximity, linkage by common colours, patterns, shapes, etc.). However, close display proximity can be harmful by causing too much clutter.
10. **Principle of multiple resources:** A user can process information from a variety of sources more quickly. Instead of showing all visual or all audio information, for example, visual and auditory information can be displayed together [14].

4. Memory principles

11. **Replace memory with visual information:** knowledge in the world. Important information should not be stored entirely in working memory or retrieved from long-term memory. A menu, checklist, or other display can help the user by reducing the amount of time they spend using their memory. However, the usage of memory can sometimes be advantageous to the user by removing the need to refer to some type of world knowledge (e.g. an expert computer operator would rather use direct commands from memory than refer to a manual). For an effective design, the utilisation of knowledge in a user's head and knowledge in the real world must be balanced.

This concludes the process, methodologies and conditions which go into developing HCI interfaces and products. The next section will describe the recent advances in HCI interfaces through the methodologies of development and applications of these advances [14].

3. Advances in HCI

The following sections describe in detail specific fields of HCI, their applications, the challenges faced in these fields and possible solutions. HCI has an infinite potential to improve as hardware becomes more powerful and efficient and its applications will continue to broaden.

3.1 Brain computer interface

The Brain Computer Interface (BCI) is an interface between the brain and a device that receives signals from the brain and converts them into commands that are communicated to output devices that carry out the intended tasks. Normal neuromuscular output channels are not used by BCIs. Its greatest contributions are in the medical field, ranging from injury prevention to neuronal recovery [15]. Mind reading and remote communication have left their imprint in a variety of industries, including education, self-regulation, production, marketing, security and games and entertainment. It establishes a shared understanding between consumers and the systems that surround them. The BCI system is made up of four main parts. Signal capture, signal preprocessing, feature extraction and classification are some of them.

The signal acquisition component is in charge of recording the brain waves and transmitting them to the preprocessing component for noise reduction and signal enhancement. Invasive and non-invasive methods of brain acquisition are the two main categories. Electrodes are neurosurgically inserted either inside the user's brain or over the surface of the brain in invasive technology, whilst brain activity is recorded via external sensors in non-invasive technology [16]. Some examples of applications of BCI were mentioned above, the next sections will delve more deeply into how BCI has contributed to different fields.

3.1.1 BCI Applications

BCI computer interfaces have contributed in various fields of research such as Medical, Neuroergonomics and Smart environment, Neuromarketing and advertisement, Educational and self-regulation, Games and entertainment and Security and authentication.

1) **Communication:** BCI can build a communication channel between the human brain and the external world, this helps handicapped people to tell and write down their opinions and ideas via variety of methods such as in spelling applications or silent speech communication [17]. It can also be used for hands free applications, essentially mind-controlling machines.
2) **Healthcare:** BCI has a variety of applications in all the phases including prevention, detection, diagnosis, rehabilitation and restoration.

i) **Prevention:** BCI can be used to study the cognitive state of a person under the influences of factors such as smoking, alcohol and motion-sickness. This information can be used to in an accident prevention system by monitoring the person’s state and sending appropriate signals [18].

ii) **Detection and diagnosis:** BCI systems have contributed in detecting health issues such as brain tumour, seizure disorder, sleep disorder and brain swelling through mental state monitoring [19].

iii) **Rehabilitation and restoration:** As discussed above, mobile robots can be utilised to assist locked-in persons with daily activities. BCI-based prosthetic limbs, also known as neuroprosthetic devices, can be used to restore normal functionality in patients who are unable to achieve former levels of mobility or communication [20]. Various reality approaches for BCI-based rehabilitation training have been presented, including real, virtual, and augmented approaches. The brain signals generated by healthy persons, as well as the decoded kinematic characteristics, are used in a real rehabilitation strategy. It helps stroke victims change their thinking patterns to mimic signals and virtual reality is used in the retraining process.

3) **Neuroergonomics and smart environment:** Lin *et al.* presented the Brain computer interface-based Smart Living Environmental Auto-adjustment Control System (BSLEACS) as a cognitive controller system that uses BCI technology. It keeps track of the user's mental state and adjusts the environment accordingly [21]. By assessing an operator's cognitive state, these can be used to help improve workplace conditions [22]. The application of using BCI systems to increase a drivers attention level in order to avoid accidents has also been researched into.
4) **Education:** BCI interfaces are used to improve brain performance by modulating human brain activity. The

subsequent response experienced by each learner is used to create a personalised engagement for them [23].

5) **Games and entertainment:** Combining the features of existing games with brain controlling capabilities has been subject to many researches to provide a multi-brain entertainment experience. Games also meant for emotional control and neuroprosthetic rehabilitation have been developed so as to provide players with amusement while training them to be more relaxed and calm [24].
6) **Security and authentication:** The usual methods for security such as passwords, object based and biometrics based authentication have vulnerabilities. Cognitive Biometrics through BCI which use brain signals as sources of identity information, gives a solution to those vulnerabilities [25]. They can also be of great value to users who are specially-abled or are missing the required physical trait [26]. Such signals are difficult to synthesize and therefore improve security.

3.1.2 BCI development challenges

Usability challenges express the limitations facing the user acceptance of BCI technology utilization. These challenges are as follows:

1) Training process

It takes place in the preliminary phase. In the preparatory phase, the user is taught how to operate the system and regulate his or her brain feedback signals, while in the calibration phase, the signal of a trained subject is used to learn the used classifier. Training a user takes time, either in terms of guiding the user through the process or in terms of the number of recorded sessions.

Using a single trial instead of a multi-trial analysis is one of the most often researched solutions to this time-consumption problem [27].

2) Information transfer rate

It is the most extensively used statistic for command BCI systems evaluation. It is determined by the amount of options available, the precision of target identification, and the average time taken to make a decision. As a result of the bigger number of options available, selective attentive tactics accomplish a better rate of information transfer.

The following are examples of technical challenges relating to the electrical qualities of brain impulses.

3) Non-linearity

The electroencephalogram (EEG) is a medical diagnostic that measures brain electrical activity. In order to do this test, a number of electrodes are placed on your scalp. The brain is a complicated nonlinear system in which chaotic neuronal ensemble behaviour can be seen. Nonlinear dynamic approaches can thus better characterise EEG signals than linear ones.

4) Nonstationary factors

Nonstationarity attribute of electrophysiological brain signals represents a major issue in developing a BCI system [28]. They are basically the continuous change of signals over time or due to different factors which are hard to control. These may include fatigue, concentration, emotional state which cause changes in used signals over time either between or during use of the interface. Noise is also a major factor in the issues that BCI technology faces, as well as the nonstationary issue. It comprises undesired signals induced by changes in electrode location as well as noise from the surroundings [29]. The obtained data also reflect a combination of movement artefacts, such as electrical activity produced by skeletal muscles electromyogram (EMG) and signals formed by eye movements and blinking Electrooculogram (EOG), making it difficult to determine the underlying pattern.

5) Small training sets

Because the training process is influenced by usability difficulties, the training sets are small. Although the subjects find the training sessions time consuming and challenging, they offer the user with the essential experience to interact with the system and learn to control his or her neurophysiological signals. The difficulty here is to develop a BCI that strikes a compromise between the technological complexity of reading the user's brain signals and the amount of training required to operate the interface successfully [30].

6) High dimensionality curse

Signals are recorded across numerous channels in BCI systems to maintain high spatial precision. R Bellman, a mathematician, coined the phrase "the curse of dimensionality" in his 1957 book "Dynamic Programming." It basically indicates that as the number of characteristics grows, the error grows as well. In general, at least five to ten times as many training examples per class as the number of dimensions is recommended. However, in a high-dimensional environment like the BCI system, this solution cannot be sustained, causing the dimensionality curse to spread [31].

3.1.3 Proposed solutions

Different solutions for the above challenges have been listed below to improve the performance of BCI based systems.

1) Noise removal

Noise is the unwanted signal that interferes with the main brain signals and thus can cause problems with the BCI interface as it results in difficulties in distinguishing between the signals. Signal to Noise Ratio (SNR) is the basis of this problem and needs to be improved in order to make the system more efficient. This is done by increasing the signal level and/or decreasing the noise level.

Independent Component Analysis is a popular spatial filtering technique (ICA). ICA performs unsupervised spatial filtering by splitting the recorded EEG into statistically independent components (ICs). It tries to improve EEG signal SNR by distinguishing task-relevant EEG components from task-irrelevant EEG components and artificial components.

Temporal based preprocessing can contribute in removing artifacts [32] from the signal using linear combination of the EOG-contaminated EEG signal and the EOG signal recorded using eye movement recording electrodes. The combination factors are determined via linear regression methods. Although it is the most frequent method for removing ocular artefacts from EEG signals, it does not achieve the same level of effectiveness when it comes to removing EMG signals due to the difficulties of putting muscular detecting electrodes.

Filtering by frequency band aids in the removal of noise and artefact. It can also be of great assistance in dealing with internal nonstationarity factors. The task-related frequencies can be chosen for use in BCI systems for further study. This filtering method does not necessitate the use of additional electrodes to detect eye or muscle movement. Filtering has the virtue of being simple. The advantage of using filtering is its simplicity. However, if the unrelated signal overlaps or is in the same frequency region as the signal of interest, the effect of this strategy declines [32].

2) Machine learning techniques

The user's intent is translated into a legitimate decision using machine learning algorithms. They make a distinction and identify the chosen group. They've been utilised to overcome some of the limitations of limited training sets, single trials, and the variability between sessions and within individual sessions, for example. They also want to improve their performance and, as a result, their ITR outcomes. Following that, we show three distinct machine learning techniques, including linear discriminant analysis (LDA), support vector machine (SVM) and k nearest neighbours (KNN).

i) Linear discriminant analysis

The LDA algorithm is used to find linear combinations of feature vectors that represent the features of a signal. LDA aims to distinguish between two or more classes of items or events that represent distinct classes. This mission is accomplished through the use of hyperplanes. The separation hyperplane is found by looking for the projection that maximises the distance between the means of the classes while minimising the interclass variation.

This approach is simple to use and has a low computational need. LDA has been successfully applied in a variety of BCI systems, including motor imagery-based BCI, P300 speller, multiclass and asynchronous BCI. However, its linearity can cause performance reduction in specific scenarios with complex nonlinear EEG data, despite the fact that it normally offers decent results due to its immunity to nonstationary problems.

ii) Support vector machine

SVM is a classification approach that uses supervised learning to separate two different classes of data. Like LDA, it uses a discriminant hyperplane to identify classes. In the case of SVM, however, the chosen hyperplane maximises the distance between the nearest training points. The support vectors, which are vectors that lie on the margin, characterise this ideal hyperplane.

SVM has a number of benefits. It is known to have good generalization properties, to be insensitive to overtraining and to the curse-of-dimensionality. Finally, SVM shows good performance results in both Evoked potential and ERD/ERS BCI.

iii) K nearest neighbors

It is classified as an unsupervised nearest neighbour classifier, in which the feature vector is assigned to the class with the fewest k neighbours. The fundamental advantage of KNN algorithms is their simplicity. Their vulnerability to the curse of dimensionality, on the other hand, is regarded the fundamental flaw that hinders their performance with BCI devices. As a result, with efficient feature selection and reduction methods, it can produce good results.

The applications, problems, and solutions for Brain Computer Interaction are now complete. The following part will look at voice recognition, its problems, and possible solutions.

3.2 Speech recognition

One of the numerous fields of HCI is speech recognition. It has been studied since the late 1950s, but progress has been slowed due to its intricacy. Automatic Speech Recognition (ASR) can attain high levels of accuracy in ideal circumstances such as a laboratory, but it degrades in real-world situations. The solution would be to create ASR that is noise robust. Below is a collection of speech recognition applications, some of which are already in use in our daily lives.

3.2.1 Applications

1) **Language weighting:** In addition to terms currently in the base vocabulary, improve precision by weighting specific phrases that are uttered frequently (such as product names or industry jargon).
2) **Speaker labelling:** Generate a transcription that references or tags each speaker's contributions to a multi-person conversation.
3) **Acoustics training:** Pay attention to the business's acoustics. Train the system to adjust to different speaking styles and acoustic environments (such as those seen in call centres) (like voice pitch, volume and pace).
4) **Profanity filtering:** Use filters to identify and sanitise voice output by identifying specific words or phrases. Natural language processing: It is applied in mobile devices which incorporate speech recognition into their systems to conduct voice search.
5) **Automotive:** Speech recognizers in car radios increase driver safety by allowing voice-activated navigation and search features.
6) **Technology:** Virtual agents, particularly on mobile devices, are becoming more and more incorporated into our daily lives. We use voice commands to control them via our smartphones, such as Google Assistant or Apple's Siri, for tasks like voice search, or through our speakers, such as Amazon's Alexa or Microsoft's Cortana, for music playback. They'll only become further integrated into the items we use on a daily basis, fueling the "Internet of Things" movement.
7) **Healthcare:** Dictation applications are used by doctors and nurses to record and log patient diagnosis and treatment notes.
8) **Sales:** Speech recognition technology can be used in a variety of sales situations. It can assist a call centre in transcribing thousands of client and agent phone calls in order to detect typical call patterns and difficulties. AI chatbots can also communicate with users through a website, answering common questions and completing basic requests without the need to wait for a contact centre agent. In both cases, speech recognition technology help shorten the time it takes to resolve customer complaints.
9) **Security:** As technology integrates into our daily lives, security protocols are an increasing priority. Voice-based authentication adds a viable level of security.

These are some of the applications of speech recognitions, the following sections details the challenges for these applications and some of their proposed solutions.

3.2.2 Challenges

1) Accuracy

Accuracy nowadays refers to more than just the word output accuracy.

On a case-by-case basis, many other factors influence the amount of accuracy. These elements are frequently specific to a use case or a certain business requirement and they include:

- Background noise
- Punctuation placement
- Capitalization
- Correct formatting
- Timing of words
- Domain-specific terminology
- Speaker identification

2) Data security and privacy

Concerns regarding data security and privacy have risen dramatically in the last year, according to the Speechmatics survey, from 5% to 42%. This could be due to apprehension following the media's characterization of tech behemoths as "data-hungry". It could also be a result of more daily interactions taking place online after the coronavirus pandemic prompted a surge in remote work.

3) Deployment

Voice technology or any software for that matter-must be simple to deploy and integrate. Whether a firm requires on-premises, cloud, or embedded deployment, integration must be simple and safe. Integrating software can be time consuming and costly if you don't have the right help or documentation. To circumvent this adoption hurdle, it is critical for technology providers to make their deployments and integrations as simple as feasible.

4) Language coverage

When it comes to language coverage, several of the main speech technology suppliers have a gap. Although most providers provide English, the absence of language coverage becomes a hurdle to adoption when multinational businesses seek to use speech technologies.

3.2.3 Solutions

1) Deployment on premises

Voice technology deployed on-premises allows customers to keep their data secure within their own environments, eliminating the need for data to be sent to the cloud. It's frequently done with virtual appliances or containers, which may be easily put into existing infrastructure.

2) Cloud deployment

Private cloud deployments are sufficiently secure to keep data safe for a wide range of applications. Cloud deployment is generally the preferred alternative due to lower operational costs and less complexity if cloud deployment security meets the business and use case needs.

3) Speech enhancement techniques

These are techniques used to suppress noise in the speech signal but at the risk degrading the original clean signal. Spectral subtraction is a method for restoration of the power or the magnitude spectrum of a signal observed in additive noise, through subtraction of an estimate of the average noise spectrum from the noisy signal spectrum [33].

4) Missing feature techniques

Missing feature methods model the effect of noise on speech as the corruption of regions of time-frequency representations of the speech signal. A variety of time-frequency representations may be used for the purpose. This technique basically overlaps the speech signal into frames and from each frame, a power spectrum is estimated, these are then compressed into a non-linear function to obtain an output called spectrogram to create a clean speech signal [34].

5) Other methods are simple and do not involve complex techniques, these methods involve using physical substances in order to reduce noise such as noise cancelling foam etc. The methods previous to this are supposed to be applied in the architecture of the system.

In the last, in [36-41] readers, students, researchers can be found interesting works on emerging topics like Industry 4.0, Society 5.0, etc. and their importance for the smart era.

4. Conclusion

Human-Computer Interaction (HCI) is a crucial component of system design. The way a system is displayed and used by users determines its quality. As a result, better HCI designs have received a great deal of attention. The Third Wave, a new research area aimed at replacing ordinary regular means of engagement, aims to integrate technology into the environment in order to make it more natural and invisible at the same time. Virtual reality is an emerging discipline of HCI that has the potential to become the common interface of the future.

This study tried to provide an overview of the field of human-computer interaction (HCI) and the design process for HCI systems. It also showcased the potential and advances of HCI through detailed examples: BCI and Speech recognition. HCI is now apart of daily life and due to this it will continue to expand to bridge to the gap between Humans and Computers.

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