Technoarete Transactions on Industrial Robotics and Automation Systems
Vol-2, Issue-1, March 2022
e-ISSN: 2583-1941

Effectiveness of Human–Machine Interaction (HMI) for Development of Communication and Interaction between a Human and a Machine to Control Machines

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Abstract

This study is based on the human-machine interaction that is the way of communication between automatic systems and people. The HMI process allows humans to control the machine through initiatives behaviours and natural. Those factors also lead to building the established communication process with the technology and digital system as well. From this study, it has been seen that H2M devices include a sensor for measuring the comments signal such as voice, touch, and gestures for constructing an updated system to control and a measurement system to measure the electrophysiological signals. This study has also focused on the Sensor HMI that can help to detect the temperature and strain pressure. It can provide the opportunity to monitor and mimic human senses and it also can improve machine control by graphene, carbon nanotubes, hydrogel composites, and Ag nanowires. These kinds of elements give the provision to build a stretchable sensor for developing the structure's stretchability. Accordingly, it can be said that the mechanical sensor process assists to apply the attachment of the enabling strain sensors in the finger joints for measuring the movements of the figure and using the pressure sensor for improving the analysis of grasping activities. This study has also shed light on the Actuators of HMI that helps to deliver all kinds of human output and also have the ability to mimic the sense of people or individual for the desired outcome of human and machine interaction. It can help to stimulate the senses of humans mechanically. In this context, it can be said that wearable gloves use the benefits of soft actuators for rehabilitation. It helps to support the force of grasping. On the other hand, the mechanical vibration process helps to stimulate the human sense that helps to provide certain information as well. Intelligence-aided devices usage is one of the other critical parts of this study and from this portion, it has been seen that the advancement of actuators and sensors in machine intelligence help to get higher detectability in soft sensors, coping with chronic problems, and decoupling unwanted stimuli in sensor process. This factor helps human hands to provide the highest degree of freedom in the body for performing a range of tasks with the development of detecting hand motions. This study has chosen a secondary process to get the data for the study and it also helps to make a proper conclusion for the study. At last, it can be said that HMI is a blessing for the world population and future generations.

Keywords

Ag nanowires, carbon nanotubes, human-machine interaction (HMI), and hydrogel compos PDMS.

INTRODUCTION

The human-machine interaction (HMI) is defined as the way people and automatic systems interact and communicate with each other with the help of the user interface. In the current time, the natural user interface utilizes gestures for increasing attention and allows humans to control the machine through natural and intuitive behaviours. This factor helps to establish communication with the computers and digital system or the device from the IoT for developing connections and automatically carrying out the task effectively. The smooth connection between the people and machine guide to develop the interface that helps to project the action for developing the user's engagement with the machine [1]. The advancement of soft sensors and accuracy helps to provide the higher potential of HMI devices in the mechanical work for providing a comfortable environment to the users. HMI indicates the bidirectional communication interface that divides human-to-machine (H2M) systems and machine-to-human (M2H) systems in the working process.

H2M devices include a sensor for measuring the comments signal such as touch, voice, and gestures for constructing better system control and a measurement system for measuring electrophysiological signals such as electrocardiography (ECG) and electromyography (EMG). These devices help to control systems with the help of sensors in various mechanisms that include strain sensors for the direct major deformation due to stretchable electrodes of humans. This factor helps to measure electrical signals of the muscles of the individual and improves the measuring process with the guidance of integration of multiple functions, logical circuitry, and multi-dimensional detecting ability. The "Indian human-machine interface growth opportunities" report shows that the demand for comfort and convenience connected car Technology helps to get $1.67 billion revenue in 2027 [2]. This factor reflects the Indian automotive HMI system market is going through a technological shift by utilising original equipment manufacturers for advancing its infotainment system in their new model launches.

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On the other hand, M2H devices provide electrical thermal, visual, and mechanical feedback in stimulating various sensations that help to develop the demand for wearable virtual and augmented reality devices such as VR and AR. These devices provide tactical feedback and thermal situations with the help of wearable assistive devices as part of system fabrication into the stretchable form for developing sophisticated technology efficiently. The M2M model accounted for 463. 3 million of all the network devices in India in the year 2022 [3]. This factor helps to point out different performances of HMI devices and also access to improve machine intelligence for developing the prediction of body motion with sensors in the electronic system. HMI devices assist to detect objects and the decoding process of neural command signals through the help of electronic systems.

The advancement of integrated systems in logic circuits and wireless platforms allows for the development of tackling feedback information of the users and developing sensor detection capability [4]. The objective of the study is to understand the efficiency of human-machine interaction in the development process of communication and interaction between humans and machines. This factor assists to understand the sensors and gestures process for developing interaction with the machines for providing control of machines.

LITERATURE REVIEW

Sensors of HMI

The stretchable sensor guides intimate human-machine interaction for the stretchable mechanism such as strain pressure and temperature that helps to study electrical sensors for providing control over robots. This factor helps to provide a better degree of freedom in monitoring mimic human senses for improving machine control with the help of graphene, Ag nanowires, carbon nanotubes, and hydrogel composites [5]. These materials assist to develop stretchable sensors in improving stretchability in the structure such as serpentine in the external deformation implementation in the circuit system. This sensor process uses a straining process to get sensitive and stretchable sensors in electrophysiology and gloves in developing the communication with the sensor process with the help of AI. The stretchable mechanical sensor utilises EGain and PDMS in the skin prosthesis to examine pressure moisture and temperature that helps to improve the sensor ability of the machines. On the other hand, the usage of hydrogel, liquid metal, temperature, and optical waveguide assists to develop multi-function, self-healing ability, and single coupling through the activity of the electrical sensor.

Figure 1: Stretchable Electronics In HMI
(Source: [6])

The mechanical sensor process helps to apply the attachment of enabling strain sensors of the finger joints for measuring the finger movements and using the pressure sensor for developing analysis of grasping action. This factor guides in mapping the contract pressure distribution that helps to demonstrate train pressure sensors in the wearable gloves for feedbacking the pressure signals to the wearer as the visual details. The feedback process helps the weather to adjust the target grasping force for controlling the response signal with the help of a sufficient single-axis strain sensor [7]. The multi-dimensional behaviour of the skin can limit traditional single-axis straining sensors that reflect the importance of sensing multi-dimensional strain on the skin of humans. The usage of silver nanowires provides flexibility and stretchability of electronics due to their excellent electrical and mechanical properties in the multi-dimensional strain measurement process.

EMG sensor guides measure electrical signals from the muscle nerve stimulation and detect subtle electrical signals transmitted from the body in the skin-mounted stretchable sensor process. The electrical signals act as the detectable sensor that helps to control the machines with human gestures and predetermined estimated mode. The “Indian industrial sensors and the transmitted market” expected a CAGR Of 7.1% in the time period of 2018- 2028 that helps to utilize motion, environmental, and vibrational sensors in monitoring health equipment in India [8]. This factor presents that the Indian industry is expanding its operations economically and demographically with the support of domestic interest and the export of the opportunities of HMI devices.

Bluetooth communication helps to develop rapid remote control and devices with high mechanical completion for skin-attached wearable devices that allow the measurement of human physiological signals. The usage of carbon nanotube networks in internal sensors helps to integrate the inductor and capacitor components for the reading circuits to offer suitable specifications in the sensing components [9]. This factor helps to maximise the response of voltage in sensor resistance of body rate, heart rate, arm movement, and leg movement measurement process with integrated sensors.

Actuators of HMI

The stretchable actuator assists to deliver the human output and mimics human sense for a better outcome of the machine and human interaction that helps to stimulate human senses mechanically. Wearable gloves utilise soft actuators that act as pneumatic actuators for rehabilitation in supporting the grasping force and mechanical vibrating for stimulating human senses to provide certain information about the actuating system. The Actuators apply soft tendons, stretchable pumps, hydraulic actuators, and skin-integrated haptic interface in monitoring the sensing process effectively [10]. Human acidity devices help to reduce the energy spent on a particular motion with the help of force assistance for specially disabled people. Robotic assistance plays a significant role in developing the rehabilitation of stroke patients with the accelerated device for stretchability that enhances the versatility of machines to humans. Flexibility and stretchability act as the alternative to rigid materials in the exoskeleton for their suitability in the manoeuvrability process that is used in wearable assistive gloves.

The slack prevention mechanism helps to provide relaxation in tendon fraction issues and allows the wearer to develop grasping of various objects such as plastic balls and spray containers. This factor helps to resolve hygiene issues by providing different types of stretchable actuators in assistive glove devices and decreasing muscular fatigue with the help of EMG signal data. The soft robotic gloves apply hydraulic actuators for analysing the finger joint movement and adjust the movement according to the arrangement of fibre reinforcement and strain-limiting layers [11]. This factor shows that disadvantage due to the greedy and external pubs of wearable devices that reflect on their probability and consist of monolithic elastomers on managing stretched conditions. This factor assists to enable device miniaturization in fluidic muscle in improving the soft actuator chamber of the stretchable pump that develops hydraulic forces in amplified self-healing electrostatic actuators.

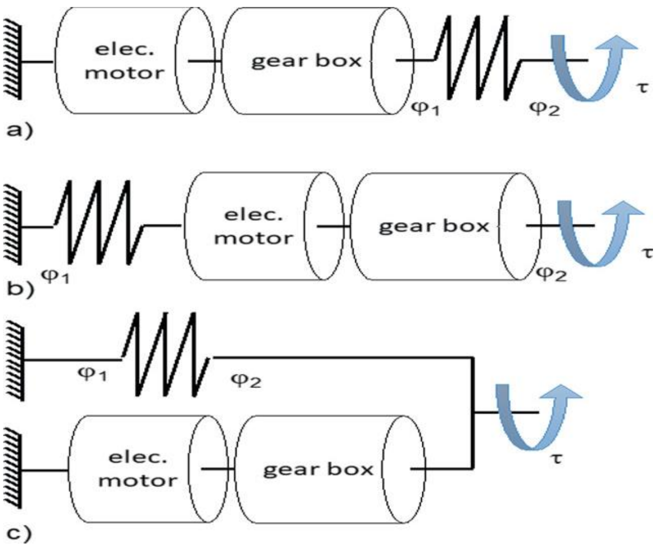

Figure 2: Design of Elastic actuators for HMI (Source: [12])

The above figure shows that elastic actuators help to provide force control on the robots in the critical environment with the help of good force control bandwidth. This factor helps to develop the shock tolerance, high force fidelity, and extremely low impedance in legged robot and exoskeleton that evaluates human performance amplification. Mechanical haptic devices use fibre actuators for developing contract lengthwise in the heat conjunction and polymer designing with the colloid structure for straining temperature-induced deformation. This factor helps to operate at a low temperature with the help of linear low-density polyethylene fibres (LLDPE) for improving the capability of implementation in haptic devices. These fibre actuators assist to combine the common fabric material without thermal degradation and overcome the mechanical weakness of LLDPE fibres [13].

e-ISSN: 2583-1941

The haptic simulation helps to analyse the feedback of actuators and develop the design of force acquisition that utilize in the communication device of the wearer for developing the interaction process.

The haptic device guide delivers information related to the shape size of the object for developing single monolithic vibration actuators for improving the shaping process of characteristics of virtual touch. This shaping process allows for demonstrating selective actuators in-game character interaction and delivers valuable information related to spatiotemporal patterns of vibration.

Intelligence-aided devices usage

The advancement of sensors and actuators utilize machine intelligence with the help of higher detectability in soft sensors, coping with chronic problems of hysteresis, and decoupling unwanted stimuli in the sensor process. This factor helps human hands to provide the highest degree of freedom in the body for performing a range of tasks with the development of detecting hand motions. This detection of hand motion helps to identify the motion with the single sensor that reflects the crack-based highly sensitive skin sensor attachment in the wrist for detecting the finger's motions [14]. This factor helps to manipulate the crack of the metal layer for controlling the annealing of ultraviolet lasers to combine long short-term memory networks for decoding the finger motion effectively. The sensor process has its transfer learning assistant in the calibration of the ability to operate in different parts of the wrist of individual users for understanding the sensor on the pelvis.

The tactical gloves reflect the combination with the neural network for providing potentiality in identifying multiple objects and pressure mapping of grasped objects for developing the representation of image data. This factor helps to develop the visualization of data in mapping the grasped object and developing the force-intensive sensor process in the gloves. The advancement of the sensor process guides the hydrophobic gloves to show better gesture decoration accuracy and provide better performance in recognizing hand gestures and finger motions [15]. This factor helps to provide algorithm quantity in the three-step for calibration process that includes ground data from webcam cameras, the analysis of train electrical single data, and the embedded sensor system of the wearable application. The electrical signal of censors helps to combine the input of principal component analysis in extracting the main features of science gesture to train the network through multiclass support vector machine (SVM) classifiers.

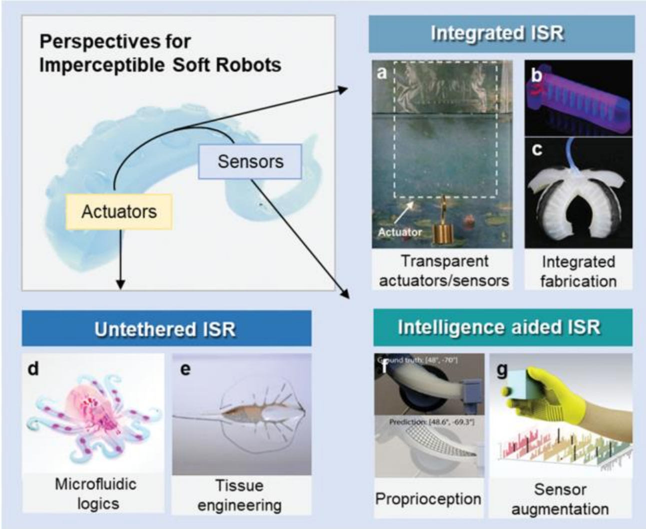

Figure 2: Application of soft actuators
(Source: [16])

The controlling process of actuators with hyper elasticity provides a challenge due to the longer properties that create an application to develop the soft robot's configuration and controlling process. Resolution of this problem helps to able machine intelligence in developing soft robotic preparation and better control to identify the complicated motion such as blending and twisting of the hand. This factor assists to apply a single output model for protecting the bent and twisting state of the body and predicting its deformation angles. The recognition of the bending and twisting process uses a multi-output regression model in the sensor modification process and provides data about fibre terminal light intensity in the training dataset.

The artificial intelligence task force submitted a report in 2018 that shows the recommendation of the Indian government in establishing standards for designing and developing and deploying the AI-based system [17]. This factor allows for providing education and re-skilling processes in the industry that helps to implement Intelligence-aided devices for reinforcement learning methods. The learning method helps to understand multi-layer perceptions in learning architecture for observing the current state of actuators to measure the radial and vertical displacement of sensors.

METHODOLOGY

Study design

The cross-sectional design assists in observing the data of population for understanding the causal effect of the independent variable on the dependent variable in the research topic analysis. This factor helps to analyse the development of human-machine interaction for maintaining communication and interaction between humans and machines. This study design helps to describe the efficiency of HMI devices in mimicking the gesture of hand and body for developing the sensors efficiently. This factor helps to develop the Singh architecture and design evolution of human-machine interaction for evaluating the user interface techniques and details of access systems in sensors and actuators. HMI assists to describe the effect of convolutional neural networks in the presence of deep learning frameworks for recognizing gestures with the help of depth and skeleton sequences [18]. This factor has to close the loop between actionable feedback and sequence with the construction of tangibility in the identified user interface principles by intuitive and efficient visualization.

Data collection

The data collection process helps to collect valid and reliable resources to get appropriate data related to the research topic and develop the research method effectively. The random sampling process is used in this study to collect data related to human-machine interaction effectiveness in controlling machines and provide insights about the sensor services provided to the users. This factor helps to evaluate results from the user interface to understand the quality and designing process of HMI devices with the help of sensors, actuators, and Intelligence-aided devices. The collected data from online resources such as news articles and journals to analyse the scope of the HMI market and segmentation of the HMI system for strategic imperative. This factor helps to understand the machine learning approach in categorizing the features that are extracted to predict the class of sensors and equators in the sensing recognition system for a smooth implementation process [19]. On the other hand, the difference between different sensory channels depends on the changes in the task context for taking visual and haptic sensing to understand the surface texture, softness, and grasping force.

Data analysis

The secondary data analysis process assists to observe the collected data in understanding the research topic and developing the research questions effectively. This factor helps to develop the potential of multi-sources in unreliability and delays to defining challenges in achieving real-time remote interaction between humans and machines. Prediction of action volitional for selecting longer time scale to predict the way human sample and weight different sensor challenge in the changes of task context. The constitution of goal-directedness helps to develop the multi-sensory process and action plan to predict the human action planning of adopting a machine learning algorithm with the help of a low latency process [20]. This factor helps to model human reasoning and behaviour in improving the mutual adaptation of algorithms for measurement in sensors and actuators with the help of HMI devices.

FINDING AND DISCUSSION

Rapid development is happening in artificial intelligence, computer cloud and big data. Technological improvement has facilitated smart manufacturing in various industries. Various countries have emphasized on smart manufacturing and for this reason development of artificial intelligence, cloud computing and big data has been prioritized. Industrial revolution 4.0 has improved digital technology a lot and for this development usability of artificial intelligence, cloud computing and big data has been increased. For example, the US is giving priorities on advanced manufacturing and the traditional manufacturing life cycle is to be changed under this move of the country [21]. In the traditional manufacturing life cycle, man power is essential and in advanced manufacturing the role of man power is to decrease as involvement of machines is to be increased. However, demands of new collaboration between machines and humans is increasing due to promoting this kind of manufacturing in the country.

In manufacturing and other works related to human and machine involvement, communication and cooperation among these has huge impact to accelerate the entire process of working. Human machine interaction provides focus on cooperation, communication and interaction between machine and human [22]. Different kinds of technologies are involved and the technologies are included for realizing virtual reality. The technologies are such as haptic interaction technology, augmented reality and voice interaction technology. Adoption of machines has changed gradually by the HMI technologies and most people have been used to the machine to provide better performance in their professional space. The entire process of improving adoption of machines by humans has four stages and humans have improved their interaction with these four stages. First, the keyboard and display, in the initial stage humans could do interaction with machines through inputting text and keyboard are essential elements to provide text to machines as orders.

Machine showed output on display and humans can understand the response of orders which were done by machine. This was the way of the interaction between machines and humans. In the second stage, computer graphic display applications have been included in HMI that helps to provide information to users through computer graphics and that was the more advanced way to interact with machines for humans. In the third stage, web and internet have been introduced in HMI and changed the entire system of interaction between machine and human. Development of the internet and web have introduced touch-based interaction, pen-based interaction, video-based interaction and voice-based interaction [23]. Touch and voice-based interaction between machine and human has changed the whole scenario and overall interaction has improved a lot. This development plays an important role in accelerating the output of collaboration between humans and machines.

In the fourth stage, multimodal technologies are involved to make interaction between machines and humans. The computer technologies such as AR, VR, eye tracking and gesture recognition are applied to make better interaction among humans and machines. Trends of smart manufacturing are rising and in these trends humans control machines to improve their performance in the workplace [24]. In most cases it is found that machines are used by humans to improve their skills, credibility, experience, expertise and adaptability in using machines. Overall production is improved due to this kind of approach of humans. HMI is used in different kinds of work such as product life cycle, designing, services and manufacturing. Robots have been developed as an experimental platform for exploring HMI mode. Robots provide facilities for interacting with mobile phones and for this reason humans can easily communicate with robots.

The process to interact through mobile has reduced time consumption in giving orders to robots. On the other hand, robots are much more capable of making designs with a short time that helps to reduce stages of the product's life cycle that has a huge impact on overall production. Multimedia mediums are included among robots and the systems are able to make physical interaction with humans. Accurate interaction is possible with physical interaction with humans and it helps humans to have more control over machines. Much more control on humans plays an important right role to increase safety as possibility of injuries is minimum. AR and VR technologies are largely used in design of HMI that help to make the process fast and safe [21]. Collaboration between machine and human helps to create human robots' interaction environment that helps to improve interaction between them.

Developing human robots' collaboration provides various benefits to humans in manufacturing activities. Robots are more capable of doing work as the robots are machines. Much more working break is not necessary for robots. Working load on humans can be decreased due to collaboration between machine and human and in dangerous works robots provide additional safety to humans [25]. Robots are capable of interacting with humans through natural language that helps to build better collaboration with machines. Simulation of assembling is developed by robots and overall time consumption of products' life cycle is decreased. On the other hand, usage of materials is reduced by using simulation of products' life cycle. Usages of man power and energy resources are also cut down through this assembly simulation. These benefits are possible due to better interaction between machine and human. In the current situation HMI is used on a large scale in product life cycle.

DT and virtual models provide opportunities to increase capabilities of HMI and for this reason usages of it have been increased in various fields. HMI technology is the direct way to occur interaction between machine and human. In recent times soft sensors are installed in HMI and as a result potential of it has become high levels. High level potential of HMI devices provides benefits to make smooth interaction with humans and for this reason a comfortable environment is provided to users [26]. Sensors work to provide sufficient response as per user's commands such as voice command and touch. In the HMI system there are two types of devices such as human to machine and machine to human.

Soft sensors are included in these devices to get commands and provide enough response as per the commands. In recent times the overall performance of HMI has been improved and in this improvement machine intelligence has a huge role. Machine intelligence can make complex decisions based on data. Multiple tasks can be performed by machine intelligence with existing resources. These capabilities of machine intelligence have improved the functionality of HMI. In recent advancement three types of stretchable electronic devices have been included in HMI [27]. Stretchable sensors, intelligenceaided system and stretchable acurating system have been installed in the process of advancement of HMI.

CONCLUSION

Technology is developing and different kinds of advanced technologies are included in the HMI system. Capabilities of this system are improving and for this reason usability is also increasing. In the technological field, artificial intelligence systems, cloud computing and big data technologies have been developed. These technological developments have improved the ability of the HMI system of doing interact with humans. Collaboration of machine and human has been improved due to involvement of these technologies in HMI. Trends of smart manufacturing are increasing and for this better collaboration between machine and human is able to provide smart manufacturing. Demand for HMI systems is increasing to improve machine and human collaboration for promoting smart manufacturing.

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