Applications and challenges in Service and Security robots

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ABSTRACT

Robotics have been swiftly progressing in tandem with developments in computer vision, speech recognition, sensors, and artificial intelligence. Progress in sensor technology, navigation systems, and machine learning is enhancing the intelligence and mobility of robots, while also reducing costs, enabling them to cater to a broader array of services. These services frequently take place in dynamic settings, necessitating the ability to navigate through populated and occasionally constrained zones. These facilities have been used for advancement in service robot sector, which in turn demanded ensuring high security in these applications. This chapter will be guided through characteristics, features and recent trends of service robots and security robots. It further discusses an elderly assistance application implemented using service and security robots. Sensor data is analyzed using Artificial Intelligence (AI) model to predict different human behaviour. The overall challenges faced during the implementation of service and security robots are discussed. The chapter concludes by presenting open research challenges faced in this area.

Keywords—AI, Elderly assistance, Robotics, Security robots, Service robots, Sensors

I. INTRODUCTION

Robots with human interaction capability is a hot topic in research. With the advancement in the technology of computing and sensing, robots can offer a wide variety of applications.[1] This chapter mainly focuses on service and security robots for elderly assistance.

Service robots, also known as service-oriented robots or assistance robots, are a type of autonomous or semi-autonomous robots designed to perform various tasks to assist or serve humans. These robots are developed with the aim of enhancing the quality of human life, improving productivity, and providing support in tasks that might be challenging, dangerous, or time-consuming for humans to perform.[2,3,4]. Key characteristics and features of service robots include: **Functionality Range:** Service robots can perform a wide range of functions, from daily routines like washing, kitchen works and lawn mowing, to more complex tasks in industries such as healthcare, logistics, and agriculture. **Autonomy:** Based on the task difficulty, service robots can operate autonomously, semi-autonomously, or under remote control. Advanced navigation systems, sensors, and artificial intelligence algorithms enable them to navigate and interact with their environment effectively. **Human Interaction:** Design of service robots demands a natural and user friendly interaction with human. This may involve speech recognition, facial expression analysis, gesture recognition, and touch interfaces. **Safety:** Safety is paramount in service robot design. Safe operation of service robots in human interactive environment is achieved by employing various sensors to detect obstacles. **Applications:** Service robots find applications in a variety of fields. They can assist the elderly and individuals with disabilities in their daily activities, perform tasks in healthcare facilities such as medication delivery or patient monitoring, provide support in manufacturing and logistics, and even be deployed in hazardous environments like disaster zones or radioactive sites.

Personalization: Some service robots can adapt to individual preferences and needs. For instance, a robot vacuum cleaner might learn the layout of a house and adjust its cleaning pattern accordingly. **Continuous Learning:** AI integrated service robots can learn and improve over time. They can adapt to new tasks, environments, and situations, making them more versatile and efficient. **Ethical Considerations:** Privacy, job displacement, human-robot interaction, and safety are the ethical issues concerned with service robots design. Striking a balance between technological advancement and societal concerns is crucial. In summary, service robots are helpers who take up the daily routine job of human to make their life easier. As technology continues to advance, the capabilities and applications of service robots are likely to expand further, contributing to a more efficient, convenient, and safe human experience.

Security robots are specialized robotic systems designed to enhance security and surveillance measures across various environments. These robots are developed to provide an additional layer of protection, monitoring, and threat detection in areas where human surveillance might be limited or risky. Their primary purpose is to improve security measures, reduce risks, and enhance situational awareness[5,6,7]. Key features and characteristics of security robots include: **Surveillance and Monitoring:** Security robots are equipped with advanced cameras, sensors, and surveillance technologies to monitor and record activities in real-time. Continuous monitoring can be provided for wider areas, reducing the need for constant human presence. **Autonomous Patrolling:** Many security robots accomplish autonomous patrolling. They follow predefined routes or patterns, ensuring comprehensive coverage of the designated area. Some models can even adapt their patrol paths based on detected activities. **Detection and Alerts:** Sensor integrated security robots can detect various anomalies such as intruders, unauthorized access, fire, gas leaks, and more. Upon detection, they can raise alerts, notify security personnel, or take predefined actions. **Remote Operation:** While some security robots are fully autonomous, others are manually operated through security personnel. This allows operators to intervene, navigation to specific locations, and manage responses in real-time. **Multimodal Communication:** Human interaction of Security robots are released by the use of communication tools like speakers and screens. They can deliver warnings, instructions, or communicate with potential intruders. **Data Collection and Analysis:** Security robots collect and transmit data to a decision making model and then analyzed for patterns and insights. This data-driven approach enhances decision-making and response strategies. **Adaptation to Environments:** Security robots are designed to operate in various environments, such as outdoor areas, industrial sites, shopping centers, and office buildings. They can handle different terrains, weather conditions, and lighting. **Reduced Human Risk:** Security robots are particularly useful in hazardous or high-risk environments where human presence might be dangerous. They can minimize human exposure to potential threats. **Integration with Other Systems:** Many security robots can integrate with existing security infrastructure, such as access control systems, alarms, and surveillance networks, creating a comprehensive security ecosystem. **Ethical and Privacy Considerations:** As with any advanced technology, secure, private data and it's potential misuse are the main issues related to security. Ensuring responsible deployment and addressing these concerns is crucial. In conclusion, security robots are critical in enhancing security measures by providing real-time monitoring, threat detection, and timely responses. Their capabilities contribute to safer environments and more effective security operations in a variety of settings, from public spaces to industrial facilities.

II. RECENT TRENDS

A. Service Robots

Service robots are machines designed to execute various tasks for humans or equipment, with the exception of applications related to industrial automation. These robots can be divided into two primary categories: professional service robots and personal service robots. Professional service robots find utility in business-oriented fields like logistics, healthcare, agriculture, security, and public relations. On the other hand, personal service robots are intended for household uses such as entertainment, education, cleaning, and providing companionship[8,9,10]. Some of the recent trends in service robots are: AI integration: Advancement in artificial intelligence made the service robots more intelligent and autonomous. AI enables service robots to learn from their environment and adapt to changing situations with multiple robots and humans[11]. Cloud-connected robots: Service robots access large volumes of data and computing resources from the cloud. Cloud connectivity allows service robots to share information and collaborate with other robots and to receive updates and improvements remotely. Robotics development platforms: Service robotics is becoming more accessible and affordable, due to robotics development platforms that provide tools and resources for creating and deploying robot applications.The platform enables developers, researchers, and hobbyists to design, test, and customize various application based on robotics. Evolving business models: Service robotics is creating new playground for businesses, as they adopt new models such as Robot as a Service (RaaS) and Software as a Service (SaaS). These models allow businesses to offer service robots as a subscription-based or pay-per-use service, rather than as a one-time purchase. This reduces the upfront costs and risks for customers, while increasing the scalability and profitability for providers. Cloud-connected robots: Service robots access large volumes of data and computing resources from the cloud. Cloud connectivity allows service robots to share information and collaborate with other robots and to receive updates and improvements remotely. Robotics development platforms: Service robotics is becoming more accessible and affordable, due to robotics development platforms that provide tools and resources for creating and deploying robot applications. The platform enables developers, researchers, and hobbyists to design, test, and customize various application based on robotics. Evolving business models: Service robotics is creating new playground for businesses, as they adopt new models such as Robot as a Service (RaaS) and Software as a Service

(SaaS). These models allow businesses to offer service robots as a subscription-based or pay-per-use service, rather than as a one-time purchase. This reduces the upfront costs and risks for customers, while increasing the scalability and profitability for providers. Some examples of personal service robots are: Domestic servant robots: They perform household chores such as cleaning, laundry, cooking, and gardening. Personal care and companionship are also their important functionalities. Automated wheelchairs: Self sustainability and mobility are provided to individuals with physical disability and aging. They can navigate autonomously, avoid obstacles, and follow commands. Personal mobility assist robots: Help people move around more easily and safely. They can provide support, balance, and guidance. Pet exercising robots: Play with and exercise pets such as dogs and cats. They can stimulate their curiosity, chase them, and reward them.[12]. Above mentioned are the examples of robots used in personal service, either available or in development. They offer humans convenience, comfort, safety, and entertainment[13,14]. Some examples of professional service robots are: **Cleaning robots**: Perform tasks such as vacuuming, sweeping, mopping, disinfecting, or sanitizing public or private spaces. They can operate autonomously or semi-autonomously, and can be equipped with sensors, cameras, or UV lights[15]. **Delivery robots**: Transport goods or materials from one location to another, either indoors or outdoors. They can navigate autonomously or remotely, which is designed to carry different types of payloads. **Fire-fighting robots**: Assist firefighters in extinguishing fires, rescuing victims, or assessing hazards. These fire and smoke resistant robots can be equipped with water cannons, thermal cameras, or sensors. **Rehabilitation robots**: Help curing patients' injuries, disabilities, or illnesses. They can provide physical therapy, cognitive training, or social interaction. They can also monitor the patient's condition and progress. **Surgery robots**: Perform surgical procedures with high precision and accuracy. They are operated by surgeon through a console or a computer, and can handle various tools like scalpels, scissors, or forceps [16,17]. Above mentioned are the examples of robots used in professional service robots, either available or in development. They deliver characteristics like efficiency, safety, quality, and innovation.

B. Security Robots

Security robots focus on the protection of people, property, or information. Their applications extend to operations such as surveillance, patrolling, detection, identification, or intervention. Security robots are well liked and advanced, thanks to the recent innovations in technology [18,19,20,21]. Listing certain trends in security robots: **Real-time video analytics**: Security robots can use machine learning to analyze video data in real-time and recognize objects and movements. This enables them to react autonomously to their situation and alert human operators if necessary. **MAC address recognition**: Security robots can scan local networks and check devices' MAC addresses, which serve as distinctive markers for phones and computers. This enables them to estimate user population in an area and identify suspects or cybercriminals. **Graphene batteries**: Security robots can use graphene batteries, which are a new type of battery that offers higher energy density, faster charging, and longer lifespan than conventional batteries. This enables them to operate for longer periods of time and reduce maintenance costs. **Hyper-spectral cameras**: Security robots can use hyper-spectral cameras, which are cameras that capture images across an extensive array of wavelengths beyond the visible spectrum. This enables them to see things that are invisible to the human eye, such as chemical signatures, heat signatures, or hidden objects. **Sound recognition**: Security robots can use sound recognition to identify and classify sounds using machine learning. This enables them to oversee the surroundings and detect anomalies or threats. Above mentioned security robot trends show potential for improving security and safety. Security robots are becoming more intelligent and autonomous, thanks to these new technologies. Some examples of security robots are: **Cobalt**: Cobalt is a security robot that can patrol indoor spaces such as offices, warehouses, or malls. It can detect anomalies, such as intruders, fire, or water leaks, and alert human guards. It can also recognize faces, scan badges, and interact with people using voice and touch screen. **PackBot**: PackBot is a military robot that executes tasks like bomb disposal, reconnaissance, surveillance, or combat support. It can navigate rough terrain, climb stairs, and operate in various environments. It can also carry different payloads, such as cameras, sensors, or weapons. **LG CLOi**: LG CLOi is a cleaning robot that can disinfect public spaces such as airports, hotels, or offices. It can move autonomously and avoid obstacles, while emitting ultraviolet (UV) light to kill bacteria and viruses. **Thermite RS3**: Thermite RS3 is a fire-fighting robot that can assist firefighters in extinguishing fires, rescuing victims, or assessing hazards. It can endure elevated temperatures and smoke, and can be equipped with water cannons, thermal cameras, or sensors. It can be teleoperated by a firefighter using a tablet or a joystick. Selected examples of security robots that are available or in development are mentioned. They can offer a range of advantages to humans, such as efficiency, safety, quality, and innovation.

III. APPLICATION

An application Elderly assistance with security cam is discussed with respect to service and security aspects.

A. Service aspect

The proposed system shown in Figure 1, is a user-friendly and a wearable device that will assist and monitor the elderly people in six major activities like daily routine assistance, health monitoring, communication, navigation, fall detection and emotion recognition. In daily routine activities the system alerts the elderly to take medicines, helps them read the newspaper and gives notifications regarding the tasks to be performed. The medical

conditioning of the patient like blood pressure, heart rate, oxygen, body temperature and occasionally monitoring of the blood sugar are also incorporated in the system. Automatic alerts are generated in the system if drastic variations in the body parameters are reported. The emergency communication is incorporated in the system by transforming the recognized gestures into speech. The system identifies the accidental fall of the elderly and notify the registered medical practitioner about the emergency situation. To recognize the different emotions during the training phase, the EEG sensor continuously monitors the emotional state of the user and identifies the activities which bring happiness to the elderly. The AI based system uses advanced machine learning algorithms to keep track of the daily activities and to automate the decision-making process. The wearable sensor captures the status of the elderly and a LSTM based machine learning model is employed for making the real time decisions. AI algorithms are deployed on a Jetson nano GPU. The device will have a direct impact on 138 million elderly population in India. The implementation of the system will make the elderly more self-sufficient, healthy and more engaged in their daily activities, remind them regarding the time to take daily medicines, and keep them motivated by improving their emotional quotient [22,23,24]. The multidimensional system will provide assistance and monitoring areas. **Characteristics of the device:** The proposed wearable device has the following features. 1. **Daily Routine**: This feature monitors the daily activities of the elderly. Alerts the elderly to take the medicine. News paper reading: The E-newspaper contents is analysed and summary is narrated to the elderly (as text or as speech) thus assisting him in times of difficulty to read the newspaper. Method: Training the system: The time taken for each activity performed for a day is recorded by the caretaker. This process is repeated for a month. These data are stored in a cloud (database). Testing phase: After the training phase is complete. Caretaker can be substituted by the system which will monitor the daily routine of the elderly person. If there are any discrepancies then an alert message is sent to the caretaker and to all the registered phone numbers so that necessary action can be taken at the appropriate time. 2. **Health Monitoring System**: This feature monitors the following: Blood Sugar level, Blood Pressure, Heart rate, Oxygen level and Body temperature. Method: The system alerts the elderly and the caretaker in case there is deviation from the normal readings. **Communication Assistance**: The speech of the elderly may lack clarity. This feature converts the gesture of the elderly to speech that enables the caretaker to understand the needs of the elderly. Method: The gesture to speech conversion is implemented. **Navigation Assistance**: The allowed navigation routes of the elderly are recorded. Any deviation from the normal alert is immediately provided to both the patient and supervisor. **Fall Detection**: The sensors (accelerometers) are used to detect fall and alert preselected contacts. **Emotion Recognition**: Training phase: EEG signals of elderly is taken and emotions such as happy, sad, angry etc are recorded. Testing phase: Whenever the emotion is matched with the recorded ones the corrective measures are taken. Ex: whenever the person is sad then a music may be played to soothe him etc.

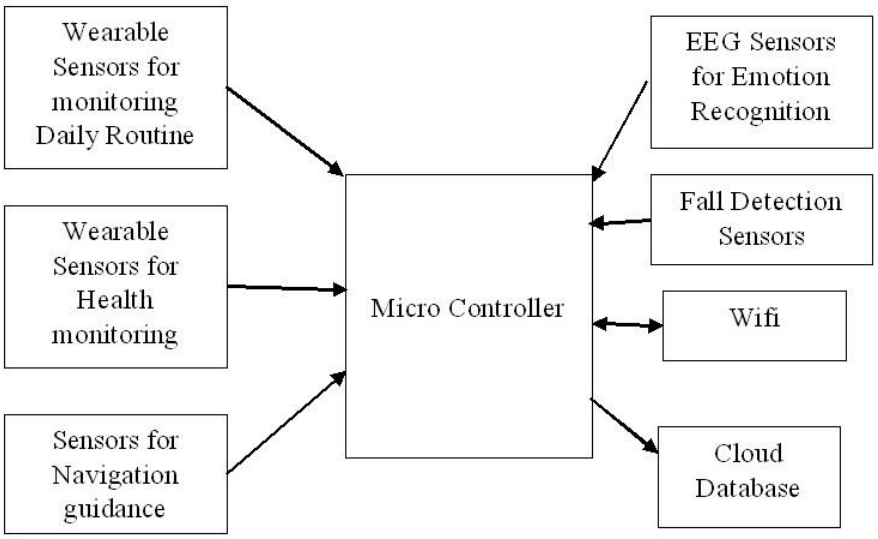

Figure 1: System Block Diagram.

Robot Controlled system has two modules. One is the user side and other is robot side. The user side is a Wearable fabric with integrated controllers and sensors. The user inputs are collected through voice recognition module, which is implanted in the fabric. Various sensors like ECG and EEG are used to track health and emotions of the user. The wearable is also equipped with a Fall detection sensor, which triggers emergency rescue messages to the caregivers.

The Robot side monitors and controls the overall activities of the system. It is also capable of self-navigation using integrated camera and navigational sensors. The user side and robot side are wirelessly connected through wifi technology. The data received on Robot side is also backed up in the cloud which is further used for data analysis. Figure 2 shows the architecture of the Robot controlled system. The emotion recognition activity of the elderly is depicted in Figure 3.

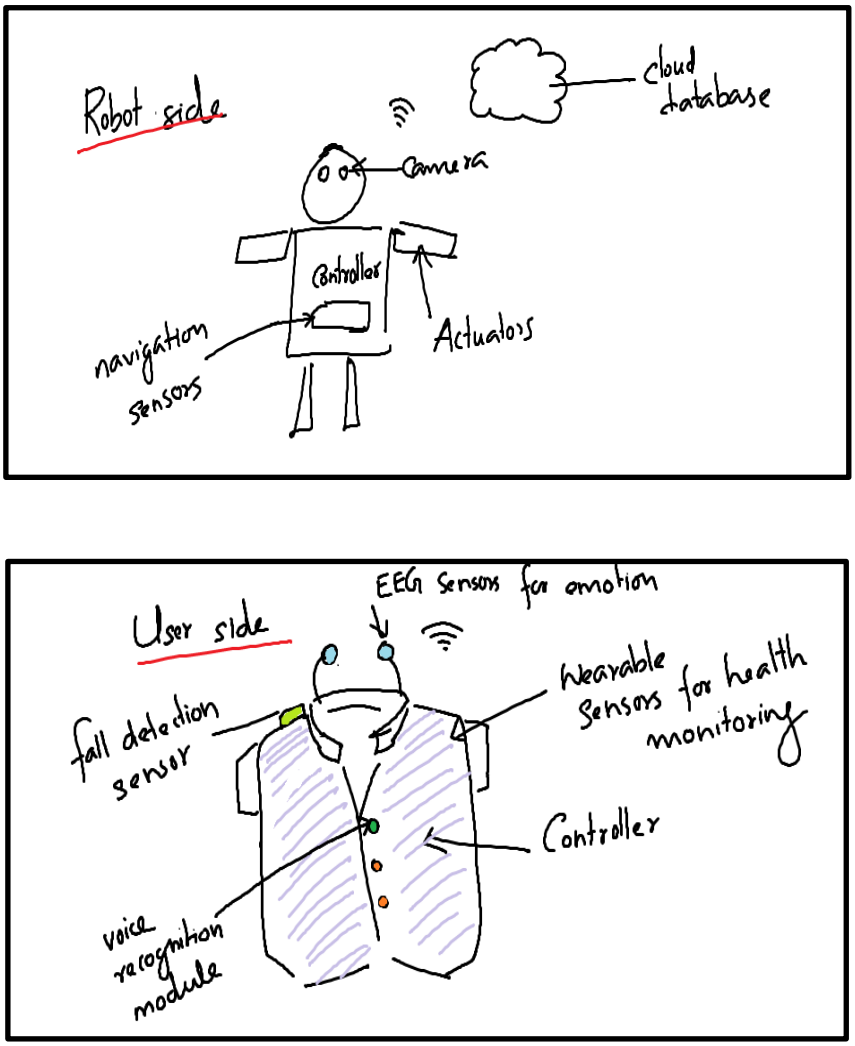

Figure 2: Robot controlled elderly assistance.

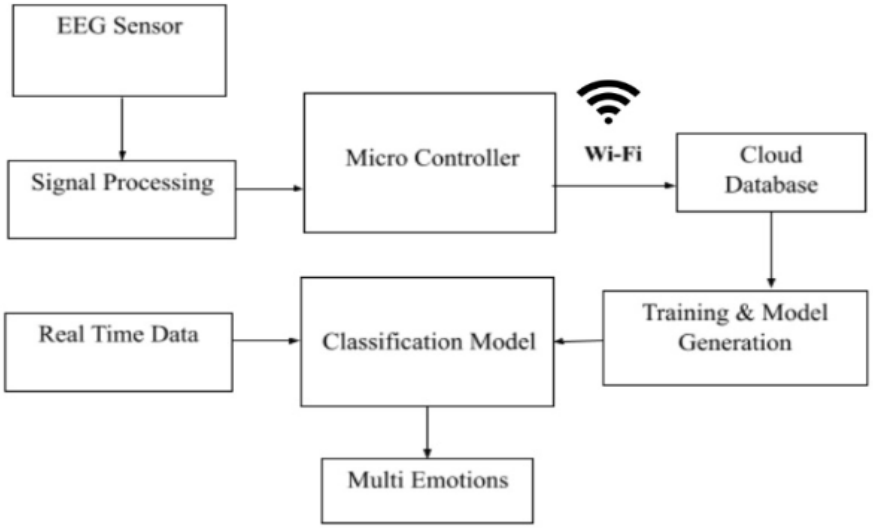

Figure 3: Emotion Recognition & Classification

B. Security Aspect

The examination of the different security threats and vulnerabilities of the service robots are depicted in Figure4. In the context of the elderly assistance application the major consequences identified is unencrypted data backup. This threat is minimized by developing a novel encryption algorithm NTSA.

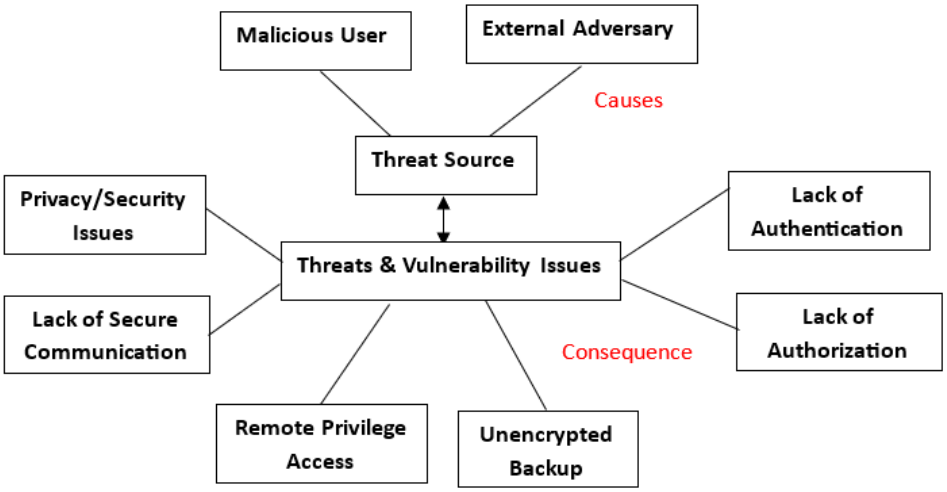

Figure 4: Security threats and vulnerabilities of Service Robots

Multiple entities in the elderly assistance system possess security threats. To ensure secure data transmission between Service Robot and Cloud Database, a novel Encryption algorithm is engaged. Figure 5 shows the secure transmission of data through the NTSA algorithm to the cloud. Similarly, the User and the Service Robot communication is also secured through the same algorithm. Moreover, the safety of the user can be obtained by capturing the real time video of the elderly through a camera module.

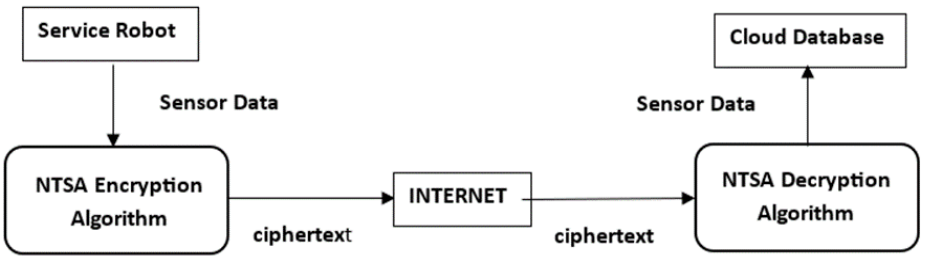

Figure 5: Secure transmission of the Sensor Data

The proposed NTSA (Novel Tiny Symmetric Algorithm) is used for secure transmission of data between Service Robot and Cloud Database, and between the User and the Service Robot. The algorithm is a symmetric block cipher with block size of 64 bits and key size of 128 bits. The algorithm has 32 cycles and each cycle consists of 2 rounds, which sums up to 64 rounds[25,26]. Significance of AI in the elderly assistance system: AI and machine learning algorithms can significantly improve the elderly assistance by completely automating the system. In the proposed model LSTM based algorithm is used for the analysis of the sensor data. Similarly, machine learning algorithms can be applied in automating the different tasks performed by the service robots. Automated navigation of the service robots can be realized using machine learning algorithms. Also the security alerts and human recognitions can also be enhanced using the AI models. In identifying and classifying the emotions different AI classifiers can be employed. Overall AI algorithms will help to enhance the life of the elderly people[27,28,29]

IV. CHALLENGES

A. Service aspect

Certain difficulties of using professional service robots are: **Connectivity**: Service robots demands connection to the internet or a network to access data and resources, but maintaining reliable connectivity can be difficult, especially for mobile robots. Wired connections can limit mobility, while wireless connections can be unstable or insecure. Also in indoor applications the range is limited and specific communication protocols will be needed to establish effective communication. **Performance**: Service robots need to execute activities demanding elevated levels of intelligence, dexterity and interaction, but these capabilities are still limited by the current state of technology. For example, service robots may struggle with advanced cognition, complex manipulation, natural language understanding, or human-robot collaboration. Elderly assistance system requires complex computational capabilities, especially in areas like automated navigation and emotion recognition.

Acceptance: Service robots require acceptance by humans who use them or operate them, which can be challenging due to psychological, social, or ethical factors. For example, service robots may face opposition from customers who favor human service, employees who fear job displacement, or regulators who demand safety and accountability. Service robot design should strictly adhere to the basic laws of robotics. **Power consumption**: Least power hungry components need to be selected to make the system power efficient. Since the service robots are battery operated, reducing the power consumption will enhance the battery life. Developing optimal power, saving algorithms are critical to service robot application. These are a few challenges that service robots face in the professional domain. They reveal opportunities for innovation and improvement. Service robots have the potential to provide various benefits for humans, such as efficiency, quality, safety, and convenience.

B. Security aspect

Professional security robots focus on protection of people, property, or information. They can be used for various purposes, such as surveillance, patrolling, detection, identification, or intervention. However, using professional security robots also presents certain difficulties, such as: **Data encryption** : Data communication between various robotic components and parts need to be properly encrypted to ensure data security. Developing efficient encryption algorithms which fit into the limited available memory is a serious challenge. **Safety and Ethical Considerations**: Ensuring the safety of humans and ethical considerations while depending security robots are critical points to be considered. **Privacy Concerns**: The use of robots equipped with cameras and sensors raises privacy concerns, especially in environments where personal data may be collected. Efficient algorithms which can block the attacks of the intruders are also needed to ensure privacy concerns. **Integration with Existing Systems**: Integrating service and security robots with existing infrastructure, protocols, and systems can be challenging, requiring compatibility and interoperability. These are certain challenges that professional security robots face in their domain, which in turn flashes light to opportunities for innovation and improvement. Professional security robots have the potential to provide various benefits for humans, such as efficiency, quality, safety, and convenience.

V. CONCLUSION

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A. Open research scope

This section discusses the challenges and opportunities in the development of service robots, focusing on four main areas: safety, security, privacy, and ethics.

Safety: The presence of noise in the sensor data used for autonomous decisions, triggers unsafe robotic actions. Service robots should make accurate decisions regarding the processing of sensor data to avoid the errors and to obtain relevant information about the environment. Proper safety measures should be taken while executing tasks related to human robot interactions. Various complex characteristics like safety-rated monitored stop, hand guiding, speed monitoring and power & force control can be introduced by making the sensors intelligent using the technology of Artificial Intelligence and Machine Learning. Researchers can study on current safety loop holes and suggest updations in the safety standards.

Security: User trust is the key element in the evaluation of every security robot system. Therefore, it demands high immunity to cyber attacks to retain trust by the user. IoT enabled robot systems are more prone to cyber attacks, therefore demands efficient encryption algorithms. Robot parameters like sensing, actuation, computation and communication capabilities are affected by cyber attacks. The security threats posed by existing systems can be avoided by developing efficient encryption algorithms And using advanced technologies like Blockchain. Mutual authentication algorithm with advanced features like user anonymity, failure recovery, attack resilience and access control is almost mandatory.

Privacy: Unauthorized collection, access and sharing of personal data is a serious issue which needs to be addressed in the service robot system .Any of the above problems can lead to loss of trust to the system by the user. User also need to be aware about the type and amount of personal data collected by the system. Different levels of authentication can be introduced for the same. Here also researchers can study existing privacy standards and suggest corrections for improvement.

Ethics: The entire design process has to consider universal human values as reference to be ethically acceptable. In human robot interaction, machine learning models may cause bias due to the vulnerable emotions of the user. So elderly assistance applications mandate establishment of the proper guidelines on ethical safety and acceptability. The vulnerable users should be educated about the over emotional attachment towards the robot that can harm their mental health. The design of safety mechanisms in the service robot are also influenced by the ethical concerns.

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