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Internet of Things Applied on Assistive Robotics

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Abstract: With the Americans with Disabilities Act (ADA), the past two decades have seen a proliferation of Assistive Technology (AT) and its enabling impact on the lives of people with disabilities in the areas of accessing information, communication, and daily living activities. Due to recent emergence of the Internet of Things (IoT), the research of assistive robotics has been contributing to assisting humans to manipulate and communicate with the robot in complex unstructured environments. The ongoing revolution of Internet of Things (IoT), together with the growing diffusion of robots applied in everyday life and industry, makes Internet of Robotic Things (IoRT) as the future direction for assistive robotics research. New advanced technologies and services are explored in assisting humans. This study provides an overview of the IoT and applications into robotics based on the building blocks of the IoT, along with recent trends and issues relevant to accessing technology for people with disabilities. This research also discusses the technologies in IoT that would benefit the applications of assistive robotics. The most important research challenges to be faced are also highlighted.

Keywords: Assistive robotics, Internet of Robotic Things (IoRT), Internet of Things (IoT), Human-robot interaction

Introduction

Robotics provides an efficient approach in the development of assistive devices, due to their enhanced functionality [1]. An important goal of the related research is to contribute to the quality of life of the elderly and individuals with disabilities and help them to maintain an independent lifestyle. The introduction of robotics and technology-supported environments will play a huge role in allowing elderly and people with physical disabilities to keep living a self-determined, independent life in their familiar surroundings. Individuals who are elderly or have a disability require novel approaches for communicating efficiently with robotic-assisted services in their living environments and even unstructured environment with safety and reliability. The development of such systems should be focused on cost effectiveness, ease of control, and safe operation, in order to enhance the autonomy and independence of such individuals, minimizing at the same time the necessity for a caregiver [2]. Currently such state-of-the-art robot with high performance for assistive applications is still under development, such as robust object recognition. Interacting with objects of varying size, shape, and degree of mobility is one of the challenges for assistive robots under unstructured environment [3].

Human Robot Interaction is another challenge in assistive robots. Human activity recognition is one of the integral parts for human robot interaction, which involves, posture analysis, gait analysis [4] and skeletal tracking [5]. Safe movement of robot without coming in to collision with obstacles in unstructured environment is still an enormous challenge when training personal assistive robots [6-7]. Finally, one of the most crucial requirements of personal robots, especially within applications of physical assistance, is to deal with unpredictable events [8] and uncertain information [9], i.e. the events for which the robot was not trained before or information that is ambiguous. Robust adaptive control techniques to deal with such situations would be required for safe operation of the robots [10].

The Internet of Things (IoT) and robotics have so far been driven by different yet highly complementary objectives for pervasive sensing, tracking and monitoring, and producing action, interaction and autonomous behaviour with robots [11]. It is increasingly claimed that the creation of an Internet of Robotic Things (IoRT) combining with assistive technology will bring a strong added value [12-13]. Low cost connected sensors that continuously monitor various environmental parameters, known as Internet of Things (IoT), enables to capture the context of an environment [13]. Assistive robots can rely on IoT in an indoor environment to understand the context and react appropriately.

IoT and Robotics in Assistive Technology

Human-machine Communication System for Assistive Robots

Human-robot interaction (HRI) not only has increased its importance significantly for any robotic applications, but also emerged into multi-functional platforms by changing its focus onto new metrics created for smart home applications. Smart or digital assistants are in the center of this behavioral and directional changes. HRI is the study of behavior between human operators or users and robotic platforms. There are two essential goals of this field, such as must-have's and must-do's which are to improve robot technology and to maintain moral integrity in doing so. Robots have been in mundane factory positions for decades; however, with the rapid improvement of computing power and other necessary technologies they have been placed in more advanced fields, e.g. search-and-rescue missions, distance awareness, work for law enforcements and EOD purposes, and also for home users, such as house cleaning robots, assistive robotic platforms, and for health care industry. Therefore, it can be stated that one of the HRIs focuses fits on these concerns such as study of human robotic interaction that assures both the furthering improvement in these technologies as well as their social competency.

Assistive robotic systems find many applications in the healthcare domain and showing great potential. Since its beginnings, robotics technology has made valiant attempts at interacting with people. Human-robot interaction is one of the most important research topics and mostly the interaction is through visual and sound (voice command) channels [14]. However, people who are elderly and people who need healthcare accommodations frequently lose partial or complete visual or auditory capabilities, thus it may be challenging for them to interact with the assistive robot using voice or to locate the robot visually [15]. Therefore, new design of human-robot communication system is significant to help people who are elderly or have a disability, especially for people with upper limb limitations, to perform some of the essential activities of daily living and improve the quality of their life.

A novel human machine interface for implementing activities of daily living, using a gesture and position tracking system based on infrared optics and cameras is developed. An intuitive and adaptive manipulation scheme with an optimum mapping between the user hand movement and the JACO-2 robot arm is implemented on a more natural human-robot interaction and a smooth manipulation of the robot.

Algorithmically, a control system used to operate the 6-DOF JACO-2 robot is developed to perform activities of daily living in a more intuitive way with the Leap Motion controller. The control system is used to monitor the user's hand, fingers, and all the accompanied positions and angles. The proposed algorithm uses the current and previous information supplied by the controller to achieve an optimum realistic mapping between the user's real arm and the JACO-2 arm.

Experimentally, a more natural human-computer interaction and a smooth manipulation of the robotic arm is considered, by constantly adapting to the user hand tremor or shake. The adaptive behavior of the system is achieved by continuously monitoring the user hand movement patters, and estimating oscillation data readings in real-time. The JACO-2 arm can be mounted to a table, a powered wheelchair, or other places at home, and supply the user with required items as shown in Fig. 1.

Fig. 1 Robotic arm system mounted to a table or a powered wheelchair [12].

Design of Assistive Robotic System with Haptic Interaction and Safety Motion Control

Many users with disabilities do not have sufficient dexterity in their finger movement. Hence, touch screen is not a good interface for them to control the robot. Most of the powered wheelchairs incorporate some form of a joystick as a default control device for wheelchair navigation [16]. A trackball is a pointing device consisting of a ball and some sensors to detect two axis rotation of the ball [17-18]. It can be easily controlled by a user through the palm of their hand. However, a large number of users in the target population are unable to operate the trackball interface due to problems with biceps/triceps control – they are just able to lift their lower arms up or down for a short time. An assistive robot which has the capability of haptic interaction may compensate well in this regard. In addition, considering the safe operation of the device is vital in the design of a user-friendly haptic interface for assistive robotic systems since any hardware or software failure may place the users at risk [19]. The user group of assistive robots is mainly seniors and people with disabilities who lose partly or completely their mobility or sensory capabilities. Due to the tight physical attachment, potential danger will be a threat for the user's life when dangerous scenario happens [18-20]. Hence, the requirement for the safety should be well considered in designing assistive robots.

Currently available assistive devices are often too cumbersome in their operation that limits their practical use. The control devices between the user and robot are sometimes limited or the provided interfaces often require numerous steps and complex sequences to achieve the desired movement of the robotic arm to reach, align, and safely grab an object [21]. In order to augment manipulation abilities of users, a research is developed with the assistive robotic arm on designing motion control strategies for object grasping related to tasks involved with activities of daily living in an unstructured environment.

The design enables the user to safely guide the movement of the robot with a very smooth manner but without much effort. In the proposed system, the user interacts with a mobile robot locally using a haptic interface to perform these tasks. Specifically, a nonlinear controller is developed to control the movement of the robot and a simple haptic rendering algorithm is conducted for calculating the feedback force. According to the user's level of disability, functional capability, and preference, different sets of human-robot interfaces can be chosen to drive the robotic system in a desirable manner. To enhance the functionality of the system, an interface is established with an Arduino micro-controller which allows for the possibility of interfacing any additional sensors, actuators, and display systems. A safety control algorithm is designed to prevent collisions in the haptic device while user operates the system. Invariance control is applied for the supervision of safe motion control of assistive robots to achieve the main control goal and to correct the control outputs if the system states are about to leave the constrained admissible state space region.

The segmentation of the robot motion into gross, fine, and grabbing components is implemented in terms of the reliability and speed of task execution. Gross motion is used to guide the robotic hand from a far-sited location within close range of the target object in a fast and reliable manner. During the gross motion phase, local structure on an object around a user-selected point of interest is extracted by using sparse stereo information that is then utilized to quickly converge on and roughly align the image plane with the object in order to be able to pursue object recognition. Fine motion via real-time monocular visual feedback is utilized to grasp the target object by relying on feature correspondences between the live object view and an appropriately selected desired image.

The object identification process is followed by fine motion control by using real-time monocular feedback in order to drive the robot's gripper to a graspable pose in front of the target object. Finally, an adaptive grabbing algorithm is facilitated via a force profile analysis. The grasping motion is controlled adaptively through a feedback of the profile of the normal interaction force during grasping, in order to be able to determine safe gripping strength not only for different objects but to be able to distinguish between different states of the same object that may not be readily obvious upon visual inspection. The measurements utilized are joint angle feedback from the robot, live video streams from an end-effector-mounted stereo camera, and embedded normal force sensing in the fingers of the gripper.

Assistive Robot with Tele-operation

While assistive robotic arms increase the accessibility of physical manipulation tasks, they are difficult to tele-operate effectively. Tele-operation is a method to operate a robot, while still being at a distance from it [12] [22]. When controlling a robot with many degrees of freedom using a lower-dimensional input, even simple tasks can become tedious and cognitively burdensome. Thus, health monitoring at home or hospitals with interactive tele-operation is crucial.

A tele-robotic system is developed to support people who are elderly or have a disability for long-term health care management. In order to help the target population in hospital or at home, the proposed system is conducted to function autonomously or semi-autonomously with tele-operation capability. Three criteria (security, modularity and reusability, friendly human-robot interface) are considered in the design. The robot should perform service tasks without human intervention and automatically plan concrete schemes considering fault detection and recovery. In addition, the robot is required to revise existing components and add new modules independently to adapt to a different application area. An optimal robotic tele-operation user interface must provide pertinent information about the robot’s states and environmental conditions in conjunction with an efficient command system to the operator.

Conclusion

The use of assistive robots is increasing in line with the growing population of older people. Internet-of-Things (IoT) has emerged as a technological background for implementation of assisted living. Support for active and independent living requires addressing the main challenges of IoT such as data veracity, integration, interoperability, privacy, reliability, security, and usability.

Current study analyzed and discussed the following research issues of IoT-based technologies in assistive domain, focusing on how machine learning and intelligent decision making and control are used in IoT based assistive robots, how IoT integration technologies and platforms are employed for assistive robots’ solutions, what methodologies and tools are used for multi-agent based intellectual applications for assisted living, how ow cognitive and affective IoT is adopted for IoT based assistive robots, and what are the needs to consider psychosocial factors of human-technology interaction, communication and usage, and how localization, tracking and activity detection technologies are integrated into IoT based assistive robots. In this paper, we have investigated the main issues of robotics applied in assistive technology. IoT aided applications in assistive robots are also analyzed. Our research development is discussed, as well as the benefits of applying IoT on robotic operations such as sensing, manipulation, grasping etc.

With IoT-aided robotics, three specific societal issues are required to be explored further in the future: (1) Implementing smart and personalized human-machine communication system; (2) Design of assistive robotic system with haptic interaction and safety motion control; (3) Enhanced security and social isolation prevention.

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