Intelligent Wheelchair Controller System for Human-Robot Interactions

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I. INTRODUCTION

Robot controllers are crucial when executing high-level algorithms. Sometimes designing these controllers from scratch will be the best solution for building robots. However, the process will consume much time to build all the electronics and other mechanical hardware from scratch. Therefore, for rapid prototyping continuing from the available hardware will help a lot to save time. Additionally, low-level controllers are crucial when it comes to autonomous robot manipulations [1]. The outcomes produced via these embedded systems [2] will directly pass to the actuators to operate robots. Therefore, the accuracy of these controllers will also cost the overall accuracy of the entire system [3].

There are many types of controlling mechanisms to control wheelchairs. The pieces of evidence from the literature give many examples[4-7]. Out of these controlling techniques, controlling via a joystick [8] is the default controlling mechanism for almost all wheelchairs. When designing novel controlling mechanisms, the way of perceiving environmental details and delivering control signals that are produced with the algorithms is very important and crucial.

When exploring the literature, it shows that layered architecture is preferred for implementing controller mechanisms[9,10]. However, the possibility of integrating hardware systems on top of available designs are challenging task to achieve. Even though the literature shows many developments for controlling mechanisms, scaling these hardware units to align with the present knowledge expansions on the algorithms is far below the expected level.

Therefore, this work proposed a novel layered hardware unit to replace existing joystick-based controllers and integrated software modules with the help of the proposed layered architecture. Moreover, the work suggests injecting the data by replacing the already available joystick controller of the wheelchairs. In the rest of the article, section II will introduce proposed architectures, and section III will showcase the results based on the observations and follow up with the discussion. Section IV will conclude the paper with future directions.

II. WHEELCHAIR CONTROLLER DESIGN

The proposed controller has a layered architecture that can be scalable as per the expansion of the Wheelchair capabilities. The following two sub-sections provide a detailed overview of the proposed mechanism. Following Fig. 1 illustrates the complete hardware and software architecture.

A. *Hardware-Layered Architecture*

The development of the main embedded system will be discussed in this section. In the process of developing an Intelligent Wheelchair System including a Robotic arm, it needs a set of controller units and a core central unit which will bring the interconnection among these controllers. Under this work, it is discussed about the sub-controller unit which is responsible for handling the kinematics of the wheelchair. The key aspect considered is the development of a scalable hardware unit while utilizing the available hardware system as much as possible. With this route, it proposed to reduce the cost while enhancing the usability of commercially existing wheelchairs.

Since electric wheelchair systems are composed of many sub-units it needs considerable computational power to handle all the respective tasks. Therefore, for this purpose separate single-board computer(Jeston Nano*) is used while the bottom-level functions will be handled by another distinct Arduino ATMEGA328p** based hardware unit. At the bottom layer wheelchair controller receives controlling signals as analog voltages via the integrated digital-to-analog(DAC) converter circuits. Then the intelligent systems can be controlled with the supplied voltages and also activate other security considerations which are added to the system when releasing the commercial product. Further, five separate DACs are used to control each unique channel separately.

B. *Software- Layered Architecture*

One of the main intentions of this work is to design a hardware layer in such a way that it will readily adapt to a novel software model presented with the continuous expansion of the knowledge generated by the research. To achieve the intention, a separate layered software architecture was designed and evaluate the feasibility of the proposed mechanism. As the central hub ROS environment was selected and joined the central controller unit with the low-level motor controller unit. Significantly the novel algorithms proposed for the controlling techniques of the wheelchair are added to the processing layer (Fig. 1). which again provides more scalability to the available functionalities.

III. RESULTS & DISCUSSION

The developed hardware design was tested with the electric wheelchair to identify the accuracy of the controller. Fig. 2 shows a complete sequence of turning the wheelchair by a user. The sub-figures depict how wheelchair control over a given specific angle at a time. As shown in Fig. 2, position and orientation vary since the user controls the speeds of the wheels separately. It is observed that the chosen turning angle has a maximum positive error of up to 21° from the required angle that again depend on various other factors including

* https://developer.nvidia.com/embedded/jetson-nano-developer-kit
** https://www.microchip.com/en-us/product/atmega328p

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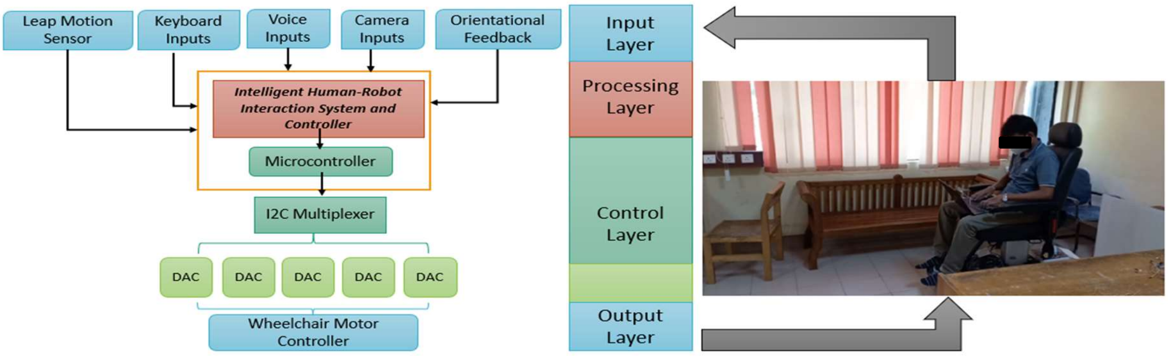

Fig. 1. Overall block diagram of the proposed layered software hardware architecture.

Fig. 2. The sequence of diagrams illustrates how a user can smoothly control the wheelchair with the developed layered hardware and software module. The sequence begins from the leftmost image which depicts the user moving in a straight course and changing his trajectory by turning the Wheelchair by 90°. The generated trajectory is a curved path since the user selects both move forward and turn functions simultaneously.

overall weight, nature of the surface, and initial orientation of the caster wheels. Further, the controller received feedback from the integrated initial measurement unit(IMU) sensor for maintaining the exact orientation. Positional variations are purely controlled with the user's inputs and can control all the movements of the wheelchair via four specific keyboard inputs which can further expand to other input mechanisms.

The results will be highly affected by the surface properties. For example, there will be a small error in the final orientation of the wheelchair which depends on the frictional coefficient of the floor. However, the error compensating mechanism of the module can bring the final rotational accuracy up to a maximum of positive 10° error which could be further examined with the floors having different frictional coefficients in the future.

While keeping all the safety features of the wheelchair system as it is, and with the identified acknowledgment sequence, the controller successfully communicates with the inbuild motor controllers via serial communication established with the proposed architecture. This illustrates that the work can be utilized to control Joystick-based state-of-the-art wheelchairs. Moreover, the understanding of the layered structures obtained from the proposed work can also be used in other autonomous robot controllers as well.

IV. Conclusion

The proposed human-robot controller produced positive results with the experiments carried out to confirm the controllability of the intelligent wheelchair system. Further software architecture proposed with the work enhances the scalability of the project as well. In the future development, all the key components of the overall controller including high-level functionalities of the Intelligent Wheelchair System with the work described by this article can be deployed to establish a fully equipped control system. Additionally, more parameters can be identified to minimize the errors discussed in the discussion section. Therefore, the effort proposed in this work is designing a layered hardware and software architecture for human-robot interaction made in intelligent wheel-chair systems.

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