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Control of a Robotic Wheel-Chair Prototype for People with Walking Disabilities

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ABSTRACT

In this paper we present a system that could be used to help people with walking disabilities. A system consists of a prototype mobile robot platform equipped with a control board and a remote computer system, running with image processing algorithms, was used to develop a system for physically disabled human to move freely in an environment. We used a camera to get visual information by a human and then arrived information was fed to a computer system. Information was processed with a run time implementation. Control of prototype was inter linked based on user-end data that shows desired direction of movement. Experiments were performed in controlled environment. Limitations and possible future works would also be identified.

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1. INTRODUCTION[1]

Walking freely and conveniently is always a human's desired objective as part of performing locomotion in daily routines. But it becomes a challenge when a person gets a disability that compromises his/her walking capability. This restricts a whole lot of possibilities to come in while bringing some real health issues as a sideline impact. Such situations demand innovative solutions to sort out likewise problems.

In recent decades, for human disabilities that relate to walking, a number of dedicated efforts were made to provide solutions in order to help people with walking disabilities. Most work of previous century in this area targeted on design aspects of wheelchairs, whereas recent works had focus on control approaches. Sarabia and Demiris [1] present an interesting idea of using a companion humanoid robot with a wheelchair. It builds on the hypothesis that to distribute and perhaps to lower the cognitive requirement on a human operator, a companion robot can be helpful to perform certain tasks through distribution of cognitive load such as providing information on directions and possible obstacles on the way. This work reports satisfactory results when a humanoid robot acts as an additional aid to extract data from the environment of a wheelchair user, with mention of the perspective that a humanoid robot significantly increases the costs of such systems when practically brought out. Carlson and Demiris [2] checked on to study human robot interaction through analysis of collaborative control strategies by investigating visual attention patterns of wheelchair users.

This work interestingly nullifies their hypothesis that an assisted collaborative system decreases the visual attention that a user requires during driving. In case of people who are blind (and our assumption that if they get walking disability), Naveen and Julian [3] worked through cognitive features based on approach to provide a possible solution. It uses virtual environment (Nintendo Wii via the Wiici application) to build a cognitive map of a place by a blind user who can then reuse this simulated interaction experience into a real world (completely the same) environment. A client uses a module to interact with virtual environment through simulation of walking and scanning of the surrounding. In other collaborative control based wheelchair systems where focus is to distribute cognitive load to achieve

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safe mobility. Carlson and Demiris [4] presented a user behavior based driving approach.

A user moves in a defined environment with and without assistance, and it was observed that with an assistive controller, cognitive load was reduced in addition to achieving safe mobility within a defined environment. However, without assistance, user experienced multiple collisions in the same environment. From eye controlled to neural control based approaches, it is interesting to observe that safe mobility performance varies significantly. Systems that detect eye movement and help in decisioning for a proposed control system are now being included for multiple applications including wheelchair systems. Neural control approaches provide more novelty as they bring in more exclusive case studies of users with more than one disability.

However, this brings more complexity and chances of mishandling of a neural signal during classification for a control strategy. Naveen, and Julian [5], Carlson et al. [6] have adopted and explored brain computer interface based on approaches. Naveen, and Julian [5] presented a brain signals' controlled system that controls a wheelchair motor imagery model. This can let robot move in four different directions (forward, backward, left and right) by motor imagery model based control of a platform. A shared control strategy between a brain computer interface and a wheelchair platform is presented [6].

A docking by two different tables while moving from one place to another by a wheelchair platform was tested with safe mobility criteria. It uses asynchronous motor-imagery approach that exhibited more dynamic behavior allowing user to interact better with a wheelchair platform with intuitive trajectory than depending on predefined paths. For such systems, inexperienced user may significantly increase the time that can be considered as optimal for a mobility scenario. Also, that mapping neural information adds complexity, and in cases, requires a ground zero buildup of an individual specific behaviors that further needs training and self-learning to improve work performance. Gupta et al. [7] presented an approach to classify EEG data in order to detect eye blinks and movements that can be used after mapping to a platform such as a wheelchair. It has been reported [8] that a virtual environment was used to evaluate navigation skills by elderly people with disabilities. More similar works include a mix of user specific neural control and other application related developments [9-18].

In making some addition to and connection with previous efforts, we have designed and implemented an indigenous prototype robotic system. A person with walking disability could control it using visual gestures in order to achieve effective mobility. This work was done through following stages which also corresponds to over work layout strategy.

- Identifying:
  - system components
  - work conditions
- System architecture
- Experimentation
- Results

2. IDENTIFYING SYSTEM COMPONENTS, WORK CONDITIONS, SYSTEM ARCHITECTURE, AND IMPLEMENTATION

A typical scenario where a disabled human needs support in performing convenient mobility requires clear identification of possible ways to integrate technology before making a support system. In our system, we are integrating visual eye ball movements and hence we need a way to record run time data of such movements. For that purpose, in our proposed system, we have included a commercially available camera that takes multiple images of eyes (of the correspondingly operating person) at each passing moment. We also need to process incoming data and for that purpose we have used a computer system running with Maltab® and its image processing tool box. After processing of data, we need to implement a control method for running our robotic wheel chair system. A four-wheeled robot was used to hypothetically perform some motion sequences of a wheelchair. In addition to eye ball detection, we have added manual joystick control as well. This could further reduce uncertainties in times of less desired operation conditions of our system. In overall, our system has three main components:

1. Data collection
2. Data processing/analysis
3. Devising control strategy

We have followed above mentioned steps in making a system effective enough so that it could help in achieving controlled locomotion. A fully functional prototype should provide support to a person who is physically disable and can operate it using his/her eye ball movement. Figure 1 shows complete picture of major interfacing components of system.

To get user end data, two system components were used that includes a camera and a joystick. A camera mounted on a person's head ahead of eyes was continuously taking images of both eyes. A joystick was used to input manually control commands. Computer system was used to initially process incoming images using Viola Jones method of image features' extraction [11].

Using this method, from incoming images, location of eyes was particularly obtained by applying MatLab code based processing. Now, a different code segment was used to separately identify a single eye. Resultant image was converted into a grayscale image from

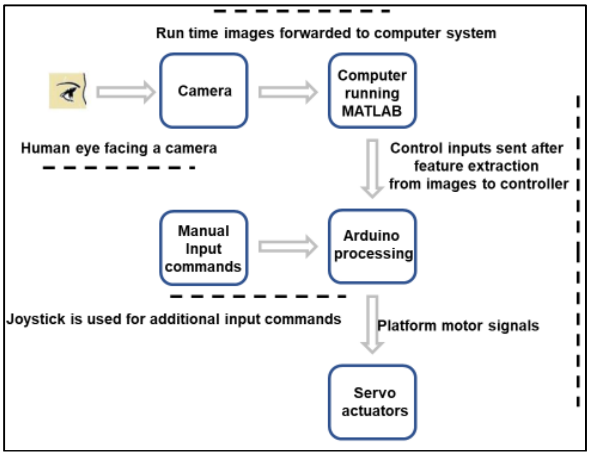

Figure 1. Overview of the system

previous scale of RGB. Another set of instructions were given to further minimize glare when images are blurred due to surrounding light or other reasons. Obtained image was converted into a binary scale with carefully adjusted threshold of detection of eye ball point. Now image was further cropped in order to obtain exact (approximate at times) location of IRIS segment of a human's eye. To make appropriate decision making based on eye ball movement, a set of behaviors were declared. Left and right movements correspond to turning left and right, respectively; while looking up (slightly) movement was declared as moving forward and looking down for a stop. Based on these definitions, our Arduino board generates corresponding pulse width modulation (PWM) in order to move actuators. Figure 2 shows a set of images (in their respective order) implementation of method and extraction of data in different parts of image processing.

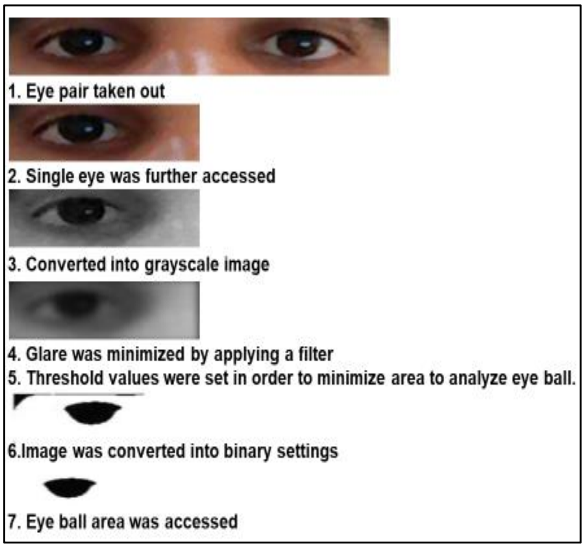

Figure 2. Steps for implementing feature extraction

There are five possibilities of black spot location. 1st one is that the black portion is in middle while watching forward. 2nd one is that the black portion is in the left while watching on left side. 3rd one is that the black portion is in the right while watching on right side. 4th one is if the user looks up, the black portion would be found in upper and middle portion of image that shows that the person is watching in upwards. Finally, the user closes eyes, the image just shows its eye lashes in the bottom of the picture showing a black curve. Program was adjusted accordingly.

Figure 3 shows another set of experiments where a person looks at his left side or when he closes his eyes. In both sets of data gathering practices, camera was

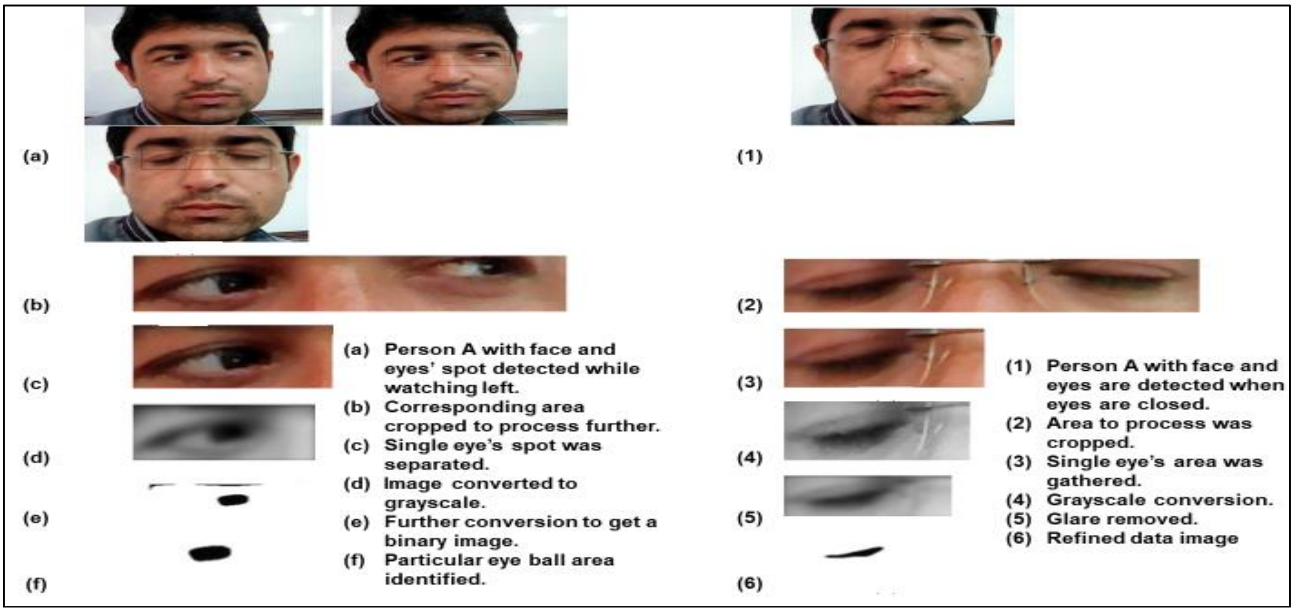

Figure 3. Process diagram for two directions

placed at one feet distance from user's eyes. Following previous procedures, useful eye ball area was identified and processed as a set of information. After clearly getting idea of eye ball movement, a computer was connected to an Arduino processing board. Arduino, with defined responsive PWM cycles, controlled our prototype robot which was hypothetically showing the behavior of a wheel chair. Four wheels of robot were running in pairs and were connected to Arduino board. A joystick was also used to move robot in four directions. Role of joystick was additional in situations where run time eye ball based control went undesired.

3. EXPERIMENTATION AND RESULTS

To support a successful transition of previously gathered information into practical implementation on robot, two experiments were performed. In experiment one, an assumed physically disable person operated our system in a hypothetical environment setting where there are more straight paths and no major corner-around movements. In second experiment, robot performed locomotion in slightly challenging environment with more corners to navigate across. Figure 4, Figures 5 (a) and 5(b) show some results where a user has controlled this system through eye ball movements in two different scenarios. In first scenario, a human operator was controlling system by looking at a camera and looking in a desired direction. Each direction was successfully integrated with corresponding movement of hypothetical wheelchair. In second scenario, same process was repeated but with objective that system is capable of a possible use in areas with more corners and indoor to outdoor and vice versa navigation.

System exhibits some sort of accessibility in controlled environment settings but also shows possibilities of limitations and areas of improvements. Those are included in next segment.

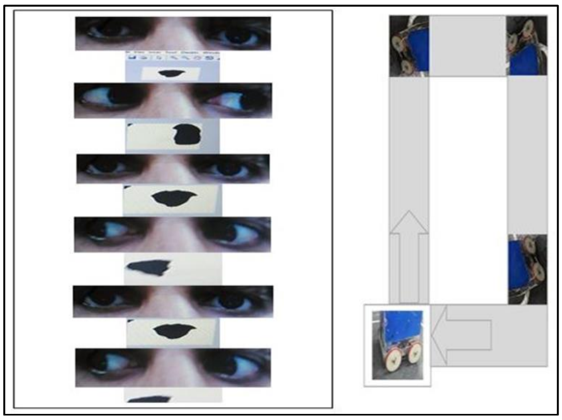

Figure 4. Implementation in basic directions. See video supplement here: https://youtu.be/opu03WDX9RM

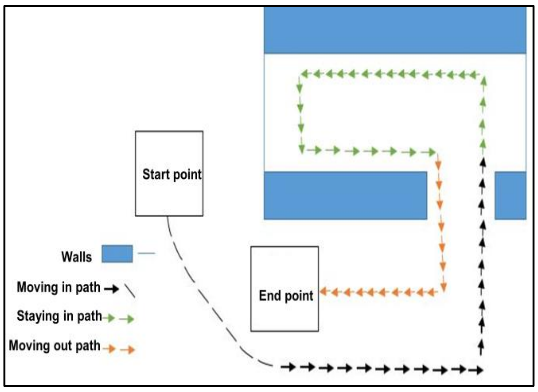

Figure 5(a). Desired navigation pattern

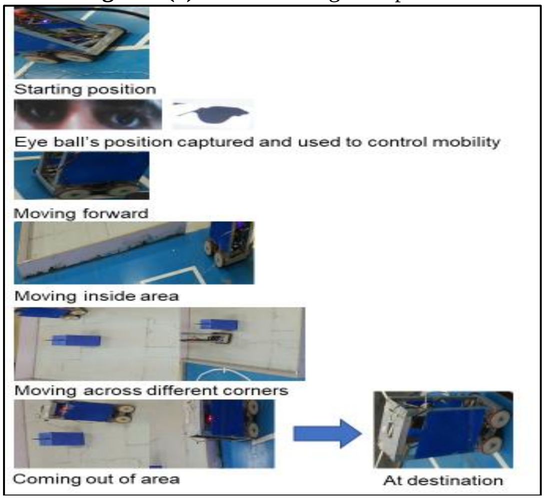

Figure 5(b). Achieved navigation pattern. See video supplement here: https://youtu.be/opu03WDX9RM

4. CONCLUSION AND FUTURE WORK

A system was devised in order to provide a support strategy for effective mobility to people with walking disabilities. A camera was used to monitor eye ball movement and a run time implementation was done in MatLab to extract useful information. After processing of data, system was tested in controlled scenarios (video supplement: https://youtu.be/opu03WDX9RM). With multiple side line applications in learning machine and user behaviors or AI, there are a number of features that could be added to improve it further. At current stage, it only works and gathers information when the line of sight and could be further improved by mounting an on-board camera that could assist in moving it more efficiently. Furthermore, a better processing system can add more robustness in the system.

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چکیده

در این مقاله با سیستم ارائه شده می تواند برای کمک به افراد دارای معلولیت جهت راه رفتن استفاده می شود. این سیستم شامل یک نمونه اولیه از پلت فرم ربات موبایل مجهز به یک صفحه کنترل و یک سیستم کامپیوتری از راه دور است که با الگوریتم پردازش تصویر در حال اجرا است، برای ایجاد یک سیستم برای افرادیکه نقص عضو دارند کمک نموده که به طور آزادانه در محیط استفاده شود. ما با یک دوربین برای دریافت اطلاعات بصری توسط انسان استفاده نموده ایم و سپس اطلاعات وارد شده به سیستم کامپیوتری تغذیه گردید. اطلاعات با اجرای زمان پردازش گردید. کنترل نمونه اولیه بر مبنای داده های پایان کاربر که مسیر مسیر دلخواه را نشان می دهد، مرتبط بود. آزمایشات در محیط کنترل شده انجام شد. محدودیت ها و عوامل دیگر ممکن در آینده نیز شناسایی می گردند.

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