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Control Strategy for Safe Descent of Power Assisted Wheelchair on Declining Road Using Regenerative Braking

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ABSTRACT: Physically weak, senior and disabled citizens use manual wheelchairs to move around places. The electrical wheelchairs provide them this required support for movement. It is difficult to control manual wheelchairs on sloping roads and hence the use of electrical power assisted wheelchair is advantageous, which can be controlled by braking. This paper proposes a new braking control algorithm to control these wheelchairs on downhill road and during its process, it is able to regenerate some power which can be stored in a charge storing device like a battery or super capacitor.

KEYWORDS: power assisted wheelchairs, braking control algorithm, regeneration of power.

1 INTRODUCTION

This project will be a study of regenerative braking control of wheelchair on downhill roads. The project is a combination of hardware and software where both the modules complement each other to achieve the desired safe braking control of wheelchair on downhill roads. Various advanced wheelchairs are available with joysticks.The user needs to smartly operate the joystick in order to control the wheelchair motion. However they are very expensive and complex to be used by the elderly people. Therefore an intelligent system that can control itself on downhill road needs to be implemented taking the cost into consideration as well.

2 LITERATURE SURVEY

This study suggests an intelligent system that can sense a downhill road and control the braking of the wheelchair on downhill roads. This study suggests a regenerative braking circuit that switches from 'assist mode' to 'braking mode' to control the braking of the wheelchair on downhill road and ensure a jerk free motion to the user and in turn allow the user to come down the declined road safely. A small part of energy involved in this process is also fed back to the power storing device, thus ensuring a regenerative braking control of the wheelchair.

Rory A. Cooper, L. M. Widman, D. K. Jones, R. N. Robertson and J. F. Ster(2000)[1] tested wheelchairs with joysticks and proved that pointing joystick is better than position sensing joystick.

Rory A. Cooper, *et al* (2002)[2] developed a push rim activated wheelchair which required a balance between human torque and electrical torque.The results showed that the wheelchair users faced difficulties.

Seiichiro Katsura and K. Ohnishi [3] developed a wheelchair based on human control and robot control. The best possible combination of human efforts and robotic control to move on straight and circular roads was attained.

Seiichiro Katsura and K. Ohnishi (2006)[4] developed an intelligent wheelchair robot to adapt to an unknown environment.The data about the environment is fed to the robot and the robot is capable of avoiding obstacles using the adaptive algorithm on which it works.

H.Seki, T. Sugimoto and S. Tadakuma [5] prepared a control system using two driving modes namely ''torque control mode'' and ''position control mode''. The system proposes proper mode switching between the two modes to control the driving process properly. Minimum jerk model is used improve ride quality using differential equations

H.Seki and S. Tadakuma [6] proposed a control system to improve ride quality of wheelchair. This is achieved by reducing the jerk and acceleration. The proposed control system generates velocity patterns by limiting acceleration and jerk and also determines the jerk at real time.

N. Mutoh, Y. Hayano, H. Yahagi and K. Takita (2007)[7] used braking operations for electric vehicles for safe driving. Braking is performed by equally distributing the torque to front and rear wheels.

Y.Takahashi and H. Seki [8] proposed a regenerative braking control system for electric powered wheelchair which are driven by electric motors in accordance with human operation. This study proposes regenerative braking control technique for smooth stopping motion of the wheelchair using a fuzzy algorithm.

H Seki K. Ishihara and S. Tadakuma [9] proposed a regenerative braking control scheme for electric power assisted wheelchair on sloping roads.

H. Seki [10] also proposed a novel capacitor regenerative braking control of power assisted wheelchair for safe downhill road driving. The electric motors providing the driving torque to the wheelchairs are controlled using step-up/down chopper circuit. The variable duty ratio of PWM controlled motors are used to control the braking of the wheelchair on downhill roads. Also a minimum jerk model is used to ensure a smooth motion of the wheelchair on sloping terrain .

3 PROPOSED WORK

3.1 HARDWARE

The wheelchair model is powered with a battery and its wheels are powered by 2 DC motors connected in series so that motor current and battery current in the circuit can be increased and the braking power can be also increased greatly. As the motors are connected in series, the braking power of the right and left wheels has to be controlled simultaneously. The motors are powered by a battery mounted on wheelchair. The motors used are rated at 12V for 300 rpm.

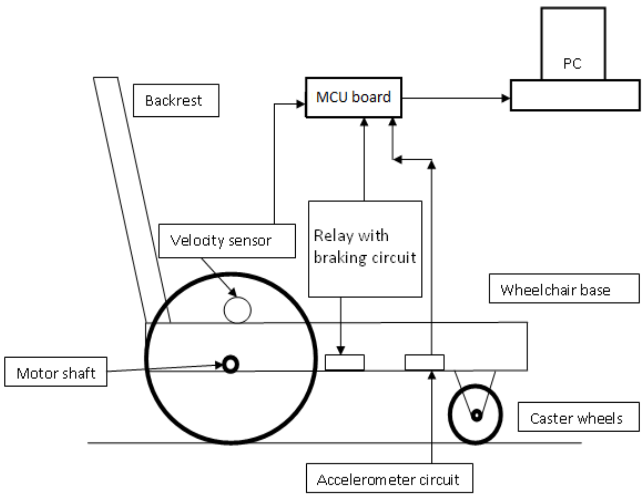

Fig.1. Experimental setup of proposed system

The experimental setup of the proposed system is shown in fig.1. The accelerometer detects the presence of sloping road and the velocity sensor calculates the velocity of the wheelchair. These sensor outputs are received by the microcontroller in which the braking control algorithm is written. Based on the sensor outputs the braking control algorithm is activated and this algorithm controls the motion of the wheelchair on downhill road.

3.2 REGENERATIVE BRAKING CIRCUIT

Figure.2 shows the primary regenerative braking circuit. The entire circuit is held together by a relay. The motors run on battery power when the wheelchair moves on horizontal road. When the accelerometer detects a declined angle of the road, a braking signal is generated by the software and is given to the coil of the relay. This braking signal energizes the relay coil causing the motor terminals to switch from ‘assist mode’ to ‘braking mode’

3.3 ACCELEROMETER

An accelerometer module will be used for detecting the slope of the road. Once the accelerometer detects the slope on the road, the wheelchair will shift from ‘assist mode’ to braking ‘control mode’ to control the wheelchair and ensures safe wheelchair descent on the road.

3.4 PROXIMITY SENSOR

Inductive proximity sensors are used for non-contact detection of metallic objects. Their principle of operation is based on a coil and oscillator that creates an electromagnetic field in the close surroundings of the surface which senses oscillations. The presence of an actuator in the operating area causes a dampening of the amplitude of the oscillation.

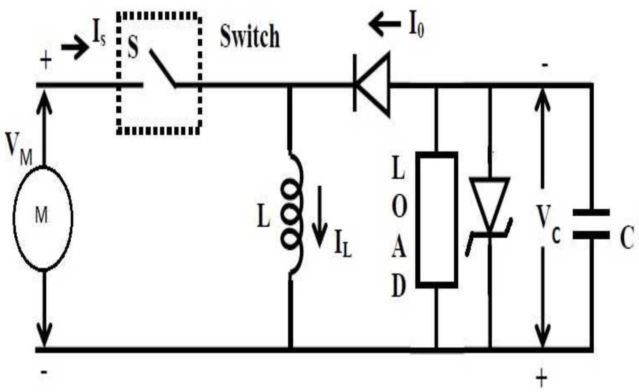

Fig.2. Primary regenerative braking circuit

The rise or fall of such oscillation is identified by a threshold circuit that changes the output of the sensor. The operating area of the sensor is dependent on the actuator's shape and size and is strictly linked to the nature of the material. This proximity sensor is coupled with an encoder to calculate the velocity of the wheelchair.

3.5 BRAKING CONTROL ALGORITHM

A new algorithm is developed to control the braking of the wheelchair on sloping roads. This algorithm will ensure a smooth motion of the wheelchair, thus ensuring the safety of the wheelchair user(fig. 3). The braking control algorithm is executed when the wheelchair is running and has detected a downhill road and keeps executing as long as the decline road exists. The ADC values are contiuously monitored to detect the occurence of a downhill road. When the occurrence of a downhill road is detected,a braking signal is generated which switches the regenerative braking circuit.The current velocity of the wheelchair is estimated at every encoder tooth edge and is compared with the reference velocity of the wheelchair.If this velocity is greater than the reference velocity then the braking signal duration is increased.Conversely, if the current velocity is lesser than the reference velocity, then braking is decreased appropriately.

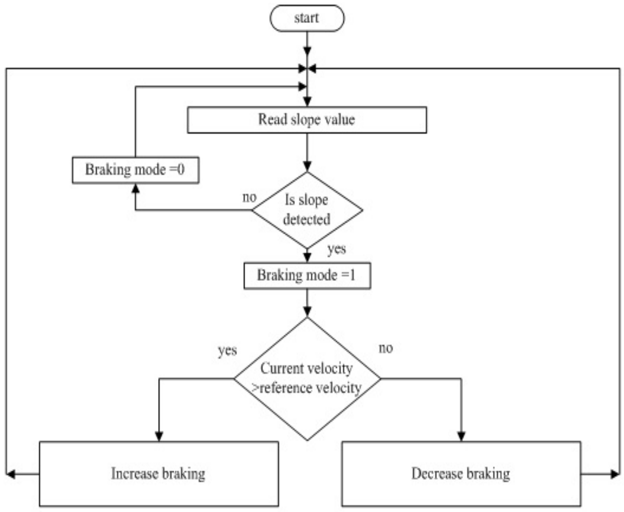

Fig.3. Braking control strategy flowchart

4 EXPERIMENTAL OBSERVATIONS

Various modules of the project were tested to study their behavior. The modules are the accelerometer sensor, PWM generation using microcontroller, the motor and the proximity sensor. A three-axis accelerometer is used to detect the occurrence of downhill road. The accelerometer has X,Y and Z axis. The acceleration of wheelchair on downhill road is monitored on Z axis. Any movement in the z-direction is detected by it as acceleration in that direction and it is the output on the axis of that direction.

The accelerometer can be represented as a set of beams attached to a movable central plate that move between fixed plates. The movable beams can be detected from their rest position by subjecting the system to acceleration. As the beams attached to the central plate move, the distance from them to the fixed beams on one side will increase by the same amount that the distance to the fixed beams on the other side decreases. The acceleration is represented by change in plate distance. The g-cell plates form two adjacent capacitors. As the center beam moves with acceleration, the change in distance between the beams changes the capacitor value.A proto board of the accelerometer is made and is tested by accelerating it in z-direction.The following Table I and fig .4 shows the accelerometer output in static position.

Table 1. Accelerometer output in static mode

Axis	**Output in volts**
X	1.72
Y	1.56
Z	2.4

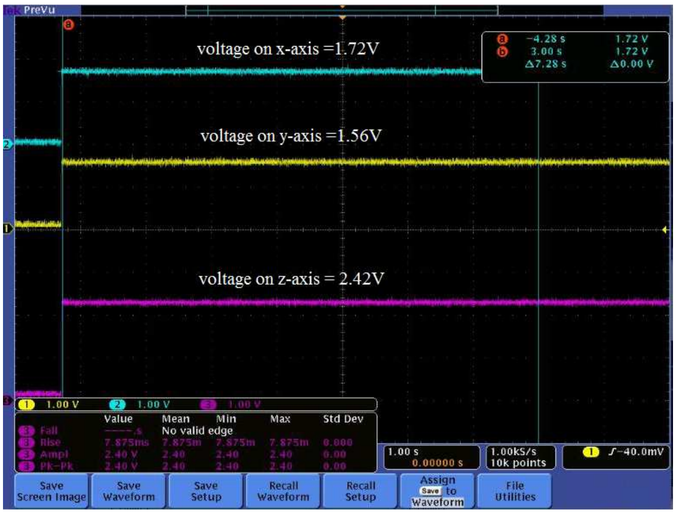

Fig.4. Accelerometer output voltages on three axes in static acceleration mode

In another experiment the accelerometer was subjected to acceleration in positive z-direction. Figure 5 is the graph of the observations of this experiment.

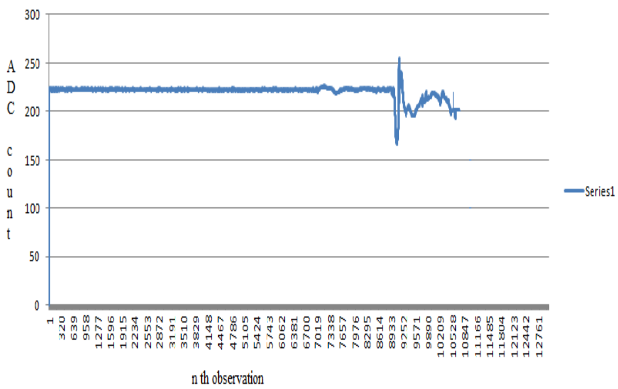

Fig.5. Digital values of accelerometer in dynamic acceleration mode

In fig.5, the vertical axis holds values for accelerometer output which are analog and are fed to the ADC for conversion to digital count so that this variation in the output can be monitored for detection of downhill roads. The converted digital values of the accelerometer are read through serial communication on a desktop computer terminal and a graph of these digital values is plotted .The horizontal axis holds values of the nth observation. From the graph it is visible that there is a considerable dip in the ADC count if there is acceleration in z direction. This decrease in values helps to detect the presence of a downhill road.

Similarly, timers of the microcontroller used are for pulse width modulation(PWM) generation for controlling the motor current of the wheelchair when on downhill roads. The digital values of the timers were also sent to a desktop terminal via serial communication to observe the correct functioning of timers. Eight or sixteen bit timers are used in the microcontroller which overflow on reaching the their maximum value.

The PWM is the most important factor that controls the motion of the wheelchair on sloping roads. This PWM controls the current through the motors to maintain a jerk free motion. PWM generation(fig.6) of 1kHz and 50% dutycycle is observed. PWM waveforms of different frequencies and duty cycles can be generated.

Fig.6. PWM generation of 1kHz and 50% duty cycle

DC shunt motor of 200 rpm was used and an external torque was applied on the motor shaft to simulate the effect of gravity on motion of wheelchair motor on sloping road. A voltage of around 5.6V was generated when the motor was made to rotate at around 100 revolutions per minute by the applied external torque(fig.7).

The proximity sensor which is to be used as velocity sensor was also tested to study its response on detection of a metal object in its sensitivity area. The operation of proximity sensor is based on a coil and oscillator that creates an electromagnetic field in the close surroundings of the sensor head. Proximity of a metallic object (actuator) in the operating area causes dampening of the amplitude of oscillation. The rise or fall of such oscillation is identified by a threshold circuit that changes the output of the sensor. The distance of operation of the sensor depends on the actuator's shape and size and is strictly linked to the nature of the material. A twelve teeth encoder disc with one missing tooth was used for the experiment. This encoder disc is mounted on one of the wheels of the wheelchair. When the proximity sensor detects a tooth, its output becomes logic HIGH and logic LOW in the tooth absence (fig. 8) .

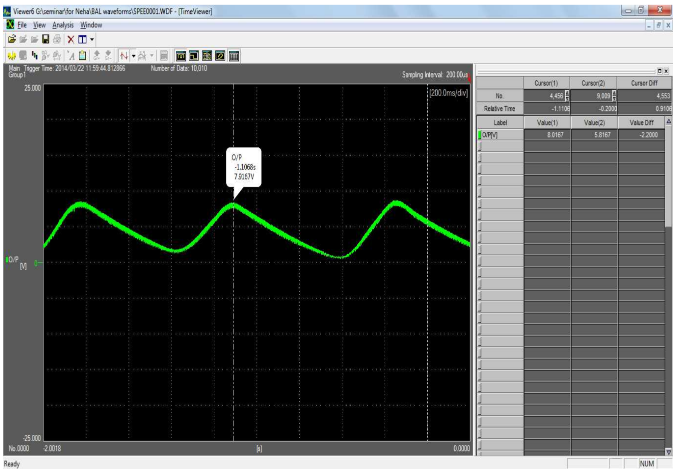

Fig.7. Voltage generated at motor terminals by applying external torque

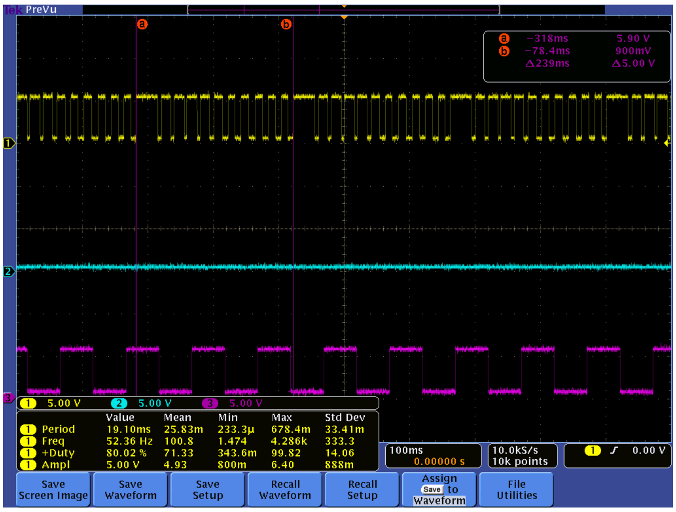

Fig.8 Response of proximity sensor on detection of a tooth of an encoder disc

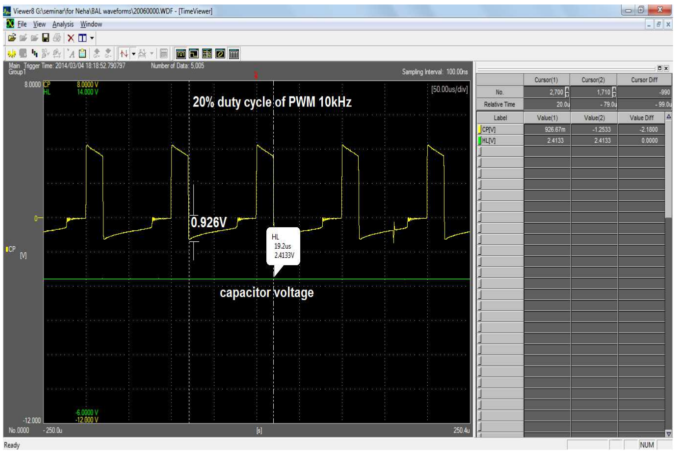

Fig.9 Inductor and capacitor response at 20%dutycyle of PWM of 10kHz

Figure 9 and fig.10 show the behavior of the inductor and capacitor voltage at different duty cycles of PWM. A PWM of 10kHz was applied to the regenerative braking circuit. At 10% duty cycle the inductor kick back is 0.926V(fig.9) and the capacitor voltage is 2.4V whereas at 80% duty cycle the inductor kick back is 2.09V and the capacitor voltage is 2.6V. It can be observed that higher the duty cycle, higher braking torque is observed. Assembly trials taken on declining road of 7 degree shows that safe motion of wheelchair can be obtained using regenerative braking and the newly developed algorithm. In fig.11 the initial burst of accelerometer value represents the motion of the wheelchair when it is on level road.

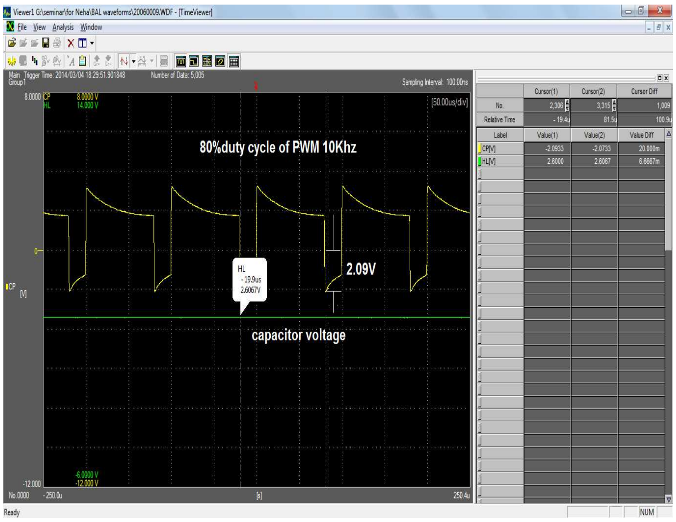

Fig.10 Inductor and capacitor response at 20%dutycycle of PWM of 10kHz

When the slope is detected using the accelerometer, the wheelchair switches to ‘braking mode’ from ‘assist mode’. The accelerometer values can be seen to be constant in ‘braking mode’ which indicates the smooth, jerk free motion of the wheelchair on sloping roads. This ensures the safety of the person on the wheelchair.

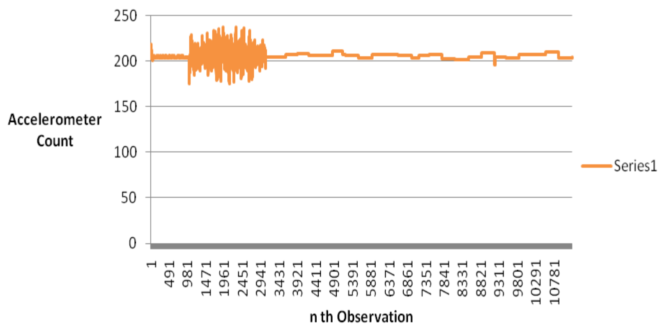

Fig.11 Accelerometer response on 7 degree declined road

Multiple trials were taken on 7 degree declined road and the results were consistent .Figure 12 shows the velocity pattern of the wheelchair on 7 degree declined road in both ‘assist mode’ and ‘braking mode’. The graph shows the average velocity of the wheelchair in all three trials is nearly the same indicating jerk free motion on the sloping road. Another experiment was carried out on sloping road of 8 degree declined road. Similar results were obtained. Similar trials were taken on 8degree declined road and the results were consistent for all the trials taken on the same road.

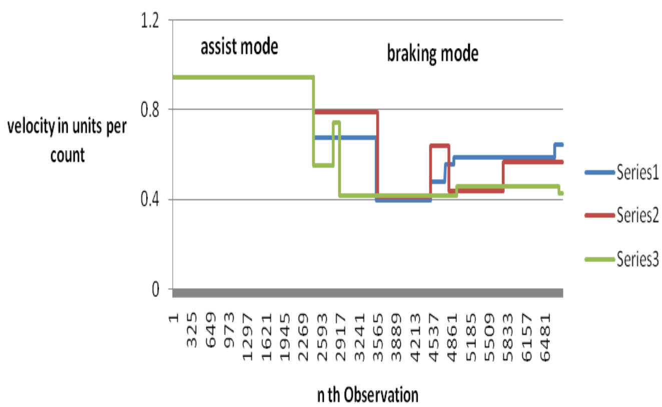

Fig.12 Velocity pattern of wheelchair for multiple trials on 7 degree declined road

Figure 13 shows accelerometer response on slope of around 8 degrees and the fig. 14 shows multiple trials observation with wheelchair on about 8 degrees.

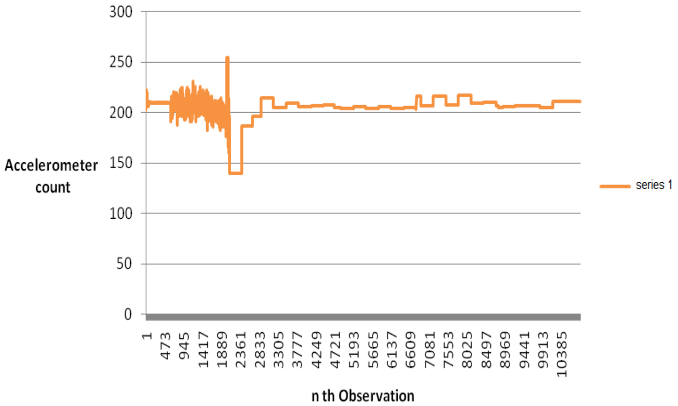

Fig.13 Accelerometer response on 8 degree declined road

5 CONCLUSIONS

Successful regenerative braking of the wheelchair is observed on declined road angles up to 8°.No jerks are observed and the motion of the wheelchair is smooth on downhill roads. Also regeneration of voltage of about 2.5V is observed in the 12V system. The code is as light as possible and no real time operating system (RTOS) is used. This proves the fact that in real time braking control can be achieved without an RTOS. The code is as light as possible and no real time operating system (RTOS) is used.

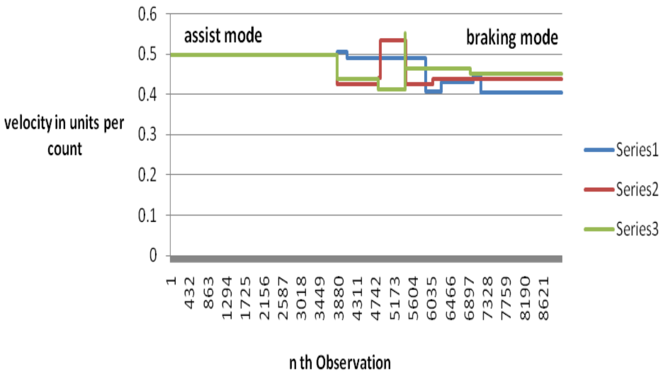

Fig.14 Velocity pattern of wheelchair for multiple trials on 8 degree declined road

This proves the fact that in real time braking control can be achieved without an RTOS. The control strategy implemented can be used to control the wheelchair motion on sloping roads. Repeated trials on various slopes show that with the implemented control strategy successful regenerative braking of the wheelchair can be achieved on downhill roads up to 8° declined angle and a smooth and jerk free motion of the wheelchair is achieved.

Further study can be done using more declined angles and multiple sloping roads. Accelerometers with different sensitivities can be used to achieve better performance. Strength and durability can be tested by conducting endurance trials. Battery performance can be averaged out by conducting trials in hot, humid, dry and cold climates. Differential braking can implemented for the wheelchair to move in curved paths. Thus different features can be still added to improve the performance of the wheelchair.

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