

## MOTORIZED WHEELCHAIR TO TRANPOSE OBSTACLES IN CHANGED LAND PLANS

### Samuel Trautvein

Universidade Paulista, Engenharia de Automação e Controle (Mecatrônica)  
Av. Jucelino Kubitschek de Oliveira, s/n°  
São José do Rio Preto, SP – Brasil  
lclulio@sc.usp.br

### Luciano Cássio Lulio

Escola de Engenharia de São Carlos, Universidade de São Paulo  
Av. Trabalhador São-carlense, 400 CP. 359  
13560-970 São Carlos, SP – Brasil  
lclulio@sc.usp.br

**Abstract.** *This paper aims to demonstrate all activities involved in developing a motorized wheel chair to avoid obstacles with the ability to pass through them such as up and down ground inclinations and move on plane and rough terrain. According to the 2010 census conducted by IBGE, the motor disabilities (paraplegia and permanent bodily dysfunction) affects approximately 6.9% of the population in Brazil, it has been in the country many people who require some sort of apparatus assistive to assist in their locomotion. Given this need for aid, the proposed work makes it available, with devices which can facilitate the daily lives of people with disabilities such as the need to use a wheelchair for mobility. The main objective is to enable wheelchair locomotion of people with physical disabilities in the legs, with the autonomy of outweigh obstacles without the intervention or assistance of others in places with nonexistent wheel chair access infrastructure. The motorized wheelchair consists of an electromechanical system comprising three gears on the rear axle which enables the chair to adjust the center of mass of the whole set (mass, motors and reducers), positioning it in dynamic equilibrium in superelevation required. The electronic part consists of adjusting the speed by actuation (PWM frequency and reverse) of motor, responsible for moving the chair, and also the inertial drive variable, limited by an IMU (Inertial Unit Measurement) consisting of an accelerometer, to make the necessary limitation of the inclination of the chair, and provide the user the transposition of obstacles with proper security.*

**Keywords:** *Motorized wheelchair; Assistive technology; Motor disability; Inclinator; Limited mobility*

## 1. INTRODUCTION

At present day, the architecture of residential, commercial, public roads, and viewing environments in large cities do not offer a planned structure in order to assist people with motor difficulties. Although, there are local and federal regulating legislation for the construction of realties and thoroughfare properties suitable for public use and transit access for people with theses mobility difficulties, there are still many places, which is very difficult for these people to access through. Based in this reason, it was conceived a project for a wheelchair capable to transpose small obstacles in a changed and uneven land.

## 2. MATERIALS AND METHODS

The development of this wheelchair was based on the recommendations of the NBR 9050:2004 (ABNT), for the physical information: mass, maximum length, maximum width to provide the user accessibility to local transit needs.

The project consists of a control drive in two DC motors, which engage the position movement, coupled with a gearing system for reducing the transmission motion to the wheels. These wheels are assembled on a triangular shape system, with three wheels in each side of the chair, which the dynamics acceleration helps to transpose obstacles on an uneven terrain (COOPER, 1998; QUAGLIA *et al.*, 2011).

The wheelchair mechanical prototype was developed using the *SolidWorks* (*Dassault Systèmes S.A*) software; the electronic schematics were projected in *ISIS Proteus* (*Labcenter Electronics*) software; and the electrical circuit boards in *Eagle CAD* (*CADSoft*). Figure 1 shows the structural modeling of wheelchair in *SolidWorks*.

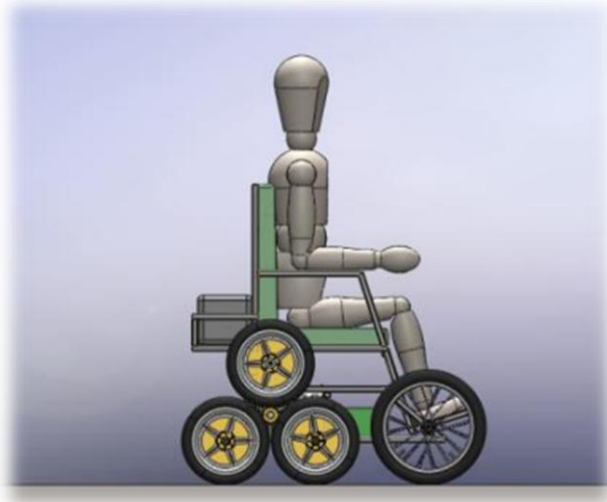


Figure 1. Structural modeling of the wheelchair.

## 2.1 Transmission System

The transmission system is responsible for the movement of the wheelchair. All following parts, make the transmission system set: motors, couplings, reducers, shafts, gears and wheels (FIELDS, 2003; PRESTES, 2011). The transmission system was designed to move the wheelchair to a speed of 6Km/h when moving on plane terrain and can support a maximum weight of 125Kgf.

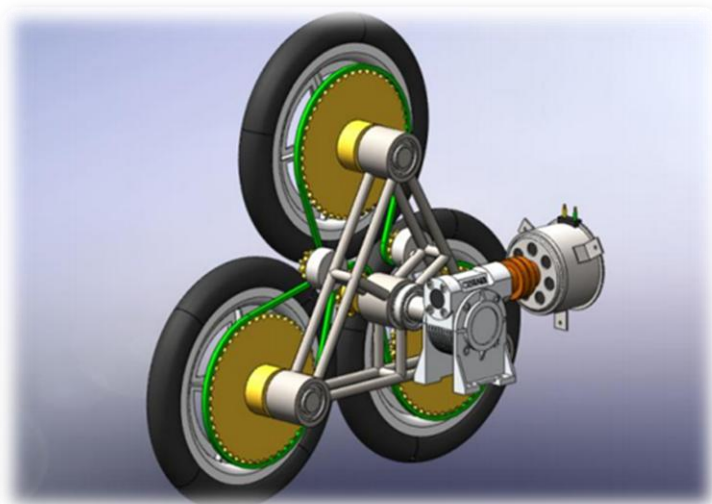


Figure 2. Transmission system set of the wheelchair.

The shafts responsible for transmitting motion to the gear coupling motor, and the shafts responsible for transmitting the rear and front movements were designed to resist the applied strain within the transmission system, and were manufactured according to the project.

The triangle shape of wheels was designed to move the wheels on steps when all the system load is transposing an obstacle. In the center of the triangle is the driven gear, which transfers the driving movement via the chain gear wheels.

The motor gears and transmission chains were defined according to the reduction ratio needed to achieve the correct speed of the wheelchair (LAWN, 2002; LAWN, 2003). Also, the transmission system, when it encounters an obstacle, exceeds it without difficulty due to wheel movement timing, as seen in Fig 3.

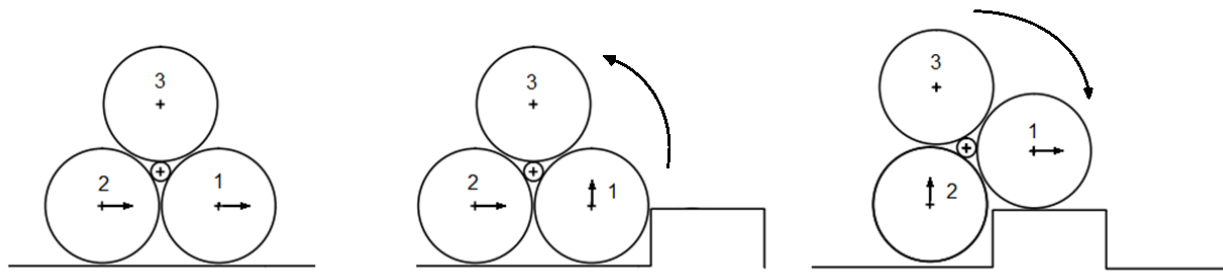


Figure 3. Transmission system during locomotion with obstacle.

## 2.2 Verification of power transmission

To reach the final balancing transmission power, it is necessary to know the initial power of two motors and its relation with the transmission chain and gears parts. The first reduction occurs on reducer component, which provides a 1:10 ratio, and a 0.8 output gain. With this data, it is possible to determine the final balancing power of first reduction.

$$P_s = P_e \cdot n \cdot i \quad (01)$$

$$P_s = 245.0,8.10 \quad (02)$$

$$P_s = 1960 \text{ W} \quad (03)$$

where:

- Pe = power input
- Ps = power output
- n = output gain reducer
- i = transmission ratio

According to equation 4 (below), the transmission ratio of the second reduction gear which is responsible for gear-driven link chains, is described.

$$i = \frac{z_2}{z_1} \quad (04)$$

$$i = \frac{45}{15} \quad (05)$$

$$i = 3 \quad (06)$$

where:

- $z_1$  = number of driving gear
- $z_2$  = number of driven gear

Having the gear transmission ratio calculated in equation 04, the power consumption output calculated in equation 1 and the incoming transmission ratio chain ( $n$ ) it is possible to calculate the final balancing transmission power.

Considering,  $n$  ratio:  $0.92 \leq n \leq 0.93$ .

$$P_s = P_e \cdot n \cdot i \quad (07)$$

$$P_s = 1960.0,93.3 \quad (08)$$

$$P_s = 5468,4 \text{ W} \quad (09)$$

### 2.3 Wheel speed validation

According to the transmission ratio for the driven gear motor ( $i = 3$ ), and rotating the driving gear, it is possible to calculate the rotation axis of the wheels as shown in equation 10.

$$i = \frac{n_1}{n_2} \quad (10)$$

$$n_2 = \frac{n_1}{i} \quad (11)$$

$$n_2 = \frac{310}{3} \quad (12)$$

$$n_2 = 103,3 \text{ RPM} \quad (13)$$

Assuming the calculated rotation, it is possible through equation 14 to calculate the angular speed of the wheel axle.

$$\omega = 2 \cdot \pi \cdot \frac{n}{\Delta t} \quad (14)$$

where:

$\omega$  = angular speed (rad/s)

$n$  = rotational axis of the wheels

$\Delta t$  = time variation

$$\omega = 2 \cdot \pi \cdot \frac{103,3}{60} \quad (15)$$

$$\omega = 10,82 \text{ rad/s} \quad (16)$$

With the radius of the wheel value, and the angular speed, it is possible through equation 15, to arrive at a linear speed of the wheelchair.

$$v = \omega \cdot r \quad (17)$$

where:

$v$  = linear velocity (m / s)

$r$  = radius of the wheel (m)

$$v = 10,82 \cdot 0,1524 \quad (18)$$

$$v = 1,65 \text{ m/s} \quad (19)$$

$$v \cong 6 \text{ km/h} \quad (20)$$

### 2.4 Tilt System

The tilt system is an electromechanical drive, that enables the tilt of the seat in rear and front movements on the wheelchair. The wheelchair is designed to tilt the seat up to  $40^\circ$  from plane surfaces, and provides the ability to lift up to 90Kg. The tilt system is mounted between the base and the under physical seat, controlled by a joystick command interface, and the limits of the slope is given by the screw mounted spindle and an accelerometer (FIGUEIREDO, 2007).

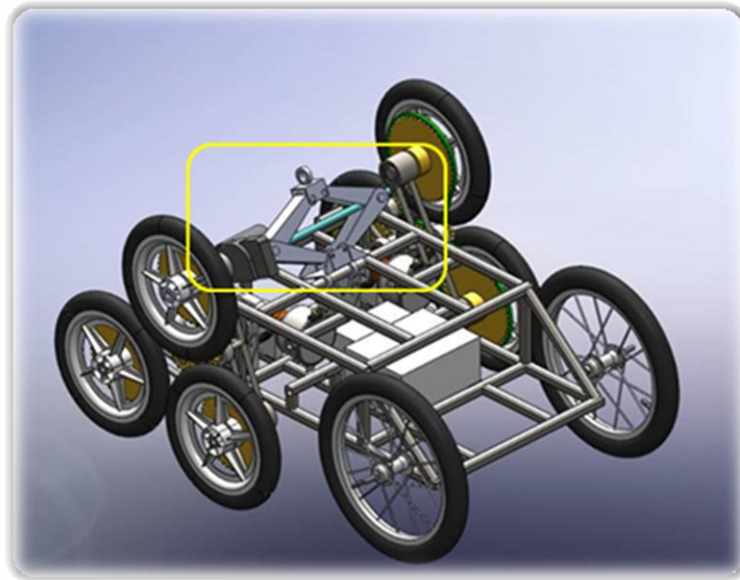


Figure 4. Tilt system.

### 3. RESULTS

Final tests collected data about the battery life on the speed of the wheelchair on plane ground, ascent and descent places and the ability to transverse obstacles, which is the main objective of the project.

#### 3.1 Autonomy

The test related to the battery life was carried out with the wheelchair moving into translational ground asphalt. Table 1 below shows the runtime on both tests.

Table 1 - Battery life.

Test	Time (min)
1	80
2	85

In this test, the battery supplying time is less than the theoretical. Assuming the datasheet, which informs an autonomy of 01h48min, empirical tests shows that after 01h20min, the battery power consumption is not enough to provide the movement of the chair.

#### 3.2 Speed

In the initial sizing, was predicted that the wheelchair could reach a top speed of 6Km/h, and after tests it was possible to prove that the wheelchair can perform translational movement on plane terrain at speeds in accordance with Table 2.

Table 2 - Data speed.

Ground	Speed (Km/h)
Concrete	4,25
Asphalt	4,10

#### 3.3 Obstacles transposition and seat tilt system

In the final test conducted with the wheelchair prototype, initial objectives were reached. It was expected that the wheelchair could perform translational motion in plane surface, ascent and descent places, and transverse small obstacles in modified planes, as culverts and gutters.

The joystick electronic circuit allows the user to tilt the chair seat with minimal and maximal limits, sensed by an accelerometer. Figure 6 shows the inclination of the seat.

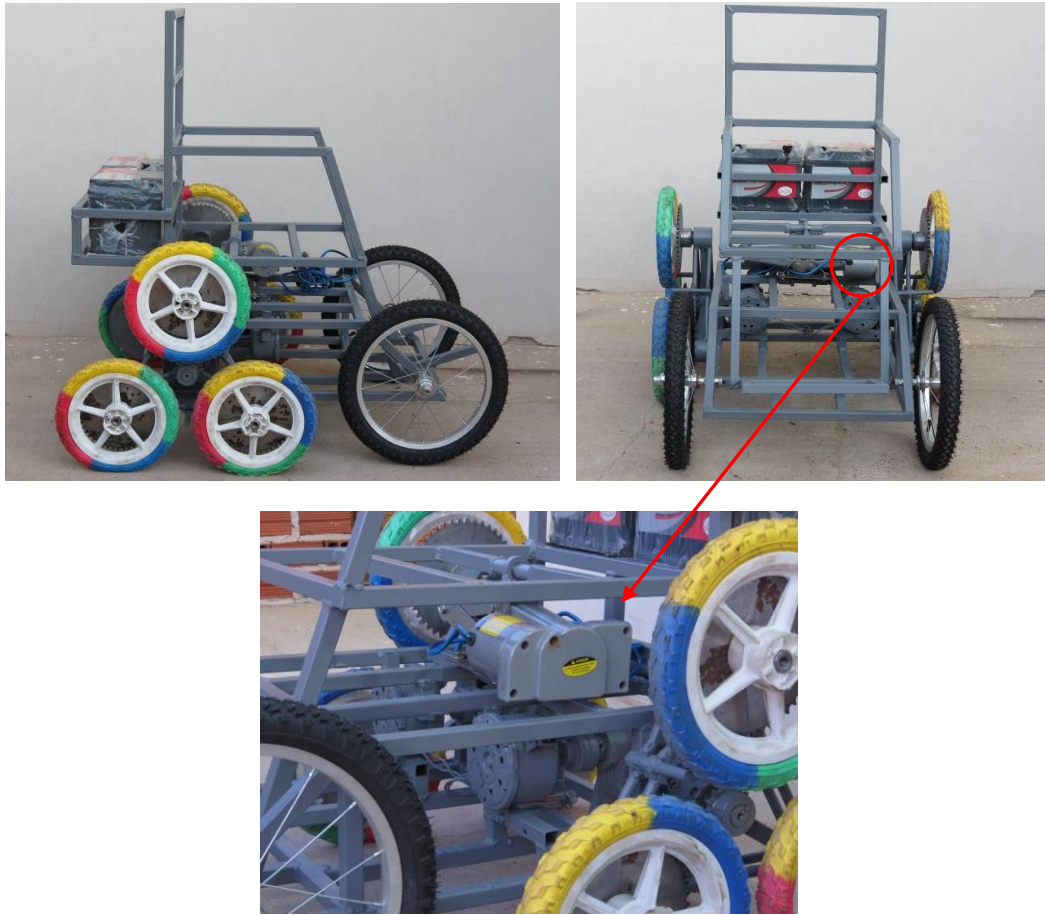


Figure 5. Wheelchair physical assembly and tilt mechanism in detail.



Figure 6. Chair transposing small obstacle and seat tilt test.

#### 4. CONCLUSION

In this work, it was possible to develop a prototype for disable people to get more autonomy in locomotion, which a final product to be allocated on public transit plausible on mobility, and could be very useful for a needed and assistive population. It also proved that the concept adopted in the wheelchair works for the proposed objective.

There are many improvements and aspects that must be analyzed in this project, but some need main attention, such as the weight and the reduction system.

#### 5. ACKNOWLEDGEMENTS

Special thanks to Instituto de Ciências Exatas e Engenharia, da Universidade Paulista, campus São José do Rio Preto/SP.

## 6. REFERENCES

Cooper, R.A. *Wheelchair Selection and Configuration*. New York: Demos, 1998.

Fields, B. Bridging Usability and Aesthetic Design of Wheelchairs. Usability interface – STC Usability SIG Newsletter, Washington-DC, Abr. 2003. Available: <<http://www.stcsig.org/usability/newsletter/0304-wheelchairs.html>>. (04/29/2012).

Figueiredo, Lígia. et. al. *Aplicações de Acelerômetros*. Lisboa: 2007.

Lawn, John. et. al. Development and practical application of a stairclimbing wheelchair. Nagasaki, 2003; Volume (11): 323–332. Nagasaki University.

Lawn, J.M. Study of stair-climbing assistive mechanisms for the disabled. Nagasaki, 2002. Nagasaki University.

Prestes, R. C. *Tecnologia Assistiva: Atributos de Design de Produto Para Adequação Postural Personalizada na Posição Sentada*. Porto Alegre: Universidade Federal do Rio Grande do Sul, 2011.

Quaglia, G; Franco, V; Oderio, R. *Wheelchair.q*, a motorized wheelchair with stair climbing ability. *Mechanism and Machine Theory*. 2011; Volume (46): 1601–1609.

## 7. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.