Design and simulation of a geriatric wheelchair with automatic bipedestation system

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***Abstract*— This project develops the conception of the design of a wheelchair with an automatic standing system that is light and portable. The target is the older adults of the Peruvian population, considered in the country from 65 years of age, so the calculations are based on national anthropometric measurements. The qualities of lightness and portability are addressed through the use of low weight materials such as aluminum for the main structure and ABS for the 3D printing of the couplings. For the validation of the design, mechanical, electronic and control guidelines involved to ensure the functionality and operation of the system can be observed throughout this paper.**

***Keywords*— wheelchair, simulation, geriatric**

I. Introduction

People over 65 years old are considered geriatric patients [1]. During this stage of life, geriatrics tend to suffer from the spread and worsening of many mental and physical pathologies along with the gradual loss of self-reliance. Having into consideration that life expectancy in Peru is 82 years old [2], people from this country live as a geriatric an average of 17 years. Therefore more than 20% of their lifetime would be spent in special health care and illness treatments, period where it is a priority reduce injuries (e.g. lumbar and scapular) with special equipment that fits well for the specific characteristics of elders. The present project, deliver an alternative that prioritize the anthropometric measures, special considerations, and standing benefits for a vulnerable population to create a standard standing wheelchair that insert new technologies (e.g. 3D printing and control practices) and deliver high quality with a competitive price.

II. Conceptual Design

A. Anthropometric conception

This project considers the comfort, convenience, and injuries prevention for a typical Peruvian. Therefore, the design is focused on the Peruvian anthropometric measures of a geriatric patient.

Height: 170 cm Weight: 80 kg

Based on the results, the concepts mentioned for Julius Panero [5] and a previous investigation in Chorrillos Rehabilitation National Institute, the following results are obtained:

B. Solution concept

The design must be focused on ergonomic, easy use and safety for the user with the following function structure:

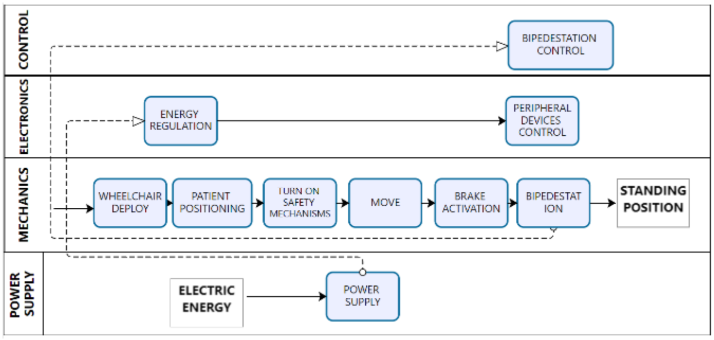

Fig. 1. Modules and components

And the following development modules:

TABLE I. Work Modules and Their Components

Modules	Components
Force	Linear actuator
Damping	Gas springs
Power and Control	Battery and circuit board
Command	Joystick
Safety	Safety belts

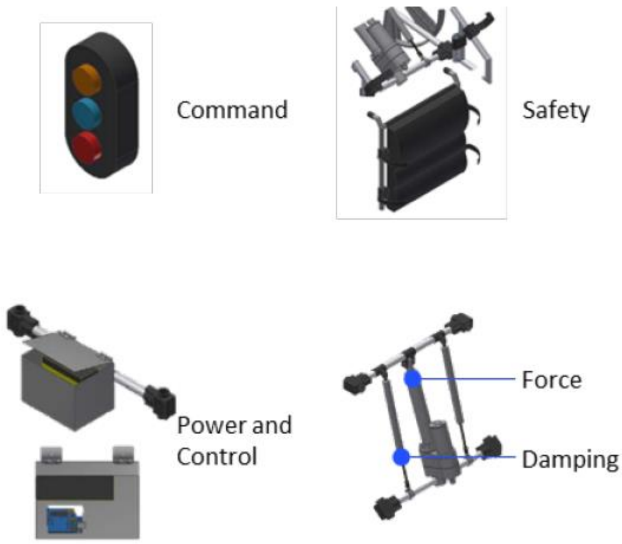

Fig. 2. Work modules

Fig. 3. Function Structure

III. MECHANIC DESIGN

The proposal is defined for the occupied space for the user [6], the support structure, and the work positions:

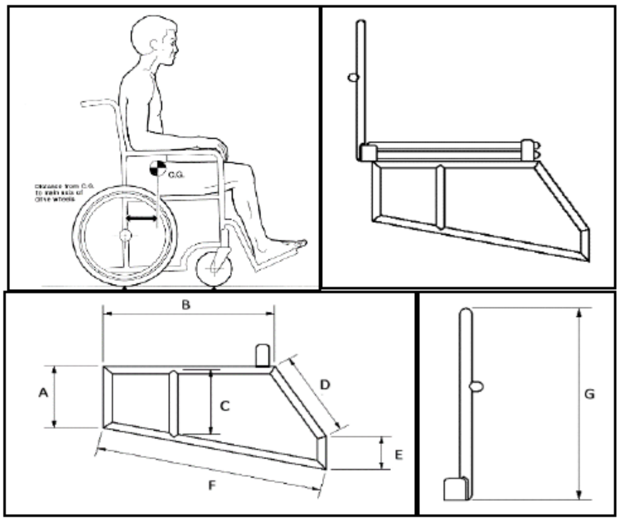

Fig. 4. Wheelchair frame’s sizing

TABLE II. MEASUREMENTS OF WHEELCHAIR FRAME

SEGMENT	LENGTH (cm)
A	20
B	50
C	22
D	30
E	10
F	65
G	50

The design must ensure stability and the rollover impossibility in any work position, to achieve these objectives the gravity center must be located on the area limited for the 4 wheels of the system. The exposed before can be verified by computer simulation and the application of the segmental method:

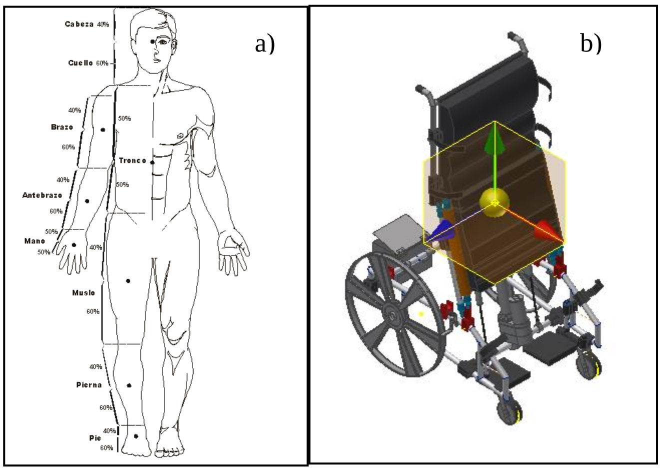

Fig. 5. a) Segmental distribution of weight in the human's body [7], b) Gravity center location on biped position

The value of the force and angle are calculated in the most unfavorable scenarios:

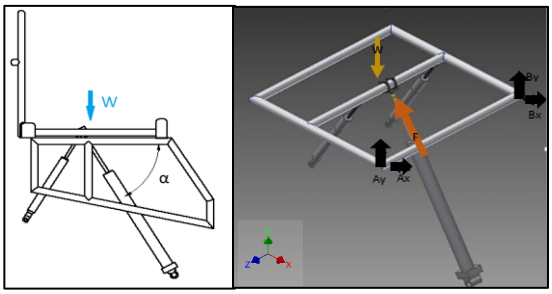

Fig. 6. Bipedestation mechanism

$$F = F * Cos\alpha\ i + F * Sen\alpha\ j \qquad (1)$$

$$\sum F_x = Ax + Bx - F * Cos\alpha = 0 \qquad (2)$$

$$\sum F_y = Ay + By + F * Sen\alpha - W = 0 \qquad (3)$$

$$\sum M_B = \begin{vmatrix} i & j & k \\ 0 & 0 & m1 \\ Ax & Ay & 0 \end{vmatrix} + \begin{vmatrix} i & j & k \\ -m2 & 0 & m2 \\ -FCos\alpha & FSen\alpha & 0 \end{vmatrix} + \begin{vmatrix} i & j & k \\ -m3 & m4 & m2 \\ 0 & 1000 & 0 \end{vmatrix} \qquad (4)$$

Applying:

$\sum M_x = 0$ $\sum M_z = 0$ $\sum M_y = 0$

$$F = \frac{P}{Cos\alpha} \qquad (5)$$

Three loading scenarios are analyzed for the linear actuator:

scenarios with a safety factor of 2.5.

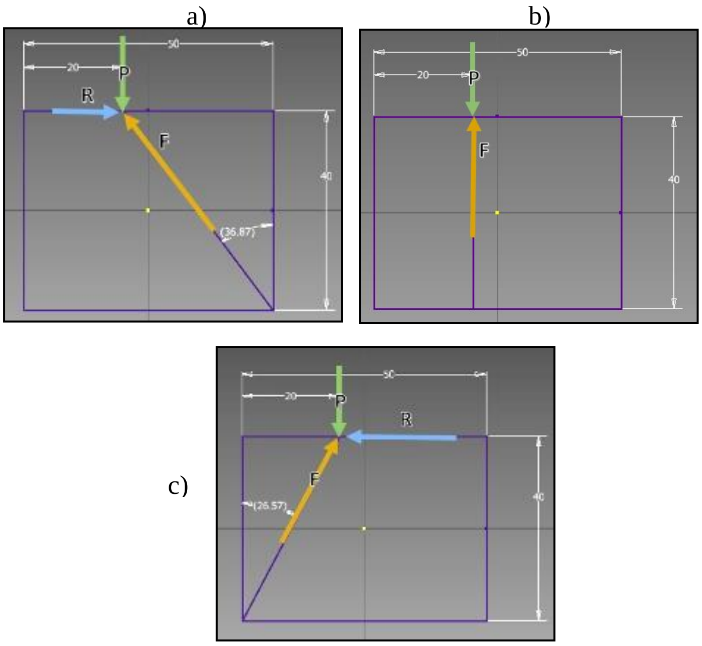

Fig. 7. Bipedestation mechanism

Along with the position of maximum length:

$$Fx^2 = a^2 + b^2 - 2 * a * b * Cos\beta \qquad (6)$$

$$Peso = F * Sen\alpha \qquad (7)$$

Solving equation system composed for (1), (2), (3), (4), (5), (6) and (7).

Results:

- The best scenario for the linear actuator is the first (Fig. 8a)
- Work angle α is between 53° and 90°
- The linear force delivered must be 1002 N

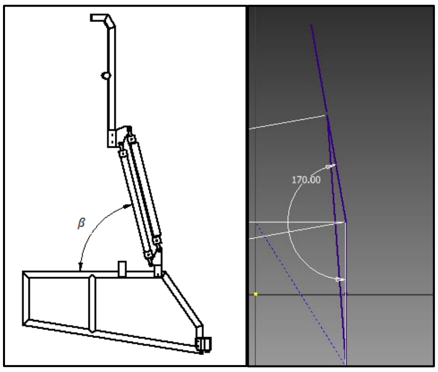

Fig. 8. Critical angle on max stroke

A. Construction materials

The frames are simulated on Aluminium 6061 tubes of 30 mm diameter and the coupling elements on PC ABS.

The stresses are simulated with the conditions calculated and stipulated for the use, materials, and possible work

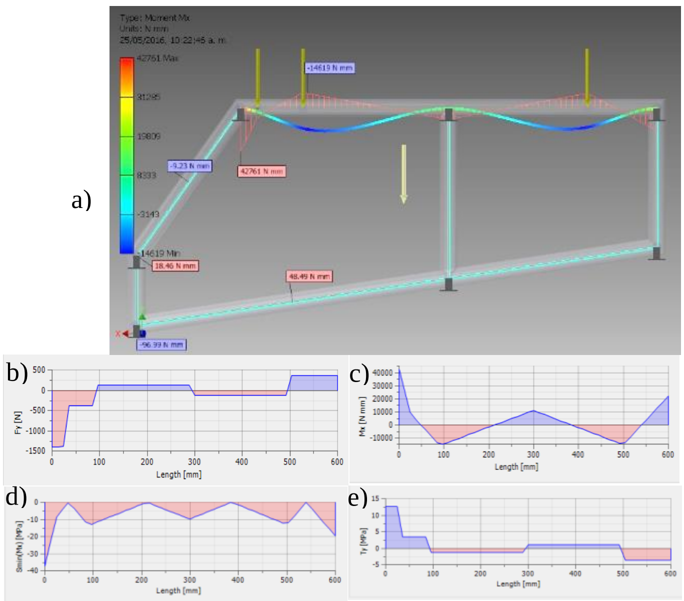

Fig. 9. a) Distribution of bending moment on principal frame | Graphics of b) Shear force c) Bending moment d) Bending stress e) Shear stress

The graphics of stress and forces deliver important information to validate the design proposed and make some final modifications on the distribution of the components based on the stress of critical points.

The coupling elements are design and simulated in critical scenarios.

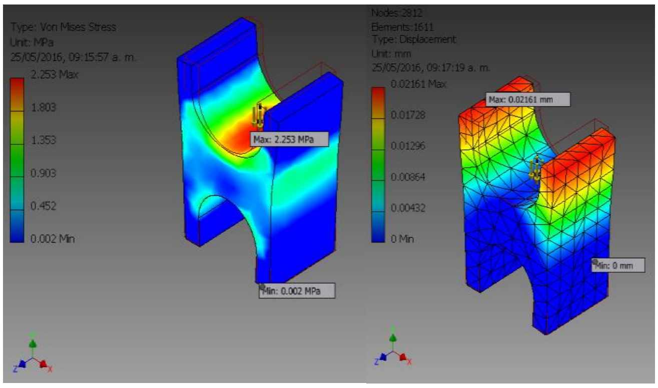

Fig. 10. Stress simulation and displacement of coupling element

Applying the Von Misses method for frame deformation in critical scenarios, high stresses are observed. Consequently, TIG welding is recommended.

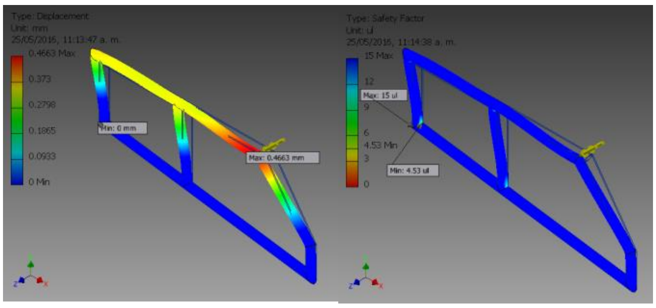

Fig. 11. Stress simulation and displacement of coupling element

IV. Electronic Design

Design of control and power stage are designed as follows:

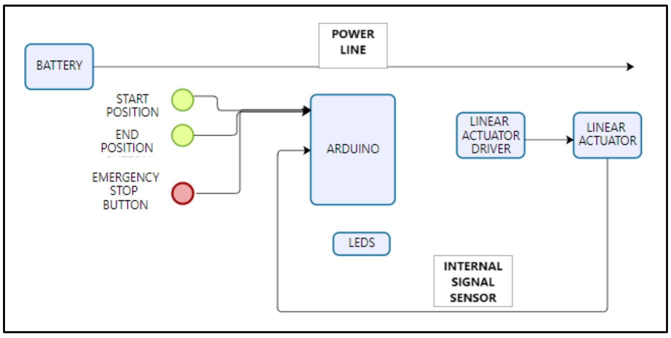

Fig. 12. Workflow of the electronic system

Electric consumption is calculated with a security factor of 1.5, obtaining a demand of 7.5 A working with 24 V [8]

For the control stage a 5 V output basic circuit is design.

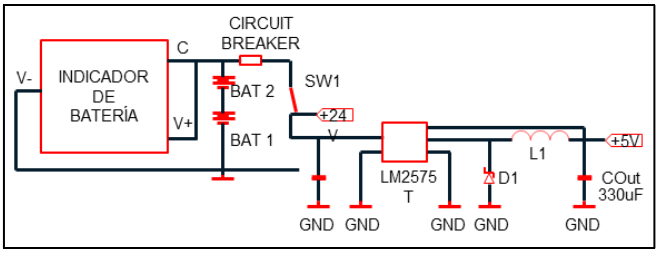

Fig. 13. Voltage circuit regulator 24 V - 5 V

A. Control architecture

To calculate position, the system processes the user decision which is provided for the joystick input. Any movement of the bipedestation system is a result of a PI control.

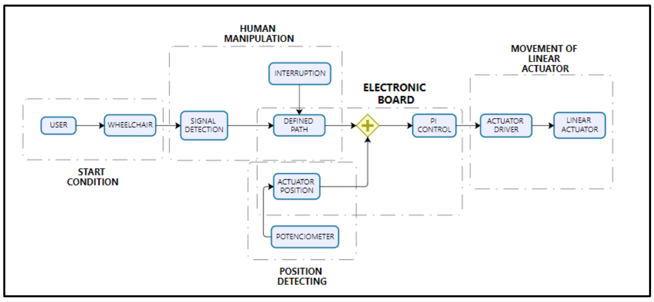

Fig. 14. Control architecture

The model is defined for:

$$F - 2b\dot{x} = m\ddot{x} \tag{11}$$

$$\frac{X(s)}{F(s)} = \frac{1}{Ms^2+2bs} \tag{12}$$

PI control can be simulated under the following conditions:

$$m = 100kg \qquad Kp = 565$$

$$Ki = 20b = 100Ns/m$$

Stabilization time: 4 sec

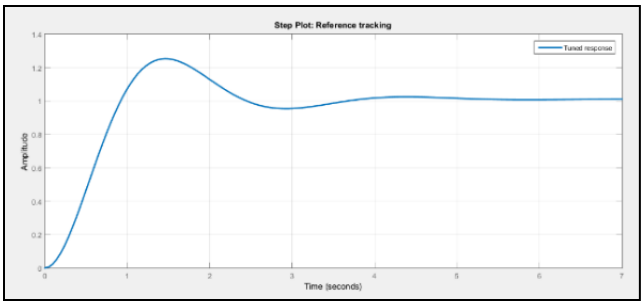

Fig. 15. PI response

V. Conclusions and Recomendations

- According to presented analysis and simulations, it is validated the mechanical, electrical and control design of a light, portable and easy to use standing wheelchair for geriatric population using 3D printing elements
- For people involved in health care, it is recommended for them to work on customization of this project and explore new functionalities to add value

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