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A fuzzy logic controller to seat comfort correction for manually propelled wheelchair – a case study

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Abstract: The subject of discussion is the construction of a fuzzy controller of the wheelchair seat correction in terms of improving the moving comfort parameter for people with physical disabilities. The Sugeno type fuzzy controller has been created for the seat comfort improvement of a wheelchair. The fuzzy controller is compared with PID and the results shows reasonable comfort improvement. The experiments have been performed in Matlab-Simulink.

Keywords: Fuzzy logic, Sugeno controller, PID controller, wheelchair model, jackscrew.

1.INTRODUCTION

Transport methods, which are generally used by people with disabilities, should be designed with the general scope of their specific needs. Also when public infrastructure facilities are constructed it should be mainly focused on people with moving dysfunction too. People with permanent disabilities indicate that there are many features but also still many barriers constitute as an obstacle. These people also can't live in multi-apartment buildings higher that first floor due to their construction. Moreover, it has to be admitted that many roads, paths with curbs, driveways and stairs can be defeated only with the help of other people. For those and many other obstacles, companies construct different versions of classic wheelchairs, which are focused for such barriers. Different wheelchair models are chosen for different disabilities and also for special use (stairs wheelchairs, sport wheelchairs, etc.) (Dobrzyński, 2012). Classic version of the wheelchair model using manual propel is better from "electrical" models in one main reason - it lets people with permanent disabilities stay with physical comfort. Also, it is the most popular wheelchair model in people with paraplegia. Worst dysfunctions determine to use more complicated electric wheelchairs. Electric wheelchairs are easy to construct, and quiet but they need to have heavy batteries on the board, which is the biggest disadvantage. The easiest constructions of electrical wheelchairs are using to move on flat ground. More advanced versions are built for special applications:

- Wheelchairs with crawler drive are used to climbing stair (TopChair SAS, website);
- Wheelchairs with multi-wheels in main wheel axis (Sunwa CO, website);

There are many outstanding selections for special applications of wheelchairs but there is one big problem - lots of them make no reaction on the wheelchair seat for changing angle of a ground. This is the problem to have a comfortable move. Moreover, no reaction from the wheelchair seat may let people fall down and suffer injury. Arrangements to ensure a stable balance wheelchair seat among the requirements imposed on the stair wheelchairs, but there are no manual propels wheelchairs that meet the above requirements. Therefore, the purpose of work is to create a model of self-levelling seat for wheelchair manually propelled by using the fuzzy controller.

2.MODEL BUILDING

2.1. Wheelchair model

In classic version wheelchair is a solid body where the seat is permanently attached to the frame, which prevents any adjustment seat position. The proposed novel concept of classic structure modification of manually propelled wheelchair model assumes the possibility of continuous adjustment of the position of the seat, both when the wheelchair is staying or moving on any road. According to the assumptions wheelchair is built with a solid frame and a seat with one fulcrum, which allow adjusting the position continuously by adding external components like DC motor and a lifting screw. DC motor and a lifting screw are modified version of the jackscrew model.

The reference surface to tilt measure on the wheelchair seat assumed position of equilibrium - 0°, while the measured value depends on the current position of the seat relative to the solid frame which angle is the same as a road. Wheelchair with manual propel nominal model is used in the simulation process with Matlab Simulink Software. Simulation process is based on a basic wheelchair model consisting of: a control system based on the controller (PID/Fuzzy), jackscrew model, DC motor model and disruption of the actual position model.

2.2. Environmental condition

Object movement takes place on the road which shape is suitable for European road design standards for uphill and

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downhill. In the simulation process disruption signal, which represents the road has a trapezoidal shape (Fig.1) with apex angles consistent with those standards (it has 10° angle on lower base apex's).

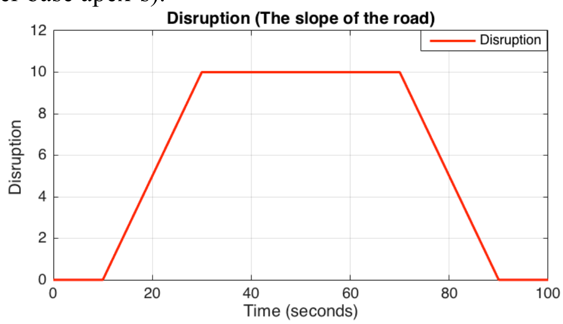

Fig. 1. Disruption character

Assume the object movement in this way, the wheelchair seat can be a material point Z, whose position in *X*, *Y* surface change at every next time step. Knowing the function describing road shape and the current position of the Z point tangent passing through the point is according to (Hussain, Understanding Calculus):

$$y - f(x_0) = f'(x_0)(x - x_0) \qquad (1)$$

where x_0 is the time value when $f(x_0)$ is the amplitude value of the road.

The tangent passing through a point Z at „t" time is inclined to the time axis beginning on α° angle. α angle is determined from (Hussain, Understanding Calculus):

$$\alpha = \mathrm{arctg}(f'(x_0)) \qquad (2)$$

Tangent inclined angle from the beginning of the time axis is equivalent to angle inclination of the road where the wheelchair is on. In a real system object, this inclination can be measured by one of the most popular systems like accelerometer, encoder, etc. Using these mathematical operations, disruption model, which affect on the actual seat correction angle value, was made. The actual disruption value in regulation system is compared with the value of reference surface 0°. The actual angle value of the seat is equal to the product of correction angle one revolution of the screw (β) and the number of revolutions of the DC motor (n). Finally, a comprehensive simulation wheelchair model consists of control system and jackscrew model (built of DC motor and a screw). Block diagram showing the concept of a wheelchair seat correction was presented in fig.2.

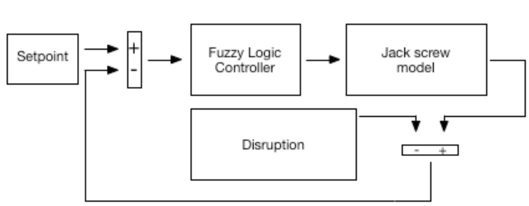

Fig. 2. Simulation model

2.3. Correction algorithm

The obstacle overcome algorithm was described as the example of wheelchair downhill ride on the road with fixed angle α. First step represents moving on a parallel road (fig. 3a). The wheelchair is riding on the parallel road, so the wheelchair seat inclination angle with respect to a road is equal 0°. First stage also skips all deviations which are less than 1° because they don't change the moving comfort and are filtered by a size of the wheels. When deviation raised more than 1°, controller notes that (fig. 3b) and starting correction of the seat (fig. 3c). In the correction process, controller sending signal to the engine, this starts to spin the screw. The jackscrew correction of the seat is working until it reaches an acceptable value. After backing of the road firstly the wheelchair seat is not parallel to the road (fig. 3d) so the controller is starting to correct the angle to the initial value 0° by changing spinning direction of the screw. Last step (fig. 3e) shows seat return to the initial value when it is again parallel to the road. Position correction sequence allows continuous adaptation of the seat to the conditions driving along a set route.

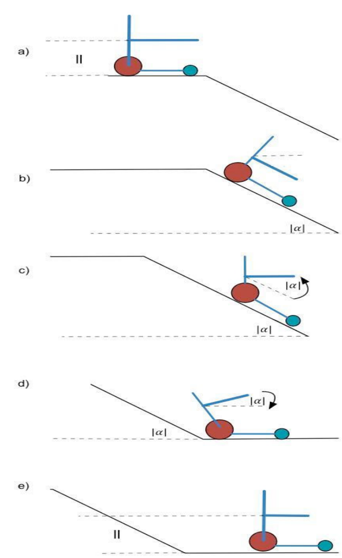

Fig. 3. Driving process

2.4. DC Motor

The DC motor is a machine, which converts electrical energy into a mechanical using a rotary motion. A DC motor machine is constructed with two main parts - rotor and stator. The rotor, which is generally cylindrical shape, moveable part generating mechanical motion and a stator, which gives mechanical support, are built with permanent magnets or copper wire windings (Valdez, 2012), (Virgala, 2013).

For a better analysis, it is necessary to clarify the symbols used in the equations. The following variables are proposed as: U_z - power source; L_w - replacement inductance; R_w - replacement resistance; I_w - winding current; ω_s - angular velocity; M_s- rotor torque; J - inertial moment, M_{load} – overall load moment placed on the seat; c_m – mechanical constant; c_E – dielectric constant. Using these variables main equations was created: Equation describing rotor torque, which is necessary to overcome object resistance and propel the rotor. Rotor torque is a sum of component moments, torque dependent on the value of angular acceleration and load