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A Size-Bed Wheelchair Design Manufacture with Scaled Prototype and Kinematic-Virtual Reality Model Simulation

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Abstract. This paper presents the design verification of a novel concept wheelchair using SimMechanics toolboxes. A wheelchair-sized bed concept (patent pending) with 3 modes of ability (sitting-lying-standing) is proposed. Design begins by deciding the actuator and the component integrated in reality. The 3D wheelchair model was done in AutoCAD 3D and in Vrealm builder to connect with simulink. All components like joint, frame, actuator, gear box and any other part of wheelchair was register in SimMechanics. To verify the kinematics model, a joystick input was connected to the model for visual movement and collision verification. Finally from virtual reality simulation and SimMechanics kinematic modeling, the movement and collision can be verified, and also the actuator condition can be reported.

Introduction

Disable people with different level of disability and limitation need a proper assistive technology, such as a wheelchair. The new concept of a transformable wheelchair is proposed. New wheelchair concept is focused on its mechanism. From observations and studies, existing transformable wheelchair have limitations in transforming. This new concept is expected can resolve comfort and functional problems when users need to sleep on wheelchair. Other advantages of this new design, wheelchair is safe for indoor and outdoor operations, since it has smart mechanism that may keep user in horizontal position while moving through slope or non-flat floor.

Design is followed up after obtaining related information from Patent Agent search, so the design is different with existing wheelchairs mechanism. Newest patented wheelchair is designed by LLYOD Linden Inc in August 2006 [1]. The chair has two rigid frames, each connected to a separate wheel. It is powered using a pneumatic actuator to transform the chair base into a standing support, by generating coupled linkages. Leg rest part, is extendable, by using motorized and rack pinion gear train. This chair has no feature in supporting user obtain a recline position. Other existing marketable wheelchairs also offer triple functions for user by PERMOBIL Inc in 2008 [2]. But those still have limitations in dimensional problem since could not provide single bed size when user need to sleep. Development of a reliable transformable wheelchair should be able to cover disadvantages of the previous one.

The rest of this paper is organized as follow. Section 2 describes the wheelchair design proposed. SimMechanics model for kinematic and virtual reality simulation is describes in section 3. Section 4 describes experimental procedure. Section 5 describes the results and discussion. Finally, the summary of our work is described in section 6.

Wheelchair Design

Wheelchair concept is designed with triple functions, and has a single bed size when transformed into sleeping state (patent pending). Smart mechanism is also designed to provide safety feature which is able keep user in horizontal position. After gaining information from Anthropometric literature [3] and standard hospital bed size(See Table 1) [4], basic design is sketched using AutoCAD to model in 2D and 3D drawing (See Fig. 1).

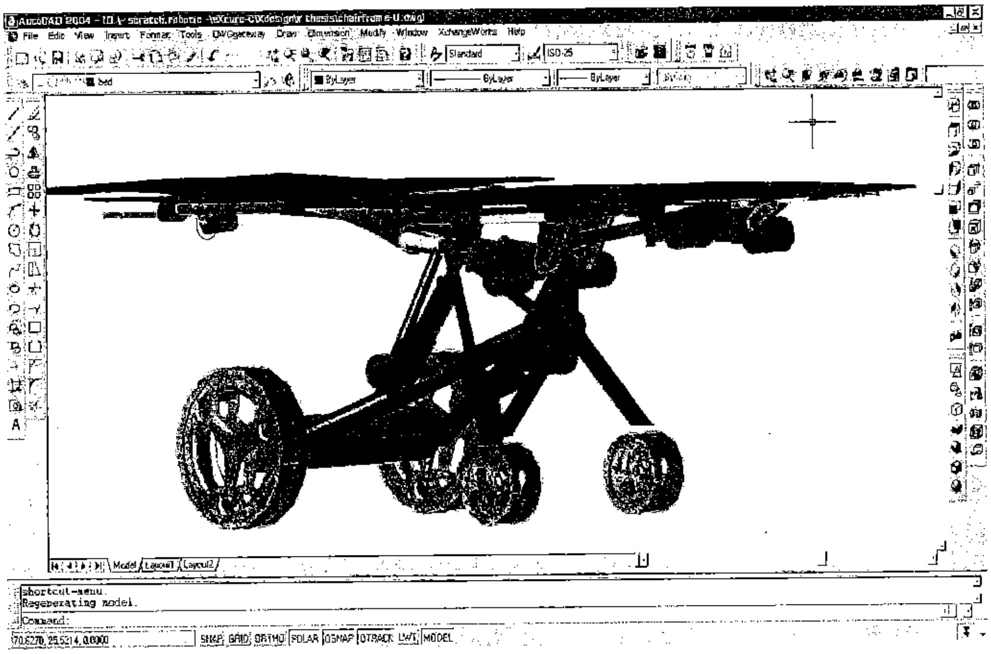

Figure 1. Original 2D dimension generate using AutoCAD

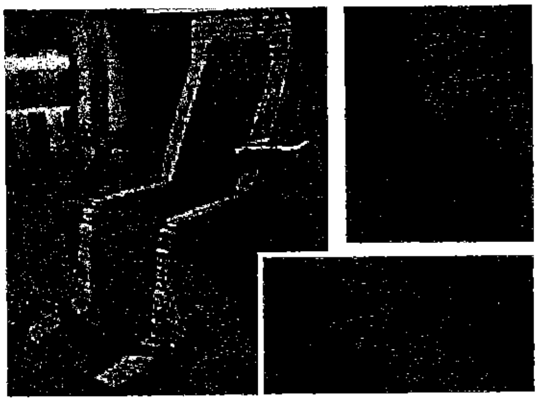

Figure 2. Wheelchair 1:15 scale

Figure 3. RAW Frame Wheelchair virtual model

Early prototyping scaled model 1:15 is made for validating basic concept. Other aims are to build documentations purpose, and apparatus which may help researcher to observe basic configuration of wheelchair. Wheelchair prototype is shown in Fig.2. Prototype is manipulated using DC servomotors, so basic transformation such as chair state, sleeping state, and standing support can be obtained during manual operations.

Since this work was only focus on the transformable mechanism then the discussion of mobile platform is not include it in this paper. In transformable mechanism, 2 things are discussed, actuator and bed frame, which all model and design in AutoCAD and then exported to WRL file to meet the virtual reality requirement (See Fig. 3). The proposed wheelchair design uses 3 types of actuator, they are: Linear DC motor [5], Pneumatic Air Muscle [6] and Brushed DC motor with gearbox [7]. Meanwhile, the wheelchair bed frame is separated into 7 parts. Each part is attached on its frame, which is independent transformable. Modeled frames based on padding dimension are: Bottom rest and joint linkages, Back rest, Arm rest, Head rest, Leg rest, Foot rest, and Flippers. Finally after all actuator and bed frame has modeled, then we assembly all in the position as shown in Fig. 1.

Kinematic-Virtual Reality Simulation

Kinematic Simulation. Kinematic modeling was carried out to verify dimensional problem between actuator movement and expected transformation within connected parts. For example, it was considered that head rest must result 45° rotation. Therefore it needs to design proper shape and dimension for linkage, so actuator movement can cover the desired rotation. Then, by using kinematic simulation we may test dimension configuration during transformation.

This research using forward kinematic solver in order to yield transformation of actuated parts. Actuator movement is controlled by an input signal. Then, movement of actuator will result transformation on certain part.

SimMechanics toolbox from MATLAB/Simulink [8,9] is quite powerful to build kinematic skeletal structure, which is called Machine Body. Machine Body model represents the *physical structure* of a machine, the mass properties, geometry, and kinematic relationships between bodies. SimMechanics toolbox converts this structural representation into an internal, equivalent mathematical model. This saves the time and effort of developing the mathematical model. There are 4 important subjects need to be mastered in building the Machine Body using SimMechanics, they are:

1. **Body Block.** This block contains skeletal coordinates of modeled part including joint coordinates which is represented in XYZ space.
2. **Joint Block.** Block which represents Degree of Freedoms between bodies and joint type, it could be revolute or rotation, prismatic or slide and so on.
3. **Actuator Block.** Block which manipulate the Machine Body movements. Actuation signal could be attached into Body Block or Joint Block.
4. **Sensor Block.** Senses and measures any values which occur during simulation. For example: angle alteration on each joint, coordinate alteration on specified point. Other sensible values are: force, torque, velocity, acceleration, and position.

Since SimMechanics use skeletal body dimension in modeling, it could be extracted the detail dimension of related part from AutoCAD model. Skeletal body coordinates from AutoCAD are used to build SimMechanics Body Block.

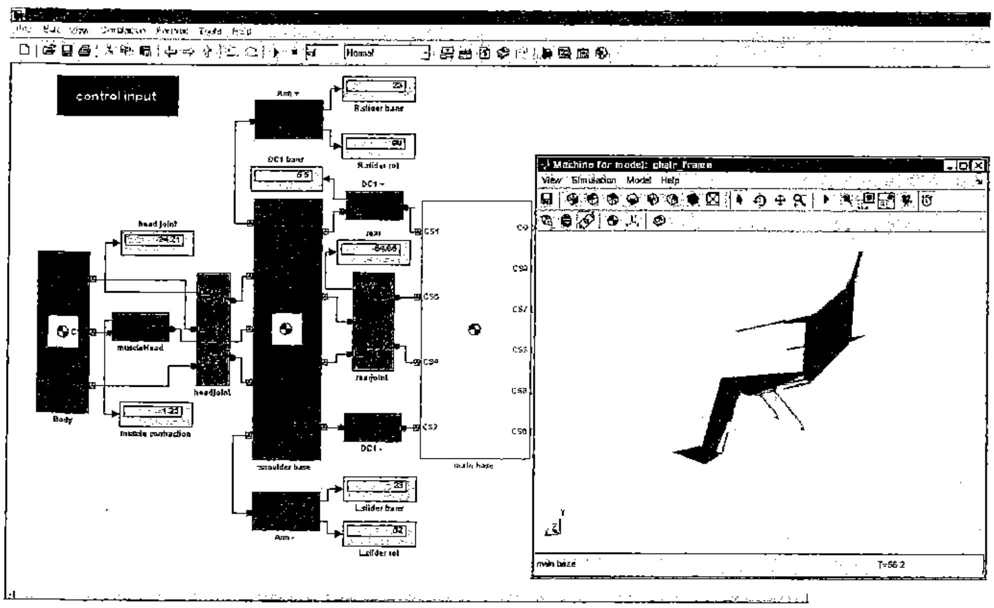

Figure 4. Wheelchair simulation in sitting position

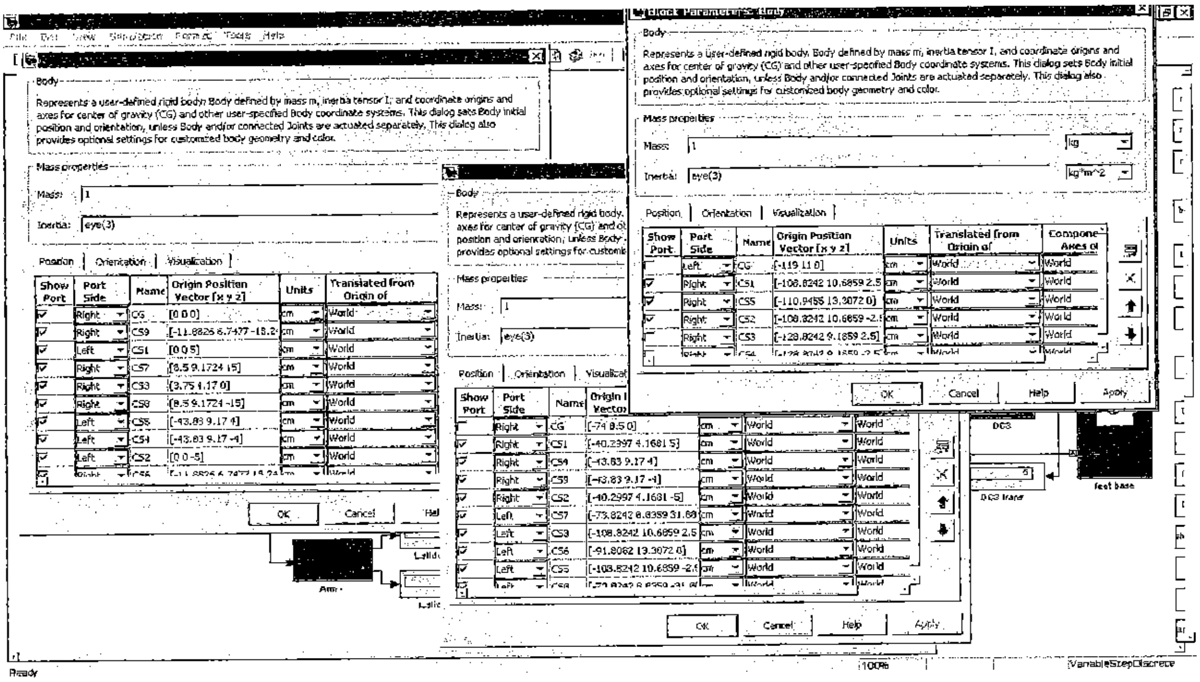

Figure 5. SimMechanics coordinates setting

Kinematic simulation is intended to test the skeletal geometry model of complete Machine Body with respect to transformation. Transformable wheelchair obtains transformations by manipulation of installed actuators to desired position. Shown in Fig. 4 the SimMechanics block design for wheelchair and the visualization window, while Fig. 5. Shown the coordinate inputs in SimMechanics block.

Virtual Reality Simulation. Every part has unique shape and dimension, so each of them has their own workspace during transformation, therefore they have potential collision problem which might be resolved using virtual reality technique. Simulation in virtual reality world is the final step of this research. It was done by connecting VRML model to SimMechanics block. Signal input for VRML model was taken from Machine Body respond.

Visual observation at transformed model is carried on to analyze collision potential problem among parts. Based on research methodology steps, redesign of wheelchair parts is done if collision is occurred at certain parts.

Experimental Procedure

Since transformable wheelchair design has independent actuator on every joint, so the simulation scenario could be done by giving an input signal to dedicated actuator. Signal manipulation came from external device, connected via USB port. It is a wireless Logitech Joystick which has 4 axes, 12 buttons, and 3 POV signals. Joystick configuration is started by map its signal and property on MATLAB Simulink, so it will be known as external input. Fig. 6. shows the joystick apparatus setting and also shows joystick mapping configurations under Simulink.

Table 1. Lying position dimension compared with standard hospital bed size

	Lying position dimension (cm)	Standard Hospital Bed (cm)
Length	213	203 - 210
Width	90.15	90 - 100
Height	62.19	60 -80

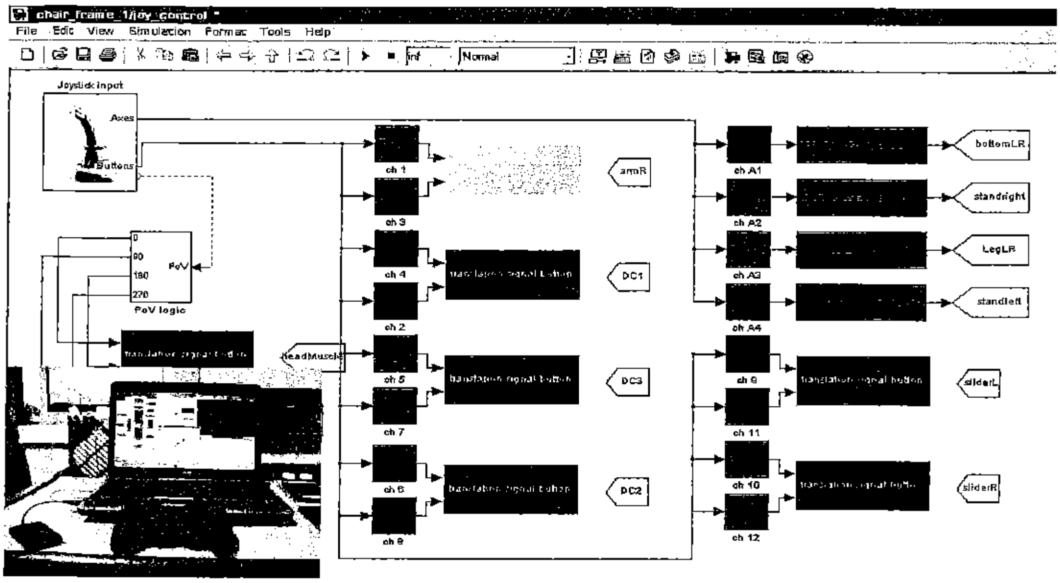

Figure 6. Joystick mapping under Simulink

Results and Discussion

This research employ forward kinematic solver to simulate the transformable wheelchair. Forward kinematic scenario was done by giving a command to dedicated actuator to start, and the result is angle alteration at its joint. This scenario was carried out to observe possible parts collision, mechanism configuration, and real time transformation values.

Experimental simulation also was done using inverse kinematic scenario. Inverse kinematic is a technique to obtain the desired value without giving a direct input. Using this scenario, transformation was triggered by programmed algorithm. Manual input was adjusted by giving a desired angle of each joint, not by manipulating the actuator directly as forward kinematic technique. This scenario was purposed to observe the transformation from one state to another, and record actuator performance in obtaining desired position. Plot of actuator response could be obtained during simulation. Fig. 7. shows random selection of actuator responses and angle alterations during simulation.

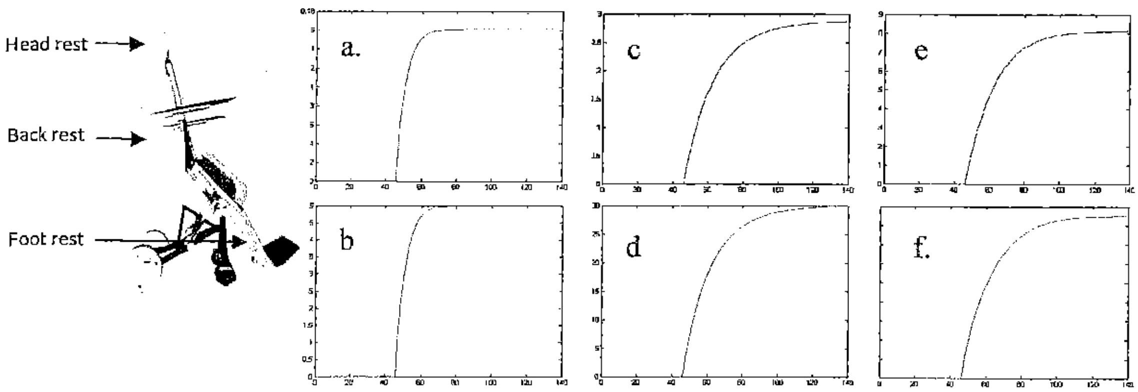

Figure 7. a,c,e Simulation time VS Actuator stroke for head rest, back rest and Foot rest consecutively. While, b,d,f Simulation time VS Joint angle for head rest, back rest and Foot rest consecutively.

Summary

In this paper we successfully present the design verification from our novel concept wheelchair using SimMechanics toolbox, one of the blockset provided by MATLAB/Simulink. The kinematic simulation was done by modeling the actuators and the bed frame parts with their real mechanism and dimension. The virtual reality simulation was used to verify collision and movement from part joints and actuators. The result shown the condition for each actuator and for the movement, no collision was reported during the test. Finally, it is proven that with kinematic-virtual simulation would saves time and cost.

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